The price of demography

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THE PRICE OF DEMOGRAPHY

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Abstract

A few studies lately explored the relationship between changes in the demographic structure and inflation using mainly cross-country analyses. In this paper we investigate how the evolution in the age structure of the population affected price dynamics in Italy, using annual data for a panel of provinces in the period 1982-2016. The within-country approach allows us to wipe out the effects of supranational shocks, as well as to better take into account the effects of monetary policy, main common driver of price dynamics over the medium-term. We use a set of indicators, namely young age, old age and overall dependency ratios, and the share of working age population. Our results suggest that the ongoing ageing process likely contributed to dampening price dynamics.

JEL classification: E31, J11
Keywords: demographic change, price dynamics, panel cointegration

Contents

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1. Introduction[2]

From Italy's Unification in 1861 to today, the population living in Italy has more than doubled, from about 26 to 60.5 million at the beginning of 2018. At the same time, along the twentieth century, Italy moved along the path – typical of a country that experiences modern economic growth – of the "demographic transition", with a gradual decline in mortality rates followed by the reduction in birth rates. Progresses in average life expectancy have been enormous and will continue in the future: the National Institute of Statistics (ISTAT) estimates that in 2065 life expectancy at birth will be 90.2 years for women and 86.1 for men (it was 84.9 years for women and 80.6 for men in 2017). Nonetheless, the Italian population is estimated to shrink back to 1970 levels in 2065, at 53.7 million.

The reduction in birth and mortality rates affected the age structure of the population, determining a gradual ageing. Since the mid-eighties of the XX century, Italy and many other industrialized countries, entered a new phase of its demographic history, a history that will undergo further changes in the next fifty years. Fertility and mortality rates have stabilized at low levels; ageing indexes are increasing, especially since the last decade of the twentieth century; the share of the working age population is shrinking and the index of structural dependency is growing (population 0-14 and >64 years, over working age population, 15-64). The contribution of demography to economic growth turned negative in the 1990s. The *demographic dividend* – the economic growth that, from an accounting point of view, can derive from an increase in the share of working age population – has become or will become negative for all industrialized countries in the next future (Barbiellini Amidei, Gomellini and Piselli 2018).

Demographic changes, indeed, affect many economic aspects, often with offsetting effects. Ageing directly alters the size of the labor force, with important impacts on production, consumption and saving decisions, productivity and other related variables.

The revived debate on secular stagnation (Hansen 1939; Summers 2014) lately emphasized that population dynamics and age structure can produce a non-negligible impact on economic growth through changes in savings preferences. All this would have significant consequences on the one hand on real interest rates, on investments and on aggregate demand (Favero and Galasso

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2015; Carvalho, Ferrero and Nechio 2016; Summers 2016); on the other hand (supply), on the pace of innovation and productivity (Gordon 2015). The contribution to the economic growth of the change in age composition of the population can thus be significant. Countries whose population shows, for example, a growing share of young people have the potential to collect a dividend from demographic change through an increase in the supply of labor in quantity and quality. The increase of the young in the working age population, also affect the age composition of employment (Feyrer 2007) producing – in addition to the direct effects on economic growth that emerge in a growth accounting scheme (via increases in employment rates and - levels of efficiency) – effects on the dynamics of productivity, first of all through the impact on innovation and entrepreneurship (Fürnkranz-Prskawetz 2015; Ciccarelli, Gomellini, Sestito 2018).

It is much less investigated which, if any, is the long run impact of demography on price dynamics. Using the words of Kim, Lee and Yoon (2014, p.19), "it is hard to tell from the theoretical perspective how various changes in demographics affects inflation and it would ultimately be an empirical issue". If the theory suggests that over the long run inflation is a monetary phenomenon, "demographic trends are among the forces that shape the economic environment in which monetary policy operates" (Bobeica et al, 2017).

Recently some studies explored the connection between changes in the demographic structure and price dynamics using cross-country analysis (e.g. Juselius and Takáts 2015, 2016, 2018; Bobeica et al. 2017), with the aim of investigating whether and how much demography contributes to the present subdued price dynamics. Although generally referring to theoretical hypotheses on the link between population ageing and inflation (theories on life-cycle consumption and savings, secular stagnation, political economy approach: cfr. infra, par.3), these papers perform reduced-form analysis and do not identify which channels underlie the transmission of demographic effects on price dynamics.

In the same vein, in our paper we make a reduced-form analysis of the relationship between the demographic structure and price dynamics in a single country, Italy, using a historical and spatial perspective (similar to Liu and Westelius 2016). We use data at the provincial level and exploit the territorial and historical variability to identify if and how demography affected price changes in the period 1982-2016. By examining the issue within a single country (rather than across countries), we can purge more effectively from the effect of monetary policy as the main determinant of price dynamics over the medium term, as well as the effect of supranational shocks which may have a more homogeneous impact in a single country in respect to the cross-country case (e.g. Broniatowska 2017).

The paper is structured as follows. After this introduction, in section 2 we trace a long run picture of demographic changes and inflation dynamics since 1900, showing Italy in international comparison. The third section reviews the extant literature which is empirical and focus mainly on the estimation of the demography-inflation relationship. In the fourth section we describe the data and the econometric specification and methodologies we use. In section 5 - estimation results are presented. Some conclusions close the paper.

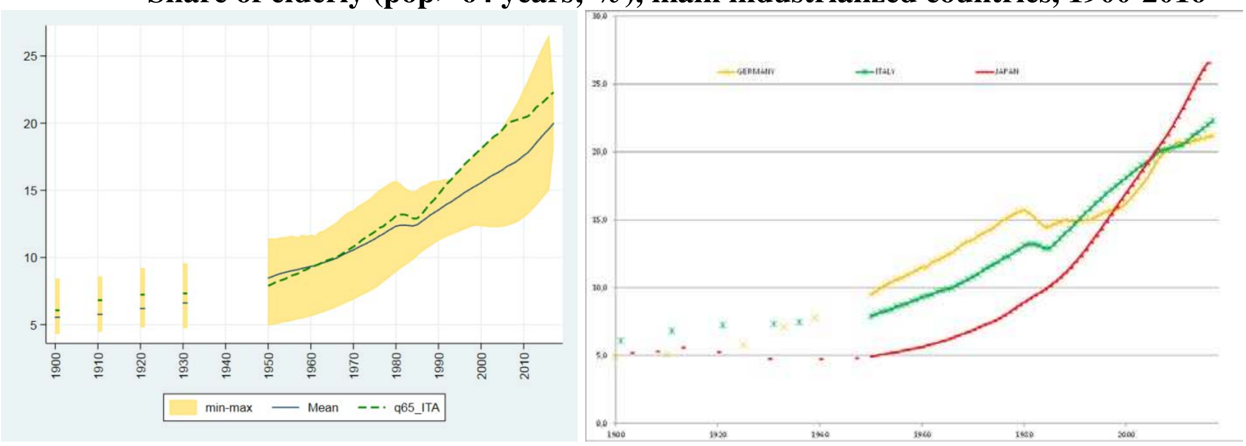
2. Demographic change and inflation dynamics: Italy in international comparison, 1900-2016

From Italy's Unification in 1861 to date, population living in Italy more than doubled, from 26 to 60.5 million. Nonetheless, the Italian National Institute of Statistics (Istat) estimates that the population in Italy should reach 53.7 million in 2065, 7 million less than today (-11%; Istat 2017).[3] The age composition will (is) dramatically change (ing) as well.

Many advanced countries are experiencing an unprecedented shift in the age composition of their populations, a sharp and fast ageing process. Forecasts over the coming decades predict a transition from an ageing to an aged society, in particular in Europe and Japan (see UN Population Prospects 2017). Italy, as many others developed countries, is facing today a demographic scenario whose impact on per capita output growth in the coming decades will be negative (Barbiellini Amidei, Gomellini and Piselli 2018). It is much more debated which, if any, will be the demographic impact on price dynamics in the long run.

Figure 1

Share of elderly (pop> 64 years; %), main industrialized countries, 1900-2016



Source: Our elaborations, data described in the text.

[3] Data specifically related to Italy are sourced from Barbiellini Amidei, Gomellini and Piselli (2018) based on http://seriestoriche.istat.it/ and http://dati.istat.it/.

Focusing on 8 main industrialized countries (Figure 1, left panel: Canada, US, Japan, UK, Spain, Germany, France and Italy) the **share of population over 64** has increased significantly in the long term, dramatically in the new millennium to unprecedented levels.[4] In the 1950-2016 period the 8 countries average share of the elderly more than doubled from 8 to 20%.

In Japan today more than a quarter of the population is aged over 64, in Italy and Germany more than a fifth (Figure 1, right panel). Falling fertility rates and increasing longevity are the driving forces underlying such demographic trends.

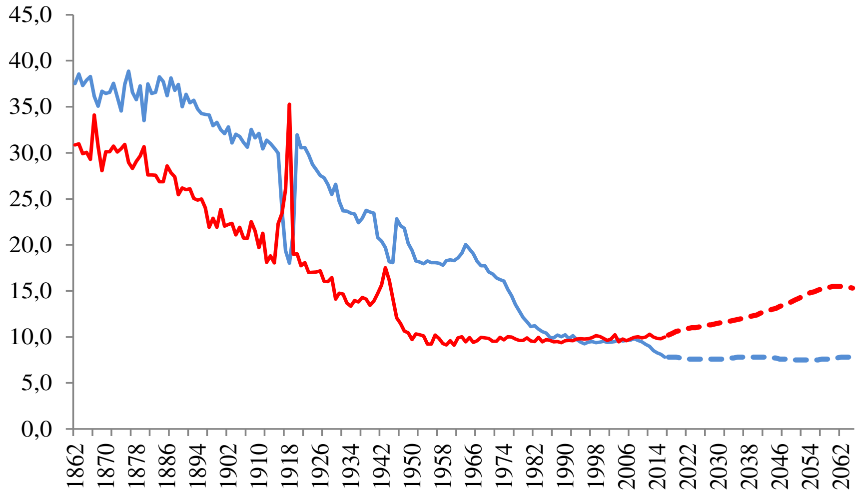
According to forecasts, the ageing process will be even stronger in the future and a truly global phenomenon (see Broniatowska 2017; Bobeica, Nickel, Sun 2017).

It is useful to look separately at the two main factors inducing such long-term changes in the size and in the age structure of the population: fertility and longevity, as proxied by birth and death rates over more than a century. Figures 2-8 provide information about country-wide birth, death and natural change of population rates for Italy and the other seven industrialized countries. Since Italian unification, birth rates and mortality rates have declined over the course of the demographic transition (Figure 2). The progresses in average life expectancy have been enormous and will continue in the future: ISTAT estimates that in 2065 life expectancy at birth will be 90.2 years for women and 86.1 for men (+5 years compared to 2017).[5]

Figure 2

The demographic transition in Italy and beyond

Number of live births (in blue) and deaths (in red) per thousand inhabitants. Dotted line: forecasts.



Source: Barbiellini Amidei, Gomellini and Piselli (2018).

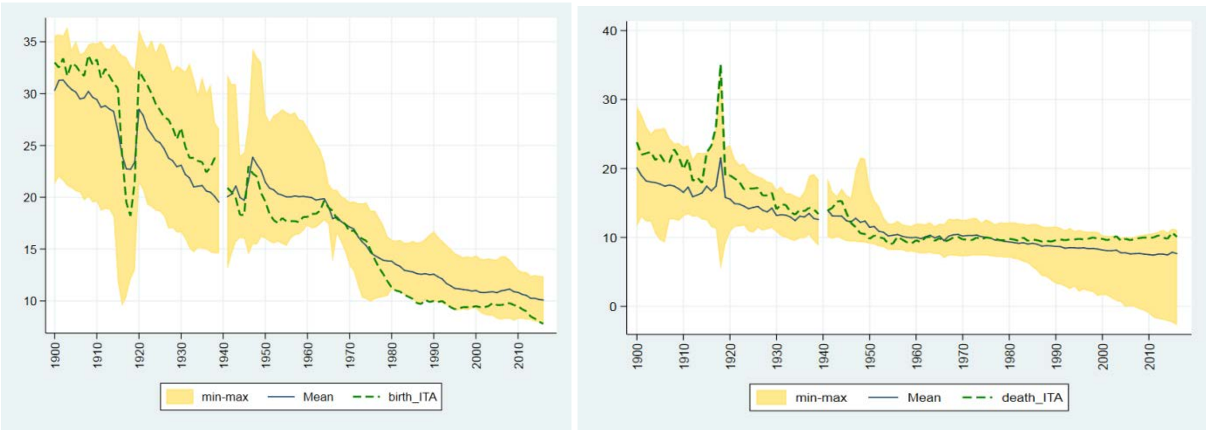
[4] Sources of reconstructed demographic historical data: Mitchell (2007a,b,c), Statistics Bureau of Japan (2108), Statistics Canada (2017), UN World Population Prospects (2017), World Bank (2018), Eurostat (2018).

[5] Life expectancy in Italy was 29 in 1861 and around 65 in 1961 (Brandolini, Vecchi 2013).

The number of **births per 1.000 population** for the 8 countries was 30 around 1900 and still around 20 in mid-1960s thanks to the baby booms experienced after WWII (especially by winning countries), but decreased significantly in the subsequent four decades, with the completion of the first demographic transition for all of them (Figure 3). The shrinking of the birth rate continued in the new millennium, notably in Japan and Italy, down to 10 on average in 2016.

Figure 3

Birth and death rates (per 1000 population; crude), main industrialized countries, 1900-2016

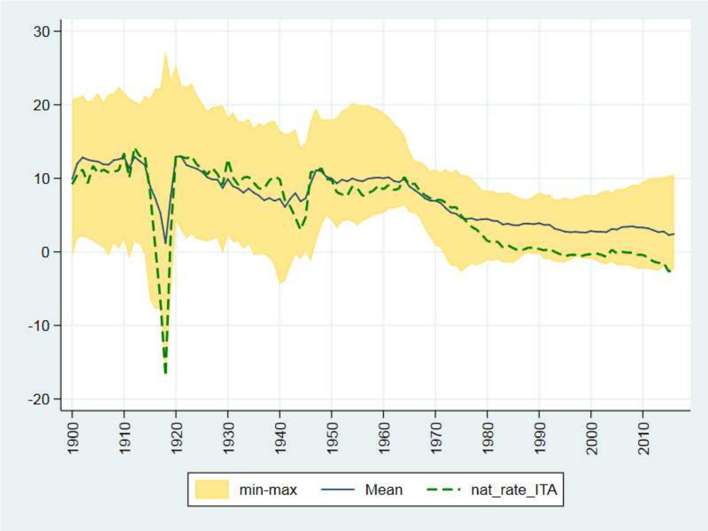


Source: Our elaborations, data described in the text.

The **death rate** (per 1000 population) in the eight countries considered decreased marginally on average in the 1950-2016 period from 11 to 9, after having completed its long run retreat and more than halving in the previous fifty years (was 21 on average in 1900). Mainly as a result of the substantial ageing process, in recent years for the first time (apart from war years) all 8 countries experienced a bounce back of the death rate, considerable in Japan.

Figure 4

Rate of natural increase (per 1000), main industrialized countries, 1900-2016



Source: Our elaborations, data described in the text.

The developments in the birth rate described above, coupled with the death rate evolution, resulted in a population natural growth slowing down progressively in past 50 years to reach zero on average in 2016. While in recent years the UK, France, the US and Canada still exhibit low but positive **rate of natural increase** (per 1000 population; Figure 4), notably Germany since the 1970s, Italy since the 1990s and Japan since the 2000s are experiencing a natural decrease of population.

Looking at **total population growth**, in order to account also for the contribution of **net migration**, the picture changes to some extent: on average, the population of the eight countries we scrutinize grew around 1% per annum up to the 1960s, slowed down in the subsequent decade to oscillate around 0.5 since early 1980s. In the past 4 decades if all countries experienced a population growth slowdown, Germany, Japan and Italy underperformed with almost nil. Entering in the new millennium Japan's population is shrinking, German one is still, and Italian barely positive only thanks to immigration.[6]

[6] Looking at countries historical experiences, Canada, US and Japan are confirmed as characterized by an higher population growth up to the 1960s, followed by Germany; Italy and Spain lost population dynamism as a result of emigration; and France is confirmed as laggard but improving significantly its performance thanks to immigrants.

Figure 5

Share of working age population (15-64; %), main industrialized countries, 1900-2016

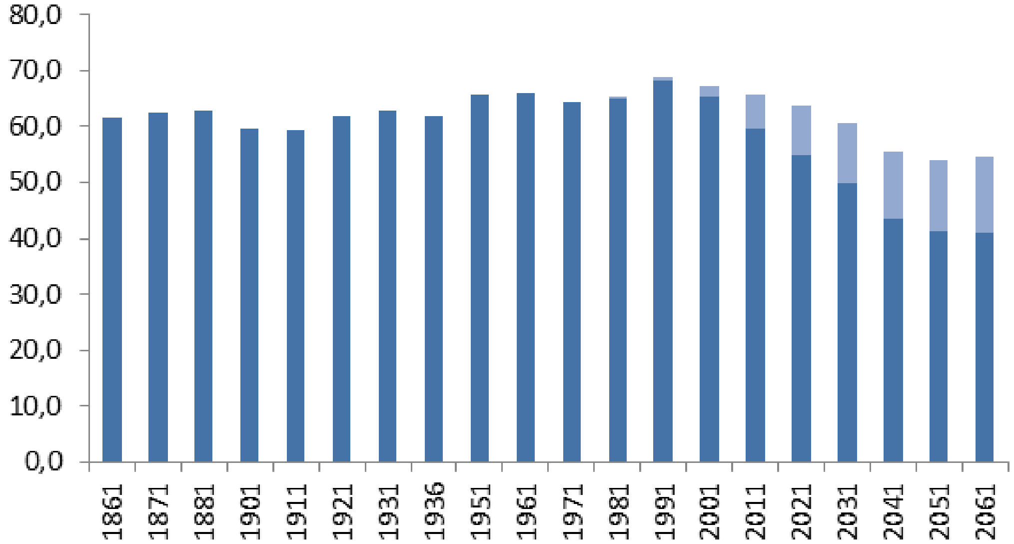
Source: Our elaborations, data described in the text.

As the share of working age population in total population is a function of young people entering the labour force and old people leaving it, the slowdown in total population growth, along with the described (lower) fertility and (higher) longevity trends, translated in recent decades in a decline of **working age population** (WAP). The eight countries' average share of working age population (people aged 15-64) over total population, after increasing from 61% at the beginning of the XX century to a pick of 67% in early 1990s, is shrinking in the last 25 years (see Figure 5 and 6). Indeed, in recent decades, if only Japan lost 10 percentage points (to a 60% WAP in 2016), all countries experienced a retrenching of WAP (below 65% in 2016). What is today quite exceptional is that, according to all forecasts, recent widespread worsening trend will be maintained by stabilized low fertility rates and higher life expectancy. Looking ahead to the next four decades, while for half of our countries the total population will shrink (Japan, Germany, Spain and Italy) and for half it will increase only moderately (US, Canada, UK and France), for all of *t*hem the WAP share will decline further and significantly, falling below 60% (close to 50% for Japan; see UN Population Prospects 2017). In Italy the share of the working age population is projected to reach 55 per cent and splitting it by citizenship, in 2061 about a quarter will be constituted by foreign citizens (Figure 6).

Figure 6

Share of working age population(15-64; %)

(Light blue: percentage of foreign citizens. From 2021: Istat forecasts)



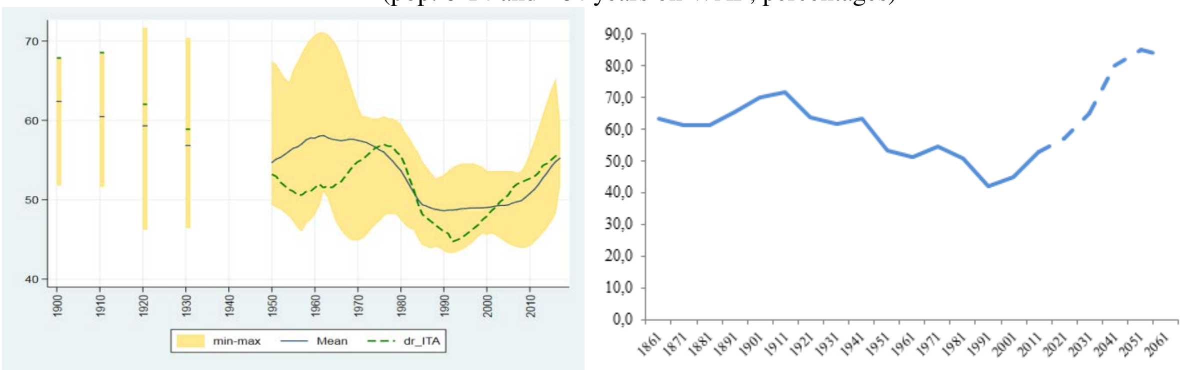
Source: Barbiellini Amidei, Gomellini and Piselli (2018).

To summarize the population age structure evolution and explore its economic consequences, we calculated the classical dependency ratios returning the relative proportions of population with different economic attributes in respect to consumption and saving behavior, as well as labour force participation (Bobeica, Nickel, Sun 2017).

Figure 7

Structural dependency ratio

(pop. 0-14 and >64 years on WAP; percentages)



Note: main industrialized countries, 1900-2016; Italy, 1861-2061, Istat forecasts. Source: our elaborations on data described in the text and Barbiellini Amidei, Gomellini and Piselli (2018).

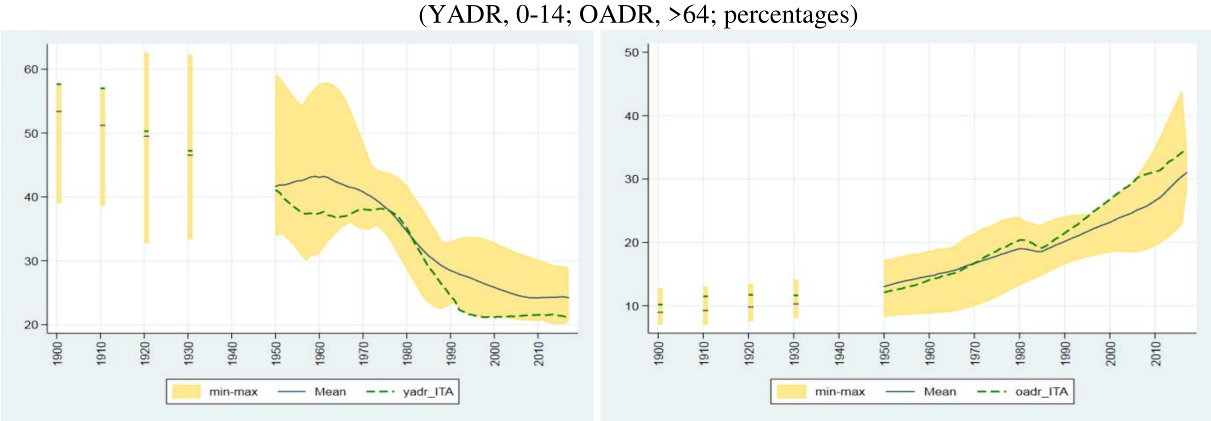
The **Structural dependency ratio** – i.e. the burden of dependents, both young and old, on active population – decreased from 63% at the beginning of the XX century to 49 in 1990 (as baby boomers had fewer children than their parents), experienced a reversal in the new millennium to reach 55 per cent on average in the eight countries considered in 2016. It is projected to rise sensibly for all countries in the next decades (Figure 7). For Italy in particular the index of structural dependence is expected to overcome 80% in the next fifty years.

In fact the **YADR** – the ratio of the youth (0-14) over working age population – since early 1970s decreased sensibly from 40 to 24 on average in 2016 (Figure 8).

Figure 8

Young age and Old age dependency ratios

(YADR, 0-14; OADR, >64; percentages)



Note: main industrialized countries, 1900-2016. Source: Our elaborations, data described in the text.

The Old Age Dependency Ratio (**OADR**, the ratio of elderly (65+), over working age population) more than tripled on average since 1900. With the new millennium, in a few years, the burden of elderly people on active population increased sharply in all countries. A gap has opened and will expand: according to forecasts, while the YADR should stabilize, the OADR should keep increasing for a wide set of countries.

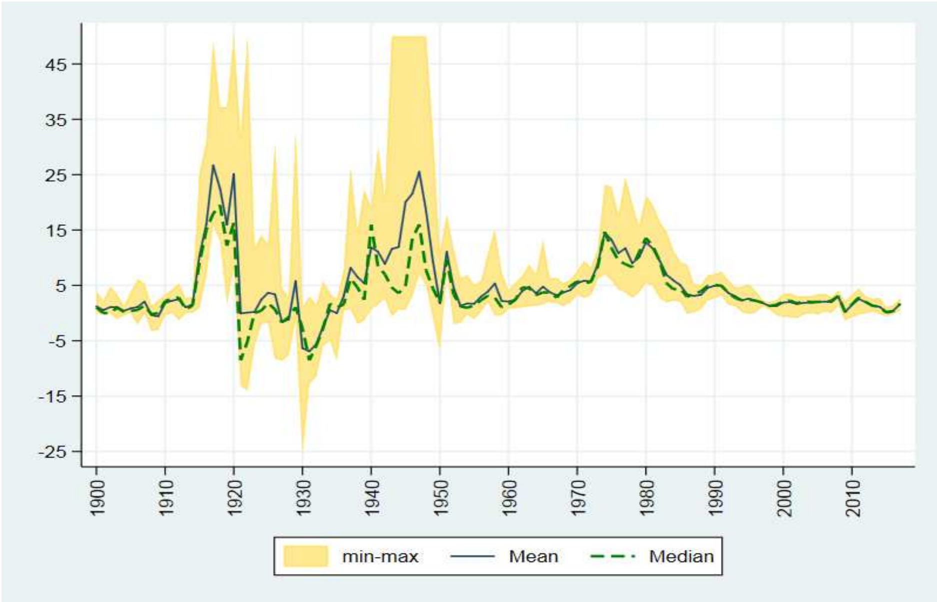
The notable changes in the population age structure that industrialized countries experienced in the past 70 and will experience in the next 50 years, may have had an impact on economic performance. In this paper we investigate the long-term **relationship** between the **demographic variables and inflation**.

Here we start with a simple graphical inspection of inflation and a summary measure of the demographic structure (Figure 9 and 10). [7]

[7] Sources of reconstructed inflation rate historical data: Mitchell (2007a,b,c), Historical Statistics of Japan (2012), de Motes (2013), BIS (2018).

Figure 9

CPI inflation rate (%), main industrialized countries, 1900-2016



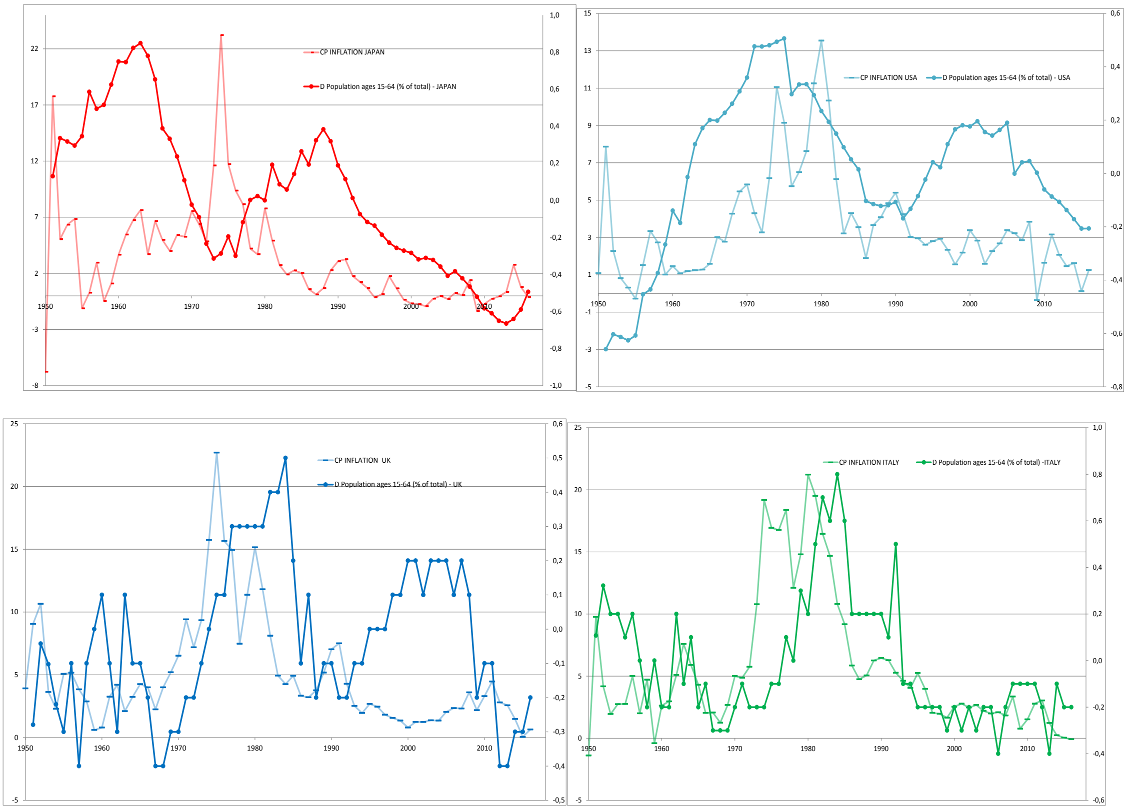
Source: Our elaborations, data described in the text.

Notwithstanding a certain degree of heterogeneity in the past 120 years, the average inflation rate in our sample dropped from 12.8 in early 1980s to 1.6% in the new millennium (Figure 9), showing a common trend across our countries, also shared by several other newly developed and developing countries. In particular in recent years attention was drawn to a more marked decline towards historically low inflation levels in ageing countries (see Juselius and Takáts 2018; Broniatowska 2017).

In Figure 10 over the 1950-2016 period we plot the change in the share of the working age population together with the inflation rate for four industrial countries (of the 8 we showed so far: they all display similar profiles). At a first glance in the long term there seems to be a positive correlation between inflation and the change in the working-age population share. While this movement from high to low inflation is mostly granted to more effective monetary policy, recent studies (reviewed in the following section) point to a role for demography too. As this correlation between population age structure and inflation may be driven by some common trends and factors, in the next sections we will perform a formal econometric analysis for Italy, exploiting the sub-national dimension (provinces).

Figure 10

Inflation rate and change in the share of the working age population (%), Japan, USA, UK and Italy, 1950-2016



Source: Our elaborations, data described in the text.

3. Measuring the effect of demography on price dynamics: a review of the literature

Demographic changes affect many crucial economic aspects. Ageing directly alters the relative size of the labor force, with important impacts on production, consumption-saving decisions, productivity and other related variables. The transmission channels are manifold, and often with offsetting effects (e.g. Carvalho et al. 2016). The demographic structure has also been lately invoked as possibly affecting price dynamics. The issue is policy-relevant, since the ongoing ageing process will substantially alter the age structure of the population in years to come.

In this paragraph we review the literature which examines the link between demography and inflation. We focus in particular on those studies which are similar to the present work in terms of aims and methodologies, and that empirically estimate the inflation-demography relationship. Existing works use different methodologies and investigate both the short run (works based on panel data cross-country analysis) and the long run (papers which use cointegration techniques). The latter approach is consistent with the idea that demography has a slow moving trend: in the words of Bobeica et al. (2017), “any impact that demographics may have on inflation is unlikely to occur over the business cycle frequency, but rather at a generational frequency”[8].

It is worth noting that none of the extant empirical studies try to identify which are the underlying mechanisms driving the relationship between demography and inflation. Nonetheless, it is useful to briefly sketch some potential channels at work.

These mechanisms may have a “quantitative” origin (e.g. a reduction in the share of working-age population which entails ceteris paribus a reduction in labour supply and an increase of dependents), or a “behavioral” origin, operating through incentives and agents’ preferences (e.g. the expectation of a longer life lead people who are in their working age to save more). Both can determine different consumption-saving patterns and demand-supply discrepancies affecting inflation.

According to life-cycle consumption-saving models (see Ando and Modigliani 1963), the increase in the average age of the population entails more households using accumulated savings to finance future consumption. Being the latter not backed by new production, this can fuel a gap between demand and supply (see Broniatowska 2017). Thus, more dependents (both young and old) could theoretically exert an inflationary pressure through excess demand: they consume more goods and services than they produce (inflation-augmenting demand-supply discrepancy). On the costs side, if ceteris paribus the share of working age people decreases, labor supply shrinks and wages can be pushed up contributing to fuel inflation.

Consumption patterns are likely to change as populations age[9]. Elderly people could exhibit lower consumption along their residual life, thus an ageing population can lead to a reduction in aggregate demand and to a lower inflation (excess supply). This mechanism can be reinforced: feeding expectations of an economic slowdown, it may in addition cause a reduction in

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[8] In this approach the proportionality between money growth and inflation in the long run, is often addressed by controlling for monetary policy variables (interest rates or money growth; we use both in our analyses). The underlying idea is that the fraction of the inflation's long-run variation explained by long-run money growth although being very high and relatively stable, could vary over different periods and in different countries. This is shown, for example, by Benati (2009), who investigates how shocks to velocity of circulation and inflationary outbursts affected the relationship over time: “ .... For long periods of time, the long-run component of inflation has moved less than one-for-one with the long-run component of money growth…”, in particular, “…following the disinflation of the early 1980s the correlation dropped below one…” (pp. 5-6).

[9] Hobijn and Lagakos (2003), Börsch-Supan (2003), van Ewijk and Volkerink (2012), Lührmann (2005, 2008), presents cross-sectional overviews of consumption-age profiles of several different expenditure groups for the U.S., Germany, the Netherlands, and UK. Groneck and Kaufmann (2017) review some micro studies on the United States and the European countries, which detect an age pattern in consumption data.

investments (Shirakawa 2011)[10]. Differently, looking at the composition of their consumption basket, elderly cohorts mainly shift their consumption habits from tradeable to non-tradeable goods and services which may exhibit higher price dynamics[11].

Finally, on the behavioral side, according to the secular stagnation hypothesis (put forth by Hansen 1938, and recently revived by Summers 2014), the increase in life expectancy raises propensity to save and this provides an additional mechanism through which demographic changes affect inflation (cfr. Carvalho, Ferrero, Nechio 2016). In particular a structural excess of savings over investment reduces the real interest rate causing the economy to operate below potential and possibly contributing to keep inflation subdued[12].

Turning to empirical studies, they reach heterogeneous conclusions about the impact of demographic changes on inflation, although the result of a negative relationship between price dynamics and ageing seems to prevail (see Table 1).

Lindh and Malmberg (2000) in a panel data analysis, estimated the relationship between inflation and age structure on annual OECD data for the period 1960–1994 for 20 countries. According to their results, an increase in the proportion of net savers (i.e. working age population), dampens inflation, whereas retirees, especially younger ones, fuel inflation as they consume out of accumulated savings (pension claims) and do not produce.

In the same vein Juselius and Takáts (2015, 2016) show that the age-structure of the population is a systematic driver of price dynamics. Using panel data for 22 advanced economies over the 1955–2010 period, they find that a larger share of dependents (both young and old) is

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[10] Shirakawa (2011), quotes Keynes (1937; who actually referred to a population decrease rather than a change in the age structure): "*in an era of a declining population, …demand tends to be below what was expected and a state of over-supply is less easily corrected. Thus a pessimistic atmosphere may ensue*".

[11] Older people tend to reduce their expenses on tradable goods (like transportation, furniture, home electronics and clothing), while demand for nontradeables (such as housing and health care goods and services) increases. Groneck and Kaufmann (2017) estimate for US in 2011 that the share of aggregate nontradable consumption of the older people (aged 65+) is on average about eight percentage points higher than in the case of the younger people (aged 15-64). Nerlich and Schroth (2018) focusing on the euro area show that population ageing entails changes in relative prices, mainly shifting demand, with demand for services rising.

[12] Some authors adopt a political economy perspective: an ageing population may contribute to low rates of inflation since a greater share of (older) people asks for lower inflation (which otherwise would hit their accumulated wealth). Bullard et al. (2012) adopt this perspective suggesting that an aged population structure (like that prevailing in Japan) may contribute to observed low rates of inflation or even deflation. They argue that monetary policy could be influenced by the inflationary preferences of dominant voter groups, therefore, when the elderly are the dominant group in a society, their tendency to prefer lower inflation rates may lead to the appearance of deflationary pressures Other authors refer to a further mechanism based on the to the so-called Fiscal Theory of the Price Level (FTPL) which could have implications for the relationship between demography and prices (Woodford 1995, Katagiri 2014). According to FTPL the current price level adjusts to equate the real value of the government's outstanding debt, with the discounted sum of current and future fiscal surpluses in real terms. Population ageing is a factor expected to reduce future fiscal surpluses due to higher social security expenditures and lower income tax revenues. Thus, in order for the FTPL to hold, one would expect ageing to generate inflationary pressures (that is, an upward pressure on current prices) which would lower the real value of outstanding debt.

correlated with higher inflation, whereas more working age population leads to lower inflation. According to their research, overall demographic changes accounted for one third of the variation in inflation for the countries they studied in the analyzed period. However, using a finer age structure, they find that the old population has an ambiguous sign: the effect is positive for most old cohorts except for the 80+ cohort, for which it is significantly negative. Thus, they argue, the deflationary effects of ageing found in previous studies could be primarily driven by the very old cohort (which, interestingly, will increase rapidly in the coming years). More recently the same authors extended the time span of their analysis to 1870-2016 confirming their early results (Juselius and Takáts, and 2018): an increase in the share of the dependant population is generally associated with higher inflation, 80+ people excluded, whereas an increase in the working age population has the opposite effect.

Other studies find that ageing has a deflationary impact. Yoon et al. (2014) show that population ageing has an economically and statistically significant impact on key macroeconomic variables. In particular, using a panel dataset covering 30 OECD economies for the period 1960-2013, they find that (conditional on country-specific population growth) the ageing process dampens inflation significantly. Anderson et al. (2014), using the IMF Global Integrated Fiscal and Monetary Model (a general equilibrium macro model), find deflationary pressures from ageing, stemming mainly from the declining GDP growth and the fall in land prices[13].

Using a sample of 34 OECD countries over 1970-2013, Gajewski (2015) shows that ageing exerts downward pressures on prices. The old-age dependency ratio coefficients (in a regression where inflation is the dependent variable) have signs supporting the deflationary effect of ageing (although they lose statistical significance in the FE model after robust SEs are calculated). According to their results, a one percentage point increase in the share of the population aged +80 translates roughly into a one percentage point decline in the average inflation rate, a significant reaction if we think about the projected rapid increase in the +80 population share in the future.

Broniatowska (2017) investigates whether inflation is linked to the population age structure, and in particular whether the old-age dependency ratio (OADR) is correlated with a lower inflation rate. To check this hypothesis, a panel data model is estimated for 32 OECD economies over the period from 1971 to 2015. The paper shows that an higher old-age dependency ratio is indeed correlated with lower inflation and thus ongoing population ageing may exert downward pressure on inflation.

[13] They also add a mechanism based on the repatriation of foreign assets by the elderly which leads to a real exchange rate appreciation, exerting a downward pressure on inflation, as result of an increased demand for relatively cheaper foreign goods and services.

According to Bobeica et al. (2017) demographics is a slow-moving process unlikely to influence inflation at the business cycle frequency. So, they perform a co-integration analysis to study the long-run relationship between demographic changes and inflation dynamics for the period 1975-2016 for the euro area. They present evidence in favor of a positive relationship between core inflation rate (stripped out of the energy and food components) and the growth rate of working-age population. Thus, a diminishing working age population (which is nowadays the other side of the coin of a higher share of the elderly), comes hand in hand with fading inflationary pressures. They also find that the relationship is mitigated by the effect of monetary policy, which they account for by including the short-term interest rate in the analysis[14].

Katagiri et al. (2014), using OLG model-based simulations, argue that it is not ageing per se that causes deflationary or inflationary pressures. In their paper, they show that potentially the direction in which population ageing affects the inflation rate depends on the origins of the process. Ageing can be deflationary when caused by increased life expectancy, as is the case in the recent past and it will be, according to demographers, in the next decades. Differently, population ageing stemming from a decline in birth rates generates inflation[15]. All in all, they show that over the past 40 years ageing caused a yearly deflation of about 0.6 percentage points in Japan.

Finally, Liu and Westelius (2016) exploit demographic and economic variation in panel data at the prefectural level in Japan between 1990 and 2007 and find that prefectures that aged at a faster pace experienced lower overall inflation. The approach we follow in the next paragraphs is characterized by the use of data at the provincial level for Italy, in the same vein of Liu and Westelius (2016).

4. Data and estimation methods

4.1 Data and descriptive statistics

The dataset we have built for our econometric analysis assemble data on prices and demographic variables at the provincial capital level for Italy for the period 1982-2016.

[14] "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." Bobeica et al. (2017), p. 8.

[15] They refer to the political economy approach and to the FTPL theory described above: when ageing is due to a decrease in birth rates, it shrinks the future tax base and raises future fiscal expenditure thus fueling inflation via FTPL. On the other hand, ageing could be deflationary when caused by an increase in longevity since the higher share of elderly people prefers lower inflation and exerts political pressures for this purpose.

We collected census and annual data on population, its age structure and various demographic variables at sub-national level. Annual data on resident population, births, deaths, marriages, registrations and cancellations (from/for abroad and other municipalities) for Italian capital provinces are sourced from Istat (the National Institute of Statistics) publications *Popolazione e movimento anagrafico dei comuni*, *Annuario di statistiche demografiche* and *Annuario Statistico italiano* from 1949 to 2016. Data on population by age and municipality are sourced: at decennial frequency at the Census years, from 1951 to 2011 from Istat *Censimenti della Popolazione*; at annual frequency since 1982 to 2016, from Istat inter-census annual reconstructions *(Ricostruzione intercensuaria della popolazione per età e sesso al 1 gennaio – anni vari*) and current demographic statistics repositories (*Popolazione residente comunale per sesso, anno di nascita e stato civile*).

We collected monthly data on price indexes at sub-national level since 1947 to date, mainly from Istat (1984), which reconstructs historical sub-national price indexes, since 1861 Italian unification[16]. The consumer price index we consider is the general cost of living index (*indice del costo della vita per famiglie di operai e impiegati*, FOI). We collected data for 99 province capitals, but as they were not always available in the time period 1982-2016 considered in our estimation exercises, we selected 74 provincial capital indexes[17]. Indexes series are re-based to 1995=100 and spliced.

Data on monetary aggregate M2 are drawn from Barbiellini Amidei et al. (2016), while data on monetary policy rate are drawn from the Bank of Italy's website,Historical statistics section, for the period up to 1998 and the ECB website for the period 1999 to present. Data on GDP are sourced from Baffigi (2013; updated).

In the current analysis we use annual data from 1982 to 2016, since we firstly focus on the role of age structure and annual data by age and capital province are available only from 1982 on. Table 2 reports main descriptive statistics of the dataset used in the econometric analysis, a balanced panel of 74 capital provinces for 34 years.

Demographic variables and inflation across provincial capitals over the 1982-2016 period are displayed in Figures 11-13.

[16] In particular: data are sourced for 1947 to 1983 from Istat (1984); data for the period 1984-1994 are unpublished and kindly provided by Istat; since 1995, data were downloaded from Istat website. For price indexes Istat uses the adjective "provincial", but the reference is always to prices surveyed in the provincial capital city.

[17] For our 74 provinces, we replaced missing data by linear interpolation up to 2-in-a-row missing years and when the final level of index was available; otherwise we used the dynamics of the closest city in the same region.

Although provincial capitals broadly share similar demographic patterns over time, heterogeneity of demographic variables is considerable across provinces. Old age dependency ratios increase significantly on average and the trend is positive in all the provinces, and even so, the overall increase in Cagliari (in Southern Italy: +180% from 1982 to 2016) is much higher than in Reggio Emilia (in Northern Italy: +25%). OADR ranges from a minimum of 13% in Brindisi in the South to a maximum of 34% in Trieste in the North at the beginning of the 1980s and from a minimum of 29% in Napoli in the South and a maximum of 48 in Northern province of Savona in 2016. OADR dispersion across provinces remained significant and stable over time, as well as within the three Italian geographical regions (except for an increased dispersion among Southern provinces). Finally, the difference between North-Center Italy and Southern provinces kept significant: an OADR equal to 23% viz a viz 16% at the beginning of the period; 41% viz a viz 34% in 2016.

The dynamics of working age population share (q1564) is more uniform across cities, but still the negative trend emerging since the beginning of 1990s in Italy is much steeper in the Northern cities (a drop by over 10% in Venezia, Aosta, Genova and Ferrara in the North) than in the Southern ones, where in some cases even reversed (Palermo +4%, but also positive in the other main Southern capital provinces Naples, Reggio Calabria, Sassari, Brindisi, Catania and Siracusa). At the beginning of the 1980s, the working age population share is at the lowest level in Palermo (64%) and at the maximum 69% in Modena in the North; 35 years later the minimum is 60 % in Savona and the maximum 67 in Sassari. WAP share dispersion across provinces was than lower (in respect to OADR) and quite stable nationally (increasing slightly only among Northern provinces), and not too dissimilar in the three Italian geographical regions.

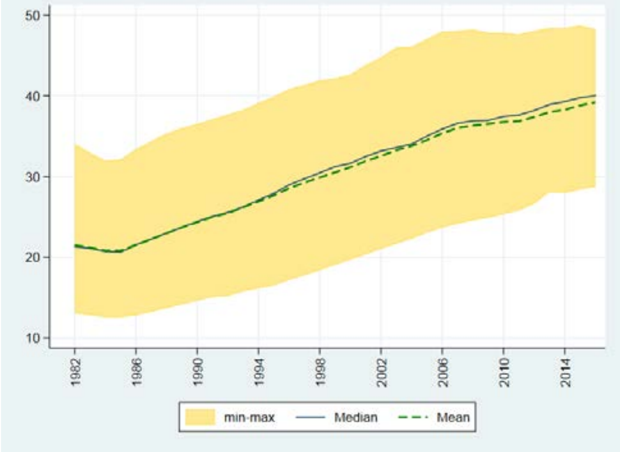
While sharing a common downward trend over the 1982-2016 period, a substantial variance also emerge with reference to inflation across provincial capitals (yet lower than for demographic variables). Inflation rates decreased dramatically on average and in all the provinces, passing from 16% on average in 1982, to 0,03% in 2016. Inflation dispersion across all provinces decreased significantly over time, as well as in the three Italian geographical regions. The difference between North-Center Italy provinces and Southern ones was not significant neither at the beginning and the end of the period, neither on average. Yet while in 1982 were registered at the provincial level inflation rates in a min max range of 13-18%, in 2016 provincial capitals inflation rates still differed widely in a -0.5-2% range.

Figure 11

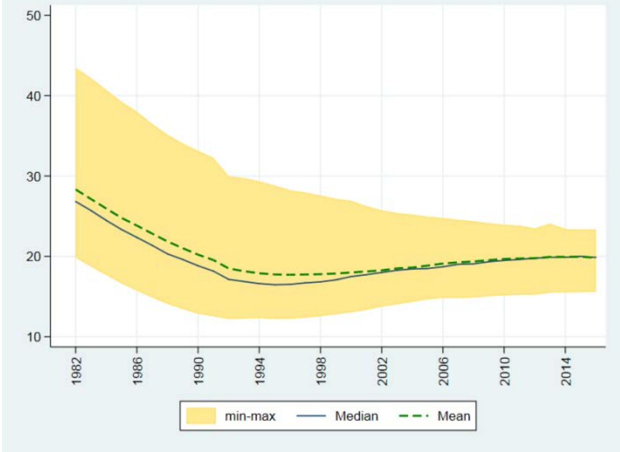
Demographic variables and their territorial variability

(ratios; percentages)

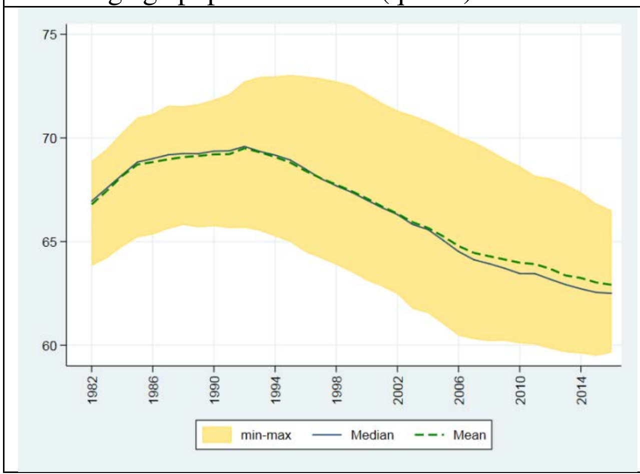
Old age dependency ratio



Young age depencency ratio



Working age population share (q1564)



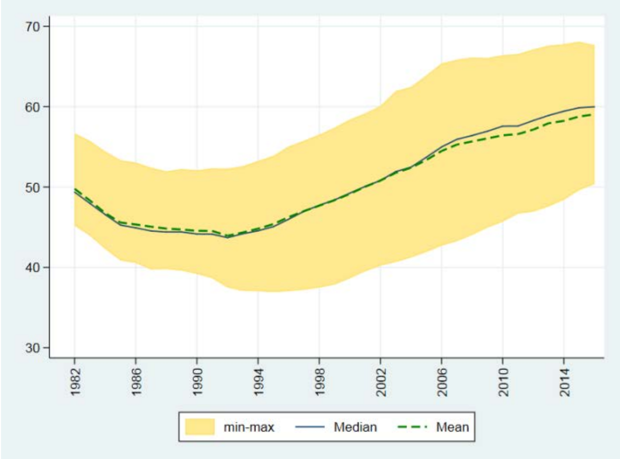
Source: Our elaborations, data described in the text.

Figure 12

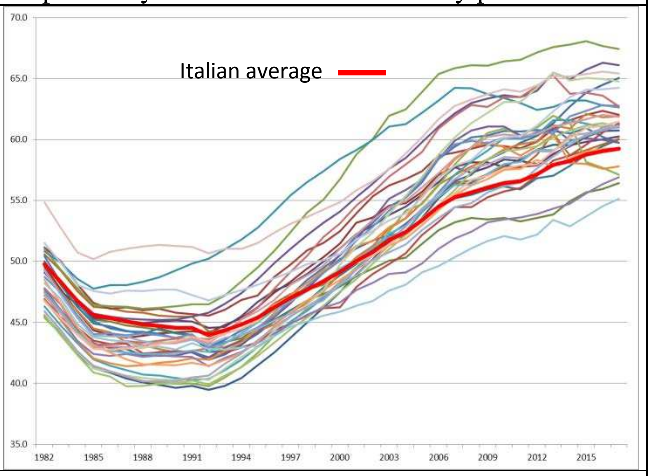
Dependency ratio and its territorial variability

(ratios; percentages)

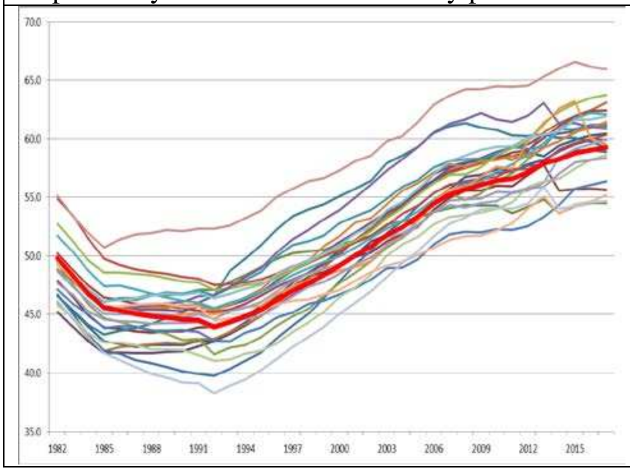
Dependency ratio across Italian provinces



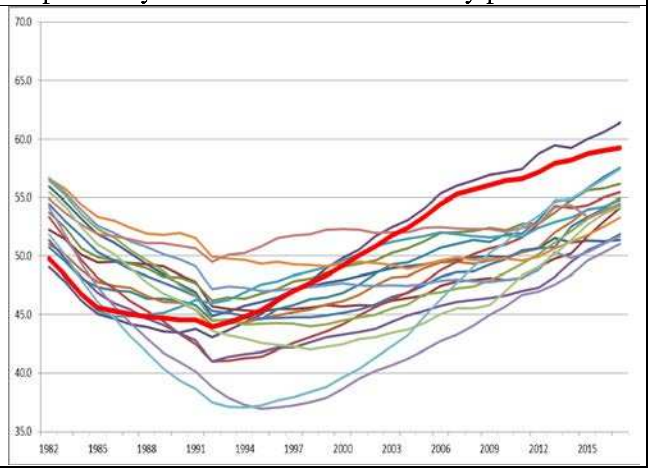
Dependency ratio across: Northen Italy provinces



Dependency ratio across: Centre Italy provinces:



Dependency ratio across: Southern Italy provinces



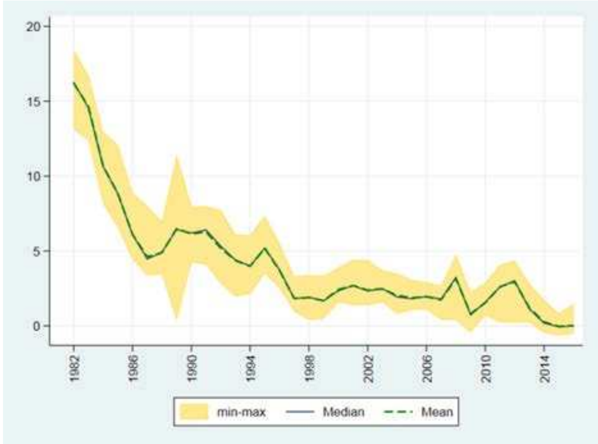
Source: Our elaborations, data described in the text.

Figure 13

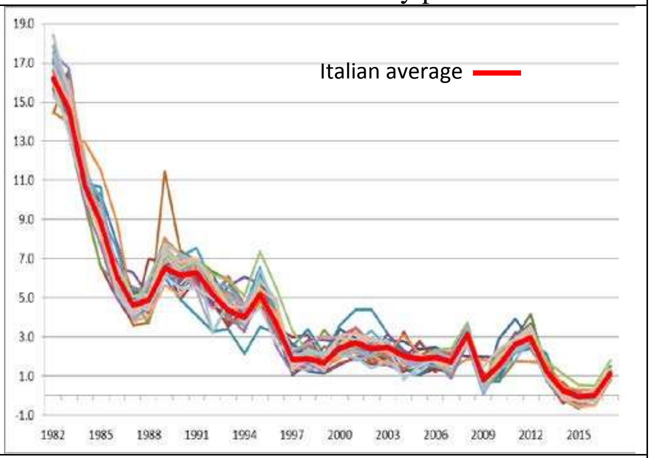
Inflation across provinces, 1982-2016

(percentages)

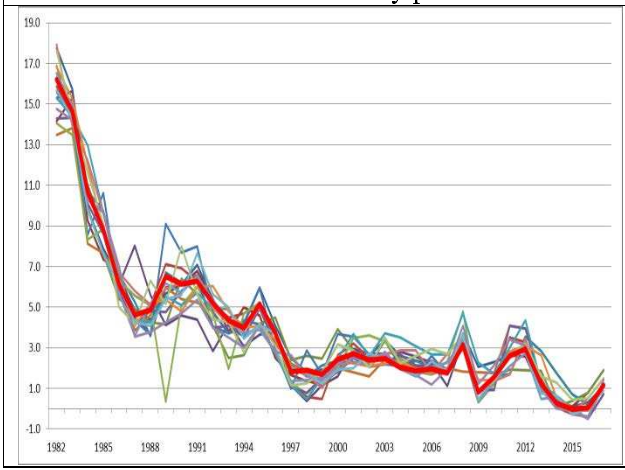
Inflation rate across Italian provinces



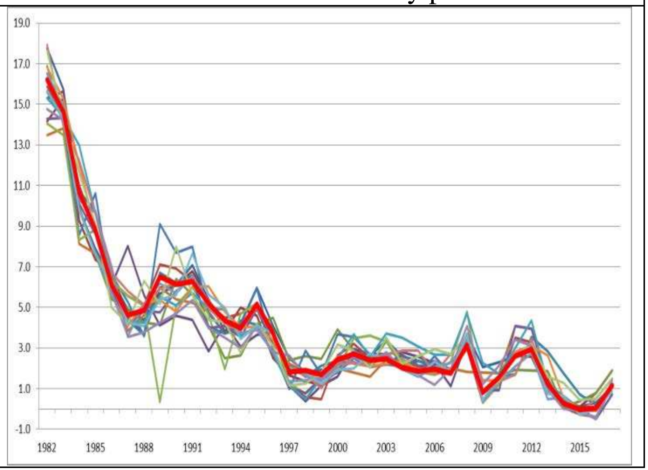
Inflation rate across: Northen Italy provinces



Inflation rate across: Centre Italy provinces:



Inflation rate across: Southern Italy provinces



Source: Our elaborations, data described in the text.

4.2 Empirical strategy

Unlike the most part of the existing literature, in order to assess the impact of demography on inflation we adopt a within-country perspective (rather than a cross country one), using the provincial capital inflation rates as dependent variable, to analyze the relative dynamics of local prices compared to national average. In this way we take into account more effectively the effect of monetary policy – which is, allegedly, the main driver of price dynamics over the medium-to-long run – and of the business cycle. Furthermore, the within-country approach allows us to wipe out the effects of supranational shocks which can have different impacts across countries and which are more homogeneous in a single country.

We estimate the following equation:

$$\pi_{p,t} = \alpha_1 \, D_{p,t} + \alpha_2 \Delta Pop_{p,t} + \alpha_3 \pi_{p,t-1} + \gamma_p + \delta_t + u_{p,t}$$

where the annual inflation for province p, at time t (our dependent variable) is denoted as $\pi_{p,t}$. The variable D is our explanatory demographic variable of interest, which in turn will be the *Working Age Population* (the population share aged >14 and <65), the *Dependency Ratio* (*DR*, the share of people aged <15 and >64 over the working age population), the *Old Age Dependency Ratio* (*OADR*, the share of people aged >64 over the working age population), the *Young Age Dependency Ratio* (*YADR*, the share of people aged <15 over the working age population). Pop is the provincial population (ΔPop is the yearly rate of change)[18].

We start by performing a standard pooled OLS and **panel estimates** with γ_p representing province fixed effects and, δ_t representing time fixed effects. Time fixed effect accounts for any time-varying common factor as, firstly, monetary policy and national business cycle, and secondly common external shocks. In some specifications we include the lagged inflation rate, $\pi_{p,t-1}$ to capture the high degree of inflation persistence, in these cases we perform Arellano-Bond (1991) estimates to account for possible endogeneity and for bias in the dynamic specification of inflation (Nickell-bias)[19].

We then extend our econometric analysis in order to explore the long-run relationships between demographics and inflation and we estimate a cointegrated panel. As previously said, demography has a slow moving trend and is likely to have an impact on inflation mostly at lower frequencies. In order to explore the role of demography as a possible structural driver of inflation at low-frequency, we use an **Error Correction Model in a panel cointegration** approach[20]. This approach also stands out as the most appropriate when the time dimension of the panel (*t*) is close to the cross-section one (*p*), and there is also evidence that the variables are not stationary over time[21]. If inflation and a set of variables are non-stationary but co-integrated (for each single province), then this relationship can be reparametrized in an error-correction form:

---

[18] Liu and Westelius (2016), in their cross-provincial analysis for Japan (limited to the 1990-2007 period), estimate the contribution on inflation of the shares of working age population (15-24, 25-44, 45-64) together with OADR. Feyrer (2007) first came out with this specification based on working age population shares in order to assess the impact of demography on productivity, using a large panel of countries.

[19] Another possible approach to deal with endogeneity when the time series dimension is of sufficient length is using a panel VAR setting (e.g. Ferrero et al. 2019).

[20] Breitung and Candelon (2006) show that a significant error correction term in a time domain specification amounts to a significant contribution of the low (zero) frequency to the dynamics of the variable of interest.

[21] It is in fact well assessed that with the increase of time observations in panel, non-stationarity can be a concern. First of all, the presence of unit roots in the variables can make the Arellano-Bond GMM estimator perform poorly (Roodman 2009). Second, standard inference for estimated coefficient can be incorrect (Entorf 1997).

$$\Delta\pi_{p,t} = -\alpha_1 (\pi_{p,t} - \beta_1 D_{p,t} - \beta_2 Pop_{p,t} - \beta_3 \Delta M2/GDP_t)_{t-1} + \alpha_2 \Delta D_{p,t-1} + \alpha_3 \Delta Pop_{p,t-1} + \alpha_4 \Delta\Delta M2/GDP_{t-1} + \varepsilon_{p,t}$$

where β_1 - β_3 are the long-run parameters (elasticities) and α_1 is the error-correcting speed of adjustment term. We include in each equation a macrovariable ΔM2/GDP, the ratio between Money (M2) and GDP in real terms as a proxy of the impact of monetary policy on inflation via a quantitative-equation channel[22], gauging also for the level of economic activity. If $\alpha_1 = 0$, then there would be no evidence for a long-run relationship. This latter parameter is expected to be significantly negative under the prior assumption that the variables show a return to a long-run equilibrium.

We firstly use the mean group estimator (MG) proposed by Pesaran and Smith (1995), where the intercepts, slope coefficients, and error variances are all allowed to differ across provinces[23]. In this specification each equation is estimated individually, a common time effect cannot be included and parameters are estimated as an average of individual coefficients[24].

To control for endogeneity[25] of right-hand variables in the long-run, we also estimate the cointegration relationship using another mean-group panel estimator: the dynamic OLS (*DOLS*) estimator (Pedroni, 2001), which controls for the endogenous feedback effects by augmenting the cointegrating regression with lead and lagged differences of the regressors.

5. Econometric analysis: results

5.1 Panel estimates

Table 3 shows the set of pooled OLS and panel estimates for each relevant demographic variable. As dependent variable we use the annual inflation (infl) of each single province capital.

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[22] Using a standard quantitative equation M·V=P·GDP, the well-known relationship between money, velocity of circulation, prices, real gross domestic product, for stable velocity of circulation, the following relationship (in growth rates) holds ΔP= ΔM-ΔGDP= Δ(M/GDP). This equation underlies for instance the quantitative reference value for the growth rate of the broad monetary aggregate in the ECB' first pillar monetary policy strategy. In the ECB formulation, however, the reference money aggregate is M3 (ECB 1999; Ferrero et al. 2011), while we use M2, the main reference aggregate of Italian monetary policy before the advent of euro (Barbiellini et al .2016), which not surprisingly turns out to be the most correlated with inflation (with respect to M1 and M3) in the whole period under scrutiny.

[23] Not constraining long-run elasticities to be equal across all panels, it makes the estimator consistent both in the hypothesis of slope homogeneity and in the case of heterogeneous slopes.

[24] We tried also by pre-transforming variables in differences from annual average, but this makes our inflation variable stationary, while long-run cointegration analysis lies on a set of non-stationary variables (see Pedroni 2001 on the impossibility of including a time effects in cointegrated panels).

[25] As Pesaran and Smith (1995) assume that regressors are exogenous, our estimation of the long-run relationship is likely to be biased.

For each demographic explanatory variable we present: pooled OLS, panel with province and time fixed effects, Instrumental Variable (IV) based on Arellano-Bond technique (AB) [26].

As regards our demographic explanatory variables the results are the following (Table 3):

a. The *dependency ratio* (DR) is significantly negatively correlated with inflation (ranging from -0.025 in FE2 fixed effects estimate to -0.061 in Arellano Bond-GMM estimates)[27].
b. The *old age dependency ratio* (OADR) is negative and significant in OLS and FE1 (province fixed effects); turns out to be not significant when considering time fixed effects and using the AB estimator.
c. The *young age dependency ratio* (YADR) is positive and significant in OLS and FE1 (province fixed effects), turning negative introducing time fixed effects in FE2 and in AB.
d. The share of *working age population* (q1564) is positive and significant in OLS and in both FE estimates (0.057 in FE2), but not significant in AB estimates.

Additionally, common features across all the estimates are the following: OLS and panel estimates are always statistically equivalent; all the models do not reject the hypothesis that fixed effects are equal to a unique constant term (F-test: FE=0) and the fixed-effects turns out to be almost always orthogonal to the regressors (corr~0); inflation turns out to be quite persistent with a significant positive autoregressive component.

All in all, this short-term analysis returning results not adequately robust – while in line with the expected negative impact of ageing process on inflation – suggests the idea that demography affects inflation at lower frequencies rather than having an year-on-year impact. Thus, we perform a cointegration analysis in order to sort out a possible long-run relationship.

5.2 Cointegration estimates

To explore the long-run relationship between demographics and inflation, thanks to the long-time span covered by our panel data we now perform a cointegration analysis.

Thus, firstly, we analyze the long-run properties of our series by running some stationary tests.

A set of standard unit root tests for panel data actually confirm that the inflation (linfl), dependency ratio (*ldr*), the old age dependency ratio (*loadr)* and the working age population

[26] Unfortunately, lagged variables fail to be a good instrument since they are not orthogonal to the errors and do not have enough explanatory power of the contemporary variables; the construction of better external instruments for our demographic ratios is still in progress.

[27] Ferrero et al. (2019) yield a similar coefficient on this demographic variable (-0.07) in a panel VAR setting for the Euro area countries.

share (*lq1564*) are not stationary; the evidence is weaker for population (*lpop*) and the young age dependency ratio (*yadr)* (Table 4) [28]. Additionally, all the series exhibit high level of persistence. The test for unit root is also accepted for M2/GDP growth variable.

In the presence of non-stationary data, we search a cointegration relationship among inflation and each demographic variable. In this specification, we include the monetary policy M2/GDP variable.

Cointegration tests (Table 5) suggest that our variables are cointegrated (the null hyphotesis of no cointegration is generally strongly rejected, except for weaker evidence for *oadr*).

Hence, we firstly perform Mean Group (MG) estimates (Table 6). Then we run DOLS estimates (Table 7), in order to correct for endogeneity in the long-run coefficients[29]. Inflation is the dependent variable. Along with our demographic variables, we introduce as additional control variables – along with population – the change in the ratio M2/GDP in order to account for the monetary nature of inflation in the long run, according to quantitative theory of money, gauging also for the level of economic activity[30].

When we correct long-run coefficients for the endogeneity bias using DOLS estimates, we obtain (Table 7):

a. a robust negative relationship between inflation and the *dependency ratio* (*ldr; -2.4)*
b. a negative contribution of the *old age dependency ratio* (*loadr; -2.0*)
c. a negative coefficient for the *young age dependency ratio*, amid an only weakly cointegrated relationship between inflation and this demographic variable (*lyadr; -0.6*);
d. the share of working age population *(lq1564*) has a positive effect on inflation (6.6).

Finally, the sign of monetary variable (*dlM2/GDP*) results positive.

[28] All the variables in this section are log-transformed. To manage some negative values for inflation (infl) expressed in percentage points, in some provincial capitals in recent crisis years, we applied the following transformation: linfl=log(infl+1).

[29] To test for exogeneity of demographic variables, we run an error-correction specification where the demographic variable is the dependent variable, in the vein of Canning and Pedroni (2006) and Bronzini and Piselli (2009). Although the ECM and the short-term coefficients of inflation are significant, the coefficients are very small (close to zero) with respect to the others in the long as well as in the short run. Hence, if any, endogeneity of demographic variables is not a big issue in our estimates.

[30] We also used the monetary policy interest rate obtaining similar results. Moreover, we performed Mean Group Estimates with time effects (Pedroni 2011), obtaining results for our demographic variables similar to those with monetary variables. However, as emphasized by Pedroni himself, including time effects could "destroy" (in his words) the cointegration relationship, making some variable stationary (as in our case it appears to happen to the inflation variable).

In MG estimates, long-run elasticities for our demographic explanatory variables exhibit mostly the same sign and similar magnitude as in Pedroni's (with the exception of *yard*).[31]

According to DOLS estimates, the negative relationship between the inflation rate and the *dependency ratio* implies that in the long run a 1 per cent increase in the DR determines a 2.4 per cent decrease in inflation[32]. This would suggest that in the period 1982-2014, when average inflation in Italy dropped 16 percentage points from 16.2 to 0.3%, the increase (from 49.8 to 58.2%) of the dependency ratio might have been responsible for more than one-third of the overall decrease in inflation, a magnitude in line with other author's findings[33].

6. Conclusions

Some studies have recently examined the long-term relationship between the changes in the demographic structure and price dynamics mainly carrying out *cross-country* empirical analyses and reaching heterogeneous results.

This paper started by documenting demography and inflation dynamics since the beginning of the twentieth century for Italy in international comparison, and then showed how the evolution of the demographic structure has influenced the dynamics of prices using annual data for a panel of Italian provinces along four decades since early 1980s. The *within-country* approach we adopt wipes out problems of *cross-country* analysis, related to the effects of different national monetary policies – main drivers of price dynamics in the medium term. It also allows results to be less distorted by unidentified supranational or nation-specific economic shocks.

In order to measure how changes in prices have been influenced by changes in the demographic structure, the latter measured by a set of ratios (dependency, old age, young age, working age population), both panel estimates (with year and province fixed effects) and cointegration estimates are used. Cointegration analysis allowed us to look at the long-term relationship between demographic change and inflation, following the idea that demography has

[31] Table 6 reports also short-term coefficients of lagged differenced variable (D_). In the MG estimation, without a correction for endogeneity, the sign of dlM2/GDP turns negative in the long run, showing both signs in the short-run, often not significant.

[32] We refer to the dependency ratio since DR combines and summarizes the overall underlying changes in the demographic structure.

[33] In particular, according to Juselius and Takats (2016, p. 9), the age structure effects capture a large part of trend inflation (with a negative sign for working age population): "The estimated age-structure effect […] explains the low-frequency evolution of inflation well, not only on average, but even in individual countries […]. 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".

a slow moving trend and is likely to impact inflation mostly at low frequencies. The results obtained, while showing that short-term effects of demographic factors are not entirely robust, imply that the deep changes in the demographic structure would have contributed to dampen price dynamics in the long term.

As in Bobeica et al (2017, p.21), “this paper did not aim to shed light on the various mechanisms through which demographics impact inflation”, but the reduced-form evidence we produced “supports theories that point to a net deflationary impact of demographic change”. From 1982 to date, average inflation in Italy fell by 16 percentage points from 16.2 to 0.3% per year, while the dependency ratio, which summarizes the overall change in the age structure, increased from 49.8 to 58.2%. Based on our estimates, demographic change gave a significant contribution to the observed decrease in the rate of inflation. Given the prevailing demographic trends, these results suggest that demography may also contribute in the next future to keep aggregate price dynamics subdued.

Bibliografia

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

Andrews, D., J. Oberoi, T. Wirjanto, C. M. Zhou (2018) Demography and Inflation: An International Study, North American Actuarial Journal 22 (2), 210-22.

Baffigi, A. (2013), National Accounts 1861-2011, in Toniolo, G. (ed.) (2013) *The Oxford Handbook of the Italian Economy Since Unification*, Oxford University Press, NY.

Barbiellini Amidei, F., R. De Bonis., M. Rocchelli, A. Salvio, M. Stacchini (2016), La moneta in Italia dal 1861: evidenza da un nuovo dataset, in Questioni di Economia e Finanza (Occasional Papers) 328, Banca d'Italia.

Barbiellini Amidei, F., M. Gomellini, P. Piselli (2018), Il contributo della demografia alla crescita economica: duecento anni di "storia" italiana, in Questioni di Economia e Finanza, (Occasional Papers) 431, Banca d'Italia.

Bank for International Settlements (2018), *Long consumer prices database*, www.bis.org/statistics/cp.htm

Benati, L. (2009), Long-Run Evidence on Money Growth and Inflation, ECB Working Papers, n. 1027, March

Bloom, D.E., D. Canning, J. Sevilla (2001), "Economic growth and the demographic transition", NBER WP 8685.

Bloom, D.E., D. Canning, J. Sevilla (2003), The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change, Population Matters Monograph MR-1274, RAND, Santa Monica.

Bobeica, E., E.Lis, C. Nickel, Y.Sun (2017), *Demographics and inflation*, ECB WP n. 2006.

Börsch-Supan, A. (2003), "Labor market effects of population aging", Labour, Vol. 17, pp. 5-44.

Brandolini, Vecchi (2013), *Standards of Living*, in G. Toniolo (Ed.), *The Oxford Handbook of the Italian Economy Since Unification*, Oxford University Press, New York.

Breitung J., Candelon B. (2006), *Testing for short- and long-run causality: A frequency-domain approach*, Journal of Econometrics, 132 (2), 305-546.

Bronzini R., Piselli P. (2009), *Determinants of long-run regional productivity with geographical spillovers: The role of R&D, human capital and public infrastructure*, Regional Science and Urban Economics 39, pp. 187–199☆

Bullard, J., Garriga, C., Walker, C. J. (2012), Demographics, Redistribution, and Optimal Inflation. Federal Reserve Bank of St. Louis Review, 94(6), 419–439.

Canning, D., Pedroni, P., (2004), *The effect of infrastructure on long-run economic growth,* The Manchester School, 76(5), Special Issue, pp. 504–527.

Ciccarelli, C., M. Gomellini, P. Sestito (2018), "Age structure and productivity in Italy", mimeo.

Carvalho, C., A. Ferrero, F. Nechio (2016), "Demographics and Real Interest Rates: Inspecting the Mechanism", *European Economic Review*, volume 88, September, pp. 208-226.

de Motes, J. M. (2013), La inflación en España. Un índice de precios de consumo, 1830-2012, Estudios de Historia Económica, N.º 64, Banco de España.

ECB (1999), "The stability-oriented monetary policy strategy of the Eurosystem", European Central Bank, Monthly Bulletin (January).

Entorf H. (1997) Random walks with drifts: Nonsense regression and spurious fixed-effect estimation, *journal of Econometrics*, 80(2), 287-296.

Eurostat (2018), Population data, Luxembourg.

van Ewijk, C., Volkerink, M. (2012), "Will ageing lead to a higher real exchange rate for the Netherlands?", De Economist, Vol. 160, pp. 59-80.

Favero, C. A., V. Galasso (2015), "Demographics and the Secular Stagnation Hypothesis in Europe", CEPR D.P., n. 10887.

Ferrero G., Nobili A., P. Passiglia (2011), "Assessing excess liquidity in the euro area: the role of sectoral distribution of money", Applied Economics, 2011, 43, 3213–3230

Ferrero, G., M. Gross. S. Neri (2019), "On secular stagnation and low interest rates: demography matters", International Finance, forthcoming.

Feyrer, J. (2007), "Demographics and productivity", Review of Economics and Statistics, v. 89, Issue 1, p.100-109, February.

Fürnkranz-Prskawetz, A. (2015), "Demographic change and economic growth", Oesterreichische Nationalbank, 43rd Economics Conference.

Gajewski, P. (2015). Is ageing deflationary? Some evidence from OECD countries. Applied Economics Letters, 22(11), 916–919.

Gordon, R. (2015), "Secular stagnation: a supply-side view", *American Economic Review: Papers & Proceedings*, 105(5): 54–59.

Groneck, M. Kaufmann, C. (2017), "Determinants of Relative Sectoral Prices: The Role of Demographic Change", Oxford Bulletin of Economics and Statistics, Vol. 79, pp. 319-347.

Statistics Bureau of Japan (2018), *Historical Statistics of Japan*, http://www.stat.go.jp/english/data/chouki/index.html.

Istat, Annuario Statistico Italiano, Rome, various years.

Istat, Popolazione e movimento anagrafico dei comuni, Rome, various years.

Istat, Annuario di statistiche demografiche, Rome, various years.

Istat, Ricostruzione Intercensuaria della popolazione per età e sesso al 1 gennaio, Rome, various years.

Istat, Censimento generale della Popolazione, Rome, various years.

Istat (1984) Indici dei prezzi al consumo per le famiglie di operai e impiegati, 1861 -1983, Collana di Informazioni, Anno VIII, n°1.

Istat (2012), *Sommario di Statistiche Storiche (1861-2010)*, cap.10, Roma.

Istat (2017), Il futuro demografico del paese, Previsioni regionali della popolazione residente al 2065, *Statistiche, Report,* 27 aprile 2017.

Juselius, M., Takáts, E. (2015). Can demography affect inflation and monetary policy? BIS Working Papers, No 485.

Juselius, M., Takáts, E. (2016). The age-structure-inflation puzzle. Bank of Finland Research Discussion Paper 4/2016.

Juselius, M., Takáts, E. (2018). The enduring link between demography and inflation, BIS Working Papers, No 722.

Katagiri, M., Konishi, H., Ueda, K. (2014). Aging and deflation from a fiscal perspective. Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute, Working Paper No. 218.

Keynes, J. M. (1937), "Some Economic Consequences of a Declining Population," Eugenics Review, Vol.19, pp. 13–17.

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

Lindh, T,A. Prskawetz (Eds) (2006), "The impact of ageing on innovation and productivity growth in Europe" Research Report 28, Vienna Institute of Demography, Austrian Academy of Sciences.

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

Liu, Y., N. Westelius (2016) The Impact of Demographics on Productivity and Inflation in Japan, IMF WP/16/237.

Livi Bacci, M. (2001), "Demographic shocks: the view from history", paper presented at the FED Boston Conference "Seismic Shifts: The Economic Impact of Demographic Change".

Lührmann, M. (2005), "Population aging and the demand for goods & services", MEA Discussion Papers, No 95-2005, University of Mannheim.

Maddison, A. (2009), Historical Statistics of the World Economy: 1-2008 AD, in http://www.ggdc.net/maddison/oriindex.htm

Mitchell, B.R. (2007a), International historical statistics 1750-2005 : Europe, Basingstoke : Palgrave Macmillan.

Mitchell, B.R. (2007b), International historical statistics 1750-2005 : Africa, Asia and Oceania, Basingstoke: Palgrave Macmillan.

Mitchell, B.R. (2007c), International historical statistics 1750-2005 : Americas, Basingstoke : Palgrave Macmillan.

Nerlich, C. J. Schroth (2018), The economic impact of population ageing and pension reforms, ECB Economic Bulletin, Issue 2, pp. 85-109

OECD (1989), *OECD Employment Outlook 1989,* OECD Publishing, Paris.

OECD (2016a), Historical population data and projections (1950-2050), https://stats.oecd.org/Index.aspx?DataSetCode=POP_PROJ

OECD (2016b), *Ageing and Employment Policies - Statistics on average effective age of retirement*, OECD, Paris.

OECD (2017), *Education at a Glance 2017. OECD Indicators*, OECD Publishing, Paris.

Pagano, P., M. Sbracia (2014), "The secular stagnation hypothesis: a review of the debate and some insights", Bank of Italy, Occasional Papers n. 231.

Pedroni, P. (2001) Purchasing power parity tests in cointegrated panels, Review of Economics and Statistics 83, 727–731.

Pesaran, M. H., Y. Shin, R. P. Smith (1997). Estimating long-run relationships in dynamic heterogeneous panels. *DAE Working Papers Amalgamated Series* 9721.

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

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

Roodman D. (2009), How to do xtabond2: An introduction to difference and system GMM in Stata, *The Stata Journal* 9, Number 1, pp. 86–136.

Shirakawa, M. (2011), Bubbles, Demographic Change and Natural Disasters, Opening Speech at 2011 Annual Int. Conference – Institute for Monetary and Economic Studies, Bank of Japan, June 1.

Statistics Bureau (2012), Historical Statistics of Japan, Ministry of Internal Affairs, Tokyo.

Statistics Canada (2017), *Population estimates*, Ottawa.

Summers L.H. (2014), U.*S. Economic Prospects: Secular Stagnation, Hysteresis, and the Zero Lower Bound*, Business Economics, 49(2).

Summers, L.H. (2016), *The Age of Secular Stagnation*, Foreign Affairs, 95(2), March/April.

Toniolo, G. (ed.) (2013) *The Oxford Handbook of the Italian Economy Since Unification*, Oxford University Press, NY.

UN Department of Economic and Social Affairs (2017), *The World Population Prospects*, New York.

Westerlund, J. 2007. Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics* 69: 709–748.

Westerlund J., Persyn D. (2008), Error-correction–based cointegration tests for panel data, *The Stata Journal* 8, Number 2, pp. 232–241.

Woodford, M. (1995), Price-level determinacy without control of a monetary aggregate. Carnegie-Rochester Conference Series on Public Policy, Volume 43, December, Pages 1-46.

World Bank (2018), Population estimates based on United Nations Population Divisions World Population Prospects, Washington.

Table 1

Empirical studies about the impact of demographic changes on inflation

Authors	Title	Methodology	Unit of observation	Period	Demograpic explanatory variables	Effect of ageing on inflation
Lindh and Malberg (2000)	*Can age structure forecast inflation trends?*	Panel data analysis	20 Countries	1960-1994	Share > 65	Positive
Juselius and Takats (2016)	*The age-structure–inflation puzzle*	Panel data analysis	22 advanced economies	1955-2014	Dependency ratio	Positive
Bullard et al (2012)	*Demographics, Redistribution, and Optimal Inflation*	OLG-based simulations	-	-	Young age and Elderly shares	Negative
Yoon et al (2014)*	*Impact of Demographic Changes on Inflation*	Panel data analysis	30 Countries Japan	1960-2013	Share > 65	Negative
Anderson et al (2014)	*Is Japan's Population Aging Deflationary?*	GIMF model- based simulations	Japan	1991-2001	Elderly share	Negative
Gajewsky (2015)	*Is ageing deflationary? Some evidence from OECD countries*	Panel data analysis	34 OECD Countries	1970-2013	Old Age Dependency ratio, OADR	Negative
Broniatowska (2017)	*Population Ageing and Inflation*	Panel data analysis	32 OECD Countries	1971-2016	OADR	Negative
Bobeica (2017)	*Demographics and inflation*	Cointegrated VAR	Euro Area	1975-2016	Working Age Pop	Negative
Liu and Westelius (2016)	*The Impact of Demographics on Productivity and Inflation in Japan*	Panel data	Japan Prefectures	1990-2007	OADR	Negative
Katagiri (2014)	*Aging and Deflation from a Fiscal Perspective*	OLG-based simulations	Japan	1970-2010	- Higher Longevity - Lower Birth rate	Negative Positive
Doug et al (2016)	*Demography and Inflation: An International Study*	Panel data analysis VAR model	22 countries OECD	1955-2010 (sub-periods)	Full age-structure	Mixed (periods and methodology)
Ferrero, Gross and Neri (2019)	*On secular stagnation and low interest rates: Demography matters*	Panel VAR	Euro Area	1990-2015	Dependency ratio	Negative

Table 2

Descriptive statistics

(1982-2016; units and percentages)

	Inflation	Dependency ratio	Old age dependency ratio	Young age dependency ratio	Working age pop. (share)	Population growth rate
	(Infl)	*(dr)*	*(oadr)*	*(yadr)*	*(q1564)*	*(dppop)*
Obs	2590	2590	2590	2590	2590	2516
Mean	4.1	50.3	30.1	20.2	66.6	-0.2
Stand. Dev.	3.7	6.3	7.9	4.6	2.7	1.0
Min	-0.6	36.9	12.6	12.2	59.5	-10.9
Max	18.4	68.1	48.7	43.5	73.0	8.6

Table 3

Panel estimates, 1982-2016

(Dependent variable: inflation)

Variables	OLS	FE1	FE2	IV-AB	OLS	FE1	FE2	IV-AB	OLS	FE1	FE2	IV-AB	OLS	FE1	FE2	IV-AB
Inflation (t-1)	.745***	.737***	.221***	-.097***	.729***	.67***	.232***	.225***	.761***	.749***	.215***	.214***	.745***	.737***	.221***	.213***
Pop. Growth	-.094***	-.068***	-.041***	-.04**	-.138***	-.062***	-.063***	-.061***	-.175***	-.219***	-.033**	-0.027	-.093***	-.068***	-.04***	-0.028
DR	-.036***	-.047***	-.025***	-.061***												
OADR					-.032***	-.081***	-0.0057	0.031								
YADR									.014**	.032***	-.037***	-.033***				
Q1564													.081***	.106***	.057***	0.09
Const	2.38***	2.96***	1.51***		1.61***	3.37***	0.247		.211*	-0.096	.76***		-4.84***	-6.44***	-3.57***	
Obs	2516	2516	2516	2442	2516	2516	2516	2442	2516	2516	2516	2442	2516	2516	2516	2442
R2	0.86	0.861	0.962		0.861	0.866	0.961		0.857	0.857	0.962		0.86	0.861	0.962	
F-test (α_i=0)		0.204	1.57			1.39	1.41			0.207	1.72			0.274	1.57	
Corr (X,α_i=0)		-0.023	0.0037			-0.121	0.012			-0.021	-0.012			-0.023	0.0038	
Prov FE		X	X	X		X	X	X		X	X	X		X	X	X
Time FE			X	X			X	X			X	X			X	X

Notes: FE1: estimates with province fixed effects; FE2: estimates with province and time fixed effects; IV-AB Arellano-Bond's(1991). Difference GMM; Robust estimates; Robust s.e.; *, ** and *** denote statistical significance at the 10%, 5% and 1% level respectively.

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Table 4

Unit roots tests

(data in levels log-transformed; 1982-2016)

Unit root test	Statistic	p-value	Statistic	p-value	Statistic	p-value
Variable	INFL		POP		DR	
Levin-Lin-Chu (1)	-6.38	0.00	-11.40	0.00	-5.41	0.00
Im-Pesaran-Shin (1)	0.96	0.83	-2.39	0.01	3.06	0.99
Breitung (1)	9.49	1.00	-4.72	0.00	3.63	0.99
Hadri LM test (2)	53.03	0.00	50.74	0.00	53.27	0.00
Variable	OADR		YADR		Q1564	
Levin-Lin-Chu (1)	-13.93	0.00	-23.57	0.00	-3.91	0.00
Im-Pesaran-Shin (1)	-1.09	0.14	-19.03	0.00	4.16	1.00
Breitung (1)	3.59	0.99	-10.35	0.00	3.45	1.00
Hadri LM test (2)	62.14	0.00	32.08	0.00	53.81	0.00

Notes:(1) H0: Panel contains a unit root/H1: Panel is stationary; (2) H0: Panel is stationary; H1: Panel contains a unit root.

Table 5

Cointegration tests

(Tests of cointegration between log levels of inflation, population, M2/gdp growth and the corresponding demographic variables)

Test	Statistic	p-value	Statistic	p-value
	DR		OADR	
Gt	-2.44	0.03	-2.58	0.00
Ga	-7.32	1.00	-9.03	0.99
Pt	-17.97	0.08	-20.06	0.00
Pa	-7.68	0.38	-10.72	0.00
	YADR		Q1564	
	Statistic	p-value	Statistic	p-value
Gt	-2.60	0.00	-2.47	0.01
Ga	-5.87	1.00	-7.42	1.00
Pt	-17.03	0.31	-18.06	0.07
Pa	-6.39	0.91	-7.78	0.33

Notes: Results for H0: no cointegration. Ga, Gt: group mean estimator; Pa, Pt: panel estimator. See Westerlund (2007) and Westerlund and Persyn (2008).

Table 6

Mean-Group estimates

(Error correction model under cointegration. Log-transformed variables
Dependent variable: inflation; 1982-2016)

Expl. variables	Coef.	z	p-value		Coef.	z	p-value
Long-run				**Long-run**			
lpop	-4.65	-0.80	0.42	lpop	-10.11	-0.87	0.38
dlM2/GDP	-5.10	-3.43	0.00	dlM2/GDP	-7.24	-2.53	0.01
ldr	-2.44	-2.53	0.01	lyadr	1.29	1.59	0.11
Short-run				**Short-run**			
L.ecm	-0.42	-20.30	0.00	L.ecm	-0.37	-17.95	0.00
d.ldr	-4.70	-4.87	0.00	d.ldr	-2.18	-2.82	0.01
d.dlM2/GDP	0.06	0.21	0.84	d.dlM2/GDP	0.38	1.72	0.09
d.lpop	-3.60	-2.09	0.04	d.lpop	-6.21	-3.50	0.00
L.d.ldr	-3.79	-3.59	0.00	L.d.lyadr	-1.53	-1.58	0.11
L.d.dlM2/GDP	-1.59	-7.23	0.00	L.d.dlM2/GDP	-1.37	-8.35	0.00
L.d.lpop	-1.91	-1.62	0.11	L.d.lpop	-3.56	-2.50	0.01
Const	45.68	5.03	0.00	Const	46.89	3.82	0.00
Long-run				**Long-run**			
lpop	7.21	0.50	0.62	lpop	-8.33	-3.51	0.00
dlM2/GDP	-5.89	-2.86	0.00	dlM2/GDP	-3.87	-3.48	0.00
loadr	-1.74	-1.25	0.21	lq1564	8.32	3.34	0.00
Short-run				**Short-run**			
L.ecm	-0.48	-20.46	0.00	L.ecm	-0.42	-20.32	0.00
d.loadr	-2.60	-4.29	0.00	d.lq1564	11.60	4.03	0.00
d.dlM2/GDP	0.31	1.08	0.28	d.dlM2/GDP	-0.26	-1.10	0.27
d.lpop	-4.05	-2.66	0.01	d.lpop	-3.29	-5.11	0.00
L.d.loadr	-0.64	-1.18	0.24	L.d.lq1564	14.90	4.61	0.00
L.d.dlM2/GDP	-1.47	-6.79	0.00	L.d.dlM2/GDP	-1.74	-9.19	0.00
L.d.lpop	-0.62	-0.61	0.54	L.d.lpop	-1.81	-1.41	0.16
Const	56.09	5.27	0.00	Const	33.92	3.27	0.00

Notes: Mean Group estimator by Pesaran and Smith (1995): the intercepts, slope and error variances are all allowed to differ across groups. The long-run cointegrating vector is normalized on inflation with a coefficient of -1 (not in table). Error-correction terms (ecm) enter the equation as lagged variables (L.); the other short-term variables are differenced (d.).

Table 7

Panel dynamic OLS

(Cointegration vectors. Log-transformed variables. Dependent variable: inflation; 1982-2016)

Equation	Coef	t-stat
lpop	-.19	0.538
dlM2/GDP	3.94	15.48
ldr	-2.41	-22.91
lpop	1.97	7.61
dlM2/GDP	2.65	12.44
loadr	-1.98	-24.18
lpop	-.54	0.740
dlM2/GDP	6.21	20.52
lyadr	-0.64	-4.64
lpop	0.18	1.88
dlM2/GDP	3.80	15.22
lq1564	6.63	20.84

Notes: Pedroni's (2001) group mean Panel Dynamic Ordinary Least Squares estimates.