Much Ado About Something? Demographics, Inflation and Asset Prices

- The world is aging rapidly, with retiring baby boomers, falling fertility and rising life expectancy as the key drivers.
- Over the next decade, we expect the following directional impacts from demographics:
  - **US**: downward pressure on stock valuations, upward pressures on inflation and real bond yields
  - **World**: stable inflation, downward pressures on real bond yields and stock valuations.
- We find that demographics alone explain only a small proportion of the variation in inflation and asset prices over time and across countries. Moreover, the magnitudes of the demographic impacts we estimate are dwarfed in size by both cyclical fluctuations and the magnitudes found in comparable studies (RHS Exhibit below). We have strong confidence in this statement of relative magnitude, but acknowledge that the exact numbers are estimated with significant uncertainty.
- Although existing studies on demographics, inflation and asset prices often predict large demographic impacts, they also frequently contradict each other in terms of both direction and timing. These inconsistencies reflect the challenges of identifying demographic impacts in the data due to the numerous channels through which demographics may be affecting inflation and asset prices, and the limited statistical power to accurately estimate them. We address these issues by using data across many countries and by modelling the entire demographic structure of a population instead of relying on simple and/or incomplete summary measures, as some earlier studies have done.
- We argue that the estimated impacts depend on how we measure demographics (LHS Exhibit below). While most studies measure demographics by segmenting people into fixed age groups, we show that human behavior adjusts as life expectancy extends so that grouping people by the percentage of their expected lifetime lived up gives a better description of actual behavior and is therefore a more accurate assumption to make for impact projections.

**THE AMOUNT OF AGING OBSERVED DEPENDS ON HOW WE MEASURE DEMOGRAPHICS**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>% of World Population</th>
<th><em>65+ age group</em></th>
<th>333% (1952-2097)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>79% of expected lifetime lived up</em></td>
<td>90% (1952-2097)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>80% of expected lifetime lived up</em></td>
<td>1200% (1952-2097)</td>
</tr>
</tbody>
</table>

**THE DEMOGRAPHIC IMPACTS WE ESTIMATE ARE DWARFED IN SIZE BY BOTH CYCLICAL FLUCTUATIONS AND WHAT OTHER COMPARABLE STUDIES HAVE FOUND**

**US**

<table>
<thead>
<tr>
<th>Measure</th>
<th>2017-27 Max abs demographic chg</th>
<th>2017-50 Max abs demographic chg</th>
<th>2007-16 Absolute peak-to-trough chg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation (%)</td>
<td>0.4</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Real 10Y Govt Bond Yield (%)</td>
<td>1.0</td>
<td>1.3</td>
<td>3.5</td>
</tr>
<tr>
<td>S&amp;P500 LTM P/E</td>
<td>5.6</td>
<td>1.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Comparative existing study**

- *Comparisons are for illustrative purposes only since, except for inflation, there are slight differences in the definitions of the variables (cf. p.3 for more details).


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Executive Summary

Economists have a long tradition of scaring people with demographics. In 1798, Thomas Malthus predicted that population growth would quickly outpace food production, leading to famines. This never happened; the world population increased from 1bn in 1804 to 7bn in 2011.

Today, the massive and accelerating aging of the world population has generated significant controversy about whether this demographic shift is inflationary or deflationary, and whether it puts upward or downward pressures on asset prices. Some of the existing demographic impact predictions are worryingly large, with studies often contradicting each other.

These conflicting views are not here by chance. Our ability to estimate the impacts of demographics on inflation and asset prices is limited by our reliance on the past experiences of certain countries. This is especially problematic in the case of asset prices for which few countries have reliable historical data.

The issue is exacerbated by the fact that some studies rely on simple and/or incomplete summary measures of the demographic structure of a population, which cannot capture the complex relationship between demographics, inflation and asset prices, illustrated in Exhibit 1. For instance, we exert upward pressures on stock valuations in the middle part of our lives when we invest primarily in stocks. However, these pressures turn negative as we start rebalancing our portfolios towards safer assets and dis-save in order to finance consumption in retirement.

Another crucial point often missing from the “demographics debate” is that predictions depend heavily on how we measure demographics. Although most studies rely on grouping people into fixed age groups, we show that human behavior adjusts as life expectancy increases, so that when comparing behavior over time and across countries and making projections, it is better to look at the people with the same proportions of expected lifetime lived up than those with the same ages in years.

Designing an approach to measure demographics that addresses both issues, we estimate demographic impacts using data covering around 100 countries for inflation and 30 countries for asset prices. Acknowledging the uncertainty in the precise impact estimates, we find that:

1. Demographics alone explain only 16%, 15% and 9% of the variation over time and across countries in annual inflation, real bond yields and stock price-to-earnings (P/E) ratios, respectively. Hence, the explanatory power assigned to demographics is probably often exaggerated.
EXHIBIT 2: DEMOGRAPHIC IMPACTS IN THE USA MEANINGFUL BUT LIKELY TO BE DWARFED BY CYCLICAL CHANGES

Demography-based predictions for the US and size of demographic changes relative to cyclical fluctuations

2. In the US, over the next decade, demographics could lift inflation by 40 bps and real bond yields by 70 bps, while lowering the stock P/E ratio by 1.3 pts (cf. Exhibit 2, LHS). However, these effects are likely to be dwarfed by cyclical fluctuations. To illustrate this point, the figure on the right-hand side in Exhibit 2 contrasts future demographic effects with the absolute peak-to-trough changes experienced over the cycle since 2007.

3. The demographic impact magnitudes we find are small relative to the predictions of comparable studies. For instance, the figure on the LHS in Exhibit 3 shows the changes in our demography-based inflation predictions for 22 advanced economies. On average, between 2010 and 2050, we forecast demographics to lift inflation in these countries by 1pp – significantly less than the 4pp average inflationary pressure predicted for the same 22 countries by BIS (2015).

This paper reveals how we reached these predictions. We start by shedding light on current demographic developments around the world, then explain our approach to measuring demographics, illustrate the complex relationship between demographics, inflation and asset prices that appears in the data, and finally, analyze our results. The Appendix contains our demography-based predictions for major economies and details about our estimation results and methodology.

EXHIBIT 3: WE FIND SMALLER DEMOGRAPHIC EFFECTS THAN OTHER COMPARABLE STUDIES

*Comparisons are with BIS (2015) for inflation, Aksoy et al. (2015) for the real bond yield and FRBSF (2011) for the stock P/E ratio. They are for illustrative purposes only since, except for inflation, there are slight differences in the definitions of the variables. For instance, we define the real bond yield as the long term government bond yield minus realized one-year inflation, whereas Aksoy et al. (2015) use the real short interest rate.

Why Demographics?

The world population is aging rapidly; according to the United Nations, between 1952 and 2097, the share of people on our planet aged 65+ is projected to increase by 333%.

Although aging is not a novel phenomenon, Exhibit 4 shows that it is in the process of accelerating. Over the past 20 years, the age group that experienced the largest gain in the share of the world population were the 50-54 year-olds. Over the next 20 years, the first place will go to the 70-74 year-olds.

EXHIBIT 4: AGING IS IN THE PROCESS OF ACCELERATING
Percentage points (pp) changes in the shares of world population by 5-year age groups

Sources: United Nations, World Population Prospects: The 2017 Revision, Goldman Sachs GPS

This world aggregate, however, conceals a significant amount of heterogeneity at the country level. As illustrated in Exhibit 5, aging has, so far, mainly affected advanced economies. Japan is currently the country with the highest percentage of population aged 65+: 27% in 2017.

EXHIBIT 5: SO FAR, AGING HAS MAINLY BEEN A STORY OF ADVANCED ECONOMIES...
Percentage of population aged 65+ in 2017

Sources: United Nations, World Population Prospects: The 2017 Revision, Goldman Sachs GPS

Exhibit 6, however, shows that aging is spreading to developing countries. For instance, between 2017 and 2050, the share of population aged 65+ is expected to rise by 15.7 pp in China and by 14.4 pp in Brazil. The largest increases should happen in South Korea (+21.4 pp) and Taiwan (+21 pp.).
EXHIBIT 6: ... BUT IS BECOMING INCREASINGLY IMPORTANT IN MANY DEVELOPING COUNTRIES
Percentage points increase in the share of population aged 65+ between 2017 and 2050

The 3 main drivers of aging

Although the degree of impact varies from country to country, the three key drivers of aging are:

1. Retiring baby boomers. This factor is especially important in advanced economies, most of which experienced “baby booms” after WWII. In the US, for instance, baby boomers correspond to the over 70m people born between 1946 and 1964. This generation started entering retirement age (65+) in 2011 and will continue doing so until 2029. However, few baby boomers are expected to survive the early 2060s.

2. A fall in fertility. The number of children per woman in the world has halved since 1952. However, as illustrated in Exhibit 7, it is not projected to fall significantly going forward.

3. Rising life expectancy. Contrary to the fall in fertility, Exhibit 8 shows that life expectancy has not only risen significantly over the past but is also projected to keep rising in the future. If this happens, given the temporary nature of the first two drivers, rising life expectancy is likely to become the key driving force behind the aging phenomenon in the long run.

EXHIBIT 7: SHARP FALL IN FERTILITY
Number of children per woman

<table>
<thead>
<tr>
<th>Year</th>
<th>US</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>3.3</td>
<td>5.0</td>
</tr>
<tr>
<td>2017</td>
<td>1.9</td>
<td>2.5</td>
</tr>
<tr>
<td>2097</td>
<td>1.9</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Sources: United Nations, World Population Prospects: The 2017 Revision, Goldman Sachs GPS.

EXHIBIT 8: CONTINUOUSLY RISING LIFE EXPECTANCY
A 65-year-old expects to live to...

<table>
<thead>
<tr>
<th>Year</th>
<th>US</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>79</td>
<td>76</td>
</tr>
<tr>
<td>2017</td>
<td>85</td>
<td>82</td>
</tr>
<tr>
<td>2097</td>
<td>91</td>
<td>87</td>
</tr>
</tbody>
</table>

Sources: United Nations, World Population Prospects: The 2017 Revision, Goldman Sachs GPS.
How Should We Measure Demographics?

**Rising life expectancy** poses a major challenge to measuring the demographic structure of a population and projecting human behavior by grouping people into **fixed age groups** because:

… **“the meaning of age is changing.** The young are staying in school longer and delaying their entry into the labor force. People in their sixties and seventies are healthier and less likely to be disabled. Arbitrary definitions of childhood or old age provide an incomplete and misleading picture of the needs and potential contributions of the young and the old.”

United Nations (2013)

Indeed, although most studies rely on using fixed age groups, many recognize this approach as a caveat to their analysis. Some ad-hoc adjustments have been proposed, like changing the definition of “old” from 65+ to 70+. However, how could we adjust all age groups continuously and simultaneously so as to be able to compare human behavior over time and across countries?

A simple and intuitive solution is to look at the **ages at which people have the same percentages of their expected lifetime lived up/remaining.**

**EXHIBIT 9: HOW OLD IS “OLD”?**

Old is typically defined as 65+. However, a **65-year-old** American has…

<table>
<thead>
<tr>
<th>Year</th>
<th>% Expected lifetime lived up</th>
<th>% Expected lifetime remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>18.1</td>
<td>23.4</td>
</tr>
<tr>
<td>2095</td>
<td>28.8</td>
<td></td>
</tr>
</tbody>
</table>

Sources: United Nations, World Population Prospects: The 2017 Revision, Goldman Sachs GPS

Exhibits 9 and 10 illustrate this idea. In 2017, a 65 year-old American had 23.4% of his/her expected lifetime remaining. In 2000, life expectancy at all ages was lower. Hence, an American who had the same 23.4% of expected lifetime remaining was not 65 but only 63.2 years old. Similarly, in India, where life expectancy is lower than in the US at all ages, a person with 23.4% of expected lifetime remaining in 2017 was only 59.8 years old.

**EXHIBIT 10: AGES AT WHICH PEOPLE HAVE THE SAME PERCENTAGE OF THEIR EXPECTED LIFETIME REMAINING AS A 65-YEAR-OLD AMERICAN IN 2017 (23.4%)**

Looking at the ages at which people have the **same percentages of expected lifetime instead of the same number of years lived up** suggests an **alternative way of grouping people**, not into fixed age groups but by the percentage of their expected lifetime lived up/remaining.
Exhibit 11 shows that doing so makes aging appear much less dramatic. In particular, between 1952 and 2097, the shares of world populations aged 65+ and 80+ are projected to rise by 333% and 1200%, respectively (Exhibit 11 (i)). By contrast, over the same period, the shares of world populations with 79% and 91% of expected lifetime lived up — which correspond to the percentages of expected lifetime lived up by 65 and 80 year-old world citizens in 2017 respectively — are projected to only rise by 90% and 147%, respectively (Exhibit 11 (ii)).

EXHIBIT 11: THE AMOUNT OF AGING OBSERVED DEPENDS ON HOW WE MEASURE DEMOGRAPHICS

Percentages of World population by…

(i) 5-year age groups (%)

(ii) 5-percentage points of expected lifetime lived up groups (%)

Sources: United Nations, World Population Prospects: The 2017 Revision, Goldman Sachs GPS.

Should we use expected lifetime or age groups to measure demographics?

When measuring the demographic composition using fixed age groups, the threshold for reaching “old” is kept constant. As life expectancy expands, the “old” group swells automatically because people stay in this group for longer. By continuously adjusting the age group thresholds, expected lifetime groups eliminate this “permanent aging” artefact and make aging appear much less dramatic.

However, the main reason for preferring expected lifetime over fixed age groups is that key aspects of supply and demand behavior, like labor force participation rates and relative consumption patterns, seem to be better described as evolving in line with life expectancy than remaining fixed at constant ages.

Exhibit 12 illustrates this point for labor force participation rates. The evolution of labor force participation rates at different ages is a crucial element in the debate about the likely impact of aging on inflation and asset prices because old people’s labor force participation determines the extent to which they exit the active labor force, thereby stopping to produce, earn and save labor income, and starting to liquidate their saved assets in order to finance consumption.

In Exhibit 12, we compare the US labor force participation rates in 1984 and 2015 of people:

(i) who are the same age in years in both 1984 and 2015
(ii) who are different ages in years but have the same proportions of their expected lifetimes lived up/remaining in 1984 as in 2015
EXHIBIT 12: THE PAST BEHAVIOR OF PEOPLE WITH THE SAME PERCENTAGES OF EXPECTED LIFETIME LIVED UP MATCHES LABOR FORCE PARTICIPATION RATES...

Labor Force Participation rates of Men...
(i) with equivalent ages in years (%)

(ii) with equivalent proportions of expected lifetime lived up (%)


Projecting labor force participation rates in 2015 based on 1984 data using the labor force participation rates of people who had the same percentages of expected lifetime lived up in 1984 as in 2015 (Exhibit 12 (ii)) leads to fewer errors than using the labor force participation rates of people who were the same ages in years in both 1984 and 2015 (Exhibit 12 (i)). In particular, comparing the two blue lines in Exhibit 12 (i), we observe that, between 1984 and 2015, labor force participation at younger ages decreased, while participation at older ages increased. No such inversion in labor force participation patterns appears when comparing labor force participation rates at the same percentages of expected lifetime lived up (Exhibit 12 (ii)).

These effects are not only about individual choices; recent policy developments suggest that labor force participation at older ages is likely to keep rising as societies respond to higher life expectancy by adjusting institutions – in particular, pension systems.

For instance, a move from defined benefit to defined contribution plans is currently underway in many OECD countries (cf. OECD, 2016). Unlike defined benefit plans, defined contribution plans do not include age-related incentives that encourage retirement after a certain point. Hence, this move is likely to contribute to rising labor force participation at older ages.

The pension age is projected to keep rising in many countries. For example, the OECD (2015) estimates that the average normal pension age across all OECD countries is expected to increase from 64 for men and 63.1 years for women in 2014, to 65.5 and 65.4 in 2054 respectively.

In fact, some governments are now explicitly linking the number of years during which people receive state pensions to life expectancy. For instance, the UK government has announced that it “will aim for ‘up to 32%’ in the long run, as the right proportion of adult life to spend in receipt of state pension” (State Pension age review, July 2017).

In Exhibit 13, we turn to demand behavior by investigating consumption patterns.

As with labor force participation rates, we investigate whether it is most accurate to project future consumption patterns by assuming that people in a certain age group continue to behave:
(i) as people in the same age group in the past, or
(ii) as people of a different age but with the same percentage of their expected lifetime remaining in the past

We use the US Consumer Expenditure Survey to measure relative consumption across 20 different expenditure categories (such as transport, life insurance, housing, etc.), for different age groups. Relative consumption of, say, transport by people aged [65,80] corresponds to the ratio between the proportion of income spent on transport by someone in the [65,80] group and the proportion of income spent on transport by someone on average across all age groups in the same year.
Exhibit 13 compares the relative consumption patterns for different age groups. The dark blue bars show the prediction errors that result from projecting 2015 relative consumption patterns based on either 1984 (figure on the LHS) or 2000 (RHS) data and assuming that people in a certain age group in 2015 behave as people in the exact same age group in 1984 or 2000. The light blue bars show the errors generated when projecting 2015 consumption patterns also based on either 1984 or 2000 data, but this time under the assumption that people in a certain age group in 2015 behave as people who had the same percentage of their expected lifetime lived up in either 1984 or 2000.

The fact that the light blue bars lie below the dark blue ones in most cases implies that projecting 2015 behavior with expected lifetime groups is more accurate than projecting it using fixed age groups.

EXHIBIT 13: ... AND RELATIVE CONSUMPTION PATTERNS BETTER THAN THE PAST BEHAVIOR OF PEOPLE WITH THE SAME NUMBER OF YEARS LIVED UP

Average absolute differences between relative consumption patterns.

Demographics, Inflation & Asset Prices: A Complex Relationship

Demographics affect inflation and asset prices through numerous channels. This is a key reason why many studies have come to contradicting conclusions about the potential impact of aging.

For instance, a key argument for aging to exert inflationary pressures is that old people stop producing but continue to consume. This implies a reduction in aggregate supply relative to aggregate demand, leading to upward price pressures (e.g., BIS, 2015). By contrast, some studies (e.g., ECB, 2017) find a long-term positive relationship between inflation and working age (15-64) population growth. As the later becomes negative because of aging, the economy starts growing at a lower potential output growth rate and we could observe deflation.

In terms of asset prices, the “meltdown hypothesis” suggests that as old people retire, stop receiving labor income and therefore need to start selling-off their accumulated savings to finance consumption, asset prices fall and yields rise (e.g., Arnott and Chaves, 2012; FRBSF, 2011). However, there are numerous factors such as bequest motives and lifetime uncertainty that could moderate this meltdown (e.g., Poterba, 2001).

Moreover, we could observe downward pressure on real bond yields if fixed income inflows due to portfolio rebalancing towards safer assets that happens as people age, outweigh fixed income inflows related to dissavings.

On the equities side, as the baby boomers age, the relatively large cohort of their children (the millennials) start reaching the stage where people mainly invest in stocks, which could lead to some tailwinds for stock prices (e.g., Geanakoplos et al. 2004; Ned Davis Research Group, 2017).

This is just the tip of the iceberg of more or less plausible arguments about the impacts of demographics on inflation and asset prices, and illustrates the complexity of the relationship.

To capture this complexity, and following the evidence presented previously, which suggests that human behavior is better described as evolving in line with life expectancy than remaining constant at fixed ages, we estimate demographic impacts by regressing inflation, stock P/E ratios and real bond yields on:

1. demographic compositions measured by grouping people by the 5 pp of their expected lifetime lived up
2. significant controls: population growth and macro variables, like output gaps and oil prices growth, that control for cyclical fluctuations

We use annual data covering around 100 countries for inflation and 30 countries for asset prices. The Appendix provides more details about our estimation methodology (compositional regressions), data and results, while here we focus on the interpretation of estimated demographic impacts.

Since the percentages of people belonging to different expected lifetime groups must sum to 100%, we cannot increase one of them without affecting the rest. Instead, Exhibit 15 illustrates how inflation and asset prices change as we conduct the experiment illustrated in Exhibit 14. Starting with two people (9.52% of the population) in the 0-4 percent of expected lifetime lived up group and one person (4.76% of the population) in every other group, we let the extra (red) person “age” by moving her from one group to the next.

EXHIBIT 14: INTERPRETING ESTIMATED DEMOGRAPHIC IMPACTS
Starting with two people (9.52% of the population) in the 0-4 group and one person (4.76% of the population) in every other group, we let the extra (red) person “age” by moving her from one group to the next...

Source: Goldman Sachs GPS

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EXHIBIT 15: ESTIMATED IMPACTS OF DEMOGRAPHICS ON INFLATION AND ASSET PRICES
…and observe what happens to inflation and asset prices as these changes in the demographic composition unfold

1. Upward pressures on stock valuations in the middle parts of our lives (25th-54th percentiles) where we invest primarily in the stock market
2. Downward pressures on stock prices (55th-89th percentiles of expected lifetime lived up) and upward pressures on real bond yields (75th-94th percentiles) as we dis-save
3. Portfolio rebalancing from stocks into bonds in-between the 55th and the 74th percentiles
4. Upward pressures on inflation in the earlier (up to the 25th percentile of expected lifetime lived up) and later (65th-89th percentiles) parts of our lives as we contribute relatively more to aggregate demand than to aggregate supply. Note, however, that the later inflationary pressures seem to fade as aging progresses (90th-100th percentiles)

This complex relationship between demographics, inflation and asset prices means that we cannot investigate demographic impacts by focusing exclusively on certain parts of the demographic composition (say, investigate the impact of aging by using the share of “old” population only), and that there are no simple answers to questions like whether aging is inflationary or deflationary.
Indeed, as shown in Exhibit 16, the relationship between aging and inflation is ambiguous. The linear relationship between the 2017-2050 changes in our demography-based inflation predictions and the shares of "old" population is weak and switches sign as we change the definition of "old" from people with 30% or less of expected lifetime remaining (blue) to people with only 20% or less of expected lifetime remaining (green).

**EXHIBIT 16: THE RELATIONSHIP BETWEEN AGING AND INFLATION IS AMBIGUOUS …**

To illustrate the importance of capturing the entire demographic composition, we compare two countries with relatively similar magnitudes of aging but opposite inflation change directions: Spain and Brazil.

Table 1 shows that between 2017 and 2050, both countries will experience around 14 pp. increases in the shares of population with 30% or less of expected lifetime remaining. However, for Spain, this increase starts from around 25% of the population already having 30% or less of expected lifetime remaining in 2017, whereas, for Brazil, the additional 14 pp. shall augment a much smaller initial group of around 15%.

Furthermore, Brazil is projected to lose much more population in the younger groups than Spain: -8% for the share of population with 75% or more of expected lifetime remaining vs. only around -2% for Spain.

**TABLE 1: … AND AFFECTED BY WHAT HAPPENS IN THE ENTIRE DEMOGRAPHIC COMPOSITION**

<table>
<thead>
<tr>
<th></th>
<th>2017-2050 pp. change in share of pop. with … of expected lifetime remaining</th>
<th>Share of population with 30- % of expected lifetime remaining in</th>
<th>2017</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30- %</td>
<td>75+ %</td>
<td>2017</td>
<td>2050</td>
</tr>
<tr>
<td>Spain</td>
<td>13.82</td>
<td>-1.76</td>
<td>25.34</td>
<td>39.16</td>
</tr>
<tr>
<td>Brazil</td>
<td>13.94</td>
<td>-8.17</td>
<td>15.30</td>
<td>29.24</td>
</tr>
</tbody>
</table>

Sources: United Nations (2017), World Bank, OECD, IMF, Penn World Table 9.0., Goldman Sachs GPS.
Demographic Impacts in the US

Demographics have recently become an oft-cited culprit for economic trends that seem difficult to explain, like disappointing inflation in the US. Indeed, given the challenges in accurately measuring demographics and estimating the complex relationship between demographics, inflation and asset prices, it is relatively easy to find “evidence” and arguments to support any demography-based view.

In practice, however, the explanatory power assigned to demographics is often exaggerated. We find that demographics alone explain only 16%, 15% and 9% of the variation across countries and over time in annual inflation, real bond yields and stock P/E ratios, respectively.

Moreover, Exhibit 17 shows that the magnitudes of the demographic impacts we predict are dwarfed by both the fluctuations experienced over the last economic cycle and the magnitudes found in comparable studies.

The left-hand side figure in Exhibit 17 contrasts the future maximum absolute changes in the US inflation, long term government real bond yield and stock P/E ratio expected from demographics with the peak-to-trough changes in the same variables experienced over the cycle since 2007. Although the magnitudes are comparable for inflation, cyclical factors rather than demographics seem to be the main driving force behind asset price fluctuations.

The right-hand side figure in Exhibit 17 contrasts our demographic impact estimates with predictions from other comparable studies. Although these comparisons are for illustrative purposes only since, except for inflation, there are slight differences in the definitions of the variables, it is clear that the magnitudes we find are much more conservative.

We have strong confidence in this statement of relative magnitude and in the direction of our predictions but acknowledge that the exact numbers are estimated with significant uncertainty. This is especially true in the case of asset prices where much less reliable data is available (cf. Table 2 in the Appendix).

EXHIBIT 17: THE MAGNITUDES OF THE DEMOGRAPHIC EFFECTS WE FIND ARE SMALL RELATIVE TO BOTH CYCLICAL CHANGES AND WHAT OTHER COMPARABLE STUDIES HAVE FOUND

![Graph](image)

*Comparisons are with BIS (2015) for inflation, Aksoy et al. (2015) for the real bond yield and FRBSF (2011) for the stock P/E ratio. They are for illustrative purposes only since, except for inflation, there are slight differences in the definitions of the variables. For instance, we define the real bond yield as the long-term government bond yield minus realized inflation, whereas Aksoy et al. (2015) use the real short interest rate.

Sources: United Nations (2017), World Bank, OECD, IMF, DataStream, Robert Shiller, Penn World Table 9.0., Goldman Sachs GPS

To illustrate this uncertainty, Exhibit 18 accompanies the demography-based predictions for the US based on the full sample (light blue) with the max and min predictions obtained from iteratively re-estimating the models after omitting one country from the sample at a time (grey bands).
EXHIBIT 18: DEMOGRAPHY-BASED PREDICTIONS FOR THE US

(i) Inflation (annual average of monthly yoy CPI growth rates)

(ii) Real 10Y Govt Bond Yield (% p.a., annual average of monthly)

(iii) Stock Price-to-Earnings ratio (S&P500 LTM P/E, annual average of monthly)

Note: The grey bands illustrate the uncertainty associated with sample selection. They show the max and min predictions obtained from iteratively re-estimating the models after removing each country in the sample, except for the US, one at a time. The main demography-based predictions use the full samples available in each case. The full models include cyclical controls such as the lags of output gaps, the real Fed funds rate and oil prices growth, etc. (cf. Appendix for more details).

Sources: United Nations (2017), World Bank, OECD, IMF, DataStream, Robert Shiller, Penn World Table 9.0., Goldman Sachs GPS
Exhibit 18 (i) also shows that, in the US, demographics have exerted upward pressures on inflation since 2008, and therefore cannot be blamed for the weakness in CPI prints in the recent years. Moreover, the full model prediction (dark red), which includes the effects of both demographics and cyclical variables, is in line with realized inflation (dark blue), suggesting that the last few years’ weakness in inflation can be explained on a cyclical basis, and that the cyclical factors were strong enough to outweigh the upward pressures on inflation from demographics.

Over the next several decades, we expect US demographics to exert some mild upward pressures on inflation and real bond yields (Exhibit 18 (i) and (ii)).

For the stock P/E ratio (Exhibit 18 (iii)), we expect some downward pressures from US demographics until around 2030 when all millennials will have reached the stage where people invest primarily in stocks, which could result in a gentle demography-induced stock market boom.

It is important to note that these impact estimates do not take into account international capital and labor flows, which could partly offset country-specific demographic pressures. Although such international spillovers are hard to model, Exhibit 19 attempts to illustrate their potential direction by showing the contributions to global inflation and asset prices from the changing world demographic structure relative to 2017.

Especially for asset prices, these global predictions should be taken with a grain of salt since they assume a fully-integrated global economy in which an individual from a developing country participates in the asset market to the same extent as his developed market counterpart.

Nevertheless, these hypothetical global predictions may become more relevant as emerging markets develop and globalization progresses. It is also interesting to observe that we are close to the peak contribution from world demographics to the global stock price-to-earnings ratio and that, going forward, global demographics could exert downward pressures on real bond yields and stock valuations, while demography-based inflation should remain stable relative to 2017.

**EXHIBIT 19: GLOBAL DEMOGRAPHIC PRESSURES RELATIVE TO 2017**

Contributions to global inflation and asset prices from the changing world demographic structure, normalized to zero in 2017

<table>
<thead>
<tr>
<th>Year</th>
<th>Inflation (%)</th>
<th>Real bond yield* (%)</th>
<th>Stock P/E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>-4</td>
<td>0</td>
<td>-4</td>
</tr>
<tr>
<td>1963</td>
<td>-3</td>
<td>0</td>
<td>-3</td>
</tr>
<tr>
<td>1973</td>
<td>-2</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>1983</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>1993</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2013</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2023</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2033</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

*Long term government bond yield – realized one year inflation

Note: Figure shows the estimated demographic coefficients times the changing world demographic structure, normalized to zero in 2017 Sources: United Nations (2017), World Bank, OECD, IMF, DataStream, Robert Shiller, Penn World Table 9.0, Goldman Sachs GPS.

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EXHIBIT 20: CHANGES IN DEMOGRAPHY-BASED PREDICTIONS FOR MAJOR ECONOMIES

Inflation (percentage points (pp) changes, sorted on 2017-2027 estimates)

Real bond yield (pp changes, sorted on 2017-2027 estimates)

Stock P/E (points changes, sorted on 2017-2027 estimates)


Note: These estimates do not take into account international capital and labor flows which could to some extent offset country-specific demographic pressures.

Sources: United Nations (2017), World Bank, OECD, IMF, DataStream, Robert Shiller, Penn World Table 9.0, Goldman Sachs GPS
TABLE 2: ESTIMATION DETAILS

<table>
<thead>
<tr>
<th></th>
<th>Inflation</th>
<th>Real bond yield</th>
<th>Stock P/E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable definition</td>
<td>(World Bank, OECD) yoy inflation growth rates Winsorized at -5 and +15</td>
<td>Long term government bond yield (annual) – realized one year inflation (IMF IFS, DataStream) Winsorized at -5 and +10</td>
<td>(DataStream, Shiller database for the US) Winsorized at +30</td>
</tr>
<tr>
<td>Number of observations</td>
<td>4,781</td>
<td>1,425</td>
<td>1,074</td>
</tr>
<tr>
<td>Number of countries</td>
<td>102</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>Adjusted R² from models with:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demographic compositions only</td>
<td>16.06%</td>
<td>15.06%</td>
<td>8.76%</td>
</tr>
<tr>
<td>Controls only</td>
<td>34.75%</td>
<td>20.11%</td>
<td>30.54%</td>
</tr>
<tr>
<td>Demographic compositions + controls (model used for predictions)</td>
<td>41.49%</td>
<td>35.59%</td>
<td>39.19%</td>
</tr>
<tr>
<td>Significant controls</td>
<td>Lag output gap</td>
<td>Lag output gap US employment gap</td>
<td>Lag output gap US employment gap</td>
</tr>
<tr>
<td></td>
<td>Lag of real Fed funds rate</td>
<td>Oil prices growth Oil prices growth</td>
<td>GDP p.c. relative to the US GDP p.c. relative to the US</td>
</tr>
<tr>
<td></td>
<td>GDP p.c. relative to the US Population growth</td>
<td>Population growth</td>
<td>Population growth</td>
</tr>
<tr>
<td>Polynomial degree</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

¹As a robustness check, we used HP filtered inflation instead of realized. The two predictions have a 0.99 correlation. Past correlations are not indicative of future correlations, which may vary. Sources: United Nations (2017), World Bank, OECD, IMF, DataStream, Robert Shiller, Penn World Table 9.1.1, Goldman Sachs GPS

ESTIMATION METHODOLOGY

Standard statistical methods cannot be used with compositions because they are not real numbers, i.e. a D-parts composition \( \theta = (\theta_1, \theta_2, \ldots, \theta_D) \) does not belong to \( \mathbb{R}^D \) but to a unit simplex:

\[
S^D = \{ \theta = (\theta_1, \theta_2, \ldots, \theta_D) \mid \theta_j \geq 0 \text{ for } j = 1, \ldots, D \text{ and } \sum_{j=1}^{D} \theta_j = 1 \}
\]

We use a field of statistics called Compositional data analysis originally developed by John Aitchison in the 1980s. The key idea in compositional data analysis is to realize that a D-parts composition \( \theta = (\theta_1, \theta_2, \ldots, \theta_D) \) provides information only about \((D - 1)\) relative proportions, e.g.:

\[
\frac{\theta_1}{\theta_D}, \frac{\theta_2}{\theta_D}, \ldots, \frac{\theta_{D-1}}{\theta_D}
\]

Hence, there exists a one-to-one correspondence between a D-parts composition and a full set of \((D - 1)\) ratios. Moreover, ratios do belong to the real space where standard statistical methods can be used. The one-to-one correspondence can then be used once again to translate our results back into conclusions about compositions.

In practice, the correspondence is more complex than simply taking the ratios of the components. We use the isometric log-ratio (ilr) transformation which associates coordinates with compositions in an orthonormal system, i.e. is an isometry between \(S^D\) and \(\mathbb{R}^{D-1}\).

Let \(y_{it}\) be our dependent variable (e.g. inflation for country \(i\) in year \(t\)):

\[
y_{it} = \alpha_i + (\beta, \theta_{it})_A + \varepsilon_{it}
\]

where \(\beta \in S^D\) is the regression “slope” composition, \((\cdot)_A\) is an Aitchison scalar product, and \(\varepsilon_{it}\) is an error term.

To work in coordinates, we transform the regression model as follows:

\[
y_{it} = \alpha_i + (\text{ilr}(\beta), \text{ilr}(\theta_{it})) + \varepsilon_{it}
\]

\[
= \alpha_i + \sum_{k=1}^{D-1} \text{ilr}(\beta)_k \text{ilr}(\theta_{it})_k + \varepsilon_{it}
\]

\(\beta\) can then be recovered by using the inverse ilr transformation ilr⁻¹:

\[
\beta = \text{ilr}^{-1}(\text{ilr}(\beta))
\]

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Another difficulty is to ensure smoothness in the predictions and effects estimated for consecutive groups. For this, we constrain the coordinates to lie on a $q$th degree polynomial:

$$i\text{lr}(\beta)_k = \xi_0 + \xi_1 k + \cdots + \xi_q k^q \text{ for } k = 1, \ldots, D - 1$$

Imposing this restriction, we can rewrite our regression model as:

$$y_{it} = \alpha_i + \xi_i x_{it}^0 + \xi_1 z_{it}^1 + \cdots + \xi_q z_{it}^q + \epsilon_{it}$$

where $z_{it}^0 = \sum_{k=1}^{D-1} i\text{lr}(\beta)_k$, $z_{it}^1 = \sum_{k=1}^{D-1} k i\text{lr}(\beta)_k$, $\ldots$, $z_{it}^q = \sum_{k=1}^{D-1} k^q i\text{lr}(\beta)_k$

We select the optimal polynomial degree ($q$) based on statistical significance of the $z$ variables, correlation between smoothed and unsmoothed predictions and out-of-sample performance.

Given estimates $\hat{\xi}_0, \hat{\xi}_1, \ldots, \hat{\xi}_q$, the implied estimates of the coordinates can be obtained as :

$$i\text{lr}(\beta)_k = \bar{\xi}_0 + \hat{\xi}_1 k + \cdots + \hat{\xi}_q k^q \text{ for } k = 1, \ldots, D - 1$$

Our final models also include country-specific and macro controls $x_{it}$ as well as population growth $\rho_{it}$:

$$y_{it} = \alpha_i + \xi_i x_{it}^0 + \xi_1 z_{it}^1 + \cdots + \xi_q z_{it}^q + \bar{x}_i \delta + \gamma \rho_{it} + \epsilon_{it}$$

Our demography-based predictions are based on the United Nations’ population estimates and constructed as follows:

$$\hat{y}_{it} = \hat{\alpha}_{adj,i} + \hat{\xi}_0 x_{it}^0 + \hat{\xi}_1 z_{it}^1 + \cdots + \hat{\xi}_q z_{it}^q + \hat{\gamma} \rho_{it}$$

where $\hat{\alpha}_{adj,i} = \hat{\alpha}_i + \bar{x}_i \delta$ with $\bar{x}_i$ being the average of the control variables over the time period for which we have data on country $i$.

Note that we only include population growth into our predictions when it is significant in the regression model.

REFERENCES

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6. ECB, Elena Bobeica, Eliza Lis, Christiane Nickel, and Yiqiao Sun (2017), “Demographics and inflation”

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