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Abstract

Demographic dynamics and the shift of population pyramids towards an inverted-pyramid shape in advanced economies are leading to relative scarcity of labour and excess savings. What are the effects of these dynamics on the relative wealth accumulation journeys of different cohorts? Within a fixed-effect cross-country panel framework, I find that savings by an increasing share of households aged between 45 and 65, a rise in retired over-65s, and a decrease in working-age and low-wealth agents in their twenties and thirties can explain most of the decline in rates of return across countries in the last few decades, and similarly a large part of the increase in wages. In this context and looking to the future, wealth accumulation out of income and capital returns by cohorts living in advanced economies and retiring in future decades is set to become increasingly difficult, as higher wages are not sufficient to compensate for lower returns over long periods of time. Current young and future generations are therefore set to face progressively lower standards of living at retirement and/or increasingly high saving ratios in working age.

KEYWORDS: Demographics, Rates of return, Inter-generational inequality, Wealth

JEL Classification: E21, E25, J11.

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Non-technical summary

Over the past decades, as a result of strong increases in life expectancies and declines in birth rates, populations in economies across the world have been going through a demographic transition, with falling population growth rates, and a general ageing of the population. These dynamics are at the most advanced stage in a number of developed economies: in these economies, population pyramids have started taking the shape of *inverted* pyramids, with large shares of the population at older ages and progressively smaller younger age groups. Such population structures are unprecedented.

Because households of different ages exhibit different patterns of consumption and saving, as well as different participation rates in the labour force, any change in the relative weight of a certain age group compared to the overall population will have an aggregate effect on the economy's consumption, saving, and the size of the labour force. The demographic trends we are witnessing in most advanced economies are shifting the weight of the population towards the age groups with the highest levels of accumulated savings (i.e. households in late working age and early retirement), while at the same time the share of individuals in late retirement is on the increase and the share of the population in early working age is falling, lowering the potential size of the labour force.

By differently affecting the employment rate of the population as well as aggregate wealth levels, each age group has a different impact on rates of return on capital and on wages, as these are affected by the quantity of labour and capital in the economy. In general, this paper finds that population structures of the type present in ageing economies are associated with more capital and less labour, typically leading to lower returns on capital and higher wages. As economies transition from a young (high-return, lower wages) population structure towards inverted population pyramids (low returns, higher wages), the ability of cohorts born at different times through the transition to accumulate wealth is affected.

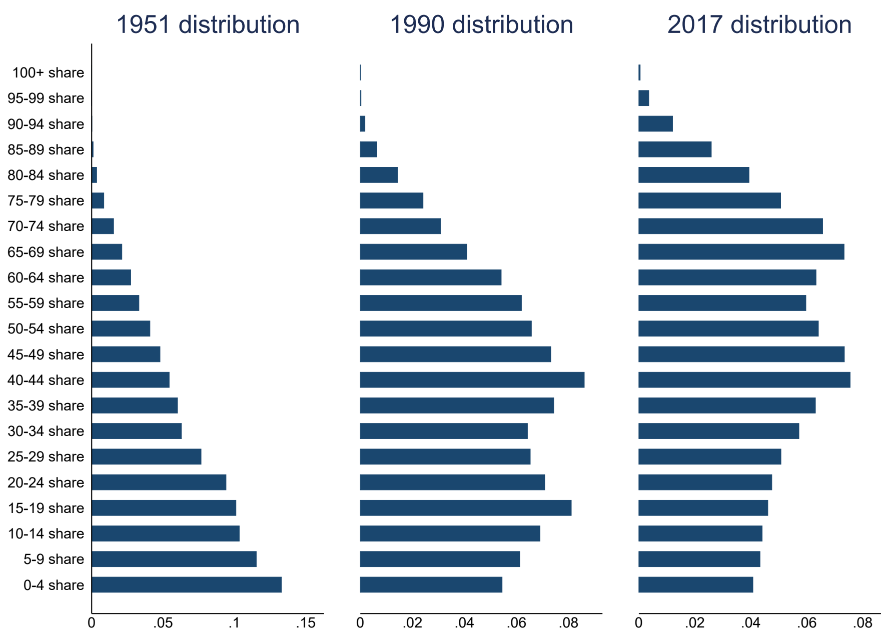
While younger cohorts can benefit from higher wages thanks to both technological advancement and the effects of ageing, I find that the negative impact of lower returns on wealth accumulated over a long period of time tends to prevail (conditional on assumptions), leading to these cohorts not being able to accumulate as much wealth as those preceding them from the same saving rates. Because younger cohorts will also need to accumulate more wealth than the previous cohorts on account of longer life expectancies after retirement, they potentially face a trade-off between decreasing standards of living at retirement and higher saving (i.e. lower consumption) during their working age.

1 Introduction

The world is in the midst of one of the most dramatic demographic shifts in history. After two centuries of exponential expansion, world population growth reached its peak in the 70s and has experienced a considerable slowdown since. The ageing of societies is already at an advanced stage in many developed economies, some of which face population declines. This is quickly becoming a global phenomenon. Life expectancies have never been as high; meanwhile, birth rates are well below replacement in an increasing number of economies.

Population pyramids in a number of countries have now started taking the shape of *inverted* pyramids, with younger generations progressively smaller and a high median age - see Figure 1 for the striking example of Japan. Population structures of this type are unprecedented. An ageing and eventually declining population has profound consequences for the prospects of an economy, in terms of productivity, equality, allocation of resources, financial markets and economic policy.

Figure 1: Evolution of the Japanese population pyramid.



Percentage of the population in each 5-year age group.

As longer lifespans push larger shares of workers towards retirement age, while the relative size of the working population shrinks, an obvious question arises: how to finance the livelihoods of current retirees while allowing the working-age population to accumulate enough wealth to fund their own retirement? With public finances increasingly strained by pension payments, a large part of retirees' income might need to originate from the private wealth accumulated during their working life. The accumulation of sufficient amounts of wealth requires not only a steady stream of savings, but also high enough real rates of return on such savings. However, population aging itself might have an adverse effect on rates of return on wealth; empirical results obtained in this paper give further evidence of this.

In the context of demographic ageing and decline, younger generations in an increasing number of countries have been worrying that their future economic prospects look rather bleak when compared to their parents' generations. When their parents could, for instance, afford a house and start a family early in life, this is becoming increasingly difficult for many young people in advanced economies, who are facing a situation of low savings with low returns, and high asset prices. Are these worries founded, and do demographic dynamics have anything to do with trends in wealth inequality?

The main purpose of this paper is to explore and quantify how the wealth accumulation journey of different generations (or cohorts) has been or will be affected by demographic trends, and to derive implications in terms of inequality (of wealth, but more generally, of standards of living) between these cohorts. While the analysis within the paper explores these dynamics across the world, particular emphasis is given to older, advanced economies at the frontier of the demographic transition.

In these economies, how do young workers today fare compared to their parents' generation? Generally speaking, will they be worse-off? I find that, in advanced, ageing economies, that appears indeed to be the case. Consistent with a growing literature, this paper presents evidence that ageing pushes down rates of return, but also positively affects wages. As these dynamics unfold, accumulating wealth becomes relatively more difficult for at least some section of the population. Because returns will be lower, any initial amount of saving will not accumulate as quickly. At the same time, wages will increase, but not enough for households to be able to reach the same levels of wealth accumulation as the generations before them with the same saving rates, unless unlikely high productivity growth is assumed in future decades. Younger generations will thus have to save more to reach the same levels of wealth as their parents, and even more to reach a level of wealth that will allow them to have an equally comfortable retirement (seeing as life expectancies are set to increase further).

I reach these findings by employing a simple fixed-effect panel estimation approach. I find that ageing demographics tend to depress rates of return and increase wages, although with different intensities, through the effect of the population structure on capital accumulation in the economy and employment. The estimation method used also allows me to show how each different age group has a markedly different impact on returns and wages through these two channels. By combining the single age-group effects together, I can then recover how the whole population pyramid affects rates of return and wages, and wealth accumulation as a result, throughout countries and years. With a number of quantitative exercises and back of the envelope calculations, I then finally quantify the implications of these dynamics for the wealth accumulation journeys of different cohorts, and how they fare compared to one another, reaching the conclusion that current young generations and those in the future are set to lose, especially compared to the generation currently at retirement age, which in the average advanced economy benefited from the most favourable combination of demographic and economic conditions.

The rest of the paper is structured as follows: Section 2 reviews some of the literature on demographics, wealth accumulation, the macroeconomy and inequality, and locates this paper in the context of this literature; Section 3 introduces the data used in the paper and addresses some issues related to these data; Section 4 looks at the impact of demographic dynamics on rates of return through different channels and explores the implications for wealth accumulation and inter-generational inequality; Section 5 repeats this analysis for wages; Section 6 combines these findings to obtain the overall impact of demographics on wealth accumulation across generations; finally, Section 7 concludes the paper.

2 Literature Review

This paper draws from a vast and established literature on demographics and the economy, of which I can identify a few strands that are most relevant in particular to the effects of demographic dynamics on rates of return, and inequality.

One of the main channels through which demographic developments affect the economy is through savings. The literature on life-cycle consumption and savings generally finds that the consumption and saving behaviour of economic agents changes as they age, as their earnings and levels of wealth change, and they prepare for retirement. Households start their working life with low earnings and quickly increase their incomes, and earn most close but before retirement age, after which their income falls. Consumption is also hump-shaped and partly follows the evolution of income, however saving rises by more for several decades before declining sharply and becoming negative well into retirement. The literature on life-cycle behaviour is vast and established - see for instance Gourinchas and Parker (2002) (17) for a life-cycle representation of income and consumption. Results in Feiveson and Sabelhaus (2019) (13) show that annual saving is typically highest when an agent is between 35 and 50, while wealth increases at the fastest pace between 40 and 60 (due to effects of returns on accumulated wealth). Aggregating this type of saving and consumption behaviour in the macroeconomy results in large effects of age on aggregate wealth, consumption, and saving rates. In particular, a large share of the popualtion in the ages with the highest accumulated lifetime wealth will lead to higher average levels of wealth per person in the economy, with implications for interest rates.

There is ample evidence, both theoretical and empirical, that population ageing leads to a reduction in interest rates - whether by interest rate we intend the natural interest rate or rates of return or other measures - although there is disagreement on the magnitude and on how other effects are also at play. A large number of papers reach these conclusions by employing an overlapping-generations (OLG) model; these for instance include Geppert, Ludwig and Abiry (2016) (15), Börsch-Supan et al. (2003) (4), and Papetti (2019) (27); Krueger and Ludwig (2006) (24) also find that, in an open economy, capital flows cause economies to "export" or "import" part of the decline in interest rates due to demographics (respectively, if ageing happens more or less rapidly compared to ROW). Carvalho, Ferrero and Nechio (2016) (5) again find, within a life-cycle model, that ageing demographics lead to a reduction in interest rates, via increasing capital per worker and higher life expectancies, although lower savings by retirees have an opposite but insufficient effect (similar results are found in Papetti (2019) (27) and Börsch-Supan et al. (2003) (4)). Ikeda and Saito (2012) (20) attribute a greater part of the reduction in interest rates in Japan to a decline in TFP, but demographics also have a large negative effect. That ageing demographics put downward pressure on interest rates is also documented empirically - see for instance Ferrero, Gross and Neri (2017) (11).

A reduction in interest rates, generally, tends to be a collateral finding of a great part of theoretical papers with demographic dynamics. These multiple results are all consistent with the literature on the life-cycle patterns of savings and consumption, as in general a higher proportion of the population in ages with high accumulated savings leads to an excess of these relative to investment, thus lowering rates. Some papers however challenge the view that demographics are the main factor responsible for decreasing rates. Goodhart and Pradhan (2017) (16) mostly attribute falling interest rates in the past decades to a shift of manufacturing production to emerging markets (especially China), and rather see ageing demographics globally as potentially reversing the trend in the near future. Mian, Straub and Sufi (2021) (25) mostly associate the fall in the natural rate of interest in the US to increases in income inequality leading to higher saving by the wealthier.

In this paper, I find again that ageing demographic structures lead to lower rates of return on capital through higher capital accumulation and lower employment. Interestingly however, thanks to the estimation I employ, I am also able to go further and break down the effects on rates of return by age group and to quantify how each specific shape of the population pyramid might impact returns. The results suggest that demographic dynamics may account for most of the variation in rates of return across the years in the countries studied.

Demographic ageing is not only associated with lower interest rates, but also with lower potential growth - papers that make this argument include Cooley and Henriksen (2017) (7) and Aksoy et al. (2019) (1). Within a context of population ageing and low or negative population growth, combined with anemic productivity growth and low interest rates (which due to demographic dynamics are all seen occurring together and persisting for the rest of the century) part of the literature talks about secular stagnation - see for instance the already cited Geppert, Ludwig and Abiry (2016) (15), and Ferrero, Gross and Neri (2017) (11). Demographics are only one of the potential explanations for the low interest rate environment in advanced economies and secular stagnation - both Sajedi and Twaites (2016) (28), and Eichengreen (2015) (9), for instance, make the case for the fall in the relative price of investment goods being one contributing factor. In his famous speech, Summers (2014) (29) lists six structural reasons for the decline in natural interest rates (which he links to secular stagnation) experienced in the US, and out of these, one is the slowdown in population growth. While in this paper I do not make considerations on economic growth and productivity as it relates to demographics, this strand of the literature informs the analysis and interpretation of results.

With life-cycle savings, rates of return and employment as main channels, the literature tends to find that ageing demographics lead to increasing wealth inequality, particularly of the inter-generational type, although there is no general consensus. Antunes and Ercolani (2020) (3) find that demographic dynamics can explain a large part of the increase in inter-generational wealth inequality in the US. Geppert (2015) (14) finds that demographic effects on wages, human capital accumulation and the skill premium will lead to different welfare effects across household types. Vandenbroucke (2016) (31) sees increases in life expectancy as increasing wealth inequality while however declines in population growth decrease it. Differently from most of this literature, this paper does not look at inter-generational wealth inequality from a cross-sectional perspective (how wealth is distributed among households of different ages in the same year), but rather examines inequality between generations in terms of cohorts, i.e. how agents born in different years compare to one another at the same age.

I focus on the different economic environment faced by different cohorts, and analyse wealth inequality between generations under this light. In Hood and Joyce (2013) (19), the authors show how in spite of higher real incomes at comparable ages, younger cohorts in the UK are so far not keeping up with previous generations in building up wealth or accessing housing. The principal contribution of this paper is to reach similar findings within a cross-country empirical framework, and additionally linking demographics as a contributing factor to these developments; I also show plausible projections for wealth accumulation for a large number of countries up to the end of the century. In addition, the results of this paper provide a specific age-bracket dimension to the well-documented negative effect of ageing demographics on rates of return and positive wage effect.

3 Data

3.1 Sources

The analysis performed in this paper makes use of a large panel dataset. Data on macroeconomic aggregates such as GDP and other national accounts components, the capital stock, employment etc. are taken from version 9.1 of the Penn World Tables (PWT 9.1) (12). The Penn World Tables are also the source of data on productivity, capital share of income and depreciation, among others. PWT variables are used to compute the return on capital, appreciation of capital, and its aggregate rate of return as detailed below in the following subsection. The dataset includes 182 countries between 1950 and 2017.

Data on countries' population are gathered from the United Nations' World Population Prospects 2019 (30). These include projections on the population of countries at each year from 1950 up to 2100 and are broken down by five-year age groups. This allows for a detailed analysis of the evolution of the demographic structure of a country over time, both in terms of growth and of age distribution.

I combine the PWT 9.1 and UN population prospects data to create a panel dataset of 64 countries, spanning between the years 1950 and 2100, where the Penn World Tables data stops at year 2017. The countries were chosen based on having a sufficient number of time series observations for the most relevant variables to the analysis conducted in this paper; having typically better data, most of the advanced economies are respresented in this final sample, with however around 20 developing economies (depending on definitions) represented as well. The final panel used for regression analysis in Section 4 contains about 3,000 observations, or an average of almost 47 years for each of the 64 countries in the panel.

The economies included in the panel are crucially at very different stages of aging and population growth, and have quite different population distributions, life expectancies and birth rates. For the countries with the most complete data, this can go back as far as 1950 and up to 2017, allowing to cover a time span of almost seventy years, during which many economies, especially in the developed world, experienced radical shifts in their population dynamics, from growth, birth rates, age distribution and migration patterns. During these years, life expectancy also quickly increased all across the world.

Before proceeding to the empirical analysis of these data, the next two subsections explore a few data issues more in detail.

3.2 Total Return on Capital

This paper investigates how demographics affect wealth inequality through the lens of rates of return. Computing an exact measure of real return on wealth requires time series of price indices as well as yields (i.e. dividends, interest, rents, etc.) for all asset classes, and the relative weight of each asset class in a typical household's portfolio. This is not generally possible apart from a handful of countries, and some strong assumptions.

The alternative approach used here to estimate return on wealth draws from David, Henriksen and Simonovska (2014) (8) and makes use of macroeconomic data. I compute returns on an economy's capital by considering what would be the before-tax annual gains, realised and unrealised, accruing to a representative agent investing into the capital of such economy, as a fraction of the amount of capital initially invested. Here I consider the returns accruing to a domestic investor who invests into the "average" unit of domestic capital.[1]

While wealth can take the form of various types of financial and non-financial assets, aggregating returns across asset types allows me to treat aggregate wealth, and its return, as equivalent to a generic capital good. In this way, developments in the return to capital can be equated to returns to the portfolio of a household with the average wealth allocation. Ultimately, returns on each type of asset can be associated with returns generated with the use of physical capital somewhere, with housing assets being the most straightforward. The return on government bonds, for instance, is linked to the domestic capital held by the government, as well as the collection of taxes that are again collected from income generated from the use of private domestic capital.

Treating domestic agents' wealth and an economy's capital as equivalent crucially relies on the assumption of closed capital markets, where all the wealth of domestic agents is invested into domestic capital, and there is no capital flow. Any differential between the return on domestic assets, and the return on the wealth of domestic agents, is due to the openness of capital and financial markets, and the extent to which agents own higher- or lower-yielding foreign capital in their portfolios.[2] While capital flows may substantially affect this differential, there is very strong evidence of home bias in equity markets (see for instance Cooper et al. (2013)(6))[3] and in government bond markets, while the largest component of wealth in most households' portfolios (and largest component of any economy's capital stock), i.e. residential housing, is in very large part held by domestic agents. Indeed, the wealth owned by the median household in most countries tends to be even more home-biased than the average, as typical households have very little exposure to equity markets and hold most of their wealth in domestic housing. For the above reasons, the rest of this

[1]This also removes complications related to changes in relative prices of consumption goods between the investor's country and the country where capital is invested.

[2]Recall the findings in Krueger and Ludwig's (2006) (24) model.

[3]Compare also Mishra (2015) (26), who finds an average equity home bias of 0.77 (with 1 being complete home bias) across 42 countries.

paper treats returns on an economy's capital and on its citizens' wealth as essentially equivalent.[4]

A measure of total return on domestic capital can be computed as the sum of two components:

- Income flows accruing to capital, such as payment of interest, dividends, or rents, depending on the type of asset, but also profits retained by corporations. These are equivalent to total income accruing to capital, divided by the stock of capital, and can be retrieved from the data as $Y_t^K = \alpha Y_t / K_t$, with α being the capital share of income. This can be interpreted as the marginal product of capital.
- Real changes in the price of capital, relative to consumption goods (appreciation of capital), $(P_{t+1}^K - P_t^K)/P_t^K$, where P_t^K represents the real price of capital goods relative to consumption goods, at time t.

Total return on capital at time t (TRK_t) is thus:

$$TRK_t = \alpha \frac{Y_t}{K_t} + \frac{P_{t+1}^K - P_t^K}{P_t^K} \tag{1}$$

with all the necessary data available within the Penn World Tables.

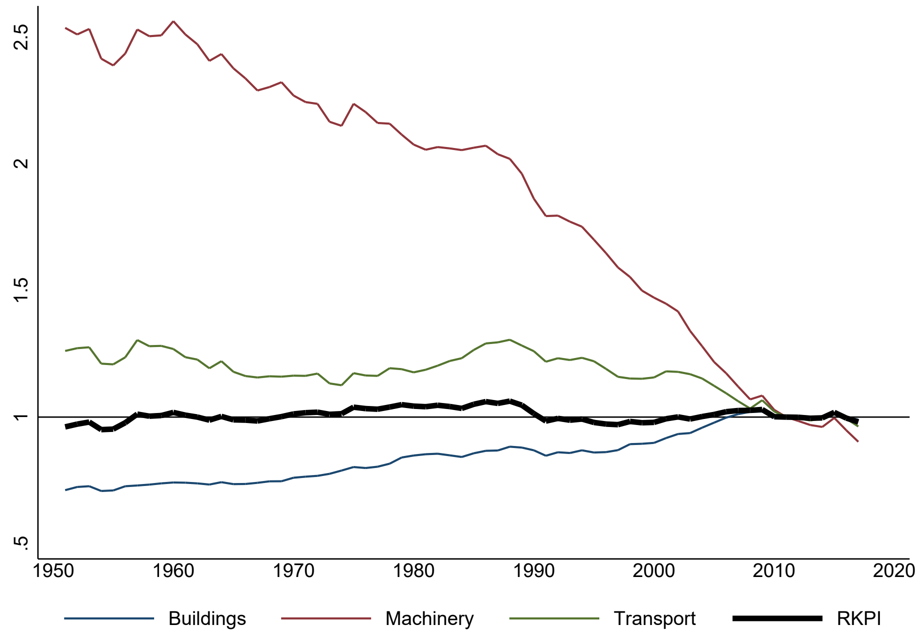
While it is informative to think of returns on capital in terms of these two components, it turns out that what matters for the questions posed by this paper is exclusively the first component. While Y^K in the long term depends on productive capacity considerations alone, which are slow moving, persistent and closely interconnected with demographic developments, the appreciation of capital appears to be a short-term phenomenon more related to the business cycle.

Appreciation of capital averages at almost exactly 0% per year for the countries in the panel, signifying that there is no general evidence of capital goods increasing in value relative to consumption goods. However, it is interesting to note that while capital has not appreciated significantly across the world in the last 70 years, this net-zero appreciation hides the fact that prices of one component of it, residential and non-residential structures, have been steadily rising while the other types of capital (machinery, transport equipment, and other) have become relatively cheaper over the years.

To illustrate this, Figure 2 shows how the average price level of the aggregate capital stock in real terms has broadly remained unchanged, while there has been a clear trend upwards

[4] Even when domestic agents invest in other economies, they tend to be biased towards countries with similar characteristics to their own, including in terms of demographic dynamics. To the extent to which demographic factors influence rates of return, as this paper argues, investing in a country with similar demographics is almost equivalent to investing domestically, further supporting this argument.

Figure 2: Average Real Capital Price Index, and Components



Real Capital Price Index (RKPI), for aggregate capital, machinery and equipment, transport equipment, and residential and non-residential structures (other assets omitted); unweighted average values across the countries in the panel (2011 = 1). For each country, the indices are calculated as the capital stock price index (PWT, 2011 = 1) divided by the GDP deflator (2011 = 1).

in the prices of buildings, and downwards in the other types of capital. Although the following section will be devoted to the analysis of developments in returns to aggregate capital only, this fact has potentially very important consequences for developments in wealth inequalities and should be kept in mind. The potential effects of such an appreciation of the value of buildings (and especially housing, which represents the largest component of most households' portfolios) on wealth inequality are discussed briefly later, however further research is warranted to fully evaluate the extent to which demographic developments have anything to do with these trends.

3.3 Population and Demographic Distribution

Populations change extremely slowly, which makes estimating the effects of such changes on economic variables, which typically have considerably more volatility, particularly challenging. Demographic changes are felt and experienced only over multiple years and even decades, as opposed to months and quarters. Nevertheless, demography remains at all times one of the most fundamental factors underpinning the performance and direction of an economy.

For this reason, while births, deaths and migration are what ultimately drive populations, because their effect is only seen years later, this paper mainly looks at demographics through the lens of the age-structure of an economy's population, or the population pyramid. Population pyramids are the result of a combination of past birth rates and death rates, evolutions in life expectancy and migration, but adequately represent where an economy's population is at the moment and where it is going. I will make use of these for most of my analysis below.

The data from the UN Population Prospects include countries' populations by five-year age groups, by number of persons and as a share of the total population in the country. This results in 18 5-year age groups (85+ year-olds are here aggregated into one only group due to the small size of the population in this age bracket), starting from 0 to 4 year-olds, and so on.

I take the working-age population to be the population between the ages of 20 and 64, inclusive. This appears to be the most appropriate choice when taking account of cross-country differences (and even differences within a country throughout the period under analysis) regarding pension age and typical age at which people get their first job.

Regression analysis presented below seeks to determine the effect of the relative size of each age-group population share on a number of variables. To do so, the first empirical approach could be to add each of these shares into a regression. However, population shares are collinear, and their sum is by definition 1 at all times. Removing one of these shares from the regression could potentially solve the issue with collinearity, however population shares that are close to one another are typically highly correlated due to the slow-moving nature of population aggregates, leading to unstable parameters. In addition, all results would have to be interpreted relatively to the omitted group rather than on their own, which adds extra complications, and using 17 variables in a regression significantly lowers the number of degrees of freedom.

In order to avoid such issues, I construct a different set of variables employing an alternative method for representing the age distribution, i.e. using a way of parametrising the shape of the population pyramid by fitting a polynomial curve to the population shares by age group. A similar method was first introduced in Fair and Dominguez (1991) (10), and as augmented in Kopecky (2021) (22) it solves both collinearity and correlation issues mentioned above.[5] In an efficient way of approximating the whole age distribution with a cubic function, the 18 age group population shares can be converted into three demographic variables, D_1, D_2 and D_3, that retain information on the shape of the population pyramid. The values of D_1, D_2 and D_3 for country i and year t are computed as follows from the 18 age-group population shares:

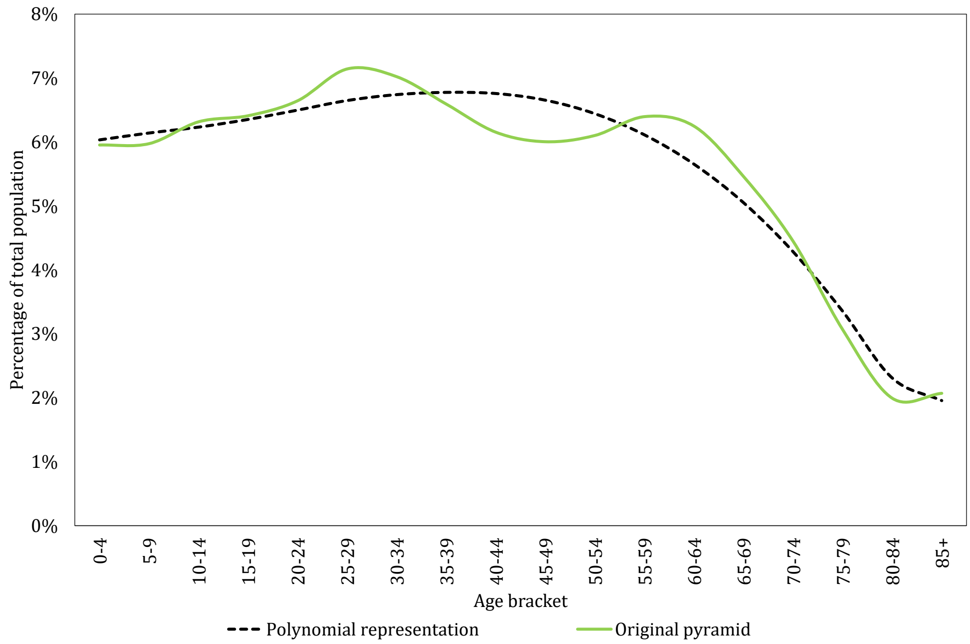
$$\begin{aligned} D_{1,i,t} &= \left(\sum_{j=1}^{18} j \frac{N_{j,i,t}}{N_{i,t}} \right) - \frac{\sum_{j=1}^{18} j}{18} \\ D_{2,i,t} &= \left(\sum_{j=1}^{18} j^2 \frac{N_{j,i,t}}{N_{i,t}} \right) - \frac{\sum_{j=1}^{18} j^2}{18} \\ D_{3,i,t} &= \left(\sum_{j=1}^{18} j^3 \frac{N_{j,i,t}}{N_{i,t}} \right) - \frac{\sum_{j=1}^{18} j^3}{18} \end{aligned} \tag{2}$$

where $N_{j,i,t}$ is the population belonging to age group j in country i and year t and $N_{i,t}$ is total population. These three variables can be used in regression analysis, and the implied coefficients of each age-group population share $N_{j,i,t}/N_{i,t}$ on the dependent variable can be subsequently recovered from the coefficients on D_1, D_2 and D_3 as further detailed in Section 4.2. Figure 3 shows an example of how the polynomial representation of the demographic distribution based on D_1, D_2 and D_3 fits the actual population pyramid. Because the fitted polynomial is of third order, at times it fails to capture double humps that would be better approximated by a higher-order polynomial (like in the example), however the fit is very close to the original distribution and the correlation between the original population shares and the implied shares based on the three demographic variables is very high.[6]

[5] See Kopecky (2021) (22) for a detailed explanation of the rationale and derivation of these variables.

[6] The average correlation between the population shares in the original population pyramids and those implied by the D_1, D_2 and D_3 variables is 94.04%, ranging from 82.80% for the 40 to 44 age-group to 99.23% for the 5 to 9 age-group. Using a fourth-level polynomial (i.e. adding a D_4 variable) does not qualitatively change any of the results shown below in any meaningful way.

Figure 3: Example of a demographic distribution and its polynomial representation based on the D_1, D_2 and D_3 variables. USA, 2021 (as from UN World population prospects 2019).



4 Demographics and Rates of Return

4.1 Working-age Population and Productive Capacity

Economic theory and abundant literature suggest that, as the share of population in working age falls, returns on productive capital should follow the same path, as the productive capacity of the economy, per unit of capital, decreases as a result of the decline in labour input. This fact can be shown empirically with a simple exercise. Start from the simple assumptions that the rate of return on capital r^k is a negative function of the capital stock per hour worked K/H and a positive function of productivity A and the capital share of income α:[7]

[7]Intuitively, working a unit of capital for longer (= lower K/H) is going to generate more income, and the same holds if productivity is higher or if a larger share of income is distributed to capital. These conditions hold for instance if we assume a standard Cobb-Douglas production function (with the labour input being hours worked, H) of the form $Y = AK^{\alpha}H^{1-\alpha}$, where we would have $MPK = \alpha\frac{Y}{K} = \alpha A\left(\frac{K}{H}\right)^{\alpha-1}$. However, the above formulation allows for a wider range of potential production functions.

$$
\begin{aligned}
r^k = f\left(\frac{K}{H}, A, \alpha, ...\right), \\
\frac{\partial r^k}{\partial (K/H)} < 0, \\
\frac{\partial r^k}{\partial A}, \frac{\partial r^k}{\partial \alpha} > 0
\end{aligned}
\tag{3}
$$

To show the effect of demographic factors on r^k, K/H can be broken down into: $K/N \times L/H \times N/L$, where N is total population, and L is the number of persons employed. In this expression therefore, each factor represents respectively (i) the capital stock per capita; (ii) the inverse of average annual hours worked per person employed; and (iii) the inverse of persons employed as a share of the population. Substituting this into the above equation results in:

$$
r^k = f\left(\overset{(-)}{\frac{K}{N}}, \overset{(-)}{\frac{L}{H}}, \overset{(-)}{\frac{N}{L}}, \overset{(+)}{A}, \overset{(+)}{\alpha}, ...\right) = f\left(\overset{(-)}{\frac{K}{N}}, \overset{(+)}{\frac{H}{L}}, \overset{(+)}{\frac{L}{N}}, \overset{(+)}{A}, \overset{(+)}{\alpha}, ...\right) \tag{4}
$$

This shows, unsurprisingly, how we should expect a higher share of population at work (L/N) to increase return on capital, and a higher number of hours worked per person employed to also lead to higher returns. L/N can be further decomposed into $L/N_w \times N_w/N$, where N_w is the working-age population. In other words, this corresponds to: (i) persons employed as a share of the working-age population (or the employment rate) times (ii) the share of the working-age population in total population. This finally gives us an expression that directly expresses the return on capital in terms of the working-age population share, where there is a positive relationship between r^k and N_w/N:

$$
r^k = f\left(\overset{(-)}{\frac{K}{N}}, \overset{(+)}{\frac{H}{L}}, \overset{(+)}{\frac{L}{N_w}}, \overset{(+)}{\frac{N_w}{N}}, \overset{(+)}{A}, \overset{(+)}{\alpha}, ...\right) \tag{5}
$$

This very simply highlights how, *ceteris paribus*, a higher proportion of the population in their working age should increase the rate of return on capital (all else equal) as it will feed into higher labour supply (hence lower K/H), increasing income.

I want now to test these facts empirically, as all the relevant variables in 4 and 5 can be easily obtained from the data. The above derivation suggests that a regression model of the following form might be appropriate within a fixed-effect panel framework to test the validity of equation 4:

$$\ln(r_{it}^{k}) = \beta_0 + \beta_1 \ln(\alpha_{it}) + \beta_2 \ln(A_{it}) + \beta_3 \ln(K_{it}/N_{it}) + \beta_4 \ln(H_{it}/L_{it}) + \\ + \beta_5 \ln(L_{it}/N_{it}) + \gamma_i + \delta_t + u_{it} \tag{6}$$

where i and t represent country and year, γ_i are country fixed-effects and δ_t are year fixed-effects, and all variables are expressed in logarithms. A corresponding equation can be derived for 5. I test 6 using the panel dataset introduced in Section 3 and display the results in Table 1. The estimation employs robust standard errors clustered at country level, and year fixed-effects in specifications (2) and (4). The regression results show that what expressions 4 and 5 suggest in terms of the signs of the effects of each component of K/H, as well as A and α, on r^k holds empirically. As displayed in Table 1, all the assumptions arising from the simple exercise above are confirmed with significance, whether or not year fixed-effects are added, with the coefficients showing the expected signs and being considerably large. Of particular interest for this paper, a greater proportion of the population in their working age appears to have a large and positive effect on return on capital, with a 1% increase in the working-age population to population ratio increasing the return on capital by 0.49% (0.57%).

Although the results in Table 1 are encouraging as they match the equation formulation of the problem, there might be potential issues with such specification. The variables used for the regression in Table 1 are slow-moving, some of them are trending upwards (e.g. K/N, TFP) or downwards (H/L) in most countries, and they might be cointegrated. A visual inspection of the data and the use of unit root tests for the above variables at the country level seem to confirm that for most of the countries, the variables included in the above specifications are generally non-stationary, and in most of cases they have a trend. (Panel unit root tests are more contradictory in this regard however, with some types of tests rejecting the null hypothesis that the variables are non-stationary in all panels for some of the variables.) There is a strong possibility that the variables might therefore be cointegrated, and indeed in the case of a few countries, a Vector Error-Correction model with one cointegrating equation would well fit the data.

To address these issues I have separately estimated specifications (1) and (3) of Table 1 (i) with all variables differenced once, and (ii) as an Arellano-Bond dynamic panel. These give similar results: in both regression models, the coefficients on all the explanatory variables remain highly significant, large and with the expected signs. The results from Table 1 do not appear to be the consequence of a spurious relationship, and can be reasonably taken as valid.[8]

Another concern lies in the choice of variable for productivity. To generate a measure of Total Factor Productivity, as calculated in PWT and used for Table 1, a certain underlying

[8]Results are available but are omitted for brevity.

Table 1: Fixed-effects panel estimation of return on capital based on equations 4 and 5.

	(1)	(2)	(3)	(4)
	$ln(r^k)$	$ln(r^k)$	$ln(r^k)$	$ln(r^k)$
	β (s.e.)	β (s.e.)	β (s.e.)	β (s.e.)
$ln(\alpha)$	0.909***	0.930***	0.909***	0.932***
	(0.09)	(0.09)	(0.09)	(0.09)
$ln(TFP)$	0.673***	0.614***	0.674***	0.617***
	(0.09)	(0.10)	(0.09)	(0.10)
$ln(K/N)$	-0.352***	-0.322***	-0.354***	-0.333***
	(0.04)	(0.05)	(0.04)	(0.05)
$ln(H/L)$	1.061***	0.902***	1.058***	0.879***
	(0.23)	(0.26)	(0.23)	(0.26)
$ln(L/N)$	0.478***	0.479***		
	(0.11)	(0.13)		
$ln(L/N_w)$			0.471***	0.442***
			(0.14)	(0.14)
$ln(N_w/N)$			0.492***	0.570***
			(0.16)	(0.19)
Constant	-4.804**	-3.878*	-4.753**	-3.540
	(1.98)	(2.09)	(1.99)	(2.13)
Country fixed-effects	✓	✓	✓	✓
Year fixed-effects		✓		✓
R^2	0.632	0.656	0.632	0.657
deg. fr.	63	63	63	63
# obs.	3000	3000	3000	3000

production function in the economy needs to be assumed; this production function might not be the true underlying function and bias the results through the addition of TFP in the regression. At the same time, omitting TFP from the regression would clearly lead to omitted variable bias. In the absence of any specific reason for choosing a different productivity measure (which would still be reliant on some different assumption), and because of its widespread and established use in the literature, in the analysis that follows I will continue using TFP as produced by the Penn World Tables. However, in Appendix A.1, I calculate alternative productivity measures and repeat the exercise done for Table 1 (as well as the following Section). The results suggest that using TFP remains appropriate.

4.2 Age Distribution and Capital Accumulation

While the above analysis suggests that the working-age population share alone has a direct impact on returns due to productive capacity considerations, economic theory also suggests that the *structure* of the population, i.e. the shape of the population pyramid, is in turn likely to affect some of the other factors into which the return on capital was decomposed in equations 4 and 5. Ignoring these channels can potentially significantly over- or underestimate the effect of the demographic distribution on returns. Indeed, even among people of working age, agents of different ages can have quite different effects on the economy.

Every item in equation 4 might be dependent on demographics. In particular, K/N stands out in this sense. An abundant literature on the consumption, savings, and wealth accumulation patterns of households throughout their life cycle shows how households typically start their working life with limited assets (or in debt); they gradually build up their wealth through the years by accumulating savings from their incomes, which also typically rise through the working years, reaching a peak after their fifties; finally, once they retire, they slowly run down their assets. Such a pattern of behaviour has been frequently observed empirically.

While every person's wealth accumulation journey is different and mostly independent, this pattern of behaviour aggregates across the population such that if an economy's population, all else equal, has relatively more people of an age at which life-cycle wealth is at its peak, then the overall level of capital per person in the economy will be higher. Note how, as K/N came with a negative coefficient on returns in Table 1, that implies that the return on capital will be lower in such an economy due to the abundance of capital relative to the population, which is in turn due to the simultaneous large holdings of wealth by a large cohort of individuals.

In addition to capital per person, the demographic distribution is likely to have a major impact on the employment rate of the population (L/N) as well. Different age groups have vastly different labour force participation rates, with some groups not participating in the labour force at all, while even within the working-age population, individuals of different ages have different likelihoods of being in employment.

Finally, although Total Factor Productivity, or its growth, might also be higher *ceteris paribus* with a relatively younger workforce, as has been argued before in the literature (see Section 2), such a relationship with the age distribution is less clear and established, and therefore TFP is taken as exogenous to the demographic distribution in the analysis that follows.

To obtain an estimate of the combined effect of the age distribution on the rate of return, while accounting for the wealth accumulation and employment rate channels (i.e. the effects of the age distribution on K/N and L/N), I estimate a panel instrumental variable regression based on specification (2) of Table 1, where however $ln(K/N)$ and $ln(L/N)$ are instrumented by the demographic variables D_1, D_2 and D_3 (calculated as explained in section 3.3), plus year fixed-effects.[9] Table 2 displays the results of the first-stage regressions on $ln(K/N)$ and $ln(L/N)$.

Table 2: Instrumental-variables estimation of r^k. First-stage regressions.

	(1) $ln(K/N)$ b/se	(2) $ln(L/N)$ b/se
D_1	0.260	0.731***
	(0.21)	(0.09)
D_2	0.097***	-0.046***
	(0.03)	(0.01)
D_3	-0.006***	0.000
	(0.00)	(0.00)
$ln(TFP)$	0.800***	-0.118***
	(0.02)	(0.01)
$ln(\alpha)$	-0.099***	0.036***
	(0.03)	(0.01)
$ln(H/L)$	0.924***	-0.104***
	(0.08)	(0.03)
Constant	3.851***	-0.309***
	(0.58)	(0.24)
Country fixed-effects	✓	✓
Year fixed-effects	✓	✓
R^2	0.919	0.648
# obs.	3000	3000

The demographic variables D_1, D_2 and D_3 are jointly significant at the 1% level for both

[9] The shape of the population pyramid is an ideal instrument, as an economy's population structure is almost entirely independent of $current$ economic conditions, due to the very slow-moving nature of population dynamics. Even migration and major events that affect both the economy and demographics (pandemics such as COVID-19, for instance), have a negligible impact on the population pyramid.

$ln(K/N)$ and $ln(L/N)$, indicating that the shape of the population pyramid that they represent has itself an impact on these variables. The implied coefficients of each age bracket on $ln(K/N)$ and $ln(L/N)$ can be recovered from the coefficients on D_1, D_2 and D_3, based on how these were calculated from the relative sizes of the age brackets (see Section 3.3). Recalling that there are 18 age brackets in the data (17 5-year age groups, plus a group including all the population above 85 years old), the implied coefficient $\beta^{j,ln(K/N)}$ of age group j on $ln(K/N)$, given the coefficients $\beta^{D_1,ln(K/N)}$, $\beta^{D_2,ln(K/N)}$ and $\beta^{D_3,ln(K/N)}$ from the first-stage of the instrumental variables regression in Table 2, can be calculated as:

$$\beta^{j,ln(K/N)} = -(\frac{\beta^{D_1,ln(K/N)}}{18}\sum_{k=1}^{18} k + \frac{\beta^{D_2,ln(K/N)}}{18}\sum_{k=1}^{18} k^2 + \frac{\beta^{D_3,ln(K/N)}}{18}\sum_{k=1}^{18} k^3) + \\ + j\beta^{D_1,ln(K/N)} + j^2\beta^{D_2,ln(K/N)} + j^3\beta^{D_3,ln(K/N)} \tag{7}$$

Figure 4: Effect of each age group on $ln(K/N)$ and $ln(L/N)$

with $j = 1$ representing the age group of persons aged 0-4 years old, $j = 2$ representing 5 to 9 year-olds, and so on at 5-year increments. The equivalent can be done for $ln(L/N)$. Figure 4 displays graphically the backed-out coefficients from the first-stage regressions for each age group population share, derived from the coefficients on D_1, D_2 and D_3 as for the equation above. The figure shows how, in accordance with the life-cycle hypothesis, agents in their late working-age and early retirement increase capital per person in the economy, as these are the years in which the highest level of wealth is accumulated before asset positions begin to be sold as individuals age further; conversely, a larger proportion of children and the elderly in the population tends to decrease capital per capita. Unsurprisingly, the coefficients on the employment rate are instead positive for all age groups of working age. The peak positive impact of an age-group on employment comes earlier than for capital accumulation: while 55 to 64 year-olds have the largest impact on $ln(K/N)$, 35 to 44 year-olds have the largest impact on employment.

Table 3: Instrumental-variables estimation of r^k. Second-stage regression.

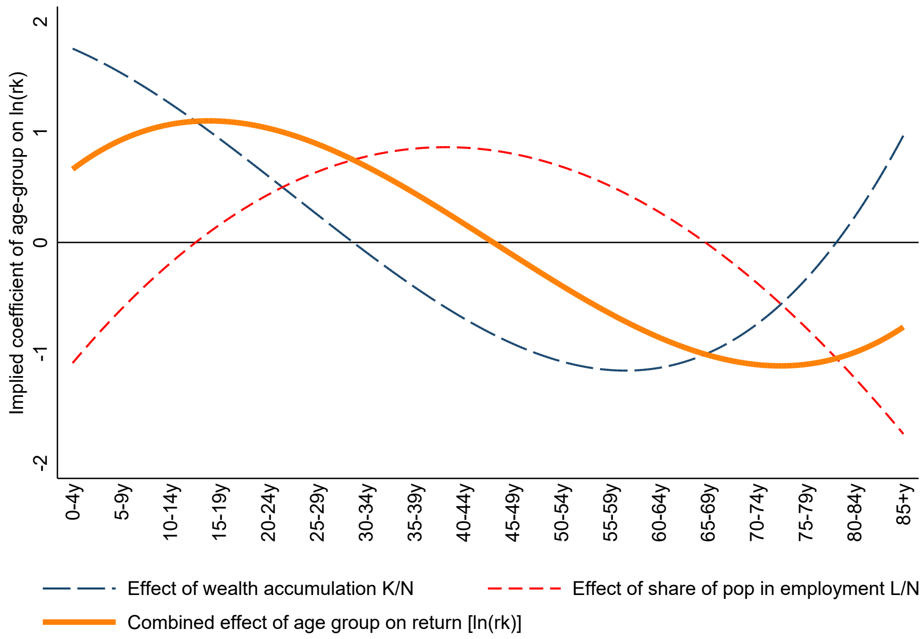
	(1) $ln(r^k)$ b/se
$ln(K/N)$	-0.443***
	(0.02)
$ln(L/N)$	0.854***
	(0.06)
$ln(TFP)$	0.773***
	(0.04)
$ln(\alpha)$	0.901***
	(0.02)
$ln(H/L)$	1.015***
	(0.06)
Constant	-3.148*
	(0.44)
Country fixed-effects	✓
Year fixed-effects	✓
# obs.	3000

The second-stage of the IV panel regression (Table 3), with $ln(K/N)$ and $ln(L/N)$ instrumented by D_1, D_2, D_3 and year fixed-effects, gives results that are very similar to those from specifications (1) and (2) in Table 1. However, this specification allows to produce an estimate of the effects of the whole age distribution on $ln(r^k)$. By multiplying the implied coefficients of the age groups on $ln(K/N)$ and $ln(L/N)$ from the first-stage regressions as displayed in Figure 4, by the coefficients of $ln(K/N)$ and $ln(L/N)$ themselves on the rate of return from the second-stage regressions, we can estimate the effect of each age group on the return on capital through wealth accumulation channel, and the employment channel. The sum of the two (see equation 8) provides an estimate of the overall impact of each age group on rates of return through the combined effect of these two channels. The results are displayed graphically in Figure 5.

$$\beta^{j,ln(r^k)} = \beta^{j,ln(K/N)}\beta^{ln(K/N),ln(r^k)} + \beta^{j,ln(L/N)}\beta^{ln(L/N),ln(r^k)} \tag{8}$$

These results are very intuitive. Not participating in the labour force, the effect of children and retired persons on returns via the labour force participation channel is negative. At the

Figure 5: Combined effect of each age group on rates of return via $ln(K/N)$ and $ln(L/N)$



same time, children and young adults, and persons in late retirement contribute a positive effect on returns via capital accumulation due to their low levels of accumulated wealth, for opposite reasons. This results in an overall positive effect on returns by young agents overall, with the peak positive impact at about 20 years of age and then steadily decreasing.

As agents enter the labour force, they increase returns to capital through their labour, but while their savings gradually accumulate, steadily increasing K/N, the negative impact on returns from wealth accumulation rises and finally overcomes the positive effects of labour force participation in the 45-49 age bracket, after which the combined effect becomes negative. With the labour-force participation effect now falling steadily and wealth accumulation remaining very high, the 70-79 age groups become the ones that most adversely affect returns. While agents above 80's typical asset decumulation leads to a positive effect on returns through the saving channel, this is not sufficient to fully compensate for the negative effect through the employment channel.

The median ages of advanced economies are now moving towards the peak earning years of the late working age (> 50), while the shares of people in their teens, twenties and thirties are rapidly falling due to falling birth rates, and the share of over-65s rises steadily. This results in lower returns on capital due to the combined effects of (i) a falling working-age population overall, and especially the younger end; and (ii) a higher proportion of people with substantial wealth, relatively less productive and close to retirement bringing up K/N.

Based on this analysis and projected demographic developments across the world, advanced economies are set to continue to experience lower and falling rates of return for many years, while an increasing number of developing economies which are starting to experience a demographic transition will also see their rates of return fall in the next decades.

These factors highlight a stark generational imbalance between those currently in or close to retirement, who were able to build up considerable amounts of wealth in the past, when the younger structure of the population, high growth and relative scarcity of capital allowed for high returns; and a cohort of young individuals facing a future of low returns impairing their ability to build wealth themselves. The effects of falling returns on intergenerational wealth imbalances are explored further in the next Section.

4.3 Returns to Wealth and Inequality Between Generations

The previous Section showed how a relatively young population positively affects rates of return on capital, as in young economies labour is abundant and capital relatively scarce. Similar results are well-established in the literature on secular stagnation, in particular with respect to the effects of population ageing on long-term equilibrium interest rates and risk-free rates.

In an ageing economy, as rates of return gradually decline, including due to demographic factors, and wealth becomes increasingly concentrated in the hands of older age groups, the accumulation of wealth becomes more and more difficult for younger generations of workers. At the same time, the lower production of income out of wealth due to declining rates puts an increasing number of retirees with limited resources into financial difficulties in the absence of generous, but increasingly expensive public pension schemes. In such an economy, production by the current, shrinking young labour force needs to generate enough returns and tax revenues to sustain the incomes of a rising number of retirees, through public pension schemes as well as capital gains.

To illustrate the link between population dynamics and wealth inequalities between generations, the results from Section 4.2 can be used to compute the overall effect of the aggregate demographic distribution of an economy on r^k, and therefore on total rates of return in the long term. To do so, for every country and year, the implied coefficients of each age bracket on $ln(r^k)$, as illustrated graphically in Figure 5, are multiplied by the share of each age bracket in the total population, to give the impact of such age bracket on $ln(r^k)$. These are then summed up in order to recover the impact of the aggregate demographic distribution itself. The effect of the demographic distribution on $ln(r^k)$ in year t on country i is therefore calculated as:

$$\beta_{i,t}^{DD} = \sum_{j=1}^{18} \beta^{j,ln(r^k)} \frac{N_{j,i,t}}{N_{i,t}} \tag{9}$$

where $N_{j,i,t}$ is population in age bracket j in country i and year t ($N_{i,t}$ is the total population in the same country and year), and the β^j's are calculated from the coefficients on D_1, D_2 and D_3 as in equation 7.

By using the values for $\beta_{i,t}^{DD}$ across countries and years, I can estimate the differential impact of age distributions on the accumulation of wealth of different generations, and explore the extent to which the impact of age distributions on returns may represent a significant source of wealth inequality between generations, in the present and future.

Figure 6: Impact of the demographic distribution on return on capital (r^k), selected advanced economies.

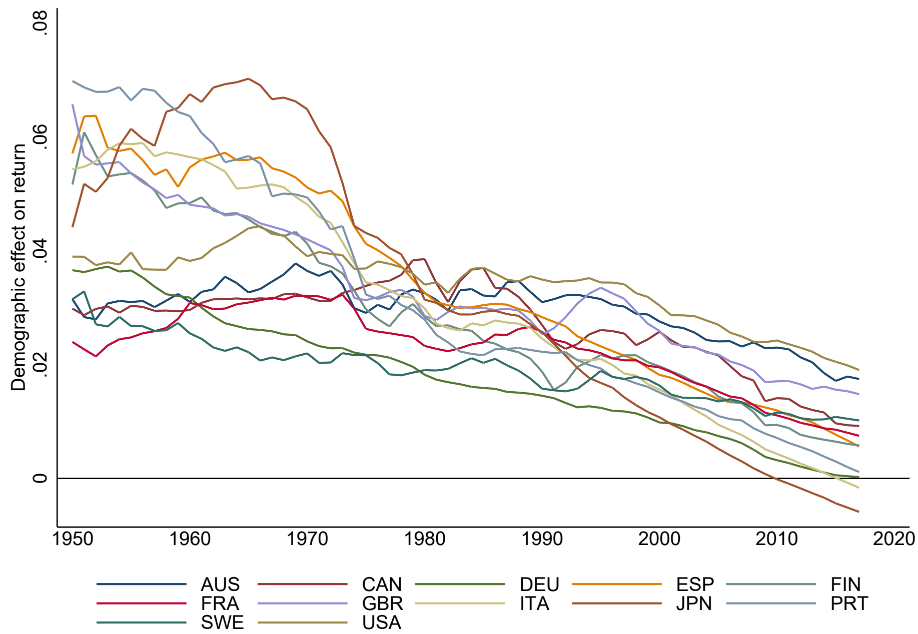


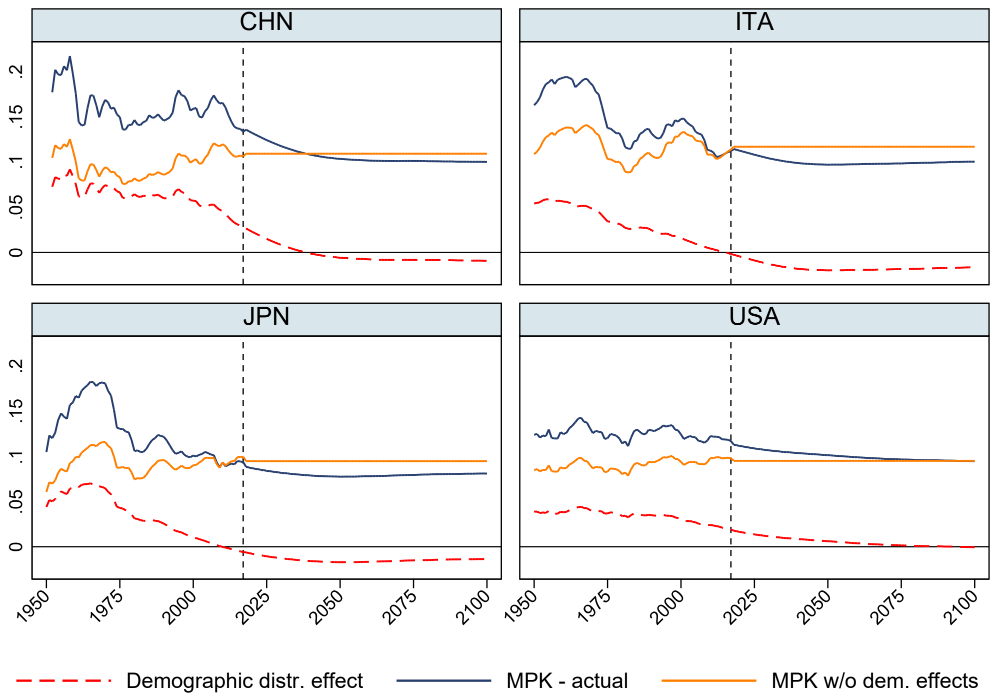
Figure 6 displays the estimated effect of the overall demographic distribution on returns on capital for a number of advanced economies. This is computed from $\beta_{i,t}^{DD}$ as per equation 9; as $\beta_{i,t}^{DD}$ is the effect of the demographic distribution on the natural logarithm of r^k, the effect on r^k itself is calculated as:

$$DD_{i,t}^{effect} = r_{i,t}^k - e^{ln(r_{i,t}^k)-\beta_{i,t}^{DD}} \tag{10}$$

While it turns out that such an effect has been considerably positive for most of the time series and countries under consideration, due to young and growing populations throughout most of the twentieth century, the trend is downwards everywhere (including countries not in the figure), with aging populations and lower birth rates moving the demographic distribution towards age groups that lower r^k.

Figure 7 further illustrates the evolution of rates of return in China, Italy, Japan and the

Figure 7: Returns to capital and demographic effect: CHN, ITA, JPN, USA



USA,[10] the estimated impact of the demographic distribution on these returns throughout the years, and finally what returns would have been in the absence of such demographic factors. As is evident for the countries displayed in Figure 7[11], rates of return after removing demographic effects (i.e., $r^k - DD_{i,t}^{effect}$) appear to be significantly more stable throughout the years in individual economies (with little to no sign of them trending up or downwards in most countries), and also more similar between economies, as countries with higher rates overall also tended to have younger populations.[12] Thus, for a large part due to demographic developments, rates of return saw a significant decline in recent decades as the positive contribution of the population structure (a "demographic dividend" that certain generations have enjoyed) fell across the world. In a few countries (e.g. Italy and Japan), the demographic distribution is now weighing on rates of return, which would have been higher otherwise, with the turning point occurring in both cases soon after the year 2000. As also shown in Figure 6, more economies are now in this position due to their ageing pop-

[10]Results for the other countries are available. These countries were chosen because they include two of the oldest populations in the world (Italy and Japan), and the two largest economies (USA and China). The case of the USA is also interesting as it remains one of the youngest advanced economies (partly due to high immigration) and did not experience as dramatic a demographic shift as most of Europe; on the other hand, the population of China is aging at a fast rate also due to its former one-child policy.

[11]But also for the rest of the countries

[12]The standard deviation of r^k across the entire sample is 0.083, while for r^k with demographic effects removed it reduces to 0.052.

ulations, or are trending towards it.

Figure 7 also presents a forecast of the evolution of rates of return through the end of the century. This is done by assuming that $r^k - DD_{i,t}^{effect}$, which as discussed has been relatively constant throughout the sample period, remains at a level equal to its country average from the year 2000 to the latest observation. $DD_{i,t}^{effect}$ is then calculated by obtaining D_1, D_2 and D_3 based on the UN population projections. r^k is then finally the sum of the two. In countries where the demographic transition is already at an advanced stage, rates of return are expected to fall further (but only slightly) for a few more decades, reaching their lowest point at around 2040/2050, to then stabilise around that level, below the rate of return that would have been achievable in the absence of any demographic contribution, and significantly below the rates of return experienced in the second half of the twentieth century. Economies at an intermediate stage of the demographic transition (e.g. China) are expected to follow the same path with a few decades' delay; their rates of return are seen declining rapidly in the next years.

Most developing economies are still expected to enjoy a high positive contribution to returns, thanks to their relatively young population, for some time to come; however, in almost all cases, rates of return are expected to decline significantly and steadily for the most part of the century. The contribution of the population of China to China's rate of return on capital, for instance, stood around 2.9% in 2017, while it is expected to reach a level of -0.7% by around 2070; this implies a decline in rates of return there of almost 7 basis points per year for over 50 years, due to a rapidly declining birth rate and rising life expectancy. Finally, countries which are expected to maintain relatively higher birth rates and/or higher levels of net migration (e.g. the US) will see rates of return declining at a much slower pace.

Young, growing and dynamic populations throughout the twentieth century have helped maintain high returns to capital/wealth, thanks to a high share of young and productive workers and a relative scarcity of capital; these high returns have allowed generations of middle-class households to accumulate sufficient wealth for a decent retirement. Indeed, throughout this time, a pyramid-shaped population distribution has sustained a pyramid scheme of sorts, where the returns on wealth of a cohort were guaranteed by income produced by the next, larger and younger cohort of workers.

As life expectancies increased, and birth rates fell, population pyramids in advanced economies started stabilising, as new generations were no longer larger than the previous ones and more people survived to older ages; in recent years, population pyramids have started to become inverted, with younger generations shrinking more and more. Recall Figure 1 and the developments in the population of Japan, where the demographic shift is currently at the most advanced stage globally. In Japan and economies with similar demographic developments, what was before a "pyramid scheme" where increasingly large younger generations supported the retirement incomes and wealth of a small older population, has slowly morphed into an *inverted pyramid scheme*, where it becomes quite hard for a shrinking young population to now do the same.

Whether an agent is young, middle aged, or retired, the age of everyone else around them matters greatly to their wealth accumulation, via the effects of the demographic distribution on returns on capital as seen above. But how much more wealth could an agent who started saving in the 1960s, with a growing and young population, accumulate over the next 20 years compared to a similar agent who started investing in the 2000s, and how much of this difference can be attributed to demographics?

If returns are compounded annually, a small difference in annual returns can lead to very significant wealth accumulation paths across a working life. With the "demographic dividend" described here starting to fall across the developed world around the 1970s and bringing down rates of return with it, each subsequent generation would have been at a disadvantage compared to the previous one in terms of their wealth accumulation. Newer generations would either accumulate less wealth out of the same savings compared to their elders, or be forced to save a larger portion of their incomes to make up for the impact of the lost returns. Figure 8 shows how a small difference in the rates of return experienced by households in subsequent generations in the countries of Figure 7 lead to widely diverging wealth accumulation journeys. An Italian household who invested 1 in 1955 and reinvested the return (r^k) every year for 20 years could expect to have accumulated a real value of 30 by 1975. By 2017, an investment of 1 20 years prior would have only returned a real value of 10. Notice how this wedge was mostly due to the very favourable demographic structure just after WWII pushing up rates of return, which then fell steadily from the 70s as population started ageing. In the absence of these demographic effects, the two households would have enjoyed virtually the same cumulated returns out of their investments.

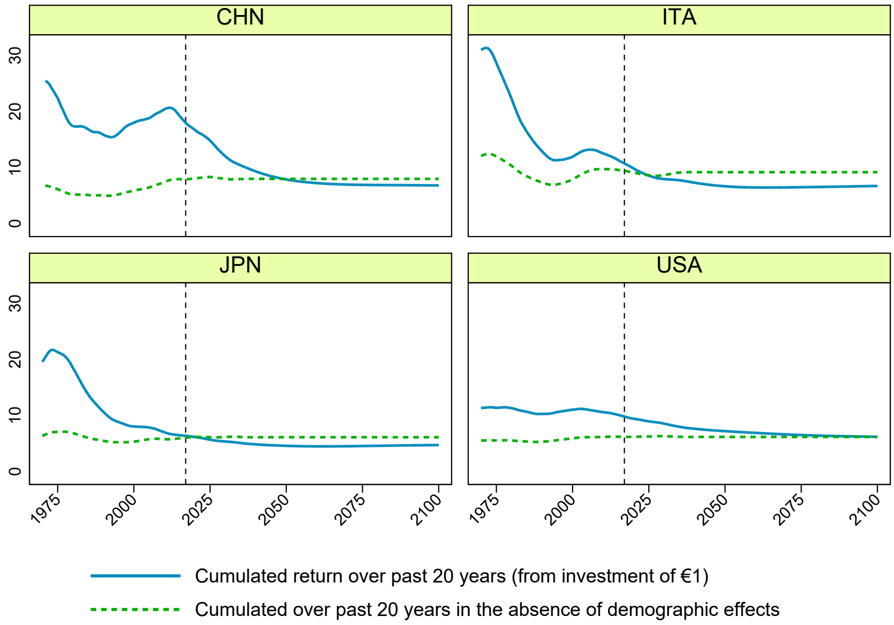
This paper largely focuses on how demographic dynamics unequally impact wealth accumulation for different generations or cohorts. However, the large imbalances between generations in the speed of wealth accumulation have an impact on wealth inequality through multiple different channels.[13]

The first is apparent from Figure 8. In general, as they more easily accumulated wealth while younger, older generations will hold a larger share of wealth. On the other hand, younger people will be further away from the average per-capita wealth level than their elders were at the same age. This leads to *inter*-generational wealth inequalities.

At the same time, falling rates of return might mitigate *intra*-generational wealth inequalities. With high rates of return, a small difference in savings between two agents of the same age can compound to become very large over decades; with lower returns, this is less of the

[13] One of these is the decline in rates of return documented here. Greenwald et al. (2021) (18), for instance, find that declining real interest rates lead to an increase in financial wealth inequality.

Figure 8: Wealth accumulated over 20 years: CHN, ITA, JPN, USA



The figure shows, for each year, the wealth accumulated if a 1 unit investment was made 20 years before, and returns were each year reinvested and compounded at the prevailing rate of return. The rates of return considered are the r^k and r^k with demographic effects removed, as in Figure 7.

case, leading to less wealth inequality between agents of the same age.[14]

Lower rates of return also tend to raise asset prices. Indeed, while Figure 2 showed how the price of capital remained unchanged overall, this was due to a combination of falling prices of machinery, transport equipment and other forms of capital, while the price of buildings and residential structures (and with it the value of housing assets) kept increasing in real terms. With the possession of housing assets very low at young ages and low wealth percentiles, the appreciation of housing assets due to falling rates, which are in turn due to demographic developments, would increase both intra- and inter-generational wealth inequalities.

While the above is true if we consider wealth as a single aggregate asset, agents of different ages tend to invest in different asset types, such that a different demographic distribution is likely to affect the relative prices and returns of different asset types. Kopecky and Taylor (2020) (23) suggest that aging demographics raise the equity risk premium; at the same time, housing has become more expensive in the past decades as seen in Section 3.2. As

[14]Note, however, that regardless of initial wealth, agents would be worse off, with lower wealth (all else equal) than in the presence of higher returns. Also, this is only the case if agents invest in the same portfolio. With different portfolio compositions, agents investing in higher-return assets might benefit if risk premia increase with lower rates of return.

agents who invest in these asset types tend to be wealthier, a falling rate of return on capital (aggregate) may affect agents in the lower end of the wealth distribution more than those in the upper end, further increasing wealth inequalities.

Intergenerational transfers (bequests) further complicate the picture. An increasing proportion of wealth being held by the elderly signifies that increasing amounts of wealth will be ultimately transferred to younger generations. In a young economy, transfers might decrease inequality by redistributing wealth to a higher number of less wealthy agents. A longer life expectancy, however, means that the average age at which agents receive such a transfer increases further.[15] With life expectancy at over 80 in many advanced economies, the age at which such transfers occur would tend to fall during an agent's late working age, i.e. at the peak of their wealth accumulation, further concentrating wealth in those age groups.[16] Lower birth rates also mean that wealth transfers will be increasingly concentrated to a decreasing average number of heirs. All in all, in an ageing society bequests are thus likely to worsen inter-generational wealth inequality (as transfers tend to go to already wealthy age groups), as well as intra-generational wealth inequality (transfers are more concentrated).

The analysis presented so far points to convincing evidence of population dynamics having a significant effect on returns, and consequently on the unequal distribution and accumulation of wealth, especially between different generations in ageing societies. The empirical evidence from this section suggests that decreasing rates of return as population ages lead to rising inter-generational inequality, if subsequent generations invest similar amounts to each other. However, does the situation change when wage levels are taken into account? The next section explores this.

5 Demographics and Wages

We have seen that population ageing contributes to a decrease in rates of return. This leads to divergences in how much wealth a household can expect to accumulate out of a certain level of savings. At parity of (real) investment, current young generations are disadvantaged compared to previous generations in terms of wealth accumulation, due to lower rates of return. However, the situation may change if wages are taken into consideration:

[15] This effect is slightly mitigated by the fact that parents' age at a child's birth has also tended to be on the increase in ageing economies. However, life expectancies have risen by longer, meaning that, overall, the average age of receipt of bequests has risen: for instance, Eurostat data (available at `https://ec.europa.eu/eurostat/web/main/data/database`) shows that the mean age of women at childbirth in Belgium has risen from 28.0 years in 1960 to 30.8 in 2020; over the same period, life expectancy increased from 69.7 to 80.8 years. Similar trends can be seen in other countries.

[16] Intergenerational gifts when the recipients are in their working age can alleviate these concerns, although these tend to be smaller than bequests.

since the 1950s, real wages have steadily increased across the world, such that in most economies an average young household today can afford to invest more (in real terms) than previous generations. Net of this, are younger generations better or worse off?

A large part of increases in labour compensation in past decades can be attributed to technological advancement and higher productivity. However, the same demographic dynamics that have been discussed for returns on capital also have a bearing on the compensation of labour, where for the most part their impact on wages is opposite to their impact on returns. In particular, a smaller proportion of the population at work and a higher capital intensity both tend to lead to higher wages.

The exercise in Section 4.1 can be repeated for wages (per hour worked). With similar arguments as for capital, I make three assumptions about the return on labour which are consistent with 3 and economic theory, i.e. wages will be higher if: (i) there is more capital relative to labour K/H (with more capital, an hour of labour can produce more); (ii) productivity is higher; (iii) the capital share of income is lower. In other words:

$$\begin{aligned} w^H = f\left(\frac{K}{H}, A, \alpha, ...\right), \\ \frac{\partial w^H}{\partial (K/H)}, \frac{\partial w^H}{\partial A} > 0, \\ \frac{\partial w^H}{\partial \alpha} < 0 \end{aligned} \tag{11}$$

Decomposing K/H as in 4 gives:

$$w^H = f\left(\overset{(+)}{\frac{K}{N}}, \overset{(-)}{\frac{H}{L}}, \overset{(-)}{\frac{L}{N}} \left(= \overset{(-)}{\frac{L}{N_w}} \overset{(-)}{\frac{N_w}{N}}\right), \overset{(+)}{A}, \overset{(-)}{\alpha}, ...\right) \tag{12}$$

i.e., contrary to the case for rates of return on capital, we expect K/N to increase hourly wages and a higher proportion of the population at work to decrease them. The average total wage earned by a worker, w^L, would be equal to $H/L \times w^H$. Assuming that the elasticity of hourly wages to hours worked per person is less than one (workers would not be working as many hours if that was not the case), we can expect H/L to have a positive effect on w^L such that:

$$w^L = f\left(\overset{(+)}{\frac{K}{N}}, \overset{(+)}{\frac{H}{L}}, \overset{(-)}{\frac{L}{N}} \left(= \overset{(-)}{\frac{L}{N_w}} \overset{(-)}{\frac{N_w}{N}}\right), \overset{(+)}{A}, \overset{(-)}{\alpha}, ...\right) \tag{13}$$

How do demographics affect wages through the channels in equation 13? We know that ageing demographics tend to increase K/N and lower L/N (recall Figure 4). Running the same instrumental variables regression as in section 4.2 (replacing r^k with w^L as dependent variable) unsurprisingly gives results that are consistent with equation 13, as shown in Table 4. The first-stage regression results are still the same as for Table 2 (the variables entering the first-stage regressions are the same), giving the age-profile of effects on K/N and L/N as per Figure 4.

Table 4: Instrumental-variables estimation of real (log) w^L. Second-stage regression.

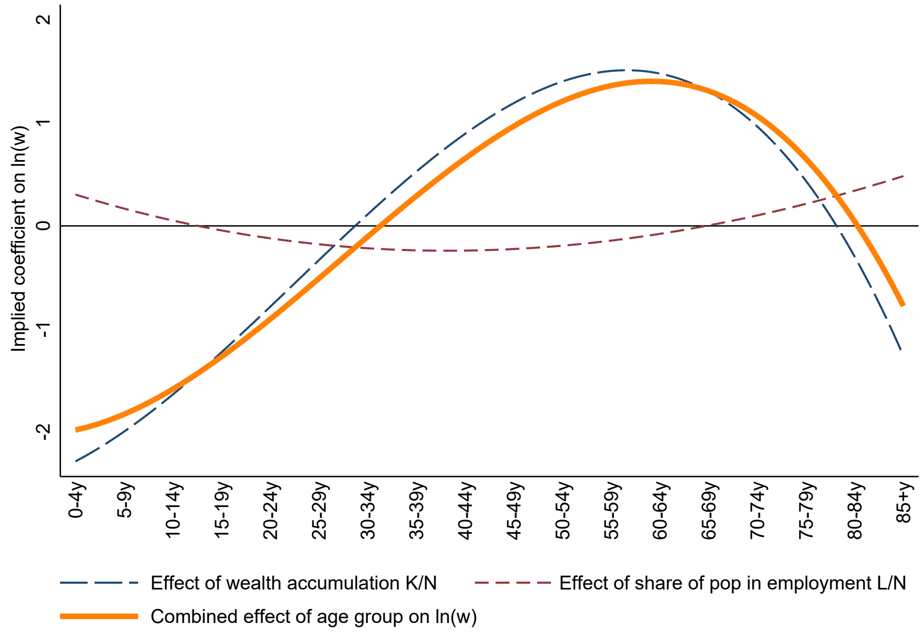
	(1) $ln(w^L)$ b/se
$ln(K/N)$	0.566*** (0.01)
$ln(L/N)$	-0.229*** (0.04)
$ln(TFP)$	0.792*** (0.02)
$ln(\alpha)$	-0.800*** (0.01)
$ln(H/L)$	0.702*** (0.03)
Constant	-2.552*** (0.22)
Country fixed-effects	✓
Year fixed-effects	✓
# obs.	3000

As done above for Figure 5, multiplying these implied coefficients of each age group on $ln(K/N)$ and $ln(L/N)$ by the coefficients of $ln(K/N)$ and $ln(L/N)$ from the second-stage regression, I can calculate the impact of each age group on labour compensation ($ln(w^L)$) through wealth accumulation, through the labour force, and the overall effect. Figure 9 shows this graphically. The strongest impact is through wealth accumulation, where age groups with high accumulated wealth lead to an abundance of capital in the economy, which generates an increase in the compensation of labour by making it more productive.

A higher employment rate of the population has the opposite effect, as less scarcity of labour pushes down its cost; this channel seems however to be smaller than the wealth accumulation channel through demographics.[17] Overall, all age groups from 35-39 to 80-84

[17] Note how in Figure 4, the effects of the age distribution on $ln(L/N)$ are flatter than those on $ln(K/N)$. This is partly because, in ageing economies, the labour force participation of the working-age population has been observed to increase (at least in part due to demographic developments) as the working-age population share itself shrinks; at the same time, labour force participation in groups outside of the typical working-age population (over 65s) has also tended to rise in these economies, also because of improving health. The overall effect of demographics on the employ-

Figure 9: Combined effect of each age group on compensation of labour via $ln(K/N)$ and $ln(L/N)$



lead to higher wages, all other things constant, while over-85s and under-35s reduce them. As a result, ageing economies tend to have higher wages due to demographic factors, and in particular due to the effect of the wealth accumulated by those from middle age to early retirement. Comparing this with Figure 5, which shows the effect of each age group on return on capital, we can see that for most age groups, having a positive impact on return on capital means having a negative impact on compensation of labour, and vice-versa. However, crucially, the magnitudes are not quite the same for all age groups (for instance, while the 65-69 age group has a large negative impact on return on capital and a large positive impact on compensation, the 45-49 group has a high positive impact on wages but only a negligible negative impact on returns); additionally, persons aged 35-44 have a positive effect on both returns and wages, while the opposite is true for over-85s.

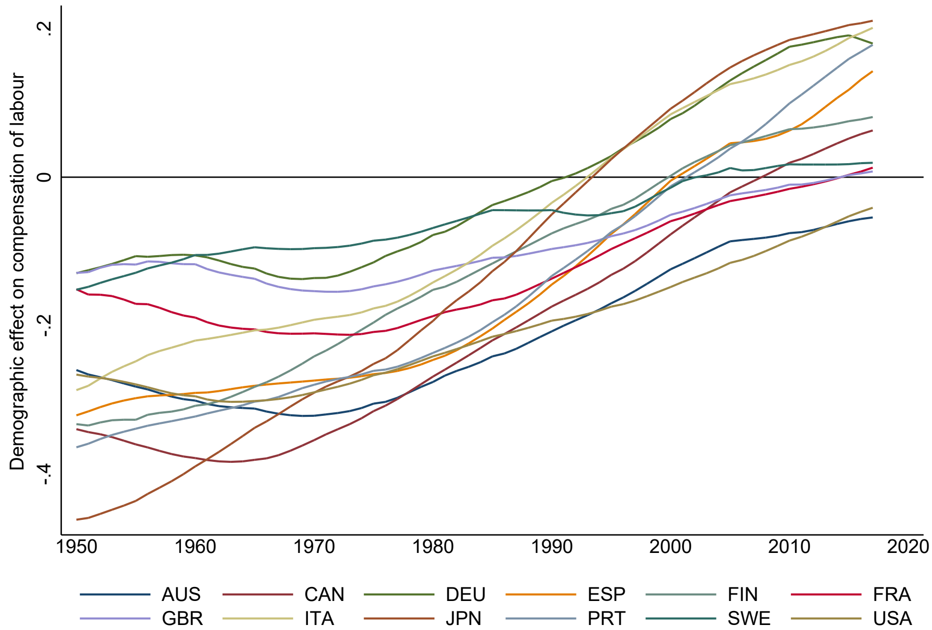
The overall effect of the population pyramid on the compensation of labour is shown in Figure 10. More specifically, the overall coefficient of the demographic distribution on $ln(w^L)$, $\beta_{i,t}^{DD}$, is calculated as in equation 9. From this (due to the fact that the regression is in log form), the effect of demographics on actual real wages (in constant 2011 US dollars) can be calculated as:

$$DD_{i,t}^{effect} = w_{i,t}^{L} - e^{ln(w_{i,t}^{L})-\beta_{i,t}^{DD}} \tag{14}$$

ment rate, while certainly strong, is therefore not as stark as might seem.

where $w^L_{i,t} - DD^{effect}_{i,t} = e^{ln(w^L_{i,t})-\beta^{DD}_{i,t}} = w^{Lnodem}_{i,t}$ can be seen as the level of labour compensation that would have prevailed in the absence of any effect due to demographics. Figure 10 shows how big $DD^{effect}_{i,t}$ is as a proportion of this $w^{Lnodem}_{i,t}$. We can see that in the 1950s to 1980s, young population pyramids, leading to higher proportions of the population at work and lower accumulated wealth per capita,[18] caused wages to be up to 30 (and more) per cent lower than would otherwise have been the case. As populations in advanced economies aged, this negative effect has progressively been reducing and has now turned positive in most of these economies; in some of them, wages would now be up to 20% lower if it were not for the scarcity of labour and abundance of capital that is due to demographic dynamics.

Figure 10: Impact of the demographic distribution on compensation of labour (w^L), selected advanced economies.

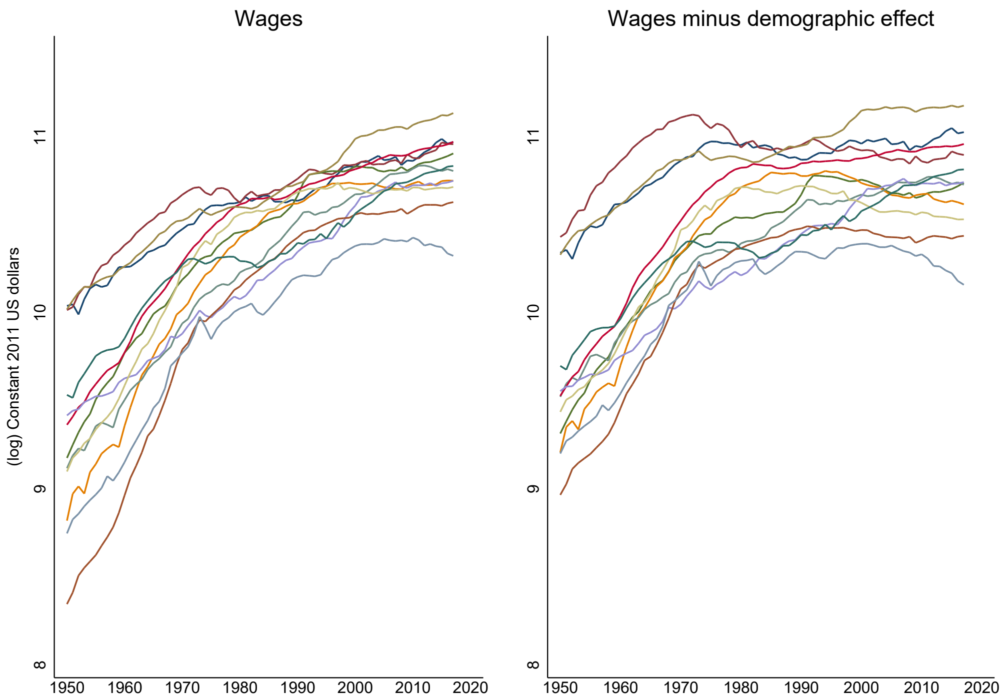


Note: Calculated as $\frac{DD^{effect}_{i,t}}{w^L_{i,t} - DD^{effect}_{i,t}}$.

According to this it appears that, in the most recent years, the impact of demographics has been the main factor behind increases in real wages in advanced economies. Productivity growth has slowed down considerably, and any potential increases in annual wages per worker due to rising productivity have been in many cases almost exactly compensated by a decrease in average hours worked. On average for these countries, real wages, once demographic effects are removed, have remained unchanged since around 2000. Figure 11 displays this.

[18]Note that this is after accounting for long-run trends in capital accumulation, labour force participation and productivity, which are dealt with in the regressions.

Figure 11: Evolution of (log) real wages per person employed (actual versus with demographic effects removed), selected advanced economies.



Note: Values are in log constant 2011 US dollars. The countries included are the same as for Figure 10.

6 Wealth Accumulation: Winners and Losers

The previous sections have detailed how demographic dynamics have contributed to a decline in rates of return while positively affecting wages. Also due to this, the experiences of subsequent generations in ageing economies have been (and will be) substantially different. This section gathers the results shown above for returns and wages and seeks to quantify the overall effect of demographic change on the wealth accumulation journeys of different generations in economies across the world, with a look at future decades. Are there generations that stand to lose or to gain due to these dynamics? What are the implications in terms of inter-generational wealth inequality?

In an environment of increasing wages but decreasing rates of return, subsequent generations are able to save more, but can also expect to *have* to save more in order to accumulate a certain level of wealth, because returns are lower. To determine what effect dominates in any given year and country, I perform a couple of simple exercises that intuitively illustrate how conditions for wealth accumulation have changed through time and across country, and the role of demographics.

Similar to the exercise done for Figure 8, I first look at the wealth accumulated out of an investment made at a point in time, but also taking the wage level into account. Specifically, I calculate how much real wealth ($W_{i,t}^{acc}$) is accumulated by time $t+20$ out of an investment of a fraction s_r of the average wage at time t, if this investment returns the relevant prevailing rate of return (r^k) every year, and all yields are reinvested.

$$W_{i,t}^{acc} = s_r w_{i,t}^{L} \prod_{j=0}^{19} (1 + r_{i,t+j}^{k}) \tag{15}$$

Compare this to a hypothetical situation where there is no effect of demographics, i.e. the wage level is $w^{L,nd}$ and the return on capital is $r^{k,nd}$. The wealth accumulated would then be:

$$W_{i,t}^{acc,nd} = s_r w_{i,t}^{L,nd} \prod_{j=0}^{19} (1 + r_{i,t+j}^{k,nd}) \tag{16}$$

After the end of the PWT sample, estimated demographic effects can be computed thanks to the UN population projections spanning until 2100. However, a forecast for $w^{L,nd}$ and $r^{k,nd}$ needs to be made.[19] As above, I take $r^{k,nd}$ as constant through 2100 for each country given its stability in the sample. In terms of wages, I formulate three very different stylised scenarios (with very different implications), with a focus on the prospects of ageing advanced economies:[20]

- (1) $w^{L,nd}$ remains constant. This scenario is possibly the most plausible for advanced economies as it has arguably been the case since 2000 (compare Figure 11). The average change in $w^{L,nd}$ since 2000 in advanced economies is 0%.[21]
- (2) It grows at a level equal to its average growth (across advanced economies, unweighted) since 1980. This is equal to around one third of a percentage point per year. The average trend Total Factor Productivity growth across the countries (including developing) in the sample is less than half this, while the average TFP growth since 2000 is around 0.5%. This scenario can represent an average country, although this growth rate is slightly optimistic for advanced economies given the slowdown in productivity in recent decades.
- (3) In each country, it grows linearly up to 2100 to reach the highest level (across

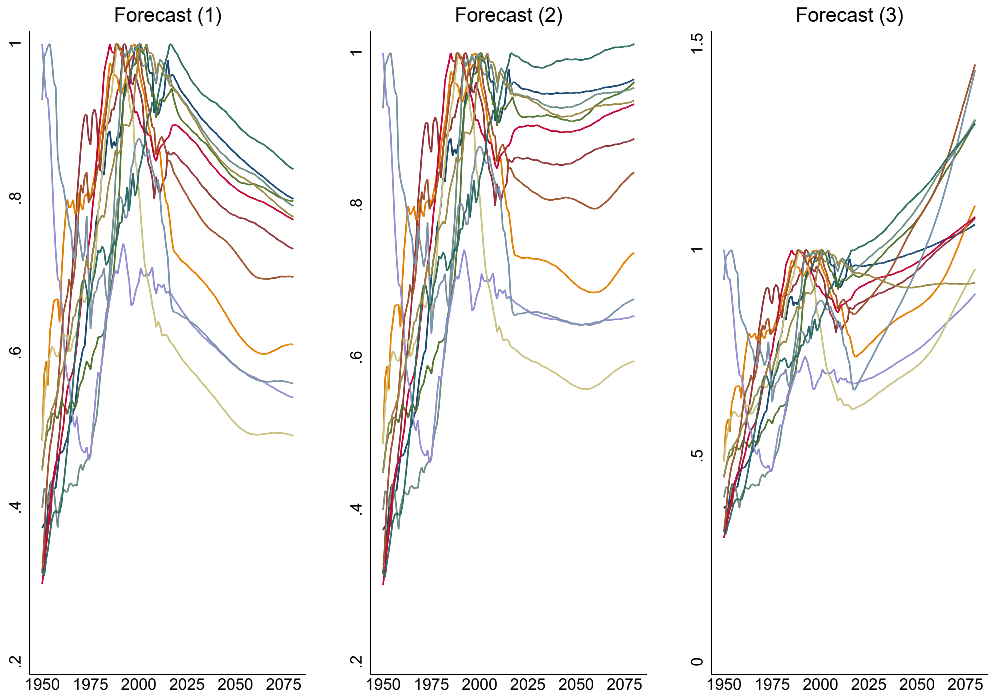
[19] w^L and r^k will then be the forecasted $w^{L,nd}$ and $r^{k,nd}$ plus the respective demographic effects calculated from D_1, D_2 and D_3.

[20] No assumption about developments so far in the future can be justified, so the approach is to try and cover as many options as possible, rather than forecast.

[21] If the vast literature on secular stagnation is to be heeded, growth is unlikely to pick up significantly in the next decades, and there are several culprits, including demographic change.

countries) reached at the end of the PWT sample.[22] This implies no or little growth for the countries closest to that level in 2017, and a very quick catch-up for those further away (most of them). This scenario would be representative if we assume convergence, although possibly a stretch in many cases, including for several advanced economies.[23]

Figure 12: Wealth accumulated over 20 years from initial investment of 10% of wage, selected advanced economies.



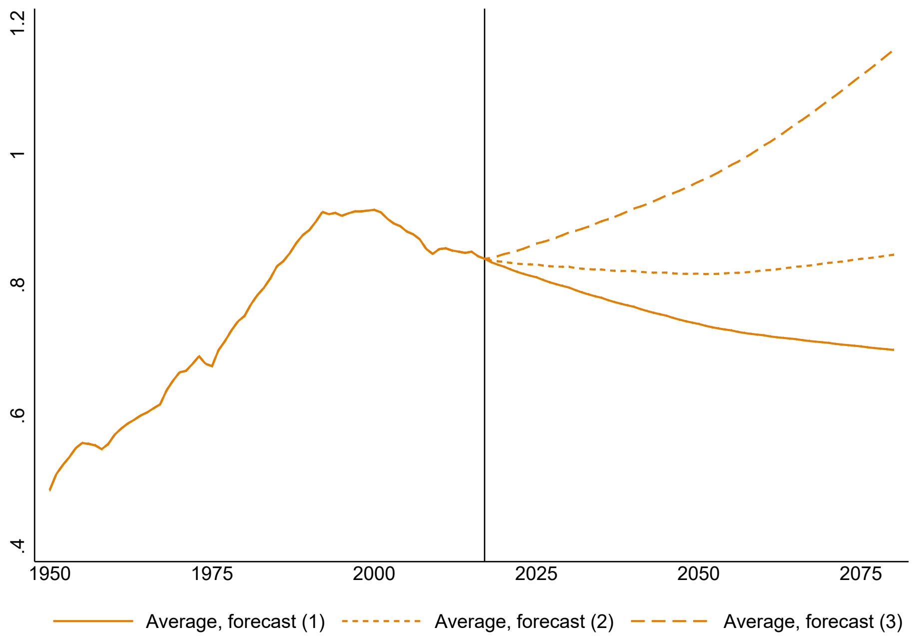
Note: Expressed as a fraction of its peak value up to 2017. The countries included are the same as for Figure 10.

Figure 12 plots the evolution of $W_{i,t}^{acc}$ for a selection of advanced economies under the three scenarios for $w^{H,nd}$, assuming a saving rate of 10%. Because of large differences in levels across countries and since we are interested in the relative increase or decrease in $W_{i,t}^{acc}$ over the years, this measure is normalised by dividing by the country's maximum observed $W_{i,t}^{acc}$ before the end of the sample, i.e. a value of 1 corresponds to the country's peak level of $W_{i,t}^{acc}$ up to 2017. To better see the trends, Figure 13 displays the simple average of each set of lines in Figure 12. A few facts appear evident from these figures:

[22] The country with the highest $w^{L,nd}$ in 2017 was Norway.

[23] For instance, the country in the 75th percentile of the distribution in the sample in 2017 had an $w^{L,nd}$ which was about 45% lower than Norway's, implying a growth rate well above (2) over the forecast horizon. The median country had an $w^{H,nd}$ 63% lower which implies an even higher growth rate.

Figure 13: Wealth accumulated over 20 years from initial investment of 10% of wage, as a fraction of peak value, average across selected countries.



Note: Averages of each set of lines in Figure 12.

- Thanks to robust technological and wage growth, wealth accumulation since 1950 has on average become steadily faster until around the year 1990, while it has declined significantly since 2000.

- Under the two more plausible scenarios for advanced economies, wealth accumulation in future decades is set to become harder or remain at current levels, which are lower than a generation ago but significantly higher than before the 1980s.

- Where $w^{H,nd}$ and $r^{k,nd}$ are both unchanged (scenario (1)), the impact of demographic dynamics on wealth accumulation through returns prevails on the impact through wages. In general, for most countries across all three scenarios, in the absence of demographic effects $W_{i,t}^{acc}$ would either not decrease as steeply or it would increase more strongly (i.e., demographic factors weigh down on the growth of $W_{i,t}^{acc}$ in all three scenarios).[24]

- Although unlikely, a return to growth levels last seen several decades ago in advanced economies could still lead to improving wealth accumulation prospects for future generations, despite demographic developments.

While the above findings relate to how one year's worth of saving can potentially accumu-

[24] Results are available but omitted for brevity.

late, I now want to explore how different generations fare once their whole life-time wealth accumulation journeys are compared. Specifically, given changing wage and return levels, how does the wealth accumulated by a worker saving throughout their working life change across generations?

Consider a worker who starts working in year t in country i and initially saves a proportion s_r of their after-tax income $(1-\tau_w)w^L_{i,t}$, where τ_w is the tax rate on labour income. I indicate this amount as $S_{0,i,t}$, corresponding to total savings (wealth) at the end of the first year of saving when saving began at year t. This saving is invested and returns $s_r(1-\tau_w)w^L_{i,t} \times (1+(1-\tau_k)r^k_{i,t})$ at year $t+1$, where τ_k is the tax rate on capital gains.[25] The worker adds additional savings equal to $s_r(1-\tau_w)w^L_{i,t+1}$, such that total savings are now $S_{1,i,t} = (1-\tau_w)w^L_{i,t} \times (1+(1-\tau_k)r^k_{i,t}) + (1-\tau_w)w^L_{i,t+1} = S_{0,i,t}(1+(1-\tau_k)r^k_{i,t}) + (1-\tau_w)w^L_{i,t+1}$. In general, for any $j \neq 0$:

$$S_{j,i,t} = S_{j-1,i,t}(1+(1-\tau_k)r^k_{i,t+j-1}) + s_r(1-\tau_w)w^L_{i,t+j} \tag{17}$$

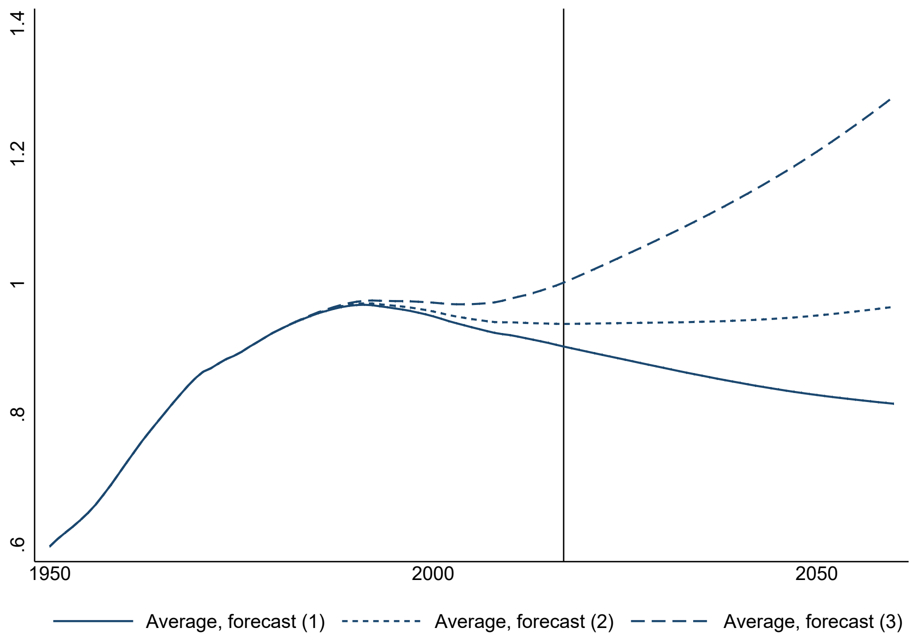
I set both τ_w and τ_k at 35%, and s_r at 20%[26], and I obtain an estimate of $S_{39,i,t}$, corresponding to 40 years of savings, for each country and year based on each of the three scenarios for $w^{H,nd}$. To obtain Figure 14 I go through all the steps as for Figure 13, i.e.: (i) I compute $S_{39,i,t}$; (ii) for each country, I divide it by its peak pre-2017 value across all years; (iii) for every year, I take the average of these values among the countries in the sample used for Figure 12 (averaging all the countries in the sample returns similar results).

A similar picture to Figure 13 emerges, where on average the peak in accumulated wealth is expected to be for the cohorts who started saving in the 1990s. Assuming they started working in their twenties, these agents are currently in their fifties and will likely retire starting from around year 2030. They are expected to have significantly higher accumulated wealth than the cohorts before them, but in advanced economies they will likely also be the last generation to experience a significant increase in wealth compared to their parents' generation. Depending on the forecast for $w^{H,nd}$, subsequent generations (i.e., people

[25] Taxation rates were not introduced above but being constant they have no impact in terms of the direction of any movements in W^{acc} etc. The effect of demographics through changes in tax rates is likely to make effects shown in this Section even larger than displayed here, as a larger proportion of retirees tends to lead to higher public expenditure and therefore higher tax rates, lowering after-tax savings and rates of return. To keep the exercises simple, I do not add these dynamics but it should be kept in mind as a potential further effect.

[26] Again, the tax rate numbers are indicative and based on representative values; changing them would have an impact on the values of W^{acc}, but not its dynamics over time. As to savings rates, it would be reasonable to assume, based on the extensive literature on life-cycle consumption and savings, that savings rates are age-dependent, however here they are kept constant (with the implication that any arbitrary choice of s_r for the sake of this exercise will have no impact on the relative sizes of W^{acc} between cohorts). Nevertheless, I find that adding age-dependent savings rates to this exercise, based for instance on saving patterns like described in Feiveson and Sabelhaus (2019) (13), has only a negligible impact on results as shown below, leading to the same conclusions.

Figure 14: Wealth accumulated over 40 years' working life, as a fraction of peak value, average across selected countries.



Note: See text for computation method. The x-axis represents the year at which the agent starts saving (i.e. year t in equation 17).

currently at work and younger than 50, and their future descendants) could experience (i) progressively lower wealth accumulation (most likely scenario for advanced economies with slow growth); (ii) broadly same level of wealth accumulation as their elders; or (iii) continuously rising wealth (most likely for economies furthest from the technological frontier). Based on this, material improvements in standards of living from generation to generation might not continue to be the case in advanced economies, while to an extent it is already so for some countries.[27]

This is not all, however. A higher level of wealth at retirement does not guarantee higher standards of living when retired, for two main reasons:

- Lower returns on capital result in lower levels of income generated from any given level of accumulated wealth.
- Longer life expectancies mean that retirees need to make sure their wealth can sustain their livelihoods for a longer period of time, decreasing the pace at which they are able to decumulate it.

Because of these facts, even if current levels of wealth accumulation were to remain, in

[27] Southern European countries being the most striking example in this case, based on these data. See below.

several countries future generations will likely not be able to maintain the same standard of living at retirement as their parents. In this last exercise, I estimate how much retirees can expect to consume out of their accumulated wealth by investing it and decumulating it, based on the rate of return on capital, their residual life expectancy, and their initial accumulated wealth.

Consider an agent aged 65 who retires at year t in country i. They started working and saving 40 years before, and have accumulated wealth equal to $S_{i,39,t-40}$. They have an expected residual life expectancy at 65 of x but they want to provision for a higher number of years in case they live longer, say $1.25x$. They want to generate a constant cash flow out of their wealth via a combination of capital returns (at rate $r^k_{i,t}$) and sale of assets, such that at year $t + 1.25x$ they have completely decumulated all of their wealth. This situation is equivalent to a hypothetical "reverse mortgage" where the agent loans out $S_{i,39,t-40}$ for $1.25x$ years at $r^k_{i,t}$; every year they receive a constant cash flow payment which includes principal repayments (i.e. the amount of asset sales) plus interest (i.e. returns on the remaining capital). Based on the typical formula for mortgage amortisation, the constant annual repayments they can expect to receive are equal to:

$$A_{i,t} = S_{i,39,t-40} \left(r^k_{i,t} + \frac{r^k_{i,t}}{(1 + r^k_{i,t})^{1.25x} - 1} \right) \tag{18}$$

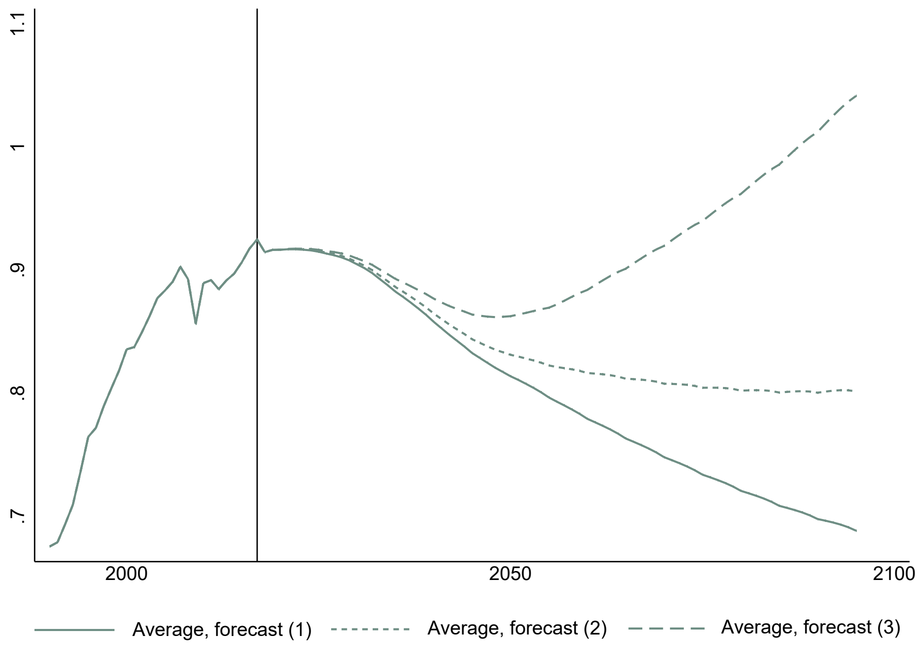
As previously, I estimate this for every country and year, and for each country I compute the annual value relative to the pre-2017 country peak, then average this for a subset of countries, as done above for Figure 14.[28] Figure 15 shows the results of this exercise, which are striking. See further Figure 16 for countries in Southern Europe, which are affected particularly hard by low productivity growth since 2000, and are seeing living standard prospects of retirees possibly reducing by a half by the end of the century.

On average, agents currently retiring[29] with the wealth accumulated during their working lives can expect to enjoy some of the highest standards of living at retirement across all cohorts in the sample; for all generations currently at work and far from retirement, prospects are expected to get progressively worse. Even under the most optimistic scenario, standards for retirees are set to decline from current levels until around 2050, and under the first and second scenarios they are seen declining all the way to the end of the projection horizon, with different intensities.

[28] Annual residual life expectancies at 65 for the purposes of this exercise are backward induced from the UN World Population Prospects projections. This method matches existing data (where available) with a sufficient level of accuracy, but may differ somewhat.

[29] I.e., they would have been born in the late fifties and sixties.

Figure 15: Annual cash flow from reverse mortgage of wealth accumulated over 40 years' working life, as a fraction of peak value, average across selected countries.



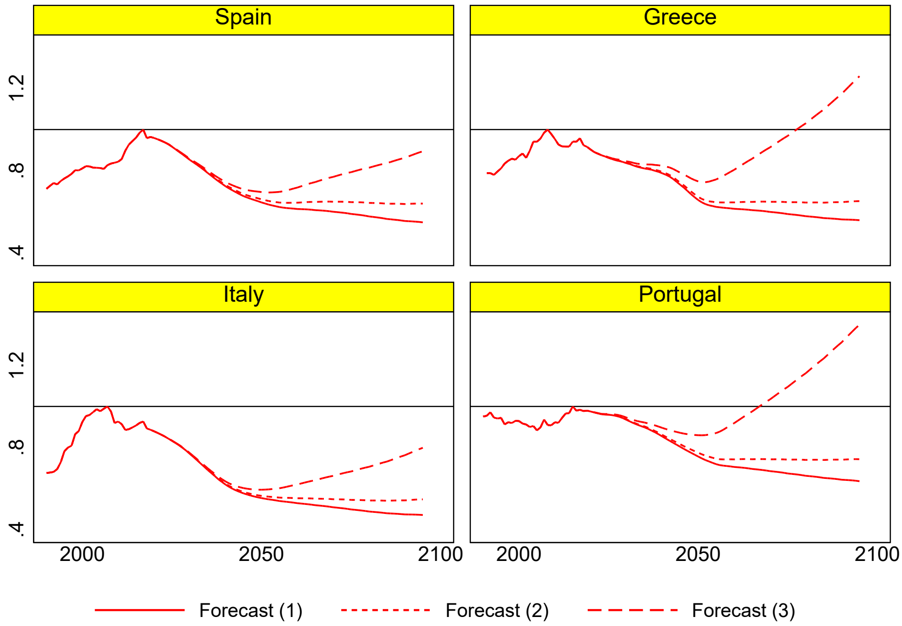
Note: Country-year values for the cash flow were calculated as per equation 18; the lines displayed in the figure are calculated as for Figure 13 and Figure 14. The x-axis represents the year at which the agent retires.

7 Conclusions

The findings in this paper highlight stark inter-generational inequalities in ageing economies when it comes to wealth and its accumulation, with the cohorts born at the start of the demographic transition benefiting most from demographic dynamics and growing economies, while subsequent generations are set to lose. This may be part of the reason why younger generations in many advanced economies have been expressing increasing unease at their future prospects when comparing themselves with their parents' generations.

They may be trapped in this "inverted-pyramid scheme" which is the economy of an ageing society. Normal pyramid schemes can only be sustained as long as an exponentially increasing number of participants join the scheme; once this is no longer the case, the scheme fails. While, like in a pyramid scheme, economies in modern times had been relying on an increasing number of new "entrants", which ensured rapidly increasing standards of living and wealth for all economic agents, positive demographic trends have now reversed in several economies, dragging down future prospects for generations to come. While in a pyramid scheme, those already in it benefit from new entrants (and every cohort but the last is set to gain), in a world of inverted population pyramids, new generations in the economy are

Figure 16: Annual cash flow from reverse mortgage of wealth accumulated over 40 years' working life, as a fraction of peak value.



Note: Country-year values for the cash flow were calculated as per equation 18. The x-axis represents the year at which the agent retires.

increasingly penalised by the existence and size of the previous generations.

The implications of the results of this paper are clear: future generations in advanced economies can expect, under reasonable assumptions, to either accumulate less wealth (restricting their retirement income), or to save a significantly higher proportion of their labour income during their working age to avoid this (thus limiting consumption during their working age). In addition, depending on the social security system in place, they may either expect to pay higher taxes during their working life, or to receive lower pension income from the state when retired. In any case, it appears that they can reasonably expect to be worse off than previous generations as far as wealth accumulation is concerned.

While the changes in society and demographics that underpin these implications are in all likelihood here to stay, there are a number of policy actions that can help mitigate the adverse effects of the demographic dynamics we are facing.

- A return to strong technological growth, of the type experienced during the second half of the twentieth century (but more sustainable), would ensure that standards of living can remain constant or keep growing, even while populations age and decline. This would require large public and private investment in research and development and human capital which might however exacerbate the existing issues arising from abundance of capital.

- Increasing focus on productive vs unproductive assets. The increasing prices of residential capital, while other forms of capital have been depreciating, probably suggest that there is over-investment in housing. This is also partly because of a lack of available opportunities for productive investments (see point above), but it goes both ways.

- Improvements in the levels of financial education of the population. Many households lack the financial education to confidently invest in riskier asset classes, and these households are usually also less wealthy to begin with. A better financial education of all households would allow a greater proportion of them to knowingly invest in riskier but higher-yielding asset types, which have typically been held by the wealthiest in society. It would also likely channel investment into more productive forms of capital.

- Increasing retirement ages, and especially allowing agents to work longer work lives as increased life expectancies mean they can also expect to stay healthy and productive for longer.

Several complex aspects and interactions between demographic developments and the macroeconomy, which might add further dynamics and insights into the effects through which population ageing affects wealth inequality, could not be covered within the scope of this paper, but warrant further study. These include (i) the impact of inter-generational transfers on the transmission of wealth inequality from generation to generation, as agents live longer and have fewer children; (ii) dynamics related to inequality *within* generations and how this translates into inter-generational inequality; (iii) portfolio allocations and returns across different asset types, and how this affects how agents with different portfolio allocations accumulate wealth; (iv) the impact of housing on reducing or increasing wealth inequalities. Many of these issues would be best analysed within the context of a general-equilibrium overlapping-generation model and are generally not suited for an empirical approach. This is left for future research.

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A Appendix

A.1 Measures of productivity

The measure of total factor productivity used in the PWT dataset implies the assumption of a certain shape of the production function (see (12)). Though this cannot be avoided, it could potentially bias the results of any regression including productivity, which however cannot be omitted from the analysis presented in this paper for obvious economic theory reasons. In Table 5, I repeat the analysis for specification (2) of Table 1 (as this is the specification that is later used for the analysis in the other Sections) using different indicative measures of productivity that I can construct from the rest of the data. These are:

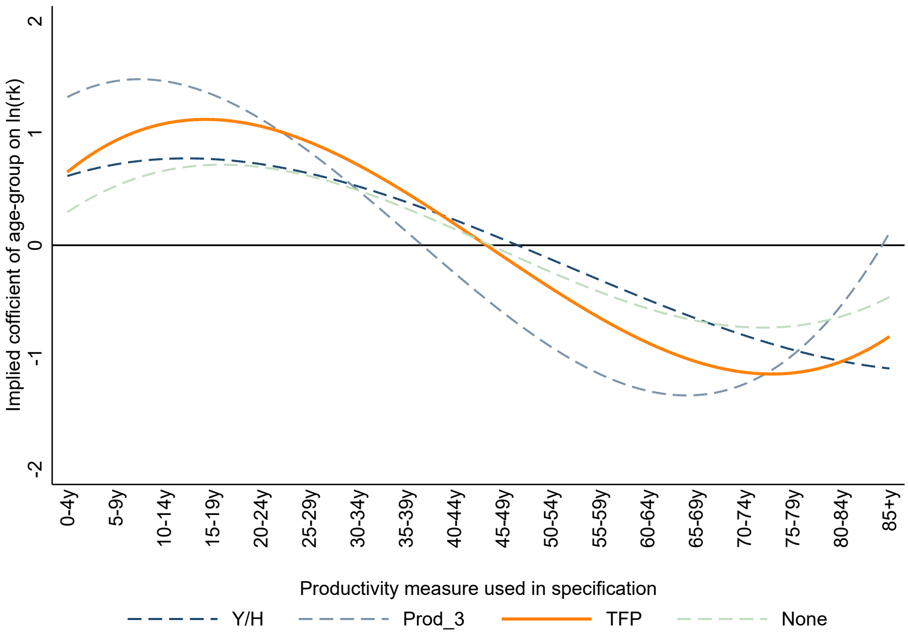
- Output per hour worked Y/H;
- Output per person employed Y/L;
- A measure of joint labour and capital productivity computed as $\frac{Y}{\sqrt{K \times H}}$, which I call $Prod_3$ here, and
- A similar measure, computed as $\frac{Y}{\sqrt{K \times L}}$, which I call $Prod_4$.

I also include TFP itself and a specification without any productivity measure. The results show several things: (i) the signs of the coefficients are not affected by the choice of productivity measure; (ii) their size, however, can change significantly; (iii) expressing productivity in terms of hours worked or per person employed does not make a difference; (iv) not having any measure of productivity leads to clear omitted variable bias. The wide range of coefficients, especially for K/N, may lead to think that, potentially, the results in the rest of the paper would not be robust to a different choice of productivity measure. This is however not the case. Replacing TFP with each of these measures, I have repeated the instrumental-variable exercise of section 4.2 and derived the combined age-group implied coefficient on $ln(r^k)$ as I have done for Figure 5 (tables omitted for brevity). The results are displayed in Figure 17 and show that the strong demographic effect on rates of return remains and is very similar regardless of the measure used. It also further supports the case for using the PWT TFP measure as the results using this measure are the closest to the average. If anything, based on the R^2 in specification (3) of Table 5, $Prod_3$ might be more appropriate; because of the larger size of the coefficients, this would lead to even stronger demographic effects on the rate of return and an even larger impact of the demographic transition on wealth accumulation as shown in Section 6.

Table 5: Specification (2) of Table 1, for different measures of productivity.

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(r^k)	ln(r^k)	ln(r^k)	ln(r^k)	ln(r^k)	ln(r^k)
ln(α)	1.012***	1.012***	1.007***	1.007***	0.930***	0.998***
	(0.10)	(0.10)	(0.05)	(0.05)	(0.09)	(0.15)
ln(K/N)	-0.615***	-0.615***	-0.459***	-0.459***	-0.322***	-0.129***
	(0.09)	(0.09)	(0.06)	(0.06)	(0.05)	(0.05)
ln(H/L)	0.918***	0.294	0.803***	0.250	0.902***	0.232
	(0.27)	(0.24)	(0.16)	(0.17)	(0.26)	(0.30)
ln(L/N)	0.643***	0.643***	0.442***	0.442***	0.479***	0.240
	(0.14)	(0.14)	(0.07)	(0.07)	(0.13)	(0.18)
ln(Y/H)	0.624***					
	(0.11)					
ln(Y/L)		0.624***				
		(0.11)				
ln(Prod$_3$)			1.105***			
			(0.06)			
ln(Prod$_4$)				1.105***		
				(0.06)		
ln(TFP)					0.614***	
					(0.10)	
Constant	-2.345	-10.972***	-1.809	-9.441***	-3.878*	-1.070
	(2.12)	(2.87)	(1.70)	(1.49)	(2.09)	(2.42)
Year f.e.	✓	✓	✓	✓	✓	✓
R^2	0.651	0.651	0.880	0.880	0.656	0.541
deg. fr.	63	63	63	63	63	63
N	3000	3000	3000	3000	3000	3000

Figure 17: Combined effect of each age group on rates of return via $ln(K/N)$ and $ln(L/N)$, by measure of productivity used in instrumental variable regression (confront Tables 2 and 3).



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