Populations have not Aged Much*

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September 10, 2007

Abstract

In this article, we argue that the conventional measure of population aging, namely the share of people aged 60 and over, essentially accounts for individual aging as captured by increases in life expectancy and fails to account for population aging. We propose a new measure of population aging that relies on optimal grouping technics initially developed for the analysis of income distributions. The main advantage of this approach is to endogenously define the notion of old age by exploiting the information contained in the entire shape of the age pyramid. We apply this methodology to a group of 12 developed countries. Our results suggest that population aging is considerably weaker than usually claimed. For instance, over the last 50 years, 7 countries out of 12 have not experienced statistically significant aging; one has even experienced a statistically significant rejuvenation.

*We are thankful to Philippe Alby for insightful discussions.

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Introduction

There is nowadays considerable concern for aging. It is however important to distinguish individual aging from population aging. Individual aging refers to the fact that the individuals composing the population live longer. This phenomenon is usually measured by increases in life expectancy. Population aging refers to the increase in the proportion of old people in total population where an old individual is usually defined as a person whose age is above a fixed number of years, typically 60 years. According to United Nations' last population aging report, the share of people aged 60 and over in total population (S60 hereafter) was 8% in 1950 and 11% in 2007, and is projected to reach 22% in 2050 worldwide. In this article we challenge these conclusions by arguing that S60 is not an appropriate measure of population aging but rather a measure of individual aging. We then propose a single indicator that better reflects changes in the entire age distribution and therefore better tracks population aging. Relying on optimal grouping technics, our approach endogenously determines the cutoff age at which an individual enters old age. We then compute the share of so defined old people in total population and use this new index (hereafter OGA index,[1]) to measure population aging. We finally use data borrowed from the Human Mortality Database[2] (HMD hereafter) to evaluate the two indices (S60 and the OGA index) and revisit the population aging phenomenon.

1 Population Aging vs Individual Aging

A widely used indicator of aging is the share of people aged 60 and over, S60, in the population. Figure 1 reports the evolution over time of this share for our sample of countries. As can be seen from the figure, S60 has skyrocketed in the last century. On average, S60 increased by 80% in the last 50 years. This is usually taken as a reliable indicator of

[1]OGA index stands for Optimal Grouping based Aging index.

[2]Tables and methodology can be obtained from `http://www.mortality.org/`. The countries under study are Australia, Austria, Canada, Denmark, England & Wales, France, Iceland, Italy, Netherlands, Norway, Sweden, Switzerland and USA.

aging. But fixing 60 as a cutoff age seems, as argued by Bourdelais, 1999, to be rather related to historical, sociological and cultural considerations than based on statistical and demographical grounds. It however largely determines the way aging is measured and may introduce some bias in our perception of population aging. Indeed, the probability that an individual be 60 in 1800 was much lower than it was in 2000. This casts doubts on the ability of S60 to accurately capture population aging and suggests that it rather accounts for the increase in life expectancy at birth that most countries have experienced since the beginning of the demographic transition. It is therefore fundamentally related to individual rather than to population aging.

A statistical examination of the data confirms this intuition. Should S60 reflect population rather than individual aging, variables accounting for individual aging, such as life expectancy, should not be helpful to forecast the evolution of the share. From a technical point of view, this can be tested using Granger causality tests.[3] In order to test for the Granger causality of life expectancy on S60, we start from a dynamic vectorial autoregressive model featuring the rate of growth in S60, the growth rate of life expectancy at age 60, the fertility rate and the death rate.[4] Table 1 reports the results. The first columns of the table give the number of lags, k, in the dynamics,[5] the value of the test and,

[3]Let Y_t be a $(n \times 1)$ vector of stationary random variables with mean 0, and assume that the data generating process of Y_t can be represented by the linear difference equation

$$Y_t = \sum_{i=1}^{k} A_i Y_{t-i} + u_t, \tag{1}$$

where u_t is a $(n \times 1)$ vector of normally distributed random variables, such that $E(u_t) = 0$, $E(u_t u_t') = \Sigma$ and $E(u_t u_\tau') = 0$ when $t \neq \tau$. Consider then two variables, $Y_{i,t}$ and $Y_{j,t}$, belonging to Y_t. $Y_{j,t}$ fails to Granger cause $Y_{i,t}$ if

$$MSE[E(Y_{i,t+s}|Y_{k,t-\ell}; k = 1, \ldots, j-1, j+1, \ldots, n; \ell = 0, \ldots)] = MSE[E(Y_{i,t+s}|Y_{t-\ell}; \ell = 0, \ldots)],$$

where MSE is the mean squared error and $E(.|Y)$ denotes the expectation operator conditional on information contained in Y. In the context of the linear model (1), testing for Granger causality just amounts to test for the exclusion of variable $Y_{j,t}$ from the dynamic equation for $Y_{i,t}$. See Granger, 1969.

[4]Note that the fertility rate is excluded from Y_t in the case of Canada and the USA as it does not add any significant information on the dynamics.

[5]The number of lags was selected relying on a likelihood ratio test.

into brackets, the associated probability value. As can be seen from the table, Granger causality of life expectancy on S60 cannot be rejected (except for Canada) at the 5% conventional level. Therefore, the observed increases in S60 are caused by increases in life expectancy at age 60 and are the by–product of individual aging rather than a reliable indicator of population aging.

An aged population is a population in which the share of old people is large. However, since life expectancy varies over time and across countries, the definition of the point of entry in old age should not be fixed. It is fundamentally related to both life expectancy and, more importantly, to the shape of the distribution by age of the population. It is therefore important to define an indicator of population aging that takes all changes in this distribution into account.

2 OGA: A New Measure of Population Aging

We propose a simple and atheoretical method that, for a given distribution of population by age, defines the age at which an individual becomes old and then characterizes the share of old people in the population, the OGA index. Our approach uses optimal grouping technics as proposed by Aghevli and Merhan, 1981, for the analysis of income distributions. It consists in grouping the data on population by age into a specified number of groups such that age differences are minimized within the groups and maximized between the groups. Intuitively, an individual is assigned to the age group for which the distance between his/her age and the average age of the group is the smallest. In this sense, optimal grouping gives statistical foundations to the notion of a *generation*. From a formal point of view, let x,y,... denote the age of individuals in the population with distribution function F, with continuous and differentiable density f and finite mean. Suppose that we want to group the data into n age intervals (a_0, a_1), (a_1, a_2), $\ldots (a_{n-1}, a_n)$, where $a_0 < a_1 < \ldots < a_n$, Aghevli and Merhan show that the optimal grouping solves the

following problem

$$\min_{\{a_i;i=1,n\}} \sum_{i=1}^{n} \int_{a_{i-1}}^{a_i} \int_{a_{i-1}}^{a_i} |x-y| \mathrm{d}F(x) \mathrm{d}F(y).$$

Among others, the optimal solution gives the cutoff age at which an individual is classified as old. It is finally straightforward to compute the OGA index which is the share of all people older than the cutoff age in total population. A first attractive feature of this approach lies in the simultaneous determination of the partition of the support of the distribution and the share of each group in total population. The cutoff age is endogenously determined rather than being imposed *a priori*. Note that Ryder, 1975, has proposed an approach that also determines the old age endogenously: an individual becomes old when his life expectation equals 10 years.[6]. But Ryder's definition only focus on a particular locus of the distribution of population by age which may bias measurement of aging as we now make clear. A second attractive feature of our approach is indeed that optimal grouping depends on the entire shape and the whole support of the distribution.[7] Indeed, the share of the population of each age affects the average age in each group and therefore largely determines the cutoff age. As a consequence, any change in either the support or the shape of the distribution affects the cutoff age. The OGA index therefore endogenously takes care of and corrects for individual aging.

In order to illustrate these properties, let us consider the impact of a "baby–boom" on the aging of a given population. The effect on S60 is clear. It diminishes as there are more young people in the population. Things are more intricate for the OGA index. The first and direct effect of a baby–boom is to reduce the average age of the youngest group. Consequently, the oldest former members of this group will be excluded and reassigned to the next group. This process extends to the rest of the distribution, and therefore the

[6]This idea has been recently extended in Sanderson and Scherbov, 2005. Their index is based on the median age of the population standardized for expected remaining years of life and aims at taking changes in the age distribution into accounts. It however requires the computation of a virtual distribution.

[7]Chu, 1997, proposes an alternative index that also attempts to be closely connected to the age distribution. His measure however requires first degree stochastic dominance relationship of the cumulative age distribution functions.

average age of the oldest decreases and hence the cutoff age. So, on the one hand the share of the old people has a tendency to diminish, while on the other hand the age at which an individual becomes old reduces. Hence, contrary to what happens when S60 is used, the overall effect of a baby–boom on aging as measured by the OGA index depends on all the changes the baby–boom implies on the initial distribution of population by age. Consider now the same population sixty years later. S60 has skyrocketed. The effects on the OGA index depend on the magnitude of the baby–boom. Let us assume it was big enough for the 60 years old to now constitute a group on their own. Two situations can then be observed. Either this group absorbs the group of the oldest and the share of population aged 60 and over is actually a good indicator of population aging. Or this group is not big enough to absorb the last group. In that case, since the share of this group is large, the cutoff age should increase and there will be a temporary relative rejuvenation of population.

More generally, any event affecting the shape of the distribution modifies the grouping and is therefore taken into account by our measure of population aging. Conversely, and contrary to S60 and Ryder's indicators, a dilatation of the support of the distribution, reflected by an increase in the maximal age, that leaves the shape of the distribution unaffected will have no effect on the OGA index. Moreover, since a proportional increase in life expectancy at each age will not affect the shape of the distribution, individual aging will not affect our measure of population aging. As discussed in the next section, a direct implication of this result is that life expectancy at age 60 should not Granger cause the OGA index.

Note that the only exogenous parameter that should be set *a priori* in the optimal grouping approach is the number of groups. An interesting benchmark to consider is a partition between two groups. In this case the cutoff age is exactly the average age of the population. Interestingly, our approach suggests that, contrary to the conventional wisdom, an increase in the average age does not necessarily correspond to population

aging[8] since it increases the age at which an individual is classified as old.

3 Results

Let us now apply the optimal grouping algorithm to the HMD data. We choose to divide the population age distribution into 4 groups. The OGA index then corresponds to the share of the population of the fourth group in total population. This choice of 4 groups is made for pragmatical reasons and comparative purposes. It indeed leads to a cutoff age for the last group of about 60 in the 1990s for most of the countries we consider in our sample. It therefore compares to Stolnitz, 1992, who measured aging using S60. We will however assess the robustness of our indicator to the number of groups.

Panel (c) of Figure 1 plots the evolution of the OGA index over time. The time series show an important similarity with S60 (see Panel (a)): it displays some fluctuations over time.[9] However the dynamic shape of the OGA index strikingly differs from that of S60 as it appears to be remarkably stable over time and remains close to 20% in most countries of our sample. It therefore indicates that aging of the society as a whole may not be as strong as usually claimed. For instance, consider the case of Sweden for which we have data for the period 1751–2005. The share of old people in total population, as computed by the OGA index, was 19.78% in 1751 and reached 20.56% in 2005, a less than 4% increase over the whole time period. This should be compared to the evolution of the share of population above 60, 9.82% in 1751 and 23.22% in 2005 —a 136% increase. In order to investigate more precisely this issue, we compute the average annual rate of growth of the share by fitting a linear trend to the logarithm of the OGA index. This is done both for the whole available time period in each country (γ in Table 1) and for the last 50 years of

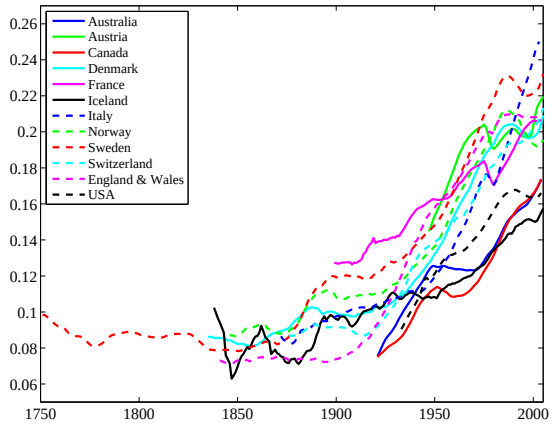
[8]See discussion in Preston et al., 1989, and Kim and Schoen, 1997. Coulson, 1968, also proposed an index close to the average age.

[9]Fluctuations of the OGA index around a linear trend, as obtained by an OLS regression, are small. For instance, the standard deviation of the cyclical component of the OGA index, as defined by the difference between the index and the fitted linear trend, is only 0.8% for Sweden over the whole time period.

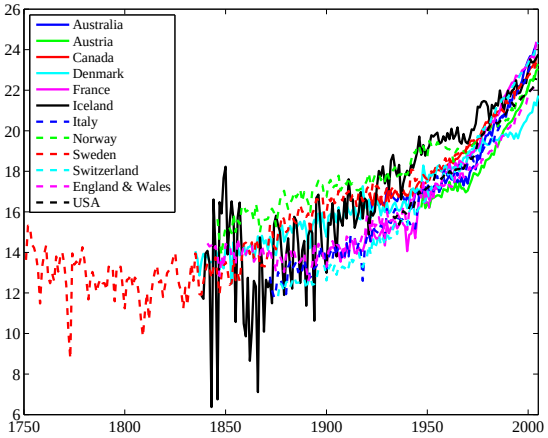
the sample (γ_{50} in Table 1). The results mitigate population aging, as the average annual rate of growth γ is always less than 0.1% whatever country we consider. As a matter of fact, Australia, Denmark, France, Norway, Sweden, England & Wales and USA have not experienced any statistically significant growth in the OGA index over the last 50 years, therefore ruling out population aging during that period. Only Canada, Iceland and Italy significantly aged in the period. Interestingly, Austria even experienced negative growth in this share over the last 50 years, suggesting a rejuvenation of its population.

Figure 1: Population Aging

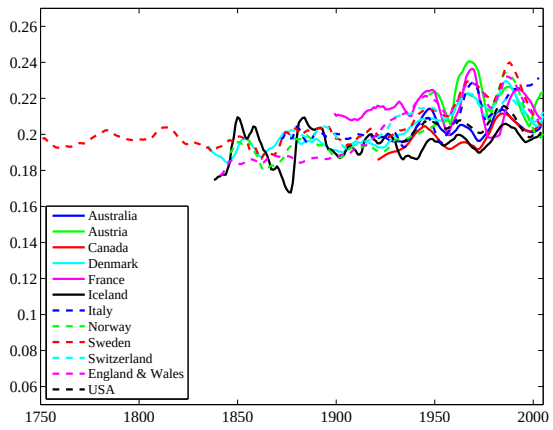
(a) S60 index



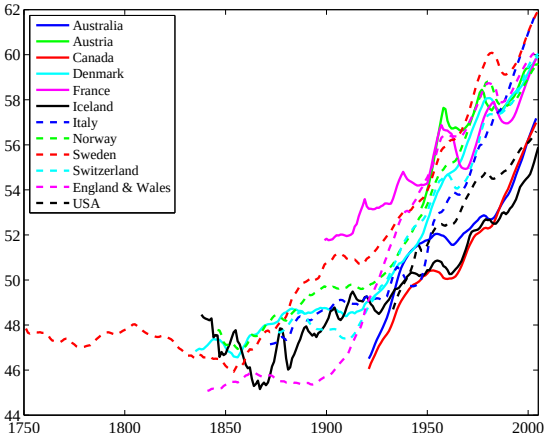
(b) Life Expectancy at 60



(c) OGA index



(d) Cutoff Age (Optimal Grouping)



The absence of a significant population aging originates in an increase in the cutoff age. For instance, in Sweden this age was 47.74 in 1751 and reached 61.95 in 2005 —a

30% increase. In order to make a better sense of this result, let us consider an individual with age 55. In 1990, no matter the country we consider, this individual would have been classified as belonging to the group of the oldest and would have therefore been included in the OGA index. In 2005, he/she would not belong to that group anymore in any country of the sample. At age 55, an individual is younger in 2005 than in 1900. This phenomenon actually accounts for individual aging, as captured by life expectancy (in Sweden, life expectancy at age 1 was 46.74 in 1751 and reached 79.94 in 2005). Therefore, our measure indeed corrects for individual aging. This is reflected by the Granger causality analysis as reported in Table 1 where we show that, unlike S60, the OGA index is not a measure of individual aging.[10] The second group of columns in the table (OGA (n=4)) reports the number of lags, k, we consider in our dynamic equation,[11] the value of the test and the associated probability value. As can be seen from the examination of the table, the growth rate of life expectancy does not Granger cause changes in the OGA index as the null of no predictive power can never be rejected at the conventional 5% critical level. Therefore, the OGA index accounts for population aging.

Let us now assess the robustness of our results to the number of groups. We consider three alternative values for the number of groups: 2, 3 and 5. The 2 groups case is interesting in that it consists in selecting the average age as a cutoff age, and is therefore available in most demographic databases. As Table 1 indicates, Granger causality analysis is essentially left unaffected by these different groupings. Life expectancy is not a good predictor of the share of the oldest no matter the grouping. For comparative purposes, Figure 2 reports the time evolution of the OGA index in Sweden for alternative number of groups. As expected the absolute level of the index varies with the number of groups, as the cutoff age is not the same. But the profile of each time series is very similar and close to what we described for the 4 groups case. No significative population aging emerges

[10] We test for Granger causality of life expectancy at age 60 on the OGA index, in a vector autoregressive model featuring the rate of growth of the OGA index, the growth in life expectancy, fertility and death rates. As for S60, fertility is excluded for Canada and the US for similar reasons.

[11] The number of lags was selected relying on a likelihood ratio test.

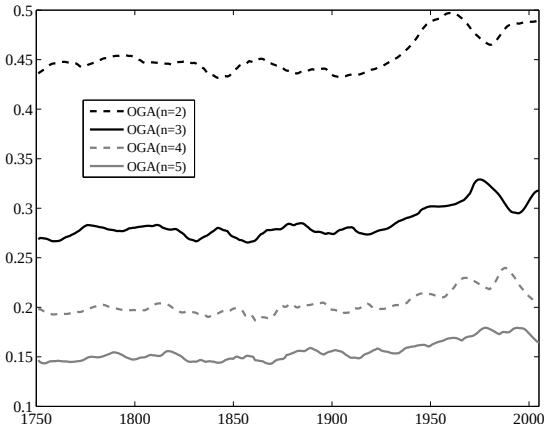
Table 1: Granger Causality Tests

	S60		OGA (n=4)				OGA (n=2)		OGA (n=3)		OGA (n=5)	
Country	k	Test	k	Test	γ%	γ_{50}%	k	Test	k	Test	k	Test
Australia	3	6.67	2	0.21	0.038	0.023	2	2.01	2	1.02	2	0.72
		[0.00]		[0.81]	(0.011)	(0.019)		[0.14]		[0.37]		[0.49]
Austria	6	2.93	2	2.94	-0.065	-0.073	2	0.43	2	0.61	2	1.08
		[0.02]		[0.06]	(0.033)	(0.037)		[0.65]		[0.55]		[0.35]
Canada	2	0.48	3	0.95	0.095	0.140	2	0.25	5	0.69	5	0.74
		[0.62]		[0.42]	(0.011)	(0.019)		[0.78]		[0.63]		[0.59]
Denmark	6	23.36	6	1.66	0.094	0.004	4	0.94	4	1.88	6	1.63
		[0.00]		[0.14]	(0.005)	(0.027)		[0.44]		[0.12]		[0.14]
France	7	3.70	4	0.23	0.018	0.018	4	1.20	7	1.30	7	1.30
		[0.00]		[0.92]	(0.012)	(0.044)		[0.32]		[0.26]		[0.26]
Iceland	3	106.31	4	1.82	0.030	0.050	5	1.14	3	4.64	3	2.44
		[0.00]		[0.13]	(0.007)	(0.016)		[0.34]		[0.00]		[0.07]
Italy	5	6.54	5	0.92	0.107	0.246	5	1.20	6	1.13	5	0.10
		[0.00]		[0.47]	(0.007)	(0.028)		[0.31]		[0.35]		[0.99]
Norway	8	4.60	4	1.95	0.108	-0.001	4	1.38	4	0.49	8	1.72
		[0.00]		[0.11]	(0.007)	(0.038)		[0.24]		[0.74]		[0.10]
Sweden	8	4.78	8	1.57	0.053	0.024	8	1.31	8	0.64	8	0.78
		[0.00]		[0.14]	(0.003)	(0.035)		[0.24]		[0.74]		[0.62]
Switzerland	4	15.66	7	1.21	0.077	-0.024	4	0.39	6	1.93	4	0.28
		[0.00]		[0.31]	(0.006)	(0.018)		[0.81]		[0.08]		[0.89]
England & Wales	4	49.59	4	0.91	0.156	0.005	4	0.97	4	0.49	4	0.78
		[0.00]		[0.46]	(0.005)	(0.028)		[0.43]		[0.74]		[0.54]
USA	10	2.26	6	1.22	0.0325	-0.013	7	1.87	5	1.75	6	1.60
		[0.04]		[0.31]	(0.013)	(0.020)		[0.10]		[0.14]		[0.17]

Note: k denotes the number of lags in the dynamic equation, Test is the value of the Granger causality test with p–value reported into brackets. γ corresponds to the growth rate of the share of the last group in the population as obtained from an OLS regression of the log of this share on a constant term and a linear trend. γ_{50} is the corresponding value over the last 50 years of the sample. Both γ and γ_{50} are expressed in percentage points. Standard deviation into parenthesis.

from the graph and the series display similar fluctuations.

Figure 2: Robustness



Because the OGA index makes use of the entire shape of the distribution of population by age, it is less sensitive to increases in life expectancy at age 60. It therefore captures the population aging phenomenon without overestimating individual aging. This leads to mitigate the common wisdom that populations age.

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