Ageing, heterogeneity and fairness[1]

Jennifer Alonso-García

Department of Mathematics, Université Libre de Bruxelles, Belgium
CEPAR, UNSW Sydney, Australia
Netspar, Tilburg University, The Netherlands

jennifer.alonso.garcia@ulb.be

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[1]Based on Jijiie et al. (2021).

List of contents

Introduction

- Life expectancy has increased from 30-40 years to 80+ since 1750.
- The variability in mortality substantially reduced over time $\rightarrow$ it is much more likely to survive to older ages
- However, heterogeneity in mortality is still at play.
- In France, life expectancy differences at 30 can be up to 4 years.
- The effect in the pension system is major if class-specific rates were to be introduced.

List of contents

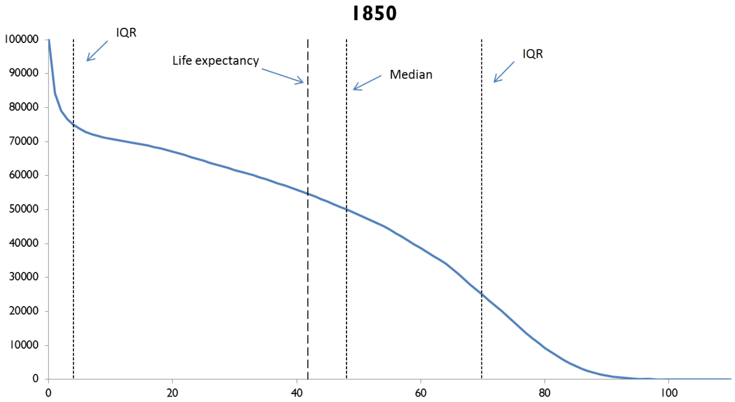
Life expectancy accross time

- *Early humans*: 20-30 years as testified by evidence that has been gained from tombstones inscriptions, genealogical records, and skeletal remains
- *Around 1750*: 35-40 years as testified first national population data is collected in Nordic countries.
- *Mid-1800s*: 40-45 years
- *From of the 19th century*: rapid improvements until achieving roughly 60-65 years by mid-20th century.
  - *First half 20th century*: significant improvement in the mortality of infants and children (and their mothers) resulting from improvements to public health and nutrition that helped to withstand infectious diseases.
  - *Since the middle of the 20th century*: gains have been due more to medical factors that have reduced mortality among older persons. Reductions in deaths due to the 'big three' killers (cardiovascular disease, cancer, and strokes).

Life expectancy accross time (C'td)

- *Begin 21st century*: life expectancy at birth reached about 70 years.
- Average lifespan has roughly tripled over the course of human history. Much of this increase has happened in the past 150 years.
- This mortality transition has contributed to a demographic transition that has resulted in **population ageing** as survival to older ages has increased and number of births have decreased ('baby-bust' in the 1970s).
- Especially important for *pension financing* and *life insurance*.

Male life table number of survivors (l_x), England and Wales 1850-2009



Source: Human Mortality Database

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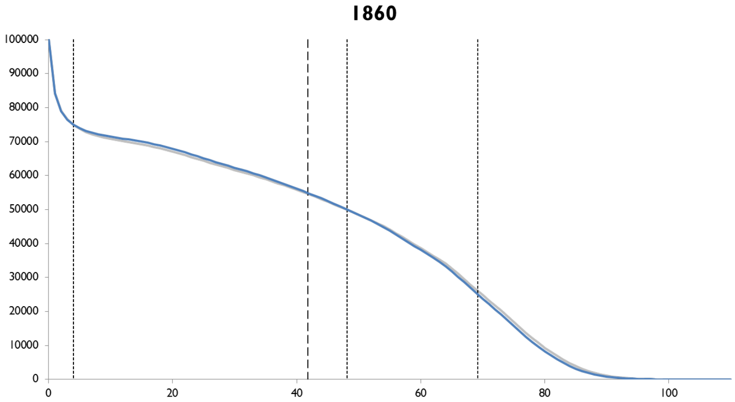

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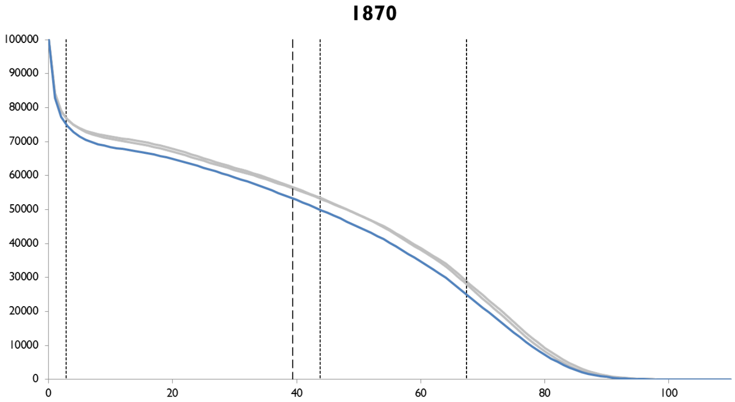

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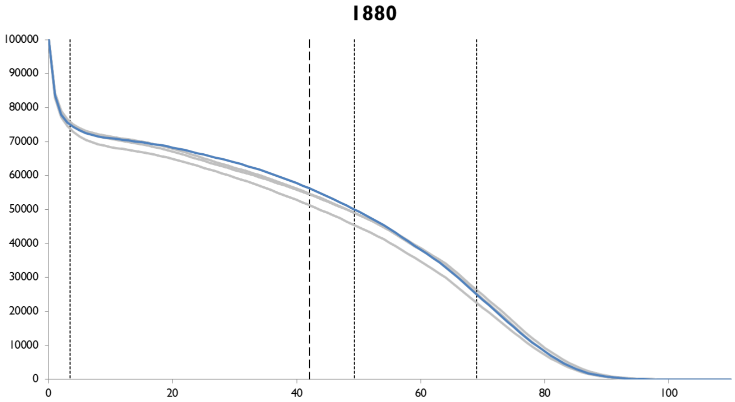

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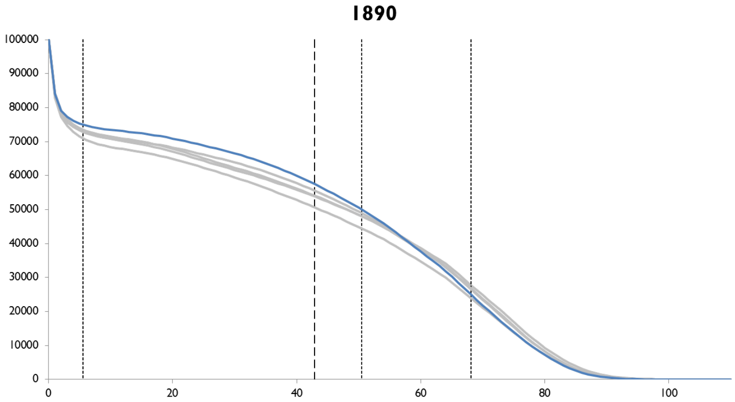

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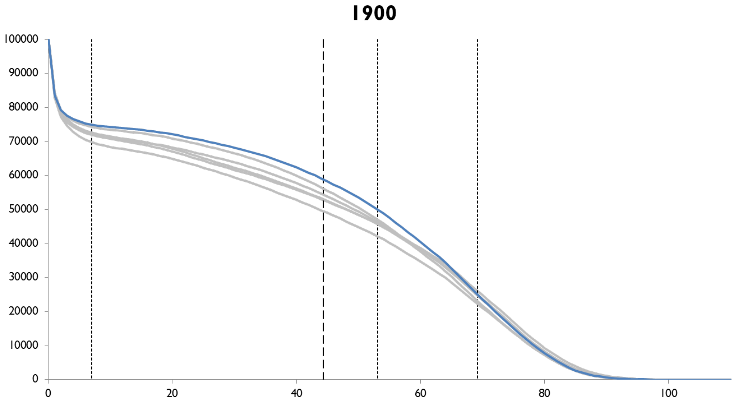

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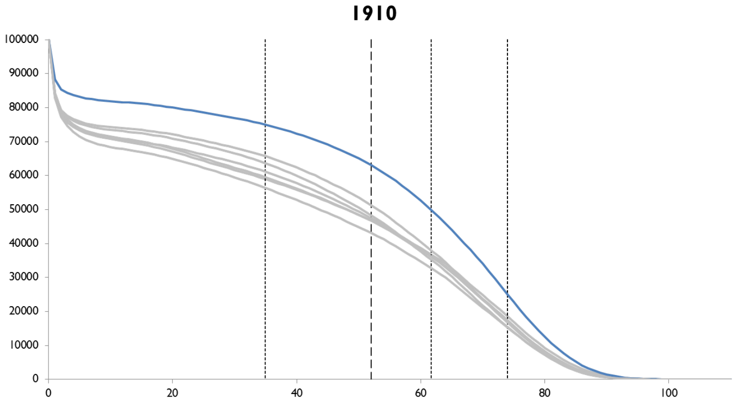

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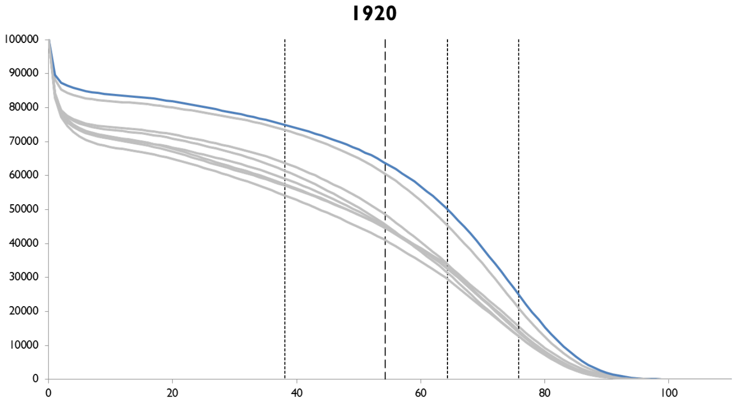

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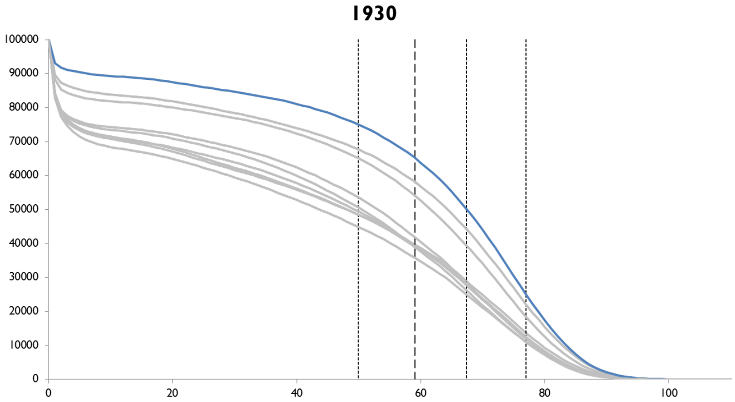

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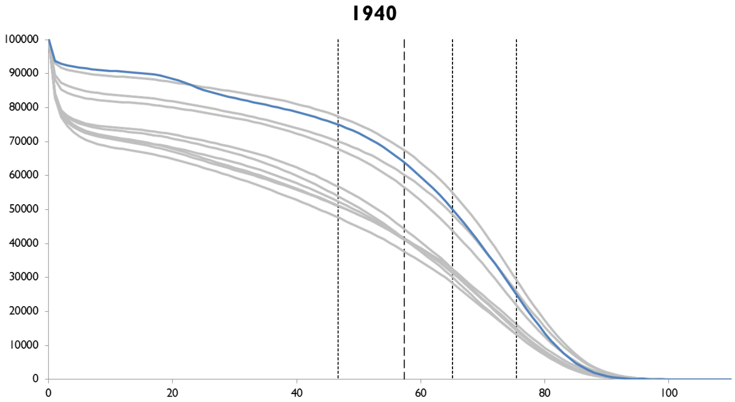

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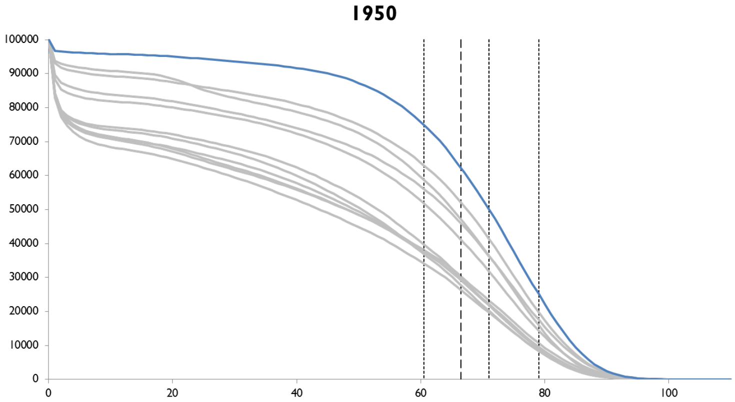

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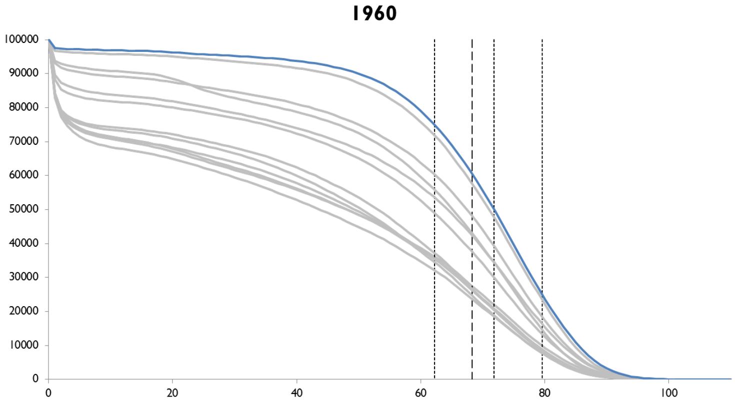

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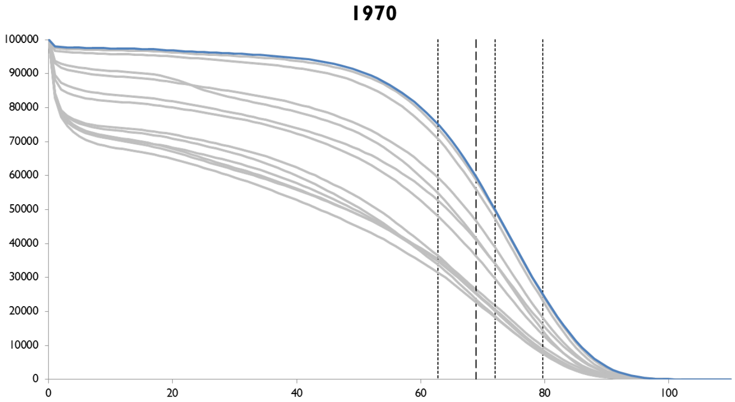

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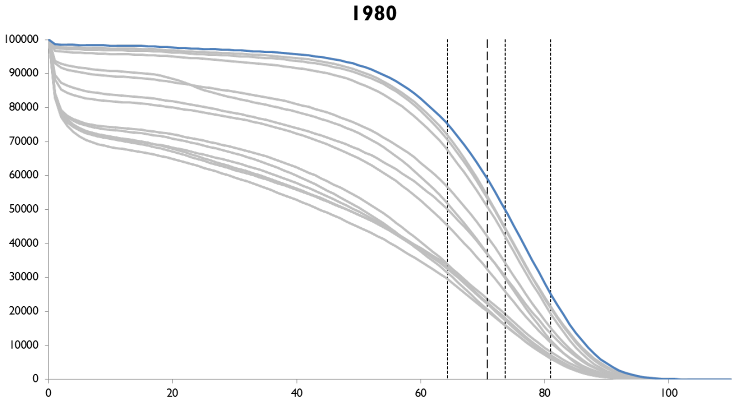

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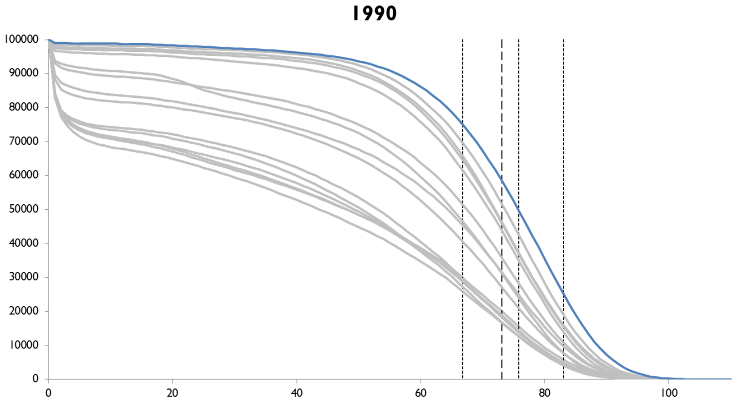

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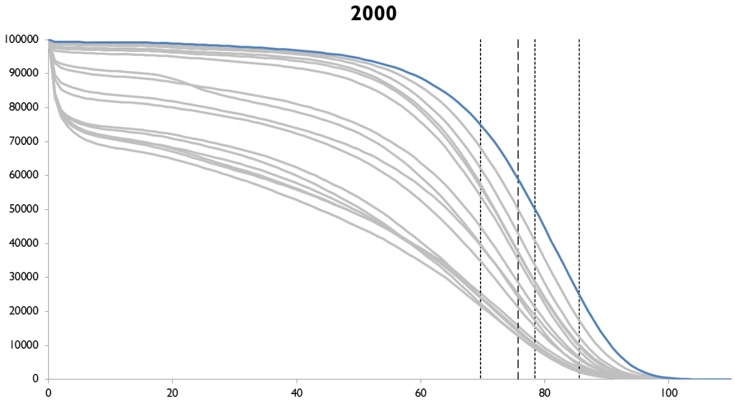

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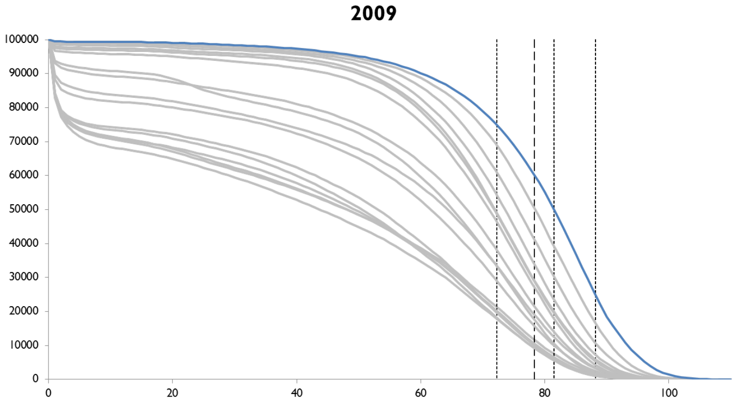


Source: Human Mortality Database

List of contents

- It is well known that any given population is affected by some degree of heterogeneity, as far as individual mortality is concerned.
- Heterogeneity in populations should be approached adressing two main issues:
  - detecting and modelling observable heterogeneity factors (e.g. age, gender, occupation, etc.)
  - allowing for unobservable heterogeneity factors (frailty models, not treated here).

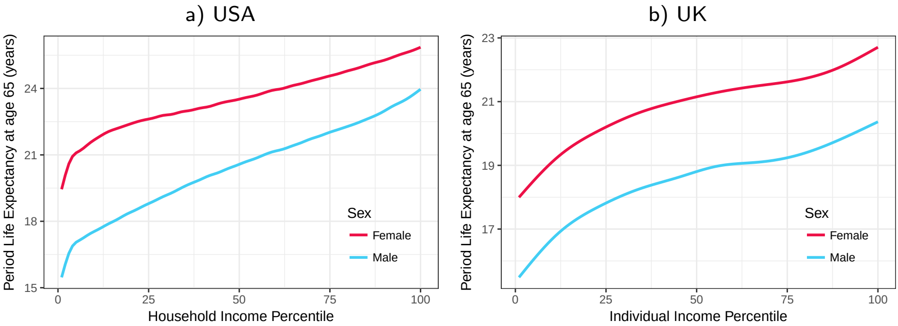
As regards to observable factors, mortality depends on:

1. biological and physiological factors, e.g. age, gender, genotype;
2. features of the living environment, e.g. climate and pollution, nutritional standards (mainly due to deficiencies in diet), hygienic and sanitary conditions;
3. occupation, e.g. professional disabilities or exposure to injury, and educational attainment;
4. individual lifestyle, e.g. nutrition, alcohol and drug consumption, smoking, physical activities and pastimes;
5. current health conditions, personal and/or family medical history, civil status, and so on.

- Some factors affect the whole population, such as the features of the living environment (item 2).
- That is why mortality tables are typically considered specifically for a given geographic area.
- Other factors concern the individual and can be observed at policy issue.
- Indeed, life insurance "*screening*" typically includes lifestyle and biological factors-related questions in the application forms.
- Sometimes an actual **medical** examination is performed, e.g. for income replacement (disability), life insurance (contingent to death), and health insurance.

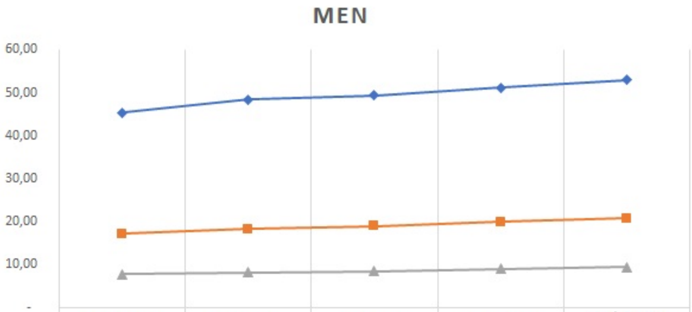
How much does life expectancy vary? US & UK

USA & UK Period Life Expectancy in 2014 at age 65 by Household Income percentile[2]



[2] Holzmann et al. (2019) using Chetty et al. (2016) data.

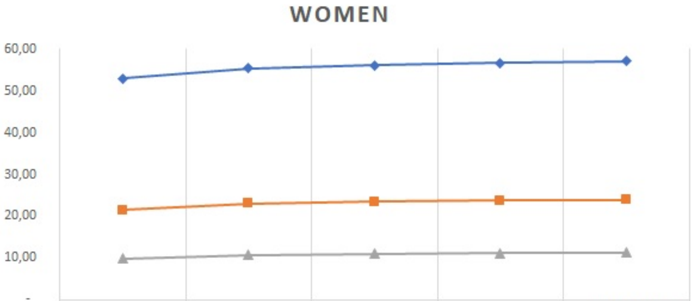
How much does life expectancy vary? French men[3] 2009-2013 series.



	Sans diplôme	Brevet, CEP	CAP, BEP	Baccalauréat	Supérieur au baccalauréat
30	45,43	48,45	49,39	51,24	53,03
65	17,18	18,28	19,04	19,90	20,83
80	7,78	8,23	8,55	8,97	9,40

[3] https://www.insee.fr/en/accueil

How much does life expectancy vary? French woman



	Sans diplôme	Brevet, CEP	CAP, BEP	Baccalauréat	Supérieur au baccalauréat
30	52,92	55,34	56,07	56,75	57,12
65	21,40	23,01	23,47	23,75	23,89
85	9,90	10,78	11,02	11,18	11,25

Will LE differences persist?[4]

Deprivation quintiles referred to as Q1 (least deprived), Q2, Q3, Q4, and Q5 (most deprived). Figure shows results of a quintile specific Lee-Carter model.

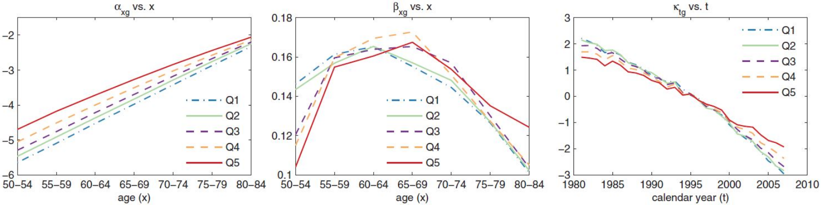


FIGURE 1. Parameter Estimates of Independent Lee-Carter Model for Male Deprivation Subpopulations. (color figure available online)

- Level of α is lower for *least deprived*
  $\rightarrow$ less mortality!
- κ improvement is steeper for *least deprived*
  $\rightarrow$ forecast indicates greater mortality improvement for low deprived populations.

[4]Villegas and Haberman (2014).

Will LE differences persist? (C’td)

In their analysis they show

- at some ages the mortality rates of the most deprived quintile can be more than twice the mortality rates of the least deprived quintile.
- a **widening** of the relative mortality gap between more and less deprived areas of England, mainly as a result of the slower mortality improvements experienced by the lowest socioeconomic subgroups.
- With gender removed from the list of admissible rating factors, socioeconomic-related rating factors gain relative importance in the modeling of longevity risk.

Impact on annuity pricing[5]

Using GLM approaches, they use data from Club Vita that amounts to almost half a million members of UK occupational pensions.

Geo-dem group	Salary band	$\mathring{e}_{65:\overline{31}\rceil}$	$\bar{a}^{2.5\%}_{65:\overline{31}\rceil}$	Monthly	$\bar{a}^{5\%}_{65:\overline{31}\rceil}$	Monthly
E-upper	48.5K	20.88	15.88	1.050	12.54	1.329
E-upper	22.5K-30.5K	18.74	14.52	1.148	11.64	1.432
E-upper	$<$ 15K	17.53	13.72	1.215	11.11	1.500
C-middle	48.5K	19.83	15.22	1.095	12.11	1.376
C-middle	22.5K-30.5K	17.55	13.74	1.213	11.12	1.499
C-middle	$<$15K	16.27	12.88	1.294	10.53	1.583
A-lower	48.5K	18.12	14.11	1.181	11.37	1.466
A-lower	22.5K-30.5K	15.63	12.45	1.339	10.22	1.631
A-lower	$<$15K	14.27	11.51	1.448	9.55	1.745

Note: all currencies are in GBP. Monthly payment is based on a 200,000 capital.

A-E represent lifestyle markers (ACORN system) based on demographic and consumer lifestyle databases designed for marketing purposes.

[5] Madrigal et al. (2011).

List of contents

Recent OECD pension reforms

- Being most pension schemes PAYG financed, the burden of the increased life expectancy is far from getting any lighter
- To address this, many countries have have proceeded to reforming their first pillars (OECD 2019), often *increasing* the minimum or legal retirement age.
- However, what about heterogeneity in mortality induced by socio-economic class?[6]
- Indeed, we have seen that lower socio-economic classes have a lower life expectancy than the higher classes, with inequalities still expected to rise (as also remarked by Ayuso et al. (2017)).
- Increasing the retirement age would lead to individuals of lower classes spending **even less** time in retirement.

[6] A non-exhaustive list of related papers: Nelissen (1999), Shkolnikov et al. (2007), Van Berkum et al. (2020), Olshansky et al. (2012), Meara et al. (2008), Ayuso et al. (2017), Sanzenbacher et al. (2015), Barnay (2007), Mazzaferro et al. (2012) or Brown (2003).

The pension schemes: numerical assumptions[7]

- Fixed contribution rate: 14.3 %
- Discounting rate 1.8% (growth covered wage bill)
- Retirement age: 65
- Defined Benefit: average of career salaries x accrual rate x (65-x_0^i)
  $\rightarrow$ Base accrual is 1%
- (Notional) Defined Contribution: lifelong contributions receive a (notional) return. At retirement the capital is transformed in a pension through an annuity factor
  $\rightarrow$ Base notional rate is 1.8%

$\Rightarrow$ we compare the pensions from these systems to the *theoretical* pension that corresponds per socio-economic class.

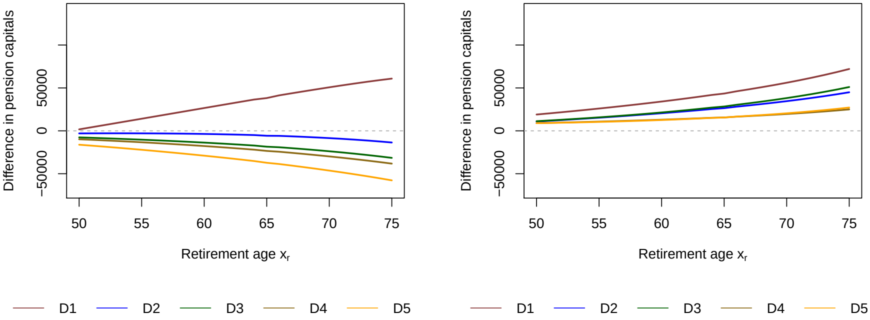
Example: same salary but different category would yield a theoretical pension of 1,200 for low ed vs 1,000 for high ed due to life expectacy differences.

[7] More information on Jijiie et al. (2021).

Category	Descriptive	x_0^i
D1	Superior to Baccalaureate	21
D2	Baccalaureate	18
D3	CPC (Certificate of professional competence), CPS (Certificate of professional studies)	17
D4	National Diploma, CPrS (Certificate of primary studies)	16
D5	No diploma	15

Table: Socio-economic categories by level of education (France) and their entry ages into the system, adapted from Hörner et al. (2007)

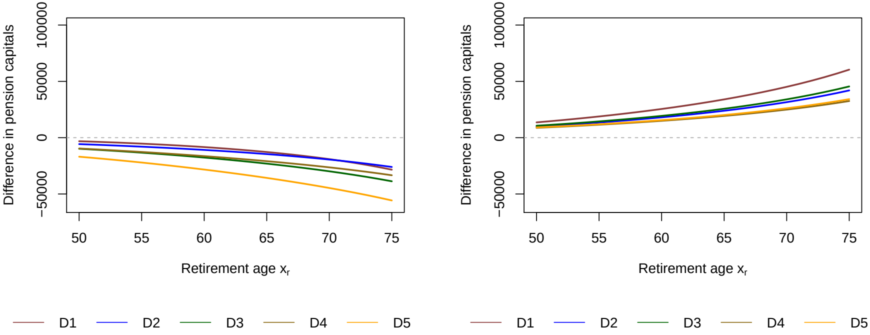
How big are the transfers?



(a) $PV^{i,DB}_{x_{ref},t}(x_r)$ for men

(b) $PV^{i,DB}_{x_{ref},t}(x_r)$ for women

Figure: DB vs theoretical pension capital, for individuals entering the system in 2016



(a) $PV^{i,NDC}_{x_{ref},t}(x_r)$ for men

(b) $PV^{i,NDC}_{x_{ref},t}(x_r)$ for women

Figure: NDC vs the theoretical pension capital, for individuals entering the system in 2016

Quantifying the differences

	Male		Female		Unisex	
Class	AR^i	nr^i	AR^i	nr^i	AR^i	nr^i
D1	0.9070	1.9033	0.8443	1.4198	0.8898	1.6560
D2	1.0206	1.9724	0.8649	1.4405	0.9620	1.7146
D3	1.0756	2.0586	0.8703	1.4554	0.9922	1.7692
D4	1.1366	2.0958	0.9028	1.4759	1.0395	1.7996
D5	1.1872	2.2319	0.9171	1.5127	1.0704	1.8848

Table: Class-specific parameters for individuals retiring at age 65 in 2066, in percentages

If we take the socio-economic differences at face value

- Lower socio-economic classes should receive higher accrual and notional rates.
- The gap between classes is smaller for women.
- Women receive lower accrual and notional rates to account for their higher life expectancy (*indicating they should get lower pensions*)
- Awarded rates are lower for those in higher classes and higher for those in lower classes.
- Interest and notional rates have the same values.
- Only those in class D5 will receive a notional rate above the initial value of 1.8%. Accrual rates above 1% are awarded to those in class D4 and D5 to compensate for their losses with respect to the actuarially fair pension

Adequacy

- So taking differences at face value would *increase* pensions for low economic status and *decrease* those for those with higher education.
- **However**, it also has the perverse effect that it would entail decreasing pensions for women as they have a higher life expectancy on average, even those with low education.
  Would that be fair?
- If we consider a minimum pension P_{min}, defined as a percentage RR_{target} of the mean salary in the system at time t:

$$P_{min,t} = RR_{target} \cdot \overline{W}_t \qquad (1)$$

results will change.

	Male		Female	
Class	AR^i	nr^i	AR^i	nr^i
D1	-	-	1.0972	2.1646
D2	1.0898	2.1585	1.6218	3.1473
D3	-	-	1.4394	2.8182
D4	1.5006	2.8169	2.0028	3.5262
D5	1.2348	2.3351	1.7189	3.1233

The — indicates that no change is needed.

Table: Class-specific parameters for individual retiring at age 65 in 2066, adjusted given $RR_{target} = 40\%$, in percentages

Comparing Table 3 to 2, we see

- given the low level of pensions of women and low educated men, we have to increase pensions for those groups,
- for example, women in class D1's accrual rate would pass from 0.8443% to 1.0972%, while the notional rate becomes 2.1646%, instead of 1.4198%.
- With no adequacy adjustment women would have to receive *less*, whilst with adjustment they should receive substantially more!

List of contents

Conclusion

- Life expectancy is heterogeneous, but a lot of the variability could be linked to the education level.
- Those with a shorter education vs highly educated should received up to extra (equivalent) 22 basis points to compensate their lower life expectancy.
- Heterogeneity is here to stay and most researchers argue that it might even get worse.
- Class-specific rates seems an impossible task, when gender can not be taken into account.
- We need to look at this on a combined level together with adequacy. By imposing fairness there might be unintended consequences for other groups!
- A way to potentially counter that is to work by means of career length or capping pension rights (but not contributions) instead of fixed retirement age, but more research is needed.

Thanks

Thank you for your attention

Questions?

email: jennifer.alonso.garcia@ulb.be

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List of contents

Mortality I

- The historical mortality rates per level of education go from ages 30 to 100 for the years 1991-2013, grouped per periods. Hence we have three sets of mortality rates, namely for the periods 1991-1999, 2000-2008 and 2009-2013.
- We use the common factor model (Li and Lee 2005) given by B.1 below, where α_x^i represents the class-specific and age-specific average mortality behaviour.

$$\log m_{x,t}^i = \overbrace{\alpha_x^i}^{\text{category specific}} + \underbrace{\beta_x^p \kappa_t^p}_{\text{from HMD}} . \tag{B.1}$$

- The category-specific base trend α_x^i is calculated as follows:

$$\alpha_x^i = \frac{\sum_{t=0}^{T} \log \hat{m}_{x,t}^i}{T+1} . \tag{B.2}$$

Mortality II

Since we only have the values of $q^i_{x,t}$ (the mortality rate for a person of age x at time t and of class i), we determine $\hat{m}^i_{x,t}$ by following Pitacco et al. (2009) as given in B.3 below.

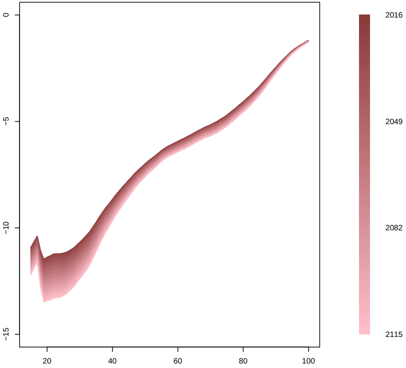
$$\hat{m}^i_{x,t} = \frac{\hat{q}^i_{x,t}}{1 - 0.5 \cdot \hat{q}^i_{x,t}} . \tag{B.3}$$

- Therefore, we start by estimating the Lee Carter parameters for the female and male French population, using log likelihoods, fitted to the data from the Human Mortality Database for the period 1816-2015. We then use an ARIMA model to project κ^p_t for each gender[8] for a horizon of 100 years, in order to further determine the mortality rates for the ages 15 to 100.
- By using B.1, we then project mortality rates for each group from D1 to D5. For ages below 30, since we do not have class-specific mortality data, we assume that $\alpha^i_x = \alpha^p_x \cdot \frac{\alpha^i_{30}}{\alpha^p_{30}}$, for $x < 30$.

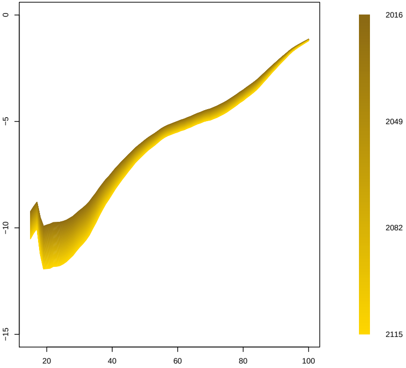
[8] We use an ARIMA(1,1,1) for men and an ARIMA(2,2,3) for women, which correspond to minimum values of AIC.

Forecast results: men

a) Mortality projection for D1

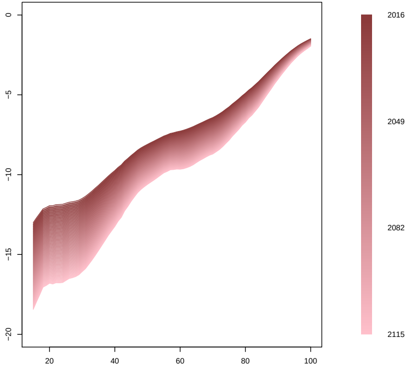


b) Mortality projection for D5

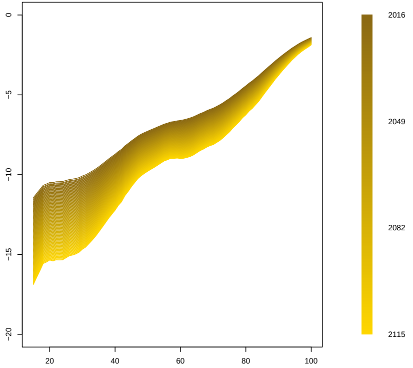


Forecast results: women

a) Mortality projection for D1



b) Mortality projection for D5



Theoretical pension

Theoretical pension for retirement ageg x_r^i and category i

$$P_{x_r^i,t}^{i,th}(r) = \frac{\pi \cdot \sum_{x=x_0^i}^{x_r^i-1} W_{x,t-x_r^i+x}^{i} \cdot (1+r)^{-(x-x_0^i)} {}_{x-x_0^i}p_{x_0^i,t-x_r^i+x_0^i}^{i}}{\ddot{a}_{x_r^i,t}^{i,\beta}(r) \cdot {}_{x_r^i-x_0^i}p_{x_0^i,t-x_r^i+x_0^i}^{i} \cdot (1+r)^{-(x_r^i-x_0^i)}} \tag{2}$$

DB pension

The DB pension is described as a function of the accrual rate AR^i.

$$P^{i,DB}_{x_r^i,t}(AR^i) = \begin{cases} \overline{W}_t^i \cdot AR^i \cdot (x_r^i - x_0^i)(1 - b_{x_r^i}\%), & \text{if } x_r^i < x_{legal} \\ \overline{W}_t^i \cdot AR^i \cdot (x_r^i - x_0^i), & \text{if } x_r^i = x_{legal} \\ \overline{W}_t^i \cdot AR^i \cdot (x_r^i - x_0^i)(1 + b_{x_r^i}\%), & \text{if } x_r^i > x_{legal} \end{cases} \tag{3}$$

Moreover, $\overline{W}_t^i$ is given by 4 below, where $W^i_{x,t+x-x_r^i}$ is the salary of a person of age x at time $t + x - x_r^i$, belonging to class i, given that the retirement age x_r^i is reached at time t.

$$\overline{W}_t^i = \frac{1}{n} \sum_{x=x_r^i-n}^{x_r^i-1} W^i_{x,t+x-x_r^i}. \tag{4}$$

NDC pension

The NDC pension is defined as a function of the notional rate:

$$P^{i,NDC}_{x^i_r,t}(nr^i) = \frac{\pi \cdot \sum_{x=x^i_0}^{x^i_r-1} L^{unisex}_{x,t-x^i_r+x} \cdot W^i_{x,t-x^i_r+x} \cdot (1+nr^i)^{x^i_r-x}}{\ddot{a}^{unisex,\beta}_{x^i_r,t}(nr^i) \cdot L^{unisex}_{x^i_r,t}} \quad (5)$$

The expression $\ddot{a}^{unisex,\beta}_{x^i_r,t}(nr^i)$, used in (5) is a classical annuity that uses the unisex mortality and the notional rate nr^i:

$$\ddot{a}^{i,\beta}_{x_r,t}(r) = \sum_{k=0}^{\omega-x_r} \left(\frac{1+\beta}{1+r}\right)^k \cdot {}_k p^i_{x_r,t} \quad (6)$$

where β represents the indexation rate, set to 0 in this study, $p^i_{x,t}$ is the class-specific survival rate, while ${}_k p^i_{x,t}$ is the probability that a person of age x at time t survives another k years.