

## WORKING PAPER

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# **NDC Schemes and Heterogeneity in Longevity: Proposals for Redesign**

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## ABSTRACT

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# NDC Schemes and Heterogeneity in Longevity: Proposals for Redesign\*

A positive relationship between lifetime income and life expectancy leads to a redistribution mechanism when the average cohort life expectancy is applied for annuity calculation. Such a distortion puts into doubt the main features of the NDC (nonfinancial defined contribution) scheme and calls for alternative designs to compensate for the heterogeneity. This paper explores five key mechanisms of compensation: individualized annuities; individualized contribution rates; a two-tier contribution structure with socialized and individual rates; and two supplementary two-tier approaches to deal with the income distribution tails. Using unique American and British data, the analysis indicates that both individualized annuities and two-tier contribution schemes are feasible and effective and thus promising policy options. A de-pooling by gender will be required, however.

**KEYWORDS:** Tax/Subsidy Structure, Two-Tier Contribution Structure, Proxied Life Expectancy, Gender De-Pooling, Heterogeneity in Mortality

**JEL CODES:** H55, D9, G22

### Abbreviations and Acronyms

DC	Defined Contribution
E&W	England and Wales
FDC	Funded Defined Contribution
NDB	Nonfinancial Defined Benefit
NDC	Nonfinancial Defined Contribution
US	United States
TATSI	Total Absolute Tax Subsidy Indicator

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## 1. Introduction

Strong and rising empirical evidence shows that longevity is highly heterogeneous in key socioeconomic characteristics, including income status. Ayuso, Bravo, and Holzmann (2017a) review the literature on the main socioeconomic dimensions of heterogeneity in longevity, their past development, and likely future trends. This international evidence, currently available only for advanced economies, suggests that heterogeneity in longevity arises across many socioeconomic dimensions, is often sizable, is becoming more prevalent, and shows few signals of abating in the near future.

The scope and trend of such heterogeneity in longevity regarding measures of lifetime income create a major concern for providers of lifetime annuities – namely, private insurance companies under voluntary and mandated funded defined contribution (FDC) schemes, and the rising number of countries that did or plan to adopt a nonfinancial defined contribution (NDC) scheme. Under an NDC approach, the initial pension benefit (lifetime annuity) is calculated at retirement by broadly dividing the notional account accumulations by the remaining (average) cohort life expectancy (see Holzmann 2019 for a primer). When heterogeneity exists in the remaining life expectancy, some individuals profit at the expense of others in the social insurance pool. If life expectancy is positively correlated with lifetime income and with the level of accumulation, lower-income groups lose and higher-income groups profit from a common risk pool and application of a common life expectancy measure.

From a policy design perspective, heterogeneity in longevity with regard to income and contribution effort breaks the tight contribution–benefit link considered the signature feature of an NDC scheme: What you paid in you get out – not less and not more. Breaking the link creates new tax wedges that the reform from nonfinancial defined benefit (NDB) to NDC schemes aimed to eliminate.

Such heterogeneity wedges also exist in NDB schemes beyond those created by explicit or implicit redistribution mechanisms, but given the benefit formula in NDB schemes, they are less visible. In an NDC scheme, one can more easily calculate the tax/subsidy wedge created

by the heterogeneity in life expectancy at retirement, which has implications for individuals' decisions regarding formal labor supply and retirement age. Hence, left unaddressed, the risks associated with heterogeneity in life expectancy are threefold as it: invalidates or at least reduces the rationale for an NDC reform; renders an increase in retirement age as the key approach to deal with population aging less powerful and highly regressive; and creates an adverse redistribution, an outcome the NDC approach seeks to eliminate.

This paper explores in depth key policy options to address heterogeneity in longevity in NDC schemes. Some options were outlined by Ayuso, Bravo, and Holzmann (2017b); this paper deepens the analytical and empirical framework. Section 2 investigates the scope of the heterogeneity issue by using much more fine-grained data for the United States (US) and England and Wales (E&W) and estimating the distributions, not just point estimates, of the tax/subsidy mechanism. Section 3 presents alternative NDC designs to address heterogeneity within a common analytical framework. Section 4 applies this analytical framework to the disaggregated data of section 2 to gain a better understanding of feasibility, additional data needs, and empirical indications. Section 5 summarizes and outlines suggested next research steps.

## **2. Scope of the issue and policy implications**

While data on heterogeneity in longevity by various socioeconomic dimensions are increasingly available in advanced economies, the disaggregated link between life expectancy and measures of lifetime income remains the exception. Where data do exist, they are typically not suitable for examining this link. However, such disaggregated estimates across the whole income strata are critical to guide policy design options.

The first part of this section presents estimated disaggregated information on the scope and distribution of heterogeneity based on data from the US and E&W. The second part uses this information to estimate the disaggregated tax/subsidy effects of heterogeneity for these two countries with regard to their measure of lifetime income. Section 2 ends with a brief discussion of the policy implications of these estimates.

## 2.1. Scope and distribution of heterogeneity in life expectancy

Individual lifetime incomes and the corresponding mortality data for a whole country are complex to establish and thus rarely available. Indeed, it requires combining various sources of data (such as tax declarations and death certificates). However, to gauge the relationship<sup>1</sup> between (lifetime) income and life expectancy, related information were obtained for the US and E&W, as follows.

### 2.1.1. United States

Chetty et al. (2016) use federal income tax and Social Security records to investigate the relationship between (lifetime) income and life expectancy in the US. This paper uses their data<sup>2</sup> to estimate life expectancy at age 65 by income percentile. The available data comprise mortality rates and population counts for the US by gender and income percentile for ages 40–76 and calendar years 2001–2014. In this dataset, income is approximated by yearly pretax household earnings adjusted to 2012 dollars using the consumer price index.<sup>3</sup> Full details of the data collection and sources can be found in Chetty et al. (2016).<sup>4</sup>

To estimate period life expectancy at age 65 by income percentile ranks 1 to 100, gender-specific life tables by income percentile are constructed using a Gompertz-type generalized additive model linking log mortality rates to age, income percentile rank, and calendar year.<sup>5</sup> Figure 2.1a and Figure 2.1b illustrate the estimated relationship between income and period life expectancy at age 65. Here, nominal lifetime income values correspond to the sum of

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<sup>1</sup> It is worth highlighting that this paper is only interested in the degree of association between lifetime income and life expectancy, and does not make any claims about the causal effects of income on mortality.

<sup>2</sup> Available at <https://healthinequality.org/data/>; in particular, data from online Table 15 are used.

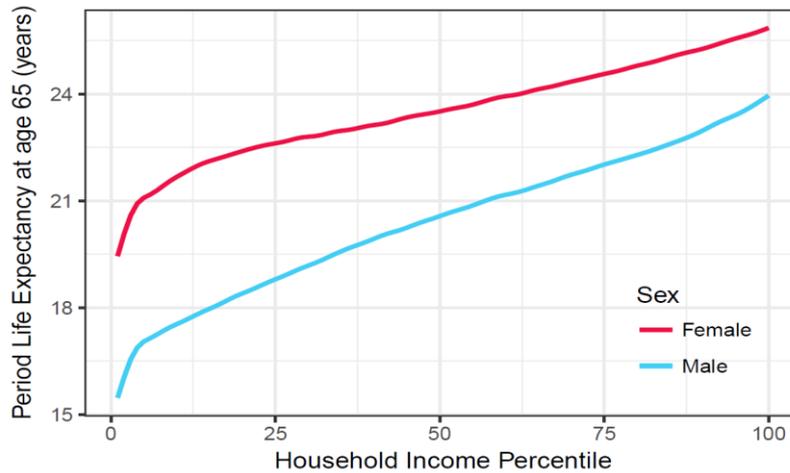
<sup>3</sup> For those who filed tax returns, Chetty et al. (2016) define household earnings as adjusted gross income plus tax-exempt interest income minus taxable Social Security and disability benefits. For those who did not file a tax return, they define household earnings as the sum of all wage earnings and unemployment benefits. Note that household income statistics differ by gender due to the effect of single-individual households.

<sup>4</sup> An alternative US dataset for exploration is that developed by the National Academies of Sciences, Engineering, and Medicine (2015). However, this dataset is not publicly available.

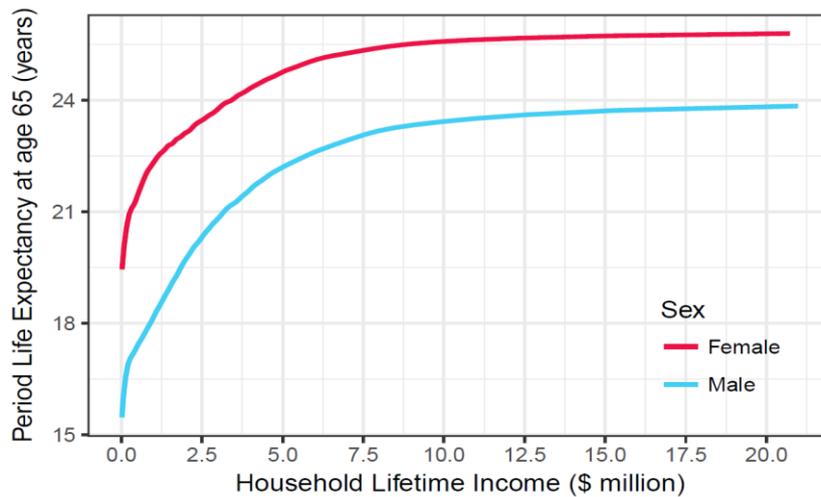
<sup>5</sup> Mortality rates beyond age 76 were extrapolated using a variant of the method of Coale and Kisker (1990) under the assumption that mortality rates at age 110 are equal to 0.7.

gender-specific, yearly pretax household earnings between ages 20 and 64, with earnings from ages 20 to 40 assumed to be equal to earnings at age 40.<sup>6</sup>

**Figure 2.1a: US period life expectancy in 2014 at age 65 by household income percentile**



**Figure 2.1b: US period life expectancy in 2014 at age 65 by nominal household income**



Source: Chetty et al. 2016, and authors' calculations.  
 Note: The top income percentile is omitted for scaling purposes.

<sup>6</sup> The available data include pretax earnings by age ( $x$ ), year ( $t$ ), and income percentile ( $k$ ),  $y_{x,t}^k$ , for years 2001 to 2014 and ages 40 to 65. To obtain income by age and income percentile,  $y_x^k$ , the data for all years are pooled and smoothed by age using a cubic smoothing spline.

Figure 2.1a indicates that in a percentile view of the income distribution, the link to life expectancy is broadly linear except in the lowest percentiles, and less pronounced in the highest percentiles. If mapped to the (real) income measure in dollars, the relationship to life expectancy is strictly concave, with the strongest curvature where most household incomes are situated.

### 2.1.2. England and Wales

E&W has no dataset linking a measure of individual lifetime income to life expectancy. Instead, area-level measures are used to approximate this relationship. In particular, the analysis uses income and mortality data for middle layer super output areas (MSOA) in E&W, which are statistical geographies used by the Office of National Statistics (ONS).

The available data comprise ONS estimates of the total (gross) weekly household income at the MSOA level for the financial year ending 2014,<sup>7</sup> number of deaths,<sup>8</sup> and midyear population estimates<sup>9</sup> by gender and MSOA for 2015 and for ages 50–89. To approximate period life expectancy at age 65 by income percentile rank 1 to 100, MSOAs are first aggregated into household income percentiles and then gender-specific life tables by income percentile are constructed using a Gompertz-type generalized additive model linking log mortality rates to age and income percentile rank.<sup>10</sup>

Figure 2.2a and Figure 2.2b show the estimated relationship between income and period life expectancy at age 65. In Figure 2.2a, nominal lifetime income values correspond to the sum of the gender-specific annual incomes between ages 20 and 64, which were approximated

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<sup>7</sup> <https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/datasets/smallareaincomeestimatesformiddlelayerssuperoutputareasenglandandwales>

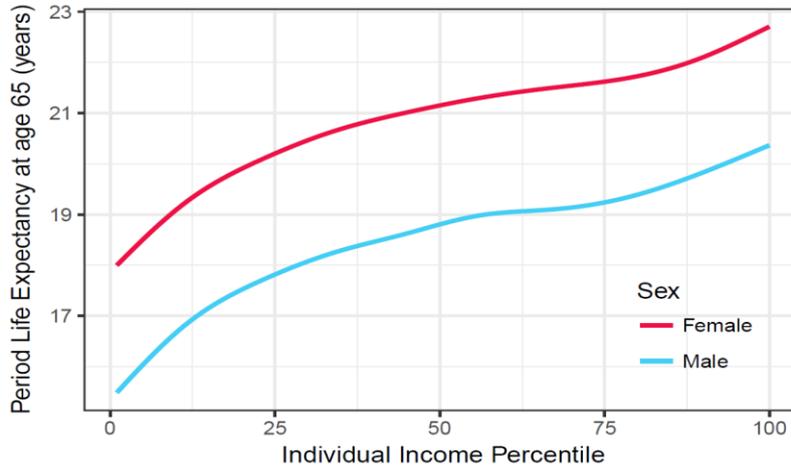
<sup>8</sup> <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/006416lowersuperoutputarealsoadeathregistrations2015>

<sup>9</sup> <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates>

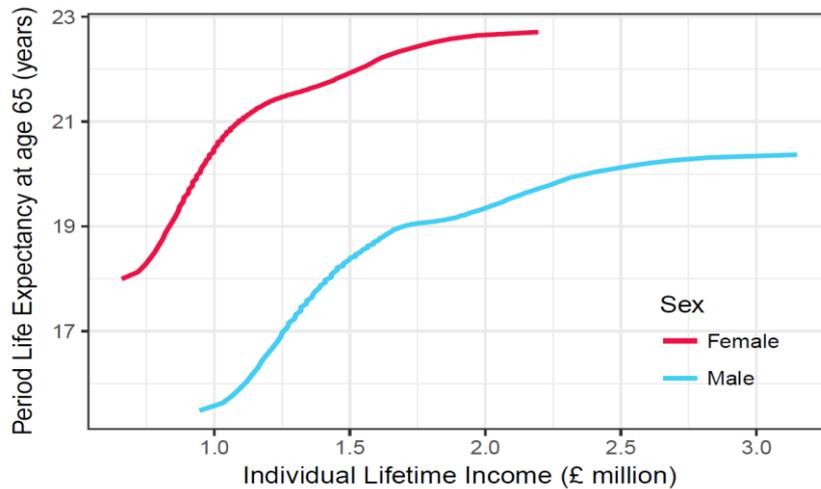
<sup>10</sup> Similar to the US case, mortality rates beyond age 89 were extrapolated using a variant of the method of Coale and Kisker (1990) under the assumption that mortality rates at age 110 are equal to 0.7.

using the distribution of pretax mean income by age and gender for the 2015 financial year as reported by the United Kingdom’s HM Revenue and Customs department.<sup>11,12</sup>

**Figure 2.2a: E&W period life expectancy in 2015 at age 65 (by individual income percentile)**



**Figure 2.2b: E&W period life expectancy in 2015 at age 65 (by nominal individual income)**



Source: Office of National Statistics and authors’ calculations.

<sup>11</sup> <https://www.gov.uk/government/statistics/distribution-of-median-and-mean-income-and-tax-by-age-range-and-gender-2010-to-2011>

<sup>12</sup> For each gender, the income at age  $x$  for someone in income percentile  $k$  is approximated by  $y_x^k = y_x \frac{w^k}{0.01 \sum_{i=1}^{100} w^i}$  where  $w^k$  denotes the weekly household income for income percentile  $k$  and  $y_x$  the gender-specific annual income for someone age  $x$  in E&W.

In comparing the results for E&W and the US it is important to bear in mind that:

- Income "percentiles" for E&W refer to percentiles of average income in local areas and not to percentiles of individual incomes. As individuals in an area will have additional heterogeneity, the actual distribution of individuals' incomes is likely to be more spread, as seen in the US data, for instance. Furthermore, unlike the US data, the E&W data will include contextual effects of geographic inequalities that could account for part of the association between income and mortality.
- Income in E&W is associated with individual income while for the US it is associated with household income. Using household income statistics instead of individual income may lead to misestimation of income by gender. This explains the greater disparity in income by gender observed in E&W as compared to the US.
- The income axis for E&W is much more compressed than for the US, even when considering household versus individual income, and £ versus \$ units.

## 2.2. Heterogeneity in longevity as tax/subsidy mechanism: Concept and estimates

The redistributive effect of heterogeneity in longevity can be easily assessed by translating the outcomes on benefit levels into a tax/subsidy mechanism (Ayuso, Bravo, and Holzmann 2017a). The approach is similar to translating differences in money-worth ratios below and above 1 into tax or subsidy rates.

The general framework is based on an individual contributing  $tc$  of her contribution base  $y^k$ <sup>13</sup> between age  $x_0$  and retirement age  $x_r$  to an NDC pension scheme, where the accumulated contributions at retirement age  $x_r$  are denoted  $Y_{x_r}^k$ . The superscript  $k$  represents her lifetime income characteristics. These contributions earn a notional rate of return  $i$  and yield an accumulated capital equal to  $AK^k(tc)$  at retirement:

$$AK^k(tc) = tc \cdot \sum_{j=0}^{x_r-x_0-1} y_{x_0+j}^k (1+i)^{x_r-x_0-j} = tc \cdot Y_{x_r}^k. \quad (1)$$

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<sup>13</sup> The contribution base does not always coincide with salaries. Indeed, the pension schemes in some countries only accrue rights up to a certain level of earnings, the remainder not being considered for benefit accrual purposes.

Upon retirement, the notional capital is transformed to an initial pension  $P_{x_r}^k$  by dividing the accumulated capital  $AK^k(tc)$  by an annuity factor  $a^k$  equal to the life expectancy of the cohort when the precharged indexation coincides with the discount rate.<sup>14</sup> The annuity factor can be individualized or can be based on the average life table of the cohort. In the latter case, the superscript  $k$  is specified to equal  $a$ . The annuity factor depends on the probability of surviving to age  $x_r + j$  after retirement, denoted as  ${}_j p_{x_r}^k$ :

$$a^k = LE^k = \sum_{j=0}^{\omega-x_r-1} {}_j p_{x_r}^k, \quad (2)$$

where  $\omega$  is the last possible surviving age.

The difference in mortality becomes more explicit whenever the pension wealth, or pension liability  $PW_{x_r}^{c,k}$ , is calculated. Indeed, the pension wealth depends on the observed mortality for an individual with characteristics  $k$ , even when the pension is based on an average annuity:

$$PW_{x_r}^{c,k} = P_{x_r}^c LE^k = AK^k(tc) \frac{LE^k}{LE^c}. \quad (3)$$

The pension wealth formulae presented above put forward two key concepts when dealing with heterogeneity. The first superscript,  $c$ , indicates the annuity factor used to calculate the pension at retirement. In practice, this is commonly based on the average life table of the population, despite observed differences in mortality.<sup>15</sup>

The second superscript,  $k$ , indicates that the individual experiences a distinct mortality that depends on lifetime income, education, and other socioeconomic characteristics. It follows from the expression that the pension wealth at retirement equals the accumulated notional capital if the pension is based on the individual's life expectancy.

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<sup>14</sup> The expression of the annuity could be generalized to consider indexation rates that differ from the discount rate. However, this analysis abstracts from this to obtain intuitive and tractable results. The authors acknowledge that a general annuity could be a tool to deal with mortality heterogeneity as well.

<sup>15</sup> As the distribution of the differences is not symmetric, the choice of the average matters. Typically, the arithmetic average is selected whereas the median would be the better choice.

Following this framework, the implicit tax or subsidy rate  $t^k$  for the individual with lifetime income characteristics  $k$  can be calculated as:

$$t^k = \frac{\text{Pension wealth}}{\text{Accumulated notional capital at retirement}} - 1 = \frac{PW_{x_r}^{c,k}}{AK^k(tc)} - 1. \quad (4)$$

A positive value of  $t^k$  represents a subsidy, since the liability in the system exceeds the accumulated contributions paid. This indicates that the individual will receive on average  $t^k$  percent more than she has contributed. On the other hand, a negative  $t^k$  represents a tax, since the realized liability is lower than the liability in the NDC books.

To clarify the distributionary effects, the current design of a typical NDC (and for this matter, also FDC) pension scheme is presented. The pension at retirement is calculated with the average life table, whereas the pensioner will have a different mortality experience on average according to her lifetime income characteristics  $k$ . In this case, the tax (subsidy)  $t^k$ , which can be positive or negative, is represented as follows:

$$t^k = \frac{PW_{x_r}^{a,k}}{AK^k(tc)} - 1 = \frac{\frac{AK^k(tc)}{LE^a} LE^k}{AK^k(tc)} - 1 = \frac{LE^k}{LE^a} - 1 \quad (5)$$

The individual receives a subsidy if  $LE^k > LE^a$ ; that is, if she belongs to a category that lives on average longer than the total population. This typically corresponds to individuals with higher lifetime income. However, those who belong to a category that lives shorter than the total population on average will bear an implicit tax due to the difference in life expectancy.

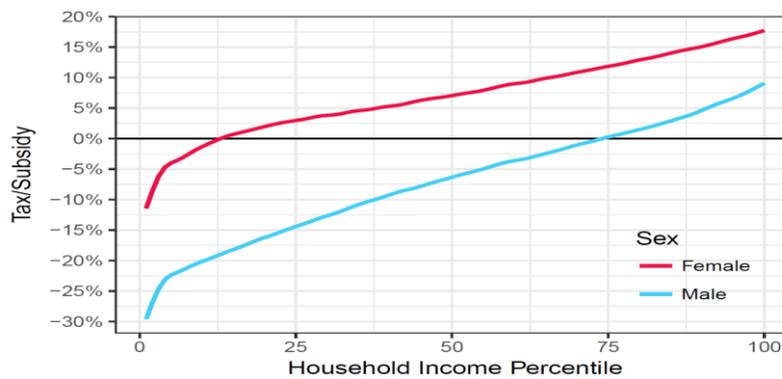
Ayuso, Bravo, and Holzmann (2017a, 2017b) offer for several advanced countries a number of point estimates of tax and subsidy rates that typically reflect the tertiles or quintiles of the income distribution. The data of Figure 2.1 and Figure 2.2 are used to estimate the whole distribution across all percentiles for the US and E&W, respectively. The results, presented in Figure 2.3 and Figure 2.4, lead to the following observations:

- Given the known higher average life expectancy of women when applying a common average annuity factor – as is the case in social security schemes – all women above

the 12<sup>th</sup> income percentile in the US (16<sup>th</sup> percentile in E&W) receive a subsidy, while all men below the 73<sup>th</sup> income percentile in the US (86<sup>th</sup> percentile in E&W) pay a tax.

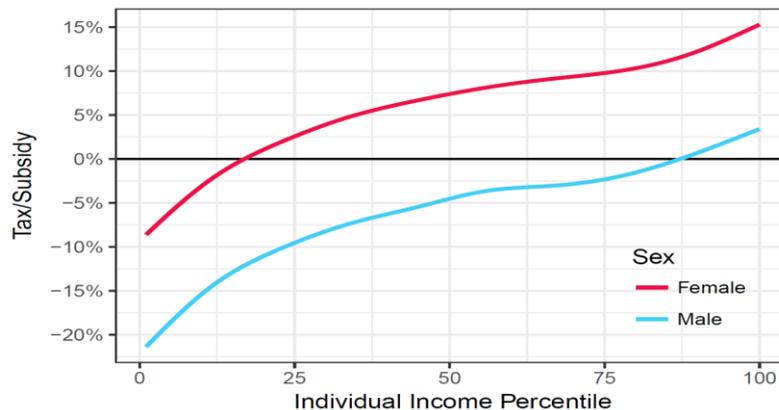
- The tax rate of men can be as high as 30 percent for the lowest percentile in the US (below 20 percent in E&W), and the subsidy rate of women can reach as high as 18 percent in the US (15 percent in E&W).
- Both men and women in the lowest 10 percent of income in both countries are particularly hit by a high tax rate of heterogeneity that is likely to affect their decisions regarding formal labor market participation and the scope of the supply.

**Figure 2.3: US tax/subsidy rates by household income percentile**



Source: Chetty et al. 2016, and authors' calculations.

**Figure 2.4: E&W tax/subsidy rates by individual income percentile**



Source: Office of National Statistics and authors' calculations.

### 2.3. Implications for scheme design and pension reform

A relevant and rising scope of heterogeneity in longevity – particularly linking higher life expectancy at retirement with higher accumulations at retirement – has major implications for scheme design and pension reform. This applies specifically to the reform movement in recent decades from defined benefit to (funded or unfunded) defined contribution (DC) schemes to establish a closer contribution–benefit link and to address population aging by increasing the retirement age(s) in line with increasing life expectancy. If relevant heterogeneity in longevity is left unaddressed in the design and implementation of DC schemes, their underlying design and reform rationale may be called into question. This section thus focuses on three main concerns with NDC schemes; the arguments apply roughly for FDC schemes as well.<sup>16</sup>

First, the beauty of NDC schemes is their simplicity and claimed fairness: what you paid in you get out, and what you get out you paid in, but no more.<sup>17</sup> Any redistributive considerations are transparent, with external financing that happens at the time the commitment is made, not when it is disbursed. This contrasts with NDB schemes, where some redistribution is part of the design but most of it is implicit, creating a tax/subsidy wedge often of unknown size and with unknown effects on distribution, financing, and scheme participation. With sizable heterogeneity among the insured and thus sizable tax/subsidy effects for contributors, the advantages of NDC schemes are lessened and the rationale for an NDC reform reduced.

Second, NDC schemes promise a linear intertemporal budget constraint in which the choice of retirement age depends only on the linear resource constraint and individual preferences for consumption and leisure. Minimum and standard retirement ages, in principle, lose their relevance in an NDC scheme, except for dealing with some behavioral restrictions by

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<sup>16</sup> For a broader discussion of heterogeneity in longevity and pension systems and reform, see Whitehouse and Zaidi (2008); for a discussion of the implications for funded pensions, see OECD (2016); and for suggestions how to address heterogeneity in longevity in the German point system, see Breyer and Hupfeld (2009).

<sup>17</sup> NDC accounts before retirement are typically not inheritable and the assets of the early deceased are distributed to the insurance pool of the survivors. This creates distortions in the presence of mortality differentials between ages 20 to 65 as well as after age 65. These (minor) distortions are ignored in the following discussion.

individuals in their decision making. As life expectancy at retirement continuously increases (for most but not all socioeconomic groups), individuals will receive a lower benefit at any given retirement age, which is expected to incentivize them to postpone retirement to smooth their lifetime consumption. This is the case when life expectancy is assumed to be homogenous. However, if individuals realize that the initial benefit is calculated by applying an average cohort life expectancy, even though they have a better assessment of their own longevity, their retirement decision risks being different. Both the poor and the rich have an incentive to retire as soon as possible – i.e., shortly after the minimum retirement age fixed by all NDC countries – as the poor cannot expect to live so long, and the rich can maximize their subsidy.

Last, a critical rationale for NDC schemes' reform is the transparency of their redistributive processes, as alluded to above. With stark heterogeneity, the envisaged distributive neutrality under NDC does not hold and redistributive interventions such as matching contributions or guaranteed income top-ups may be miscalculated. This calls for a clear understanding of the magnitude of heterogeneity and the design alternatives to address it, and a full understanding of how external redistributive interventions will affect individuals with life expectancies that deviate from the applied common average.

### **3. A formal framework to present alternative NDC designs**

This section presents five alternatives to the design of the pension paid at retirement, either by modifying the annuity rate or the contribution rate. The government can intervene either at retirement or during accumulation. Three designs are analyzed that deliver a tax or subsidy of zero when life expectancy is known with certainty. However, in practice, individual-specific improvements and aggregate mortality risk raise the need to perform approximations, as presented in Designs 3, 4, and 5.

Design 1 considers individualized annuities. Design 2 individualizes the contribution rate during the accumulation phase instead of paying individualized annuities. As an approximation, Design 3 splits the total contribution rate  $tc$  to accrue both a social and individualized pension. The contribution split suggested in Design 3 works very well only as

long as the relationship between life expectancy and lifetime income is broadly linear (in percentile or log income) across the whole income strata, so Designs 4 and 5 address heterogeneity when this is not the case. Design 4 deals with the upper tail of the established longevity–income link and explores the extent to which caps on contributions paid into the individual account but not on contributions levied on income/wages can address deviations for the highest income group. Design 5 explores the extent to which individualized contribution rates that build on the two-tier design structure are needed to address deviations for the lowest income group.

### 3.1. Design alternative 1: Individualized annuities

The most effective way to reduce the distortionary effects of heterogenous mortality – as defined in equations (4) and (5) – is to pay pensions that depend on the individualized mortality experience instead of using the average mortality rate. If everyone pays the contribution rate  $tc$ , the tax or subsidy is reduced to zero:

$$t^k = \frac{\frac{AK^k(tc)}{LE^k} LE^k}{AK^k(tc)} - 1 = 0 \quad (6)$$

### 3.2. Design alternative 2: Individual contribution rates – Versions a and b

An individual approach during the accumulation stage can be achieved in two ways. The first one considers that everyone pays the same rate  $tc$  whereas the contribution allocated into the individual notional account is adjusted by differences in life expectancy. A second approach consists of allocating the average notional contribution rate while collecting an individualized contribution rate  $tc^k$  that is adjusted for heterogeneity. Both approaches lead to a zero tax/subsidy component but to different allocations/benefit levels at equal retirement age that may lead to different retirement incentives.

In version 2a, participants pay  $tc \cdot y^k$  but are credited  $tc \cdot y^k \frac{LE^a}{LE^k}$  to ensure actuarial fairness. The accumulated capital then becomes  $AK^k(tc) = tc \frac{LE^a}{LE^k} Y_{x_r}^k$ . Indeed, individuals who live longer than average are credited a lower amount than they have contributed to

correct for the additional years during retirement. This adjustment also increases the replacement rate for those with a lower life expectancy, facilitating their early withdrawal from the labor force. Upon retirement, the pension is calculated based on the average life table. In this case, the realized liability corresponds to the one present in the books and the tax or subsidy becomes zero:

$$t^k = \frac{tc \cdot \frac{LE^a}{LE^k} Y_{x_r}^k}{tc \cdot Y_{x_r}^k} LE^k - 1 = 0. \quad (7)$$

Alternatively, in version 2b, participants pay the individual contribution rate  $tc^k = tc \cdot \frac{LE^k}{LE^a}$ , which is related to their life expectancy. If they live longer (shorter) than average they pay more (less) into the pension system. However, they are credited an amount corresponding to the average contribution rate  $tc$ . Their accumulated capital at retirement therefore coincides with the expression (1) presented earlier and the replacement rate is equal across the different categories. If the pension is calculated with the average life table, the tax or subsidy becomes zero:

$$t^k = \frac{tc \cdot Y_{x_r}^k}{tc \cdot \frac{LE^k}{LE^a} Y_{x_r}^k} LE^k - 1 = 0. \quad (8)$$

### 3.3. Design alternative 3: Two-tier contribution schemes with flat and individualized contribution rates – Versions a and b

This alternative works at the accumulation stage and assumes that pensions paid during retirement are based on the average annuity. To reduce the distortions, individuals pay a total contribution rate  $tc$  equal to the one in Design 1. However, the contribution rate is further split between a social contribution  $sc$  and an individual contribution  $nc$ . The rights of the individual depend on the two-tier split: the social contribution  $sc$  accrues rights on the median salary  $y^a$ , whereas the individual contribution  $nc$  accrues pension rights on the individualized contribution base  $y^k$ . The accumulated capital at retirement is then given as follows:

$$\begin{aligned}
AK^k(sc, nc) &= \sum_{j=0}^{x_r-x_0-1} (sc \cdot y_{x_0+j}^a + nc \cdot y_{x_0+j}^k) \cdot (1+i)^{x_r-x_0-j} \\
&= sc \cdot Y_{x_r}^a + nc \cdot Y_{x_r}^k
\end{aligned} \tag{9}$$

The two-tier allocation can be rewritten to highlight the redistribution as follows:

$$sc \cdot y_{x_0+j}^a + nc \cdot y_{x_0+j}^k = tc \cdot y_{x_0+j}^k + sc \cdot (y_{x_0+j}^a - y_{x_0+j}^k)$$

An individual earning less than  $y_{x_0+j}^a$  receives an additional pension right equal to  $sc \cdot (y_{x_0+j}^a - y_{x_0+j}^k)$ , whereas someone earning more than the reference level sees her accrued rights decrease by  $sc \cdot (y_{x_0+j}^a - y_{x_0+j}^k)$ . The split between the social and individual contributions needs to be made at a cohort level to jointly reduce the distortions due to the differences in life expectancy. A way to achieve this goal is to minimize on a cohort basis the squared difference between the pension  $P_{x_r}^k(tc)$  from Design 1 based on the unique contribution rate  $tc$  and an individualized annuity, denoted as  $P_1^k$  for an individual  $k$ , and the pension  $P_{x_r}^a(sc, nc)$  based on the split contribution rate and the average annuity, denoted as  $P_2^k$  for simplicity (Design version 3a):

$$\min \sum_{k \in I} (P_1^k - P_2^k)^2 = \min \sum_{k \in I} \left( tc \cdot \frac{Y_{x_r}^k}{LE^k} - sc \cdot \frac{Y_{x_r}^a}{LE^a} - (tc - sc) \frac{Y_{x_r}^k}{LE^a} \right)^2 \tag{10}$$

It can be shown that the optimal social contribution  $sc^*$  is then equal to:

$$sc^* = tc \cdot \frac{\sum_{k \in I} \frac{Y_{x_r}^k}{LE^k} (LE^k - LE^a) (Y_{x_r}^k - Y_{x_r}^a)}{\sum_{k \in I} (Y_{x_r}^k - Y_{x_r}^a)^2} \tag{11}$$

In this case the tax rate (4) is:

$$\begin{aligned}
t^k &= \frac{\frac{AK^k(sc, nc)}{LE^a} LE^k}{AK^k(tc)} - 1 = \frac{sc \cdot Y_{x_r}^a + nc \cdot Y_{x_r}^k}{(sc + nc) \cdot Y_{x_r}^k} \frac{LE^k}{LE^a} - 1 \\
&= \left( 1 + \frac{sc}{tc} \left( \frac{Y_{x_r}^a}{Y_{x_r}^k} - 1 \right) \right) \frac{LE^k}{LE^a} - 1
\end{aligned} \tag{12}$$

If  $Y_{x_r}^k > Y_{x_r}^a$  and  $LE^k > LE^a$ , then it is unclear whether a tax or subsidy arises, since the first part of equation (12) would be less than 1 and the life expectancy ratio would be greater than 1.

Alternatively, in version 3b, the difference in replacement rates is minimized instead, yielding:

$$\min \sum_{k \in I} \left( \frac{P_1^k}{y_{x_r-1}^k} - \frac{P_2^k}{y_{x_r-1}^k} \right)^2 \quad (13)$$

The optimal social contribution  $sc^*$  is then equal to:

$$sc^* = tc \cdot \frac{\sum_{k \in I} \frac{Y_{x_r}^k}{LE^k} (LE^k - LE^a) \left( \frac{Y_{x_r}^k - Y_{x_r}^a}{(y_{x_r-1}^k)^2} \right)}{\sum_{k \in I} \left( \frac{Y_{x_r}^k - Y_{x_r}^a}{y_{x_r-1}^k} \right)^2} \quad (14)$$

In this case the mathematical expression of the tax rate (4) coincides with the one presented in equation (12). However, it will differ in its magnitude as the split between the total contribution in a social and individual contribution will differ.

A tax or subsidy rate of zero can be achieved by either individualizing the annuity or the contribution rate. However, as an approximation, implementing a two-tier contribution scheme can help reduce the distributionary effects of current typical NDCs. If the contribution rate  $tc$  is split into (i) a social contribution rate  $sc$  accruing rights on the median salary, and (ii) an individual contribution rate  $nc$  accruing rights on the individual salary, then the tax or subsidy rate can be reduced.

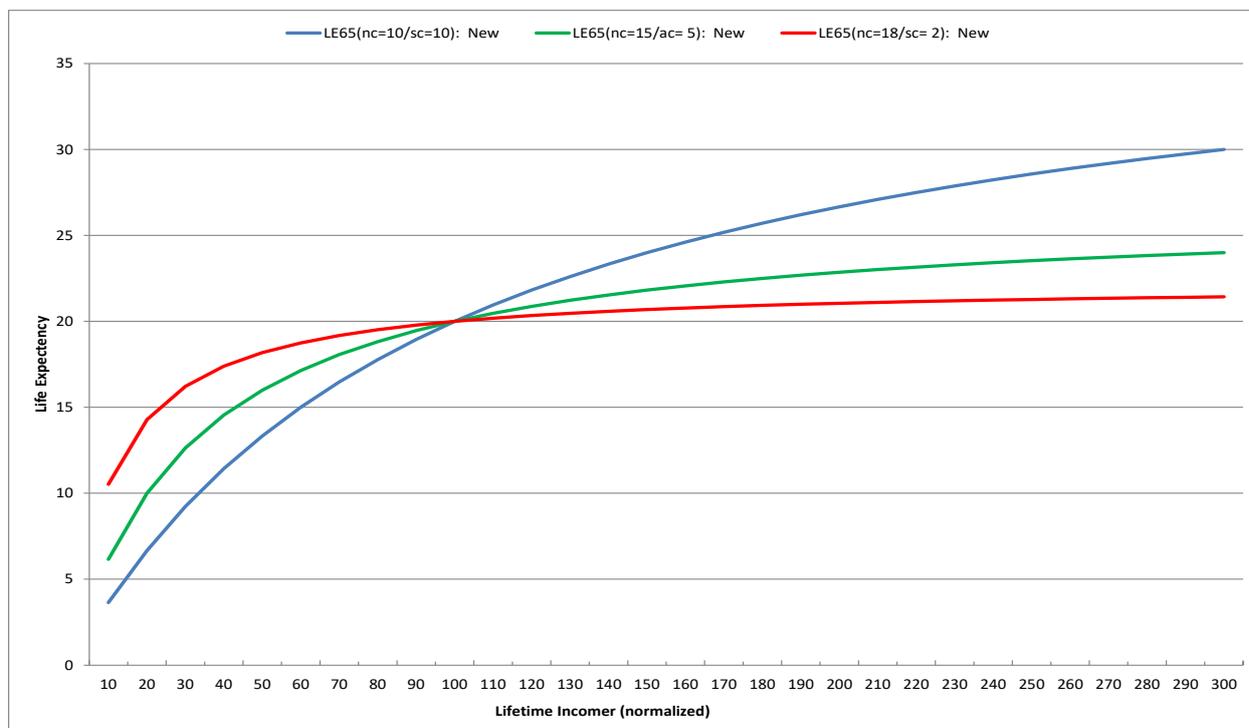
Setting the tax rate in equation (12) to zero derives a link between individual life expectancy as a function of average life expectancy and the relationship between individual and median lifetime income. The closer the empirical link to this functional relationship, the lower the tax/subsidy would be.

$$LE^k = LE^a \left( \frac{tc \cdot Y^k}{tc \cdot Y^a + nc(Y^k - Y^a)} \right) \quad (15)$$

Figure 3.1 presents the implied relationship between life expectancy and lifetime income for three pairs of individual and social contribution rates. The higher the social contribution rate relative to the individual rate, the more Design 2 is able to compensate for the higher heterogeneity of longevity that is linked to lifetime income inequality.

The concave curvature of this relationship is consistent with empirical observations (discussed in section 2).<sup>18</sup>

**Figure 3.1: Actuarial fairness under heterogeneous life expectancy in a two-tier contribution scheme for alternative contribution rate splits**



Source: Authors, based on equation (15) with E&Ws' average life expectancy 20.88 and average lifetime income of GBP 1,183,902.

### 3.4. Design alternative 4: Two-tier contribution scheme (Design alternative 2a) with caps on the contributions

This alternative seeks to complement Design 2a with the two-tier contribution system when the relationship between lifetime income percentile and life expectancy is not concave in the upper tail (as highlighted with US data in Figure 2.1a): In this case the highest income group gains overproportionally in life expectancy to all other groups and the effect cannot be

<sup>18</sup> In Ayuso, Bravo, and Holzmann (2017b) a linear relationship between individual life expectancy and lifetime income position is explored. It is derived by equating the tax/subsidy rate under current design for heterogeneous life expectancy with the subsidy/tax rate of a two-tier approach under homogeneous life expectancy.

corrected by the two-tier scheme alone. As before, the total contribution rate is split into a social contribution  $sc$  and an individual contribution  $nc$ . However, the individual and social contribution base is capped for accumulation purposes. In this case, the accumulated capital at retirement  $CAK^k(sc, nc)$  is:

$$CAK^k(sc, nc) = \sum_{j=0}^{x_r-x_0-1} \left( sc \cdot y_{x_0+j}^a + nc \cdot (y_{x_0+j}^k + (Cap - y_{x_0+j}^k)1_{y^k > Cap}) \right) \quad (16)$$

$$\cdot (1+i)^{x_r-x_0-j} = sc \cdot Y_{x_r}^a + nc \cdot CY_{x_r}^k.$$

This expression indicates that accumulated capital at retirement consists of the following two parts: the social contribution  $sc$  applied to the accumulated average wage  $Y_{x_r}^a$ , plus the individual contribution rate  $nc$  applied to the accumulated capped individual wage  $CY_{x_r}^k$ . If the individual earns more than the cap, the contribution allocated to the individual account remains constant at the cap level.

In this case, the tax is given as follows:

$$t^k = \frac{\frac{AK^k(sc, nc)}{LE^a} LE^k}{AK^k(tc)} - 1 = \frac{sc \cdot Y_{x_r}^a + nc \cdot CY_{x_r}^k}{(sc + nc) \cdot Y_{x_r}^k} \frac{LE^k}{LE^a} - 1 \quad (17)$$

The cap varies substantially across countries, ranging from median income (thus fully covering only 50 percent of the insured) to a multiple of the average income (thus fully covering 90 or even 95 percent of the population). The scope of coverage below the ceiling often has historical reasons and is codetermined by the role of supplementary pensions for those above the ceiling. Historically, the cap did not take account of heterogeneity. However, differences in longevity could inform the selection of the ceiling. If those in the upper 5<sup>th</sup> or 10<sup>th</sup> percentile deviate upwards in their life expectancy from an empirically established concave pattern for the large majority of the population, then such a ceiling selection under a Design 4 approach would make sense. How well the Design 4 approach is able to correct for such a deviation needs to be investigated in a country setting.

### 3.5. Design alternative 5: Two-tier contribution scheme (Design alternative 3a) with individualized contribution rates

Design 5 blends Design alternative 3a – i.e., a two-tier contribution rate structure – with Design alternative 2b – i.e., an individualized total contribution rate. The individual pays an individual contribution rate  $tc^k$  but credits the total contribution rate under a social and individual contribution rate split. The individual contribution rate  $tc^k$  is a proportion  $\alpha$  of the total contribution rate  $tc$  calculated such that the contributions made result in actuarially fair benefits. Upon retirement, the accumulated capital is transformed into a pension with the average life table. The tax is then given as:

$$t^k = \frac{sc \cdot Y_{x_r}^a + nc \cdot Y_{x_r}^k LE^k}{(sc + nc) \cdot \alpha \cdot Y_{x_r}^k LE^a} - 1$$

It follows from the expression above that the proportion  $\alpha$  that adjusts the total contribution rate needs to be chosen as:

$$\alpha = \frac{sc \cdot Y_{x_r}^a + nc \cdot Y_{x_r}^k LE^k}{(sc + nc) \cdot Y_{x_r}^k LE^a} \quad (18)$$

to achieve a zero tax or subsidy, that is, an actuarially fair pension scheme ( $t^k = 0$ ). Consistent with Design 3, it is not straightforward to determine whether the correction to the contribution rate  $\alpha$  will be higher or lower than 1, increasing or decreasing the contribution rate accordingly.

A second and more operationally oriented Design alternative 5b could seek to complement the two-tier Design 3 for the lowest tail of the income distribution.

As Figure 2.1 and Figure 2.2 for the US and E&W suggest, the lowest 5 percent of the population's estimated life expectancy seems below even that of the established concave curvature of a two-tier approach. If this were the case for the most marginalized insured, compensation through the social contribution share would not be sufficient to establish broadly actuarial neutrality.

#### 4. Empirical application and exploration

This section offers some empirical evidence regarding the effectiveness of the key policy options in reducing the effects of heterogeneity. To compare among policy options, a total tax measure is applied to aggregate the individual tax/subsidy rates across the available percentile data of lifetime income and the related period life expectancies at age 65. For this aggregate average measure, the absolute values are used so that tax and subsidy rates are added up across the full income spectrum at retirement; both taxes and subsidies are an indication of fairness distortions. This Total Absolute Tax Subsidy Indicator (TATSI), defined as the averaged sum of the absolute values of the individual tax and subsidy rates, is fully comparable across all policy options.

Two policy options are explored: individualized annuities and the two-tier contribution scheme. Both appear empirically, politically, and operationally feasible. The individual contribution Design 2 that would be applied during the accumulation phase is left out, as it raises a number of operational and policy issues. For data and space reasons, the alternatives that deal with the tails of the distribution are also omitted. When presenting Designs 1 and 3, the current situation, denoted Design alternative 0, is the benchmark.

##### 4.1. Design alternative 0: Almost status quo

Starting with the results of TATSI for Design alternative 0 – the benchmark – two rate estimations are explored: the rate for pooled life expectancy and the rate when life expectancies between men and women are separated; i.e., the individual tax/subsidy rate is calculated based on gender-specific average life expectancy. Table 4.1 summarizes the results.<sup>19</sup> In separate pools the average taxes match the average subsidies that make the nominal tax rates zero<sup>20</sup>; in joint pools men pay taxes that are subsidies to women (first row).

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<sup>19</sup> For the following estimations, the observed data used are the smoothed mortality data for both E&W and the US. Using the raw data would not make any difference in scope and conclusions.

<sup>20</sup> Despite individual tax and subsidies, on average the tax is equal to zero because of the assumption of the annuity equal to the average life expectancy, which is calculated based on the individual experience across the whole income spectrum.

Calculating the average taxes and subsidies in absolute terms reveals the distortions in both joint and separate pools (second row). Aggregating the nominal taxes and subsidies across genders gives a tax rate of zero (third row) but not when absolute values are aggregated (fourth and last row), which is the average of the results in the second row.

**Table 4.1: Design alternative 0 – Aggregate tax/subsidy rate indicators for E&W and the US**

	E&W				US			
	Joint pool		Separate pools		Joint pool		Separate pools	
	Women	Men	Women	Men	Women	Men	Women	Men
Nominal tax/subsidy rate	6.02%	-6.02%	0.00%	0.00%	7.05%	-7.05%	0.00%	0.00%
Absolute tax/subsidy rate	7.34%	6.48%	4.28%	5.00%	8.02%	9.16%	4.73%	8.31%
	<b>Total</b>		<b>Total</b>		<b>Total</b>		<b>Total</b>	
Nominal tax/subsidy rate	0.00%		0.00%		0.00%		0.00%	
TATSI	6.91%		4.64%		8.59%		6.52%	

Note: TATSI =Total Absolute Tax/Subsidy Indicator.

Table 4.1 indicates for E&W a TATSI of 6.91 percent for the traditional joint pool of both genders. The gender-specific tax/subsidy rates differ slightly between women and men, being higher for men as the difference between the highest tax and subsidy is larger. Applying separate pools reduces the gender-specific absolute rate significantly for women, but little for men. The TATSI value for E&W is reduced to 4.64 percent, or by one-third. The results for the US are similar in the direction of change but with altogether higher values. The joint pool value of 8.59 percent is reduced through separate pooling to 6.52 percent, or almost by one-quarter. These results suggest that risk pool separation could be a critical ingredient for the reduction of TATSI in countries, but it is not sufficient.<sup>21</sup>

#### 4.2. Design alternative 1: Individualized annuities

In many existing annuity markets, annuity rates are derived using age and gender as the only rating factors, ignoring any socioeconomic variation in mortality. However, in more advanced

<sup>21</sup> For European Union countries, separate pooling for pricing and benefit design was barred as discriminatory by the European Court of Justice as of December 2012 (Court of Justice of the European Union 2011).

markets such as the United Kingdom, the importance of considering differential mortality for the valuation of pension liabilities and the pricing of annuities has been recognized. Lifestyle and socioeconomic mortality profiling is common in the UK bulk annuity market and is increasingly being used in the pricing of individual annuity products and in the valuation of pension portfolio liabilities (Richards 2008; Ridsdale and Gallop 2010; Gatzert and Klotzki 2016). Variables used by insurers and pension providers in estimating an individual's mortality include postcode, salary, pension, smoking status, and occupation. As illustrated in Madrigal et al. (2011) and Richards, Kaufhold, and Rosenbusch (2013), such variables are typically considered using generalized linear models or survival models applied to large and detailed datasets of historical individual mortality. Life expectancy per lifetime income over the years would lead to better estimate impacts of alternative pension designs over generations. Here it is hypothesized that public institutions running NDC schemes at a national level would be able to produce such data: estimates for lifetime income along the income distribution – e.g., for each percentile – and the corresponding estimated period or cohort life expectancy, and differentiated by gender. Estimations by the National Academies of Sciences, Engineering, and Medicine in the United States in 2015 offer a possible approach in addition to the datasets for the US and E&W applied above. The estimation of individual life expectancy for individuals within a percentile cohort may be enhanced by other socioeconomic characteristics such as education and geography if considerations of magnitudes and relevance suggest so.<sup>22</sup> A much simpler approach is followed here. It seeks to measure by how much TATSI is reduced compared to the starting position – Design alternative 0 – if the life expectancy of a percentile (compared to the untreated estimate) is estimated through a simple life expectancy–lifetime income relationship. Two specifications are explored:

Quadratic 
$$LE_k = a + b \cdot Y_k + c \cdot Y_k^2$$

Logarithmic 
$$LE_k = a + b \cdot \log Y_k$$

Figures 4.1a-c and Figure 4.2a-c illustrate the observed and approximated link between life expectancy and lifetime income – for joint and separated gender pools – for E&W and the US,

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<sup>22</sup> For references and recent use of area-level deprivation measures to quantify mortality inequalities for England see Dunnell et al. (2018) and Mayhew, Harper, and Villegas (2018).

respectively. As the figures clearly show, the individualization of annuities works broadly well when the gender pools are disaggregated. The simple quadratic specification does a reasonable job of approximation for E&W, as does the logarithmic specification for the US.

**Figures 4.1a-c: E&W** **Figures 4.2a-c: US**  
**Observed and approximated life expectancies – individualized annuities**

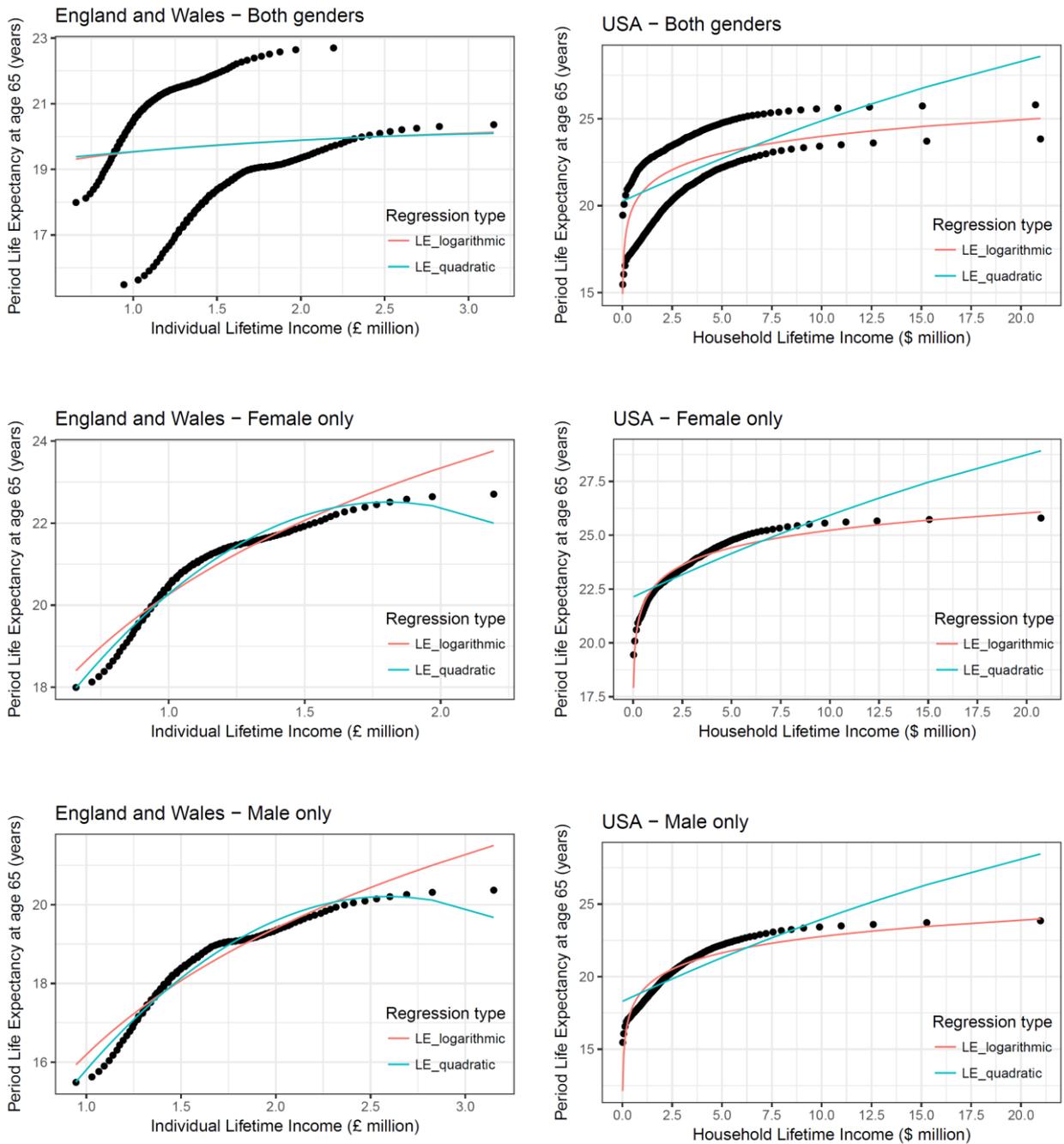


Table 4.2 presents the data behind Figure 4.3 and Figure 4.4. The mere approximation of individual life expectancy in the joint pool brings a moderate reduction in TATSI for the US and a slight deterioration for E&W. However, when the pools are separated by gender, even simple individualization of annuities leads to a reduction in TATSI in the US compared to the gender-separated value in Table 4.1, from 6.52 to 4.12; the reduction is even stronger in E&W, from 4.64 to 0.95 (i.e., by about 80 percent). Note that as opposed to Table 4.1, where the nominal tax/subsidy rate is exactly 0 percent, in Table 4.2 the nominal tax/subsidy rate is not exactly 0 percent. This results from a negligible approximation (model) error induced by the regression.

**Table 4.2: Individualized annuities – aggregate tax/subsidy rate indicators**

	E&W				US			
	Joint pool		Separate pools		Joint pool		Separate pools	
	Women	Men	Women	Men	Women	Men	Women	Men
Nominal tax/subsidy rate	6.47%	-6.47%	0.00%	0.00%	7.28%	-7.26%	0.00%	0.04%
Absolute tax/subsidy rate	7.44%	6.59%	0.88%	1.02%	7.36%	7.33%	1.09%	7.16%
	<b>Total</b>		<b>Total</b>		<b>Total</b>		<b>Total</b>	
Nominal tax/subsidy rate	0.00%		-0.01%		0.03%		-0.03%	
TATSI	7.01%		0.95%		7.34%		4.12%	
	Quadratic		Quadratic		Logarithmic		Logarithmic	

Note: TATSI = Total Absolute Tax/Subsidy Indicator.

### 4.3. Design alternative 3: A two-tier contribution scheme

The other promising approach to reduce the distortionary effects of heterogeneity in longevity in an NDC scheme is to introduce the two-tier contribution approach presented in section 3.

Carving out a social contribution rate  $sc$  under a total contribution rate of 20 percent (the assumed rate for the exploratory calculations) and linking this rate to the average, not the individual income/contribution base, offers this correction. It creates a tax for those with income above the average that counteracts the subsidy they receive from living longer than the average, and vice versa for those below the average.

Table 4.3 presents the estimated social contribution rate for alternative policy specifications as per equation (11).

Essentially one can calculate separate social contribution rates under common life expectancies, common social contribution rates under gender-separated life expectancies, and separate social contribution rates under gender-separated life expectancies.

The results indicate that the magnitude of the social contribution rate is moderate. It remains well under 4 percentage points out of 20 percent (i.e., a share of lower than one-fifth).

**Table 4.3: Social contribution rates for alternative specifications**

<b>E&amp;W</b>		<b>US</b>	
<b>Common life expectancy</b>			
sc population	0.58%	sc population	2.45%
sc women	1.15%	sc women	3.16%
sc men	0.34%	sc men	1.70%
<b>Separate gender life expectancies</b>			
sc population	3.21%	sc population	2.56%
sc women	2.58%	sc women	1.89%
sc men	3.42%	sc men	3.09%

Note: sc = social contribution.

Figure 4.3a-d present again the observed life expectancies for both E&W and the US, but this time with the approximated life expectancies implied by the two-tier scheme (as per equation (15)) and based on the estimated social contribution rates from Table 4.3.

The approximations presented differ by the choice of the social contribution rate (common across both genders (CSC) or gender-separated (GSC)); in all cases, life expectancies are separated by gender (GLE). T

he casual observation suggests that the approach works broadly well, particularly when the genders are separated.

**Figure 4.3a-d: Observed and approximated life expectancies – two-tier contribution scheme**

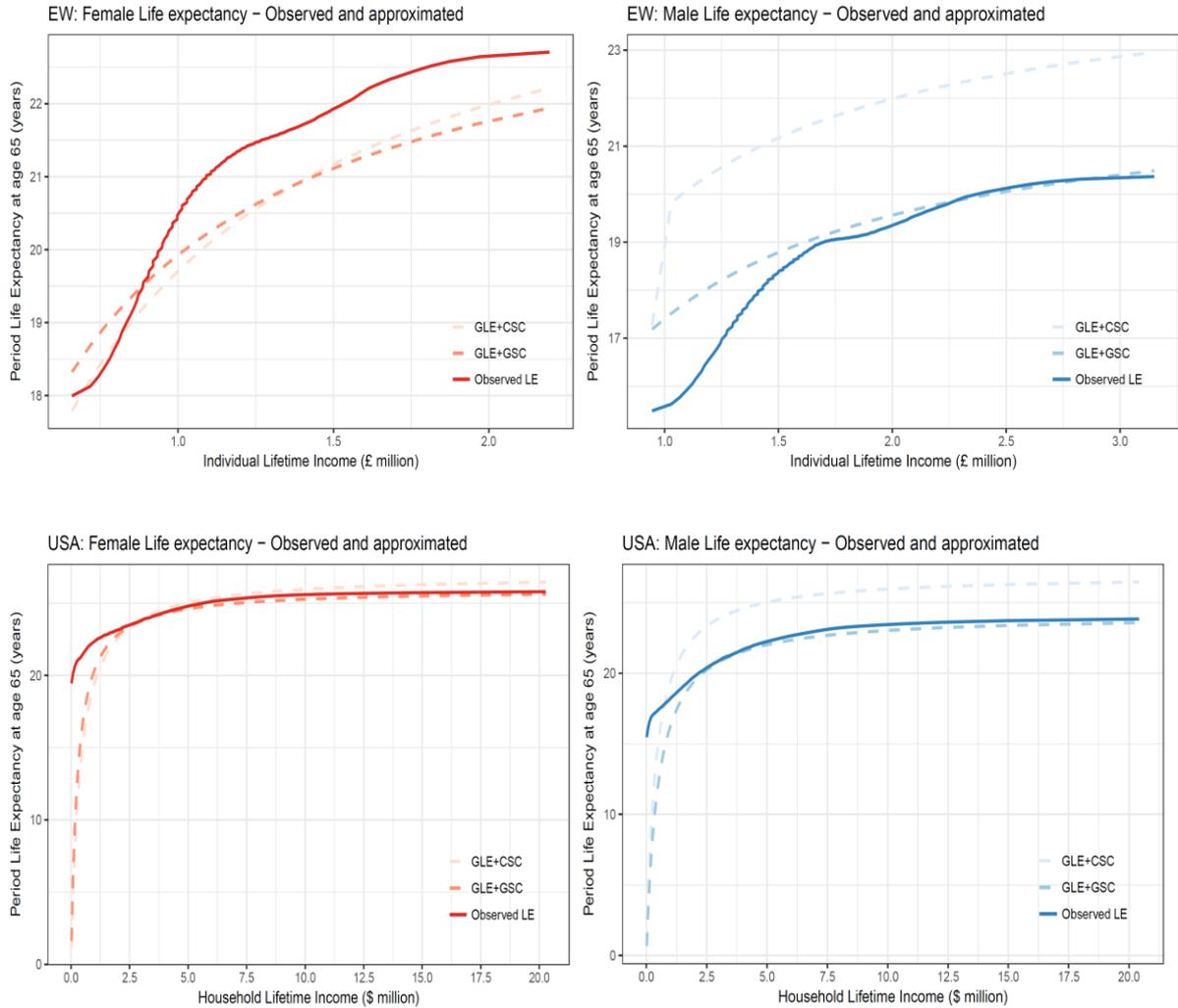
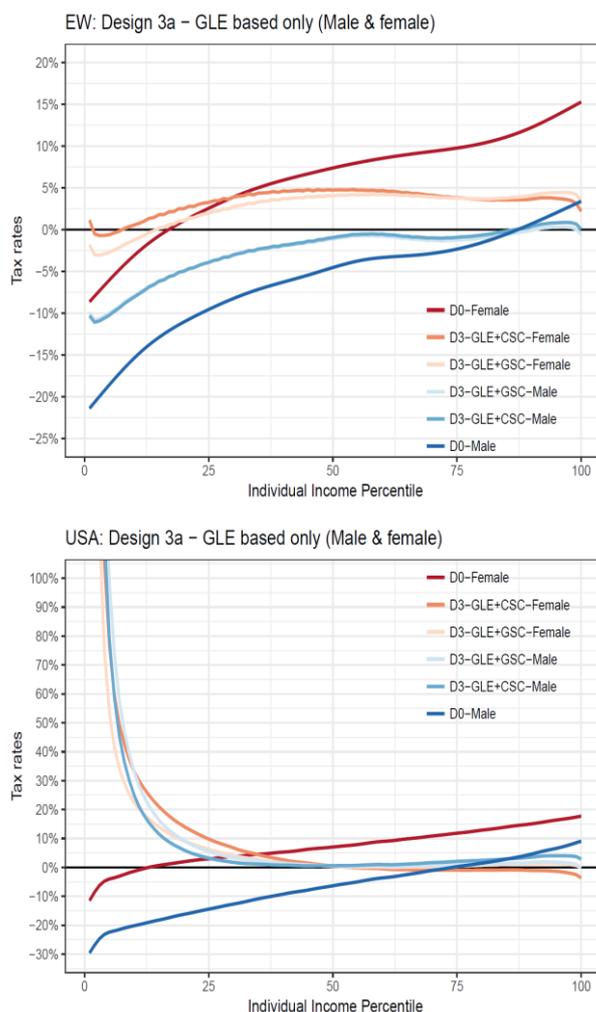


Figure 4.4a-b map the approximated life expectancies into the tax/subsidy space to see how well and for which percentiles the two-tier scheme succeeds in keeping TATSI close to the zero tax line. Here, proximity in the lines is not the issue, but how close the TATSI approximations are to the zero tax rate axis.

Table 4.4 translates the data for Figure 4.4 into the TATSI values.

**Figure 4.4a-b: Observed and approximated TATSI**



**Table 4.4: Two-tier contribution scheme – aggregate tax/subsidy rate indicators**

	E&W				US			
	Separate pool		Separate pool		Separate pool		Separate pool	
	Women	Men	Women	Men	Women	Men	Women	Men
Nominal tax/subsidy rate	3.41%	-2.52%	2.74%	-2.68%	27.15%	30.35%	20.04%	36.61%
Absolute tax/subsidy rate	3.47%	2.67%	3.23%	2.72%	28.07%	30.35%	20.04%	36.61%
	<b>Total</b>		<b>Total</b>		<b>Total</b>		<b>Total</b>	
Nominal tax/subsidy rate	0.89%		0.05%		57.49%		56.64%	
TATSI	3.07%		2.98%		29.21%		28.32%	
	Pooled sc		Separate sc		Pooled sc		Separate sc	

Note: TATSI = Total Absolute Tax/Subsidy Indicator; sc = social contribution.

The results in Table 4.4 signal that for E&W a two-tier scheme does a reasonable job in reducing TATSI values under Design alternative 0 – the starting value of Table 4.1. The TATSI value is more than one-half compared to that of joint pooling but only one-third compared to that of separate gender pooling. Hence, most of the reduction results from separate pooling. The lifetime income approximations via the two-tier scheme add some, but altogether moderate, further reductions.

This design alternative for E&W, however, is dominated by the option of gender-separated individualized annuities. Interestingly, little difference arises between pooled or separately calculated social contribution rates. Recall, however, that the lifetime income measure for E&W is based on small area measures of income and not individual income measures as in the US data: this might account for part of the difference in effectiveness of the two-tier scheme between the two countries.

The latter result also applies for the US, but TATSI increases to a multiple of the starting value and is well above that seen in the individualized annuity design alternative. Furthermore, in the US, the result for TATSI differs little between the joint and the separate gender pool. This outcome is due to the high subsidies the lowest 20<sup>th</sup> percentile receives under a two-tier contribution option – both men and women.

The lowest income decile in the US has both low income and low contribution density, which translates into these very high subsidy rates. For the other 80 percent of the insured, the tax/subsidy rate under a two-tier scheme is around +/-1 percent or less and thus almost perfect. Hence, for the US a two-tier NDC scheme could address three policy objectives with one instrument: a close contribution–benefit link for the vast majority of the population; elimination of the distortionary effects of heterogeneity in longevity for this population; and a major old-age income support for those in the lowest income percentiles.

The US actually already has a very progressive benefit structure that limits the replacement rate for individuals at the ceiling to about 36 percent, while offering a replacement rate of over 100 percent for the lowest income percentiles. The difference between both approaches will be explored in detail later.

## 5. Summary and next steps

Increasing international evidence shows that heterogeneity in longevity is high and relevant for policy outcomes. It is hypothesized that this negatively impacts pension schemes' performance, including recently reformed schemes that moved toward DC schemes to improve the contribution–benefit link. Heterogeneity in longevity risks undoing this link and, given the transparency of DC schemes on the link between initial benefit and average life expectancy at retirement, makes the resulting distortions even more relevant.

This paper moves the analytical and policy discussion forward, using two country datasets that are able to present the whole distribution space on the link between life expectancy and measures of lifetime income. These data for the US (provided by Chetty et al. 2016) and E&W (self-constructed from national data) allow analysis of the tails of the income distribution, where the distortions are highest. Building on the tax/subsidy conceptualization of heterogeneity in longevity, the distribution data over all lifetime income percentiles allow construction of aggregate measures of distortions. TATSI (Total Absolute Tax and Subsidy Indicator) can be applied to alternative policy designs to compare their capability to reduce the distortions. Alternative designs are modeled under a common framework and include: individualized annuities; individualized contribution rates/account allocations; a two-tier contribution structure with socialized and individual rate structure; and two supplementary approaches under the two-tier approach to deal with the distribution tails, and the distortions above a ceiling and below a floor.

This paper uses these new data to explore the two most promising design alternatives: individualized annuities and the two-tier contribution approach. Compared to the status quo, both design alternatives succeed in reducing tax distortions. This happens through the approximation of the observed individual life expectancy with estimated individual life expectancy, and perhaps more importantly by disaggregating life expectancy by gender when the calculations are made. Applying the two-tier contribution scheme in the US may improve efficiency and the redistributive outcome over the current progressive tax-benefit approach, but the relevant comparative analysis has not yet been done.

De-pooling life expectancy by gender reduces distortions/improves efficiency, but further increases the gap between men's and women's pension levels due to a not-yet-eliminated gender wage gap and continued reduced income prospects for women with children. This begs the question whether gender pooling is the best instrument to address the gender pension gap or whether it would be better addressed through: (i) direct labor market policies to reduce the wage gap; (ii) social policies to compensate for the contribution loss due to childbearing and rearing; and/or (iii) an annual contribution-splitting between partners to balance labor market outcomes. A direct approach may allow appropriate pension design to efficiently separate allocative and redistributive considerations. However, such arguments may only matter outside the European Union.<sup>23</sup>

The next steps for this research are to:

- Access or construct similar life expectancy/lifetime income data for other countries and improve on lifetime estimates, and the link to other heterogeneity characteristics, particularly education. This would improve the estimates and make them even more policy-relevant.
- Explore empirically the full set of policy alternatives developed and presented, and develop new ones. In particular, deeper investigation of the tails of the distribution is required.
- Empirically compare results across countries to better understand what may simply be a statistical issue or artifact, or whether issues exist that require policy interventions beyond heterogeneity.

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<sup>23</sup> In 2011, the Court of Justice of the European Union ruled out the possibility to use individuals' gender to assess their risk profile on discrimination grounds (Court of Justice of the European Union 2011).

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