Chapter 1

Responding to the challenges posed by population ageing and longevity risk

This chapter discusses the impact of population ageing and stresses how future improvements in mortality and life expectancy may affect pension systems. The chapter focuses thereafter on how to address the challenges faced by funded pension systems coming from the uncertainty around future improvements in mortality and life expectancy (i.e., longevity risk). It first describes the mortality tables commonly used by pension funds and annuity providers to value their liabilities, then assesses the amount of longevity risk that those mortality tables may implicitly have, and finally discusses policy options to address longevity risk.

The ageing of populations poses significant challenges for the economy in general and for pension systems in particular. This chapter first discusses population ageing by introducing past and future trends and examining the main contributing factors. Secondly, it briefly highlights the impact of population ageing on the broader economy and discusses its impact on pension systems. The discussion of the impact that population ageing has on pension systems focuses on both PAYG-financed defined benefit pensions (generally public) and funded pensions (generally private), which includes defined benefit (DB) and defined contribution (DC) pension plans. The analysis stresses two messages in particular for DB and DC pension plans. Firstly, people need to contribute and to contribute for long enough periods, ideally to keep the ratio of the number of years contributing to the number of years in retirement at a certain level. Secondly, policy makers need to address the problem posed by future improvements in mortality and life expectancy, especially for pension funds and annuity providers.

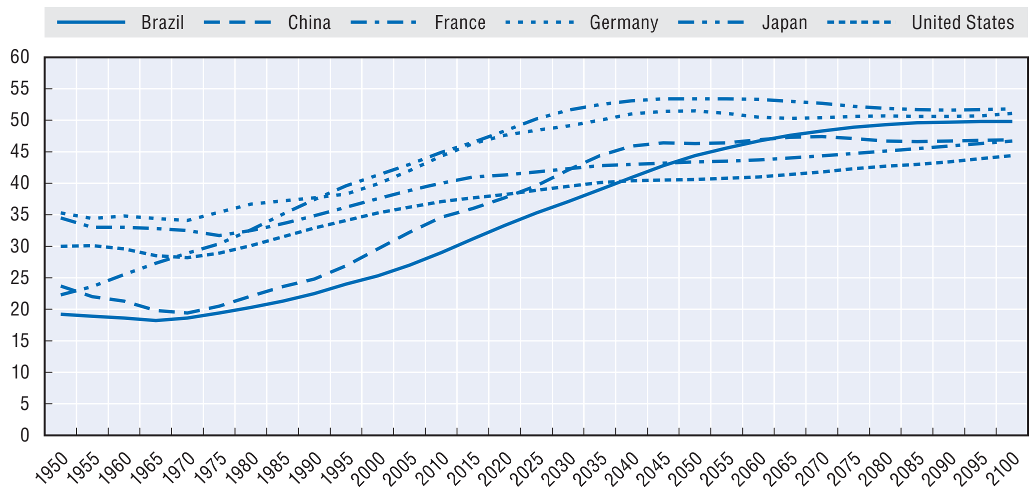
The chapter then focuses on longevity risk. Pension funds and annuity providers risk experiencing unexpected increases in their liabilities as a result of unanticipated improvements in mortality and life expectancy, and individuals run the risk of outliving their retirement savings. The OECD recommends in its Roadmap for the Good Design of Defined Contribution Pension Plans that people receiving most of their retirement income from DC pension plans may need to annuitize part of their assets accumulated to protect themselves from longevity risk.[1] Thereafter, Section 1.4 assesses the amount of longevity risk that pension funds and annuity providers may be exposed to by relying on at the standard mortality tables commonly used in different countries. Section 1.5 discusses options to manage longevity risk and some of the conditions that may be required in order to develop capital market solutions for hedging longevity risk.

1.1. Population ageing

Population ageing is generally defined as an increase in the median age of the population. Figure 1.1 below shows that the median age of the population in a selected number of OECD and non-OECD countries has increased more than 10-15 years since the 1950s, and is projected to continue increasing for several more decades.

This ageing of the population is driven partly by declines in fertility rates from the high levels following the post-WWII generations and partly from increases in life expectancy. These trends translate into fewer young people and an increasing number of older people, which has pushed up the median age. In most OECD countries fertility rates increased significantly in the first decades after WWII, but by the late 1960s or early 1970s had returned to previous or lower levels and have remained more or less constant since then (Figure 1.2). The post-war explosion in fertility is the so-called "baby boom", which resulted in a population cohort larger in size than the preceding and succeeding generations. In contrast to the pattern in OECD countries, fertility rates in developing countries have continued to fall over the last decades. Meanwhile mortality rates have continued to

Figure 1.1. **Increase in the median age of the population for selected countries, 1950-2100**



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2012 Revision.

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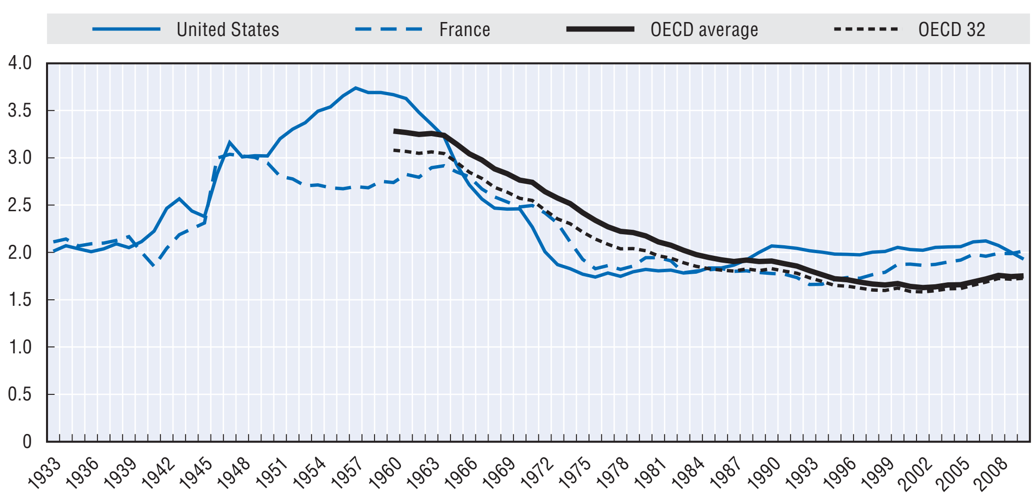
Figure 1.2. **Fertility rates fall and stabilize at lower levels in OECD countries**



Source: Human Fertility Database, INSEE and OECD Family database. OECD 32 is an OECD average excluding Mexico and Turkey.

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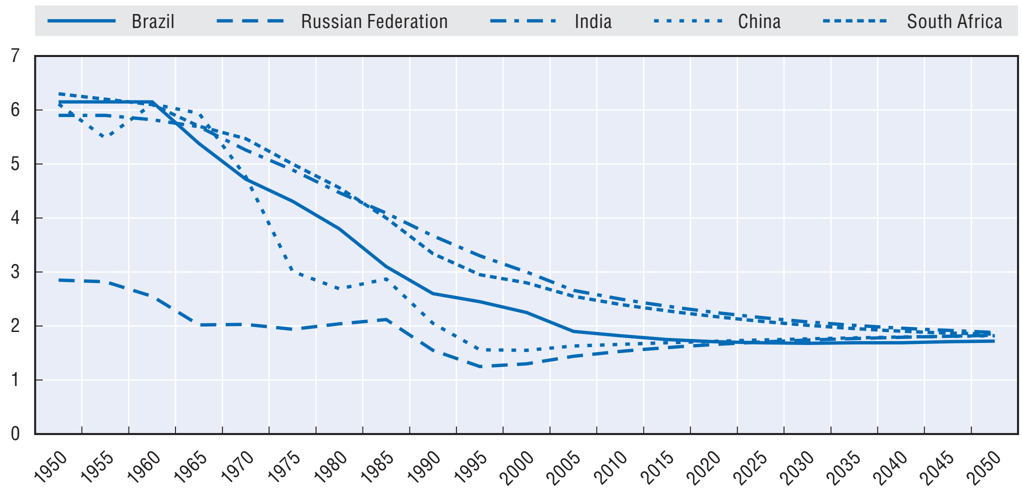
decline in OECD and non-OECD countries alike resulting in significant increases in life expectancy (Figure 1.4). Life expectancy at birth and at age 65 has increased on average by 2.2 years and 1 year per decade, respectively, since 1960 (Table 1.1).

As a result of population ageing, the old-age dependency ratio will increase markedly. Figure 1.5 shows that the number of people of working age per person aged 65 or above – the inverse of the old-age dependency ratio – will fall in OECD countries from an average of around four people of working age per retiree (around 9 for developing countries, Brazil and China) to somewhere between one and two persons of working age per retiree. As a

Figure 1.3. **Fertility rates in developing countries will continue to fall**



Note: Fertility rates and projections in the BRICS, 19950-2050 (Children per women).
Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2012 Revision.

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Table 1.1. **Average increase in life expectancy per decade over specified period in selected OECD countries**

(years per decade)

	1900-50	1950-2000	1950-2010	2000-10
		At birth		
France	4.1	2.5	2.5	2.4
Japan	..	4.4	4.0	2.1
Spain[1]	4.8	3.5	3.4	2.5
United Kingdom[2]	4.1	1.8	2.0	2.6
United States[3]	4.2	1.8	1.8	2.0
OECD average[4]	..	2.3	2.4	2.7
		At age 65		
France	0.5	1.1	1.2	1.7
Japan	..	1.5	1.6	1.6
Spain[1]	0.6	1.0	1.2	1.6
United Kingdom[2]	0.5	0.8	1.0	2.0
United States[3]	0.7	0.8	0.9	1.7
OECD average – Females[4]	..	1.0	1.2	1.7
OECD average – Males[4]	..	0.7	0.9	1.9

.. Means not available.
1. Data for the period 1900-50 refer in fact to the period 1908-50.
2. Data for the period 1900-50 refer in fact to the period 1922-50.
3. Data for the period 1900-50 refer in fact to the period 1933-50.
4. The OECD average life expectancy has been calculated for each year between 1960 and 2010 on the basis of the available data. The countries used in the calculation of the average may differ from one year to another, but only in the early decades. Data for the period 1950-2000 and 1950-2010 refer respectively to 1960-2000 and 1960-2010.

Source: Human Mortality Database.

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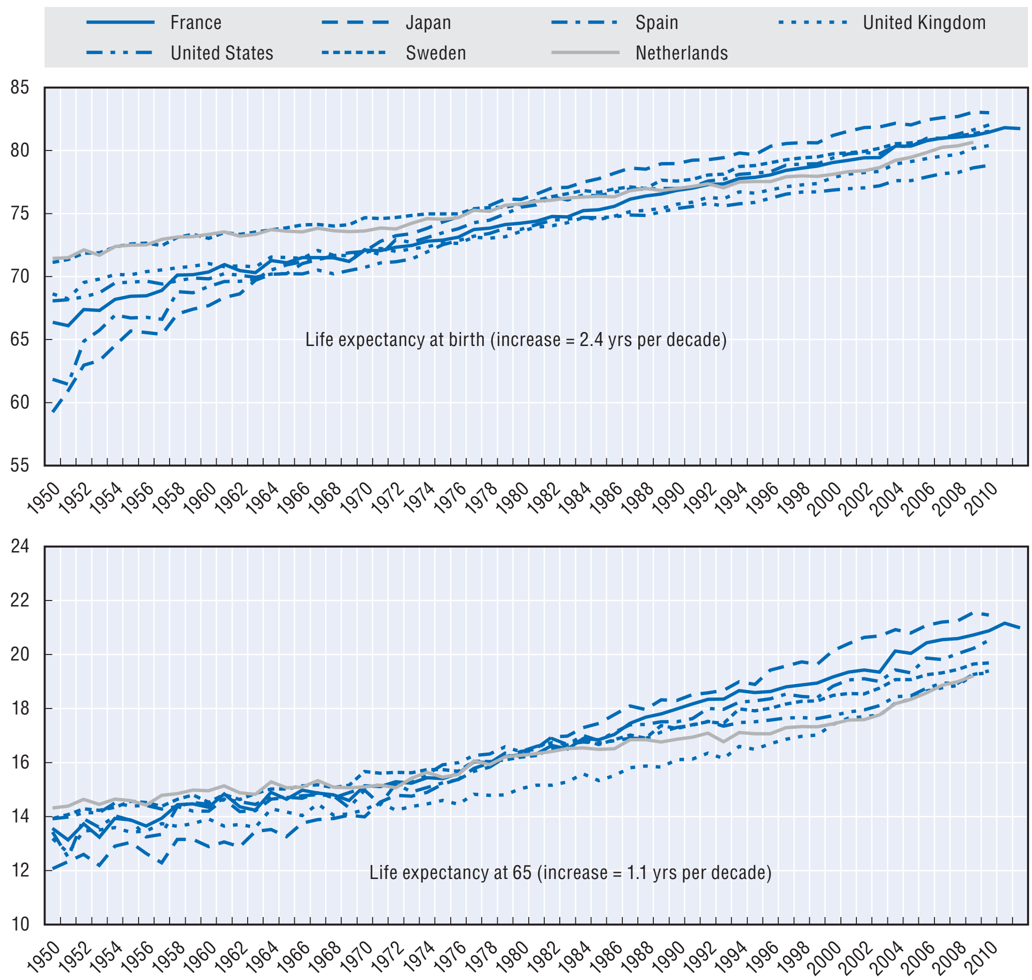
Figure 1.4. **Evolution of life expectancy at birth and at age 65 in selected OECD countries, 1950-2012**



Source: Human Mortality database.

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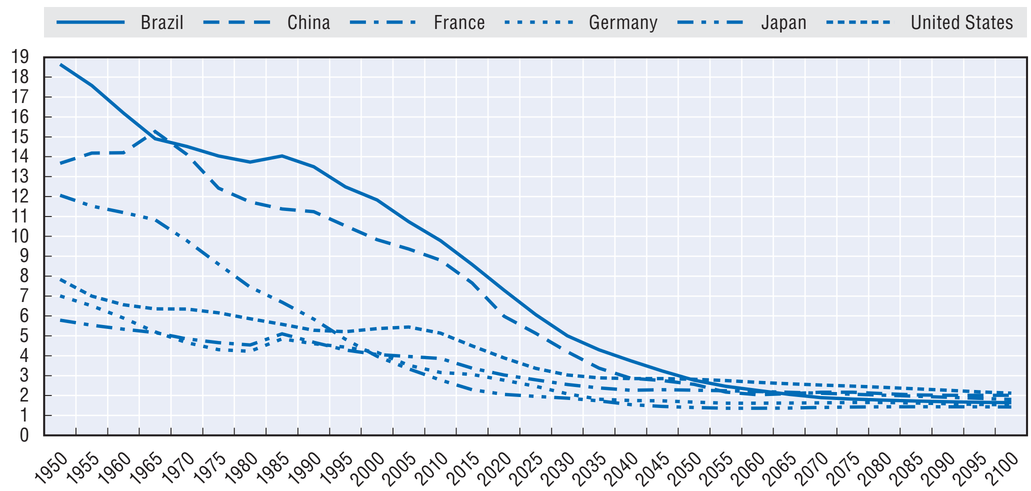
consequence, there will be fewer people in the workforce per retiree than today, which with all else equal will put tremendous pressure on economies in general and on pension systems in particular.

Increases in life expectancy are the main driving force behind population ageing, particularly in the long term. While the impact of the baby boom (the cohorts born when fertility rates were high) is a significant factor, its impact will be temporary as these cohorts pass away. In contrast, the increases in life expectancy are more permanent and are expected to continue. The ratio of people of working age relative to people aged 65 or above (Figure 1.5) is driven in the next 20 years by both the baby boom and improvements in life expectancy, and by improvements in life expectancy alone thereafter. Improvements in life expectancy will be the only driving force as long as fertility rates are constant (as it has been for the last several decades) and thus the cohorts entering the labour market will be the same size as the ones exiting into retirement.

Figure 1.5. **Proportion of the working age population compared to the population aged 65 or more in selected countries**



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2012 Revision.

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The implication of these observations is that the policies required to address population ageing differ depending on whether the focus is on the medium term – the baby boom cohort – or on the long term, on increasing life expectancy. In order to address the impact of increases in life expectancy for the long term, policies need to focus on making sure that people contribute sufficient amounts to savings by encouraging contributions, as well as ensuring that people save for long enough, for example by delaying the age at which they retire.

1.2. The impact of population ageing on the economy

Population ageing has several potentially important economic effects (Martins et al., 2005). One way in which ageing may have an impact on GDP is through its impact on productivity. A number of studies argue, for example, that productivity is expected to fall with age. As cognitive knowledge does likely fall with age, this argument has some intuitive appeal. However, some types of knowledge and skills increase over time with learning and experience, that is, they may increase with age, which runs counter to the argument of decreasing productivity. Unfortunately, using actual data of people in the labour market to assess whether productivity increases with age may be susceptible to self-selection bias, as potentially only people with the highest productivity remain in the workforce.

Population ageing could also have a negative impact on GDP growth to the extent that it leads to a smaller workforce. As the baby-boom cohorts retire and are replaced by smaller cohorts, the workforce will shrink. However, if fertility rates remain constant, the workforce will also remain constant once the baby-boom cohorts have exited the labour force, all else equal. Additionally, policies aiming at increasing participation rates – in particular among workers aged 55 and older – and policies that encourage later retirement would be expected to increase the effective retirement age, which may offset if not reverse the reduction of the size of the total workforce.[2]

There are, however, other ways in which population ageing could have a negative impact on GDP growth, for example through changes in savings patterns across generations. To the extent that retirees' saving rates remain lower than those of the working age population, overall savings will fall with population ageing. However, if working people over the age of 40 have higher saving rates than younger workers, the increase in the average age of the population may actually increase saving rates. Ultimately this is an empirical issue which depends on the structure of the population and the different saving rates across different population subgroups in each country.

Similarly, the effect of ageing on national savings would also affect total investment or its composition. Total investment might fall as a result of lower national savings, or it might remain constant, in which case borrowing from abroad would need to fill the gap.

Population ageing might also have an impact on financial markets. Effects which are often cited include the impact on portfolio strategies, asset prices, and the impact on annuity markets. As the population ages, and in the current context as the baby-boom generation enters retirement, there may be a tendency towards higher portfolio allocations to fixed-income securities. Life-cycle strategies or target date funds would serve to increase the relative share of fixed-income assets, which would likely have an impact on equity valuations. The asset meltdown hypothesis is an extreme case of this scenario whereby the drawdown of assets associated with the retirement of the baby-boom generation would result in a collapse of asset prices. However a more general equilibrium view taking into account behavioural adjustments suggests a much smaller reduction in asset prices (Martins et al., 2005). The third hypothesised effect arises from an increasing dependence on defined contribution (DC) pension plans to finance retirement, which along with increasing longevity, may prompt a surge in the demand for annuities to gain protection from longevity risk.

Population ageing will also affect public finances through pensions and healthcare. Public expenditures on healthcare are bound to increase sharply as the population ages, although this effect will be a combination of increased demand, since healthcare utilization increases with age, and rising prices, which some studies argue are one of the main drivers of the increase in healthcare expenditure (OECD, 2006). However the extent to which there is a compression or expansion of morbidity will affect the extent to which increasing life expectancy has an impact on healthcare costs. Most of the health care costs of old age occur in the years just prior to death as this period is associated with higher disability levels. If increasing life expectancy also translates into longer periods of disability, medical costs will increase. However in the scenario of the compression of morbidity, the period spent in disability will not increase and people will live longer, healthier lives. On the other hand, the increasing prevalence of age-related diseases such as Alzheimer's represents a large burden on healthcare finances.

With respect to pensions, increases in life expectancy and the retirement of the baby boomers will clearly increase the number of people with claims on GDP, especially if the effective retirement age remains unchanged. Pensions, whether PAYG-financed or funded through assets accumulated, are a claim on GDP. The European Union projects public expenditure on pensions to increase by 1.5 to 2 percentage points of GDP in the next 50 years.[3] However, the increase from one country to the next varies significantly. For instance, pension expenditure in the United States is expected to increase by 1.8 percentage points (pp) of GDP over the next 50 years, compared with 0.5 pp in France, 2.8 pp in Germany and 1.5 pp in the United Kingdom, even taking into account several factors which could offset the full impact of ageing populations such as increased labour force participation (European Commission, 2012). The next section discusses more in detail the impact of population ageing on pensions.

1.3. The impact of population ageing on pensions

The main impact of population ageing on pensions, in particular in the long-term, is through increases in life expectancy. The extent to which increasing longevity will impact pensions is driven by the changes in the relationship between what goes into and what comes out of the pension pot. The future value of savings is what it goes into the pension pot and it is determined by the level of contributions to pension savings, the contribution period and the rate of return on these contributions, whether guaranteed or subject to the investment return of the market. The present value of pension payments is what it comes out of the pension pot and it will primarily depend on the level of pension payments or pension promises, and the length of time which the payments will be made, which in turn depends on the age of retirement and is clearly impacted by increasing life expectancy. If the age of retirement remains constant, the relationship between these two variables will change with increasing life expectancy as the length of time which pensions are paid out increases as a proportion of the time spent saving for retirement. This situation will most likely result in insufficient assets and/or resources for financing retirement. In order to address this either higher contribution rates or longer periods of savings will be required.

The retirement of the baby-boom cohort will also have a significant impact on pensions. The large cohort of baby-boomers retiring from the workforce is being followed into the workforce by a much smaller generation, resulting in fewer active persons for every retired person. For PAYG-financed pensions, contributions will therefore not be able to cover all pension payments, and net pension expenses along with debt will also increase. Moreover, the retirement of the baby-boom generation may also have a negative impact on investment returns, as discussed above, thus reducing the future value of savings. Nevertheless, the impact of the baby boom is temporary, while the increases in life expectancy are expected to continue.

The impact of population ageing varies according to the type of pension arrangement as each arrangement involves different drivers for the calculation of the future value of savings and the present value of pension payments. For PAYG-financed public pensions, population ageing will create *sustainability* problems. To the extent that pension benefit promises are not in line with the expected increases in life expectancy, the present value of pension payments will be underestimated. Moreover, the retirement of the baby-boom generation will result in a decrease in the number of active employees making contributions to pay for these pensions and an increase in the number of people receiving pensions. A decrease in contributions, an increase in retirees and longer periods for which the payments have to be paid out will lead to a misalignment between current contributions and value of benefit payments. These drivers will translate into large increases in public pension expenditures that will strain public finances.

Public pension expenditure is projected to increase by 8 to 10 percentage points of GDP as a result of population ageing (Table 1.2). However, government policies on future coverage of public pensions, labour market participation and employment ratios along with the ratio of pension benefits to productivity are expected to largely offset the impact of population ageing on public pension expenditure (last three columns in Table 1.2). However, there are some important questions to consider regarding the real offsetting impact of these factors. Will governments manage to reduce coverage ratios by increasing the effective retirement age? Will employment ratios increase for older workers over the age of 55? Will average pension benefits increase at a lower rate than average productivity, particularly given the trend towards more women having full working careers?

Table 1.2. **Contributions of the main drivers to the projected increase in public pension expenditure from 2010 to 2060 for selected EU countries**

Country	Total	Dependency Ratio	Coverage	Employment	Benefit Ratio
France	0.7	9.1	-3.5	-1.2	-3.1
Germany	2.6	7.9	-1.8	-0.5	-2.2
Spain	3.6	9.7	-0.8	-2.2	-2.3
EU27	1.6	8.5	-2.9	-0.8	-2.7

Source: European Commission 2012 projections.

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The main risk from population ageing on defined benefit funded pension arrangements is on their *solvency*. As with public pensions, if pension promises are calculated based on a life expectancy which is underestimated, the present value of pension payments will also be underestimated and actual pension payments will be larger than expected. Therefore, DB pension funds may lack sufficient assets to cover their future liabilities, and consequently their funding ratios will fall below 100% as they will need to pay pension benefits for a longer period than planned for. With respect to the future value of savings, the retirement of the baby-boom generation will potentially have a negative impact on asset values coming from a shift in preferences and portfolio allocations towards less risky assets, resulting in falling investment returns. This will result in a lower future value of assets accumulated, which may not be sufficient to meet the promised pension benefit payments.

The main impact of population ageing on defined contribution pension arrangements will be on their *adequacy*. As long as there is no level of guaranteed pension income in retirement for DC plans, the future value of pension savings and the present value of pension benefits will be equal by definition, leaving only the question of whether this amount is adequate to maintain the desired standard of living in retirement. As discussed above, returns on investment may not be as high as expected as a result of the shift in asset preferences of the older generation and lower potential economic growth as a result of lower workforce growth. In addition, accumulated assets must fund longer retirement periods if people do not adjust their retirement age. Therefore people will have to save at a higher rate or for a longer period in order to accumulate sufficient assets to finance retirement.

Addressing the impact of population ageing on pensions

The OECD recommends diversifying the sources to finance retirement and encouraging complementary funded private pensions. Consequently, a pension system should be comprehensive and include a PAYG-financed component, whose size depends on political choices, as well as a funded component. The latter will include occupational as well as personal funded pension plans, normally run by private institutions.

The discussion in previous sections highlighted the impact of population ageing on the different types of pension arrangements. The main risks faced if current assumptions remain the same, particularly with respect to life expectancy, are sustainability for PAYG financed pensions, solvency for DB funded pensions and adequacy for DC plans.

Linking the age at which a person retires and begins collecting a pension, the retirement age, to changes in life expectancy would go a long way to addressing the problems posed by population ageing on PAYG-financed pensions (OECD, 2012). An alternative option could be to link the number of years contributing or saving for retirement to improvements in life expectancy (e.g. France). In this way people entering the labour market at different ages will be required to have the same saving effort in terms of years contributing. Moreover, it may also to some extent adjust for differences in life expectancy according to different socio-economic characteristics (Box 1.1).

Adjusting actuarial pension parameters regularly and automatically will also help in addressing sustainability and solvency problems. One of the main features of DC pension arrangements is that the link between contributions and pension benefits is direct and straightforward. Notional defined contribution arrangements (e.g., Italy, Poland, or Sweden) create a direct link between contributions and benefits in PAYG-financed public pensions. NDC arrangements allow for assessments of the impact of different actuarial parameters and adjust benefits and contribution periods accordingly.

For retirement pension plans in which pension benefits depend on assets accumulated, the approach to address the adequacy problem posed by population ageing is to contribute and contribute for long periods, combined with making sure that part of the assets accumulated are annuitized.[4] Any analysis of the impact of ageing on pension systems also needs to keep recent developments in mind, such as the increased prevalence of retirement pension plans in which benefits depend on assets accumulated (e.g. 401(k) plans in the United States and Riester plans in Germany), which have become in some countries the main source to finance retirement.

A direct approach to increase accumulated contributions and/or contribution periods is to postpone retirement. However, one needs to keep in mind that mortality rates and life expectancy are different across different socio-economic groups (Box 1.1). Additionally, in order to increase overall savings for retirement it is necessary to increase participation in funded pension systems. This could be achieved through improvements in the design of incentives, especially around matching contributions and auto-enrolment mechanisms, as in New Zealand and the United Kingdom (Chapter 4 and 6 OECD, 2012).

These types of pension plans, like DC plans, bring to the forefront the importance of designing the payout phase adequately in order to provide protection from longevity risk and allocate accumulated assets efficiently to make sure pension benefits are as adequate as possible. In this regard, there is a need to strike a balance between flexibility and liquidity on one side and protection from longevity risk on the other. Increases in life expectancy are uncertain by nature and, therefore, individuals whose main source of

Box 1.1. **Life expectancy across different socio-economic groups**

Life expectancy differs across various socio-economic groups of the population. Indeed, while populations of developed countries have been experiencing dramatic increases in life expectancy, as reported previously, numerous studies have demonstrated persistent and sometimes increasing differences in life expectancy across socio-economic groups (Adam, 2012, 2014; Blanpain and Chardon, 2011; ONS 2011; and Society of Actuaries 2000, 2014), with occupational classification commonly used as a proxy for socio-economic status. These studies have been carried out for Canada, France, United Kingdom and the United States by statistical institutes (France and the United Kingdom) and by the actuarial organisations (Canada and the United States). Statistical organisations in France and the United Kingdom have defined standardized occupational based socio-economic classes to be used in data collection and statistical exercises which have been used to analyse inequalities with respect to mortality.[1] In the United States, the Society of Actuaries has collected mortality data from public and private pension plans to develop mortality tables, for which they also distinguish between blue and white collar plans. In Canada, work commissioned by the Institute of Actuaries reported mortality data according to different income groups for pensioners.

The most recent difference in life expectancy at age 65 between the highest and lowest socio-economic groups shown in the figures below is 3.8 years in France, 2.6 years in England & Wales and 2.7 in the United States. Moreover, the difference has increased over the span of around two decades, by 1.2 years in France, 0.5 years in England & Wales, and 1.1 years in the United States.

Differences in life expectancy have implications for the ratio of years contributing to pensions to years spent in retirement. Given a certain number of years spent contributing, this ratio will be lower for people with higher life expectancy (e.g., blue collar, higher income, or people in higher occupation levels). According to the data on life expectancy across various socio-economic groups reported above, those in higher socio-economic groups will receive pension payments for longer periods than those in lower socio-economic groups assuming these two groups retire at the same age.

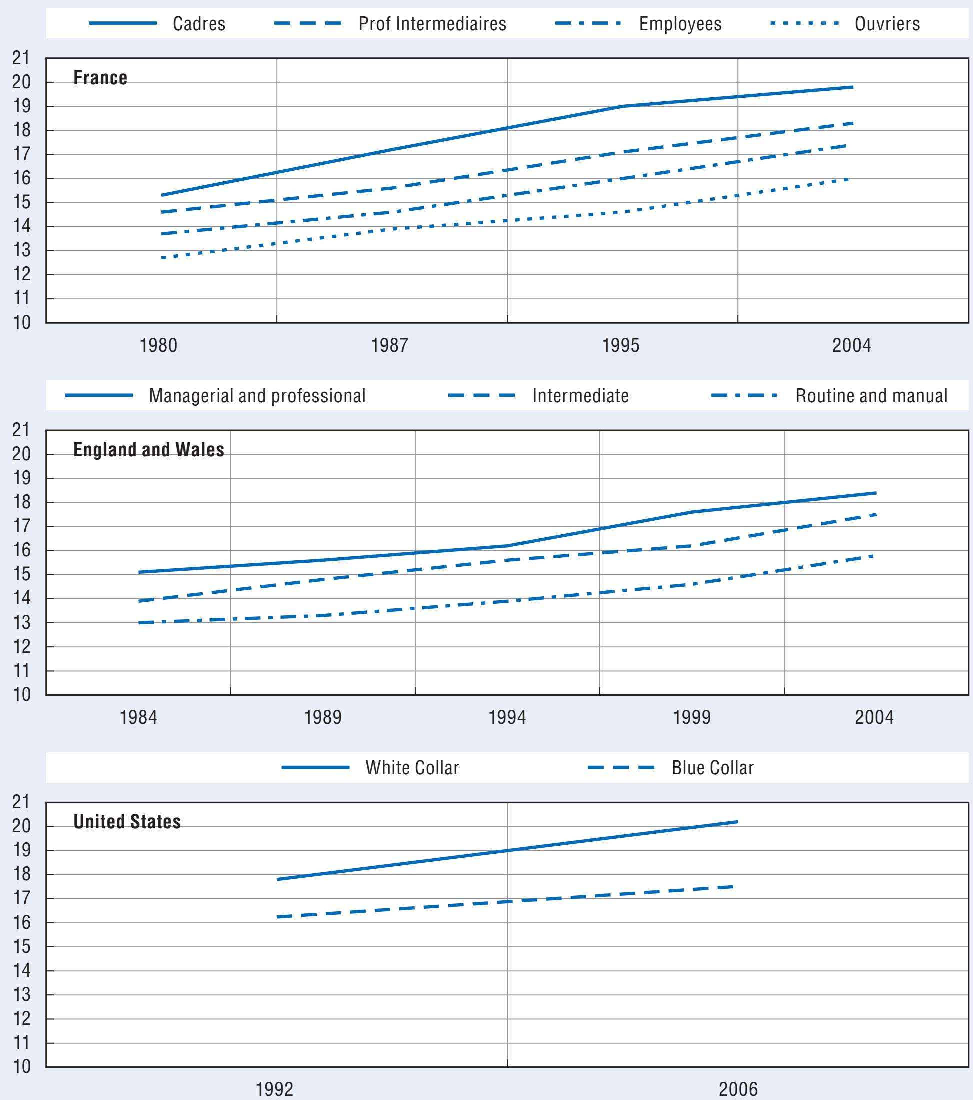
The age of entry into the labour market also has an impact on this ratio as it affects the number of years spent saving to finance retirement for a given retirement age. Differences across socio-economic groups with respect to the number of years spent contributing to pensions could exist to the extent that those in higher socio-economic groups may enter the labour market later than those in lower socio-economic groups as they may spend more years in education. This would imply that individuals in lower socio-economic groups spend a longer time contributing to pensions for a given retirement age, resulting in a higher ratio of years contributing to years in retirement as compared to an individual in a higher socio-economic group.

Furthermore, the disparity of this ratio across socio-economic groups could increase in the future to the extent that higher socio-economic groups also experience higher mortality improvements. The figure below clearly shows that white collar workers in the US have experienced a more rapid increase in life expectancy compared to the blue collar workers. The same is true for England & Wales and France. The Canadian studies on pensioners found significant differences in the mortality trend over the last 15 years for the highest income group, particularly for males aged 60-75, with differences surpassing even 1% of annual improvement for some age groups (Adam, 2012). If this type of pattern were to continue, the ratio of years contributing to years in retirement for higher socio-economic groups would decrease more than for lower socio-economic groups.

1. Socio-professional categories (CSP) in France and the National Statistics Socio-economic Classification (NS-SEC) in the United Kingdom.

Box 1.1. **Life expectancy across to different socio-economic groups** *(cont.)*

Evolution of male period life expectancy at age 65 across socio-economic groups[1]



1. Period life expectancy reflects the mortality of a given year and makes no assumption regarding future changes in mortality.

Source: Blanpain and Chardon, 2011; ONS, 2011; Society of Actuaries 2000, 2014.

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retirement income may come from these pension plans need to have some of their balances allocated to a life annuity that protects them from longevity risk. However, they also need flexibility and liquidity during the first years in retirement to be able to address any contingencies (e.g. pay down debts, health care). It is in this context that the OECD recommends to combine programmed withdrawals during the first years in retirement with a deferred life annuity that starts paying later in retirement, for example at age 80 (OECD, 2012).[5]

Support for partial annutization of the balances accumulated in DC pension plans brings the attention to annuity markets. Annuity markets face several challenges. On the demand side, there are problems of framing (annuity products are not investment products but insurance) and taxation that deter individuals from purchasing annuities. On the supply side, apart from adverse selection, the main problem facing annuity providers is how to manage longevity risk, in particular, when there are not sufficient or appropriate instruments to hedge longevity risk.

The remaining of the chapter focuses first on assessing the amount of longevity risk faced not only by providers of annuity products (e.g. insurance companies) but also by pension funds providing defined benefits. A discussion of options to manage longevity risk follows thereafter.

1.4. Mortality assumptions and longevity risk

Future improvements in mortality and life expectancy can pose serious problems for funded pension plans and annuity providers. Pension plans and annuity providers promise to pay retirees a certain level of future income and they need to set aside reserves or funds in order to meet their future payment obligations. The amount necessary is driven by two main factors: the return on the assets under management and how long the payments will be made. Analogous to a discount rate being assumed to account for the time value of money, assumptions must also be made regarding mortality rates to determine how long payments are expected to be made, as payments are usually paid until the death of the retiree. While investment returns could be negatively impacted by the ageing of the population, as discussed above, this section focuses on addressing the potential impact of increasing life expectancy on the solvency of pension plans.

The uncertainty around future mortality rates and the longevity risk coming from underestimating life expectancy stems largely from the uncertainty as to how mortality will evolve and the future improvements in mortality rates.[6] Figure 1.4 showed that expectancy for individuals aged 65 has increased by an average of around one year per decade. Each additional year of life expectancy not provisioned for can be expected to add approximately 3-4% to current liabilities. Thus the improvements in mortality cannot be ignored when establishing the mortality assumptions which determine how long pension and annuity payments are expected to be made.

Despite this risk, mortality assumptions used to value pension and annuity liabilities do not always receive the necessary attention. Regulation does not consistently acknowledge the need to account for the improvements in mortality, and though in practice pension sponsors often do provision for these improvements, this is not always the case and assumptions can sometimes be out of date and not reflective of recent mortality experience.

The analysis in this section shows a potential shortfall of provisions for future pension and annuity payments in several of the countries examined based on standard mortality tables used.[7] The magnitude of this potential shortfall proves the need for regular monitoring of mortality experience and for updating the mortality assumptions accordingly. While countries failing to account for increasing longevity in their regulatory and market tables are also those who face the most significant potential shortfall in liabilities, even countries where improvements are assumed but not reflective of recent experience could find that they are exposed to a moderate to significant shortfall in provisions for pensions or annuities.

Mortality assumptions in the regulatory framework and in practice

This section examines the mortality tables commonly used by pension funds and annuity providers to provision for future improvements in mortality and life expectancy. It looks at whether these standard tables include future improvements in mortality and life expectancy and how those improvements are incorporated. The regulatory framework can require specific mortality tables to be used. These tables specify minimum mortality assumptions and may or may not account for future improvements in mortality and life expectancy. However when minimum tables are required, pension funds and annuity providers are also typically allowed to use mortality tables that are more conservative than those required so as to account and provision for larger future improvements in mortality and life expectancy if deemed to be appropriate. Where the regulatory framework does not establish specific mortality tables, pension funds and annuity providers may use their own tables or the tables most commonly used by the industry.

The extent to which mortality assumptions are regulated varies widely from one country to the next and is not necessarily consistent for pension funds and annuity providers within the same country. Table 1.3 shows *a)* whether the regulation requires minimum mortality assumptions – whether or not a specified minimum level of mortality is mandated regardless of whether this requirement includes mortality improvement – and *b)* whether the regulation requires accounting for future improvements in mortality in valuing pension and annuity liabilities, though the exact assumptions to be used do not necessarily need to be specified. The analysis also considers whether the common market practice is to account for the future improvement of mortality in the valuation of liabilities, even if regulation does not require it.

The common market practice in some countries goes above and beyond the minimum mortality assumptions technically required by law, while in other countries market practice follows the minimum requirement rather closely. Where specific tables are not mandated by regulation, industry bodies often play a role in setting the standard which pension funds and annuity providers are expected to abide by in practice.

Six of the sixteen countries assessed require a minimum level of mortality for both pension funds and annuities, and another five do not have a minimum requirement for either. Five additional countries have a minimum requirement for only one or the other.

Half of the countries assessed do not require that both pension funds and annuity providers account for future mortality improvement. Six of the sixteen countries have no requirement for annuity providers or pension funds, and two additional countries have no requirement for one or the other.

Despite the lack of a legal requirement to provision for improvements in mortality, the majority of countries do so in practice, though annuity providers do so more often than pension funds. Annuity providers in thirteen of the sixteen countries examined use mortality improvement assumptions in practice, whereas pension funds in only eleven of the countries tend to do so.

Table 1.3. **Mortality tables and improvements required by regulation and used in practice**

	Minimum table required by regulation		Mortality improvements required by regulation		Mortality improvements used in practice	
Country	Annuity providers	Pension plans	Annuity providers	Pension plans	Annuity providers	Pension plans
Brazil	No	Yes	No	No	No	No
Canada	No	Yes	Yes	Yes	Yes	Yes
Chile	Yes	Yes	Yes	Yes	Yes	Yes
China	Yes	Yes	No	No	No	No
France	Yes	Yes	Yes	Yes	Yes	Yes
Germany	Yes	Yes[1]/No[2]	Yes	Yes	Yes	Yes
Israel*	Yes	Yes	Yes	Yes	Yes	Yes
Japan	No	Yes	No	No	Yes	No
Korea	No	No	No	No	No	No
Mexico	Yes	No	Yes	No	Yes	No
Netherlands	No	No	Yes	Yes	Yes	Yes
Peru	Yes	Yes	No	No	Some	Some
Spain	No	No	Yes	Yes	Yes	Yes
Switzerland	No	No	No	No	Yes	Some
United Kingdom	No	No	Yes	Yes	Yes	Yes
United States	Yes	Yes	No	Yes	Yes	Yes

* The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.
1. For non-regulated Pensionskassen and insurance oriented Pensionsfonds.
2. For regulated Pensionskassen and non-insurance oriented Pensionsfonds.
Source: Author's calculations.

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Regulatory Requirements

Behind these results there are variations in the extent to which requirements are specified and the freedom given to pension funds and annuity providers to set their own assumptions.

There are no specific regulatory minimum requirements for mortality assumptions for either annuity providers or corporate pension plans in **Korea**, **Spain** and **Switzerland**. Annuity providers in **Japan** and **Brazil** and pension plans in **Mexico** are not subject to any minimum mortality requirements either. While there are no minimum requirements for mortality itself, some countries do have stipulations regarding the experience on which assumptions are based, with **Spain** and **Switzerland** requiring that the assumptions be based on more recent experience and **Korea** having credibility requirements for the experience used for assumption setting based on the number of observations.

Requirements in **China** and **Peru** as well as for pension plans in **Brazil** and **Japan** and annuity providers in the **United States** stipulate a minimum level of mortality or life expectancy for valuing liabilities, though taking into account future mortality improvements is not required. A minimum level is also imposed for pension funds in **Canada** for solvency valuations. The minimum level to be used for US annuity providers is determined at a state level, and while some types and generations of products are required to account for future improvements the majority are not.

Specific tables accounting for future improvements in mortality are required as a regulatory minimum for valuing liabilities in **Chile**, **France** and **Israel** as well as for annuity providers, Pensionskassen and Pensionsfonds in **Germany**, annuity providers in **Mexico** and pension plans in the **United States**.

Canada requires that standards set by the Canadian Institute of Actuaries (CIA) be followed, and as the CIA standard suggests the basis for mortality improvements, the effective regulation is that mortality improvements are included for valuation. Similarly the **Netherlands** and the **United Kingdom** require that future changes in mortality be taken into account, though the level is not specified.

For annuity providers, premiums are set based on provider discretion in all countries except **France**, where the generational tables TGH/TGF05 have been a minimum requirement for pricing annuities since 1 January 2007. However in other countries certain restrictions are imposed such as in Spain where older Swiss tables, commonly used before standard Spanish tables were developed, are now forbidden.

Market Practice

The extent to which practice deviates from the requirements above and how mortality improvements are taken into account, if at all, also varies.

No provision for mortality improvement is typically taken into account for **Brazil**, **China** or **Peru**, or for **Japanese** pension funds, and the regulatory minimum in these countries tends to be relied upon, though sometimes more conservative assumptions are used in practice. For example **Brazilian** pension funds and annuity providers often tend to use the more recent US table (US Annuity 2000 tables), though future improvements in mortality are usually still not accounted for. Additionally, some evidence indicates that annuity providers and pension funds in **Peru** do take improvements into account up through the valuation date, and may be taking future improvements into account as well. Pension funds in **Japan** are allowed to include up to a 10% margin for males and 15% for females for funding purposes, though many do not do this in practice.

No minimum tables are required for corporate pension plans in **Mexico**, and in practice they typically rely on an older table from 1997, which accounts for improvements up to a certain date.

The minimum regulatory tables incorporating future mortality improvements are normally relied upon in **Chile**, **France** and **Israel** as well as for annuity providers in **Mexico** and pensions funds in the **United States**.

While not specifically required as a minimum, standard assumptions developed by industry bodies tend to be relied upon for **Canada** (apart from solvency calculations), **Korea**, the **Netherlands**, **Spain**, **Switzerland** and the **United Kingdom**. This is also true for annuity providers in **Japan** and the **United States**. All of these standard tables account for future improvements in mortality, though for pension plans in Switzerland this has only recently been the case as historically the tables used have not incorporated improvements. Pension funds in Switzerland, however, are required by law to use mortality assumptions which reasonably reflect the actual mortality experience and therefore typically adapt the standard mortality tables to reflect the mortality of their members. The new standard tables being developed in Switzerland are generational tables (e.g. the BVG2010 and VZ2010 tables) which provide both estimates of current mortality assumptions as well account for future improvements. In Spain the mortality assumptions used must fall within specific confidence intervals, implying a requirement to take future improvement into account. For the United Kingdom the magnitude of mortality improvement is not specified by the industry, rather a common modelling methodology has been developed to project future mortality improvements. While the tables in Korea do not explicitly account for mortality improvements, the margins are significant and thus effectively cover the risk of decreasing future mortality.

Accounting for future improvements in mortality in practice

The way in which future mortality improvements are accounted for in assumptions may also differ.

Tables developed by the Institute of Actuaries in **Japan** for annuitants are static, though they contain a margin which is meant to account for future decreases in mortality. **Korea** also issues standard tables which seem to have significant margins covering the increasing life expectancy. Pension plans in **Mexico** typically use a static table which has been improved to 2011 for males and 2013 for females.

Pension funds in the **United States** and **Canada** have the option of applying static tables projected to some future date in order to account for the improvement in mortality rather than using fully generational tables. Pension funds in the United States tend to more often use static projections, while in Canada generational tables are more commonly used. Annuity providers in both countries tend to use fully generational tables.

Fully generational tables tend to be used by both pension funds and annuity providers in **Chile**, **France**, **Germany**, **Israel**, the **Netherlands**, **Spain**, **Switzerland** and the **United Kingdom** as well as for annuity providers in **Mexico**. Two models have been developed for the estimation of future mortality rates for Switzerland: the Nolfi model which projects constant improvements into the future and the Menthonnex model which eventually converges to a lower long term improvement rate. Tables developed in the **United Kingdom** are rather flexible. Initial mortality assumptions there are often based on base mortality tables developed by the Continuous Mortality Investigation (CMI) which is supported by the British actuarial profession. However to project mortality beyond this point, the CMI has developed a model where users can specify a long term future rate of improvement, which can be set at a higher rate depending on the purpose of the calculations.

Cohort-based generational tables where future improvements are projected based on generations rather than age only have been developed in **France**, **Israel**, **Switzerland** and the **United Kingdom**.

Tables developed in **Germany**, **Israel**, the **Netherlands**, **Switzerland**, **the United Kingdom** and more recently the **United States** project improvements which vary by age across time, that is having a higher short-term improvement assumption reflecting recent improvements gradually reverting to a lower long-term trend. The recently proposed pensioners' mortality table in **Canada** also takes into account short term vs. long term trends.

Assessing longevity risk

The longevity risk for the pension fund and annuity provider is that the risk that the pensioners live longer than expected, expectations being based on the mortality assumptions being used, and that payments will have to be made longer than provisioned for. If the mortality assumptions used to value these pension and annuity liabilities underestimate the future increases in life expectancy, the fund will face challenges to its solvency position.

The general approach taken here to assess the potential longevity risk which pension plans and annuity providers may be exposed to is based on comparing the life expectancy and annuity values given by the standard mortality tables used with the life expectancy and annuity values suggested by alternative mortality projection models.

Historical population data for each country is used to calibrate four alternative models to project mortality into the future. These mortality rates are then adjusted to the level of mortality for the pensioner or annuitant population.

The potential shortfall in provisions to cover the risk of longevity of pensioners and annuitants is quantified by comparing the resulting annuity values. A smaller annuity value based on the standard table as compared to the value implied by the models indicates a potential exposure to longevity risk.

Mortality projection models

The four mortality projection models which have been used to assess the adequacy of mortality assumptions are the Lee-Carter, Cairns-Blake-Dowd, P-spline and CMI models.

The first two models listed are stochastic models, while the second two are deterministic. Stochastic models allow for assessment of longevity risk at a given confidence level, whereas deterministic models provide only a best estimate view of future longevity. Depending on the purpose of the projections, one type or the other may be preferable.

In general, the stochastic models presented here are relatively easy to understand and implement compared to the deterministic models, for which the underlying modelling is quite complex in terms of the procedures used to calibrate the parameters of the models. Beyond this broad difference, each model presents shortcomings which must be considered when interpreting the results of the projections.

The Lee-Carter model is the simplest model, and its projections maintain the pattern of improvements by age which was experienced over the historical period used for the calibration of the model. This can pose a problem, however, as in many developed countries the pattern of improvements across ages has been changing over time. Decreases in infant mortality have been followed by decreasing mortality for adults coming from improvements in healthcare and the development of vaccines and antibiotics, and more recently, medical advances in fields such as cardiology which have impacted the mortality rates at older ages. As this acceleration of mortality improvement at older ages has only occurred more recently, the Lee-Carter model tends not to capture this shift of improvements, potentially underestimating the increase in life expectancy at these ages. In addition, the stochastic projections tend to result in rather narrow confidence levels making risk assessment at more extreme percentiles problematic.

Compared to the Lee-Carter model, the Cairns-Blake-Dowd model allows for a more complex correlation structure for improvements across different ages, which is arguably more realistic than a scenario of perfect correlation. The model was developed with the focus on providing reasonable mortality projections for older ages, which is also the focus of the analysis presented in this paper. However this model still tends to demonstrate a poorer fit compared with the other models.

The P-spline model is very good at smoothing out the noise in raw historical data; however, future projections can be rather unstable as they are very sensitive to the most recent years of input experience.

While the underlying modelling of the CMI model is extremely complex, the projected scenario is influenced by a long-term improvement assumption determined by the user, resulting in scenarios that both reflect recent experience in the short term but converge to a long-term scenario judged to be plausible by the user.

The assessment presented here relies on deterministic projections of all models. Although the term "longevity risk" is often used to imply a certain level of confidence, here longevity risk is considered to be the risk that the actual increase in longevity experienced in the future is greater than what has been assumed, regardless of the confidence level. Thus, if the deterministic scenarios of all models are predicting that future improvements will be greater than what is currently being assumed, a reasonable conclusion would be that the pension plan or annuity provider using these assumptions is exposed to this "longevity risk", synonymous with the probable shortfall of provisions which we attempt to quantify here.

Basis of the calculations and comparison

The projection models have been calibrated to the mortality of the overall population for each respective country, therefore the direct output of the projection models is the predicted future mortality for the overall population. However, the standard mortality tables used by pension funds and annuity providers typically intend to represent the mortality for subgroups of the total population.

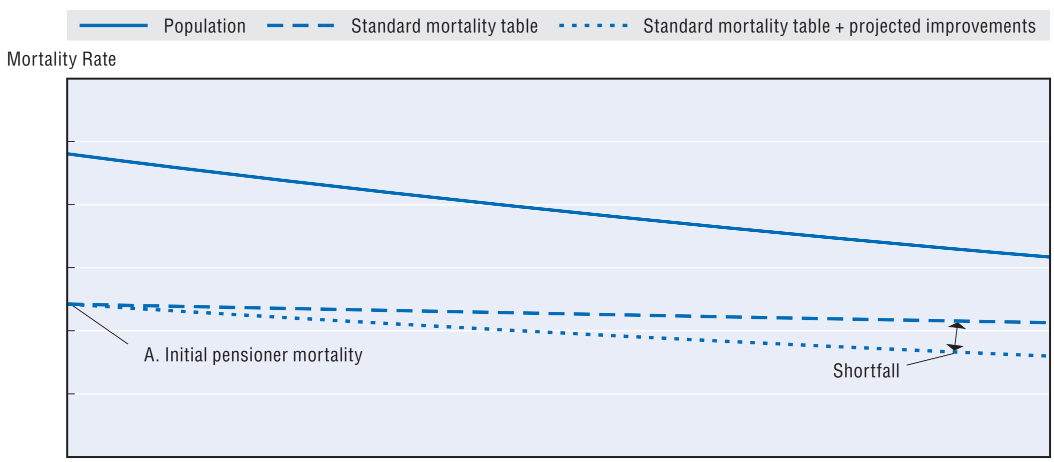
Pensioners and annuitants are subsets of the overall population who often have lower expected mortality (higher life expectancy) than the population in general. Pensioners, and even more so annuitants, tend to have a higher average income level (and/or have higher educational attainment levels) than the population as a whole. This has been shown to be positively correlated with longevity and life expectancy, and the mortality assumptions applied to these subpopulations reflect these differences (see Box 1.1). Indeed, the mortality tables used for pensioners and annuitants are typically established based on the mortality experience of these subsets. However the extent to which the mortality of these two populations differs depends largely on the structure and coverage of the pension system itself, as if the coverage rate is quite high the pensioner population will be largely similar to the overall population.

The life expectancy and annuity rates obtained from the standard mortality tables are therefore not directly comparable in most cases to the outputs of the models which give the life expectancy for the entire population. To the extent that the life expectancy given by the standard tables is lower than that predicted by the models it is possible to conclude that the standard tables likely do not account sufficiently for longevity, as we expect the inverse relationship, that is, for pensioners and annuitants to have a higher life expectancy. However, it is not possible to quantify the amount of longevity risk from this result.

In order to quantify the potential shortfall in provisions that pension funds and annuity providers may be facing, the population mortality coming from the models is adjusted proportionally to match the level of the pensioner/annuitant mortality based on the most recent mortality experience available for these populations (typically the experience on which the standard table was based). In this way, it is possible to compute a life expectancy predicted by the model which is comparable to that which is assumed in the standard mortality tables.

This approach is demonstrated in the figure below. The mortality rates for the general population which are output by the model are represented by the solid line. These mortality rates are adjusted downward – using the ratio of actual insured/pensioner mortality rates to population mortality rates – to the level of the pensioner mortality, point A in Figure 1.6. The annual rates of mortality improvement for the general population and the pensioner/annuitant population are assumed to be the same, so the difference in the mortality given by the standard table and that predicted by the model is then driven only by the differences in the assumed and modelled mortality improvements. The resulting shortfall is therefore coming from the gap between the two dashed lines, and includes the retrospective differences based on the evolution of actual historical mortality from the time of the development of the table to the current point in time, as well as differences in improvements projected into the future.

Figure 1.6. **Illustration of mortality adjustment for projections**



Source: Author's illustration.

However, the shortfall presented here could potentially be understated with this approach as a result of the underlying assumptions. The assumption that pensioners and annuitants follow the same pattern of mortality improvement as the general population is strong, and there has been some evidence presented showing that factors such as income which influence the lower mortality for pensioners and annuitants also impact the rate at which their mortality improves. A study on pensioners in Canada found significant differences in the mortality trend over the last 15 years for the highest income group, particularly for males aged 60-75, with differences surpassing even 1% of annual improvement for some age groups (Adam, 2012). Similarly, male annuitants aged 70 in Switzerland have experienced improvements of 2.4% as opposed to 1.3% for the general population (Pasolika, 2005). The difference for females was less obvious in these studies. Nevertheless it is difficult to say whether this divergence in mortality could continue in the long term, therefore the assumption of a common trend is considered to be a reasonable concession.

This analysis also relies on the assumption that the initial mortality established by the regulatory and industry mortality tables accurately reflected the mortality of the population for which the table is being used. This is clearly not always the case, particularly for example if the tables are based on a population in a different country. In these cases an effort has been made to use an initial mortality which is the most representative of the best estimate mortality based on available data. Similarly, if the mortality table includes margins, these have generally been removed when calculating the life expectancies coming from the models so as to recognise the extra conservatism embedded in the tables when assessing the potential shortfall in funding.

The actual quantification of the shortfall in this exercise relies on the computation of the annuity values based on these two sets of mortality rates.[8] The annuity value represents the premium an individual would have to pay to receive one unit of currency per annum. It also represents the present value of the expected payments which the pension fund or annuity provider owes to the individual, and therefore can be seen as the amount that needs to be held in reserve in order to meet future payment obligations. The current funding and reserve requirements of pension funds and annuity providers are assumed to be based on the standard mortality tables.

Therefore, the ratio of the annuity value based on the mortality model outputs over the annuity value based on the mortality tables used by pension funds and annuity providers measures the potential shortfall in provisions to which they may be exposed.

Potential shortfall of provisions based on standard mortality tables[9]

The following analysis is based on the projections of the population mortality adjusted to the mortality level of the pensioners and annuitants by using the initial level of mortality established by the standard mortality tables and applying the mortality improvements given by the projection models.

Overall, pension plans face more longevity risk than annuity providers, who more often tend to include assumptions for future mortality improvement and whose tables tend to be more up to date. Six tables used for pension funds lead to a potential shortfall in provisioning for longevity risk of over 5%, whereas only two tables used by annuity providers lead to such results. In countries where different tables are used for pension funds and annuity providers, tables used by pension funds tend to be less adequate than those used by annuity providers in all cases except the United Kingdom, where both pension funds and annuity providers seem to sufficiently account for the future improvement in mortality, and Mexico, where projected mortality improvements tend to be relatively low. New tables which are meant to replace the older existing tables shown here clearly reduce the expected shortfall for Brazil (BR-EMS 2010 compared to US Annuity 2000), Canada (CPM compared to UP94) and the US (RP2014 compared to RP2000).[10] Of the tables for which little to no longevity risk was assessed, four are used by annuity providers whereas only two tables used by pension funds met the criteria.

The table below classifies the mortality tables used for pension plans and annuity providers in each country by the percentage of additional reserves which would be required based on the results of the projection models compared to the table.[11, 12, 13, 14]

None of the tables classified as having greater than a 10% shortfall in provisions take future mortality improvement into account. However the extent to which the EVK2000 table in **Switzerland** is used in practice is minimal, with fewer than 8% of pension funds relying on this table in 2012 and an increasing number of funds moving towards the more recent generational tables BVG 2010 and VZ 2010. Furthermore in practice the standard mortality tables in Switzerland are adjusted to the actual mortality experience of the

Table 1.4. **Classification of standard mortality tables by potential shortfall in provisions**

Classification	Potential Shortfall	Pension Plans	Annuity Providers
Serious	10-20%	Brazil (*US 1983IAM*), China (*CL2000-2003*), Switzerland (*EVK2000*)	Brazil (*US Annuity 2000*), China (*CL2000-2003*)
Significant	5-10%	Canada (*UP94-ScaleAA*), Japan (*EPI2005*), US (*RP2000-ScaleAA*)	
Moderate	2-5%	Chile (*RV2009*), Spain (*PERM/F C 2000*)	Brazil (*BR-EMS 2010*), Canada (*GAM94-CIA*), Chile (*RV2009*), Spain (*PERM/F C 2000*), US (*GAM94-ScaleAA*)
Monitor	< 2%; specific issues to address	Canada(*CPM*), France (*TGH/F 2005*), Israel*, Mexico (*EMSSA 1997*), Spain (*PERM/F P 2000*), Switzerland (*BVG 2010, VZ 2010*), US (*RP2000-ScaleBB*)	France (*TGH/F 2005*), Israel*, Mexico (*EMSSA 2009*), Japan (*SMT 2007*), Spain (*PERM/F P 2000*)
OK	little to no expected shortfall	Netherlands (*AG-Prognosetael 2010*), UK (*SAPS1-CMI*), UK (*SAPS2-CMI*), US (*RP2014*)	Germany (*DAV 2004 R*), Netherlands (*AG-Prognosetael 2010*), Switzerland (*ERM/F 2000*), UK (*PCMA/PCFA 2000-CMI*)

* The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.
Source: Author's calculations.

pension fund itself, and the funds are required to ensure adequate reserves to meet future payment obligations.

For the tables classified as having a significant shortfall, some account for future improvements while some do not. While **Japanese** regulation permits occupational pension plans to take into account the future mortality improvements to the extent that the Employees' Pension Insurance Scheme does so in its actuarial valuation, in practice pension plans tend to not take them into account and the assessment for the EPI2005 table here therefore does not consider improvements. Although **Canada** and the **United States** do take improvements into account with the Scale AA, the assumptions are lower than the level that recent experience implies, resulting in a larger discrepancy between the results using the models and those coming from the tables. Furthermore, recent pensioner mortality studies in Canada show that life expectancy is higher than the United States experience on which the UP94 table was based.

Annuity providers in **Canada** and the **United States** use tables which result in a moderate expected shortfall in provisions, as mortality improvement assumptions are not entirely reflective of recent experience, and again the GAM94 table used by Canada is based on United States mortality experience, though this classification for Canada excludes the additional margins which are typically applied in practice. The assumptions used in **Chile** also incorporate mortality improvements, though these assumptions do not seem to reflect the most recent improvements in life expectancy of the population.[15] The table used by **Spain** for policies issued prior to 2000 is also classified at this level, whereas the more prudent table developed concurrently for policies issued later than 2000 has lower risk, though slightly more potential risk for males than females.

Besides these latter tables for Spain, the regulatory tables used in **France** and **Israel** also show little potential risk of an expected shortfall, though the assumptions should be closely monitored as the assumptions for females at high ages in France may be insufficient in light of recent experience, and recent improvements in Israel have been quite high even compared to the relatively prudent assumptions used. The newer generational tables used by pension funds in **Switzerland** (BVG 2010, VZ 2010) and the **United States** (Scale BB) are a significant improvement compared to the older tables used, though as neither of these newer assumptions are required it is not clear how widely these tables have been adopted for use. The assumptions used by **Japanese** annuity providers seem also to be sufficient on average, though attention should be paid to the demographic distribution of the populations for which these tables are used, as over-provisioning for longevity improvements for ages over 65 tends to compensate for the under-provisioning for younger ages. While the tables used in **Mexico** also seem to sufficiently provision for expected mortality improvements for now, recent improvements in mortality have been slowing and Mexico currently has rather low life expectancy compared to other OECD countries. Therefore the potential for longevity to accelerate in Mexico and life expectancy to catch up to other OECD countries exists, and mortality experience should be closely monitored for changing patterns to ensure that the tables remain adequate.

Tables used by pension funds in the **Netherlands** and the **United Kingdom** seem to sufficiently account for future improvements in mortality. Both of these tables were developed by actuarial associations in the respective countries, and while commonly used in practice, neither table is legally required. This also holds true for the tables used by annuity providers in these two countries. In **Germany** the tables are required by regulation. The recent US RP2014 table with the MP2014 improvement scale also shows little to no expected shortfall in provisions, and this table is expected to replace the older RP2000.

Brazil and **Canada**, the two countries using tables based on experience outside of their own country, have both recently developed mortality tables based on their own populations. While no mortality improvement assumptions have been incorporated into the new tables for **Brazil**, this update does significantly reduce the potential longevity risk to a moderate level. The potential shortfall in provisions also reduces for Canadian pensioners under the new CPM tables recently issued.

Several countries (**Canada**, **Israel**, **United Kingdom** and **United States**) have also developed specific mortality tables for pensioners or annuitants based on socio-economic factors such as income and employment type. The results of these tables clearly show that liabilities increase relative to the total pensioner or annuitant population for those with higher income levels and white collar employment. However, in all cases income matters more than the type of employment, and the impact for males is much more significant than for females. These results highlight the fact that attention should be paid to the demographic characteristics of the population for which standard mortality assumptions are being used, and should be adjusted accordingly if the population tends to be of a higher socio-economic level.

This analysis shows that the failure to account for future improvements in mortality can result in a shortfall of provisions of well over 10% of the pension and annuity liabilities. Likewise, the use of assumptions which are not reflective of recent improvements in mortality can expose the pension plan or annuity providers to the need for a significant increase in reserves.

Improvements in mortality and in life expectancy are a phenomenon which cannot be ignored when setting mortality assumptions for the future. Mortality assumptions have a significant influence on the liability value for pension funds and annuities and realistic assumptions are necessary in order to sufficiently provision for future payment obligations and ensure the solvency of the providers.

Pension funds and annuity providers must actively assess and manage their longevity risk, keeping assumptions up-to-date and recognizing the risk to which they are exposed. Demand for protection against longevity risk will only increase as individuals expect to live longer, and the sustainability of pension funds and annuity providers providing this protection for individuals has to be ensured. Sufficient provisioning for longevity is essential to guarantee that future payments will be met, and the ability for providers to manage and mitigate this risk will allow continued protection to be offered in the future.

1.5. Managing longevity risk

Pension funds and annuity providers need to manage their longevity risk. Pension funds and annuity providers can manage longevity risk in-house as part of their internal risk management systems, for example, by retaining the risk and holding enough capital to withstand fluctuations.[16] This arrangement has traditionally been facilitated by the actuarial valuation process. Longevity risk can be measured by using appropriate models to estimate future improvements in mortality and life expectancy (e.g. stochastic models that allow probabilities to be calculated). In this context, the longevity risk will be the difference between the improvements in mortality and life expectancy assumed in the actuarial valuations and the actual improvements that occur in the future. Hence, the first step in managing longevity risk is to recognise that it exists and incorporate reasonable expectations regarding mortality improvements in mortality assumptions. Mortality and life tables should be updated regularly to support the process.

Insurers can to some extent reduce their aggregate longevity risk exposure by offering both life insurance and annuities. The liabilities of life insurance decrease as mortality improves while those of annuities increase. However, life insurance and annuity portfolios often cover different population groups, so this arrangement is not a perfect hedge and there is residual longevity exposure since annuities are concentrated among the older population groups.

One of the main issues faced by annuity providers is a capacity constraint in the amount of longevity risk they are able to accept and insure. This capacity constraint is largely driven by regulatory requirements surrounding the required capital which needs to be held and the increased focus on enterprise risk management. Therefore instruments need to be available to mitigate this risk if necessary.

Pension funds and annuity providers can mitigate longevity risk by transferring it to a third party. There are several solutions that allow pension funds or annuity providers to either transfer or hedge longevity risk with a third party. The first type is referred to as a bulk annuity, where both investment and longevity risk are transferred to the third party (usually (re)insurers), and can be done either as a buy-out or buy-in structure. The second type is via a longevity swap, a hedge which transfers only the longevity risk to the third party. Most of the transactions implemented in the market in the past years have been based on fully transferring longevity risk from one party to another via buy-outs and buy-ins, and recently via bespoke longevity swaps based on the mortality of actual pensioners or annuitants. One of the main problems with these types of arrangements is the capacity constraints that (re)insurers face for the amount of longevity risk they are able to accept. Capital markets may have the potential to provide additional capacity if standardised instruments to hedge longevity risk via longevity bonds, swaps and other derivative contracts were available. For purposes of standardisation, these instruments may need to use longevity indices based on the general population.

Pension buy-outs and buy-ins

The most common arrangements for transferring longevity risk from pension funds in the private sector have up to now been pension buy-outs and buy-ins. Both of these solutions remove the longevity risk as well as investment risk from the pension fund or plan, transferring these risks to an insurer or reinsurer. These hedges usually cover only the current pensioners and are especially attractive for defined benefit pension plans in termination.

In a pension buy-out, the pension fund and/or plan sponsor hands over all the assets and liabilities of the fund to an external provider. After the conclusion of the contract, the responsibility for making payments to members passes to the provider (typically an insurer or reinsurer) and removes the pension liabilities from the sponsor's balance sheet. While the plan sponsor offloads all risk, this arrangement exposes plan members to counterparty risk, or the risk that the insurer becomes insolvent, as the structure no longer has the same benefit protection mechanisms in place as the pension plan.

In a pension buy-in, the pension fund or plan sponsor retains the liabilities and assets and remains responsible for the payment of pension benefits to members, but effectively insures these payments with an external provider. In exchange for a premium, the provider fully or partially insures the pension plan's liabilities. Thus, in effect, the pension fund buys an annuity contract with an insurance company so that annuity payments coincide with some or all the benefit payments of the pension plan.

While these types of arrangements maximize the risk transfer for the sponsor, both types of contracts tend to require significant upfront premiums, making them a less feasible solution for underfunded plans.

Longevity swaps

As an alternative to buy-ins and buy-outs, pension funds and annuity providers can retain the investment risk and pass only the longevity risk to a third party through the use of longevity hedges. These instruments can be structured as perfect hedges in bespoke transactions, or they can be based on an objective longevity index. Insurance and reinsurance companies are the usual counterparty in the case of bespoke longevity hedges, which are the most common form of transaction, but capital market solutions using index-based arrangements are also beginning to emerge in practice. Compared to bulk annuities, longevity derivatives can be a more economical solution to hedging longevity risk as they typically do not require large upfront premiums.

One of the more commonly used longevity derivatives is a longevity swap. In a longevity swap, the party seeking to hedge their longevity risk pays a series of fixed amounts for the duration of the contract ("fixed leg") based on pre-specified mortality or survival rates in exchange for receiving a series of variable payments ("floating leg") which are linked to actual mortality experienced. The net payments are settled at regular intervals, and the fixed plus variable payments should track closely with the actual pension or annuity payments being made, thereby providing a hedge for the longevity risk of the pension fund or group of annuitants. Box 1.2 provides an example of the structure and payments for a bespoke longevity swap.

Box 1.2. **Hypothetical example of a longevity swap**

Consider a hypothetical example of a homogeneous pension plan with 100 000 members aged 65 years as of 1st January. Each month, the pension plan has to pay €10 to each member of the plan. The pension plan wants to hedge its exposure to longevity risk and enters the fixed side of the longevity swap based on survival rates with starting date of 1st January. The table below shows the cash flows for the first four months.

Assume that after one month, every pension plan member is still alive. Therefore, the pension plan has to pay €1 000 000 to the plan members, whereas the predefined cash flow is €950 000 as 5 000 pensioners were expected to die. Therefore, the pension plan has to pay more money to the members than expected, but it receives this extra money from the hedge provider. The amount received from the hedge provider is €50 000.

Assume that after the second month, 5 000 pension members have passed away and so the pension plan has to pay €950 000 to the surviving pensioners. However as only 93 000 pensioners were still expected to be alive, the pension plan receives €20 000 from the hedge provider, which is the difference between the actual payments made and the expected payments.

Assume that between the second and the third month, another 5 000 people pass away making the actual pension payment €900 000 compared to an expected €910 000 leading to fewer payments to the pensioners than planned for. Therefore, the pension plan has to pay €10 000 to the hedge provider.

Date	Actual Pension Payment	Predefined cash flow	Payment to the pension plan
Feb. 1st	1 000 000	950 000	50 000
March 1st	950 000	930 000	20 000
April 1st	900 000	910 000	-10 000
May 1st	900 000	890 000	10 000

Longevity bonds

A longevity bond is another example of an index-based longevity hedging instrument. These bonds have no principle repayment, but pay regular coupons which are linked to a longevity index typically based on the mortality experience of the general population. The coupon payments are proportional to the survival rate of the specified reference population. For example, if a longevity bond is based on the survival of a cohort of males aged 65 at the time of issuing the bond, the coupons payable in 10 years will depend on the proportion of 65-year-old males who survive to age 75. Purchasers of the bond will thus receive a higher coupon in the event that mortality improvements have been higher than expected. Box 1.3 shows an example of the structure and payments from a longevity bond.

Compared to longevity derivatives, longevity bonds require a much larger upfront investment from the hedger of longevity risk, and the longevity protection which they offer can be limited due to the coupons' reference of a very specific population of individuals which may not correspond well with the specific demographic profile of the pension plan or annuity portfolio being hedged.

Box 1.3. **Hypothetical example of a longevity bond**

The EIB/BNP bond attempt in 2004 had a 25-year maturity and coupons were linked to a cohort of English and Welsh males aged 65 in 2003, which entailed a potentially large basis risk for other populations. The initial coupon payment was £50 million. Let q(x,t) be the mortality rate of a person aged x in the year t. The survivor index S(t) was constructed as follows:

$S(0) = 1$

$S(1) = S(0) * (1 – q(65,2003))$

$S(2) = S(1) * (1 – q(66,2004))$

$S(t) = S(t-1) * (1 – q(64+t,2002+t))$

The coupon payment was calculated as £50 million • S(t) with t = 1, 2, …, 25 and the issue price was £540 million determined by projected coupons which were discounted at LIBOR minus 35 basis points. The projected coupons were based on survival rates calculated by the UK Government Actuary's Department.

A hypothetical scenario is assumed here in order to describe the coupon payments in the first three years. The table below shows a possible development of the mortality rates, where those for the cohort aged 65 in 2003 are in **bold** as they are needed for the calculation of the survivor index.

Age x\Year t	2003	2004	2005
65	**2.05%**	2.00%	1.95%
66	2.15%	**2.10%**	2.05%
67	2.25%	2.20%	**2.15%**

Thus, the coupon payment at time t = 1 is 48 975 000 = (1–.0205) • 50 000 000

All hypothetical coupon payments in the first three years can be found in the table below

Time	Mortality rate q(64+t,2002+t)	Survivor index S(t)	Coupon payment
t = 1	2.05%	97.95%	48 975 000
t = 2	2.10%	95.89%	47 945 000
t = 3	2.15%	93.83%	46 915 000

Until now, buy-in and buy-out transactions have been the preferred way to transfer the longevity risk of pension funds to a third party. Longevity swaps have been gaining in popularity in recent years, however, and the volume of swap transactions in the United Kingdom surpassed that of buy-ins and buy-outs in the United Kingdom in 2013 (Hymans

Robertson, 2014). The vast majority of these transactions have been bespoke, with floating payments based on the actual mortality of the pensioners.

While a few attempts at issuing a longevity bond have been made, none have yet been successful. Hedging longevity with a longevity bond would expose the pension fund or annuity provider to arguably more residual basis risk than a longevity swap, as the reference index on which the coupons is based has to be quite generic (e.g. the cohort of 65 year old males). In addition, hedging with a longevity bond requires a significant upfront investment, making it economically less attractive compared to a swap. Basis risk and the significant upfront capital required are two main reasons why longevity bonds have not yet attracted a sufficient number of investors to be issued.

Requirements for the development of capital market solutions for managing longevity risk

The development of capital market instruments for hedging longevity risk requires certain conditions to be met, namely relating to the increased standardisation, liquidity and transparency of longevity hedging instruments. The misalignment of incentives between the insurers and pension funds seeking protection from longevity risk and those of the capital markets investors need to be addressed. Appropriate legislation and regulation need to be in place so as to increase the understanding of the magnitude and significance of longevity risk. Finally, benchmarks could greatly facilitate the pricing and risk assessment of such instruments.

Addressing the misalignment of incentives through index-based longevity hedging instruments

Pension funds and insurance companies want to be guaranteed that they are fully protected against longevity risk and therefore have a preference for bespoke transactions based on the actual mortality of the underlying population being hedged, which is why these types of transactions have been by far the most popular. The traditional transaction involves the longevity risk being passed to an insurance or reinsurance company, as this type of risk forms a core part of their business and expertise. However, the trend towards risk based requirements and the increased emphasis on enterprise risk management will require increasing levels of capital to be held to cover the risk exposures faced and protect from the risk of insolvency, so the capacity for the insurance industry to absorb all of the demand for longevity protection is not endless. These capacity constraints therefore need to be addressed in order to ensure a supply of longevity protection sufficient to meet the needs of society.

Capital markets have the potential to provide the additional capacity for longevity risk and offer some relief from the concentration in the supply of longevity protection. One of the main incentives for capital markets investors to invest in longevity risk is that longevity is largely uncorrelated with typical market risks, and therefore could offer a diversifying investment opportunity.

However, bespoke transactions pose several problems for the capital markets investor. First of all is the lack of transparency of such a transaction, where the insurer or pension fund possesses asymmetrical information regarding the mortality experience of the population being hedged. Secondly, a bespoke transaction can be extremely time-consuming to implement as the investor must assess the specific longevity characteristics of the portfolio or fund in order to price the transaction. Finally the long-term nature of longevity risk would expose the investor to a very long-tailed investment with a duration upwards of fifty years. These characteristics are not conducive to the creation of an attractive investment vehicle, for which cash flows would need to be based on an easily understood and independent measure, be transacted in a timely manner and reflect a duration more in line with the preferred investment strategy of the investor.

Index-based longevity hedges could address the above shortcomings and provide a potentially attractive investment for capital markets investors by increasing the standardization and transparency of longevity derivatives. Rather than payments being based on the actual underlying mortality of the plan or portfolio being hedged as in a bespoke transaction, an index-based transaction is based on the mortality of an independent mortality index, such as the mortality of the general population of the country. This structure would address the concerns of capital markets investors as cash flows would be based on an independent longevity index with clearly defined indicators, providing full transparency for the investor with respect to the calculation of payments. As cash flows would not be based on the mortality of the portfolio itself, the counterparty does not need to have any information about the portfolio and a transaction could be executed more quickly based on a standardized model. Finally there can be more flexibility around the design of the structure of the transaction so the duration of the instrument could be defined for a shorter time horizon and the tail risk limited.

Furthermore, as index-based hedges are much easier to standardise, they represent a more attractive investment vehicle for private investors since this standardisation makes index-based hedges more tradable in capital markets. This may lead to the development of secondary markets for longevity instruments, which would help increase liquidity and perhaps make the instruments less costly. These standardised instruments could then be more easily traded on exchanges.

Nevertheless, as opposed to a bespoke transaction, with an index-based hedge the pension fund or annuity provider would have to accept to be exposed to some remaining residual and tail risk, primarily that coming from basis risk. Basis risk exists as the mortality on which the index is based is not guaranteed to evolve in the same way as the mortality of the portfolio or fund being hedged, so there can be some discrepancy between the cash flows the hedger receives from the investors and the payments to be made to the pensioners.

This basis risk would be potentially larger for smaller plans or portfolios, which would be exposed to more idiosyncratic longevity risk – which is the risk that any specific individual will live longer than expected – and therefore are exposed to more volatility of mortality experience. This implies that index-based solutions may be less effective for a small group of lives where these individual differences are not sufficiently diversified as with a large pool of lives. Index-based transactions may be much more effective in transferring the systemic longevity risk, which comes from the overall shifts in longevity trends, for example as a result of medical advances or better diet, and cannot be diversified away by pooling risks. One solution to the challenge smaller plans and portfolios face in mitigating their longevity risk would be for an insurer or reinsurer act as an intermediary to the capital markets by providing bespoke hedges with these small plans to acquire and pool the risks, subsequently transferring the systemic longevity risk of this pool to the capital markets.

Legislation and regulation

It is vital to have a realistic and appropriate valuation of pension liabilities and to recognize the full potential impact of longevity risk in order for capital market solutions for hedging longevity risk to develop. In this context, up-to-date mortality tables as well as assumptions that include future mortality and life expectancy developments would help in recognising the amount of longevity risk.[17] Additionally, risk-based capital requirements could help in communicating the significance of longevity risk.

Longevity hedges benefit pension funds and annuity providers by reducing the risk they are exposed to. If risk management and mitigation were reflected in capital reserving requirements, pension funds and annuity providers would have more incentive to hedge their longevity risk. For instance, the Pension Act introduced in the United Kingdom in 2004 implied sufficient capital relief to make longevity transactions attractive, which is one reason why transactions to hedge longevity risk have become so prevalent in the United Kingdom. It is crucial that the regulatory framework allows for pension funds and annuity providers to reduce their capital requirements if they hedge their longevity risk to reflect the lower risk exposure compared to those who do not hedge their longevity risk.

Risk based capital requirements should lead to reductions in capital requirements when using instruments to reduce longevity risk exposure. This would be a step in the right direction for annuity providers to have incentives for using longevity hedging instruments. The underlying concept of "mark-to-market" valuation, i.e. valuation via market prices or, if no market prices are available, valuation according to market principles, should force annuity providers to assess their longevity risk on a realistic basis. In the case of mortality and longevity, this implies the use of "best estimate" mortality tables (company specific) in combination with a risk margin for uncertainty with respect to non-hedgeable risks. Once a deep and liquid longevity market has been developed, the mark-to-market valuation of longevity risk will be possible. Thus, a longevity market could also be very helpful in determining appropriate capital requirements.

In addition to capital requirements, accounting rules are crucial for a realistic assessment of longevity risk. In some countries, certain mortality tables and fixed interest rates are prescribed for the computation of pension liabilities. Pension funds are obliged to use these specifications, e.g. for tax reasons, even if they know that they are not realistic for their specific case. Here, discussions with the International Accounting Standards Board (IASB) and governments are necessary to ensure that mortality and interest rate assumptions are always up-to-date and that realistic values for pension liabilities are disclosed. When this has been achieved there is a better chance that pension funds and annuity providers will address their longevity risk and consider mitigating their risk, possibly via capital market transactions

Accounting rules and standards also need to allow for the accurate valuation of longevity hedging instruments. For example, improvements in mortality and life expectancy beyond those initially assumed may render longevity hedges more valuable than their purchase price which could offset the increase in liabilities resulting from higher life expectancy. Accounting rules which do not accurately value such instruments may make longevity hedges rather unattractive. For example, some countries do not allow insurance companies to value longevity instruments at a higher value than the purchase price. Thus, if longevity – and consequently the fair value of the hedging instrument –

increases, insurers will not be able to show the increased value of the longevity hedge on their statutory balance sheets to offset the increased value of the liabilities.

Another example where regulation may restrict the benefit which can be realized from a longevity hedge would be where policyholders are entitled to a certain part of an insurer's unrealized gains with each payment they receive. In this case, an increase in the fair value of a longevity hedge could only partly be used to offset an increase in liabilities as a portion of the increase would need to be distributed to policyholders.

Benchmarks to promote standardisation, liquidity and transparency

A capital market for financial instruments to hedge longevity risk requires standardisation, liquidity and transparency for its proper functioning. As discussed above, index-based instruments are much more conducive to these requirements than bespoke transactions.

As such, publicly available reference points for pricing index-based longevity transactions could be used by potential market participants to enter the market. Unfortunately, most longevity transactions carried out thus far have been bespoke over-the-counter deals whose pricing have not been made public, and therefore have not contributed to the standardisation and transparency of the market.

The issuance of index-based longevity bonds has often been discussed as a solution to kick-start the purchase of longevity risk by the capital markets by providing this standardization and transparency. A longevity bond would allow prices to become publicly available as a reference point for other transactions, establishing a riskless term structure which the private sector could use as a basis to issue index-based longevity derivatives. This term structure could also be used by regulators as a check for the appropriateness of the level of capital which the insurers are holding to cover longevity risk.

There are several arguments for the government issuance of a longevity bond. Compared to solutions offered by the private sector, such a bond would provide a longevity hedge with little to no counterparty risk which could increase the capital relief insurance companies could potentially receive from such a hedge. The government would also be better positioned to offer a hedge in line with the long duration of longevity risk, which capital markets investors have been so far reluctant to do. The government is also arguably in a better position to support the systemic longevity risk. Benefits for the government itself could include the reduction of its cost of borrowing compared to traditional government bonds since it would be receiving a risk premium for taking on the longevity risk. However, the longevity bond market is likely to remain fairly illiquid and the coupons would have to include a certain level of illiquidity premium, therefore it is not certain that the cost of borrowing could be reduced in reality (Brown and Orszag, 2006).

Nevertheless this solution would have to be very carefully assessed as many governments already hold significant longevity risk on their balance sheet from public pensions and health programs. Some commentators (Blake at al., 2010) argue that governments could hedge some of its exposure to increases in aggregate or systemic longevity through adjustments to the state pension. Governments are currently proving these types of adjustments – such as increasing retirement age or decreasing pension levels – are very slow to implement and face strong political resistance. However if insurance companies are not able to insure the longevity risk of individuals, it is possible that more elderly would fall into poverty and their longevity risk would have to be covered by the government anyway through the safety nets which are in place. Therefore issuing longevity-indexed bonds could help to alleviate pressure on public finances in the long term.

A regular and reliable publication of a longevity index could also further the standardization and transparency. This index could provide a basis for the calculation of future swap payments as well as provide a price reference from which market participants could decide how much they are willing to pay for a given transaction. Such an index should include both metrics relating to current mortality as well as mortality projections which reflect the most up-to-date expectations of future mortality improvement and life expectancy. The methodology and data used to develop the index should be clear and transparent so that the market understands the basis of the calculations and will be confident in the reliability of the index going forward. As governments have access to all necessary data needed to publish such indices on an ongoing basis, perhaps national statistical institutes could be in charge of publishing annual indices for their respective countries.

1.6. Concluding remarks

The ageing of the population, particularly with respect to the continued increases in life expectancy, poses significant challenges to all types of pension plans. PAYG will face problems of sustainability, defined benefit schemes will need to ensure their continued solvency and defined contribution plans will have to consider ways to ensure an adequate income throughout retirement.

Policy needs to focus on implementing solutions to confront the fact that people are living longer lives to avoid undue financial burdens from the financing of retirement. Linking the age at which retirement benefits can begin to the changes in life expectancy would help ensure the sustainability of defined benefit and earnings based schemes in the future. However the way in which these two are linked needs to be carefully considered as mortality rates and life expectancy vary with socio-economic status. An alternative solution could be to link the number of contribution years to the life expectancy in a way which maintains a certain ratio of years in retirement relative to years contributing.

Pension and annuity providers which have promised a certain level of future income in retirement will need to make sure the mortality assumptions used for the valuation of their liabilities are adequate. If these assumptions are not in line with the expectations regarding the continued increase in life expectancy, the pension plan may not have sufficient assets to meet future payment obligations and runs the risk of insolvency. Regulation with respect to the mortality tables used, such as requiring the assumptions to be up-to-date and account for expected mortality improvement, could encourage pension plan and annuity providers to monitor their assumptions and assess their adequacy on a more regular basis.

The increased reliance on defined contribution pension arrangements has led to individuals running the risk of outliving their assets and not having an adequate retirement income throughout their retirement. In addition to encouraging increased pension savings for longer periods, protection from longevity risk should also be ensured through the purchase of annuity products for the payout phase which guarantee a certain level of income for life. However, the capacity for insurers to be able to continue to provide annuities to meet the need of longevity protection in society will have to be addressed.

While insurers can benefit to a certain extent from the diversification of longevity risk with the mortality risk coming from their life insurance business, this diversification is limited and they will face constraints in the amount of longevity risk they will be able to continue to accept.

Capital markets have the potential to offer additional capacity for longevity risk, but the transparency, standardization and liquidity of instruments to hedge longevity need to be facilitated. Index-based instruments address these issues by offering increased transparency and the ability to standardize the basic structure of longevity derivatives. However the regulatory framework will also need to reflect the reduction of risk exposure these instruments offer by ensuring they can be appropriately valued by accounting standards and lowering the level required capital for entities hedging their longevity risk. In addition, the issuance of a longevity bond or the publication of a longevity index to serve as a benchmark for the pricing and risk assessment of longevity hedges could greatly facilitate their eventual liquidity.

Ultimately, the ageing of the population and increasing life expectancy does not necessarily have to lead to significant negative financial consequences with respect to the financing of retirement. However the awareness and understanding of the dynamics of longevity risk needs to increase in order to implement appropriate solutions to address it, and the groundwork for these solutions needs to be laid soon in order to allow for a smooth transition to an older society.

Notes

1. *www.oecd.org/daf/fin/private-pensions/50582753.pdf*.
2. It is important to distinguish between the effective and the statutory retirement age. Increasing the statutory retirement age will only have a positive effect as long as it leads to an increase in the effective retirement age, which is generally lower. An increase in the effective retirement age even if the statutory retirement age remains unchanged will still help to partially offset the reduction in the workforce.
3. *The 2012 Ageing Report Economic and budgetary projections for the EU-27 Member States (2010-2060)* and *The 2012 Ageing Report: Underlying Assumptions and Projection Methodologies* by the EcoFin presents the latest projections on the fiscal impact on ageing population and the underlying assumptions. The impact of ageing on pension expenditure from 2007 until 2060 ranges from -2.2 percentage points of GDP in Poland to 9.4 in Luxemburg with an average increase of 1.5 percentage points of GDP for EU27.
4. The OECD Working Party on Private Pensions has recently released a Roadmap for the Good Design of Retirement Saving Pension Plans that includes contributing and contributing for longer periods, as well as combining deferred annuities with programmed withdrawals as part of the 10 recommendations (*www.oecd.org/finance/privatepensions/designingfundedpensionplans.htm*).
5. See also the *OECD Roadmap for the Good Design of Retirement Saving Plans*. Lump-sums withdrawals are when individuals withdraw a large portion of their accumulated assets immediately, whereas programmed withdrawals are regular withdrawals of a certain percentage of the accumulated assets in their accounts. Lump-sums withdrawals should be limited to avoid running out of money in retirement.
6. Mortality and life expectancy are two sides of the same coin. Decreasing mortality rates directly imply that people are living longer on average, and therefore that life expectancy is increasing.
7. The study assesses fifteen countries: Brazil, Canada, Chile, China, France, Germany, Israel, Korea, Japan, Mexico, the Netherlands, Spain, Switzerland, the United States and the United Kingdom.
8. Annuity values are calculated with a discount rate of 4.5%.
9. All calculations were made as at 2010, with the exception of the UK tables and the Swiss VZ2010 table for which calculations were as at 2012.

10. The SAPS2 table will replace the SAPS1 in the United Kingdom, and the United States RP-2014 table was not yet officially released for use at the time of analysis.

11. The tables used by German pension funds (Heubeck 2005 G) were not available so could not be assessed.

12. The results shown in the table list the country and the name of the standard mortality table used in the following format: **Country (*Standard Mortality Table Name*)**.

13. The quantification here is based on the present value of whole life annuities discounted at 4.5%. However, one needs to bear in mind that the discount rate used to value liabilities differs across countries. For the sake of the comparability and in order to isolate the impact of changes in mortality, the analysis herein assumes a common discount rate of 4.5%. Nevertheless it should be kept in mind that the valuation of liabilities is highly sensitive to changes in discount rates, and the underlying longevity risk is exacerbated in scenarios of low interest rates. In this context, we could expect that if the current scenario of low interest rates remains (*IMF World Economic Outlook*, Spring 2014, Chapter 3) the potential shortfall shown here would be underestimated.

14. The expected shortfall could not be reasonably assessed for Korea as the margins included in the table could not be determined, though given the high level of life expectancy assumed by the standard table, the 6th EMT, it would be classified as having little to no expected shortfall.

15. Chile is planning to update their mortality table in 2016, at which point they plan to set mortality improvement assumptions to be more in line with observed historical experience and the results presented here.

16. In the case of pension funds, there are additional sources of protection beyond the pension fund's own reserves. First, additional contributions can be made by sponsoring employers and plan members to cover a situation of underfunding. Second, the pension fund can have a residual claim on the plan sponsor's assets or access to a guarantee arrangement in case of sponsor insolvency. Third, benefits may be adjusted and renegotiated. These risk sharing features of pension funds vary across countries, but are generally distinct.

17. An example would be the use of stochastic modelling of mortality and life expectancy.

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