Mortality Assumptions and Longevity Risk

IMPLICATIONS FOR PENSION FUNDS AND ANNUITY PROVIDERS

OECD

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Foreword

This publication on mortality assumptions and longevity risk is part of the research and policy program of work of the OECD's Insurance and Private Pension Committee (IPPC) and, in particular, its Working Party on Private Pensions (WPPP). The OECD WPPP is an international body that brings together policymakers, regulators and the private sector of almost 40 countries to discuss issues related to the operation and regulation of funded retirement income systems.

The publication assesses how pension funds, annuity providers and the regulatory framework account for future improvements in mortality and life expectancy. The analysis then examines the mortality tables commonly used by pension funds and annuity providers against several well-known mortality projection models with the purpose of assessing the potential shortfall in provisions. Finally, the publication identifies best practices and discusses the management of longevity risk, putting forward a set of policy options to encourage and facilitate the management of longevity risk.

This publication was prepared by Pablo Antolín and Jessica Mosher of the Financial Affairs Division of the OECD Directorate for Financial and Enterprise Affairs. It has greatly benefited from the comments of national government delegates of the Insurance and Private Pension Committee (IPPC) and the WPPP. Delegates assisted in verifying the accuracy of the data and tables corresponding to their respective countries. All errors are solely the responsibility of the authors and by no means of the national authorities concerned. We would also like to thank Vincent Jalbert, Jacqueline Kucera, Jean-Francois Poels, Hector Rodriquez and Marie-Claude Sommer for their helpful assistance with some of the information presented. Manuel Aguilera, Chair of the OECD IPPC, Ambrogio Rinaldi, Chair of the OECD WPPP, and Juan Yermo of the Office of the Secretary-General also provided useful advice, support and valuable inputs to the project.

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Executive summary

This publication presents the results of the OECD project on mortality assumptions and longevity risk. The project looks first at the mortality tables typically used by pension funds and annuity providers to determine the amount of funding needed to meet future expected pension and annuity payments. These can be specific tables required by the regulatory framework or those most commonly used by practitioners. The study then assesses whether these standard mortality tables account for future improvements in mortality and life expectancy and looks at how those future improvements are included. In general annuity providers are found to account more often for mortality improvements in their assumptions than are pension funds. The analysis herein also provides details regarding the standard mortality tables and assumptions used in 15 countries.

The publication then examines the extent to which the assumptions included in the standard mortality tables expose pension funds and annuity providers to longevity risk. Longevity risk is the risk that future mortality improvements and life expectancy outcomes prove to be greater than assumed and reflected in provisions. Inaccurate or unreasonable assumptions can result in serious challenges for pension funds and annuity providers to keep pension and payment promises. The study assesses whether the assumptions for future improvements in mortality and life expectancy embedded in the standard mortality tables used are sufficient to account for the expected increase in longevity of pensioners and annuitants by benchmarking the assumed evolution in mortality with that which is predicted by four well-known models for projecting future mortality: the Lee-Carter, the Cairns-Blake-Dowd, P-Splines and the CMI mortality projection models. Conclusions based on the results of the analysis take into consideration the historical evolution of mortality in each country as well as the advantages and limitations of each model.

The results from the analysis show that failure to account for future improvements in mortality can expose pension funds and annuity providers to an expected shortfall of provisions of well over 10% of their liabilities. Likewise, the use of assumptions which are not reflective of recent improvements in mortality can expose the pension plan or annuity provider to the need for a significant increase in reserves.

Consequently, the discussion focuses on various approaches for pension funds and annuity providers to manage this potential impact of longevity risk. The first aspect the discussion focuses on is the need to account for the expected longevity risk by aligning the mortality assumptions used with reasonable future expectations. The second aspect looks at the potential financial impact of unexpected increases in longevity to determine whether this risk can be retained in light of any protection mechanisms which are in place, such as having a sufficient capital buffer, or should be mitigated with the help of reinsurance or capital markets.

Based on these discussions and the results of the analysis a set of policy options is put forth to highlight best practices in accounting and provisioning for future improvements in mortality and life expectancy as well as ways to encourage the management of longevity risk.

Key findings and conclusions

1. The regulatory framework should ensure that pension funds and annuity providers use appropriate mortality tables to account and provision for expected future improvements by establishing clear guidelines for the development of mortality tables used for reserving for annuity and pension liabilities.
   - Mortality tables should include the expected future improvements in mortality.
   - Mortality tables should be regularly updated to accurately reflect the most recent experience and avoid significant increases in reserves.
   - Mortality tables should be based on the mortality experience of the relevant population.
2. Governments should facilitate the measurement of mortality for the purposes of assumption setting and the evaluation of basis risk of index-based hedging instruments.
   - Accurate and timely mortality data should be publicly available.
   - Mortality data by a socio-economic indicator should be made publically available.
3. The regulatory framework should provide incentives for the management and mitigation of longevity risk.
   - Capital and funding requirements should be based on the risks faced in order to account for the specific exposure to longevity risk and allow institutions using instruments to hedge longevity risk to adjust their requirements accordingly. These requirements could be based on results from stochastic models which provide probability distributions.
   - Accounting standards should ensure the appropriate valuation of longevity hedging instruments.
4. Governments should encourage the development of a market for instruments to hedge longevity in order to ensure the capacity for pension plans and annuity providers to continue to provide longevity protection to individuals. Index-based products in particular have the most potential to address the misalignment of incentives between the hedging party and the capital markets investor. Governments could encourage this development by facilitating transparency and standardisation of longevity hedges.
   - A reliable longevity index could be developed to provide price reference and encourage liquidity and standardisation.
   - Over-the-counter standardised transactions could be brought into exchanges or electronic trading platforms and centrally cleared.
   - The issuance of a longevity indexed bond could be considered, though with care. While it may be helpful in kick-starting the market for longevity hedging instruments by providing standardisation, a benchmark for pricing and liquidity, it would also significantly increase the exposure of the government to longevity risk, to which many governments already have significant exposure on their balance sheets.

Demand for protection against longevity risk will only increase as individuals are expected to live longer, and the sustainability of pension funds and annuities 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 them to continue offering protection in the future.

Mortality Assumptions and Longevity Risk
Implications for Pension Funds and Annuity Providers

Chapter 1

Mortality assumptions used by pension funds and annuity providers

This chapter examines the mortality tables that pension funds and annuity providers use for valuing pension and annuity liabilities. The mortality tables commonly used comprise assumptions on mortality rates and future improvements that are the basis for accounting for the length of time pension funds and annuity providers are expected to make payments. The risk that future mortality improvements and life expectancy outcomes prove to be different than assumed in provisions is the longevity risk that pension funds and annuity providers may be exposed to. This would mean that they may have to make payments for longer than provisioned for.

Introduction: Longevity risk

Longevity risk is the risk that people live longer than expected or provisioned for. While longer lives are generally positive, living longer can also have significant financial implications, enough to qualify longevity as a major risk. At the individual level, this risk is generally taken to mean outliving one's retirement savings. But pension plan sponsors, pension funds and annuity providers are all exposed to longevity risk as well, as they are in the business of funding individuals' retirement and often promise to make payments for the lifetime of the individual. In other words, they accept and insure the longevity risk of the individual.

Plan sponsors, pension funds and annuity providers with liabilities contingent on longevity 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 accumulated and how long the payments will be made. Analogous to a discount rate being assumed to account for the time value of money, mortality rates must also be assumed to determine how long payments are expected to be made, as payments are usually paid until the death of the individual. If the individual lives longer than expected, more payments will have to be made than were provisioned for, which could leave the pension fund or annuity provider with insufficient funds to do so.

The uncertainty around mortality rates, and the potential shortfall in pension or annuity provisions from underestimating life expectancy, stem largely from the uncertainty as to how mortality will evolve and the future improvements in mortality rates.[1] Globally, life expectancy at birth has more than doubled over the last two centuries. For the countries examined in this paper, life expectancy for individuals aged 65 has increased by an average of nearly two months per year over the last decade.[2] Each additional year of life expectancy not provisioned for can be expected to add around 3-5% to current liabilities.[3] 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.

Nonetheless, mortality assumptions used to value pension and annuity liabilities are not always given the due attention they deserve. Regulation does not consistently acknowledge the need to account for improvements in mortality, and though in practice pension sponsors and annuity providers 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. Policy must ensure that mortality assumptions adequately reflect the mortality of the population for which they are used and encourage active assessment and monitoring of longevity assumptions by pension funds and annuity providers in order to avoid any unexpected increases in future payments related to the underestimation of longevity.

Background: Mortality assumptions and tables

Mortality assumptions used in the valuation of pension and annuity liabilities are usually found in the form of a table, with the probability of death over the next year, q_x, given for each individual age x. Usually, separate assumptions are made for males and females, though in some districts regulation requires unisex rates to be used.

Mortality tables can be one-dimensional, accounting only for the differences in mortality by age, or two-dimensional, accounting for the evolution of mortality over time. One-dimensional tables are referred to as ***static tables***, and have only a single mortality rate for a given age. For example, a 70 year old man could have a probability of dying before he turns 71 of 2.0%, regardless of whether he turns 70 today or next year or forty years from now. A ***generational table*** gives probabilities of death which change over time, so the 70 year old this year has a 2.0% probability of dying within the year, whereas a 70 year old next year would have only 1.96% chance of dying within the year, implying an annual mortality improvement of 2.0% from the previous year, i.e. $1-\frac{1.96\%}{2.00\%}$.

Occasionally, due to the operational constraints of valuation and projection systems, one-dimensional static tables are used with a margin which is meant to account for future mortality instead of the more complex two-dimensional generational table. For example, mortality rates could be projected 10 years in the future and these rates used for all years if the present value of liabilities is expected to be roughly equal to the calculation using a fully generational table. With the advances in technology, this approach is in general becoming less common.

Two components must be assessed in order to develop a fully generational table: the current level of mortality and the expected trend of mortality, often referred to as mortality improvement since mortality is generally expected to decline in the future.

The level of mortality is usually assessed on a limited number of recent years of mortality experience for a specified population, for example the population of pensioners in a given country from 1999-2001 to establish the expected mortality in 2000, the central year of observation.

Establishing assumptions for the expected mortality improvement requires significantly more data and is therefore more challenging to set, as many years of sufficient mortality experience are needed. As a result general population mortality is often used as the basis of mortality improvement assumptions.

Once mortality improvement assumptions have been established, they can then be applied to the initial mortality level to establish a generational table giving the mortality assumption at any future point in time. They are typically applied in the following manner, where here 2000 is the year for which the initial level of mortality was established and r the annualized rate of mortality improvement for age x:

$$q_{x,2000+t} = q_{x,2000}\left(1-r_x\right)^t$$

In practice r may vary over time, but most often only varies by age and gender.

Mortality assumptions in regulation and 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.[4] 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 1.1 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 that future improvements in mortality are accounted for in the valuation of 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.

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

Table 1.1. **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

Source: OECD
Notes: * 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

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 United States 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 United States 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

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.

Notes

1. 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.
2. The countries assessed include Brazil, Canada, Chile, China, France, Germany, Israel, Korea, Japan, Mexico, the Netherlands, Spain, Switzerland, the United States and the United Kingdom.
3. Based on the analysis presented in Chapter 5.
4. Chapter 2 provides a detailed description of the standard mortality tables used in each country.

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Chapter 2

Overview of countries' mortality tables

This chapter provides general details on the mortality tables used in each country. After briefly describing the pension systems, the chapter presents the regulatory and market practice mortality tables used in each country by pension funds and annuity providers. These mortality tables are the basis on which the longevity risk is assessed in the following chapters.

The country profiles contained in this chapter are meant to provide the context in which the standard mortality tables are used by pension funds and annuity providers. The explanations of these tables which are provided here form the basis for the analysis in later chapters regarding their adequacy. For each country, an overview of the pension system is given, followed by details regarding how the standard mortality tables were constructed and how they are used in practice.

Brazil

In contrast to the fundamental reforms of much of Latin America to mandate individual accounts for workers, Brazil has made more marginal reforms focusing on the safety-net aspects of the social security system to try to address the high rates of inequality within the society.

The retirement framework is currently composed of three parts:

- A general system, mandatory for private sector workers, which is managed by the federal government and financed through payroll taxes. It provides a safety-net social assistance benefit and a benefit linked to length of service. The first is payable to those exempt from contributing and those who contribute too little to qualify for the second.
- A system for public sector workers which is supported by contributions from workers and public employers and until recently was based on a defined benefit arrangement. These plans are now moving towards becoming defined contribution structures (Dias, 2006) and consolidated into a new type of entity.
- A complementary, voluntary system of open and closed plans. Open plans are established by pension entities or life insurance companies and offered to employers and to individual employees. Closed plans are not-for-profit entities established with the sole legal purpose of managing the administration of contributions and benefits for the employees of an employer, or of a group of employers. For covered employees, participation is voluntary (OECD et al, 2008).

Open and closed plans are supervised by different regulatory bodies. Closed funds are regulated by the National Superintendency of Complementary Social Security (PREVIC). At the end of September 2009, there were 372 closed pension funds with 475 billion reais (around USD 250 billion) in assets under management (Pension & Development Network). Open funds are supervised by the Insurance Supervisory Authority, an agency under the Ministry of Finance, and have total assets comparable to the corresponding assets in closed funds, amounting in July 2009 to 390 billion reais (a little over USD 200 billion) (Pension and Development Network).

Many closed plans are defined benefit in nature, under which benefits are usually integrated with the social security benefits through a form of benefit offset. Recently established closed plans, however, have more commonly been set up as defined contribution arrangements. Open plans are more commonly defined contribution than defined benefit in nature.

Life annuities are a payment option under both open and closed plans. The responsibility of the payment of annuities for open pension funds is taken by life insurance companies. However, with closed plans, the pension fund itself provides the annuity payment and assumes the risk of adequately funding future liabilities. For many open funds, annuitization is mandatory at retirement and the accumulated funds are usually used to purchase an inflation-indexed annuity.

Though Brazil does not yet have a well-developed life annuity market, several types of annuities are available in addition to life annuities, such as annuities certain paid out over a defined period of time or joint-life annuities continuing payments to a spouse or dependent in the event of death.

Mortality tables, regulatory requirements and market practice

Resolution CGPC/MPS nº 18 issued in March 2006 established that the mortality assumptions used to value liabilities within closed pension funds result in a life expectancy no less than that implied by the AT-83 mortality table, which is equivalent to the US 1983 IAM table, otherwise called the 1983a. This table is based on US individual annuitant mortality from 1971-1976. To establish the mortality rates for 1983, the rates established based on this time period were projected to 1983 using US white population experience over 1961-1965 to 1971-1976 (SOA, 1981). The AT-83 table does not make any allowance for future mortality improvement beyond 1983.

Beyond this minimum requirement, pension funds are free to set their own mortality assumptions with reference to a standard table, and are expected to set assumptions appropriate to the population for which they are being used.

In practice pension funds tend to make use of the AT-2000 table. This table is equivalent to the US Annuity 2000 table, which was issued in 1996. This table is an updated version of the 1983 IAM table which was projected to the year 2000 based on an older US improvement scale, and includes a safety margin of 10% (without this margin the table is referred to as the US Annuity 2000 Basic table). No mortality improvements beyond 2000 are allowed for in the table.

Insurers are free to set their own mortality assumptions. Market dynamics put some pressure on insurers to price competitively, though solvency rules require that the assumptions are appropriate for their business.

In practice insurers tend to use the US Annuity 2000 Basic table, or the AT-2000 Basic, with no allowance for future mortality improvement, though some insurers have begun to adopt independently developed tables which do allow for mortality improvements.

The industry has now begun to develop mortality tables based specifically on the Brazilian insured experience in an attempt to improve the appropriateness of the mortality assumptions being used. The BR-EMS table for annuitants developed in 2010 by SUSEP is based on Brazilian insurance experience in 2004-2006 (Oliveira et al, 2010). This data was obtained from a group of insurance companies representing 82% of the market. These tables remain static and do not make any assumptions regarding the future evolution of mortality. Nevertheless, the use of these tables in the Brazilian market seems limited for the time being.

Canada

The Canadian pension system is essentially composed of three main parts:

- The Old Age Security program providing means-tested pensions.

- The Canada Pension Plan (CPP) (or the Quebec Pension Plan, QPP) which is a state-run, mandatory earnings-related pension scheme that is financed solely through contributions by employees, employers and self-employed individuals (Service Canada, 2011).
- Voluntary occupational pension schemes, which may or may not be collectively bargained, and private pension savings.

Voluntary occupational pension schemes in Canada are typically defined benefit in nature, although the trend has been towards defined contribution.

According to OECD statistics at the end of 2007, 5.7 million Canadian workers were participating in employer-sponsored pension plans and about 4.6 million were active members of trusteed plans. Approximately 1.1 million workers were mainly covered by insured pensions (OECD, 2008).

Mortality tables, regulatory requirements and market practice

While there are no specific requirements for mortality assumptions used in Canada, pension regulation requires that liabilities be valued in line with the standards of the Canadian Institute of Actuaries (CIA), and regulators reserve the right to require reports to be refilled if they are judged to use inappropriate assumptions. In general assumptions are expected to be appropriate for the business and based on a review of industry tables and experience.

The CIA recommends that that best-estimate mortality assumptions (including the improvement scale) be used to fund pension liabilities, however the Uninsured Pensioner 1994 (UP-94) table with the American Scale AA improvements are used for most funding valuations. The UP-94 table is based on experience from 1986 to 1990 of the US Civil Service Retirement System, US Social Security, US Military Retirement System, the Public Service for Canada, as well as 24 private sector pension systems and on the US state pension system. If a static table is used for valuation, these improvements should be projected forward to a date beyond the valuation date reflecting the duration of the liabilities; otherwise a fully generational table projecting the improvements indefinitely into the future should be used.

The CIA regularly publishes annuitant experience studies to aid annuity providers in setting their mortality assumptions. In practice, the GAM-94 table is often used, which is equivalent to the UP-94 table with a 7% margin for random variation, or volatility, and variations in business mix such as socio-economic differences and geographic concentration. Scale AA was previously recommended for the improvement basis, but since 2011 the CIA has promulgated a new minimum improvement basis based on the experience of Canadian population mortality from 1921 to 2002 (Pelletier, 2011). For annuities, 150% of these rates should be applied to the GAM-94 table for the first 25 years from the valuation date, and 100% of the rates applied thereafter. These improvements are overall more conservative than the Scale AA, and do not vary by gender. Providers also typically apply an additional margin on the base mortality rate between 2% and 8%.

In 2008, the CIA commissioned a study to develop the first generational mortality table based on pensioner mortality experience in Canada. The first study was based on pensioner data from the CPP and QPP pension plans. The second phase of this project established an initial level of mortality based on data from 2005 to 2007, and the third phase published at the end of 2012 included recommendations of a projection scale to be applied based on experience from 1967 to 2007 (Louis, 2012). These improvement assumptions vary by gender, with the short-term rates reflecting the higher improvements experienced since 1992 gradually decreasing to expected long-term rates. Income class was found to be a significant variable in the resulting mortality rates, therefore separate base mortality rates were established for the various income classes as well.

The second study commissioned by the CIA was to develop a mortality table based on a subset of the mortality experience of Canadian Pension Plans (RPP Study). This study relied on mortality experience from 1999 to 2008. Separate tables were developed for public and private sector plans, and adjustment factors were included to account for the size of the pension. The improvement scale was developed based on the C/QPP study as well as the assumptions used in the 26th CPP Actuarial Report, and varies by age, gender and duration; however a scale which varies only by gender and age was also developed to offer the option for simplified calculations in the transition to the new table.

Chile

In the early 1980s, Chile was the first country to launch a system of mandatory individual retirement saving accounts for all workers. The system has developed in a number of ways since then, not least in its annuity markets, and the level of assets invested in pension funds is now comparable with some of the most advanced pension systems in the world.

Individual retirement savings is complemented by a social security safety net that has recently been extended to provide improved protection.

Pension fund administrators (*Administradora de Fondos de Pensiones,* AFP) accept the contributions of workers and manage their assets in the individual accounts during the working phase. At retirement, system participants are granted a range of choices:

- a partial lump sum if the individual has sufficient savings for the remaining balance to finance a pension at least as great as a stipulated threshold
- a programmed withdrawal from the account, with income determined by a fixed formula taking into account life expectancy,[1] in which case the worker accepts the investment and longevity risk, but retains the option to switch to a guaranteed annuity at any time
- a temporary withdrawal lasting for a fixed number of years combined with a deferred guaranteed annuity
- a guaranteed immediate life annuity, though if the resulting annuity does not exceed the basic solidarity pension, the individual must take a programmed withdrawal
- a combination of a programmed withdrawal and guaranteed annuity

Variable annuities are also allowed as an option since 2004, but the regulation of these products has not yet been published so they are not yet available on the market.

All guaranteed annuities are payable in inflation-linked units of currency, with values specified by an independent entity.

Annuities are not provided by the AFP itself, rather the funds accumulated in the AFP are used to purchase an annuity from a registered insurer, and individuals do so with the assistance of a centralised quotation system (*Sistema de Consultas y Ofertas de Montos de Pensiones,* SCOMP) under which providers post quotes. Retirees are free to choose the quote that best meets their needs but are nudged towards those offering the best price.

Individuals may also contribute to voluntary savings accounts offered by financial intermediaries. Voluntary savings can also be transferred to the mandatory accounts to increase retirement income (Shelton, 2012).

The market for annuities is competitive, with strong evidence of sophisticated risk analysis and providers seeking to price to meet their preferred profile of customers, subject to the constraints of the expected mortality profile (Rocha & Thorburn, 2007).

Mortality tables, regulatory requirements and market practice

For the purposes of determining the technical reserves, Chilean annuity providers are required by law to utilise the mortality tables specified by the SVS. The most recent table is the RV-2009, which is based on Chilean pensioner experience from 2002-2007 (SP & SVS, 2010). The mortality tables distinguish between males and females and are produced separately for healthy pensioners, their surviving beneficiaries and recipients of special annuities for the disabled. Improvement factors by age and gender are also defined based on CELADE projections of the Chilean population, and are meant to be applied indefinitely into the future. Base mortality rate include a security margin of up to 3%.

The tables are updated on a regular basis, following a review of the annuitant mortality experience, and are republished approximately every five years. The methodology to derive the discount rates used for these calculations is also specified by the SVS and is based on long-term government bond rates.

In addition to the protection provided by the margins in the mortality rates specified by the supervisory authority, additional solvency capital must be held to protect annuitants against unanticipated variations in experience.

Annuity providers in Chile are free to use their own mortality assumptions to price products, producing a vibrant, competitive market with a range of individual factors being taken into account in the pricing. However, there are restrictions on the factors used. While providers may take into account age, gender and the relationship to the original annuitant (for example a surviving spouse), they may not price on the basis of the health of the annuitant, except in the case of those who have been certified disabled.[2]

China

China's social security system includes a basic pension and mandatory individual accounts for employees of urban enterprises. Self-employed workers in urban areas are also required to participate in the individual accounts, but in practice, participation is low. As of 2005, coverage of workers in urban areas for these types of accounts was 42%. At retirement, the accumulated funds in the individual accounts are paid out as annuities (IOPS country0020profile, 2011).

As a complement to the basic state pension and individual accounts, there are two main types of voluntary pension options: enterprise annuities and commercial insurance. Most enterprise annuity plans pay their benefits out as lump sums, whereas most insurance products give policyholders the option of receiving an annuity.

The China Insurance Regulatory Commission has recognised longevity risk as a potentially significant systemic risk. However, the regulation is not currently developed to the point of being able to take longevity risk into account. There has not been much analysis of the appropriateness of the current level of provision for longevity risk in the industry as a whole.

Mortality tables, regulatory requirements and market practice

The mortality table used in practice by life insurers and plan sponsors is called the CL(2000-2003) table. This table was created by the China Insurance Regulatory Commission with the assistance of the Chinese Association of Actuaries. It was completed in November 2005 based on the experience of approximately 100 million policies collected from 2000 to 2003 from the Chinese life insurers China Life, China Pacific Insurance Company, Ping An, New China Life, Tai Kang Life and AIA. The table is intended to be used from 2006 to 2015. The CL(2000-2003) table contains separate rates for non-pension business and for pension business. No allowance for future mortality improvement is made.

Insurers determining their solvency positions must comply with the following requirements:

1. Businesses other than whole life annuity should use 100% of the non-pension life table.
2. The whole life annuity business is required to use the maximum of 80% or 120% of the pension life table.

The CL(2000-2003) table is typically used by corporate pension plan sponsors to determine their accounting obligations.

Insurance companies are allowed to use their own assumptions when pricing annuities, and typically base their assumptions on the standard table with adjustments to reflect each insurer's particular experience.

France

The pay-as-you-go state pension system is the main source of retirement financing for most French people. However, there are two mandatory occupational schemes which complement the state pensions – ARRCO for workers and AGIRC for management – which are also financed on a pay-as-you-go basis. In addition, collective bargaining determines membership to a PERCO scheme. PERCO schemes can be either defined contribution or defined benefit in nature and benefits can be paid out as annuities or lump sums. Personal annuities may also be purchased by individuals on a voluntary basis.

Given the large role of pay-as-you-go pensions in France, the annuity insurance market is small relative to some other countries (Rusconi, 2008).

Mortality tables, regulatory requirements and market practice

Regulation in France imposes a mortality table which must be used as the minimum basis for valuing pension and annuity liabilities. The latest table is the TGH/TGF 05, and is based on the experience of approximately 700 000 annuities in payment and 1.3 million deferred annuities over the observation period of 1993 to 2005. The tables were developed on a cohort basis, and reflect future improvements in longevity based on the improvements experienced by the general French population between years 1962 and 2000 (Tassin, 2007).

Since 2007 these tables are also required as a minimum basis for the pricing of annuities, though as with valuing liabilities, alternative mortality assumptions are allowed to be used as long as they are no less conservative than this table.

Germany

Since the German pension system was reformed in 2001, German employees have had a legal right to deferred compensation. Benefits provided by German occupational pension plans are defined benefit. Employers have five options to finance these occupational schemes:

- Direct commitments, which are funded on a book reserve basis with the employer acting as the pension institution.

- Support funds, which are non-autonomous funds which offer no direct entitlement to the employee and may be not fully funded due to tax reasons.
- Direct insurance, where the employer purchases pension coverage from an insurance company on behalf of the employee.
- Pensionkassen, which are similar to insurance companies set up specifically to provide pensions for one or several employees.
- Pensionsfonds, which are separate entities set more like a mutual pension fund association.

Since 2002, individuals have also had the option to purchase Riester pension products. These products are mostly offered by life insurance companies, banks and other credit institutions, capital investment companies and financial service providers. They take the form of private annuity insurance, bank savings plans and investment fund savings plans.[3]

Occupational pension benefits are generally paid out as a lump-sum or as a life annuity. Riester pensions can be paid out as a life annuity or a programmed withdrawal, with a maximum of 30% of the capital available to be taken as a lump-sum.

Historically, the commercial German annuity market has been relatively small. Occupational schemes have traditionally provided life annuities. Demographic changes have put pressure on the state pension, which led to the introduction of the Riester pensions. Since this time, the commercial annuity market has grown significantly.

The market concentration of insurers in Germany is generally somewhat lower than in other parts of Europe, France and the United Kingdom. Annuities make up a relatively small proportion of total insurer premiums.

Mortality tables, regulatory requirements and market practice

There are no commonly used mortality tables for regulated Pensionskassen and non-insurance oriented Pensionsfonds. A couple of institutions for occupational retirement provision (IORPs) use the Heubeck 2005 generational tables, which were created by the firm Heubeck AG and are based on the experience of German employees. Generally the table is modified according to the mortality rates observed for the respective IORPs. The Heubeck 2005 generational tables are updated when considered appropriate, but not on a regular basis. The most recently published Heubeck tables were published in 2005 and are based experience from 2002 to 2004 (JP Morgan Pension Advisory Group, 2008).

The DAV 2004 R, produced by the German Institute of Actuaries, is prescribed by the supervisor to be used for the valuation of the liabilities of life insurers, non-regulated Pensionskassen and insurance oriented Pensionsfonds unless actual mortality experience differs significantly. As a result of local GAAP principles and competition, these tables tend to be used for pricing as well.[4] The DAV 2004 R was based on the experience of the insured population from 1995 to 2002. Improvement assumptions are age and gender specific and are expected to be applied indefinitely. Initial mortality trend assumptions were based on the German population experience from 1995 to 1999, with this initial trend converging to a target trend based on the 75% of the German population experience from 1972. These improvement assumptions are loaded by an additional 0.2% annually to reflect the expected differences between the insured and general populations (Pasdika, Wolff, 2005).

The DAV 2004 R table is a 1st order table containing extra provisions for adverse deviation and parameter risk. This table was derived from a 2nd order table reflecting best estimate assumptions. Both types of tables provide aggregate rates reflecting the mortality of all experience combined, as well as select tables which reflect lower mortality in the years immediately following the commencement of payments in order to account for anti-selection effects. Regulation forbids the use of best estimate assumptions for valuation purposes, requiring the more conservative 1st order assumptions. These tables are reviewed every four years.

Israel

Since 2008, contributions to defined contribution pension funds have been required to complement the state pension, which pays a universal old age insurance pension as well as a means-tested income support. Contribution rates were initially set at 2.5%, but have increased to 15% in 2013, with a third of this being paid by the employee and two-thirds by the employer.

The majority of insurance savings plans sold in Israel include a guaranteed annuity option (GAO) to convert accumulated savings into an annuity at a guaranteed rate. These types of guarantees offered a wide variety of options before 2001. Since then these guarantees have been restricted to apply only to single life annuities payable for 20 years certain and thereafter for life. Since 2013, the minimum age at which an individual can purchase an annuity with a GAO is age 60 in an attempt to further limit the risk of these options for the insurance company. The insurance company, however, does not typically bear the investment risk once the annuity payment begins. This risk is borne by the annuitant, with the insurance company only retaining the longevity risk (Raphael, 2012).

Mortality tables, regulatory requirements and market practice

The Israeli government actuary publishes mortality tables which are required to be used by insurance companies and pension funds for pricing and valuation. These tables are based on the mortality experience of Israeli pension funds and are updated every few years, the latest being based on experience from 2006 to 2010. Since 2001, the tables have included future mortality improvement based on the experience of the Israeli population. The most recent tables were adopted by all pension funds and insurance companies at the end of 2012.

Separate tables are published for active lives and pensioners and for pension funds and insurance annuities. Additional tables are also provided for white collar and blue collar pensioners, as well as tables applicable to the second life receiving payments after the death of the first life.

Future mortality improvements are specific by age and gender, with separate rates for the best estimate assumptions and those used for reserving. These latter assumptions are more conservative and are based on a long term improvement rate of 1% for females and 0.75% for males. There are also specific improvement rates for the 'golden cohort' of males born between 1929 and 1945. Cohort tables are not produced for females.

Japan

The public pension system in Japan is comprised of a basic flat pension and Employee Pension Insurance, an earnings related component.

Voluntary occupational plans take several forms (Pension Funds Online). Termination indemnity plans are the most common type of occupational pension plan in Japan. These plans are based on a book reserve system and are typically not funded outside the employer.

They generally offer a lump sum upon termination of employment or retirement which is often determined based on the length of service and position within the company.

Employees' Pension Funds (EPF) are defined benefit schemes provided by employers which can be partially used as a substitution for benefits from the Employee Pension Insurance (EPI). Complementary pension benefits can also be offered under these plans. Benefits replacing the EPI must be paid out as annuities, as well as at least half of the additional benefits. The plans can be managed in-house or contracted out.

"Fund-type" and "contract-type" defined benefit corporate pension plans are typically managed by an independent entity, though fund-type plans may be managed by the employer.

Defined contribution plans were introduced in 2001 and are managed by the public National Pension Fund Association when not contracted out to a pension management organization by an employer. Benefits are commonly paid out as lump sums.

Tax Qualified Pension plans were typically funded by employers and could pay benefits as a lump sum or an annuity, but were phased out in March 2012 due to underfunding.

Japan has a rapidly aging population, though the demand for life annuities remains limited. Available annuity products tend to be seen more as investment vehicles and so annuities certain tend to be more popular. The products are for the most part provided by insurance companies.

The variable annuity market in Japan rapidly expanded from the early 2000's, with products often containing complicated guarantees. The recent financial crisis hit annuity providers severely, as the expensive nature of the guarantees became apparent. As a result, several high-profile annuity providers have exited the market or suspended their operation for a time as the appetite for risk-exposed products has been dampened by the financial crisis (Towers Watson, 2009).

Mortality tables, regulatory requirements and market practice

The EPI mortality tables are developed for pension schemes using census data, taking into account the experience from the public Employees' Pension Insurance. They are updated every five years.

The funding regulatory framework for pension schemes requires the EPI tables to be used with the factors multiplied by 90-100% for males and 85-100% for women. Multiples less than 100% would be used for schemes that wished to load their provisions for future improvements in longevity. In practice, schemes tend to use the EPI tables with no load for future longevity increases. For wind-up valuations, schemes must use the EPI tables multiplied by 95% for males and 92.5% for females.

For accounting, scheme sponsors must use their best estimates. In practice, they use the EPI tables without any adjustments. Often, male rates will be used for both males and females if the effect is not expected to be material.

The standard mortality table for annuitants is issued by The Institute of Actuaries of Japan with the entrustment of the commissioner of the Financial Services Agency who inspects the table. The latest of these tables is called the SMT 2007 table. Individual life insurance companies can decide whether or not to use the table as the basis for calculating contribution rates.

The SMT 2007 was developed based on the population census for 2000 (19^{th} mortality table) with a factor of 85% applied to this population mortality to account for the risk margin. While the table is static, it includes an additional load for future mortality improvements which was determined based on actual mortality improvements from 1980 to 2000 by gender, five-year age groups and cause of death.

Korea

Private sector employers in Korea must provide their employees with a Retirement Pension Plan (RPP) which can be defined benefit or defined contribution in nature or a Retirement Pay Scheme (RPS) which is defined benefit in nature. Benefits paid from an RPP can be paid out either as an annuity or as a lump sum. Benefits paid out of an RPS must be paid out as a lump sum.

Defined benefit plans are currently dominant in Korea. Most of the manufacturing industry offers defined benefit, whereas defined contribution plans are more prevalent in financial institutions.

Annuities can be provided by banks, insurance companies and securities firms.

Insurance-provided annuities have only existed in Korea since 2005, and are therefore still gaining in popularity. As such, longevity exposure in Korea is relatively limited for the time being.

Mortality tables, regulatory requirements and market practice

Korean regulation does not mandate the use of particular mortality tables. However, regulations specify that the tables used must be credible and must meet certain specifications as to the size of the backing data and the time period of collection.

The standard experience mortality tables are the EMT tables. The 6th EMT mortality table was produced for both insured and annuitant lives based on data from 2003 to 2005. These tables have been updated every three years since 2010. These tables are typically used by annuity providers and corporate sponsored pensions, and contain separate rates for annuity providers for the period before and after annuity payments begin, as well as separate rates for corporate-sponsored pensions. The table for annuity providers was created in 2009 based on the experience of insured lives and the corporate table was created in 2009 based on the experience of all sponsored corporate pension schemes.

The standard tables are static, although they do contain significant margins which could account for future longevity risk. Life insurers often use the standard tables modified to reflect their own experience.

Mexico

The Mexican pension system broadly follows the Chilean model. The Social Security Law of 1995 brought into existence the system of mandatory private pensions for private companies' workers and defined the regulation of the relationship between the publicly managed social security system and its successor, the individual account system.

This law was followed in 1996 by the Retirement Savings Systems Law that established all of the elements of the new system, the regulatory and supervisory agency of pension funds (CONSAR, *Comisión Nacional del Sistema de Ahorro para el Retiro*), the retirement fund administrators (AFOREs, *Administradoras de Fondos para el Retiro*) and the investment funds for retirement saving (SIEFOREs, *Sociedades de Inversión Especializadas de Fondos para el Retiro*).[5]

All covered individuals must become a member of a mandatory private pension scheme, which is defined contribution in structure. The fund is run by an administrator, a registered AFORE, which sets up and manages the assets in investment funds registered for this purpose, the SIEFORE. Contributions are accumulated in individual accounts. Benefits are paid largely as guaranteed annuities, and all annuities are payable for life and are linked to inflation.

Additionally, in 2007 the Social Security Institute for State Employees Law was introduced which expanded the individual account system for State Employees affiliated to the Social Security Institute for State Employees (ISSSTE).

As in Chile, however:

- workers under the Old Age Insurance have some flexibility to take a programmed withdrawal, in which case they retain the investment and longevity risk
- workers may elect a combination of programmed withdrawals and guaranteed annuities
- programmed withdrawals are mandatory for those workers retiring with savings insufficient to fund a reasonable level of pension
- the formula used to determine the maximum income benefit under programmed withdrawals references life expectancy
- the rest of non-disabled pensioners must select an annuity provider which offers them guaranteed annuities

Although individual saving for retirement has now been mandatory for some time, pension funds and the regulation which supports them still exist. The individuals who contributed to the old system have the option to receive benefits under this system or to use their savings from the individual accounts.

Private pensions outside of the mandatory social security system are offered by entities authorised to provide life insurance. Guaranteed annuities, however, are provided only by registered insurers.

Mortality tables, regulatory requirements and market practice

No minimum requirements for mortality assumptions are imposed on corporate plan sponsors, who typically rely on the EMSSA97 table. This table is based on population mortality experience and in practice is typically improved to 2011 for males and 2013 for females based on projections by CONAPO from 1990-2030.

Generational mortality tables are imposed on annuity providers for the valuation of their liabilities. These minimum tables for the purpose of valuing liabilities for non-disabled pensioners are called EMSSAH-CMG-09 and EMSSAM-CMG-09 and were updated in 2009 based on data provided by IMSS and ISSSTE rather than population data. Future mortality improvements in these tables are specified by age and gender.

Insurers generally price their annuity products using their own set of assumptions, though they have been free to do so only since August 2009. The insurers frequently use the generational 2009 tables listed above for non-disabled pensioners. These tables are updated from time to time in an effort to ensure that they appropriately reflect up-to-date experience of mortality rates.

The Mexican regulatory framework includes an additional level of provision for improvements in longevity above and beyond those already included in the standard tables in their financial reporting or in their embedded value metrics, and are required to hold an additional reserve of 2% to cover the possibility of unexpected demographic experience. However, an additional load would not typically be applied for pricing or solvency purposes.

To provide additional production to policyholders, regulation has also set up a special fund to assist insurers in the case that an external event, such as a financial market upheaval or demographic experience deviations, threatens the ability of the insurer to meet its obligations to the policyholder.

Netherlands

The pension system in the Netherlands has two main pillars, the first being a flat rate public scheme and the second occupational plans. Occupational schemes, typically sponsored by employers, cover 91% of employees. These plans are not required by law, however can be seen as quasi-mandatory.

The private pension system consists of 656 pension funds as of the end of 2008, 550 single-employer plans and another 46,000 schemes operated by insurance companies for smaller employers. Approximately 90% of employees are covered by defined benefit schemes, with the remaining having defined contribution schemes. For the vast majority of participants in the DB schemes, benefits are based on lifetime average earnings.

These two pillars may be complemented by voluntary annuities bought by individuals (OECD, 2008).

Mortality tables, regulatory requirements and market practice

Pension plans and insurance companies providing annuities are required by law to account for the expected future trend in mortality for solvency, minimum contributions, accounting and premium setting purposes.

No specific table is required by law, but common practice is to use the table produced by the Dutch Actuarial Association, the Actuarieel Genootschap (AG), with adjustments by age to match specific portfolios where deemed appropriate. The AG publishes generational tables for males and females every two years which contain projections for future mortality for the Dutch population. The latest generational tables published in 2010 are based on Dutch population data from 2007 to 2008, and combine a higher short term trend based on experience from 2001 with a lower long term trend based on experience from 1988. The tables are projected to the year 2060.

The AG also publishes one-dimensional period tables annually, and the CBS (Statistics Netherlands) publishes generational tables every two years.

Peru

Peru launched a system of individual accounts, broadly following the Chilean model, in the early 1990s, though the legislative framework establishing and regulating pension fund administration followed only in 1997. Participation in the defined contribution system is automatic but workers may opt out of participation as long as they indicate their preference to do so in writing.

Participants must indicate their preference for one of the pension fund administrators (AFP, *Administradora privada de Fondos de Pensiones*), which are licensed and regulated by the banks, insurance and pension funds regulator (SBS, *Superintendencia de Banca, Seguros y AFP*). Among the countries studied, this is the only instance of a single regulator covering both pension fund administrators and insurers.[6]

Options that individuals have at retirement are similar to those in their Spanish-speaking neighbours and include:

- programmed withdrawals from their individual accounts based on tables provided by the regulator, in which case the AFP continues to manage the accounts
- guaranteed annuities from registered life insurance companies
- a temporary withdrawal from the individual account combined with a deferred annuity from the insurance company.[7]

Annuities, however, are available in a number of variations not available in other countries. They can be linked to inflation, increasing at a pre-defined rate, or payable in either Peruvian soles or United States dollars.

Mortality tables, regulatory requirements and market practice

Since 1993, Peru has required the use of Chilean mortality tables for determining the solvency position of annuity providers. A resolution in 2006 approved updating the table from the outdated RV85 to the newer RV-2004, and in 2010 a new resolution required the use a version of the RV-2004 table modified and adjusted to Peruvian experience. The legislation, however, does not impose that the mortality improvement factors be applied, though in practice there is some evidence that pension plans and annuity providers are applying the Chilean AA factors specified for the RV-2004.

Insurers are permitted to use their own assumptions, mortality and discount rate, to price annuities. They compete freely for customers on the basis of price, providing a wide range of choices on product and on price. There are no differences in the tax or accounting treatment of providers as they are registered under the same legislation and subject to uniform requirements.

Spain

Occupational pension plans in Spain are typically defined contribution in nature. However, approximately one-third of plan members belong to occupational plans that are both defined benefit and defined contribution in nature. A small number of plans, mainly for the banking industry, are defined benefit and are externalised through pension schemes or insurance contracts.

Pensioners in Spain can choose to receive their benefits as annuities or as lumps sums. According to OECD statistics, as of 2006, approximately 22% of benefits were payable in annuitized form. Around 8% of the active population is covered by these plans (OECD, 2008).

Mortality tables, regulatory requirements and market practice

The mortality tables used by pension plans and annuity providers must be based on local or foreign experience that is no more than 20 years old at the valuation date and projected using recognised actuarial techniques that result in a mortality rate which falls within specific defined confidence intervals. The PERM/F 2000 tables are recommended by the private insurance supervisor, with separate rates applicable for policies in force as of 1 November 2000 and those issued after that date. The PERM/F 2000 tables are generational and were created based on the experience of the Spanish population in 1990 with an adjustment to reflect the mortality of the insured population based on the differences observed in Switzerland (Mateos-Aparicio Morales, 2010). Another alternative is to use tables that are based on the actual experience of the pension plan population, though strict conditions are imposed (Pugh, 2006 and la Dirección General de Seguros y Fondos de Pensiones, 2000). The PERM/F 2000 tables are typically used in practice.

Before the PERM/F 2000 tables were introduced it was common to use Swiss mortality tables such as GRM/F 80, GRM/F 80-2 and GMR 95. However, the legislation that introduced the PERM/F 2000 tables specifically disallowed the use of these tables.

Switzerland

A mandatory occupational pension system, financed via pension funds, was introduced in 1985. Swiss law requires that, at a minimum, employers should provide a cash-balance plan (Berufliche Vorsorge (BVG) or Prévoyance Professionnelle (LPP)).

Employees whose annual earnings exceed CHF 19 890 with the same employer are required to join the pension fund established by their employer. The system is voluntary for self-employed persons and those not eligible for mandatory insurance (OECD, 2008).

According to statistics from the CP and FINMA, assets in Swiss pension funds amounted to CHF 812 billion in 2012. The Swiss system is, however, so dominated by the occupational environment that insurer-provided products form a relatively small part of the system (Rusconi, 2008).

Mortality tables, regulatory requirements and market practice

The 2006 Insurance Supervisory Act allowed insurance companies to use their own experience to create mortality tables. However, the tables need to be adjusted to reflect new data at least every ten years, and must be seen as sufficient if used to write new business. Currently, most life insurers use ERM/F 2000 generational mortality tables for their premium-setting. The Swiss private insurance industry has a history of accounting for improvements in mortality, and has included some form of mortality trend in their assumptions since 1960 (Swiss FDF, 2003).

Swiss occupational pension funds rely on a number of standard mortality tables, though they usually adjust these tables to their specific needs based on their own experience. Historically, standard tables have not provisioned for future longevity increases, though the newest of these tables are generational, such as the BVG 2010 and VZ 2010 tables. The BVG 2010 table was created based on the experience from 2005 to 2009 of fourteen large autonomous occupational pension funds that cover approximately 1.2 million active participants and 750 000 pensioners (BVG, 2010). The tables are meant to replace the previous BVG/LPP 2005 tables which are commonly used for Swiss occupational plans. Another recently developed generational table is the VZ 2010, based on the mortality experience of 21 funds between 2006 and 2010. Two projection methodologies are provided with this table, the first being Nolfi factors, giving constant improvements by age over time, and the second based on a study performed by Methonnex on the Swiss population (Menthonnex, 2009). This latter methodology is the same that is typically employed for the BVG 2010 table. An older static table whose use is declining is the EVK 2000 table based on experience by the Federal Insurance Fund. The law prescribes that sufficient technical reserves must be built up in order to guarantee the provision for actual and future retirees, particularly in the case for the application of tables such as the EVK where a supplementary provision is necessary. Each pension fund calculates the necessary resources according to their insured population on the calculated capital resources necessary to finance actual and future pensions.

United Kingdom

The United Kingdom has a long history of occupational pension plans. Traditionally these plans have been defined benefit in nature, although recent years many have been closed and converted to defined contribution, in part to limit longevity risk. Occupational pension plans pay out their benefits as annuities to their pensioners. Occupational defined benefit plans typically pay these out of their pension plan assets, unless insurance has been purchased to cover the liabilities.

On the supply side, the United Kingdom has the largest insurance annuity market in the world. There is a wide and diversified variety of immediate life annuity products sold by insurers, supported by both defined benefit schemes seeking to de-risk their longevity risk exposure and by defined contribution pension schemes which effectively required, until March 2014, the annuitisation of member account balances at retirement (Rusconi, 2008).

Longevity risk and other risks associated with defined benefit plans have been the subject of heated and extensive debate in the United Kingdom. Risk transfer mechanisms such as buy-outs, buy-ins and longevity swaps have become prominent in the United Kingdom market.

Mortality tables, regulatory requirements and market practice

The Pensions Regulator has issued guidance for trustees and sponsoring employers on the use of mortality tables, but there are no specifically prescribed tables. Rather, pension schemes and annuity providers must use their best estimate or prudent assumptions depending on the particular purpose of the valuation, and are required to account for the expected future trend in mortality.

In practice, corporate plan sponsors and pension plan trustees tend to use the tables called the Self-Administered Pension Scheme (SAPS) tables series 1 for funding and accounting purposes. These tables were published in 2008 by the Continuous Mortality Investigation (CMI) which is supported by the UK's actuarial profession. The tables were created based on pooled experience from 2000 to 2006 of UK pension schemes with over 500 participants. The tables have separate rates for healthy and disabled members. Also, the tables have different rates that may be applied for members with benefit amounts that are low or high. The benefit amounts are meant as a proxy for various determinants of mortality and users must consider their appropriateness (CMI, 2009). The CMI mortality projections models are generally applied to the tables which would typically imply a long-term future rate of improvement 1.25% to 2% depending on the purpose of the calculation.

The updated SAPS table series 2 based on data from 2004 to 2011 was published in early 2014 and is expected to replace the table series 1.

UK insurers tend to use slightly older tables for their reserving and premium-setting. The typical table is the PCMA/PCFA 2000 tables published in 2006 and based on the experience of UK insurance company annuitants from 1999 to 2002. The tables have separate rates for smokers and non-smokers and for individuals in early or normal retirement. As with pensions, the tables tend to be used with the CMI mortality projections.

United States

The United States has a wide variety of occupational and personal pension arrangements. Occupational pension schemes can be defined benefit, defined contribution or hybrid. Public sector pension schemes tend to be defined benefit in nature. Historically defined benefit pension schemes were the norm in the private sector as well, but these have been surpassed by defined contribution schemes. The most popular defined contribution arrangement is the 401(k) plan, from which accumulated assets may be paid out as a lump-sum, via programmed withdrawals, or in some cases used to purchase an annuity.

Defined benefit plans typically give the option to take a lump sum or receive an annuity. Defined contribution plan members in the United States are not required to annuitize, and if given the option, lump sum distributions are by far more popular. Annuity products sold by insurance companies are unpopular for a number of reasons such as the members' fear of losing control of their pension savings, the inability to bequeath to children and non-transparent pricing (Orth, 2006). Therefore, although the United States has a significant market for insured annuity products this market is small relative to the size of the economy and in comparison to, for example, the size of the market for insured annuities in the United Kingdom (Rusconi, 2008).

Mortality tables, regulatory requirements and market practice

Since 2008, the US Internal Revenue Service has prescribed mortality tables and interest rates that are required to be used for purposes of minimum funding in defined benefit plans. The mortality tables are based on the RP2000 table, with separate tables for periods before and after payments are expected to begin. The RP2000 tables are based on the experience of uninsured pension plans from 1990 to 1994. Mortality improvements are also required to be taken into account, with plan sponsors permitted to choose between generational tables projected using Scale AA, or static tables with a projection using Scale AA for 7 years beyond the valuation date for participants in pay status and 15 years beyond the valuation date for participants not yet in pay status (72 FR 29456, May 29, 2007, at *www.federalregister.gov*). Similar interest rates and unisex mortality assumptions also apply for the purposes of converting a plan participant's accrued DB plan benefit to a minimum lump sum.

The Scale AA mortality trend which was developed with the RP2000 table was based on social security data from 1977 to 1993. In 2012 the Society of Actuaries issued an updated mortality improvement scale for pensioners, termed Scale BB, which was developed based on experience through 2007 and established using techniques similar to the CMI model using a long term improvement assumption of 1%. These resulting improvements were converted into age specific mortality improvements so that they may be applied to the RP 2000 in the same manner as Scale AA with no modification to projection systems. This scale is meant to provide interim assumptions while the SOA worked on a replacement for the RP2000 and Scale AA assumptions. However the extent to which this interim Scale BB has been adopted for use by pension funds is not clear.

The RP2014, an update to the RP2000, was published in October 2014 and includes generational improvement assumptions which vary by age, gender and duration. This table along with its projection scale MP2014 is expected to replace the use of the RP2000 with Scale AA/BB.

For purposes of valuing terminating pension plans, the Pension Benefit Guaranty Corporation (PBGC) uses the GAM-94 with a static ten-year projection beyond the valuation year using Scale AA. This regulatory requirement came into effect in 2006 and was meant to bring the PBGC valuation requirements in-line with the private sector pricing of group annuity products. Premiums owed to the PBGC are based on the RP2000 mortality table.

A survey made on behalf of the PBGC in 2002 concluded that five of ten insurers surveyed used the GAM-94 table to price their group annuity contracts, and six of the ten at that time included no provision for future longevity improvements. Those which included improvements used the Scale AA (PBGC, 2005).

Since that time, insurers have strengthened their mortality assumptions. Currently, they tend to use GAM-94 generational tables incorporating the Scale AA. Adjustments may be made to allow for experience differences based on such factors as state of residency, type of industry or salary levels.

The GAM-94 tables are the same as the tables called UP-94 (which are in broad use in Canada), but with a 7% margin for conservatism. UP-94 was initially planned to be based on uninsured pensioner experience from 1985-1989 and GAM-94 was based on group annuitant experience from 1986 to 1990. When the data in the two mortality tables were compared, it was found that the data was similar, so the same rates were adopted for the two tables. As GAM-94 was intended for insurance reserving, the 7% margin was added for conservatism (Kessler, 2005).[8]

When GAM-94 is used together with the Scale AA projection tables on a generational basis, it may also be referred to as "GAR-94".

Table 2.1. **Summary of the standard mortality tables**

Country	User	Table name	Base data for level / trend	Base data years for level / trend	Type of mortality improvement model	Notes on construction
Brazil	annuity providers	1996 US Annuity 2000 Basic table	US individual annuitant mortality	1971-1976	none	projected 1983 IAM table to 2000 using 100% male Scale G and 50% female Scale G
	pension plans	1996 US Annuity Female / Male	A loading of 10% is deducted from the 1996 US Annuity 2000 Basic table.			
	pension plans	1983IAM (1983a)	US individual annuitant mortality	1971-1976	none	10% load included from the IAM basic table; projected from 1973 to 1983 based on the white population experience over 1961-1965 to 1971-1976
	annuity providers	BR-EMS 2010	13 economic conglomerates, comprising 23 insurance companies representing an 82% share of the market	2004-2006	none	Plan to update every 5 years
Canada	annuity providers	GAM-94 / CIA minimum improvement base	US Civil Service Retirement System (CSRS), US Social Security, US Military Retirement System, the Public Service for Canada, 24 private sector pension systems and one US state pension system / Canadian population mortality	1986 to 1990 / 1921 to 2002	age-specific - CIA minimum improvement basis	GAM-94 is equivalent to the UP-94 with a margin of 7%.
	pension plans	UP-94 / Scale AA	US Civil Service Retirement System (CSRS), US Social Security, US Military Retirement System, the Public Service for Canada, 24 private sector pension systems and one US state pension system	1986 to 1990 / 1977 to 1993	age and gender specific - Scale AA	For UP-94, mortality projected forward from 1988 to 1994 using CSRS average mortality trends 1987-1993
		CPM4	Canada Pension Plan (CPP) and Quebec Pension Plan (QPP) earning >35% of the maximum pension	2005-2007 / 1967-2007	Gender and age specific, with higher short term improvements converging to lower long term improvements	More emphasis placed on experience 1992-2007 in setting the trend assumptions
		CPM2014	Canadian Registered Pension Plans / CPP and QPP experience	1999-2008 / 1967-2007	Gender and age specific, with higher short term improvements converging to lower long term improvements	The 26th CPP Actuarial Report was also considered when setting improvement assumptions
Chile	all	RV2009	Annuities' experience, Social Security experience / CELADE projections of Chilean population	2002-2007 / 1952-2002	gender and age specific	Up to a 3% margin is included in the base mortality rates for males
China	all	CL(2000-2003)	insured lives of 6 life insurance companies representing 98% market share	2000-2003	none	80% of table mortality rates used for life annuities

Table 2.1. **Summary of the standard mortality tables** *(cont.)*

Country	User	Table name	Base data for level / trend	Base data years for level / trend	Type of mortality improvement model	Notes on construction
France	all	TGH/TGF 2005	insured lives / French population	1993-2005 / 1962-2000	gender and generation specific	
Germany[1]	annuity providers	DAV 2004 R	insured population / General population with additional load for insured population of 0.2% annually	1995-2002 / initial 2nd order trend 1990-1999; target 2nd order trend 1972-1999 multiplied by 75%	Age, gender and duration specific	Separate tables for 'best estimate' (2nd order) and conservative valuation (1st order). 2nd order improvement assumptions grade down to a lower long term improvement. Aggregate tables with combined deferred/ payment mortality and select tables with select mortality for the 5 year period following commencement of annuity payments. Volatility and parameter risk margin applied to 1st order tables: base rates of 15.6%/16.5% for males/ females and +0.25% applied to initial annual trend assumption with no reduction to lower long term trend
	pension plans	Heubeck 2005 G	German employees	2002-2004 / *	generational	
Israel**	all	Israel Mortality Tables 2013	pension funds / Israeli population	2006-2010 / *	age and gender specific, cohort specific for males	
Japan	annuity providers	SMT 2007	Japanese population	2000 Census / 1980-2000	Additional margin to account for future improvements	85% applied to the 2000 population mortality for base rates
	pension plans	EPI tables	developed using census data, taking into account the experience from the public Employees' Pension Insurance	*	5-7.5% load applied for wind-up valuation; optional load of up to 10%/15% for males/females respectively for funding	
Korea	all	6th EMT	Insured lives and corporate pension schemes	2003-2005	Static margin	
Mexico	annuity providers	EMSSAH-CMG-09 EMSSAM-CMG-09 (minimum mortality tables)	Supported by data provided by IMSS and annuitants statistics	1998-2008 / *		
	pension plans	EMSSAH 97 EMSSAM-97	Supported by the National Population Bureau (CONAPO)	*	To 2011 (men) and to 2013 (women)	
Netherlands	all	AG-Prognosetafel 2010-2060	Netherlands population	2007-2008 / short term trend 2001-2008 ; long term trend 1988-2008	age and gender specific, short term trend moving to long term trend	

Table 2.1. **Summary of the standard mortality tables** *(cont.)*

Country	User	Table name	Base data for level / trend	Base data years for level / trend	Type of mortality improvement model	Notes on construction
Peru	all	RV2004 modified adjusted	experience of Chilean annuity beneficiaries and social security pensioners modified to Peruvian experience	1995-2003 (Chile)	If applied, age and gender specific	
Spain	all	PERM/F 2000	Spanish population and Swiss population and insureds / Spanish population	Spanish population in 1990 adjusted by the ratio of the Swiss insured 1981-94 over the Swiss population 1978-83 / 1960-1990	age and gender specific	Mortality projected forward from 1990 to establish the initial mortality of 2000; PERM/F C applies to policies issued before November 2000; PERM/F P applies to policies issued since
Switzerland	annuity providers	ERM/F 2000	Insured persons/ Swiss population	* / 1900-2004	age and gender specific	
	pension plans	BVG 2010	Fourteen large autonomous occupational pension funds that cover approximately 1.2 million active participants and 750 000 pensioners	2005-2009 / Swiss population 1900-2008	Menthonnex Model - age and gender specific, converges to lower long term trend	
		VZ 2010	21 pension funds, approximately 1.4 million individuals	2006-2010 / Swiss population 1900-2008	Nolfi and Menthonnex Model - age and gender specific	
United Kingdom	annuity providers	PCMA/PCFA 2000 tables	UK insurance company annuitants	1999 - 2002	Continuous Mortality Investigation (CMI) mortality projections model - gender and generation specific	Mortality rates based on pension amounts rather than lives
	pension plans	Self-Administered Pension Scheme (SAPS) tables series 1	Pooled pension plan experience	2000 - 2006	Continuous Mortality Investigation (CMI) mortality projections model - gender and generation specific	Mortality rates based on pension amounts rather than lives
		Self-Administered Pension Scheme (SAPS) tables series 2	Pooled pension plan experience	2004 - 2011	Continuous Mortality Investigation (CMI) mortality projections model - gender and generation specific	Mortality rates based on pension amounts rather than lives

Table 2.1. **Summary of the standard mortality tables** *(cont.)*

Country	User	Table name	Base data for level / trend	Base data years for level / trend	Type of mortality improvement model	Notes on construction
United States	annuity providers	GAM-94 generational tables using Scale AA for solvency (Similar assumptions or RP2000 generational tables for premium-setting)	US Civil Service Retirement System (CSRS), US Social Security, US Military Retirement System, the Public Service for Canada, 24 private sector pension systems and one US state pension system / CSRS and Social Security experience	1986 to 1990 / 1977 to 1993	age and gender specific - Scale AA	The GAM-94 Static table is the UP-94 table, but with a 7% margin for conservatism; mortality was projected forward from 1988 to 1994 using CSRS average mortality trends 1987-1993
	pension plans	RP2000; projected beyond 2000 using Scale AA (updated scale BB using observations 1994-2007 an option from 2012)	experience of uninsured pension plans / social security data	1990-1994 / Scale AA 1977 to 1993, Scale BB to 2007	age and gender specific - Scale AA [BB]	Mortality projected forward from 1992 to 2000 using analysed improvements for Social Security, uninsured pensioners, and Federal Civil Service data
		RP2014/ MP2014	experience of private and public pension plans / social security data	2004-2008 / 1950 - 2009	Age, gender and duration specific	Mortality projected forward from 2006 to 2014 using improvements developed for the table

1. For Germany he term annuity provider refers to life insurance companies while pension plans include those provided by Pensionskassen and Pensionsfonds.
* not available
** 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.

Notes

1. Workers may take less, as long as it exceeds the basic solidarity pension specified by the authorities. They may not take more.
2. Impaired life annuities, in other words, are not permitted, except where restricted to a certain clearly defined set of lives receiving a special type of benefit.
3. The Privately Owned Home Pension Act (Eigenheimrentengesetz) of 29 July 2008 introduced special incentives for the purchase of owner-occupied housing by incorporating them into the possible products that are state subsidised.
4. As of 21 December 2012, German life insurance products must be priced on a unisex basis according to a decision of the European Court of Justice. Undertakings may keep gender-specific tables for valuation purposes, however, in most cases unisex tables are used in the balance sheet. DAV 2004 R (gender-specific or a unisex version based on the gender-specific table) continues to be the benchmark, unless experience differs significantly.
5. The information for this summary has been provided by members of the regulatory of financial services companies, the Comisión Nacional de Seguros y Fianzas (CNSF), responsible for supervising the insurers that provide the annuities covered herein.
6. Input to this research was received from the SBS, the single regulator.
7. As in other countries, this arrangement is subject to limits. The deferred annuity must be no greater than the level of the first temporary withdrawal and no less than half of this level.
8. Furthermore, Kessler states that the table called "GAM-94 Basic" is exactly the same as UP-94 and both these tables are typically referred to as UP-94. The "GAM-94 Static" is the same as UP-94, but contains the 7% margin for conservatism. If the GAM-94 mortality table is cited without distinction as to if it is the basic (same as UP-94) or the static table (UP-94 but with the 7% margin for conservatism), then it is likely to be the GAM-94 Static table.

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Mortality Assumptions and Longevity Risk
Implications for Pension Funds and Annuity Providers

Chapter 3

Trends in life expectancy and mortality improvements: Implications for pension funds and annuity providers

The analysis in this chapter provides an overview of the trends in life expectancy for the countries considered. It also examines whether the standard mortality tables used by pension funds and annuity providers to value their liabilities could potentially expose them to an expected shortfall in provisions to meet future pension and annuity payments. Historical trends in the population's mortality drive the expectations about what the improvements in life expectancy will be in the future, and if assumptions are not in line with these expectations, a shortfall in provisions set aside to fund future payments is more likely to result.

Life expectancy has rapidly increased over the last decade, with the average gain being around two months per year for the countries assessed in this report. The analysis presented here relies upon historical mortality experience to project estimations of future mortality which could reflect reasonable current expectations with respect to the evolution life expectancy. In order to determine whether or not the assumptions included in the standard mortality tables are in line with such expectations, and therefore whether or not a shortfall in provisions is more likely, they are compared to the results of four common mortality projection models. The results of the models are adjusted to reflect the level of mortality of the relevant population for which each standard mortality table is being used so as to be able to measure the differences on a comparable basis.

The analysis reveals a potential shortfall of provisions for future annuity and pension payments for several of the standard mortality tables examined based on this expected evolution and improvement in mortality and life expectancy. The magnitude of this potential shortfall confirms the need for regular monitoring of mortality experience and the updating of mortality assumptions to account for any emerging divergence between actual experience and the assumptions being used. While countries failing to account for mortality improvements in the standard mortality tables are also those who face the most significant potential shortfall in provisions, even countries where improvements are assumed but not sufficiently reflective of recent experience could find that they, too, are exposed to a moderate to significant shortfall in provisions to fund pension or annuity liabilities.

Overview of trends in population life expectancy

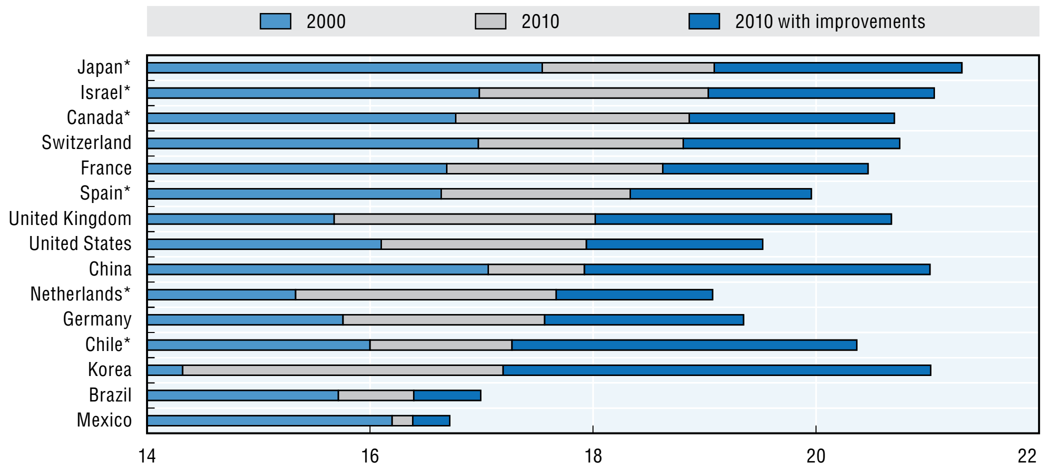
The information presented in this section focuses on the evolution of the life expectancy for the general population of each country in order to provide insights into the impact that mortality improvements have had on life expectancy historically and the impact future mortality improvements are expected to have on life expectancy.

Figures 3.1 and 3.2 below show the evolution in population life expectancy at age 65 for males and females for the countries assessed, demonstrating the increase in period life expectancy from 2000 to 2010 as well as the average additional life expectancy taking into account future mortality improvements as predicted by the projection models (i.e. cohort life expectancy for 2010).[1]

The countries experiencing the highest increase in life expectancy from 2000 to 2010 for both genders have been **Israel**, **Korea**, the **Netherlands** and the **United Kingdom**. **Canada** also makes the top five for males and **China** for females.

The difference between the period life expectancy and the cohort life expectancy of 2010 shows the impact that future improvements are expected to have on life expectancy. On average, the projected mortality improvements add two years of life expectancy for males and 2.5 years for females. **Chile**, **China**, **Japan**, **Korea** and the **United Kingdom** are expected overall to have the highest increase in life expectancy for both genders. Of these

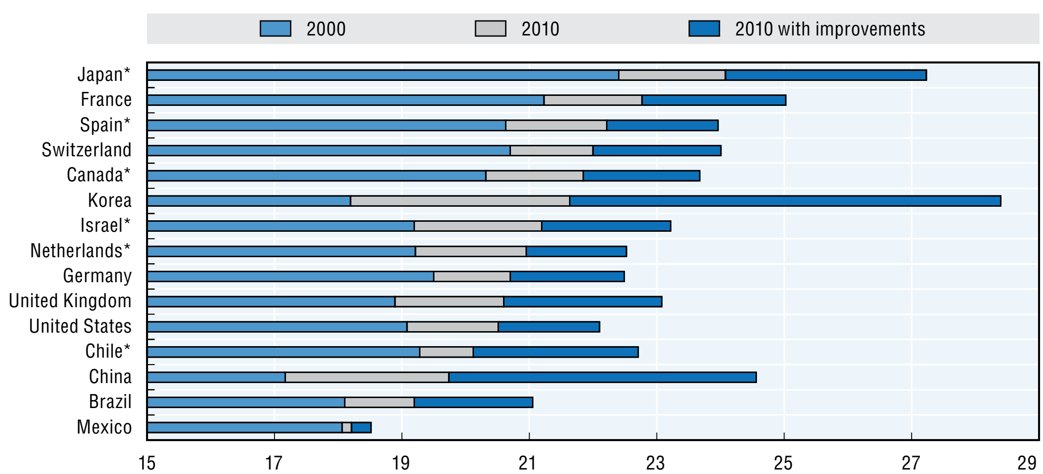
Figure 3.1. **Male population life expectancy at age 65**



* Period life expectancy 2010 estimated based on the average annual increase of the last five years of available data
Source: Historical data from Human Mortality Database (HMD) where available, cohort life expectancy based on average OECD projections
** 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.

StatLink http://dx.doi.org/10.1787/888933152926

Figure 3.2. **Female population life expectancy at age 65**



* Period life expectancy 2010 estimated based on the average annual increase of the last five years of available data
Source: Historical data from Human Mortality Database (HMD) where available, cohort life expectancy based on average OECD projections
** 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.

StatLink http://dx.doi.org/10.1787/888933152931

countries, **Chile**, **China** and **Korea** have relatively low life expectancies compared to that in other countries, and the high improvements projected by the models likely reflect the fact that life expectancy in these countries is catching up with the other countries, particularly for Korea for whom projected improvements have the largest impact on life expectancy. Once life expectancy is more in line with the other countries, it could be expected that the mortality improvement beyond that point will also align with average levels, thus the analysis presented here may overstate somewhat the longevity risk in these countries.

Brazil and **Mexico** also have relatively low life expectancies, although as mortality improvements in these countries have not been as high relative to other countries, the projected improvement in life expectancy is also relatively low. Nevertheless, as with the countries just mentioned, there is room for life expectancy for these countries to catch up with the others, and therefore a good chance that the longevity risk as assessed here could be understated and that mortality improvement could accelerate in the near future.

Table 3.1 shows the gap in period life expectancy at age 65 for males and females in 2010. The number of years females can expect to live longer than males ranges from 2 years in **Mexico** and **China** to 5 years in **Japan**. However, the difference has been shrinking in most countries, with the exception of **Brazil**, **China**, **Japan** and **Korea** where females have continued to experience increasing life expectancy at a higher rate than males.

Table 3.1. **Evolution of the gender gap in life expectancy at age 65**

Country	Gender Gap 2010	Change from 2000
Mexico	1.9	(0.0)
China	1.9	1.7
Israel*	2.2	(0.0)
United States	2.6	(0.4)
United Kingdom	2.6	(0.6)
Brazil	2.8	0.4
Chile	2.9	(0.4)
Canada	3.0	(0.5)
Germany	3.2	(0.6)
Switzerland	3.2	(0.5)
Netherlands	3.3	(0.6)
Spain	3.9	(0.1)
France	4.2	(0.4)
Korea	4.5	0.6
Japan	5.0	0.2

Source: Human Mortality Database (HMD) where available

* 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.

Methodology for assessing the adequacy of the standard mortality tables

The study assesses whether pension funds and annuity providers are exposed to longevity risk in terms of an expected shortfall in provisions by 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.[2] If the mortality assumptions being used for the valuation of liabilities are significantly different from improvements which have been experienced and the future expectations based on this experience, entities are more likely exposed to longevity risk which will result in current provisions underestimating future liabilities.

The analysis uses historical population data for each country to calibrate four alternative models to project mortality into the future. The level of the modelled population mortality is adjusted to the level expected for the given pensioner or annuity population, typically based on the initial rates of mortality given by the standard mortality table, and assumes the projected mortality improvements as implied by the model.

The potential shortfall in provisions or reserves to cover the expected 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 inadequacy of mortality assumptions.

Mortality projection models

The general population data for each country presented in the overview above served as inputs into the four mortality projection models which have been used to assess the adequacy of mortality assumptions. These models are the Lee-Carter (LC), Cairns-Blake-Dowd (CBD), P-spline (PS) and CMI models.[3]

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, therefore 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, 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 have impacted the mortality at older ages. As this acceleration of mortality improvement at the older ages has only occurred more recently, the Lee-Carter model tends not to capture this shift of improvements to the older ages, 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 aim to provide reasonable mortality projections for older ages, which is the focus of the analysis presented in this paper. However this model still tends to demonstrate a poorer fit compared to 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.

Assumptions and methodology

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.

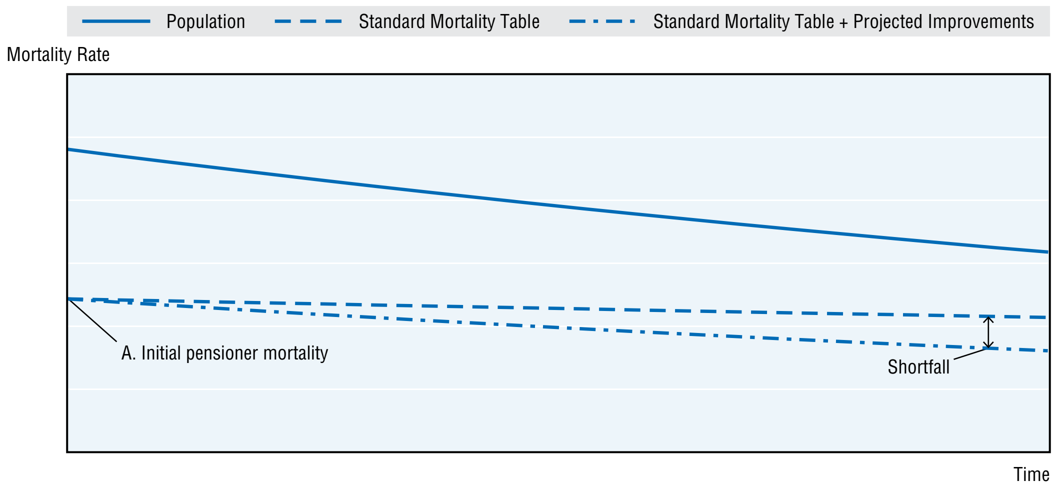
Pensioners and annuitants are subsets of the overall population who often have lower expected mortality (higher life expectancy) than the population in general. Pensioners, and even more so annuitants, tend to have a higher average income level (and/or have higher educational attainment levels) than 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 (Deaton, 2003). 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 Figure 3.3 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 the figure. 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 3.3. **Illustration of mortality adjustment for projections**



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.[4] 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, which can be viewed as an abstraction from reality and from country specificities but greatly simplifies the analysis and isolates the impact of the mortality assumptions themselves. Various adaptations of these tables have also been assessed where considered feasible and appropriate, for example by considering the impact from using a static projection of the table or from applying a specified margin.[5] The resulting 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 is the measure used in this analysis to indicate the potential shortfall in provisions to which they may be exposed.

The shortfall presented here could potentially be understated with this approach as a result of the underlying assumptions, however. 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.

Results of the assessment of the adequacy of standard mortality tables[6]

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 (or other more relevant and available data) and applying the mortality improvements given by the projection models.[7,8]

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).[9] 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 standard mortality tables used by pension funds 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.[10,11,12,13]

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 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 pension funds in **Canada** and the **United States** do take improvements into account with the Scale AA, the assumptions

Table 3.2. **Classification of standard mortality tables by potential shortfall in provisions**

Classification	Potential Shortfall	Pension Plans	Annuity Providers
Serious	10-20%	Brazil (*US 1983 IAM*), 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-MP2014*)	Germany (*DAV 2004 R*), Netherlands (*AG-Prognosetael 2010*), Switzerland (*ERM/F 2000*), UK (*PCMA/PCFA 2000-CMI*)

Source: Author's calculations

* 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.

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.[14] 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 for annuity providers. The recent 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 socioeconomic 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.[15] 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 socioeconomic level.

Table 3.3. **Data used for calibrations and calculations**

Country	Historical data used in model calibration	Table name	Basis (Table: year) for adjustment of model outputs	Comments
Brazil	IBGE Brazil Life Tables 1998-2011 through age 79, thereafter graduated mortality rates used to age 110 derived from the Kannisto method	1996 US Annuity 2000 Basic table 1996 US Annuity Female / Male 1983 IAM BR-EMS 2010	BR-EMS: 2005	The BR-EMS table has been relied upon as a starting point for all analysis as no other Brazilian experience data is available for the insured/pensioner population
Canada	HMD Data 1960-2009	GAM-94 / CIA improvements	CPM2014: 2008	CPM2014 used as a starting point as it is based on a relevant subset of Canadian Pensioners (RPP)
		UP-94 / Scale AA	CPM2014: 2008	CPM2014 used as a starting point as it is based on a relevant subset of Canadian Pensioners (RPP)
		CPM4	CPM4: 2006	CPM proposed rates for pensioners with incomes over 35% of the maximum pension have been used; i.e. the most disadvantaged population is excluded
Chile	HMD Data 1992-2005	RV2009	RV2009: 2009	Base mortality rates include up to a 3% margin, which was not removed for the purpose of this study, but the difference in results in negligible.
China	China Population Data Smoothed with Kannisto method: 1995-2008	CL(2000-2003)	CL(2000-2003): 2001	
France	HMD Data 1960-2010	TGH/TGF 05	TGH/TGF 05: 1996	
Germany	HMD Data for West Germany 1960-2011	DAV 2004 R	DAV 2004 R:1999	2nd order aggregate assumptions used as a basis for adjustment
		Heubeck 2005 G	NA	
Israel*	HMD Data 1983-2009	2013 Insurance Tables 2013 Pensioner Tables	Best Estimate: 2008 Best Estimate: 2008	Where separate rates are given for active and retired lives,active rates are assumed before age 65, and pensioner rates from age 65
Japan	HMD Data 1960-2009	SMT 2007	85% of the 2000 population census (19th Table)	This adjustment was assumed in the development of the table; here we assume this margin accounts for the difference between annuitant mortality and that of the population, which has not been confirmed.
		EPI2005	EPI2005: 2005	
Korea	KOSIS Korean Life Tables 1997-2011 through age 84, graduated mortality rates used to 110 derived from the Kannisto method	6th EMT	6th EMT: 2004	
Mexico	CONAPO data 1990-2009 through age 79, graduated mortality rates used to age 110 thereafter derived from the Kannisto method	EMSSA97 EMSSA09	EMSSA97: 1997 EMSSA09: 2009	
Netherlands	HMD Data 1960-2009	AG-Prognosetafel 2010-2060	AG-Prognosetafel: 2008	
Spain	HMD Data 1960-2009	PERM/F 2000	PERM/F 2000: 2000	The difference in construction between the PERM/F C and PERM/F P is not clear, thus the respective initial mortality was used for each table
Switzerland	HMD Data 1960-2011	ERM/F 2000	ERM/F 2000: 1993	
		VZ 2010	VZ 2010: 2012	Non-disabled rates used
		BVG 2010	BVG 2010: 2007	Non-disabled rates used
		EVK 2000	EVK 2000: 1996	

Table 3.3. **Data used for calibrations and calculations** *(cont.)*

Country	Historical data used in model calibration	Table name	Basis (Table: year) for adjustment of model outputs	Comments
United Kingdom	HMD Data for UK Total Population, 1960-2011	PCMA/PCFA 2000 tables; 1.75% / 1.25% long term improvement assumed for males/females respectively	PCMA/PCFA 2000: 2000	Total UK population data used, though England and Wales has typically experienced lower mortality than the rest of the United Kingdom; however using only E&W data does not alter the conclusions made for this study
		Self-Administered Pension Scheme (SAPS) tables series 1; S1PMA/S1PFA; 1.5% long term improvement assumed	S1PMA/S1PFA: 2003	
		Self-Administered Pension Scheme (SAPS) tables series 2; S1PMA/S1PFA; 1.5% long term improvement assumed	S2PMA/S2PFA: 2007	Improvement scale was derived from CMI projections for England and Wales based on the OECD model and is for illustrative purposes only
United States	HMD Data 1960-2010	GAM-94 generational tables / Scale AA	1988 ; no margins	
		RP2000 generational / Scale AA	RP2000: 1992	Where separate rates are given for annuitants and non-annuitants, non-annuitant rates are assumed before age 65, and annuitant rates from age 65
		IRS Static; 7 years after valuation for annuitants, 15 years for non-annuitants		IRS generational tables not shown as they are based on RP2000 so have very similar results
		RP2000 generational / Scale BB		
		RP2014 / MP2014 Scale	RP2014: 2006	Employee rates through age 64, healthy annuity rates thereafter

* 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.

Notes

1. Period life expectancy makes no allowance for changes in mortality beyond the year in question, whereas cohort life expectancy is calculated taking into account future improvements in mortality and uses probabilities of death which follow a given group of the population. The cohort life expectancy shown here is the average given by the four projection models.
2. Chapter 4 describes the models used, the actuarial concepts and measures relating to longevity as well as further justification for the methodology used.
3. Chapter 4 provides technical details on each of these models.
4. Annuity values are calculated with a discount rate of 4.5%.
5. Detailed results are presented in Chapter 5.
6. All calculations were made as at 2010, with the exception of the United Kingdom and the VZ2010 table in Switzerland for which calculations were as at 2012. Chapter 5 provides the detailed results of the assessment for each country.
7. Details of the data used for each country can be found in Table 3.3.
8. Tables for disabled lives were not assessed.
9. 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.
10. The tables used by German pension funds (Heubeck 2005 G) were not available so could not be assessed.
11. 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*)**

12. 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.
13. 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.
14. 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.
15. Some analysis of this can be found in Chapter 5.

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Mortality Assumptions and Longevity Risk
Implications for Pension Funds and Annuity Providers

Chapter 4

Measuring and modelling mortality and life expectancy: Methods and limitations

This chapter presents the models used to project future improvement in mortality and life expectancy. The mortality projection models implemented are widely used and recognized, however each has its own advantages and weaknesses which must be considered when drawing conclusions from their results. The analysis here first covers the details of some of the mathematical concepts useful for understanding the measurement and modelling of mortality, and then goes into details regarding the models themselves. Finally the inputs used to calibrate the models are discussed, along with justification of the choices made and their limitations.

Measures of mortality

There are a number of key actuarial concepts underpinning any mortality model. The simplest and most intuitive of these is the *probability of death* for an individual aged x years. Denoted $q_{x,t}$, this measure represents the probability of an individual who is aged exactly x at time t will die in the next year (i.e. before age $x+1$ and time $t+1$). Usually, x and t are integers and so, for instance, $q_{65,2010}$ is the probability that an individual who has their 65th birthday on 1st January 2010 will die on or before 31st December 2010.

Inversely, $p_{x,t}$ is equal to the probability that an individual aged x at time t will survive the next year, thus

$$p_{x,t} = 1 - q_{x,t}$$

This notation can be expanded to denote the probability that an individual aged x at time t will survive the next k years as ${}_kp_{x,t}$.

The *force of mortality* denoted $\mu_{x,t}$ is the continuous time hazard rate for mortality - i.e. the instantaneous rate of mortality for an individual aged exactly x and at exact time t. The force of mortality is related to the probability of death as

$$q_{x,t} = 1 - \exp\left(-\int_0^1 \mu_{x+\tau,t+\tau} d\tau\right)$$

It is also useful to introduce a related measure known as the *central mortality rate*, $m_{x,t}$. If we were to estimate $q_{x,t}$ directly, we would need a large number of individuals aged x at time t and to observe them over the interval $[t,t+1)$ and count how many died. In practice, however, this measure is not usually available. What is available is usually the number of individuals who died aged x in $[t,t+1)$ (the "death count" $D_{x,t}$) and the average population of people aged x in that interval (known as the "central exposure to risk" or $E^c_{x,t}$). From this we can calculate the central mortality rate, given by

$$m_{x,t} = \frac{D_{x,t}}{E^c_{x,t}}$$

If we assume that the force of mortality is approximately constant over the intervals $[x,x+1)$ and $[t,t+1)$ and the number of deaths observed follows a Poisson distribution, then we have

$$E\,[m_{x,t}] = \mu_x + 0.5, t + 0.5 = \mu_{x,t}$$

$$q_{x,t} = 1 - \exp(-m_{x,t})$$

These approximations are reasonably good until high ages (typically above 90) or at birth. In this report, we make no distinction between the force of mortality and the central mortality rate and use the symbol $\mu_{x,t}$ for both. We also use these approximations as the basis for the conversion between models of the central mortality rate (such as the Lee-Carter model and the P-splines model) and the calculation of probabilities of death.

The rate at which mortality changes over time is often referred to as the mortality trend, or mortality improvement since the general trend in mortality has been decreasing over time. Mortality improvements are often presented as annualized rates and are calculated as the percentage change in mortality from one year to the next:

$$r_{x,t} = 1 - \frac{q_{x,t}}{q_{x,t-1}}$$

Life expectancies

Life expectancy is the additional number of years on average an individual of a given age x can expect to live at time t, and is often denoted as $e_{x,t}$.

Life expectancy is most often quoted at birth, in which case it is equivalent to the total expected lifespan. However life expectancy can be calculated for any given age, in which case the individual's age plus their life expectancy is equal to their total expected lifespan.

Curtate life expectancy is the expected future lifetime in whole years, and the formula can be simplified to

$$e_x = \sum_{k=1}^{\infty} {}_k p_x$$

Assuming that individuals live on average half of the year in which they die, complete life expectancy can then be calculated as $e_x + 0.5$.

Life expectancy is commonly quoted as a snapshot indicator of mortality at a certain point in time. These are referred to as *period life expectancies*, and make no allowance for changes in mortality beyond the year in question. For instance, the period life expectancy at age 65 in 2010, $e_{65,2010}$ will use the probability of death at age 65 in 2010, at age 66 in 2010, at age 67 in 2010, etc. This means that it can be calculated directly from the probabilities of death observed in a given year without recourse to a projection, making it an objective, standard measure of longevity across different populations.

However, because longevity tends to improve with time, period life expectancies systematically underestimate the actual expected length of time an individual will live. *Cohort life expectancy* is calculated taking into account future improvements in mortality and uses probabilities of death which follow a given group of the population. For instance, the cohort life expectancy for an individual aged 65 in 2010 will use probabilities of death at age 65 in 2010, at age 66 in 2011, at age 67 in 2012, etc. From this, one can see that cohort life expectancies for any group of people who are still alive will require a projection of future probabilities of death, which makes them subjective and model dependent.

Annuity values

An annuity pays an individual a series of payments at regular intervals for a certain period of time. In this paper we focus on life annuities, for which these payments are made until the individual dies.

The value of the annuity is the present value of the expected future payments to the individual. As the payments are contingent on the survival of the individual, it is necessary to take this probability into account to determine the liability. Therefore if v represents the discount rate used, the value of the annuity beginning payments at the end of the period for someone aged *x* can be calculated as

$$a_x = \sum_{t=1}^{\infty} v^t \, {}_t p_x$$

If payments begin immediately, the value is $\ddot{a}_x = 1 + a_x$ as it is certain that the first payment will be made.

Mortality projection models

A mortality model is any mathematical model which examines the structure of probabilities of death or central mortality rates across ages and/or years. The simplest such models are static "laws" of mortality such as the Gompertz law ($\mu_x = \exp(A + Bx)$), the Makeham law ($\mu_x = A + B\exp(Cx)$) or the Perks law ($logit(q_x) = ln\frac{q_x}{1-q_x} = A + Bx$) which do not have any time dependence. These models often form the basis for more modern dynamic mortality models by allowing the parameters to vary with time. A dynamic mortality model can be deterministic or stochastic, depending on whether future mortality is projected with certainty or according to an underlying distribution[1].

A variety of models have been used in this assessment in order to try to limit the model risk of relying on a single model. The range of outcomes presented should be interpreted with the advantages and disadvantages of each model in mind.

Most of the models assessed here do not consider cohort effects, which allow for patterns in mortality to vary from one generation to the next. Cohort effects have been observed in many different populations, although they are most prominent in the United Kingdom where a "golden cohort" of individuals born between 1925 and 1935 is believed to exist (for example, as documented in Willets (2004) in data collected by the Continuous Mortality Investigation). This cohort's life history includes a number of different factors that have resulted in systematically lower mortality and faster rates of improvement than the cohorts born earlier and later – these factors have included avoiding fighting in any major conflicts, the introduction of universal alth care, the adoption of healthier lifestyles (such as campaigns to reduce smoking rates) and new medications for heart disease in later life. More specific cohort effects have also been observed for individual years of birth, for instance relating to individuals born in 1918. However, it is debatable whether these are genuine effects caused by the 1918 influenza epidemic or a statistical artefact of the data caused by the end of the First World War (Richards, 2008).

Fitting cohort effects can be problematic however, as more recent cohorts have only been observed for a limited number of years, making parameter estimates unstable. Fitted cohort effects for these years of birth can also cover for other deficiencies in the model, for instance the lack of additional period trends, which may therefore lead to implausible projections of longevity as these are extrapolated into the future. Intuitively, a cohort effect should refer to specific features of a cohort that make its mortality different from average.

Another issue with these models is how to project cohort effects. Cohort features should be mean reverting around zero by definition if we have correctly separated any period and cohort trends. However, they should also be highly persistent as circumstances relating to lifestyle, etc. should not vary hugely from one year to the next. This makes fitting a time series structure to them highly complex.

Whilst excluding cohort effects from the mortality models implemented may affect the results obtained, it is unlikely to make a material difference to the projection of period life expectancies. This is because the calculation of period life expectancies uses probabilities of death across a broad range of different cohorts, which should give an average cohort effect close to zero. However, for calculations performed on a cohort basis (for cohort life expectancies or for annuity values) then the absence of cohort effects may be important.

In this paper four mortality projection models are used for analysis, all of which are widely known by actuaries, demographers and other professionals working in the field of mortality projections. These are:

1. the Lee-Carter model (LC), introduced by Lee and Carter (1992)
2. the Cairns-Blake-Dowd model (CBD), introduced by Cairns et al (2006)
3. the P-splines model (PS), introduced by Currie et al (2004)
4. the CMI mortality projection model, introduced by the Continuous Mortality Investigation (2009)

Each of these models has distinct advantages and disadvantages, depending on the underlying structure and assumptions made by the model.

The Lee-Carter model

The Lee-Carter model was introduced in Lee and Carter (1992) and has become the benchmark mortality model against which others are compared. It is a stochastic model, although deterministic projections from it are possible, and works in a discrete age/time framework. It assumes that the force of mortality (or equivalently, the central mortality rate) at age *x* and time *t* can be decomposed as

$$\ln(\mu_{x,t}) = \alpha_x + \beta_x k_t$$

In other words, there is a characteristic shape to the log of central mortality rates across ages given by α_x and the evolution of mortality is governed by the process k_t across all ages (though the magnitude of change at any age *x* is determined by β_x).

The parameters in the model are not fully identified (i.e. there exist transformations of the parameters which leave observed central mortality rates unchanged), and so to deal with this, Lee and Carter (1992) enforced that $\Sigma_t k_t = 0$ and $\Sigma_x \beta_x = 1$. These constraints have since become standard although many others have subsequently been suggested.

In the original paper of Lee and Carter (1992), this structure was fit to data using the method of single value decomposition. This method assumes that the errors in observed rates compared with those fitted by the model are independent and identically distributed normal variables. The values of k_t were then adjusted slightly to ensure that the total number of deaths across all ages predicted by the model in each year was equal to the number actually observed.

Subsequently however, Brouhns et al (2002) has proposed a fitting procedure that takes advantage of the assumption that the death count $D_{x,t}$ can be assumed to be a Poisson variable with mean $E^c_{x,t}\mu_{x,t}$ and that the natural logarithm is the canonical link function for the Poisson distribution to use maximum likelihood methods to estimate parameter values. This method is generally superior to the original method of Lee and Carter (1992) as it allows the errors between the model and the observed rates to vary with age and time (for instance, observed central mortality rates at very high ages are likely to be very uncertain due to the relatively low numbers of people alive at those ages). However, in order to use this Poisson likelihood maximisation method, the projection model needs to calculate notional central exposures to risk and death counts based on the raw $q_{x,t}$ values.

Lee and Carter (1992) observed that the pattern of the k_t's was approximately linear for data for the United States, with variations around a decreasing trend for different years (and an especially large outlier in respect of 1918 attributed to the influenza epidemic in that year). They therefore fit a random walk with drift to these parameters and used this to project central mortality rates into the future stochastically.

$$k_t = k_{t-1} + \mu + \varepsilon_t$$

This pattern has subsequently been observed across a wide range of datasets in the 20th century, so much so that it has been christened a "universal pattern of mortality decline" by Tuljapurkar et al (2000) and has become the standard. This time series structure is implemented in the projection models used for all datasets under consideration, with the relevant parameters estimated from the fitted k_t's using least squares minimisation. However, other time series patterns have been suggested (such as trend stationary models in Li et al (2007) and methods of detecting and accounting for outliers in Li and Chan (2005)).

A more pressing issue however has been the potential for changes in the trend rate of improvement, which has the potential to dramatically impact the range of mortality forecasts. Trend changes were first considered by Carter and Preskawetz (2001) and a method for limiting the data to the most recent trend developed in Booth et al (2002) (more sophisticated analytic detection and correction methods have since been implemented by Coelho and Nunes (2011)). The projection model used for this paper assumes that there have been no changes in trend in fitting the time series structure for the k_t's - however, it is an option for the user to only use a subset of the fitted k_t's to estimate the time series parameters if it is believed there has been a change of trend that makes previous data unreliable. The impact this has on the forecasts of central mortality rates is discussed further below.

The Lee-Carter approach is a very powerful model, as evidenced by the fact that it remains the benchmark mortality model 20 years after it was first proposed. The advantages of the model are that:

- It provides a good fit to the historic data. The α_x age function allows the model to be used across all ages, even at young ages where the shape of the life table can be quite complex, whilst the k_t term captures the dominant trend in the evolution of mortality; so much so that variants of the Lee-Carter model with two or more $\beta_x k_t$ terms such as proposed in Renshaw and Haberman (2003) are not widely used as they add comparatively little to the fit with historic data.
- It is easy to fit. There are relatively few parameters, especially compared with other, more complex models, and both the original single value decomposition and Brouhns et al (2002) Poisson likelihood methods of fitting are well understood and simple to implement.
- It is easy to project. Because the linear trend in the k_t's is common to most datasets, the random walk with drift time series structure is widely used to give estimates of future central mortality rates.
- It is easy to explain. Both a_x and k_t are quite intuitively explained as the shape of mortality across ages and the level of mortality in a given year, which helps when communicating results to a wider audience.

However, the Lee-Carter model does have a number of drawbacks which make it unsuitable for some purposes. These include:

- It only has one period term k_t. This means that in any given year of projection, the change in all central mortality rates are perfectly correlated which is unrealistic and a problem when looking to determine the riskiness of liabilities and securities based on central mortality rates.
- β_x has no universal interpretation and may give implausible projections. For instance, when fitted to a long range of historic data, for most countries β_x will be high for young ages (0-30) and relatively low for high ages (60-90) as the majority of observed mortality improvements occurred at younger ages. However, when the data is curtailed to more recent periods, the shape of the β_x function will change to reflect the different pattern of mortality improvements which has occurred more recently. When projecting central mortality rates, this becomes important as a model fitted to a long range of historic data will continue to project very high rates of improvement at younger ages and correspondingly low rates of improvement at higher ages, which may be felt to be unlikely. Related to this is the fact that the variability of projected central mortality rates is proportional to β_x and hence the magnitude of the change in central mortality rates, which may be unrealistic and also gives projections of future central mortality rates at high ages which may be felt to be too certain. This is less of an issue when looking at life expectancies, but becomes important when considering the riskiness of financial positions linked to mortality, such as life assurance reserves or mortality linked securities. In addition, there is no requirement for the β_x's to be continuous, which may lead to sharp discontinuities in projected central mortality rates when projected into the future, although this can be solved by smoothing the parameters as suggested in Delwarde et al (2007).
- It does not contain any allowance for "cohort" effects depending on an individual's year of birth. These are believed to be important in United Kingdom data (for instance, see Willets (2004)) but have also been found in the data for other countries. Models based on the Lee-Carter model but incorporating cohort effects have since been introduced, most notably by Renshaw and Haberman (2006).
- Confidence intervals resulting from the stochastic projections tend to be quite narrow, posing challenges when using the model to assess longevity risk at extreme percentiles.

The Cairns-Blake-Dowd model

The Cairns-Blake-Dowd model was introduced in Cairns et al (2006) in order to model the survivor bond proposed by the European Investment Bank. It was deliberately introduced to try to tackle some of the perceived problems with the Lee-Carter model and so takes a significantly different approach to the modelling of mortality.

The Cairns-Blake-Dowd model assumes that probabilities of death can be modelled as

$$logit\left(q_{x,t}\right) = \kappa_t^1 + \left(x - \bar{x}\right)\kappa_t^2$$

It is a time dependent version of the Perks law of mortality.[2] This assumes that the logit of probabilities of death is a linear function of age, which is a reasonable approximation for high ages (approximately 50 and above) but is not true at younger ages (due to features such as the relatively high probabilities of death observed for ages 15-25 - the "accident hump" - and due to infant mortality below age 2). This may be an issue when using the model across the full age range, especially for periods of high mortality at younger ages. In the Cairns-Blake-Dowd model, the k_t^1 parameter determines the level of mortality in a given year across all ages, whilst k_t^2 determines the "rate of aging" (i.e. the increase in mortality between one age and the next) for the year.

In Cairns et al (2006), the model was fitted using ordinary least squares regression on the $logit(q_{x,t})$ values for each year. In subsequent papers (for instance Cairns et al (2009)) an alternative procedure based on Brouhns et al (2002) and maximising the Poisson likelihood has been used. However, because the logit function is the canonical link function for the binomial distribution, it makes sense to maximise the binomial loglikelihood instead, as this is numerically quicker and more accurate. For this, notional initial exposures to risk need to be used ($E^0_{x,t}$ the number of individuals aged x at the start of year t) which can be estimated as $E^0_{x,t} \approx E^c_{x,t} + 0.5\ D_{x,t}$ once notional central exposures to risk and death counts have been calculated. This assumes that deaths occur on average half way through the year, which is reasonable except at birth or at very high ages. Using this approach also allows for the variability of the observed death rates to change depending on the number of individuals alive at each age, unlike using least squares methods.

Cairns et al (2006) projected the model by using a bivariate random walk with drift to allow for the correlation between the two k_t's:

$$\begin{pmatrix} \kappa_t^1 \\ \kappa_t^2 \end{pmatrix} = \begin{pmatrix} \kappa_{t-1}^1 \\ \kappa_{t-1}^2 \end{pmatrix} + \begin{pmatrix} \mu^1 \\ \mu^2 \end{pmatrix} + \begin{pmatrix} \sigma_{1,1} & \sigma_{1,2} \\ 0 & \sigma_{2,2} \end{pmatrix} \begin{pmatrix} Z_t^1 \\ Z_t^2 \end{pmatrix}$$

This model for the time series structure has become standard and is implemented by the projection models used in this project, with the time series parameters estimated by least squares methods.

As with the Lee-Carter model, the time series for the k_t's may contain structural changes which cannot be adequately modelled by a simple bivariate random walk with drift model. The projection model assumes, however, that there have been no changes in trend over the duration of the data used when projecting, although a subset of the data may be used to remove any trend changes the user thinks may distort the projections.

The Cairns-Blake-Dowd model is a widely used mortality model, especially amongst practitioners who are concerned with the riskiness of liabilities linked to probabilities of death at high ages, such as annuities. This is because:

- It allows for a more complex correlation structure between different probabilities of death than the Lee-Carter model. This is especially important when considering the potential riskiness of liabilities, for instance for solvency purposes in an insurance context.
- It is easy to fit. The model is very parsimonious due to the absence of age functions and so, when used over high ages where the simplifying assumptions are most appropriate, it can be fitted using least squares or likelihood maximisation procedures to achieve a good fit to the historic data.
- It gives values for the probabilities of death which are smooth for any individual year. This is desirable if it is felt that the underlying processes governing mortality should not have any discontinuities as individuals age.
- It is easy to project. The bivariate random walk with drift has proven to be a reliable and robust model for projecting the k_t parameters across a number of different countries.

- It gives stochastic projections, with confidence intervals for individual $q_{x,t}$'s which are felt to be plausible in comparison with historic data in addition to aggregate measures of longevity such as period life expectancy.
- It is easy to explain. At high ages, the assumption of linearity for logit($q_{x,t}$) is reasonable and both k^1_t and k^2_t have relatively intuitive interpretations.

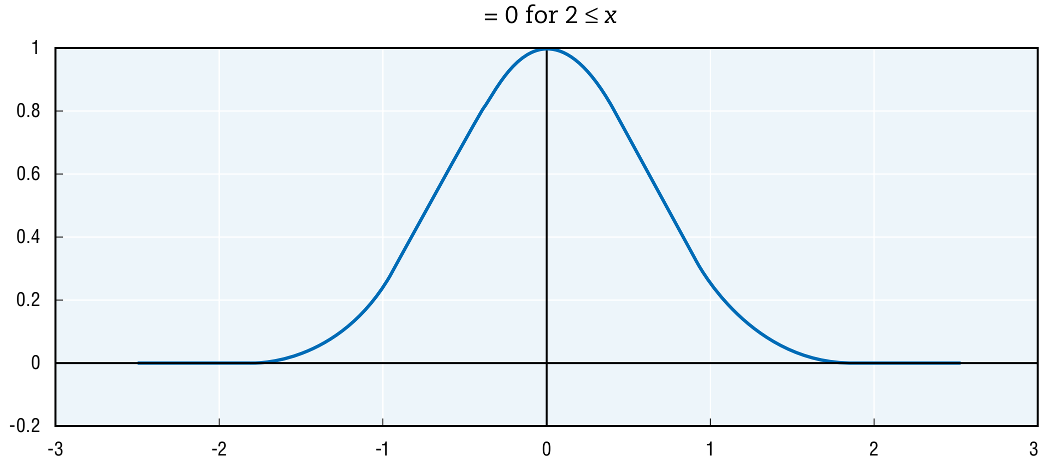
However, the Cairns-Blake-Dowd model also suffers from a number of drawbacks which make it unsuitable in certain contexts. These include:

- It provides a poor fit to data across the whole age range. Below age 50, the assumption of linearity in $logit(q_{x,t})$ is no longer reasonable, and it may not be reasonable at very high ages (above 90). Attempts have been made to allow for this by introducing an age function α_x similar to that found in the Lee-Carter model, for instance in Plat (2009).
- Use of logit($q_{x,t}$) and binomial likelihood maximisation requires initial exposures to risk. These are generally less available than central exposures to risk, and so approximations are needed.
- It does not contain any allowance for "cohort" effects, however models based on the Cairns-Blake-Dowd model but incorporating cohort effects have since been introduced, most notably in Cairns et al (2009) and Plat (2009).

The P-splines model

The P-splines model was introduced in Currie et al (2004) as a method for both smoothing and projecting central mortality rates consistently. It is based on the use of penalised B-splines introduced in Eilers and Marx (1996). A "spline" is a simple polynomial function defined piecewise over a given range. For example, a cubic spline is a function defined over a given range divided into subintervals by "knots". The value of the spline is zero outside of the range and within the range is given by series of cubic polynomials, the parameters of which are chosen so that the function and its first two derivatives are continuous at the knots. To illustrate, a cubic spline defined over the range [-2,2] and with knots at 0, 1, 2, 3 and 4 takes the values:

$$B(x) = 0 \text{ for } x < -2$$
$$= 0.25(x+2)^3 \text{ for } -2 \le x < -1$$
$$= 0.25(-3x^3 - 6x^2 + 4) \text{ for } -1 \le x < 0$$
$$= 0.25(3x^3 - 6x^2 + 4) \text{ for } 0 \le x < 1$$
$$= 0.25(2 - x)^3 \text{ for } 1 \le x < 2$$
$$= 0 \text{ for } 2 \le x$$



A basis of splines (often called B-splines) constitutes a family of splines sufficient to cover the entirety of a range of interest. Any discontinuous function over this range can then be smoothed by taking an appropriate linear sum of the B-splines. The smoothing achieved by this method depends critically upon the number of splines used and the placing of the knots.

The method of P-splines introduced in Eilers and Marx (1996) improves on this approach by using a large number of splines and closely placed regular knots (which would normally result in under-smoothing of the raw data), but adding a penalty term to the model which tries to minimise the change in size of one spline compared with its neighbours. The use of these penalised splines (hence P-splines) allows the model to give a good fit to the data whilst keeping the effective number of free parameters low.

Currie et al (2004) applied this P-splines method (which had previously been applied to one-dimensional data) to two-dimensional mortality data in order to smooth the crude estimates of central mortality rates across both ages and years. They also projected central mortality rates into the future by leaving future years as missing values in the model. The P-splines method then fills in these values by extending the smooth surface fitted on the historic data into the future. Subsequently, it has been found that this method is very numerically intensive as it requires the manipulation of very large matrices - often of the order of millions of entries – and so faster numerical routines have been introduced in Eilers et al (2006) and Currie et al (2006).

The P-splines model assumes that the force of mortality can be modelled as a linear combination of smooth functions across age and time, i.e.

$$\ln\left(\mu_{x,t}\right) = \sum_{i,j} B^{X}_{x,i} A_{i,j} B^{T}_{j,t}$$

The parameters $A_{i,j}$ are then found by maximising the Poisson likelihood, allowing for a penalty function of the form $\lambda_x \sum_j A'_{.,j} D'_x D_x A_{.,j} + \lambda_t \sum_i A_{i,.} D_t D'_t A'_{i,.}$ where D_x and D_t are difference matrices penalising the nth order difference of the parameters and λ_x and λ_t are smoothing parameters. In Currie et al. (2004) the smoothing parameters are chosen iteratively in order to maximise the Bayes Information Criteria for the model. However, the modelling implemented here specifies the values of λ_x and λ_t based on data considerations in order to improve the speed of fitting the P-splines model.

The P-splines method has become widely used for smoothing historic data, most notably by the Continuous Mortality Investigation in the United Kingdom for producing deterministic projections of mortality – for instance in CMI (2002) and CMI (2009b). However, it is relatively infrequently used for projecting mortality for the reasons discussed below, although attempts have been made for this purpose in CMI (2006) and CMI (2009a). The advantages of the P-splines model are that:

- It gives values for the central mortality rates which are smooth across age and time, and so is excellent at removing the impact of random noise from the crude data.
- It is relatively parsimonious. The smoothing procedure reduces the total number of parameters used by the model and the penalty function reduces the effective number of free parameters even further.

- It gives projections that allow central mortality rates at different ages to change independently based on the data observed.

However, the P-splines model has a number of important disadvantages, which include:

- It is complex to explain and implement. The parameters do not have any intuitive meaning and the fitting procedure implemented in Currie et al (2004) and Currie et al (2006) involves manipulating very large matrices which reduces the speed of fitting and may cause problems with computer memory allocation.
- It produces fitted surfaces that might be considered too smooth. By its very nature, the P-spline method attempts to reduce the impact of shocks to the data and so soothes out potentially valid features such as a one off increase in central mortality rates due to an epidemic.
- It produces forecasts of longevity that are unstable and might be deemed unreasonable. The underlying parameter values are very sensitive to the positioning of the knots and any trends observed in the last few years of the data at an age are projected into the future without reference to longer term trends or trends in mortality at other ages (see below). This can result in relatively implausible projections in longevity (for instance, life expectancies falling abruptly or increasing rapidly as seen in some of the projections in CMI (2009a)). The projections of future changes in longevity can also change abruptly as extra data is added to the end of the range. The modelling implemented here attempts to avert this by weighting the final years of data relatively lightly and having a high degree of smoothing.
- It does not provide stochastic projections. The P-splines model fits a deterministic surface to the data and extends this into the future, rather than allowing future rates to be generated by a stochastic process. Attempts at providing "confidence intervals" for future projections have been made in Currie (2006), but these depend on the errors in estimating the underlying parameters rather than being truly stochastic.
- It does not contain any allowance for "cohort" effects. The P-splines model can be reformulated from an age/period to an age/cohort model if desired as described in CMI (2006), but this removes the period effects which are usually felt to be dominant and give rise to problems as some cohorts have limited observations.

The CMI model

The CMI mortality projection model was introduced by the Continuous Mortality Investigation (2009).[3,4] It is a model for mortality improvement rates rather than mortality rates themselves, as the models for mortality discussed previously. The mortality improvement rates are defined as

$$r_{x,t} = 1 - \frac{q_{x,t}}{q_{x,t-1}}$$

The structure of the mortality improvement rates in a population is analysed across ages, periods and years of birth to derive the pattern of mortality improvements in the recent past. The age/period and cohort components thus found are then assumed to continue for a number of years into the future before blending into a "long term rate of improvement" which is set by the user.[5]

The CMI model produces a single, deterministic projection of mortality rates with two parameters:

1. a long term rate of improvement in mortality rates, which is assumed to apply in the more distant future; and
2. a constant additional rate of mortality improvements, which increases all mortality improvement rates (even those in the near future) by a constant amount.

In practice, only the long term rate of improvement is widely used, with the constant additional rate implicitly set to be equal to zero. The projection model used here has therefore not included the constant additional rate.

The CMI mortality projection model operates in the following manner:

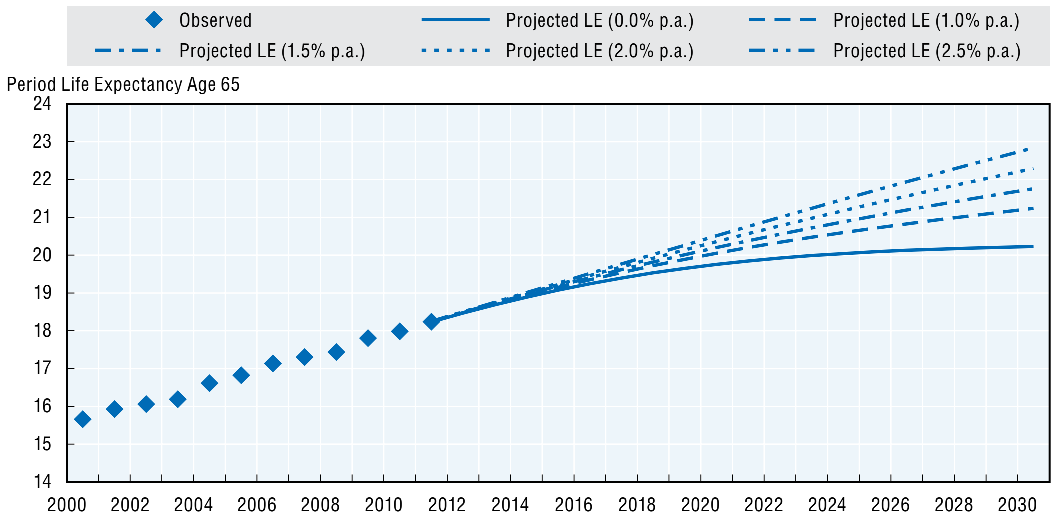
1. The observed data is smoothed using P-splines on an age/cohort rather than the age/period basis. This re-orders the data to be categorised by age and year of birth rather than age and period. The smoothed mortality rates are then rearranged back onto an age/period basis.
2. Probabilities of death and mortality improvement rates are calculated from these smoothed mortality rates.
3. The mortality improvement rates are analysed using an age/period/cohort model, i.e. $r_{x,t} = a_x + k_t + \gamma_{t-x}$. The fitted parameters are then smoothed using one-dimensional P-splines.
4. Parameters are then adjusted to provide a better fit to the data at the end of the period and to reduce the impact of cohort parameters for the most recent years of birth.
5. The age/period and cohort components of the mortality improvement rates are then projected into the future by blending them into a long term assumption over a specified time period. These final improvement rates can then be applied to the current probabilities of death.

This is a complicated procedure. The majority of the complexity in the CMI mortality projection model relates to the analysis of historic data (steps 1-4) rather than the projection of probabilities of death into the future (step 5). This is a deliberate choice on the part of the CMI in order to give the end user a simple projection model which has already been calibrated, and so conceal much of the complexity in the model.

The projection model used in this report outputs the fitted age, period and year of birth parameters found in Step 4. It is worth noting especially that the period parameters κ_t carry the average level of mortality improvement in the model and so give a guide as to a sensible long term rate of improvement should be. It is also worth noting that the CMI Model "steps back" two years from the end of the fitted data in order to avoid the edge effects which bedevil P-splines projections. This gives the CMI model greater robustness.[6]

The CMI left the choice of the long term improvement rate entirely at the discretion of the user, although they did publish some research to guide this assumption in Working Paper 39.[7] In the United Kingdom, actuaries typically use a value in the range 1.0% to 2.5% p.a. depending on the context, which are slightly below the average mortality improvement rates observed in recent years in the United Kingdom. A range of long term rates of improvement can be used to illustrate the uncertainty surrounding the projection, as in Figure 4.1 below. Alternatively, this assumption can be set to give a broadly equivalent output from the CMI model to that from an alternative mortality projection model, such as the Lee-Carter model. The graph below shows the projected period life expectancies at age 65 for men in the United States with a range of long term trend assumptions.

Figure 4.1. **Sensitivities to long term improvement rate assumption**



Source: Author's calculations based on HMD data

The CMI model has the advantage that it can quickly generate a central projection of mortality rates based on a single and relatively intuitive input from the user. This is of great advantage for actuarial consultants working in mainly deterministic settings (for instance, valuation of pension schemes or reserving for life assurance). It also can provide a "common currency" in this context for translating the pattern of improvements in mortality rates or life expectancies observed in another model (for instance, the Lee-Carter model) into a broadly equivalent long term rate of improvement.

However, the inability of the CMI model to produce stochastic projections of mortality rates means that it is not appropriate for measuring the risk inherent in any projection, except on the basis of comparing competing scenarios. It is also a very complex model compared with the other models used, although this complexity is largely hidden for the intended end user and only visible here as the methodology needs to be applied to different datasets.

Model inputs

Data sources

Any model can only be as reliable as the data that it is used with. Where available, mortality rates by individual ages and gender from the Human Mortality Database (HMD) have been used for the calibration of the projection models as this data is reputable and widely used by academics and practitioners.

While the HMD is highly reputable source, it is important to be aware of the limitations of the data and how these may affect the results of the projection models used. The "Methods Protocol for the Human Mortality Database"[8] discusses the process applied to the raw data from contributing organisations before it can be included in the database. It should be especially noted that the estimation of populations alive at each age (a key component of calculating central mortality rates and probabilities of death) is approximate in nature, especially for older datasets. The Human Mortality Database also use various techniques to extend and smooth death rates for high ages, again especially for older datasets, as reported ages of death are frequently inaccurate and exposures to risk are very low, leading to highly changeable death counts in successive years.

For countries which are not included in this database (Brazil, China, Korea, Mexico), historical mortality data was obtained from the government statistical agencies, most often taken from life tables where mortality rates have been smoothed across ages for each year.

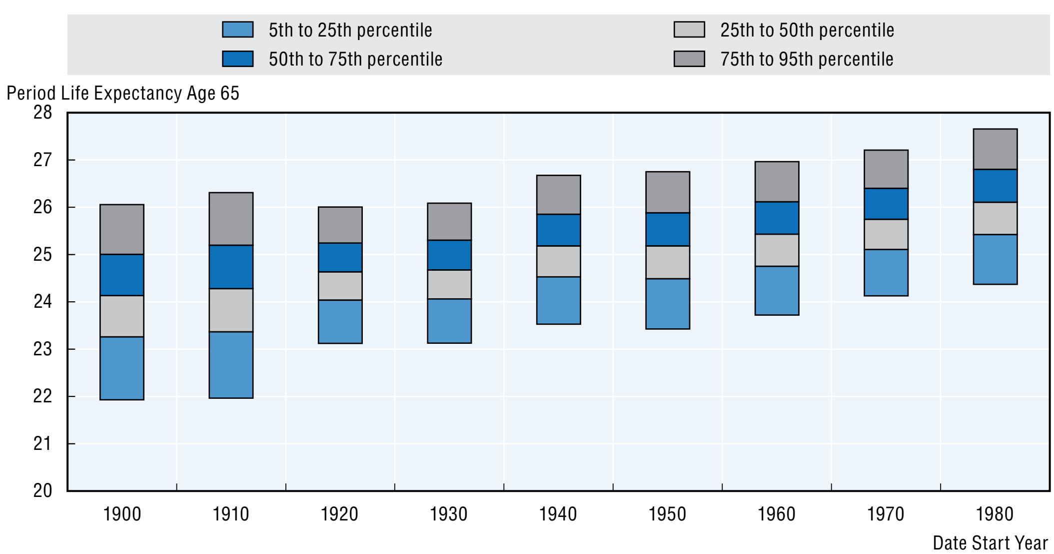
Historical range

One critical decision when projecting longevity is the choice of the range of historic data to use in making a forecast. By necessity, there is a trade-off between choosing a long sample period, which enables more robust estimates of the underlying parameters of the mortality model and more observations of unusual events such as pandemics, and using a shorter period covering data that is likely to be more relevant to projecting mortality into the near future.

As an example, if we use the Lee-Carter model with 100 or more years of data, it will tell us that for most countries, the largest reductions in central mortality rates have occurred at young ages (i.e. below age 30). Projecting this forward can therefore lead to diminishing returns (as overall mortality at young ages is now very low) and cause us to overlook the observation that the most recently observed decreases in central mortality rates have occurred at higher pensioner ages.

The figure below shows an illustration of this problem using data on Italian women and the Lee-Carter model projected stochastically to the year 2040 using different ranges of data. As you can see, using more recent data tends to result in faster median rates of improvement in period life expectancy at age 65 but with lower forecast uncertainty. The largest forecast uncertainty comes from including data from before 1920, presumably due to the impact of the First World War and the 1918 influenza epidemic.

Figure 4.2. **Sensitivity to historical data range**



Source: Author's calculations based on HMD data

StatLink http://dx.doi.org/10.1787/888933155961

Ultimately however, there is no "right" answer to this problem as it may be that the two features observed in more recent data – faster declines in mortality at older ages and the absence of large shocks in mortality – are connected. Good practice recommends thorough robustness testing of the choice of data and clear communication of the reasons and limitations of that choice.

For the purposes of the analysis presented in this paper, the historical period on which the calibrations were based was from 1960 to the most recent year of available data, typically 2009 to 2011 depending on the country. Using a longer historical series than this tends to result in a lower projected life expectancy as mortality improvements –and therefore the rate at which life expectancy has been increasing – have accelerated in many countries in recent decades, particularly at ages over 65. The choice to use data from 1960 also avoids including the major shocks to mortality from the Spanish Flu and World Wars, and the data from this point is more reliable avoiding, for example, age heaping which has been observed in the Spanish data prior to 1960.

For countries where historical data from 1960 were not available (Brazil, Chile, China, Korea, Israel, Mexico) all available data were used. Interpretation of the results should thus consider the limited experience used in the calibrations, though in all cases an understanding of the model outputs in light of the historical evolution in mortality is necessary.

Age range

The age range chosen for the calibrations was 40 to 110. Younger ages were not included in the calibration for two reasons, one being that the objective of this analysis is to assess longevity risk for pensioners and annuitants and thus the focus is at older ages, and secondly this avoids any distortions of the results coming from the spike in deaths for young adults due to accidents, commonly referred to as the 'accident hump', which the Cairns-Blake-Dowd model is particularly sensitive to. With regard to the older ages, mortality rates used have been those computed in the life tables of the HMD, which smooth the mortality at older ages where actual data is less reliable by fitting a logistic function known as the Kannisto function (HMD). For the countries for which HMD data was not available, graduated mortality rates were used for the older ages based on this same function.

As the maximum age used in the calibrations is 110, the results for life expectancy and annuity values from the projection models assume an ultimate age of 110, whereas the results calculated based on the regulatory and industry tables maintain the ultimate age assumed in the table, though the difference is negligible.

Input parameters

The only model requiring user input and judgment beyond the dimensions of the data on which the model is calibrated is the CMI model, where users can define a long term improvement rate. This rate has been determined separately for each country based on the average annualized improvement by age for the historical period used for the calibration, weighted by exposure. This rate has been set equal for males and females and therefore assumes the gender gap will remain more or less steady in the future, which seems appropriate given the widely varying patterns of divergence and convergence over time for each country. Where limited historical data is available on which to base this long term assumption, some judgment has been used in setting the assumption.

Interpretation of results

The advantages and limitations of each of the models described here must be taken into account when interpreting the model output and drawing conclusions regarding the appropriateness of the standard mortality tables which are assessed. The data source and the historical range of data available will also heavily influence the results. The analysis in Chapter 5 attempts to qualify the results for each country in light of these limitations, and therefore relies on both the quantitative outputs and qualitative reasoning for the interpretation of results for each country.

Notes

1. However, even in a deterministic mortality model, the time of death $T_{x,t}$ for an individual is a random variable, albeit with known probability distribution. This random variable can sometimes be modelled using an analytic probability distribution (such as the Weibull distribution) rather than a life table. However, this is more common when modelling the time to failure of mechanical components, etc, than human mortality.
2. A slightly different but equivalent parameterisation was introduced in Cairns et al (2006) - however, this is the formulation that has subsequently become widely used and is implemented for the analysis in this paper.
3. The CMI is a committee of the Institute and Fellowship of Actuaries in the United Kingdom. The CMI introduces its model in 2009 in Working Papers 38 and 39 (CMI (2009b and 2009c)). It has subsequently been updated to reflect feedback on the initial prototype model and the release of new data in Working Papers 41, 49 and 55 (CMI (2009d, 2010 and 2011)).
4. The CMI model is intended for use by pensions and life assurance actuaries in the United Kingdom and therefore has been designed with their needs in mind. It is available for use at the CMI website as a spreadsheet already calibrated to data for England and Wales with the majority of the parameters already set. (*http://www.actuaries.org.uk/research-and-resources/pages/cmi-working-paper-*55)
5. CMI (2009b) contains a discussion of the observed rates of improvement in mortality rates across a number of countries and over long periods of time to help the user obtain an estimate for a reasonable value for this parameter which is otherwise set at the user's discretion.
6. Accordingly, the projection period is lengthened by two years to compensate (e.g. if the data ends in 2010, the CMI Model will start projections from 2009 not 2011 as in the other models. If a "Projection Period" of 20 years is used however, the projection model will actual project for 22 years in order to still give results up to 2030.)
7. The Model however limits this assumption to the range -5% p.a. to +10% p.a.
8. *www.mortality.org/Public/Docs/MethodsProtocol.pdf*

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Mortality Assumptions and Longevity Risk
Implications for Pension Funds and Annuity Providers

Chapter 5

Assessment of the potential longevity risk in the standard mortality tables

This chapter assesses the potential longevity risk implicit in the standard mortality tables used by pension funds and annuity providers in each country. It provides a detailed analysis on which the conclusions presented in Chapter 3 regarding the potential shortfall of the standard mortality tables are based. Results of the mortality projection model outputs are compared to historical population experience as well as to the life expectancy and annuity values given by the standard mortality tables. The potential shortfall of provisions from using each standard mortality table is calculated based on each of the mortality models and across a range of ages. Where available, the potential impact of socio-economic differences on the annuity value is also shown.

This chapter provides additional details on the historical evolution, analyses and projections performed for each country. Specifically, the following items are quantified in the section for each country, which then ends with an overall summary and conclusion based on the results and analysis presented.

- ***Historical Life Expectancy at age 65*** – Looking at the historical evolution of period life expectancy for males and females aids in understanding the pattern of evolution of mortality improvements at older ages as well as the differences between the genders.
- ***Historical and future mortality improvements predicted by tables and projection models*** – The evolution of mortality improvement from one decade to the next shows the shift of mortality improvement across age groups over time.[1] This aids not only in judging the appropriateness of assumptions given in existing tables, but also the appropriateness of the model outputs.
- ***Cohort life expectancy, annuity values[2], and payments at age 55, 65 and 75*** – Life expectancy and annuity values are key indicators of pension and annuity liabilities. The two are closely related, with the latter taking into account the time value of money. The payment which is shown as a percentage indicates the annual payment as a percentage of the present value of the annuity.
- ***The percentage change in liability value based on the alternative models*** – A proxy for the change in the liability value can be directly estimated by taking the ratios of the annuity values given by the models over those computed with the standard mortality tables. This corresponds to the change in reserves or funding needed to meet future pension and annuity payments as estimated by the alternative model.
- ***Additional analysis*** – Additional analysis related to population and sub-populations differences (e.g. socio-economic status) is included for countries where available and/or relevant.

Interpretation of results

The results of each projection model cannot be accepted blindly, and must be placed into the context of the recent evolution in mortality to assess the appropriateness of the model outputs and judge whether or not the shortcomings of each model summarised above render the results more or less plausible.

For example, if mortality improvements have accelerated rapidly in the past decade compared to previous decades, the improvements projected by the Lee-Carter (LC) and Cairns-Blake-Dowd (CBD) stochastic models will likely be low compared to recent experience, as projections will reflect more the average improvement over the entire historical period used. By contrast, in this same scenario, the P-spline (PS) model could project these recent high improvements indefinitely into the future, as it is quite sensitive to the most recent data. Therefore, when considering the results one must form an expectation of plausible future scenarios in order to aid interpretation. The analysis which led to conclusions presented here has therefore attempted to use both quantitative and qualitative reasoning.

The historical data available used in the calibrations also vary by country. When available, data from the Human Mortality Database (HMD) were used from 1960. However a more limited number of historical years was available for Brazil, Chile, China, Israel, Korea and Mexico. Therefore the results for these countries reflect the shorter observation period of historical experience. Brazil, China, Korea and Mexico are not included in the HMD therefore these results are also subject to slight methodological differences which are explained in their respective sections.

Calculations

The cohort life expectancies and annuity factors are calculated for age 55, 65 and 75 to give a better sense of how liabilities could be impacted depending on the age demographics of the pensioners or the annuity portfolio.

The annuity calculation for age 55 assumes that payments begin at age 65. Annuity calculations for ages 65 and 75 assume payments begin immediately. Therefore, if v is the discount rate of (1/1.045) = 0.9569:

- ${}_{10|}a_{55} = \sum_{t=10}^{\infty} v^t \, {}_t p_{55}$
- $\ddot{a}_{65} = \sum_{t=0}^{\infty} v^t \, {}_t p_{65}$
- $\ddot{a}_{75} = \sum_{t=0}^{\infty} v^t \, {}_t p_{75}$

This initial rate of mortality can be denoted q_{x,t_0}, where t_0 is the initial year for which mortality is established in the table, or the central year on which experience was based to set the initial mortality level of the table, with any known margins embedded in the table removed.

In cases where the mortality of the table is clearly not based on the population for which the table is being used, for example in the case where the tables are based on experience in a different country, q_{x,t_0} is based on any available experience for pensioners or annuitants in that country.

If $q_{x,t}^{pop}$ represents the population mortality as projected by the four mortality models considered in this paper, future mortality $q'_{x,t}$ of the pensioner or annuitant of attained age x as modelled by the mortality models is then calculated as

$$q'_{x,t_0+k} = q_{x,t_0} \times \frac{q_{x,t_0+k}^{pop}}{q_{x,t_0}^{pop}}$$

Life expectancy and annuity calculations for pensioners and annuitants based on the projection models are then based on the resulting $q'_{x,t}$'s.

If a'_x is the annuity value calculated based on the $q'_{x,t}$ and a_x is based on the mortality rates found in the standard tables, the potential shortfall in provisioning for longevity risk as calculated for each projection model is then

$$1 - \frac{a'_x}{a_x}$$

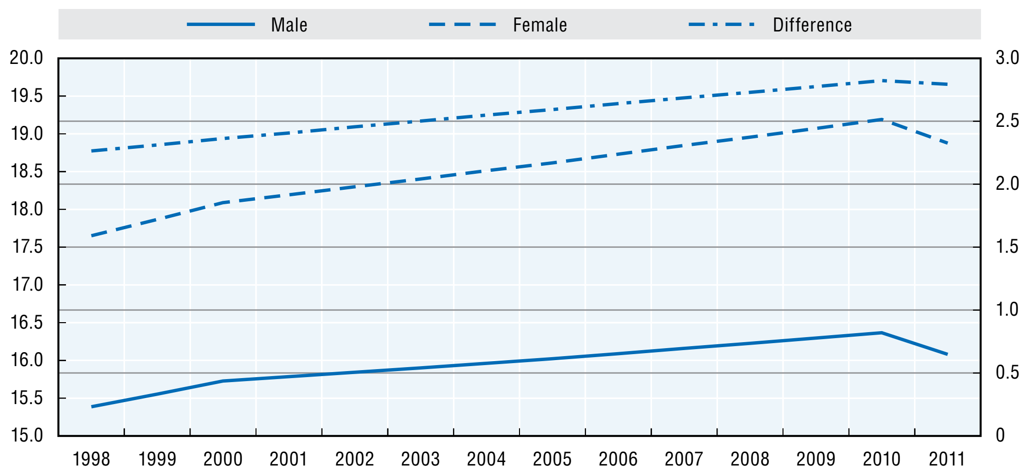
Brazil

The data used for the assessment for Brazil was based on Brazilian life tables produced by the IBGE from 1998 to 2011. These tables included mortality rates for individual ages through age 79. For older ages, mortality rates were extrapolated for each year using the Kannisto methodology (Tesarkova, 2012).

Historical life expectancy at age 65

Figure 5.1 shows the evolution in period life expectancy at age 65 for males and females. The life expectancy for both genders has been increasing, with that for females increasing at a faster rate. Life expectancies of the two genders have therefore been diverging, with the difference between the two (shown on the right axis) currently at just under 3 years.

Figure 5.1. **Life expectancy at age 65 in Brazil**



Source: IBGE Brazilian Life Tables.

StatLink http://dx.doi.org/10.1787/888933152949

Historical and future mortality improvements

Table 5.1 below shows the annualized improvement to mortality rates for age groups of five years. From the left, historical improvements in the population's mortality are shown. Ages 55-64 have been experiencing the highest improvements, with improvements for females surpassing those of males. Mortality improvements projected by the models used for this study are in line with the limited historical experience available, although the improvements from the stochastic models are somewhat more conservative than historical experience.

A long term improvement of 1.5% has been assumed for the CMI model for Brazil based on the weighted average improvement of the two genders across all ages used in the calibration, though is based on limited recent experience so may not represent the true long term improvement rate for Brazil. This assumption however does not result in unreasonable projections compared to the outputs of the other models.

Table 5.1. **Evolution of annual mortality improvements in Brazil***

	Population	LC		CBD		PS		CMI	
Males	1998-2011	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.9%	2.4%	1.9%	2.4%	1.9%	1.7%	1.7%	1.6%	1.5%
60-64	1.7%	2.2%	1.7%	2.1%	1.6%	1.4%	1.4%	1.5%	1.5%
65-69	1.4%	1.7%	1.4%	1.7%	1.4%	1.2%	1.2%	1.3%	1.5%
70-74	1.2%	1.5%	1.1%	1.4%	1.1%	1.0%	1.0%	1.2%	1.5%
75-79	0.8%	0.9%	0.7%	1.0%	0.8%	0.7%	0.7%	0.9%	1.4%
80-84	0.5%	0.6%	0.5%	0.6%	0.5%	0.3%	0.3%	0.8%	1.4%
85-89	0.3%	0.2%	0.2%	0.3%	0.3%	0.1%	0.0%	0.8%	1.5%
90-94	0.0%	-0.1%	-0.1%	0.0%	0.0%	-0.1%	-0.1%	1.0%	1.4%
95-99	-0.2%	-0.3%	-0.3%	-0.3%	-0.2%	-0.3%	-0.3%	1.0%	1.1%
100-104	-0.3%	-0.5%	-0.4%	-0.5%	-0.3%	-0.3%	-0.3%	0.8%	0.9%
105-110	-0.4%	-0.6%	-0.5%	-0.7%	-0.5%	-0.3%	-0.3%	0.5%	0.6%
	Population	LC		CBD		PS		CMI	
Female	1998-2011	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.4%	3.0%	2.5%	3.1%	2.4%	2.1%	2.2%	1.9%	1.5%
60-64	2.4%	2.9%	2.4%	2.8%	2.2%	2.1%	2.0%	1.9%	1.6%
65-69	2.0%	2.5%	2.1%	2.5%	2.0%	1.8%	1.8%	1.8%	1.6%
70-74	1.9%	2.3%	1.9%	2.2%	1.8%	1.6%	1.6%	1.7%	1.6%
75-79	1.6%	2.0%	1.6%	2.0%	1.6%	1.5%	1.4%	1.5%	1.5%
80-84	1.4%	1.6%	1.3%	1.7%	1.4%	1.1%	1.1%	1.3%	1.5%
85-89	1.1%	1.3%	1.1%	1.4%	1.2%	0.9%	0.8%	1.2%	1.5%
90-94	0.9%	1.0%	0.8%	1.1%	1.0%	0.6%	0.6%	1.2%	1.4%
95-99	0.7%	0.7%	0.6%	0.8%	0.8%	0.4%	0.4%	1.1%	1.1%
100-104	0.5%	0.4%	0.4%	0.5%	0.6%	0.3%	0.3%	0.8%	0.9%
105-110	0.3%	0.2%	0.1%	0.3%	0.3%	0.2%	0.2%	0.6%	0.6%

Source: Author's calculations.
**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153545

Life expectancy and annuity values

Table 5.2 and 5.3 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a percent of the initial investment (net of margins and fees). Model outputs for the general population as well as the figures resulting from the application of the adjustment to the pensioner/annuitant mortality are shown. This adjustment was based on the BR-EMS 2010 table as no other insured or pensioner experience is available for Brazil. The differences in life expectancy shown based on the BR-EMS 2010 capture the impact of mortality improvements from 2005, the date on which the experience was established.

Table 5.2. **Brazilian males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
AT-2000 Basic		27.9	19.5	12.4	7.7	12.8	9.4	13.0%	7.8%	10.6%
AT-2000 M		28.9	20.4	13.2	7.9	13.2	9.8	12.6%	7.6%	10.2%
AT-83 (1983a)		26.8	18.6	11.7	7.3	12.4	9.0	13.6%	8.1%	11.1%
BR-EMS 2010		29.8	21.4	14.1	8.2	13.5	10.3	12.3%	7.4%	9.7%
Modelled Mortality										
Population	*LC*	24.5	16.8	10.8	6.6	11.5	8.4	15.2%	8.7%	11.9%
	CBD	24.5	16.9	11.0	6.6	11.5	8.6	15.2%	8.7%	11.7%
	P-Spline	24.0	16.5	10.7	6.4	11.4	8.4	15.6%	8.8%	11.9%
	CMI	25.7	17.6	11.3	6.8	11.7	8.6	14.8%	8.6%	11.6%
Adjusted										
BR-EMS 2010: 2005	*LC*	31.1	22.1	14.3	8.6	13.8	10.4	11.7%	7.2%	9.6%
	CBD	31.3	22.1	14.3	8.6	13.9	10.5	11.6%	7.2%	9.5%
	P-Spline	30.7	21.8	14.2	8.5	13.8	10.4	11.8%	7.3%	9.6%
	CMI	33.0	23.3	14.9	8.9	14.2	10.7	11.3%	7.1%	9.3%

Source: Author's calculations.

Table 5.3. **Brazilian females**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
AT-2000 Basic		31.1	22.2	14.1	8.6	14.0	10.4	11.6%	7.2%	9.6%
AT-2000 M		32.0	23.0	14.9	8.8	14.3	10.8	11.3%	7.0%	9.3%
AT-83 (1983a)		30.8	22.0	14.0	8.5	13.9	10.3	11.7%	7.2%	9.7%
BR-EMS 2010		33.7	24.7	16.5	9.2	14.9	11.6	10.8%	6.7%	8.6%
Modelled Mortality										
Population	*LC*	30.4	21.1	13.5	8.2	13.2	9.9	12.2%	7.6%	10.1%
	CBD	30.5	21.3	13.7	8.2	13.3	10.0	12.2%	7.5%	10.0%
	P-Spline	29.5	20.6	13.2	8.0	13.0	9.7	12.5%	7.7%	10.3%
	CMI	30.6	21.3	13.6	8.2	13.2	9.9	12.3%	7.6%	10.1%
Adjusted										
BR-EMS 2010: 2005	*LC*	36.9	26.8	17.7	10.0	15.5	12.2	10.0%	6.4%	8.2%
	CBD	37.1	27.0	17.8	10.0	15.6	12.2	10.0%	6.4%	8.2%
	P-Spline	36.2	26.3	17.4	9.8	15.4	12.0	10.2%	6.5%	8.3%
	CMI	37.4	27.2	17.9	10.0	15.6	12.2	10.0%	6.4%	8.2%

Source: Author's calculations.

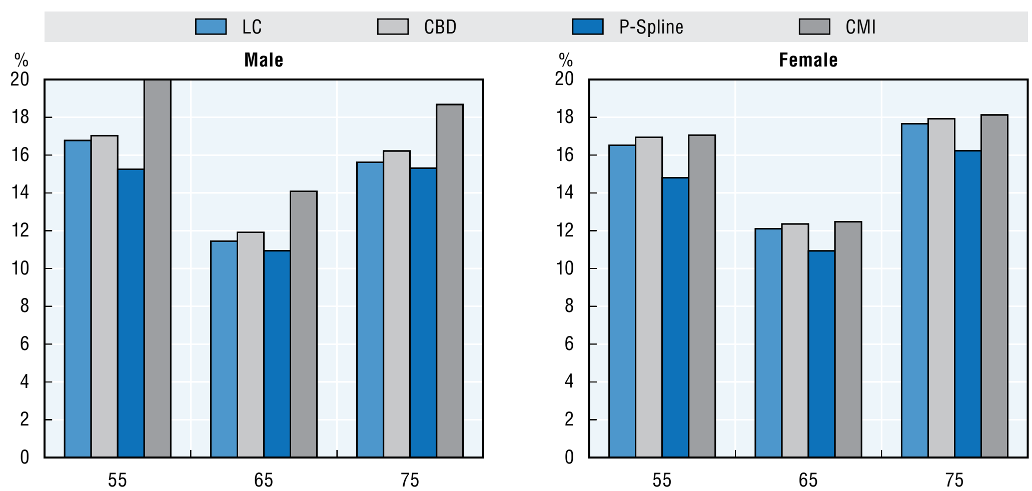
Change in liability value

The figures below show the change in liability value for pensioners and annuitants given by the models studied based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. All results show that the lack of incorporating mortality improvement assumptions in the valuation of liabilities results in a significant shortfall in provisions and exposes pension plans and annuity providers to a large amount of longevity risk. This exposure is exacerbated by the fact that the common practice in Brazil is to use outdated tables based on United States population mortality. Historically these assumptions may have included some margins as the Brazilian life expectancy is lower than that of the United States, but these margins have quickly disappeared over time as Brazilian mortality has improved.

Pension regulation requires as a minimum the most outdated table (AT-83), evidently resulting in the largest shortfall of liabilities of around 12-15% on average, shown in Figure 5.2. However even the more updated table commonly used by pension funds (AT-2000) results in an 7-11% shortfall in Figure 5.3, with the difference being larger for females. The AT-2000 Basic tables commonly used by annuity providers imply a shortfall of provisions in Figure 5.4 on average of around 10-14%.

Given the use of outdated tables based on the United States experience, the creation of the BR-EMS 2010 table based on Brazilian experience was a commendable initiative, and does significantly reduce the expected shortfall in provisions for annuity providers, shown in Figure 5.5. However residual risk still remains of around 3-5% of liabilities as future mortality improvements are not taken into account.

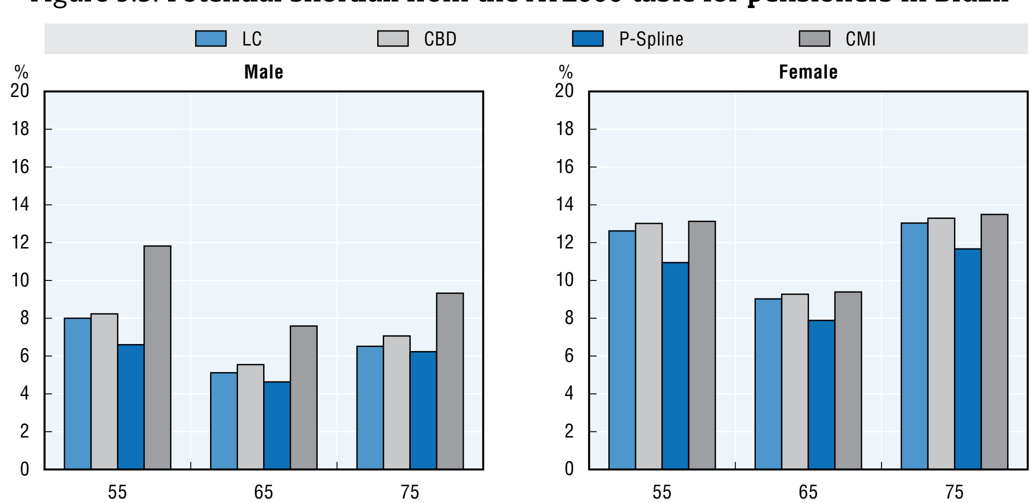
Figure 5.2. **Potential shortfall from the AT83 table for pensioners in Brazil**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933152953

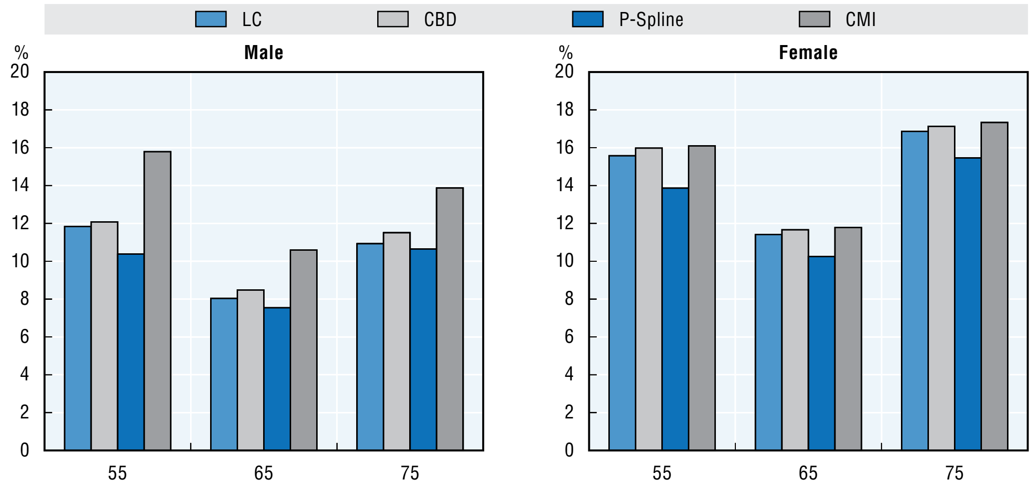
Figure 5.3. **Potential shortfall from the AT2000 table for pensioners in Brazil**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933152963

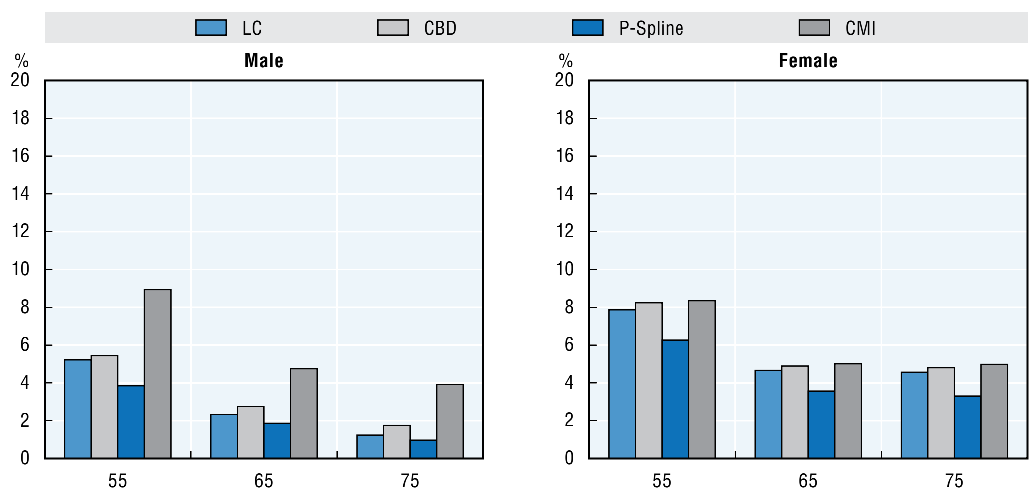
Figure 5.4. **Potential shortfall from the AT2000 Basic table for annuitants in Brazil**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933152978

Figure 5.5. **Potential shortfall from the BR-EMS 2010 table for annuitants in Brazil**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933152981

Main conclusions

Life expectancy at age 65 for males and females has been increasing over the last decade, with female mortality decreasing at a higher rate overall. As a result of these improvements, the use of outdated United States mortality tables has resulted in a significant shortfall of technical provisions for both pension funds and annuity providers. Adoption of the BR-EMS 2010 tables based on recent Brazilian experience would significantly reduce some of this exposure, though unless future mortality improvements are accounted for providers can continue to expect to face an increasing shortfall in provisions.

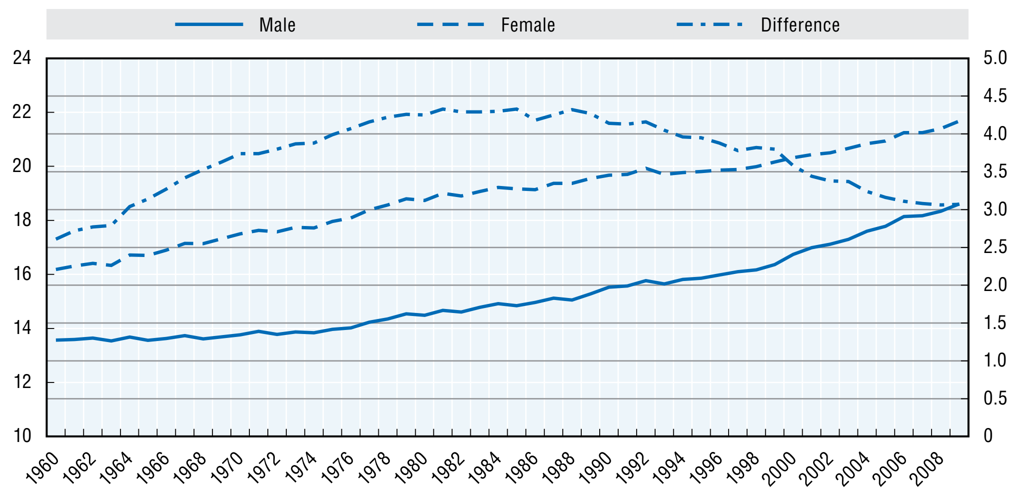
Canada

The assessment for Canada relied on HMD data from 1960 to 2009.

Historical life expectancy at age 65

Figure 5.6 shows the evolution in period life expectancy at age 65 for males and females. The life expectancy for males seems to have been increasing at an accelerating rate since 1960, while the growth for females appears to have been increasing at a steadier rate, with a slight slowdown in the 1980s. This has resulted in a convergence in life expectancy for 65 year old males and females since around 1990, with the difference (shown on the right axis) peaking at around 4.25 years and decreasing to about 3 years currently.

Figure 5.6. **Life expectancy at age 65 in Canada**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933152993

Historical and future mortality improvements

Table 5.4 below shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (HMD) have been accelerating over the past two decades for both genders, with the highest improvements for those in their 60s and 70s, though improvements have been higher for males than females. Scale AA, typically used to forecast mortality for pension funds, does not come close to meeting these observed improvements of mortality over the last decade. The improvements promulgated by the CIA, used by annuity providers, seem more in line on average though still lower than recent experience. The CPM assumptions derived from Canadian pensioner data continue the higher improvements experienced over the last decade into the coming decade, with improvements then decreasing to a more long term average, this latter being more or less in line with outputs from the Lee-Carter and Cairns-Blake-Dowd models for males, though for females the assumptions are somewhat lower than recent historical experience and projections for most other models. The stochastic models are projecting rather low improvements compared to recent experience, particularly for males. The P-spline seems to project forward continuously the high improvements experienced in the last decade,

Table 5.4. **Evolution of annual mortality improvements in Canada***

	HMD		ScaleAA		CIA		CPM4		CPM2014		LC		CBD		PS		CMI	
Males	1990-2000	2000-09	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30
55-59	2.4%	2.0%	1.7%	1.7%	1.7%	1.7%	2.8%	1.8%	2.0%	1.2%	2.1%	2.1%	1.9%	1.9%	1.9%	1.9%	1.5%	1.6%
60-64	2.6%	2.8%	1.5%	1.5%	1.5%	1.5%	2.8%	1.8%	2.4%	1.3%	2.0%	2.0%	1.7%	1.7%	2.6%	2.5%	1.7%	1.5%
65-69	2.2%	2.6%	1.4%	1.4%	1.5%	1.5%	2.8%	1.8%	2.6%	1.4%	1.8%	1.8%	1.6%	1.6%	3.0%	3.0%	2.0%	1.4%
70-74	1.9%	3.2%	1.5%	1.5%	1.5%	1.5%	2.6%	1.8%	2.6%	1.4%	1.5%	1.5%	1.4%	1.4%	3.1%	3.1%	2.3%	1.5%
75-79	1.6%	2.8%	1.3%	1.3%	1.5%	1.5%	2.4%	1.6%	2.5%	1.3%	1.3%	1.3%	1.3%	1.3%	3.1%	3.1%	2.5%	1.7%
80-84	1.5%	2.5%	0.8%	0.8%	1.5%	1.5%	1.9%	1.4%	2.1%	1.2%	1.0%	1.0%	1.1%	1.1%	2.9%	2.9%	2.4%	1.8%
85-89	0.5%	2.2%	0.6%	0.6%	1.5%	1.5%	1.0%	0.9%	1.3%	0.8%	0.7%	0.7%	0.9%	0.9%	2.6%	2.6%	2.2%	1.8%
90-94	-0.1%	2.0%	0.3%	0.3%	1.2%	1.2%	0.3%	0.3%	0.5%	0.4%	0.4%	0.4%	0.8%	0.8%	2.1%	2.1%	1.8%	1.6%
95-99	-0.5%	1.6%	0.2%	0.2%	0.4%	0.4%	0.0%	0.0%	0.1%	0.2%	0.2%	0.2%	0.6%	0.6%	1.1%	1.2%	1.3%	1.2%
100-104	-0.8%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.0%	0.0%	0.4%	0.4%	0.3%	0.3%	0.9%	1.0%
105-110	-0.5%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	-0.1%	-0.1%	0.2%	0.2%	-0.3%	-0.3%	0.7%	0.7%
	HMD		ScaleAA		CIA		CPM4		CPM2014		LC		CBD		PS		CMI	
Females	1990-2000	2000-09	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30	2010-20	2020-30
55-59	1.4%	1.8%	0.6%	0.6%	1.7%	1.7%	2.0%	1.3%	1.3%	1.0%	1.6%	1.6%	1.9%	1.9%	1.6%	1.6%	1.4%	1.6%
60-64	1.3%	1.6%	0.5%	0.5%	1.5%	1.5%	1.9%	1.3%	1.5%	1.0%	1.6%	1.6%	1.8%	1.8%	1.9%	1.8%	1.5%	1.5%
65-69	1.3%	2.1%	0.5%	0.5%	1.5%	1.5%	1.6%	1.2%	1.6%	1.1%	1.6%	1.6%	1.7%	1.7%	1.9%	1.9%	1.7%	1.5%
70-74	1.1%	2.0%	0.6%	0.6%	1.5%	1.5%	1.5%	1.2%	1.6%	1.1%	1.6%	1.6%	1.5%	1.5%	2.0%	2.0%	1.8%	1.5%
75-79	1.1%	2.1%	0.7%	0.7%	1.5%	1.5%	1.5%	1.2%	1.6%	1.1%	1.7%	1.7%	1.4%	1.4%	2.1%	2.0%	1.8%	1.6%
80-84	1.3%	1.8%	0.7%	0.7%	1.5%	1.5%	1.3%	1.1%	1.6%	1.0%	1.4%	1.5%	1.3%	1.3%	2.1%	2.1%	1.7%	1.6%
85-89	0.3%	1.8%	0.4%	0.4%	1.5%	1.5%	0.8%	0.8%	1.3%	0.8%	1.2%	1.2%	1.2%	1.2%	2.2%	2.2%	1.7%	1.6%
90-94	0.0%	1.8%	0.3%	0.3%	1.2%	1.2%	0.3%	0.3%	0.5%	0.4%	0.8%	0.8%	1.0%	1.0%	2.0%	2.0%	1.6%	1.5%
95-99	-0.5%	1.4%	0.1%	0.1%	0.4%	0.4%	0.0%	0.0%	0.1%	0.2%	0.4%	0.4%	0.8%	0.9%	1.4%	1.5%	1.3%	1.2%
100-104	-0.7%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.2%	0.2%	0.7%	0.7%	0.6%	0.6%	0.9%	1.0%
105-110	-0.5%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.0%	0.0%	0.5%	0.5%	-0.3%	-0.2%	0.7%	0.7%

Source: Author's calculations.

**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153555

reflecting the model's sensitivity to the most recent data, whereas the CMI model follows a similar pattern to the improvements assumed by the CPM table, with somewhat higher improvements over the next decade, moving towards a lower rate in the 2020s. A long term improvement of 1.6% has been assumed for the CMI model for Canada.

Life expectancy and annuity values

Tables 5.5 and 5.6 show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees). Model outputs for the general population as well as the figures resulting from the application of the adjustment to the pensioner/annuitant mortality are shown.

Table 5.5. **Canadian males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
GAM-94 / CIA imps		30.4	20.8	12.7	8.3	13.3	9.6	12.0%	7.5%	10.4%
UP-94 / Scale AA		28.8	19.5	11.8	8.0	12.8	9.1	12.6%	7.8%	10.9%
UP-94 to 2020 / Scale AA		28.1	19.4	12.0	7.8	12.8	9.3	12.8%	7.8%	10.8%
CPM4		29.7	20.0	11.8	8.3	13.1	9.2	12.1%	7.7%	10.9%
CPM2014		31.0	21.7	13.2	8.6	13.8	9.9	11.6%	7.2%	10.1%
Modelled Mortality										
Population	*LC*	28.8	19.5	11.7	8.0	12.8	9.1	12.5%	7.8%	11.0%
	CBD	29.1	19.7	12.1	8.0	12.8	9.2	12.5%	7.8%	10.8%
	P-Spline	32.4	22.0	13.2	8.8	13.7	9.8	11.4%	7.3%	10.2%
	CMI	30.9	21.3	12.9	8.4	13.4	9.7	11.9%	7.5%	10.3%
Adjusted										
CPM4: 2006	*LC*	29.1	19.4	11.6	8.1	12.8	9.0	12.4%	7.8%	11.1%
	CBD	29.4	19.7	11.9	8.1	12.9	9.1	12.3%	7.8%	10.9%
	P-Spline	32.8	21.9	12.9	8.9	13.7	9.7	11.2%	7.3%	10.3%
	CMI	31.3	21.2	12.7	8.5	13.4	9.6	11.7%	7.5%	10.4%
CPM2014: 2008	*LC*	30.4	21.1	12.8	8.4	13.5	9.7	11.9%	7.4%	10.3%
	CBD	30.7	21.4	13.1	8.5	13.6	9.9	11.8%	7.3%	10.1%
	P-Spline	33.7	23.4	14.0	9.2	14.3	10.3	10.9%	7.0%	9.7%
	CMI	32.3	22.7	13.8	8.8	14.1	10.2	11.4%	7.1%	9.8%

Source: Author's calculations.

Table 5.6. **Canadian females**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
GAM-94 / CIA imps		33.5	23.6	15.0	9.2	14.4	10.8	10.9%	6.9%	9.2%
UP-94 / Scale AA		31.3	22.0	13.9	8.6	13.8	10.3	11.6%	7.2%	9.7%
UP-94 to 2020 / Scale AA		30.7	21.8	14.0	8.5	13.8	10.4	11.7%	7.3%	9.6%
CPM4		32.7	22.8	14.2	9.1	14.2	10.5	11.0%	7.0%	9.5%
CPM2014		33.8	24.2	15.3	9.3	14.7	11.1	10.7%	6.8%	9.0%
Modelled Mortality										
Population	*LC*	33.0	23.2	14.6	9.0	14.3	10.6	11.1%	7.0%	9.4%
	CBD	33.1	23.1	14.5	9.0	14.2	10.5	11.1%	7.1%	9.5%
	P-Spline	34.8	24.5	15.3	9.4	14.6	10.9	10.7%	6.8%	9.1%
	CMI	33.9	23.9	15.0	9.2	14.5	10.8	10.9%	6.9%	9.3%
Adjusted										
CPM4: 2006	*LC*	33.7	23.4	14.6	9.3	14.4	10.7	10.8%	6.9%	9.4%
	CBD	33.9	23.6	14.8	9.3	14.4	10.7	10.8%	6.9%	9.3%
	P-Spline	35.7	24.8	15.5	9.6	14.8	11.1	10.4%	6.8%	9.0%
	CMI	34.8	24.3	15.2	9.5	14.6	10.9	10.6%	6.8%	9.2%
CPM2014: 2008	*LC*	34.5	24.5	15.5	9.5	14.8	11.1	10.6%	6.7%	9.0%
	CBD	34.7	24.7	15.6	9.5	14.9	11.2	10.5%	6.7%	8.9%
	P-Spline	36.3	25.8	16.2	9.8	15.2	11.4	10.2%	6.6%	8.7%
	CMI	35.5	25.3	16.0	9.6	15.0	11.3	10.4%	6.7%	8.8%

Source: Author's calculations.

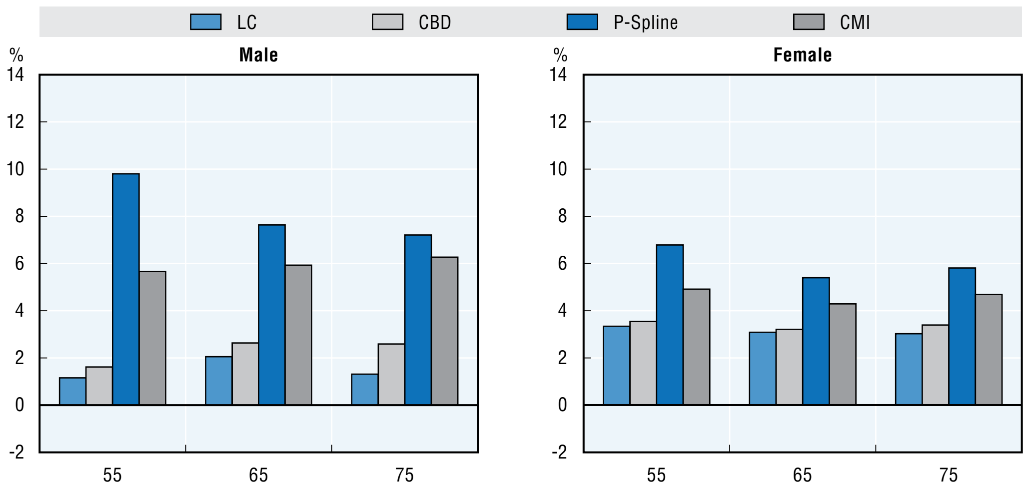
The model outputs were adjusted based on the mortality from the Canadian Pensioners' Mortality studies, which are the most recent data available for Canadian pensioners.

It can be noted that even though the UP-94 Static table intends to capture the impact of future mortality improvements, it falls short of the other generational tables except at the oldest ages.

Change in liability value

The figures below show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. The results for the GAM-94 and UP-94 are based on the modelled mortality adjusted to the 2008 mortality from the CPM2014 table, which represents the mortality from the Registered Pension Plans (RPP), a subset of the total Canadian pensioner population. This experience is the Canadian experience available which is most likely to be representative of the populations for which these mortality tables are used. The results of the P-spline model tend to be outliers, particularly for males, which is logical given the observation above that the model projects forward continuously the very high improvements of the last decade. Nevertheless, there seems to be a shortfall in the current provisions for longevity. While the stochastic models indicate less of a shortfall, the results from these models were also much less conservative compared to recent experience. The shortfall for the annuitant table (GAM94, Figure 5.7) is around 3-5%, though this result does not take into account the additional load of 2-8% which annuity providers typically apply to their base mortality assumptions which would minimise any existing shortfall. The shortfall for the old pensioner table (UP94) in Figure 5.8 is higher at around 6-9% for both genders for the generational table, and even higher with the static application of the table in Figure 5.9. The results of the four projection models converge more for females than for males, for whom the difference between the results of the stochastic models and deterministic models is larger. Adoption of the CPM tables for pensioners would reduce the potential shortfall, shown in Figure 5.10 and 5.11, though there may still be some residual risk of up to around 2% if the high improvements of the last decade continue for the next several years.

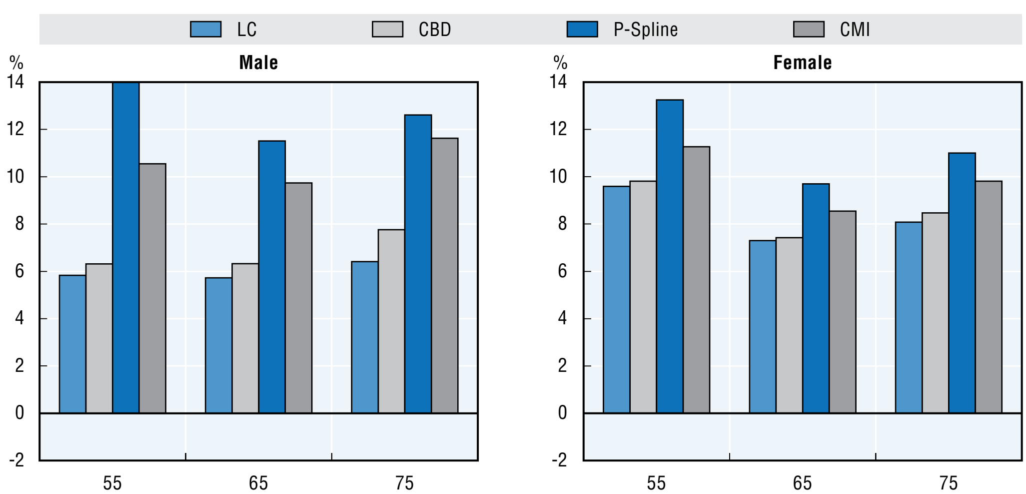
Figure 5.7. **Potential shortfall from the GAM94 table with CIA improvements for annuitants in Canada**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153007

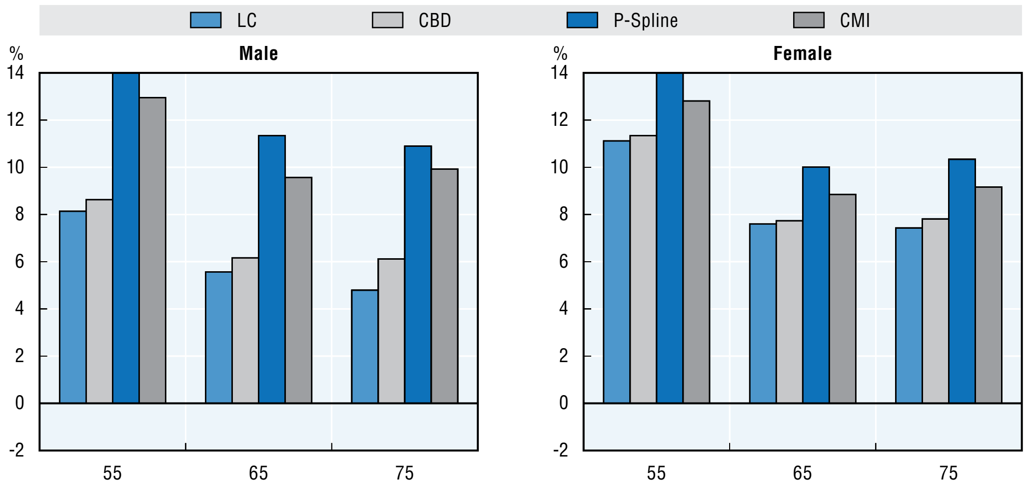
Figure 5.8. **Potential shortfall from the UP94 table with Scale AA improvements for pensioners in Canada**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153016

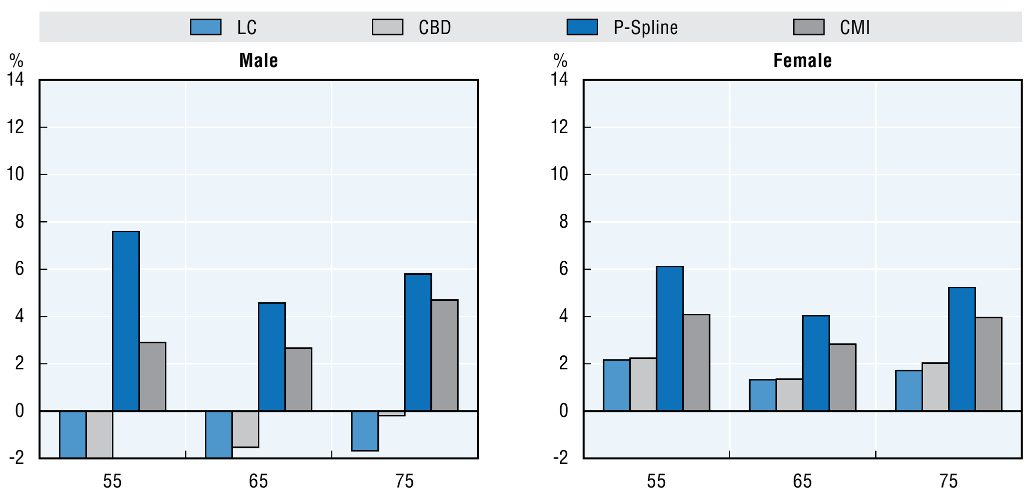
Figure 5.9. **Potential shortfall from the static UP94 table projected to 2020 for pensioners in Canada**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153023

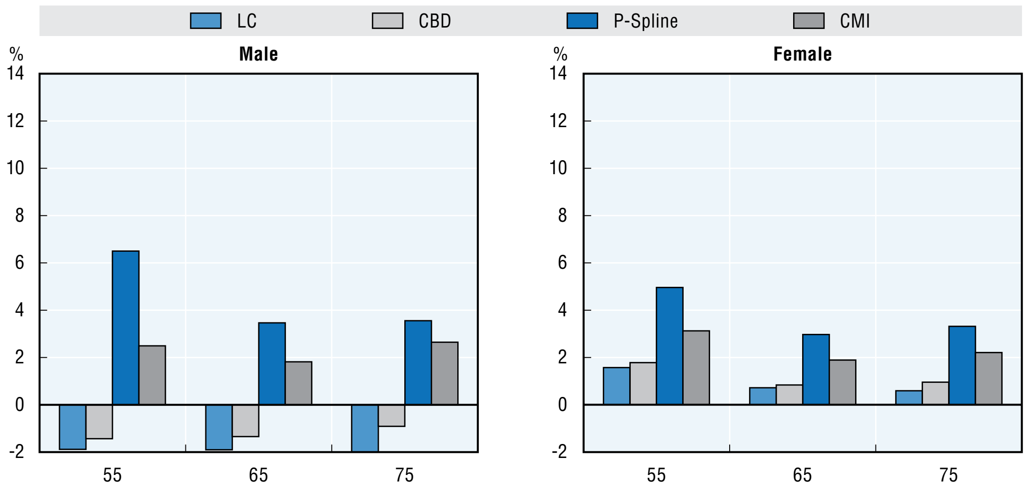
Figure 5.10. **Potential shortfall from the CPM4 table for pensioners in Canada**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153030

Figure 5.11. **Potential shortfall from the CPM2014 table for pensioners in Canada**



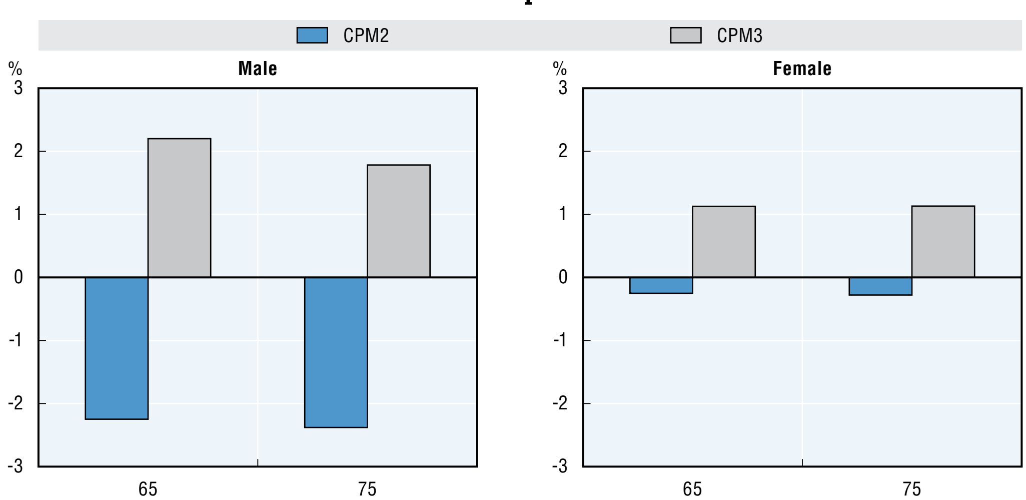
Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153045

Impact of socio-economic variables

The study of the Canadian pensioner mortality to develop the proposed CPM tables also looked at the impact of income on mortality. Figure 5.12 shows the impact on liabilities for pensioners in the C/QPP system having between 35% and 95% of the maximum pension (CPM2) and over 95% of the maximum (CPM3) relative to the total group having over 35% (CPM4, presented above). The impact of income is much higher for males, changing the value of the liabilities by over 2% for both lower and higher incomes. For females the impact is smaller, with little change for the lower income group and just over a 1% increase for those with the highest income.

Figure 5.12. **Impact of medium (CMP2) and high (CMP3) income on Canadian pensioner liabilities**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153058

It should be noted that these results reflect only the differences in the level of mortality, as common trend assumptions were developed across all income categories. However, the author of the study found significant differences in 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). This finding poses a challenge to the assumption used in this study that pensioners and annuitants should all follow a common trend with the overall population, and implies that the expected shortfall presented here could potentially be understated. However it is difficult to say whether this divergence in mortality could continue in the long term, and despite this finding the author of the study considered common trend assumptions across income groups to be a reasonable concession.

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, though the two genders have been converging since the 1990s. Both genders have been experiencing an acceleration of mortality improvement over the last decade. The projection models overall are in line with historical improvements, though the P-spline model appears to be overly sensitive to the very high improvements of the past decade, resulting in rather elevated projections of life expectancy particularly for males.

Comparing model outputs to calculations based on assumed tables, a shortfall of provisioning for longevity seems likely in most cases, especially for pensioners under the UP94 table. Developing a table specific to the Canadian population, as was done with the Canadian Pensioner Mortality study, is very important to bring assumptions in line with the population for which they are being used and reduce the potential shortfall in the liability valuations. This is evident as an average Canadian can expect to live around a year longer than his or her American counterpart. Furthermore, given the significance of the difference in mortality for higher income pensioners, attention should be paid to the socio-economic profile of the population, and adjustments to the level of mortality considered accordingly.

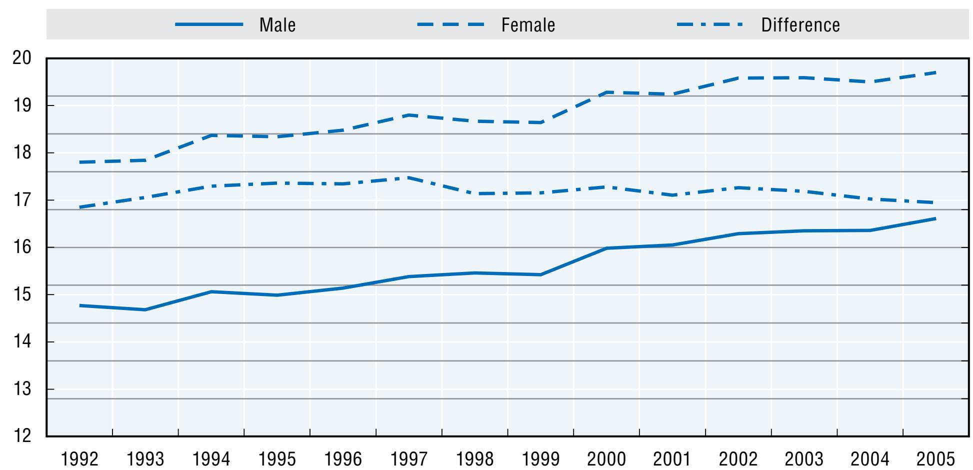
Chile

The assessment for Chile was based on HMD data from 1992 to 2005.

Historical life expectancy at age 65

Figure 5.13 shows the evolution in period life expectancy at age 65 for males and females for the Chilean population. The life expectancy for both genders seems to have been increasing at a fairly steady rate on average from 1992-2005. The difference in life expectancy between males and females (shown on right axis) has remained relatively constant at around 3 years.

Figure 5.13. **Life expectancy at age 65 in Chile**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153060

Historical and future mortality improvements

Table 5.7 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages over time. From the left, the Chilean population experience has been broken down into two periods of seven years to show the progression over time, as well as showing the average improvement over the entire period available. Improvements for both sexes have remained similar on average over the whole period of observation for ages up to 90, with females experiencing higher improvements than males overall. All of these improvements have outpaced those assumed by the RV2009 table. All projection models show similar estimations of future improvements, more or less in line with observed experience. A long term improvement of 1.5% has been assumed for the CMI model for Chile.

As historical population data from the HMD database is limited, another perspective to look at more recent mortality improvements specifically for the Chilean pensioner population would be to compare the mortality rates set for the RV2004 table with the updated mortality in the RV2009 table. Table 5.8 shows, from left to right, the historical improvements of the Chilean population, the annualized improvements implied by the update of mortality assumptions from RV2004 to RV2009, and the improvements projected forward with the RV2009 table for both males and females.

Table 5.7. **Evolution of annual mortality improvements in Chile***

	HMD			RV2009		LC		CBD		PS		CMI	
Males	1992-1999	1998-2005	1992-2005	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.1%	3.0%	1.9%	0.9%	0.9%	1.9%	1.9%	1.7%	1.7%	2.7%	2.7%	1.7%	1.5%
60-64	2.9%	1.7%	2.1%	0.9%	0.9%	2.1%	2.1%	1.7%	1.7%	2.3%	2.4%	1.7%	1.5%
65-69	1.3%	2.5%	2.1%	0.9%	0.9%	1.9%	1.9%	1.8%	1.8%	2.1%	2.0%	1.7%	1.5%
70-74	2.1%	1.4%	1.6%	0.9%	0.9%	1.7%	1.7%	1.9%	1.9%	1.8%	1.6%	1.6%	1.5%
75-79	1.0%	1.9%	1.9%	0.8%	0.8%	1.8%	1.8%	1.9%	2.0%	1.3%	1.4%	1.5%	1.5%
80-84	1.1%	0.2%	1.1%	0.5%	0.5%	0.9%	0.9%	2.0%	2.0%	1.7%	1.9%	1.4%	1.5%
85-89	0.9%	2.4%	1.7%	0.1%	0.1%	2.2%	2.2%	2.0%	2.0%	2.3%	2.4%	1.5%	1.5%
90-94	-0.9%	5.9%	2.6%	0.1%	0.1%	2.3%	2.4%	2.0%	2.0%	3.4%	3.2%	1.4%	1.4%
95-99	-1.1%	4.9%	2.3%	0.0%	0.0%	2.5%	2.6%	1.9%	2.0%	3.5%	3.7%	1.2%	1.1%
100-104	-1.3%	5.1%	2.3%	0.0%	0.0%	2.6%	2.7%	1.8%	1.9%	2.7%	2.9%	0.9%	0.9%
105-110	-1.3%	4.8%	1.4%	0.0%	0.0%	1.7%	1.6%	1.6%	1.7%	1.3%	1.4%	0.6%	0.6%

	HMD			RV2009		LC		CBD		PS		CMI	
Females	1992-1999	1998-2005	1992-2005	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.1%	2.7%	2.4%	0.7%	0.7%	2.0%	1.9%	2.4%	2.4%	2.3%	2.4%	1.7%	1.5%
60-64	3.0%	1.8%	1.8%	0.7%	0.7%	1.9%	1.8%	2.3%	2.3%	2.1%	2.1%	1.7%	1.5%
65-69	2.3%	2.3%	2.7%	0.7%	0.7%	2.2%	2.2%	2.1%	2.1%	2.1%	2.0%	1.7%	1.5%
70-74	2.6%	1.9%	2.1%	0.7%	0.7%	2.2%	2.2%	2.0%	2.0%	1.9%	1.8%	1.7%	1.5%
75-79	2.1%	2.4%	2.3%	0.6%	0.6%	2.2%	2.2%	1.8%	1.8%	1.6%	1.6%	1.5%	1.5%
80-84	0.8%	0.6%	1.1%	0.5%	0.5%	1.2%	1.2%	1.6%	1.6%	1.5%	1.6%	1.4%	1.4%
85-89	0.3%	1.3%	1.0%	0.3%	0.3%	1.6%	1.6%	1.4%	1.4%	1.5%	1.6%	1.4%	1.5%
90-94	-0.4%	2.6%	1.4%	0.2%	0.2%	1.2%	1.2%	1.2%	1.2%	1.9%	1.8%	1.4%	1.4%
95-99	-0.5%	2.2%	1.2%	0.2%	0.2%	1.1%	1.1%	1.0%	1.0%	1.8%	1.8%	1.1%	1.1%
100-104	-0.6%	2.2%	1.1%	0.0%	0.0%	0.9%	0.9%	0.8%	0.8%	1.1%	1.1%	0.9%	0.9%
105-110	-0.6%	1.9%	0.9%	0.0%	0.0%	0.5%	0.5%	0.5%	0.5%	0.3%	0.4%	0.6%	0.6%

Source: Author's calculations.

**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153568

For males, improvements of the more recent experience for pensioners have been higher than those of the latest population data for ages 65-84. All ages, except at the very oldest ages where limited data is available, have experienced much higher improvements than those assumed by the RV2009. This is also true for females aged 55-69, who have experienced significantly reduced mortality with the revised mortality tables, though contrary to the experience of the population, the mortality for ages over 75 has been revised upward.

Table 5.8. **Annualized mortality improvements in Chile: population experience, pensioners and annuitants, and future assumptions in the regulatory table**

	HMD	RV 09/04	RV2009		HMD	RV 09/04	RV2009
Males	1992-2005	2004-2009	2009+	Females	1992-2005	2004-2009	2009+
55-59	1.9%	1.4%	0.9%	55-59	2.4%	2.7%	0.7%
60-64	2.1%	1.3%	0.9%	60-64	1.8%	6.0%	0.7%
65-69	2.1%	2.5%	0.9%	65-69	2.7%	4.1%	0.7%
70-74	1.6%	2.2%	0.9%	70-74	2.1%	0.3%	0.7%
75-79	1.9%	2.0%	0.8%	75-79	2.3%	-1.3%	0.6%
80-84	1.1%	1.6%	0.5%	80-84	1.1%	-1.0%	0.5%
85-89	1.7%	0.9%	0.1%	85-89	1.0%	-1.2%	0.3%
90-94	2.6%	0.6%	0.1%	90-94	1.4%	-2.0%	0.2%
95-99	2.3%	0.7%	0.0%	95-99	1.2%	-2.7%	0.2%
100-104	2.3%	-1.0%	0.0%	100-104	1.1%	-2.1%	0.0%
105-110	1.4%	-3.4%	0.0%	105-110	0.9%	-1.2%	0.0%

Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153570

Life expectancy and annuity values

Tables 5.9 and 5.10 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

The figures given for each of the projection models applied are given based on the population and also adjusted the initial level of the 2009 mortality set for the RV2009, thus capturing only the impact of the differences in improvements between what is assumed to what is projected in the future.

Table 5.9. **Chilean males**

		Life Expectancy 2010			Annuity factors			Annuity payment		
Mortality tables		55	65	75	55	65	75	55	65	75
RV2009		28.1	19.4	12.0	7.8	12.8	9.2	12.9%	7.8%	10.8%
Modelled Mortality										
Population	*LC*	29.8	20.2	12.6	7.8	12.6	9.2	12.8%	7.9%	10.8%
	CBD	29.9	20.3	12.7	7.9	12.8	9.4	12.7%	7.8%	10.7%
	P-Spline	31.0	20.9	13.1	8.0	12.8	9.4	12.4%	7.8%	10.6%
	CMI	28.3	19.1	11.8	7.6	12.4	9.0	13.2%	8.1%	11.2%
Adjusted										
RV2009: 2009	*LC*	31.9	21.8	13.4	8.5	13.4	9.8	11.8%	7.4%	10.2%
	CBD	31.9	21.8	13.3	8.5	13.5	9.8	11.7%	7.4%	10.2%
	P-Spline	33.1	22.6	13.9	8.7	13.6	10.0	11.5%	7.3%	10.0%
	CMI	30.3	20.8	12.8	8.2	13.2	9.6	12.1%	7.6%	10.4%

Source: Author's calculations.

Table 5.10. **Chilean females**

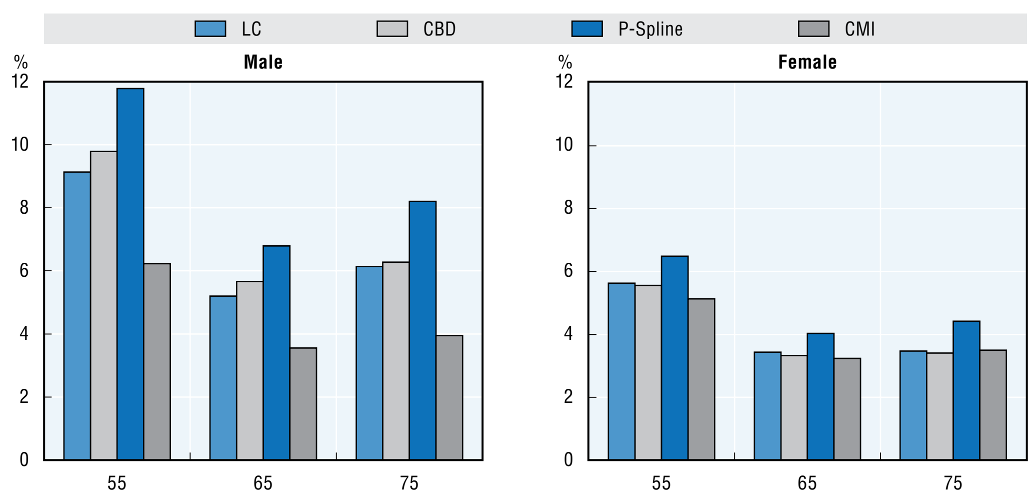
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
RV2009		33.7	24.3	15.5	9.3	14.8	11.1	10.7%	6.8%	9.0%
Modelled Mortality										
Population	*LC*	31.5	22.5	13.8	8.8	13.9	10.2	11.3%	7.2%	9.8%
	CBD	32.4	22.3	13.8	8.8	13.8	10.1	11.4%	7.2%	9.9%
	P-Spline	33.1	22.9	14.1	8.9	14.0	10.3	11.2%	7.1%	9.8%
	CMI	32.3	22.4	13.8	8.8	13.9	10.1	11.4%	7.2%	9.9%
Adjusted										
RV2009: 2009	*LC*	36.4	26.0	16.4	9.8	15.3	11.5	10.2%	6.5%	8.7%
	CBD	36.3	25.9	16.3	9.8	15.3	11.5	10.2%	6.5%	8.7%
	P-Spline	37.0	26.4	16.7	9.9	15.4	11.6	10.1%	6.5%	8.6%
	CMI	36.2	25.9	16.4	9.8	15.3	11.5	10.2%	6.5%	8.7%

Source: Author's calculations.

Change in liability value

Figure 5.14 shows the change in liability value based on the annuity values for the standard mortality table and the adjusted model outputs presented in the section above. All models are predicting a shortfall in the current provisions for longevity by around 4-6% for males and 3-5% for females. The results of the four projection models converge reasonable well for females, though there is more divergence for males.

Figure 5.14. **Potential shortfall from the RV 2009 table for annuitants in Chile**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153074

If the annuities are calculated based on the projected improvements applied to the initial level of the RV 2009 with the 3% margin removed, these results decrease by only around 1%, therefore the overall range of the conclusion remains similar.[3]

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last couple of decades at a similar pace. If recent mortality experience is anything to go by, the mortality improvements embedded in the RV 2009 table may not be sufficient, particularly for males of all ages and females under age 70. This understatement of improvements could potentially increase pension liabilities by up to 5%.

China

Mortality data for China was obtained from China's annual yearbook of statistics for the years 1995-2008. This data demonstrated significant variability from one year to the next and population coverage diminished over time to about 90% of the population for the latest data available, calling into question the reliability of the data source. The following analysis has been based on this data smoothed on an annual basis using the Kannisto function (Tesarkova, 2012), which reduces some of the variability in the data though significant discrepancies remain. As such, results should not be interpreted strictly. Rather, the aim of the results presented here is to give only a sense of the magnitude and direction of the evolution in mortality in China an idea of the potential shortfall in provisions for longevity.

Historical and future mortality improvements

Table 5.11 shows the annualized improvement to mortality rates for age groups of five years. From the left, historical improvements in the population's mortality are shown, split into two periods of seven years each. Improvements seem to have been accelerating over time, particularly for males who have recently been experiencing overall higher improvements than females. The high level of mortality improvement shows that China has been catching up to other OECD countries in terms of life expectancy. This fact along with the very short observation period on which the projections are based imply that the results of the stochastic models are likely overly optimistic in the long term, as realistically speaking the rate of the increase in life expectancy could be expected to be more in line with other OECD countries in the future. Similar conclusions could be drawn regarding the P-spline model, which is highly sensitive to the most recent data. For such situations the CMI model may give the most plausible results, as recent high improvements eventually converge to a lower long term rate, which was assumed to be 2% here.

Table 5.11. **Evolution of annual mortality improvements in China***

	Population		LC		CBD		PS		CMI	
Males	1995-2002	2001-2008	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.2%	3.0%	1.7%	1.7%	2.8%	2.8%	2.3%	2.2%	2.3%	2.0%
60-64	2.0%	3.4%	2.1%	2.1%	3.0%	3.0%	2.2%	2.2%	2.4%	2.0%
65-69	1.7%	3.8%	2.5%	2.6%	3.1%	3.1%	2.3%	2.3%	2.4%	2.0%
70-74	1.4%	4.1%	2.9%	2.9%	3.2%	3.3%	2.5%	2.5%	2.3%	1.9%
75-79	1.1%	4.4%	3.2%	3.2%	3.3%	3.4%	2.5%	2.5%	2.2%	1.9%
80-84	0.9%	4.5%	3.5%	3.5%	3.4%	3.5%	1.9%	1.8%	1.9%	1.9%
85-89	0.6%	4.5%	3.6%	3.7%	3.5%	3.6%	0.3%	0.3%	1.6%	1.9%
90-94	0.4%	4.3%	3.7%	3.8%	3.4%	3.6%	-2.1%	-2.0%	1.7%	1.8%
95-99	0.2%	3.9%	3.8%	4.0%	3.3%	3.6%	-4.5%	-3.6%	1.5%	1.5%
100-104	0.0%	3.3%	3.8%	4.0%	3.1%	3.5%	-5.6%	-2.8%	1.2%	1.2%
105-110	0.0%	2.6%	3.6%	3.9%	2.8%	3.3%	-5.1%	-1.1%	0.8%	0.8%
	Population		LC		CBD		PS		CMI	
Females	1995-2002	2001-2008	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.5%	4.4%	2.6%	2.6%	3.8%	3.8%	4.0%	4.0%	2.9%	2.0%
60-64	2.5%	4.1%	2.8%	2.8%	3.7%	3.7%	4.2%	4.2%	3.1%	2.1%
65-69	2.5%	3.7%	2.9%	2.9%	3.5%	3.5%	4.3%	4.3%	3.2%	2.1%
70-74	2.4%	3.4%	3.1%	3.1%	3.4%	3.4%	4.4%	4.4%	3.2%	2.1%
75-79	2.3%	3.0%	3.2%	3.2%	3.2%	3.3%	4.4%	4.4%	3.1%	2.1%
80-84	2.2%	2.6%	3.2%	3.2%	3.1%	3.1%	4.3%	4.4%	2.8%	2.0%
85-89	2.0%	2.2%	3.0%	3.1%	2.9%	2.9%	4.1%	4.1%	2.3%	2.0%
90-94	1.7%	1.7%	2.7%	2.8%	2.6%	2.7%	3.7%	3.7%	1.9%	1.8%
95-99	1.4%	1.2%	2.3%	2.4%	2.3%	2.4%	3.0%	3.1%	1.5%	1.5%
100-104	1.1%	0.8%	1.9%	2.0%	1.9%	2.1%	2.3%	2.4%	1.2%	1.2%
105-110	0.7%	0.5%	1.5%	1.5%	1.5%	1.6%	1.7%	1.8%	0.8%	0.8%

Source: Author's calculations.

**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153583

Table 5.12 compares the average annualized improvements for the Chinese population over the observation period available with the annualized improvements implied by the update of the China Life Insurance Mortality Table issued in 2006. This table was based on Chinese insured data from 2000-2003, updating a table based on data from 1990-1993, and therefore provides another source of deriving mortality improvements in China. This comparison implies an overall higher improvement in mortality for the insured population than what is implied by the general population data.

Table 5.12. **Comparison of implied annual mortality improvements for the general and insured population in China***

	Population	CL Mortality		Population	CL Mortality
Males	1995-2008	1990->2000	Females	1995-2008	1990->2000
55-59	2.9%	6.4%	55-59	3.9%	6.7%
60-64	3.0%	5.1%	60-64	3.7%	6.0%
65-69	3.1%	4.6%	65-69	3.6%	5.2%
70-74	3.2%	3.9%	70-74	3.4%	4.6%
75-79	3.3%	3.4%	75-79	3.2%	3.9%
80-84	3.2%	2.7%	80-84	2.9%	3.2%
85-89	3.1%	2.0%	85-89	2.6%	2.4%
90-94	2.9%	1.2%	90-94	2.2%	1.3%
95-99	2.5%	0.3%	95-99	1.8%	0.4%

Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153590

Life expectancy and annuity values

Table 5.13 and 5.14 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees). Modelled figures are shown for the general population as well as adjusted to the level of insured mortality in 2001, the median date on which the experience was established.

Table 5.13. **Chinese males**

		Life Expectancy 2010			Annuity factors			Annuity payment		
Mortality tables		55	65	75	55	65	75	55	65	75
CL(2000-2003)		29.1	20.4	13.0	8.0	13.2	9.8	12.4%	7.6%	10.2%
Modelled Mortality										
Population	*LC*	34.5	23.3	14.4	8.6	13.5	10.0	11.6%	7.4%	10.0%
	CBD	34.5	23.1	14.0	8.8	13.6	9.9	11.4%	7.4%	10.1%
	P-Spline	26.8	17.7	10.5	7.4	12.1	8.4	13.5%	8.3%	11.9%
	CMI	29.2	19.6	11.9	7.8	12.6	9.0	12.8%	7.9%	11.1%
Adjusted										
CL(2000-2003): 2001	*LC*	40.3	28.2	17.7	10.1	15.4	11.7	9.9%	6.5%	8.5%
	CBD	40.1	27.8	17.3	10.1	15.3	11.6	9.9%	6.5%	8.6%
	P-Spline	29.6	19.9	11.6	8.3	13.2	9.2	12.0%	7.6%	10.9%
	CMI	32.5	22.2	13.3	8.9	13.9	10.0	11.3%	7.2%	10.0%

Source: Author's calculations

Table 5.14. **Chinese females**

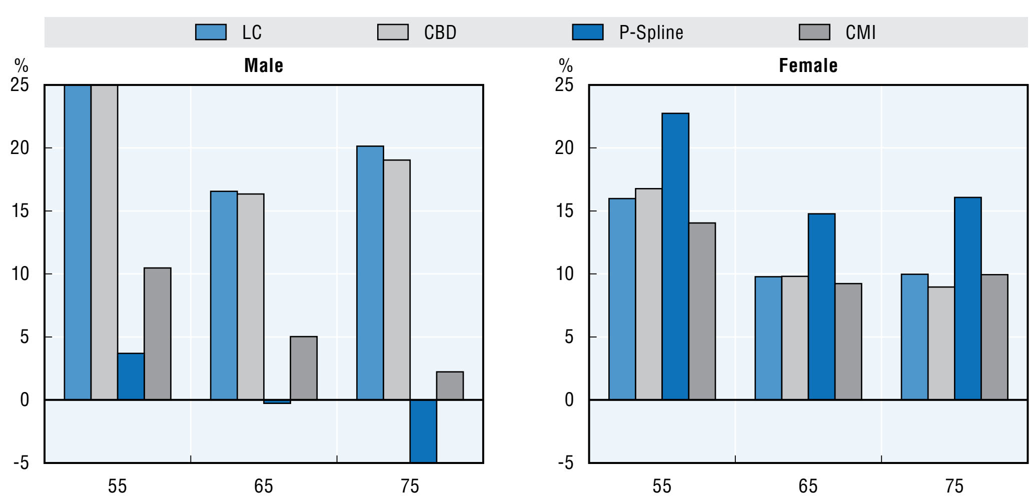
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
CL(2000-2003)		31.9	22.8	14.7	8.8	14.2	10.7	11.3%	7.0%	9.3%
Modelled Mortality										
Population	*LC*	35.4	24.0	14.7	9.2	14.2	10.4	10.8%	7.0%	9.6%
	CBD	35.5	24.0	14.4	9.4	14.2	10.3	10.7%	7.0%	9.7%
	P-Spline	39.2	26.8	16.3	10.0	15.0	11.1	10.0%	6.7%	9.0%
	CMI	34.0	23.5	14.5	9.1	14.2	10.4	11.0%	7.1%	9.6%
Adjusted										
CL(2000-2003): 2001	*LC*	39.1	27.5	17.2	10.2	15.6	11.8	9.8%	6.4%	8.5%
	CBD	39.2	27.4	16.9	10.3	15.6	11.7	9.7%	6.4%	8.6%
	P-Spline	42.2	29.9	18.7	10.8	16.3	12.4	9.2%	6.1%	8.0%
	CMI	37.6	26.8	17.0	10.1	15.5	11.8	9.9%	6.5%	8.5%

Source: Author's calculations

Change in liability value

Figure 5.15 shows the change in liability value given by the models studied based on the annuity values for the standard mortality table and the adjusted model outputs presented in the section above. Results for each of the models do not converge well for males, likely due to the higher underlying volatility of the data. The CMI model, which arguably gives the most plausible results, implies a potential shortfall of provisions of around 5-10%. The shortfall for females seems to be slightly higher, at up to 15%.

Figure 5.15. **Potential shortfall from the CL (20000-2003) table for annuitants in China**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153084

Main conclusions

China seems to have been experiencing a rapid increase in life expectancy over the last decade or so as it catches up to the level of OECD countries. While the results of most of the models presented here exaggerate this elevated improvement in mortality into the future, the conclusion that mortality improvements should be taken into account when provisioning for lifetime pensions and annuities is clear.

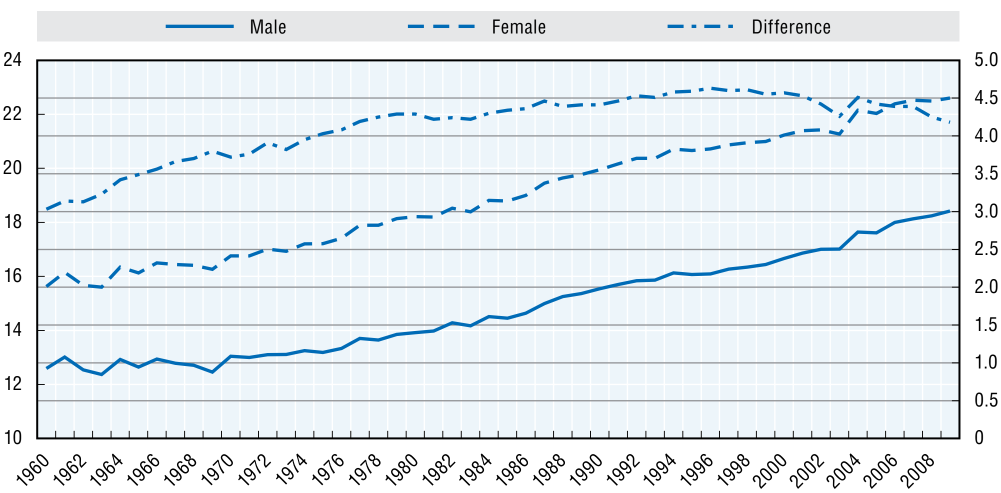
France

The assessment for France relied on HMD data from 1960 to 2010.

Historical life expectancy at age 65

Figure 5.16 shows the evolution in period life expectancy at age 65 for males and females. The life expectancy for both genders has been increasing at a fairly steady rate since about 1970, with females increasing at a faster rate than males overall. This has resulted in a divergence of life expectancies between the two genders through the mid-1990s, at which point the gap (shown on the right axis) has been decreasing somewhat, standing at just over four years currently.

Figure 5.16. **Life expectancy at age 65 in France**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153090

Historical and future mortality improvements

Table 5.15 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (HMD) have accelerated for both genders over the past decade, with improvements being the highest for those in their 70s and 80s. The TGH/TGF 05 tables will not keep up with these high improvements over age 65 in the coming decade, with the difference being larger for females, though improvements are assumed to accelerate in the decade which follows. Stochastic models are projecting overall lower improvements than what are assumed for males and higher than assumed for females. The P-spline model is predicting the highest improvements, reflecting its sensitivity to the most recent experience. The CMI model reverts eventually to the long term improvement assumption which has been set at 1.6% for France.

Table 5.15. **Evolution of annual mortality improvements in France***

	HMD		TGH05		LC		CBD		PS		CMI	
Male	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.4%	0.8%	2.2%	2.2%	1.5%	1.5%	1.8%	1.8%	1.1%	1.2%	1.6%	1.6%
60-64	2.5%	1.7%	2.3%	2.3%	1.7%	1.7%	1.7%	1.7%	1.9%	1.9%	1.7%	1.7%
65-69	1.5%	2.8%	2.2%	2.3%	1.8%	1.8%	1.6%	1.6%	3.0%	2.8%	1.9%	1.6%
70-74	1.3%	3.2%	2.1%	2.1%	1.8%	1.8%	1.5%	1.6%	3.5%	3.4%	2.3%	1.5%
75-79	1.7%	2.6%	2.1%	2.1%	1.7%	1.7%	1.5%	1.5%	3.2%	3.3%	2.5%	1.6%
80-84	1.7%	2.3%	1.8%	1.8%	1.5%	1.5%	1.4%	1.4%	2.6%	2.7%	2.3%	1.8%
85-89	1.2%	1.8%	1.5%	1.5%	1.1%	1.1%	1.2%	1.3%	2.0%	2.0%	1.9%	1.8%
90-94	0.7%	1.4%	1.1%	1.2%	0.7%	0.7%	1.1%	1.1%	1.4%	1.3%	1.5%	1.6%
95-99	0.5%	0.6%	0.9%	1.1%	0.4%	0.4%	0.9%	1.0%	0.8%	0.8%	1.2%	1.2%
100-104	0.3%	0.2%	0.7%	1.0%	0.2%	0.2%	0.8%	0.8%	0.3%	0.3%	0.9%	1.0%
105-110	0.1%	0.0%	0.8%	0.8%	0.0%	0.0%	0.6%	0.6%	-0.1%	-0.1%	0.6%	0.7%
	HMD		TGF05		LC		CBD		PS		CMI	
Female	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.7%	0.3%	1.1%	1.4%	1.7%	1.7%	2.4%	2.4%	0.6%	0.6%	1.0%	1.5%
60-64	1.7%	0.9%	1.2%	1.4%	1.9%	1.9%	2.3%	2.3%	1.2%	1.2%	1.1%	1.4%
65-69	1.5%	1.7%	1.3%	1.6%	2.2%	2.2%	2.2%	2.2%	2.0%	2.0%	1.4%	1.3%
70-74	1.7%	2.5%	1.6%	1.9%	2.4%	2.4%	2.0%	2.0%	2.7%	2.7%	1.8%	1.3%
75-79	2.3%	2.5%	1.8%	2.2%	2.3%	2.3%	1.9%	1.9%	3.0%	3.0%	2.0%	1.4%
80-84	2.2%	2.3%	1.9%	2.3%	2.0%	2.0%	1.7%	1.7%	2.9%	2.8%	2.1%	1.5%
85-89	1.4%	2.2%	1.5%	1.8%	1.6%	1.6%	1.5%	1.6%	2.4%	2.5%	1.9%	1.6%
90-94	1.2%	1.6%	1.1%	1.3%	1.1%	1.1%	1.3%	1.4%	1.9%	1.8%	1.7%	1.5%
95-99	0.7%	0.9%	0.8%	1.0%	0.7%	0.7%	1.1%	1.1%	1.2%	1.3%	1.3%	1.2%
100-104	0.4%	0.5%	0.7%	0.9%	0.3%	0.4%	0.9%	0.9%	0.7%	0.7%	0.9%	1.0%
105-110	0.1%	0.1%	0.6%	0.8%	0.1%	0.1%	0.6%	0.6%	0.0%	-0.1%	0.6%	0.7%

Source: Author's calculations.

**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153603

Life expectancy and annuity values

Tables 5.16 and 5.17 show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

The figures given for each of the projection models applied are shown for the population and also shown adjusted to the initial mortality in 1996 given by the TGH/F 05, capturing both the retrospective differences of assumed improvements compared to experienced improvements from this date as well as the differences between what is assumed and projected in the future.

Table 5.16. **French males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
TGH 05		33.7	23.4	14.1	9.3	14.4	10.4	10.8%	6.9%	9.6%
Modelled Mortality										
Population	*LC*	28.9	19.9	12.0	8.0	13.0	9.3	12.6%	7.7%	10.8%
	CBD	28.8	19.5	11.9	7.8	12.7	9.1	12.8%	7.9%	11.0%
	P-Spline	30.9	21.3	12.6	8.4	13.5	9.6	11.9%	7.4%	10.4%
	CMI	29.9	20.9	12.6	8.1	13.3	9.5	12.3%	7.5%	10.5%
Adjusted										
TGH 05: 1996	*LC*	33.0	23.1	14.1	9.1	14.3	10.4	10.9%	7.0%	9.6%
	CBD	33.2	23.1	14.1	9.1	14.3	10.4	11.0%	7.0%	9.6%
	P-Spline	34.8	24.3	14.6	9.5	14.8	10.7	10.5%	6.8%	9.3%
	CMI	34.2	24.1	14.7	9.3	14.6	10.7	10.7%	6.8%	9.4%

Source: Author's calculations.

Table 5.17. **French females**

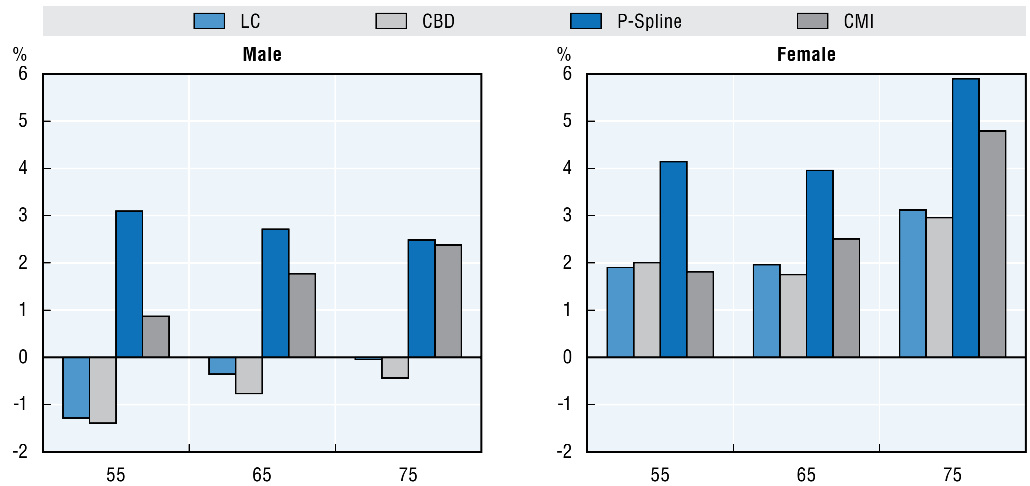
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
TGF 05		37.4	26.8	16.9	10.1	15.6	11.8	9.9%	6.4%	8.5%
Modelled Mortality										
Population	*LC*	34.9	24.8	15.3	9.6	15.0	11.1	10.4%	6.7%	9.0%
	CBD	34.8	24.3	15.1	9.5	14.6	10.8	10.6%	6.8%	9.2%
	P-Spline	36.4	25.9	16.1	9.8	15.3	11.4	10.2%	6.5%	8.8%
	CMI	35.0	25.1	15.7	9.5	15.0	11.2	10.5%	6.7%	8.9%
Adjusted										
TGF 05: 1996	*LC*	37.9	27.5	17.6	10.2	15.9	12.2	9.8%	6.3%	8.2%
	CBD	38.2	27.7	17.7	10.3	15.9	12.2	9.7%	6.3%	8.2%
	P-Spline	39.3	28.7	18.4	10.5	16.2	12.5	9.5%	6.2%	8.0%
	CMI	38.3	28.1	18.1	10.2	16.0	12.4	9.8%	6.3%	8.1%

Source: Author's calculations.

Change in liability value

The graphs in Figure 5.17 show the change in liability value based on the annuity values for the standard mortality table and the adjusted model outputs presented in the section above. The stochastic models estimate the liability to be lower than the deterministic models, with the P-spline models predicting the highest shortfall. Overall the provisions for males seem to sufficiently account for expected improvements in longevity, though there seems to be a shortfall of provisions for females, particularly older females, of around 2-4%.

Figure 5.17. **Potential shortfall of using the TGH/F 05 in France**



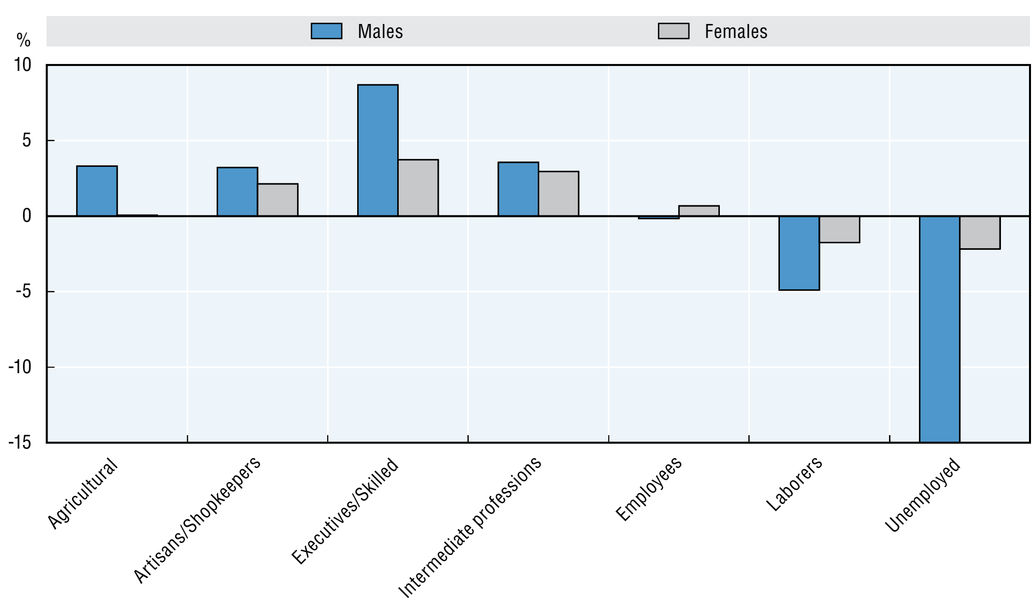
Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153108

Impact of socio-economic factors

Figure 5.18 shows the impact on annuity value at age 65 for various socio-economic categories in France relative to the total population, assuming the mortality of all populations evolve in the pattern assumed by the TGH/F 05. The highest expected life expectancy is for executives and skilled employees, who presumably also have the highest level of income and education, and the unemployed experience the lowest life expectancy. The difference from one category to the next is much higher for males than for females.

Figure 5.18. **Impact of socio-professional category on annuity liability value in France**



Source: OECD calculations (Blanpain and Chardon, 2011)

StatLink http://dx.doi.org/10.1787/888933153114

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, with the two genders diverging until the 1990s, but converging somewhat since then. Mortality improvements for both genders have accelerated over the past decade. Assumptions in the regulatory table seem to account for future mortality improvements for males, however there could be a shortfall of provisions for females, particularly older females.

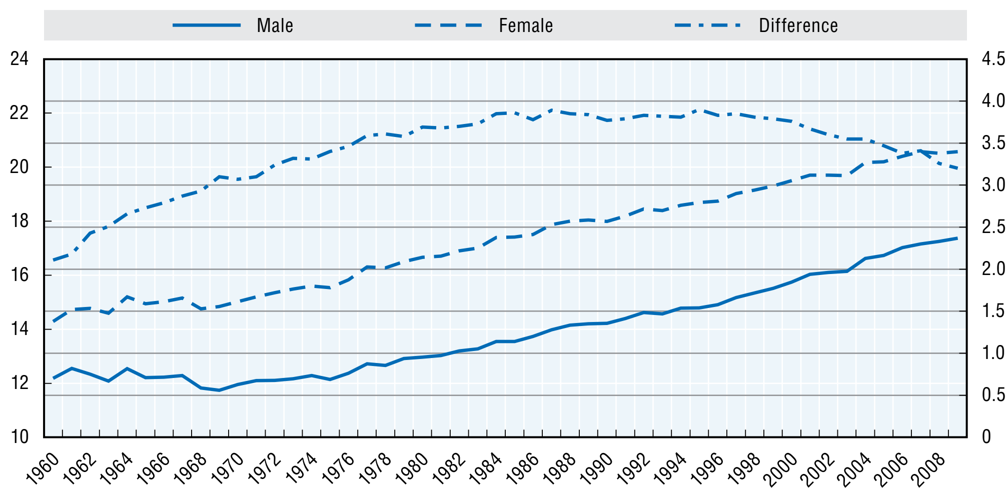
Germany

The assessment for Germany relies on West German HMD data from 1960 to 2011.

Historical life expectancy at age 65

Figure 5.19 shows the evolution in period life expectancy at age 65 in Western Germany for males and females. The life expectancy for both genders has been increasing at a fairly steady rate since about 1970. Females were increasing at a faster rate until around 1980, when the gap in life expectancy between the two genders (shown on the right axis) stabilised at just under four years. Over the last decade the life expectancies have been converging, standing at around three years currently.

Figure 5.19. **Life expectancy at age 65 in West Germany**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153123

Historical and future mortality improvements

Table 5.18 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (West German HMD) have been relatively high for both genders, at over 2% for several age groups. The DAV 2004 1st order assumptions as well as the 2nd order initial trend assumptions continue these high rates of improvements on average, whereas the 2nd order target assumptions decrease to a lower level.[4] In practice companies can decide themselves the timing of a linear convergence from the initial trend to the long term trend. Note that the annual improvements in the DAV2004 include a 0.2% absolute margin with the expectation that the insured population will experience slightly higher improvements than the general population, whereas results from the projection models here are calibrated directly to the general population. Improvements coming from the stochastic models fall more or less between the initial and target 2nd order assumptions. The P-spline model projects surprisingly low improvements for females compared to recent experience. The CMI model mirrors somewhat the transition from initial to target 2nd order trend assumptions, reverting eventually to the long term improvement assumption which has been set at 1.6% for Germany.

Table 5.18. **Evolution of annual mortality improvements in Germany***

	HMD (West Germany)		DAV 1st Agg		DAV 2nd Initial		DAV 2nd Target		LC		CBD		PS		CMI	
Male	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.5%	1.5%	2.5%	2.5%	2.2%	2.2%	1.4%	1.4%	1.8%	1.5%	1.9%	1.8%	1.6%	1.7%	1.9%	2.0%
60-64	2.6%	1.8%	2.5%	2.5%	2.2%	2.2%	1.4%	1.4%	2.0%	1.7%	1.9%	1.7%	1.9%	2.0%	1.9%	2.3%
65-69	2.1%	2.7%	2.7%	2.7%	2.4%	2.4%	1.6%	1.6%	2.1%	1.8%	1.8%	1.6%	2.7%	2.6%	2.0%	2.3%
70-74	2.0%	3.0%	2.8%	2.8%	2.6%	2.6%	1.7%	1.7%	2.0%	1.8%	1.7%	1.5%	3.0%	2.8%	2.2%	2.1%
75-79	2.3%	2.3%	2.6%	2.6%	2.4%	2.4%	1.5%	1.5%	1.8%	1.6%	1.6%	1.4%	2.5%	2.6%	2.2%	2.1%
80-84	2.2%	1.9%	2.2%	2.2%	1.9%	1.9%	1.2%	1.2%	1.5%	1.3%	1.5%	1.3%	1.9%	2.1%	1.9%	2.1%
85-89	1.5%	1.9%	1.7%	1.7%	1.5%	1.5%	0.9%	0.9%	1.1%	1.0%	1.4%	1.2%	1.7%	1.7%	1.5%	2.0%
90-94	0.8%	1.3%	1.4%	1.4%	1.1%	1.1%	0.8%	0.8%	0.7%	0.6%	1.2%	1.1%	1.5%	1.4%	1.2%	1.6%
95-99	0.5%	0.9%	1.3%	1.3%	1.0%	1.0%	0.8%	0.8%	0.4%	0.3%	1.1%	0.9%	1.0%	1.0%	1.0%	1.2%
100-104	0.2%	0.6%	1.2%	1.2%	1.0%	1.0%	0.8%	0.8%	0.2%	0.1%	0.9%	0.7%	0.4%	0.4%	0.7%	1.0%
105-110	0.0%	0.2%	1.2%	1.2%	1.0%	1.0%	0.8%	0.8%	0.0%	0.0%	0.6%	0.5%	-0.1%	-0.1%	0.5%	0.7%
	HMD (West Germany)		DAV 1st Agg		DAV 2nd Initial		DAV 2nd Target		LC		CBD		PS		CMI	
Female	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.6%	1.0%	2.4%	2.4%	2.2%	2.2%	1.6%	1.6%	1.6%	1.5%	2.1%	2.1%	0.7%	0.8%	1.6%	1.7%
60-64	2.3%	0.5%	2.4%	2.4%	2.2%	2.2%	1.6%	1.6%	1.9%	1.7%	2.0%	2.1%	0.9%	1.1%	1.6%	1.9%
65-69	2.3%	1.8%	2.6%	2.6%	2.3%	2.3%	1.7%	1.7%	2.2%	2.0%	1.9%	2.0%	1.8%	1.7%	1.7%	2.0%
70-74	2.2%	2.6%	2.8%	2.8%	2.5%	2.5%	1.9%	1.9%	2.3%	2.2%	1.9%	1.8%	2.6%	2.4%	2.1%	1.8%
75-79	2.3%	2.1%	2.8%	2.8%	2.5%	2.5%	1.9%	1.9%	2.3%	2.1%	1.8%	1.7%	2.4%	2.4%	2.3%	1.8%
80-84	2.2%	1.6%	2.5%	2.5%	2.2%	2.2%	1.7%	1.7%	1.9%	1.8%	1.7%	1.6%	1.7%	1.8%	2.1%	1.8%
85-89	1.7%	1.0%	2.0%	2.0%	1.7%	1.7%	1.3%	1.3%	1.4%	1.3%	1.6%	1.5%	1.0%	1.1%	1.7%	1.9%
90-94	1.3%	0.7%	1.5%	1.5%	1.3%	1.3%	0.9%	0.9%	0.9%	0.9%	1.4%	1.3%	0.5%	0.5%	1.4%	1.6%
95-99	0.9%	0.1%	1.3%	1.3%	1.0%	1.0%	0.8%	0.8%	0.5%	0.5%	1.2%	1.1%	0.3%	0.3%	1.1%	1.2%
100-104	0.6%	-0.1%	1.2%	1.2%	1.0%	1.0%	0.8%	0.8%	0.2%	0.2%	1.0%	0.8%	0.1%	0.1%	0.9%	1.0%
105-110	0.2%	-0.1%	1.2%	1.2%	1.0%	1.0%	0.8%	0.8%	0.0%	0.0%	0.7%	0.6%	-0.1%	-0.1%	0.6%	0.7%

Source: Author's calculations.

**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153614

Life expectancy and annuity values

Tables 5.19 and 5.20 show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees). The figures given for the mortality tables represent the figures resulting from the application of the various forms of the DAV2004 R. In practice, for 2nd order assumptions users can set the timing of the linear transition from the initial trend to the target trend, so the actual life expectancy will lie between these two values.

The figures given for each of the projection models are shown for the general population as well as adjusted to initial overall best estimate mortality for the standard table, that is the 2nd order aggregate rates. The adjusted figures therefore capture both the retrospective differences of assumed improvements compared to experienced improvements from 1999, when the table was established, as well as the differences between what is assumed and projected in the future.

Table 5.19. **German males**

		Life Expectancy 2010			Annuity factors			Annuity payment		
Mortality tables		55	65	75	55	65	75	55	65	75
DAV 1st Agg		35.4	24.7	15.3	9.6	14.8	10.9	10.5%	6.8%	9.2%
DAV 1st Sel		35.3	24.6	15.3	9.5	14.7	11.0	10.5%	6.8%	9.1%
DAV 2nd Agg Initial improvement		32.8	22.6	13.6	9.0	14.0	10.1	11.1%	7.1%	9.9%
DAV 2nd Agg Target improvement		30.8	21.2	12.8	8.5	13.5	9.7	11.7%	7.4%	10.3%
DAV 2nd Sel Initial improvement		32.7	22.4	13.7	9.0	14.0	10.2	11.1%	7.2%	9.8%
DAV 2nd Sel Target improvement		30.7	21.0	12.8	8.5	13.5	9.7	11.8%	7.4%	10.3%
Modelled Mortality										
Population	*LC*	28.0	18.9	11.2	7.7	12.6	8.8	12.9%	8.0%	11.4%
	CBD	28.1	18.8	11.3	7.7	12.4	8.8	13.0%	8.1%	11.4%
	P-Spline	29.5	19.8	11.5	8.1	12.9	8.9	12.4%	7.8%	11.2%
	CMI	29.1	19.6	11.5	7.9	12.8	8.9	12.6%	7.8%	11.2%
Adjusted										
DAV 2nd Order Aggregate: 1999	*LC*	31.7	21.9	13.3	8.8	13.9	10.0	11.4%	7.2%	10.0%
	CBD	32.2	22.2	13.6	8.8	13.9	10.1	11.3%	7.2%	9.9%
	P-Spline	33.3	23.0	13.8	9.1	14.2	10.2	11.0%	7.0%	9.8%
	CMI	33.1	22.9	13.7	9.0	14.1	10.1	11.1%	7.1%	9.9%

Source: Author's calculations.

Table 5.20. **German females**

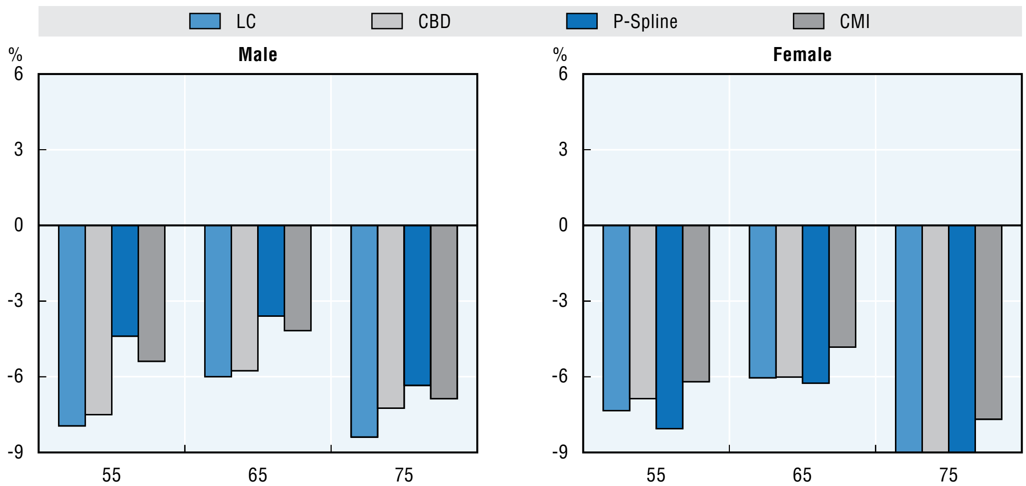
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
DAV 1st Agg		39.5	28.5	18.2	10.4	16.0	12.3	9.6%	6.2%	8.1%
DAV 1st Sel		38.8	27.8	17.9	10.3	15.8	12.2	9.7%	6.3%	8.2%
DAV 2nd Agg Initial improvement		36.8	26.1	16.3	9.9	15.4	11.5	10.1%	6.5%	8.7%
DAV 2nd Agg Target improvement		35.3	25.1	15.6	9.6	15.0	11.2	10.4%	6.7%	8.9%
DAV 2nd Sel Initial improvement		36.5	25.8	16.3	9.9	15.2	11.5	10.1%	6.6%	8.7%
DAV 2nd Sel Target improvement		35.0	24.7	15.6	9.6	14.9	11.2	10.4%	6.7%	9.0%
Modelled Mortality										
Population	*LC*	32.4	22.4	13.4	9.0	14.1	10.1	11.2%	7.1%	9.9%
	CBD	32.5	22.1	13.3	8.9	13.9	10.0	11.2%	7.2%	10.0%
	P-Spline	32.1	22.3	13.3	8.9	14.1	10.0	11.2%	7.1%	10.0%
	CMI	33.0	23.0	13.8	9.0	14.3	10.2	11.1%	7.0%	9.8%
Adjusted										
DAV 2nd Aggregate: 1999	*LC*	35.2	25.0	15.6	9.7	15.1	11.2	10.3%	6.6%	8.9%
	CBD	35.7	25.3	15.7	9.7	15.1	11.2	10.3%	6.6%	8.9%
	P-Spline	34.8	24.8	15.3	9.6	15.0	11.1	10.4%	6.7%	9.0%
	CMI	36.1	25.8	16.0	9.8	15.2	11.4	10.2%	6.6%	8.8%

Source: Author's calculations.

Change in liability value

The figures below show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs from the aggregate tables presented in the section above. The 1st order tables shown in Figure 5.20 clearly have significant margins for longevity risk, and indeed the assumptions do incorporate margins for volatility and parameter risk. The 2nd order assumptions which represent the best estimate assumptions are more or less in line with the projection models used here. Use of the target improvement for males, however, results in a shortfall in provisions, as shown in Figure 5.21. This implies that given the very high improvements experienced recently by males perhaps the initial improvement shown in Figure 5.22 should be applied for a longer period of time before reverting to the target improvement.

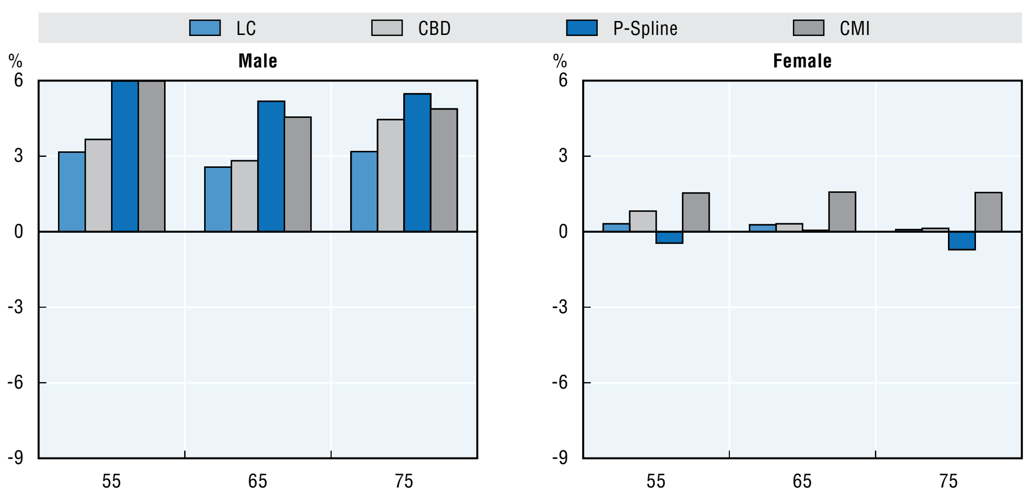
Figure 5.20. **Potential shortfall from the DAV 2004 R 1st Order Aggregate table for German annuitants**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153134

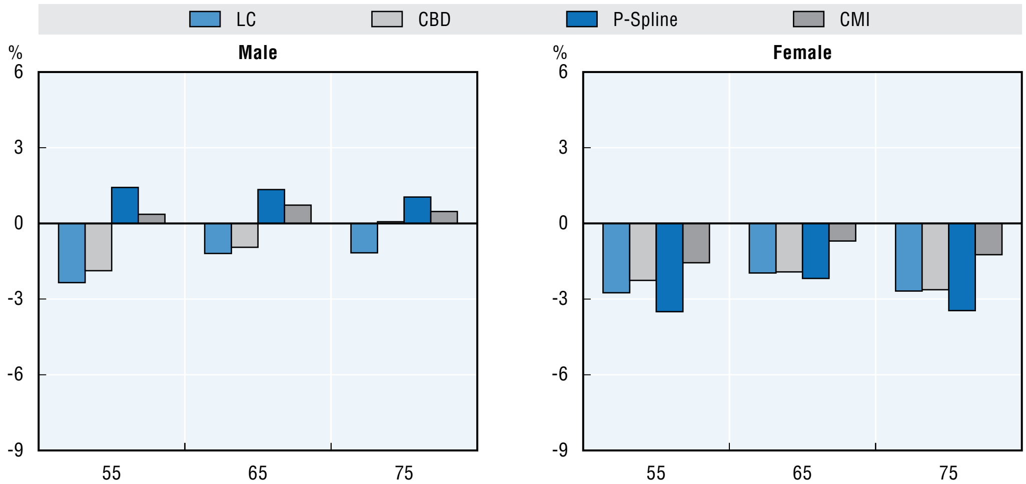
Figure 5.21. **Potential shortfall from the DAV 2004 R 2nd Order Aggregate table with target improvement assumptions for German annuitants**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153155

Figure 5.22. **Potential shortfall from the DAV 2004 R 2nd Order Aggregate table with initial improvement assumptions for German annuitants**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153149

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, with the two genders diverging until the 1980s, but converging over the last decade. Mortality improvements for both genders have accelerated over the past decade, with male improvements being overall higher. The DAV2004 R table contains significant margins in the 1st order assumptions, with the combination of initial and target trends for the 2nd order assumptions being on target for the best estimate. Given the continued high improvements over the last decade for males, the initial improvement should perhaps be applied for a longer period of time when using 2nd order assumptions before reverting to the target improvements in order to minimize the risk of a potential shortfall in provisions.

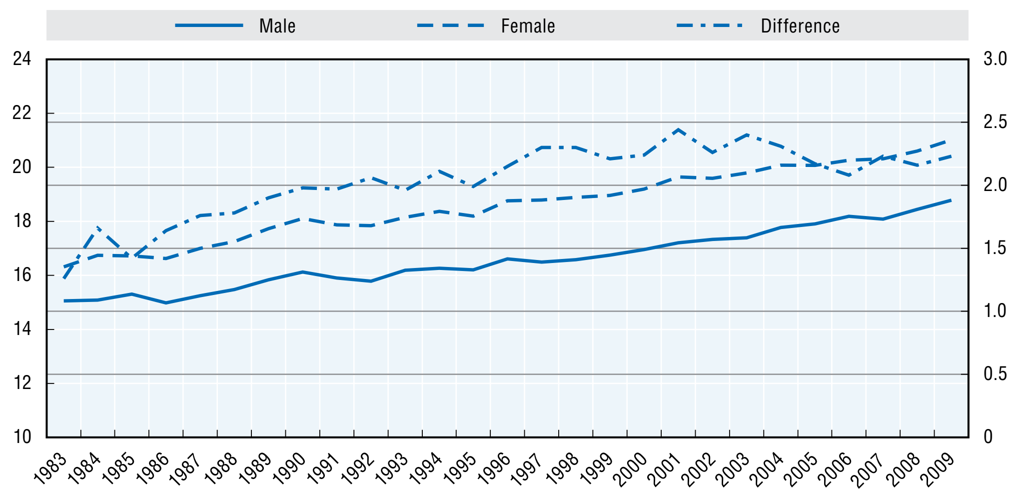
Israel

The assessment for Israel relied on HMD data from 1983 to 2009.

Historical life expectancy at age 65

Figure 5.23 shows the evolution in period life expectancy at age 65 for males and females. The gap between the two genders (shown on the right axis) has been increasing, though has decreased somewhat in recent years, standing at around 2.25 years currently.

Figure 5.23. **Life expectancy at age 65 in Israel***



Source: Human Mortality Database.

* 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.

StatLink http://dx.doi.org/10.1787/888933153161

Historical and future mortality improvements

Table 5.21 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (HMD) have been accelerating over the past two decades, topping 3% per year for ages 60-74 for both genders over the last decade. The regulatory tables predict somewhat lower mortality improvements than what has recently been experienced, though note that here the average improvement for males is understated as the figures shown are on a periodic basis rather than a cohort basis. The regulatory tables assume higher improvements for the male cohorts aged 65-81 in 2010, so the improvements by age are lower on average as the lower mortality for this 'golden cohort' reverts back to standard mortality for those not in this cohort within the coming decade. Nonetheless the averages by age are somewhat low compared to recent experience. The stochastic and P-spline models continue high improvement into the future, while a long term improvement of 2% has been assumed for the CMI model for Israel.

Table 5.21. **Evolution of annual mortality improvements in Israel***

	HMD		Israel Best Estimate		Israel Reserving		LC		CBD		PS		CMI	
Male	1990-2000	2000-2009	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.1%	2.7%	1.8%	1.6%	1.8%	1.6%	2.8%	2.8%	2.5%	2.5%	2.5%	2.5%	1.9%	2.0%
60-64	2.5%	3.3%	1.8%	1.6%	1.8%	1.6%	2.7%	2.7%	2.3%	2.3%	3.2%	3.2%	2.1%	1.9%
65-69	1.9%	3.4%	1.4%	1.4%	1.4%	1.4%	2.3%	2.3%	2.1%	2.1%	3.5%	3.4%	2.4%	1.8%
70-74	1.2%	3.3%	1.5%	1.5%	1.5%	1.5%	2.1%	2.1%	1.9%	1.9%	3.1%	3.0%	2.6%	1.9%
75-79	1.1%	2.6%	2.2%	1.0%	2.2%	1.0%	2.0%	2.0%	1.7%	1.8%	2.2%	2.3%	2.5%	2.1%
80-84	0.9%	1.8%	1.5%	1.2%	1.5%	1.2%	1.5%	1.5%	1.5%	1.6%	1.6%	1.8%	2.1%	2.2%
85-89	-0.3%	1.8%	0.9%	0.8%	0.9%	0.8%	1.2%	1.2%	1.3%	1.4%	1.6%	1.6%	1.9%	2.2%
90-94	0.2%	1.2%	0.5%	0.4%	0.7%	0.7%	0.7%	0.7%	1.1%	1.1%	1.7%	1.6%	1.8%	1.9%
95-99	-0.4%	1.8%	0.2%	0.2%	0.7%	0.7%	0.7%	0.7%	0.9%	0.9%	1.3%	1.4%	1.5%	1.5%
100-104	-0.6%	1.6%	0.0%	0.0%	0.6%	0.6%	0.4%	0.4%	0.6%	0.7%	0.9%	0.9%	1.2%	1.2%
105-110	-0.4%	0.9%	0.0%	0.0%	0.7%	0.0%	0.2%	0.2%	0.4%	0.4%	0.1%	0.1%	0.8%	0.8%

	HMD		Israel Best Estimate		Israel Reserving		LC		CBD		PS		CMI	
Female	1990-2000	2000-2009	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.7%	1.7%	2.8%	2.5%	2.8%	2.5%	2.8%	2.8%	3.2%	3.2%	2.9%	3.0%	2.4%	2.0%
60-64	3.0%	3.2%	3.0%	2.8%	3.0%	2.8%	3.1%	3.1%	3.0%	3.0%	3.4%	3.4%	2.8%	2.1%
65-69	2.4%	4.3%	3.1%	2.8%	3.1%	2.8%	3.4%	3.4%	2.8%	2.8%	3.7%	3.6%	3.0%	2.1%
70-74	3.0%	3.8%	2.9%	2.7%	2.9%	2.7%	3.0%	3.0%	2.5%	2.5%	3.4%	3.4%	3.1%	2.2%
75-79	1.8%	2.9%	2.5%	2.2%	2.5%	2.2%	2.9%	2.9%	2.3%	2.3%	2.6%	2.7%	2.8%	2.2%
80-84	-0.1%	2.6%	1.8%	1.5%	1.8%	1.5%	1.6%	1.6%	2.0%	2.0%	1.9%	1.9%	2.2%	2.2%
85-89	-0.1%	1.6%	1.0%	0.9%	1.1%	1.0%	1.2%	1.2%	1.7%	1.7%	1.1%	1.1%	1.8%	2.1%
90-94	0.5%	0.5%	0.6%	0.5%	1.0%	1.0%	0.8%	0.8%	1.4%	1.4%	0.6%	0.6%	1.6%	1.9%
95-99	0.3%	0.5%	0.4%	0.3%	1.0%	1.0%	0.7%	0.7%	1.1%	1.1%	0.2%	0.3%	1.5%	1.5%
100-104	0.3%	0.1%	0.1%	0.1%	0.8%	0.8%	0.4%	0.4%	0.8%	0.8%	0.3%	0.2%	1.2%	1.2%
105-110	0.2%	-0.1%	0.0%	0.0%	1.0%	0.0%	0.2%	0.2%	0.4%	0.5%	0.0%	0.0%	0.8%	0.8%

Source: Author's calculations.

* 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.

***Statlinks file shows a coloured heat map of the improvements shown in the table*

Life expectancy and annuity values

Tables 5.22 and 5.23 show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a percent of the initial investment (net of margins and fees). The figures given for the mortality tables show both the best estimate assumptions and the assumptions used for reserving.

The figures are shown for each of the projection models for the Israeli population as well as adjusted to the best estimate mortality for insurance and pensions as of 2008, the central year on which the assumptions were based.

Table 5.22. **Israeli males***

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
Insurance Best Estimate		32.1	22.3	13.4	8.9	14.0	10.1	11.2%	7.1%	9.9%
Insurance Reserving		32.5	22.5	13.6	9.0	14.1	10.1	11.1%	7.1%	9.9%
Pension Best Estimate		31.4	21.6	13.0	8.7	13.7	9.8	11.5%	7.3%	10.2%
Pension Reserving		31.7	21.8	13.1	8.8	13.8	9.9	11.4%	7.3%	10.2%
Modelled Mortality										
Population	*LC*	30.3	20.5	12.4	8.3	13.2	9.4	12.0%	7.6%	10.6%
	CBD	30.4	20.7	12.6	8.3	13.2	9.5	12.0%	7.6%	10.5%
	P-Spline	31.6	21.2	12.7	8.6	13.4	9.5	11.6%	7.5%	10.5%
	CMI	31.7	21.6	12.9	8.6	13.5	9.6	11.7%	7.4%	10.4%
Adjusted										
Insurance: 2008	*LC*	33.1	22.6	13.7	9.2	14.1	10.2	10.9%	7.1%	9.8%
	CBD	33.5	22.9	13.9	9.2	14.2	10.3	10.9%	7.1%	9.8%
	P-Spline	34.4	23.4	14.1	9.4	14.3	10.3	10.6%	7.0%	9.7%
	CMI	34.8	23.9	14.3	9.4	14.4	10.4	10.6%	6.9%	9.6%
Pension: 2008	*LC*	32.4	21.9	13.2	9.0	13.8	9.9	11.1%	7.2%	10.1%
	CBD	32.7	22.1	13.4	9.0	13.8	10.0	11.1%	7.2%	10.0%
	P-Spline	33.7	22.6	13.6	9.2	14.0	10.0	10.8%	7.1%	10.0%
	CMI	34.1	23.1	13.8	9.2	14.1	10.1	10.8%	7.1%	9.9%

Source: Author's calculations.
* 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.

Table 5.23. **Israeli females***

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
Insurance Best Estimate		34.7	24.3	14.9	9.6	14.9	10.9	10.4%	6.7%	9.2%
Insurance Reserving		35.5	24.8	15.2	9.8	15.0	10.9	10.3%	6.7%	9.1%
Pension Best Estimate		34.3	23.9	14.5	9.5	14.7	10.7	10.5%	6.8%	9.4%
Pension Reserving		35.0	24.3	14.8	9.6	14.8	10.8	10.4%	6.8%	9.3%
Modelled Mortality										
Population	*LC*	33.5	23.1	13.9	9.2	14.3	10.3	10.8%	7.0%	9.7%
	CBD	33.9	23.3	14.1	9.3	14.3	10.4	10.8%	7.0%	9.7%
	P-Spline	33.1	22.7	13.5	9.2	14.2	10.1	10.9%	7.0%	9.9%
	CMI	34.5	23.8	14.2	9.4	14.5	10.4	10.7%	6.9%	9.6%
Adjusted										
Insurance: 2008	*LC*	35.7	24.9	15.2	9.8	15.0	11.0	10.2%	6.6%	9.1%
	CBD	36.5	25.5	15.6	9.9	15.2	11.1	10.1%	6.6%	9.0%
	P-Spline	35.2	24.5	14.9	9.7	14.9	10.9	10.3%	6.7%	9.2%
	CMI	37.0	25.8	15.7	10.0	15.3	11.2	10.0%	6.6%	9.0%
Pension: 2008	*LC*	35.2	24.4	14.8	9.7	14.9	10.8	10.3%	6.7%	9.2%
	CBD	36.0	25.0	15.2	9.8	15.0	11.0	10.2%	6.7%	9.1%
	P-Spline	34.7	24.0	14.5	9.6	14.7	10.7	10.4%	6.8%	9.4%
	CMI	36.4	25.3	15.3	9.9	15.1	11.0	10.1%	6.6%	9.1%

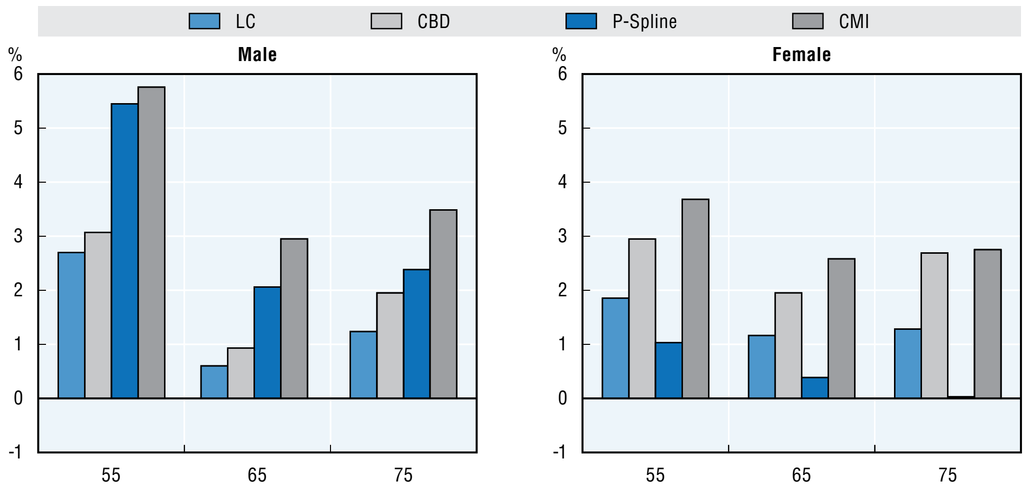
Source: Author's calculations.

* 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.

Change in liability value

The figures below show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. Despite the lower mortality assumptions for the 'golden cohort' of males, it appears there could still be a slight shortfall of provisions if mortality continues to improve at such a high rate. This shortfall could be around 1-3% for males under the best estimate (Figures 5.24 and 5.26), with reserving assumptions adding a buffer of about 0.5% (Figure 5.25 and 5.27). The assumptions for females seem more on target, with the potential shortfall around 1-2% for the best estimate, with the reserving assumptions adding a cushion of around 0.8%.

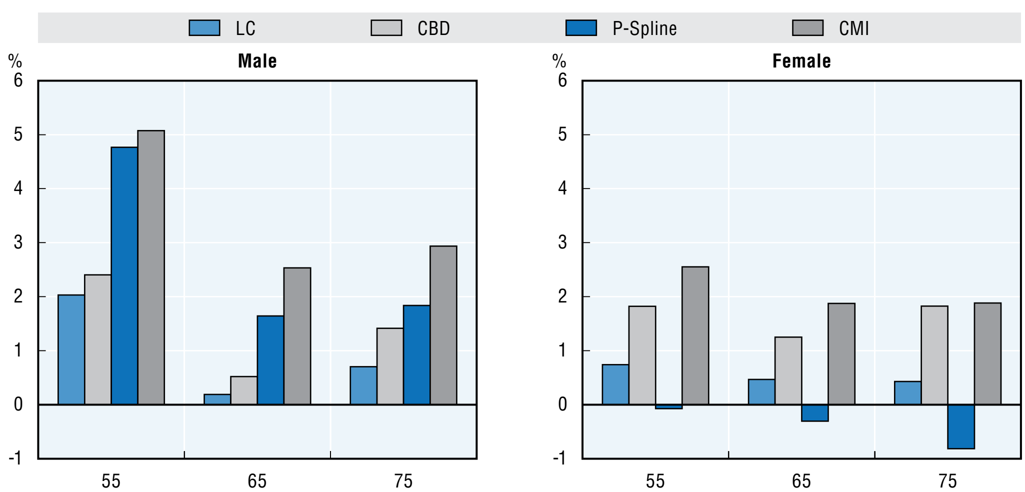
Figure 5.24. **Potential shortfall from the Insurance Best Estimate table for annuitants in Israel**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153176

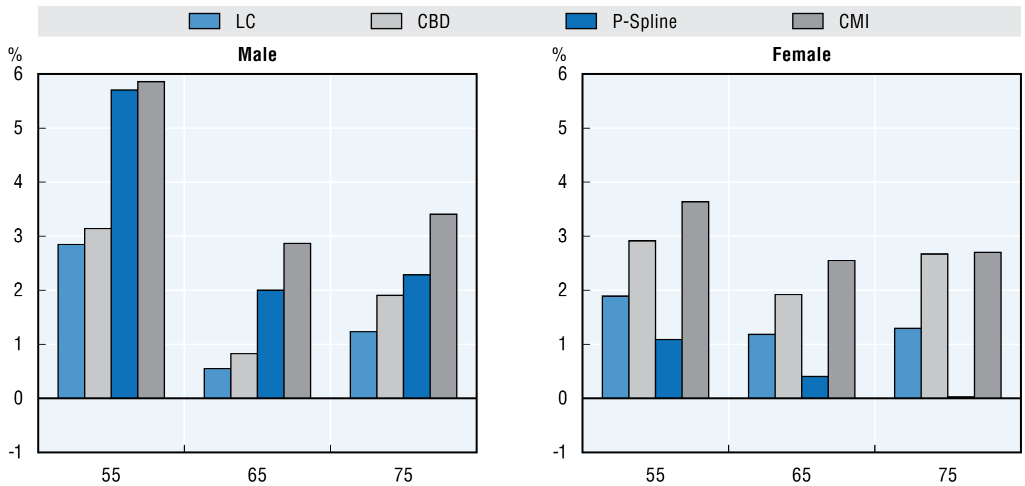
Figure 5.25. **Potential shortfall from the Insurance Reserving table for annuitants in Israel***



Source: Author's calculations.
* 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.

StatLink http://dx.doi.org/10.1787/888933153189

Figure 5.26. **Potential shortfall from the Pensions Best Estimate table for pensioners in Israel***

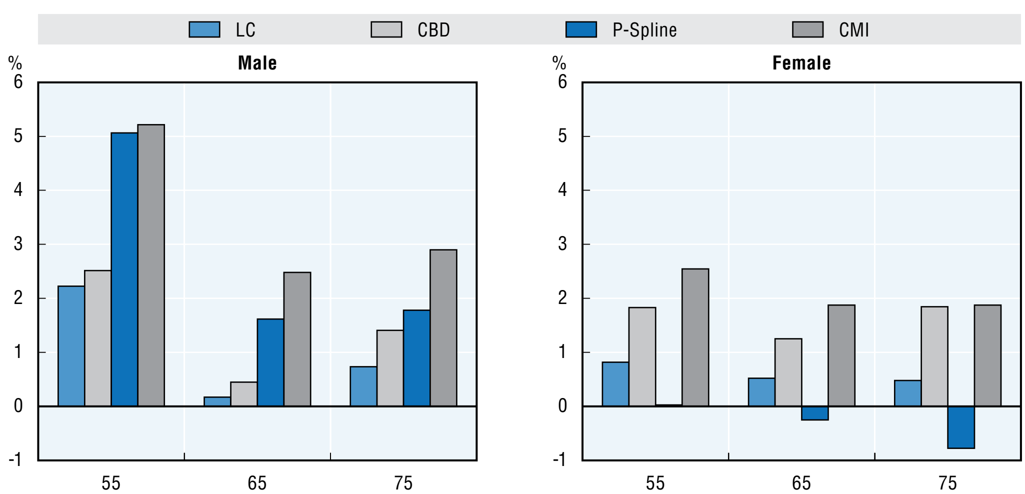


Source: Author's calculations.

* 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.

StatLink http://dx.doi.org/10.1787/888933153195

Figure 5.27. **Potential shortfall from the Pensions Reserving table for pensioners in Israel***



Source: Author's calculations.

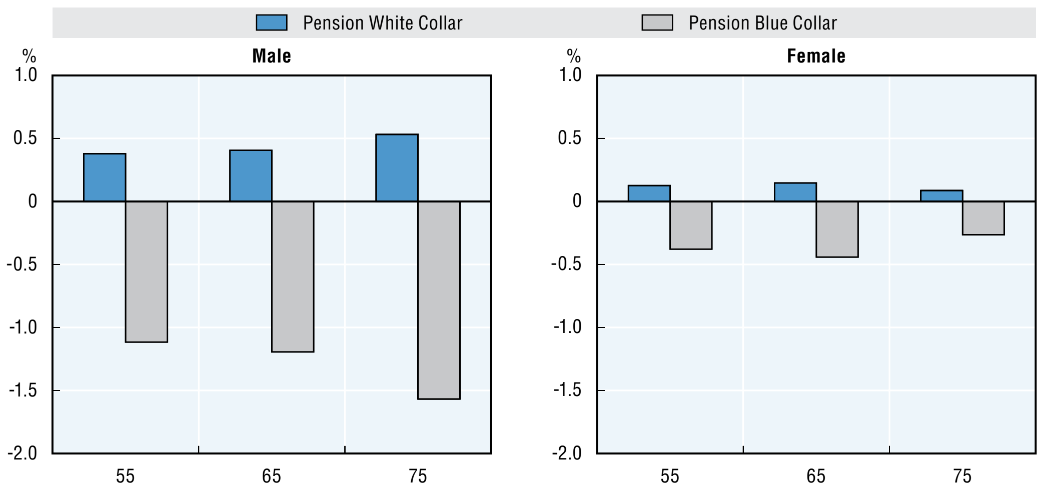
* The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

StatLink http://dx.doi.org/10.1787/888933153206

Impact of socio-economic variables

The government actuary for Israel also produces mortality tables for white and blue collar workers. The impact of these variables on the liability value are shown in Figure 5.28. The increase in liabilities for white collar workers is much less than the decrease for blue collar workers, with the former increasing less than 0.5% for males but the latter decreasing by up to 1.5%. The impact for females is much smaller, with little change with respect to white collar workers and a decrease of liabilities of up to 0.5% for blue collar workers.

Figure 5.28. **Impact of employment type on pension liabilities in Israel***



Source: Author's calculations.

* 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.

StatLink http://dx.doi.org/10.1787/888933153216

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, with a rapid acceleration in mortality improvements for both genders over the most recent decade.

The outputs from the models assessed indicate that there could still be a slight shortfall in provisions despite accounting for the lower mortality of the male 'golden cohort' due to the extremely high improvements in mortality which Israel has been experiencing recently.

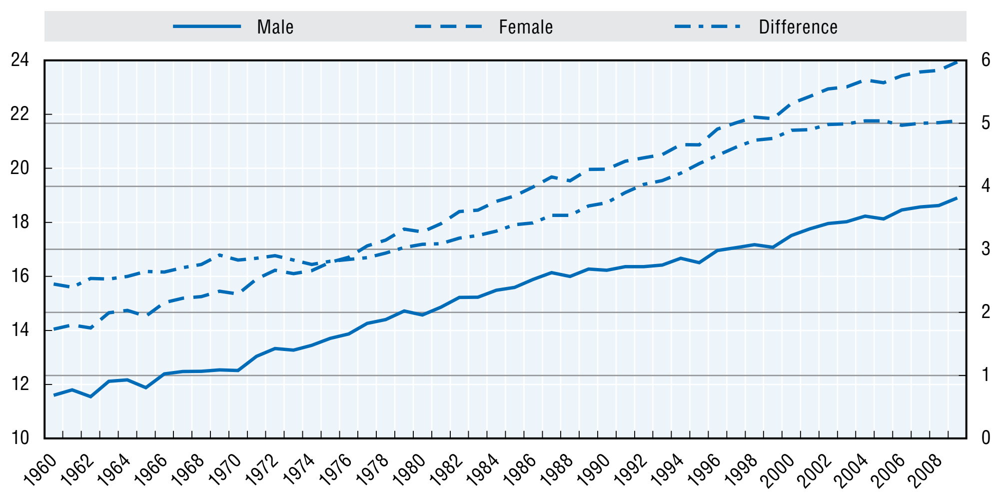
Japan

The assessment for Japan relied on HMD data from 1960 to 2009.

Historical life expectancy at age 65

Figure 5.29 shows the evolution in period life expectancy at age 65 for males and females. The life expectancy for both genders has been increasing at a fairly steady rate since 1960, with females increasing at a faster rate than males. This has resulted in a divergence of life expectancies between the two genders, with the gap currently at around 5 years (shown on right axis), though this difference seems to have stabilised somewhat over the last decade.

Figure 5.29. **Life expectancy at age 65 in Japan**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153223

Historical and future mortality improvements

Table 5.24 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (HMD) have been overall higher for females than males, though over the last decade improvements have decelerated somewhat from the very high rates of improvement experienced in the 1990s, particularly for females. The stochastic models are projecting forward rather high improvements coming from the steadily high rate of improvements in life expectancy since 1960, whereas the P-spline model reflects more the improvements experienced in the last decade, demonstrating the model's sensitivity to the most recent data. The CMI model reverts eventually to the long term improvement assumption which has been set at 2.35% for Japan.

Table 5.24. **Evolution of annual mortality improvements in Japan***

	HMD		LC		CBD		PS		CMI	
Males	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.6%	1.9%	1.9%	1.9%	2.2%	2.2%	1.7%	1.8%	1.8%	2.3%
60-64	1.6%	1.7%	2.1%	2.1%	2.2%	2.2%	2.1%	2.2%	1.8%	2.2%
65-69	0.8%	2.6%	2.2%	2.2%	2.1%	2.1%	2.6%	2.5%	2.0%	2.1%
70-74	1.4%	2.7%	2.3%	2.3%	2.0%	2.0%	2.4%	2.3%	2.3%	2.2%
75-79	2.1%	1.7%	2.2%	2.2%	2.0%	2.0%	1.6%	1.8%	2.3%	2.3%
80-84	2.2%	1.6%	1.9%	1.9%	1.9%	1.9%	1.2%	1.3%	2.1%	2.4%
85-89	2.0%	1.5%	1.6%	1.6%	1.7%	1.8%	1.2%	1.2%	2.1%	2.5%
90-94	1.5%	1.5%	1.3%	1.3%	1.6%	1.6%	1.3%	1.3%	2.1%	2.2%
95-99	1.2%	1.2%	1.0%	1.0%	1.4%	1.5%	1.2%	1.3%	1.8%	1.8%
100-104	0.9%	0.9%	0.7%	0.7%	1.2%	1.2%	0.9%	1.0%	1.4%	1.4%
105-110	0.4%	0.5%	0.4%	0.4%	0.9%	1.0%	0.2%	0.2%	1.0%	1.0%
	HMD		LC		CBD		PS		CMI	
Females	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.6%	1.8%	2.7%	2.7%	3.4%	3.4%	1.6%	1.7%	1.6%	2.3%
60-64	2.1%	1.9%	2.9%	2.9%	3.3%	3.3%	2.1%	2.1%	1.6%	2.1%
65-69	2.2%	2.7%	3.1%	3.1%	3.1%	3.1%	2.6%	2.5%	1.9%	1.9%
70-74	3.1%	2.7%	3.2%	3.2%	2.9%	2.9%	2.7%	2.7%	2.2%	2.0%
75-79	3.3%	2.7%	3.1%	3.1%	2.7%	2.7%	2.4%	2.4%	2.4%	2.1%
80-84	3.8%	2.4%	2.8%	2.8%	2.5%	2.5%	2.1%	2.0%	2.4%	2.3%
85-89	3.7%	2.0%	2.4%	2.4%	2.3%	2.3%	1.6%	1.6%	2.4%	2.4%
90-94	3.0%	1.9%	1.9%	1.9%	2.0%	2.1%	1.3%	1.3%	2.3%	2.2%
95-99	2.5%	1.4%	1.5%	1.5%	1.7%	1.8%	1.2%	1.3%	1.8%	1.8%
100-104	1.8%	1.0%	1.1%	1.1%	1.4%	1.4%	1.3%	1.3%	1.4%	1.4%
105-110	0.8%	0.4%	0.5%	0.5%	1.0%	1.0%	0.3%	0.2%	1.0%	1.0%

Source: Author's calculations.
**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153633

Life expectancy and annuity values

The Tables 5.25 and 5.26 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

The figures given for each of the projection models are shown for the general population as well as adjusted to the initial mortality for the standard tables. A starting point of 85% of the 19th table based on the 2000 census was used to assess the SMT 2007 as this was the basis of the development of the mortality table. This assumes that this adjustment was meant to account for the differences in mortality between annuitants and the general population. The beginning point to assess the EPI was the 2005 rates of the tables themselves. This application allows for capturing both the retrospective differences of assumed improvements compared to experienced improvements from the date of issue of the table as well as the differences between what is assumed and projected in the future.

Table 5.25. **Japanese males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
SMT2007		31.2	22.9	15.5	8.5	14.0	11.0	11.8%	7.1%	9.1%
EPI2005		27.5	19.3	11.8	7.6	12.8	9.2	13.1%	7.8%	10.9%
EPI2005 * 90%		28.5	20.1	12.5	7.9	13.1	9.5	12.7%	7.6%	10.5%
Modelled Mortality										
Population	*LC*	31.0	21.2	12.7	8.5	13.4	9.6	11.8%	7.4%	10.5%
	CBD	31.1	21.1	12.8	8.4	13.3	9.6	11.9%	7.5%	10.4%
	P-Spline	30.4	20.8	12.5	8.3	13.3	9.4	12.0%	7.5%	10.6%
	CMI	32.0	21.9	13.1	8.6	13.6	9.7	11.6%	7.4%	10.3%
Adjusted										
SMT2007: 85% 19th Table 2000	*LC*	32.6	22.6	14.0	8.8	13.9	10.3	11.3%	7.2%	9.8%
	CBD	33.0	22.8	14.2	8.9	13.9	10.3	11.3%	7.2%	9.7%
	P-Spline	32.2	22.3	13.8	8.7	13.8	10.1	11.4%	7.2%	9.9%
	CMI	33.9	23.6	14.5	9.0	14.2	10.4	11.1%	7.1%	9.6%
EPI2005: 2005	*LC*	32.3	22.4	13.5	8.8	13.9	10.0	11.4%	7.2%	10.0%
	CBD	32.7	22.6	13.7	8.8	13.9	10.1	11.3%	7.2%	9.9%
	P-Spline	31.6	21.8	13.1	8.6	13.7	9.8	11.6%	7.3%	10.2%
	CMI	33.3	23.1	13.8	8.9	14.1	10.1	11.2%	7.1%	9.9%

Source: Author's calculations.

Table 5.26. **Japanese females**

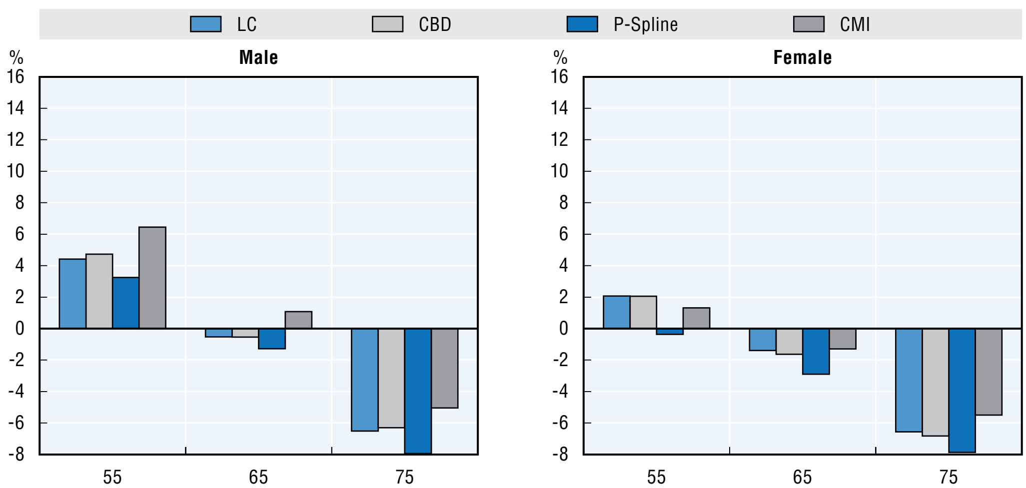
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
SMT2007		38.9	29.7	20.7	10.4	16.4	13.4	9.7%	6.1%	7.5%
EPI2005		33.9	24.7	15.9	9.4	15.0	11.4	10.7%	6.7%	8.8%
EPI2005 * 85%		35.2	25.9	17.0	9.7	15.4	11.9	10.3%	6.5%	8.4%
Modelled Mortality										
Population	*LC*	38.6	27.5	17.2	10.3	15.8	11.9	9.7%	6.3%	8.4%
	CBD	38.6	27.2	17.1	10.2	15.6	11.8	9.8%	6.4%	8.5%
	P-Spline	37.1	26.6	16.8	10.0	15.5	11.7	10.0%	6.5%	8.5%
	CMI	38.3	27.6	17.5	10.1	15.7	12.0	9.9%	6.4%	8.3%
Adjusted										
SMT2007: 85% 19th Table, 2000	*LC*	40.1	29.0	18.6	10.6	16.2	12.5	9.5%	6.2%	8.0%
	CBD	40.3	29.1	18.7	10.6	16.2	12.5	9.5%	6.2%	8.0%
	P-Spline	38.8	28.2	18.2	10.3	15.9	12.3	9.7%	6.3%	8.1%
	CMI	40.2	29.3	19.1	10.5	16.2	12.7	9.5%	6.2%	7.9%
EPI2005: 2005	*LC*	40.1	29.1	18.5	10.6	16.3	12.5	9.4%	6.1%	8.0%
	CBD	40.3	29.2	18.6	10.6	16.3	12.5	9.4%	6.1%	8.0%
	P-Spline	38.6	28.0	17.9	10.3	16.0	12.2	9.7%	6.3%	8.2%
	CMI	39.9	29.1	18.7	10.5	16.2	12.5	9.5%	6.2%	8.0%

Source: Author's calculations.

Change in liability value

The graphs below show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. The results of all models converge reasonably well with no obvious outliers, though the P-spline model tends to give lower results than the others as it is the most sensitive to the deceleration of mortality improvement over the last decade. The tables used by annuity providers (SMT2007, Figure 5.30) appear to account sufficiently for expected mortality improvements overall, although under-provisioning at ages under 65 seems to be offset with overprovisioning at older ages. The mortality tables used by pension funds (EPI2005, Figure 5.31) demonstrate a potential shortfall in provisions which is slightly greater for males than females, with a shortfall of around 8-10% for the unloaded tables, decreasing to around 4-6% for the loaded tables shown in Figure 5.32. The margin applied for the latter is the maximum load used for funding, and is twice the level required for wind up valuations.

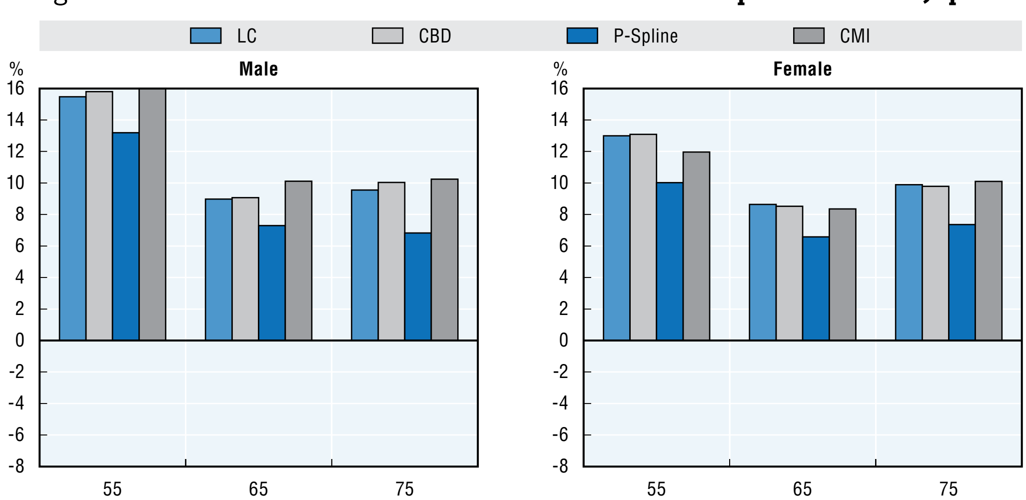
Figure 5.30. **Potential shortfall of the SMT 2007 table for annuitants in Japan**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153230

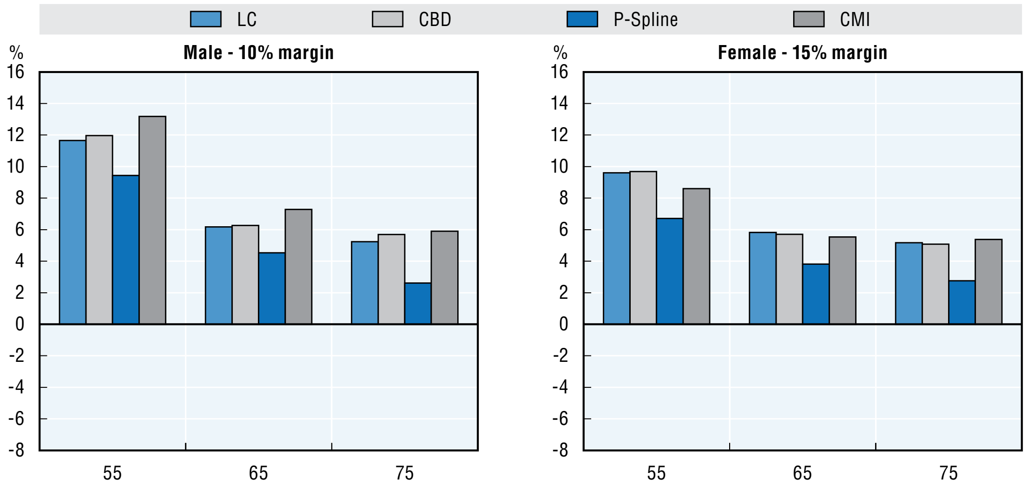
Figure 5.31. **Potential shortfall of the EPI 2005 table for pensioners in Japan**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153245

Figure 5.32. **Potential shortfall of the EPI 2005 loaded table for pensioners in Japan**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153255

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, though the two genders have been diverging. This divergence seems to have stabilised over the last few years as mortality improvements for females have decelerated particularly at ages 70-89.

Annuity providers seem to be making appropriate provisions for mortality improvements under the SMT2007 overall, though attention should be paid to the age distribution of the annuitants as under-provisioning for ages under 65 seems to be offset by overprovisioning at higher ages. Pension plans can expect a shortfall of provisions as no mortality improvement is taken into account in the EPI2005 tables.

Korea

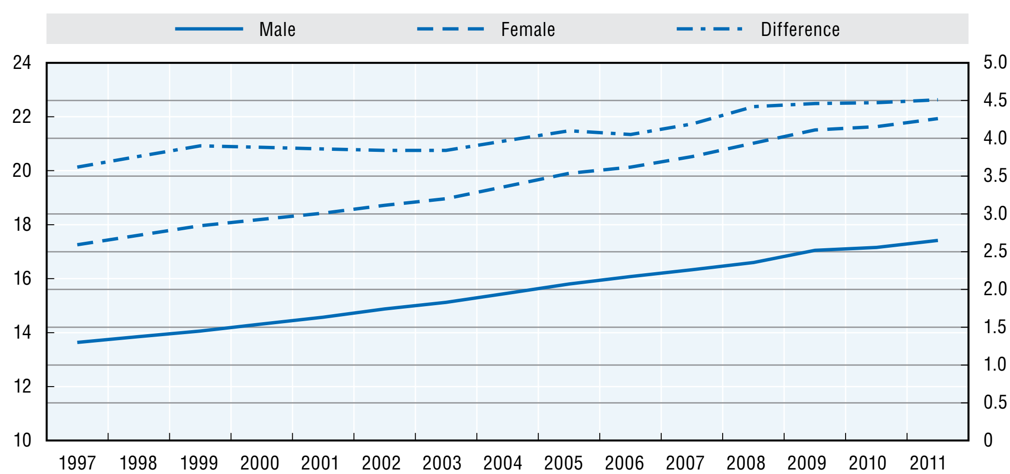
The data used for the assessment for Korea was based on life tables issued by KOSIS from 1997-2011. Mortality rates from these tables were used through age 84. For older ages, mortality rates were extrapolated for each year using the Kannisto methodology (Tesarkova, 2012).

Given the very short period of historical data available and the dramatic increase in life expectancy during this time for Korea, it is very difficult to determine what the future patterns in mortality will be as the projection models considered in this assessment essentially extrapolate the historical experience into the future. As such, direct outputs can be viewed as being rather conservative.

Historical life expectancy at age 65

Figure 5.33 shows the evolution in period life expectancy at age 65 for males and females. The steady and rapid increase seems to have slowed recently, with the gap in life expectancy (shown on the right axis) stabilizing around 4.5 years after increasing from around 3.5 years in 1997.

Figure 5.33. **Life expectancy at age 65 in Korea**



Source: KOSIS Life Tables for Korea

StatLink http://dx.doi.org/10.1787/888933153269

Historical and future mortality improvements

Table 5.27 below shows the annualized improvement to mortality rates for age groups of five years. From the left, historical improvements in the population's mortality are shown for two periods of seven years each. Improvements in mortality have been extremely high and have been shifting towards the older ages. All projection models continue these high improvements indefinitely into the future, with the exception of the CMI model, which has been assumed to converge to a 2% long term improvement.

Table 5.27. **Evolution of annual mortality improvements in Korea***

	Population		LC		CBD		PS		CMI	
Males	1997-2004	2004-2011	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	5.3%	4.0%	4.8%	4.8%	4.8%	4.8%	4.9%	5.0%	3.7%	2.1%
60-64	4.7%	4.9%	5.2%	5.1%	4.5%	4.5%	5.3%	5.2%	4.1%	2.3%
65-69	4.2%	5.3%	4.8%	4.7%	4.2%	4.2%	5.3%	5.2%	4.1%	2.2%
70-74	3.8%	4.3%	4.2%	4.2%	3.9%	3.8%	4.7%	4.7%	3.8%	2.3%
75-79	3.1%	4.0%	3.6%	3.6%	3.5%	3.5%	4.0%	4.0%	3.4%	2.3%
80-84	2.5%	2.9%	2.7%	2.7%	3.1%	3.1%	3.4%	3.5%	2.8%	2.2%
85-89	2.0%	2.8%	2.5%	2.5%	2.7%	2.7%	2.7%	2.7%	2.3%	2.1%
90-94	1.5%	2.3%	2.0%	2.0%	2.3%	2.3%	2.3%	2.2%	1.9%	1.9%
95-99	1.0%	1.8%	1.5%	1.5%	1.8%	1.9%	1.6%	1.7%	1.5%	1.5%
100-104	0.6%	1.3%	1.0%	1.1%	1.4%	1.4%	1.0%	1.1%	1.2%	1.2%
105-110	0.3%	0.8%	0.8%	0.8%	1.0%	1.1%	0.6%	0.6%	0.9%	0.9%
	Population		LC		CBD		PS		CMI	
Females	1997-2004	2004-2011	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	5.1%	4.8%	4.9%	4.8%	5.3%	5.3%	5.2%	5.2%	3.7%	2.1%
60-64	5.3%	5.4%	5.4%	5.2%	5.1%	5.1%	5.8%	5.8%	4.3%	2.2%
65-69	5.4%	5.7%	5.7%	5.5%	4.9%	4.9%	6.2%	6.2%	4.6%	2.2%
70-74	4.8%	6.3%	5.6%	5.5%	4.7%	4.6%	6.3%	6.2%	4.6%	2.3%
75-79	3.7%	5.9%	4.9%	4.8%	4.5%	4.4%	6.1%	6.2%	4.4%	2.4%
80-84	2.4%	4.9%	3.9%	3.8%	4.2%	4.2%	5.9%	6.0%	4.0%	2.3%
85-89	2.1%	5.0%	3.9%	3.8%	3.9%	3.9%	5.5%	5.6%	3.5%	2.2%
90-94	1.4%	4.6%	3.4%	3.4%	3.5%	3.6%	5.1%	5.1%	2.6%	2.0%
95-99	0.8%	3.9%	2.8%	2.8%	3.1%	3.2%	4.0%	4.2%	1.8%	1.5%
100-104	0.4%	3.0%	2.2%	2.2%	2.5%	2.7%	2.6%	2.8%	1.3%	1.2%
105-110	0.1%	2.1%	1.5%	1.5%	1.9%	2.1%	1.3%	1.3%	0.9%	0.8%

Source: Author's calculations.
**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153641

Life expectancy and annuity values

The Tables 5.28 and 5.29 show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

Despite the fact that no mortality improvements are explicitly applied in the standard mortality table, the life expectancy they imply seems very conservative compared to the assumptions of other countries, indicating that the tables do, in fact, account for future improvements in mortality.

The figures given for each of the projection models applied are shown for the general population as well as adjusted to the initial mortality of the 6th EMT table. However, as the exact margins contained in the standard mortality table are not known, these figures cannot be taken as representative of the true annuitant/pensioner mortality.

Table 5.28. **Korean males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
6th EMT		33.3	24.3	15.7	9.2	14.8	11.3	10.8%	6.7%	8.8%
Modelled Mortality										
Population	*LC*	31.9	20.8	11.9	8.6	13.2	9.1	11.6%	7.6%	11.0%
	CBD	32.0	21.0	12.3	8.6	13.1	9.3	11.7%	7.6%	10.8%
	P-Spline	32.8	21.4	12.2	8.8	13.4	9.2	11.3%	7.5%	10.9%
	CMI	30.9	20.6	12.0	8.4	13.1	9.1	12.0%	7.6%	11.0%
Adjusted										
6th EMT: 2004	*LC*	39.7	28.7	18.3	10.6	16.2	12.5	9.4%	6.2%	8.0%
	CBD	40.5	29.3	18.7	10.7	16.4	12.7	9.3%	6.1%	7.9%
	P-Spline	40.3	29.1	18.5	10.7	16.4	12.6	9.3%	6.1%	7.9%
	CMI	39.3	28.5	18.3	10.5	16.2	12.5	9.5%	6.2%	8.0%

Source: Author's calculations.

Table 5.29. **Korean females**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
6th EMT		38.1	28.5	19.1	10.4	16.3	13.0	9.6%	6.1%	7.7%
Modelled Mortality										
Population	*LC*	40.9	28.2	16.7	10.6	15.8	11.5	9.4%	6.3%	8.7%
	CBD	41.1	28.2	17.1	10.5	15.7	11.6	9.5%	6.4%	8.6%
	P-Spline	44.3	30.9	18.3	11.2	16.5	12.1	9.0%	6.1%	8.3%
	CMI	37.2	26.2	16.0	10.0	15.3	11.2	10.0%	6.5%	8.9%
Adjusted										
6th EMT: 2004	*LC*	46.7	35.1	23.5	11.8	18.0	14.7	8.5%	5.5%	6.8%
	CBD	47.9	36.0	24.2	12.0	18.2	14.9	8.4%	5.5%	6.7%
	P-Spline	48.6	36.8	24.8	12.1	18.4	15.1	8.3%	5.4%	6.6%
	CMI	43.9	33.1	22.4	11.4	17.6	14.3	8.7%	5.7%	7.0%

Source: Author's calculations.

Main conclusions

Korea has experienced very high mortality improvements over the last decade as life expectancy catches up to other OECD countries. The short period of historical data available results in rather conservative projections for future life expectancy, though the results from the CMI model are likely the most plausible compared to the other models as it allows for the assumption of convergence to a lower long term improvement rate. In reality, it is expected that this acceleration of life expectancy will eventually slow and converge to a rate of increase more in line with other countries. Given the relatively high life expectancy based on the 6th EMT table, pension funds and annuity providers are likely setting aside sufficient provisions for longevity based on these tables, nevertheless this could not be quantified here as no precise information regarding the margins embedded in the table could be obtained.

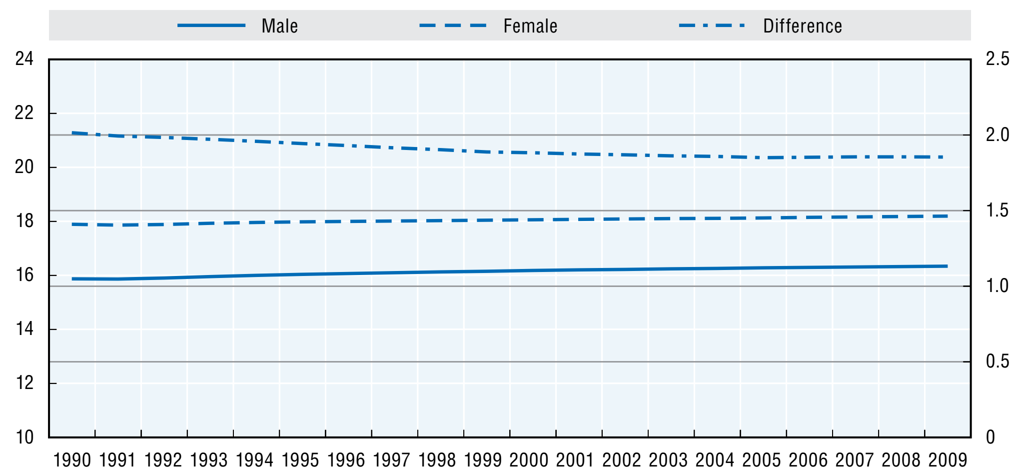
Mexico

The data used for the assessment for Mexico was based on Mexican population and death estimates from 1990 to 2009 published by CONAPO. Mortality rates based on this data were used through age 79. For older ages, mortality rates were extrapolated for each year using the Kannisto methodology (Tesarkova, 2012).

Historical life expectancy at age 65

The figure below shows the evolution in period life expectancy at age 65 for males and females. While the life expectancy for both genders has been increasing, it has been doing so relatively slowly over the last two decades. The gap in life expectancy between the two genders (shown on the right axis) has decreased slightly but has been overall stable at just under 2 years.

Figure 5.34. **Life expectancy at age 65 in Mexico**



Source: CONAPO

StatLink http://dx.doi.org/10.1787/888933153276

Historical and future mortality improvements

Table 5.30 shows the annualized improvement to mortality rates for age groups of five years. From the left, historical improvements in the population's mortality are shown. Improvements in mortality have slowed in the last decade for both genders, with the assumptions in the EMSSA09 being optimistic compared to recent experience. The stochastic models project forward a pattern in line with the overall average improvements, while the P-spline model continues the low improvements of the recent decade, and the CMI converges to the 1% long term improvement which has been assumed for Mexico in the longer term.

Table 5.30. **Evolution of annual mortality improvements in Mexico***

	Population		EMSSA09		LC		CBD		PS		CMI	
Males	1990-2000	2000-2009	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.5%	0.5%	1.3%	1.3%	1.0%	1.0%	1.0%	1.0%	0.5%	0.5%	0.8%	1.0%
60-64	1.2%	0.4%	1.1%	1.1%	0.8%	0.8%	0.8%	0.8%	0.4%	0.4%	0.6%	0.9%
65-69	0.9%	0.3%	0.9%	0.9%	0.6%	0.6%	0.6%	0.6%	0.3%	0.3%	0.5%	0.9%
70-74	0.6%	0.3%	0.8%	0.8%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%	0.4%	0.8%
75-79	0.3%	0.2%	0.6%	0.6%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.5%	0.9%
80-84	0.0%	0.2%	0.6%	0.6%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.6%	1.0%
85-89	-0.2%	0.0%	0.6%	0.6%	0.0%	0.0%	-0.1%	-0.1%	0.2%	0.2%	0.8%	1.0%
90-94	-0.5%	0.0%	0.5%	0.5%	-0.2%	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%	0.9%	1.0%
95-99	-0.6%	0.0%	0.4%	0.4%	-0.3%	-0.3%	-0.3%	-0.3%	-0.1%	-0.1%	0.8%	0.8%
100-104	-0.7%	-0.1%	0.0%	0.0%	-0.3%	-0.3%	-0.4%	-0.4%	-0.2%	-0.2%	0.6%	0.6%
105-110	-0.8%	-0.1%	0.0%	0.0%	-0.4%	-0.4%	-0.5%	-0.5%	-0.4%	-0.3%	0.4%	0.4%
	Population		EMSSA09		LC		CBD		PS		CMI	
Female	1990-2000	2000-2009	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.3%	0.5%	1.8%	1.8%	0.9%	0.9%	0.9%	0.9%	0.5%	0.5%	0.8%	1.0%
60-64	1.0%	0.4%	1.5%	1.5%	0.8%	0.8%	0.7%	0.7%	0.4%	0.4%	0.6%	0.9%
65-69	0.7%	0.3%	1.3%	1.3%	0.6%	0.6%	0.5%	0.5%	0.3%	0.3%	0.5%	0.9%
70-74	0.5%	0.3%	1.0%	1.0%	0.4%	0.4%	0.4%	0.4%	0.3%	0.2%	0.5%	0.9%
75-79	0.2%	0.2%	0.9%	0.9%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.4%	0.9%
80-84	0.0%	0.2%	0.7%	0.7%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.5%	1.0%
85-89	0.0%	0.0%	0.6%	0.6%	0.1%	0.1%	-0.1%	-0.1%	0.1%	0.1%	0.8%	1.0%
90-94	-0.6%	0.0%	0.5%	0.5%	-0.2%	-0.2%	-0.2%	-0.2%	-0.1%	0.0%	0.9%	1.0%
95-99	-0.7%	-0.1%	0.3%	0.3%	-0.3%	-0.3%	-0.4%	-0.4%	0.0%	-0.1%	0.8%	0.8%
100-104	-0.8%	-0.1%	0.0%	0.0%	-0.4%	-0.4%	-0.4%	-0.4%	-0.1%	-0.1%	0.6%	0.6%
105-110	-0.8%	-0.1%	0.0%	0.0%	-0.4%	-0.4%	-0.5%	-0.5%	-0.3%	-0.3%	0.4%	0.4%

Source: Author's calculations.
**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153654

Life expectancy and annuity values

The Tables 5.31 and 5.32 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees). The figures given for each of the projection models applied are shown for the general population as well as adjusted to the level of insured and pensioner mortality.

Table 5.31. **Mexican males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
EMSSA97		25.3	17.1	10.3	7.0	11.8	8.3	14.4%	8.5%	12.1%
EMSSA09		29.6	21.7	14.8	7.9	13.5	10.6	12.6%	7.4%	9.4%
Modelled Mortality										
Population	*LC*	23.8	16.5	10.6	6.4	11.3	8.3	15.7%	8.8%	12.0%
	CBD	23.8	16.5	10.8	6.4	11.3	8.5	15.7%	8.8%	11.8%
	P-Spline	23.8	16.5	10.7	6.3	11.3	8.4	15.8%	8.8%	11.9%
	CMI	25.0	17.2	11.1	6.6	11.5	8.6	15.1%	8.7%	11.7%
Adjusted										
EMSSA97: 1997	*LC*	25.0	16.8	10.1	6.9	11.6	8.1	14.5%	8.6%	12.3%
	CBD	25.0	16.8	10.1	6.9	11.7	8.1	14.5%	8.6%	12.3%
	P-Spline	25.0	16.9	10.1	6.9	11.7	8.2	14.6%	8.6%	12.2%
	CMI	26.1	17.5	10.4	7.1	11.9	8.3	14.1%	8.4%	12.0%
EMSSA09: 2009	*LC*	28.6	21.0	14.4	7.7	13.2	10.5	12.9%	7.6%	9.6%
	CBD	28.5	20.9	14.3	7.7	13.2	10.4	13.0%	7.6%	9.6%
	P-Spline	28.5	21.0	14.5	7.7	13.2	10.5	13.0%	7.6%	9.5%
	CMI	29.9	22.0	15.0	8.0	13.5	10.7	12.6%	7.4%	9.3%

Source: Author's calculations.

Table 5.32. **Mexican females**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
EMSSA97		29.3	20.6	13.0	8.1	13.3	9.8	12.3%	7.5%	10.2%
EMSSA09		34.0	24.3	15.1	9.5	15.0	11.1	10.5%	6.7%	9.0%
Modelled Mortality										
Population	*LC*	26.2	18.2	11.8	7.1	12.2	9.0	14.0%	8.2%	11.1%
	CBD	26.2	18.3	11.9	7.1	12.2	9.1	14.0%	8.2%	11.0%
	P-Spline	26.3	18.3	11.9	7.1	12.2	9.1	14.0%	8.2%	11.0%
	CMI	27.6	19.2	12.3	7.4	12.4	9.3	13.5%	8.0%	10.8%
Adjusted										
EMSSA97: 1997	*LC*	28.7	20.0	12.6	8.0	13.0	9.6	12.6%	7.7%	10.4%
	CBD	28.7	20.0	12.6	8.0	13.1	9.6	12.6%	7.7%	10.4%
	P-Spline	28.8	20.1	12.7	8.0	13.1	9.6	12.6%	7.6%	10.4%
	CMI	30.2	21.0	13.2	8.3	13.3	9.8	12.1%	7.5%	10.2%
EMSSA09: 2009	*LC*	32.9	23.6	14.7	9.3	14.7	10.9	10.8%	6.8%	9.1%
	CBD	32.8	23.5	14.7	9.2	14.7	10.9	10.8%	6.8%	9.2%
	P-Spline	33.0	23.7	14.8	9.3	14.7	11.0	10.8%	6.8%	9.1%
	CMI	34.3	24.5	15.2	9.5	15.0	11.2	10.5%	6.7%	9.0%

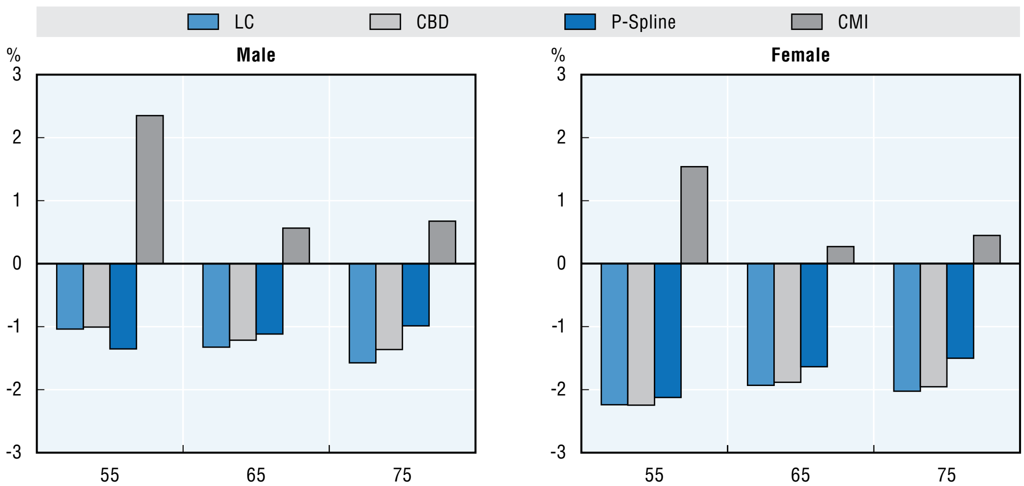
Source: Author's calculations.

Change in liability value

The graphs in Figure 5.35 and 5.36 show the change in liability value given by the models studied based on the annuity values presented for the standard mortality tables and the adjusted model outputs in the section above. Both tables demonstrate little to no potential shortfall in provisions.

On the other hand the recent low mortality improvements in Mexico result in a slight over-provisioning for longevity for annuities as measured here, as the improvements assumed are more conservative than recent population experience shows.

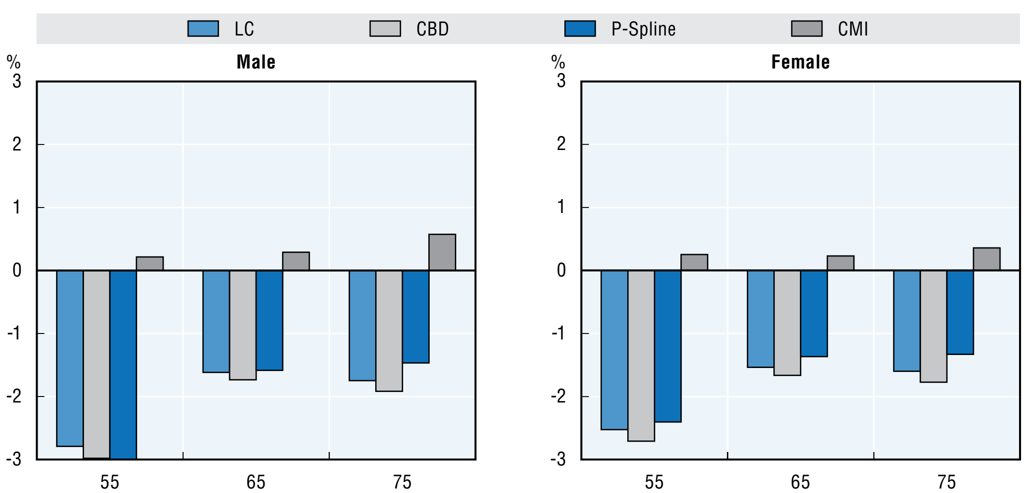
Figure 5.35. **Potential shortfall from EMSSA 97 tables for pensioners in Mexico**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153285

Figure 5.36. **Potential shortfall from EMSSA 09 tables for annuitants in Mexico**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153290

Main conclusions

Life expectancy has been increasing in Mexico, albeit at a rather slow pace over the last two decades. The gender gap has remained fairly stable at just under two years. Improvements in mortality have decelerated in the last decade.

Both pension funds annuity providers seem to be in a comfortable position for the time being in terms of expected longevity as the mortality improvement assumptions assumed surpass those experienced by the population in recent decades. Nevertheless, as the current life expectancy in Mexico lags somewhat behind other OECD countries, there is significant room for Mexico to catch up, meaning that there is a potential for mortality improvements to accelerate rapidly depending on social and economic developments in the country. Therefore mortality should be closely monitored to make sure any such acceleration is reported and assumptions updated accordingly.

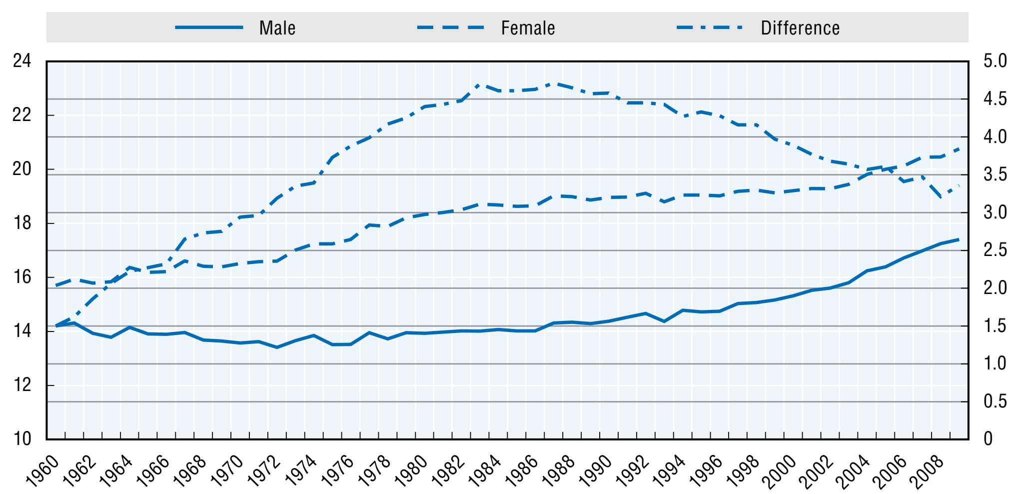
Netherlands

The assessment for the Netherlands relied on HMD data from 1960 to 2009.

Historical life expectancy at age 65

Figure 5.37 shows the evolution in period life expectancy at age 65 for males and females. The life expectancy has been increasing in bursts for females, while life expectancy for males remained stagnant or decreased through the mid-1970s, at which point it began an exponential increase. The most impressive increase for both genders has come over the last decade. As a result of these differing patterns of growth, the gap between the two genders (shown on the right axis) increased dramatically until the 1980s, when life expectancy began a steady convergence, arriving at just under 3.5 years currently.

Figure 5.37. **Life expectancy at age 65 in the Netherlands**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153304

Historical and future mortality improvements

Table 5.33 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (HMD) accelerated dramatically over the last decade, particularly for ages 65-79. Male improvements have been overall higher than those for females. As constructed, the AG-Prognosetafel 2010 continues these high trends in the short term, reverting eventually to a long term rate. The stochastic models do not capture these high improvements for males due to the historical patterns of stagnant mortality followed by an exponential increase, thus seem less plausible in light of recent experience. The P-splines continue these very high improvements into the future, reflecting its sensitivity to the most recent data, while the CMI model gradually reverts to the long term improvement assumption which has been set at 1.2% for the Netherlands.

Table 5.33. **Evolution of annual mortality improvements in the Netherlands***

	HMD		AG-Prognosetafel 2010		LC		CBD		PS		CMI	
Males	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.1%	3.2%	2.9%	2.7%	1.6%	1.6%	1.3%	1.3%	2.7%	2.8%	1.8%	1.2%
60-64	2.0%	2.9%	3.0%	2.8%	1.5%	1.5%	1.2%	1.2%	3.4%	3.4%	2.1%	1.3%
65-69	2.1%	3.8%	3.9%	3.3%	1.4%	1.4%	1.1%	1.1%	4.1%	4.0%	2.4%	1.4%
70-74	1.9%	3.6%	4.0%	3.2%	1.1%	1.1%	1.0%	1.0%	4.2%	4.2%	2.8%	1.5%
75-79	1.1%	3.3%	3.1%	2.4%	0.8%	0.8%	0.9%	0.9%	3.8%	3.9%	2.9%	1.6%
80-84	0.5%	2.7%	2.4%	1.8%	0.5%	0.5%	0.8%	0.8%	3.1%	3.2%	2.6%	1.7%
85-89	0.2%	1.9%	1.5%	0.5%	0.3%	0.3%	0.6%	0.6%	2.2%	2.2%	2.0%	1.7%
90-94	-0.3%	1.2%	0.0%	0.0%	0.1%	0.1%	0.5%	0.5%	1.2%	1.2%	1.3%	1.3%
95-99	-0.4%	0.7%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.3%	0.9%	0.9%
100-104	-0.5%	0.3%	0.0%	0.0%	-0.1%	-0.1%	0.2%	0.2%	-0.2%	-0.2%	0.7%	0.7%
105-110	-0.3%	0.1%	0.0%	0.0%	-0.1%	-0.1%	0.1%	0.1%	-0.2%	-0.2%	0.5%	0.5%
	HMD		AG-Prognosetafel 2010		LC		CBD		PS		CMI	
Female	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	0.3%	1.8%	1.8%	1.8%	0.9%	0.9%	1.6%	1.6%	1.0%	1.0%	0.8%	1.2%
60-64	0.8%	1.5%	1.7%	1.8%	1.1%	1.1%	1.5%	1.5%	1.7%	1.7%	1.0%	1.1%
65-69	0.4%	2.6%	2.5%	2.1%	1.4%	1.4%	1.5%	1.5%	2.5%	2.4%	1.4%	1.0%
70-74	0.4%	3.0%	2.8%	2.1%	1.7%	1.7%	1.4%	1.4%	3.0%	2.9%	1.8%	1.0%
75-79	0.7%	2.7%	2.6%	1.9%	1.7%	1.7%	1.3%	1.3%	2.9%	3.0%	1.9%	1.2%
80-84	0.3%	2.4%	3.3%	1.6%	1.5%	1.5%	1.2%	1.3%	2.7%	2.8%	1.8%	1.3%
85-89	0.3%	1.9%	2.8%	1.0%	1.1%	1.1%	1.1%	1.2%	2.4%	2.4%	1.6%	1.3%
90-94	-0.1%	1.4%	1.9%	0.0%	0.6%	0.7%	1.0%	1.0%	1.8%	1.8%	1.3%	1.2%
95-99	-0.2%	0.9%	1.0%	0.0%	0.3%	0.3%	0.9%	0.9%	1.0%	1.0%	0.9%	0.9%
100-104	-0.2%	0.5%	0.6%	0.0%	0.1%	0.1%	0.7%	0.7%	0.3%	0.3%	0.7%	0.7%
105-110	-0.1%	0.2%	0.5%	0.0%	0.0%	0.0%	0.5%	0.5%	-0.2%	-0.2%	0.5%	0.5%

Source: Author's calculations.
**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153663

Life expectancy and annuity values

The Tables 5.34 and 5.35 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

The figures given for each of the projection models applied are shown for the general population as well as adjusted to the initial mortality for the standard mortality table in 2008. As the standard mortality table was based on the Dutch population, these two figures are understandably quite close.

Table 5.34. **Dutch males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
AG-Prognosetafel		29.2	19.6	11.1	8.2	12.9	8.8	12.2%	7.7%	11.4%
Modelled Mortality										
Population	*LC*	26.9	17.7	10.2	7.5	12.1	8.2	13.4%	8.2%	12.1%
	CBD	27.1	18.0	10.7	7.5	12.2	8.5	13.4%	8.2%	11.8%
	P-Spline	31.1	20.5	11.5	8.6	13.2	9.0	11.6%	7.6%	11.2%
	CMI	29.3	19.8	11.4	8.1	12.9	8.9	12.4%	7.7%	11.2%
Adjusted										
AG-Prognosetafel: 2008	*LC*	26.9	17.9	10.4	7.5	12.2	8.4	13.4%	8.2%	12.0%
	CBD	27.2	18.2	10.7	7.5	12.3	8.5	13.3%	8.1%	11.8%
	P-Spline	31.2	20.6	11.6	8.6	13.3	9.0	11.6%	7.5%	11.1%
	CMI	29.5	20.0	11.5	8.1	13.0	9.0	12.3%	7.7%	11.2%

Source: Author's calculations.

Table 5.35. **Dutch females**

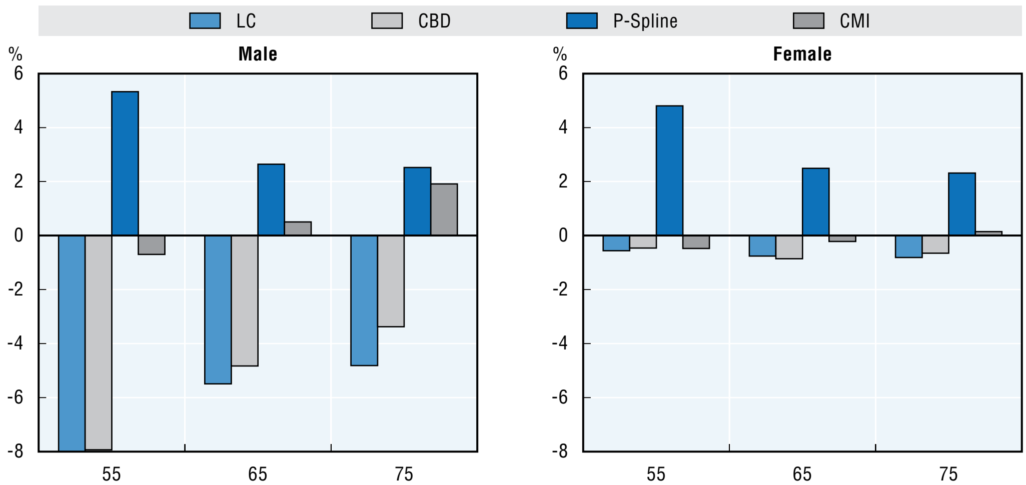
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
AG-Prognosetafel		31.9	22.5	13.7	8.9	14.1	10.2	11.3%	7.1%	9.8%
Modelled Mortality										
Population	*LC*	31.8	22.2	13.5	8.8	14.0	10.1	11.4%	7.1%	9.9%
	CBD	31.8	21.8	13.3	8.8	13.8	9.9	11.4%	7.3%	10.1%
	P-Spline	34.0	23.6	14.1	9.3	14.4	10.4	10.8%	6.9%	9.6%
	CMI	31.9	22.5	13.7	8.8	14.0	10.2	11.4%	7.1%	9.8%
Adjusted										
AG-Prognosetafel: 2008	*LC*	31.9	22.3	13.5	8.8	14.0	10.1	11.3%	7.1%	9.9%
	CBD	32.1	22.4	13.6	8.8	14.0	10.2	11.3%	7.1%	9.8%
	P-Spline	34.1	23.7	14.2	9.3	14.5	10.5	10.7%	6.9%	9.6%
	CMI	32.1	22.6	13.8	8.8	14.1	10.2	11.3%	7.1%	9.8%

Source: Author's calculations.

Change in liability value

The graphs in Figure 5.38 show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. The stochastic models seem to be underestimating longevity for males as shown with the low projected improvements above, so are implying here an overprovisioning for longevity. The P-spline projection seems to be a conservative outlier as the high recent improvements are continued indefinitely into the future. The results of the CMI model are very close to the AG Prognosetafel, assumptions, which seem to appropriately account for the expected longevity for males. For females the CMI and stochastic models converge fairly closely, with the P-spline remaining an outlier, so the provisions for longevity for females also seem appropriate.

Figure 5.38. **Potential shortfall from the AG Prognosetafel in the Netherlands**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153318

Main conclusions

While life expectancy has been increasing overall since 1960, the speed of this increase has not been steady for either gender. The gap between the two was increasing through the 1980s, and since then the two genders have been converging. Annual mortality improvements have increased dramatically over the last decade for both genders.

The periods where life expectancy for males was not increasing poses a challenge to the calibration of the stochastic models, and as a result these models seem to underestimate the expected longevity for males. At the same time, the P-spline model seems to overestimate it as it continues the very high improvements over the last decade into the future. The assumptions in the AG-Prognosetafel 2010 fall between these two extremes, and are not far from the results of the CMI model which takes a similar approach of modelling short term improvements converging to a long term average. The provisioning for longevity using this industry table seems appropriate.

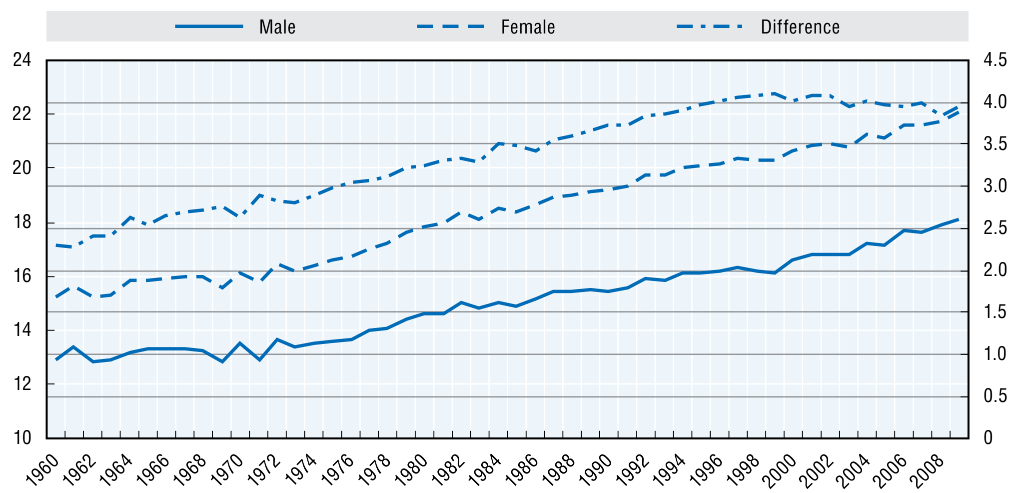
Spain

The assessment for Spain relied on HMD data from 1960 to 2009.

Historical life expectancy at age 65

Figure 5.39 below shows the evolution in period life expectancy at age 65 for males and females. The life expectancy for both genders has been increasing at a fairly steady rate since the 1970s. Life expectancy for females increased at a faster rate up to around 2000, when the difference between the two genders (shown on the right axis) decreased somewhat and seems to be stabilizing for the moment at around four years.

Figure 5.39. **Life expectancy at age 65 in Spain**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153329

Historical and future mortality improvements

Table 5.36 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (HMD) have accelerated for both genders over the past decade and have shifted towards higher ages, especially for those aged 65-79, with improvements being overall higher for females. Mortality improvements assumed in the standard mortality table are overall lower than recent experience, particularly for males, though they are more or less in line with what is predicted by the stochastic models. The P-spline model continues the projection of the very high improvements of the last decade, reflecting its sensitivity to the most recent data. The CMI model reverts eventually to a long term improvement which has been set at 1.7% for Spain.

Table 5.36. **Evolution of annual mortality improvements in Spain***

	HMD		PERMC		PERMP		LC		CBD		PS		CMI	
Males	1990-2000	2000-2009	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.6%	1.7%	1.1%	1.1%	1.5%	1.5%	1.3%	1.3%	1.6%	1.6%	1.6%	1.6%	1.7%	1.7%
60-64	1.6%	2.0%	1.3%	1.3%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	2.0%	2.0%	1.8%	1.7%
65-69	1.7%	2.4%	1.3%	1.3%	1.5%	1.5%	1.6%	1.6%	1.5%	1.5%	2.6%	2.5%	1.9%	1.7%
70-74	1.9%	2.7%	1.3%	1.3%	1.5%	1.5%	1.6%	1.6%	1.4%	1.4%	2.8%	2.8%	2.1%	1.7%
75-79	1.3%	2.5%	1.2%	1.2%	1.5%	1.5%	1.5%	1.5%	1.3%	1.3%	2.6%	2.6%	2.2%	1.8%
80-84	1.5%	1.7%	1.0%	1.0%	1.5%	1.5%	1.3%	1.3%	1.2%	1.3%	2.2%	2.3%	2.0%	1.9%
85-89	1.2%	1.3%	1.0%	1.0%	1.5%	1.5%	1.0%	1.0%	1.1%	1.2%	1.7%	1.8%	1.8%	1.9%
90-94	0.9%	1.6%	0.9%	0.9%	1.3%	1.3%	0.6%	0.6%	1.0%	1.1%	1.5%	1.4%	1.6%	1.7%
95-99	0.6%	1.1%	0.4%	0.4%	0.6%	0.6%	0.4%	0.4%	0.9%	0.9%	0.9%	0.9%	1.3%	1.3%
100-104	0.4%	0.9%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%	0.7%	0.8%	0.4%	0.4%	1.0%	1.0%
105-110	0.2%	0.4%	0.0%	0.0%	0.6%	0.0%	0.1%	0.1%	0.5%	0.6%	0.0%	0.0%	0.7%	0.7%
	HMD		PERFC		PERFP		LC		CBD		PS		CMI	
Female	1990-2000	2000-2009	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.4%	1.3%	2.3%	2.3%	2.5%	2.5%	2.2%	2.2%	2.9%	2.9%	1.5%	1.5%	1.3%	1.6%
60-64	2.6%	2.0%	2.4%	2.4%	2.5%	2.5%	2.4%	2.4%	2.6%	2.6%	2.2%	2.2%	1.5%	1.5%
65-69	2.3%	3.0%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.4%	2.4%	2.8%	2.8%	1.9%	1.4%
70-74	2.6%	3.1%	2.4%	2.4%	2.5%	2.5%	2.6%	2.6%	2.1%	2.1%	3.0%	3.0%	2.2%	1.5%
75-79	2.3%	3.0%	2.0%	2.0%	2.5%	2.5%	2.3%	2.3%	1.9%	1.9%	2.8%	2.8%	2.2%	1.7%
80-84	2.0%	2.3%	1.6%	1.6%	2.2%	2.2%	1.8%	1.8%	1.6%	1.6%	2.4%	2.4%	2.1%	1.8%
85-89	1.5%	1.3%	1.1%	1.1%	1.8%	1.8%	1.2%	1.2%	1.3%	1.3%	1.7%	1.8%	1.9%	1.9%
90-94	1.1%	1.2%	0.7%	0.7%	1.3%	1.3%	0.6%	0.6%	1.0%	1.0%	1.2%	1.2%	1.7%	1.7%
95-99	0.8%	0.5%	0.2%	0.2%	0.6%	0.6%	0.3%	0.3%	0.7%	0.7%	0.7%	0.7%	1.3%	1.3%
100-104	0.5%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.3%	0.3%	1.0%	1.0%
105-110	0.2%	0.0%	0.0%	0.0%	0.6%	0.0%	-0.1%	-0.1%	0.2%	0.2%	-0.1%	-0.1%	0.7%	0.7%

Source: Author's calculations.
**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153670

Life expectancy and annuity values

The Tables 5.37 and 5.38 show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

Table 5.37. **Spanish males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
PERM P		29.3	20.2	12.5	8.0	13.0	9.5	12.5%	7.7%	10.6%
PERM C		31.4	21.9	13.9	8.5	13.7	10.2	11.7%	7.3%	9.9%
Modelled Mortality										
Population	*LC*	28.6	19.5	11.7	7.9	12.8	9.1	12.7%	7.8%	11.0%
	CBD	28.6	19.3	11.7	7.8	12.6	9.0	12.8%	7.9%	11.1%
	P-Spline	30.2	20.5	12.0	8.3	13.1	9.2	12.1%	7.6%	10.8%
	CMI	29.8	20.4	12.1	8.1	13.1	9.2	12.4%	7.7%	10.8%
Adjusted										
PERM C 2000	*LC*	30.3	21.1	13.0	8.3	13.4	9.8	12.0%	7.5%	10.2%
	CBD	30.6	21.2	13.2	8.3	13.4	9.8	12.0%	7.5%	10.2%
	P-Spline	32.1	22.2	13.5	8.7	13.8	10.0	11.5%	7.3%	10.0%
	CMI	31.7	22.1	13.6	8.6	13.7	10.0	11.7%	7.3%	10.0%
PERM P 2000	*LC*	31.4	22.0	13.8	8.6	13.8	10.2	11.6%	7.3%	9.8%
	CBD	31.7	22.1	14.0	8.6	13.7	10.2	11.6%	7.3%	9.8%
	P-Spline	33.2	23.2	14.3	9.0	14.1	10.4	11.1%	7.1%	9.6%
	CMI	32.9	23.1	14.4	8.9	14.1	10.4	11.3%	7.1%	9.6%

Source: Author's calculations.

Table 5.38. **Spanish females**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
PERM P		34.8	24.6	15.1	9.6	14.9	11.0	10.4%	6.7%	9.1%
PERM C		37.0	26.4	16.6	10.1	15.5	11.7	9.9%	6.4%	8.6%
Modelled Mortality										
Population	*LC*	33.9	23.7	14.2	9.4	14.6	10.5	10.6%	6.8%	9.5%
	CBD	33.9	23.4	14.2	9.3	14.4	10.5	10.7%	6.9%	9.5%
	P-Spline	34.8	24.3	14.6	9.6	14.8	10.7	10.4%	6.7%	9.3%
	CMI	34.8	24.5	14.8	9.5	14.8	10.8	10.5%	6.7%	9.3%
Adjusted										
PERM C 2000	*LC*	35.3	25.0	15.4	9.8	15.1	11.1	10.3%	6.6%	9.0%
	CBD	35.5	25.1	15.5	9.7	15.1	11.1	10.3%	6.6%	9.0%
	P-Spline	36.3	25.7	15.8	9.9	15.3	11.3	10.1%	6.5%	8.9%
	CMI	36.4	25.9	16.0	9.9	15.3	11.4	10.1%	6.5%	8.8%
PERM P 2000	*LC*	36.1	25.8	16.1	9.9	15.4	11.5	10.1%	6.5%	8.7%
	CBD	36.4	25.9	16.2	9.9	15.3	11.5	10.1%	6.5%	8.7%
	P-Spline	37.1	26.5	16.5	10.1	15.6	11.6	9.9%	6.4%	8.6%
	CMI	37.3	26.8	16.8	10.1	15.6	11.7	9.9%	6.4%	8.5%

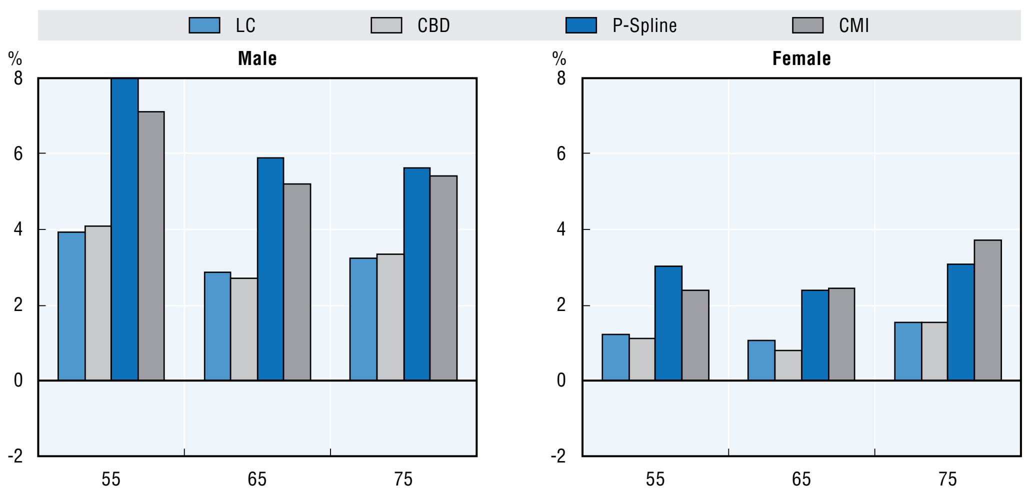
Source: Author's calculations.

Figures for the standard mortality tables are shown as well as figures from the application of the projection models for the general population and adjusted to the estimates for the insured population, the latter of which are based on the initial starting mortality given for the respective table in 2000. However it is not clear how the difference in the mortality for the policies issued before (PERM/F P) and after November 2000 (PERM/F C) was established. Furthermore the level of insured mortality compared to that of the population was based on the experience of Switzerland, whose pension system has entirely different structure from that of Spain. This implies that the subset of the insured population to which these mortality tables apply would not necessarily be similar either, and could result in mortality differences compared to the general population of a different magnitude compared to the experience of Switzerland due to selection effects.

Change in liability value

Figures 5.40 and 5.41 show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs from the tables presented in the section above. There seems to be more of a potential shortfall in provisions for longevity for males than for females, as well as for policies issued before November 2000 which are valued using the PERM/F C tables. This generation of annuities is faced with a potential shortfall of provisions of 3-5% for males and 1-2% for females.[5]

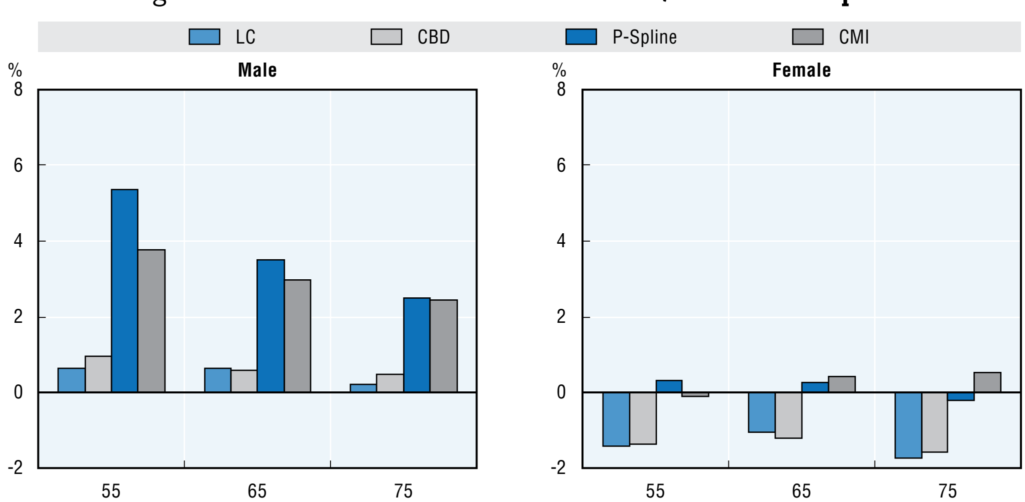
Figure 5.40. **Potential shortfall from PERM/F C table in Spain**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153335

Figure 5.41. **Potential shortfall from PERM/F P table in Spain**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153347

The newer generation of annuities is better provisioned for, though males may still be facing some residual shortfall along the lines of 1-2% of liabilities.

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, with the two genders diverging until the last decade, with the gap then stabilizing somewhat around four years. Mortality improvements for both genders have accelerated over the past decade, with female improvements being overall higher, and higher improvements shifting towards older ages.

Provisions for mortality improvements under the PERM/F C table seem to fall slightly short, particularly for males, though assumptions under the PERM/F P for the newer generation of annuities are more in line with outcomes predicted by the models assessed here. However sufficient provisioning for annuities issued since November 2000 will likely not make up for the shortfall in provisions for the policies issued previously. Furthermore the extent to which the differences between the mortality of the insured population and that of the general population should be more carefully assessed to ensure appropriate assumptions regarding the current level of mortality.

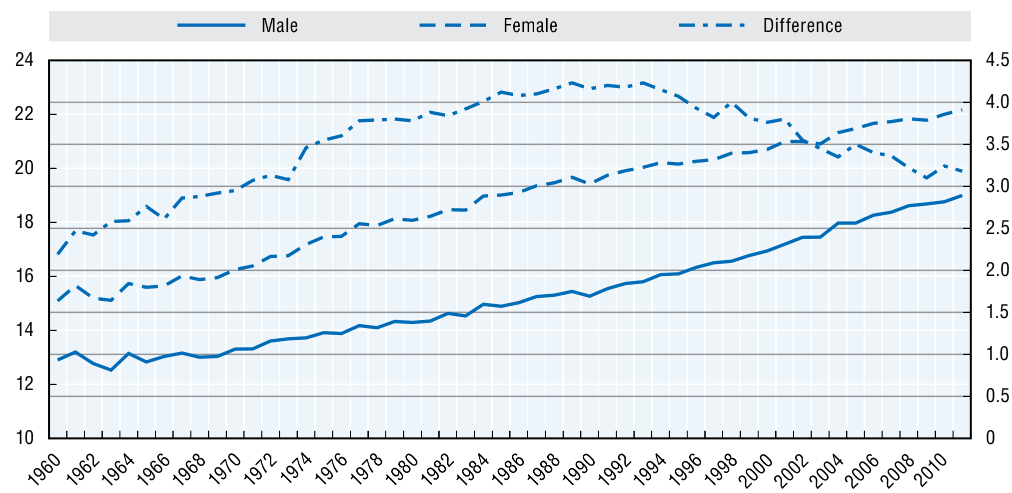
Switzerland

The assessment for Switzerland relied on HMD data from 1960 to 2011.

Historical life expectancy at age 65

Figure 5.42 below shows the evolution in period life expectancy at age 65 for males and females. The life expectancy for both genders has been increasing at a fairly steady rate since around 1970, with females increasing at a faster rate than males until around 1990. The gender gap in life expectancy (shown on the right axis) peaked at around four years, but has since decreased to just over three years.

Figure 5.42. **Life expectancy at age 65 in Switzerland**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153353

Historical and future mortality improvements

Table 5.39 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it can be observed that historical improvements for the general population (HMD) have accelerated over the last two decades for both genders, with males now experiencing overall higher improvements than females. The Menthonnex improvements, on which the BVG 2010 and VZ 2010 rely, seem to be relatively similar to the outputs of the stochastic models, while the Nolfi improvements also used with the VZ 2010 table seem relatively low. The assumptions embedded the ERM 2000 tables used for annuitants are close to the output of the P-spline model for males, though the assumptions for females are overall higher than those predicted by the models. The CMI model reverts eventually to the long term improvement assumption which has been set at 1.9% for Switzerland.

Table 5.39. **Evolution of annual mortality improvements in Switzerland***

	HMD		ERM 2000		Nolfi		Menthonnex		LC		CBD		PS		CMI	
Males	1990-2000	2000-2010	2010-2020	2020-2030	2012-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.4%	2.0%	3.1%	3.1%	1.7%	1.7%	2.1%	1.9%	2.2%	2.0%	2.5%	2.3%	2.5%	2.5%	2.7%	2.1%
60-64	2.6%	2.8%	3.0%	3.0%	1.7%	1.7%	2.1%	1.8%	2.3%	2.1%	2.3%	2.1%	2.5%	2.6%	2.8%	2.4%
65-69	2.2%	2.6%	3.0%	3.0%	1.7%	1.7%	2.0%	1.7%	2.3%	2.1%	2.1%	1.9%	2.8%	2.9%	2.7%	2.5%
70-74	1.9%	3.2%	2.8%	2.8%	1.6%	1.6%	1.8%	1.6%	2.2%	2.0%	1.9%	1.8%	3.1%	3.0%	2.8%	2.4%
75-79	1.6%	2.8%	2.6%	2.6%	1.6%	1.6%	1.7%	1.4%	1.9%	1.7%	1.7%	1.6%	2.8%	2.8%	2.8%	2.3%
80-84	1.5%	2.5%	2.3%	2.3%	1.4%	1.4%	1.6%	1.3%	1.5%	1.4%	1.5%	1.4%	2.2%	2.2%	2.5%	2.3%
85-89	0.5%	2.2%	2.0%	2.0%	1.3%	1.3%	1.4%	1.1%	1.1%	1.0%	1.3%	1.2%	1.5%	1.6%	2.1%	2.2%
90-94	-0.1%	2.0%	1.7%	1.7%	1.1%	1.1%	1.3%	1.0%	0.7%	0.6%	1.1%	0.9%	1.0%	1.0%	1.7%	1.9%
95-99	-0.5%	1.6%	1.4%	1.4%	1.0%	1.0%	1.1%	0.8%	0.3%	0.2%	0.8%	0.7%	0.5%	0.5%	1.3%	1.5%
100-104	-0.8%	1.2%	0.7%	0.7%	0.8%	0.8%	1.0%	0.6%	0.0%	0.0%	0.6%	0.5%	0.0%	0.1%	1.0%	1.1%
105-110	-0.5%	0.6%	0.0%	0.0%	0.7%	0.7%	0.7%	0.4%	-0.1%	-0.1%	0.3%	0.3%	-0.2%	-0.2%	0.7%	0.8%
	HMD		ERF 2000		Nolfi		Menthonnex		LC		CBD		PS		CMI	
Female	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	-0.2%	2.3%	2.6%	2.6%	1.4%	1.4%	2.2%	1.4%	1.9%	1.7%	2.7%	2.6%	1.6%	1.6%	2.1%	2.0%
60-64	1.3%	1.8%	2.9%	2.9%	1.5%	1.5%	2.1%	1.6%	2.1%	2.0%	2.5%	2.4%	1.4%	1.4%	2.0%	2.3%
65-69	1.7%	2.1%	3.1%	3.1%	1.6%	1.6%	2.0%	1.7%	2.4%	2.2%	2.4%	2.3%	1.6%	1.6%	1.9%	2.3%
70-74	2.5%	2.0%	3.2%	3.2%	1.6%	1.6%	1.9%	1.7%	2.6%	2.4%	2.2%	2.1%	2.0%	2.0%	1.9%	2.2%
75-79	2.4%	2.2%	3.2%	3.2%	1.6%	1.6%	1.7%	1.6%	2.6%	2.4%	2.1%	1.9%	2.3%	2.2%	2.0%	2.0%
80-84	1.7%	2.1%	2.8%	2.8%	1.4%	1.4%	1.6%	1.4%	2.2%	2.0%	1.9%	1.8%	2.3%	2.2%	2.0%	1.9%
85-89	1.5%	1.7%	2.2%	2.2%	1.2%	1.2%	1.4%	1.2%	1.6%	1.5%	1.7%	1.6%	1.7%	1.8%	1.9%	1.9%
90-94	0.8%	1.0%	1.5%	1.5%	1.0%	1.0%	1.3%	1.0%	1.0%	0.9%	1.4%	1.3%	1.0%	1.1%	1.8%	1.8%
95-99	0.6%	0.5%	0.9%	0.9%	0.8%	0.8%	1.1%	0.9%	0.5%	0.5%	1.2%	1.1%	0.6%	0.6%	1.4%	1.5%
100-104	0.3%	0.1%	0.2%	0.2%	0.6%	0.6%	0.9%	0.6%	0.1%	0.1%	0.9%	0.8%	0.3%	0.2%	1.0%	1.1%
105-110	0.1%	0.0%	0.0%	0.0%	0.6%	0.6%	0.6%	0.4%	0.0%	0.0%	0.5%	0.5%	-0.1%	-0.1%	0.7%	0.8%

Source: Author's calculations.

**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153687

Life expectancy and annuity values

The Tables 5.40 and 5.41 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees). The figures from the projection models are shown for the general population as well as those adjusted to the initial mortality for pensioners and annuitants based on the respective tables and the years indicated.

Table 5.40. **Swiss males**

		Life Expectancy 2010			Annuity factors			Annuity payment		
Mortality tables		55	65	75	55	65	75	55	65	75
ERM 2000		37.0	26.0	16.3	9.9	15.2	11.4	10.1%	6.6%	8.8%
BVG2010		31.0	21.0	12.5	8.6	13.5	9.6	11.6%	7.4%	10.5%
VZ2010 - Nolfi*		32.1	21.7	13.0	8.9	13.8	9.8	11.2%	7.3%	10.2%
VZ2010 - Methonnex*		31.9	21.7	13.0	8.9	13.8	9.8	11.3%	7.3%	10.2%
EVK2000		25.8	17.6	10.7	7.1	12.0	8.6	14.1%	8.3%	11.7%
Modelled Mortality										
Population	*LC*	29.7	20.2	11.9	8.3	13.1	9.2	12.1%	7.6%	10.8%
	CBD	29.8	20.0	11.9	8.2	13.0	9.2	12.1%	7.7%	10.9%
	P-Spline	31.0	21.0	12.3	8.6	13.5	9.4	11.7%	7.4%	10.6%
	CMI	31.8	21.6	12.6	8.7	13.6	9.6	11.5%	7.4%	10.4%
Adjusted										
ERM 2000: 1993	*LC*	33.8	23.7	14.8	9.3	14.6	10.8	10.7%	6.9%	9.3%
	CBD	34.1	23.9	14.9	9.3	14.5	10.7	10.7%	6.9%	9.3%
	P-Spline	35.0	24.6	15.1	9.6	14.9	10.9	10.4%	6.7%	9.1%
	CMI	36.1	25.4	15.7	9.7	15.0	11.1	10.3%	6.6%	9.0%
BVG 2010: 2007	*LC*	30.8	20.7	12.3	8.6	13.4	9.5	11.6%	7.5%	10.6%
	CBD	31.0	20.8	12.4	8.6	13.4	9.5	11.6%	7.5%	10.5%
	P-Spline	32.1	21.5	12.6	8.9	13.7	9.6	11.2%	7.3%	10.4%
	CMI	32.8	22.1	13.0	9.0	13.9	9.8	11.1%	7.2%	10.2%
VZ2010:2012*	*LC*	31.7	21.4	12.8	8.9	13.7	9.7	11.3%	7.3%	10.3%
	CBD	32.0	21.6	12.9	8.9	13.7	9.8	11.3%	7.3%	10.2%
	P-Spline	33.0	22.2	13.1	9.2	14.0	9.9	10.9%	7.1%	10.1%
	CMI	33.9	22.9	13.6	9.3	14.2	10.1	10.8%	7.7%	9.9%
EVK2000: 1996	*LC*	30.9	21.2	12.8	8.6	13.6	9.8	11.6%	7.4%	10.2%
	CBD	31.0	21.2	12.8	8.6	13.5	9.7	11.6%	7.4%	10.3%
	P-Spline	32.1	22.1	13.2	8.9	13.9	10.0	11.2%	7.2%	10.0%
	CMI	32.8	22.5	13.5	9.0	14.0	10.1	11.1%	7.1%	9.9%

Source: Author's calculations.
* Figures are for 2012

Table 5.41. **Swiss females**

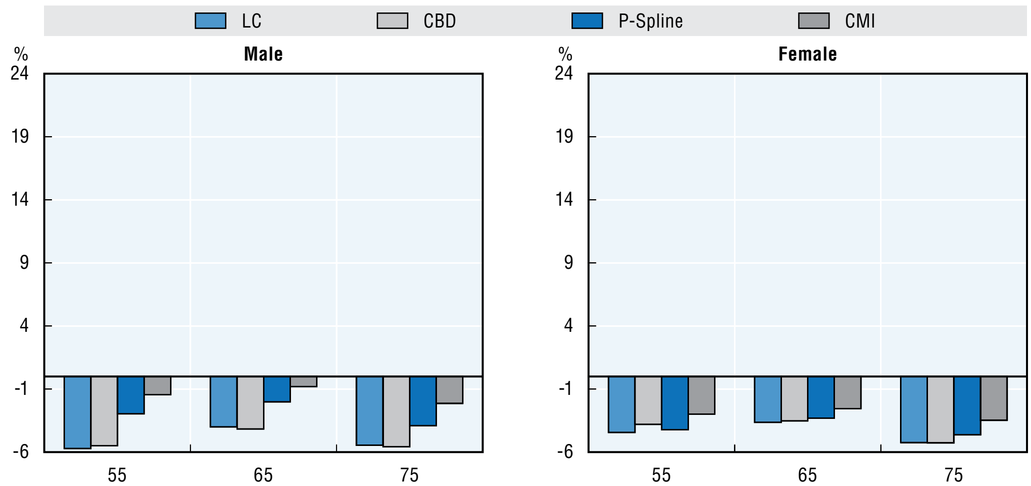
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
ERF 2000		38.9	28.1	17.8	10.5	16.2	12.3	9.5%	6.2%	8.1%
BVG2010		33.8	23.5	14.3	9.4	14.5	10.5	10.7%	6.9%	9.5%
VZ2010 - Nolfi*		35.1	24.5	15.1	9.7	14.9	11.0	10.3%	6.7%	9.1%
VZ2010 - Methonnex*		35.2	24.6	15.2	9.7	14.9	11.0	10.3%	6.7%	9.1%
EVK2000		28.7	20.4	12.9	8.0	13.3	9.8	12.5%	7.5%	10.2%
Modelled Mortality										
Population	*LC*	34.0	23.9	14.5	9.4	14.7	10.7	10.6%	6.8%	9.3%
	CBD	34.3	23.7	14.4	9.4	14.5	10.5	10.6%	6.9%	9.5%
	P-Spline	34.1	24.0	14.7	9.4	14.7	10.8	10.6%	6.8%	9.3%
	CMI	34.8	24.4	14.9	9.5	14.8	10.9	10.5%	6.8%	9.2%
Adjusted										
ERF 2000: 1993	*LC*	36.6	26.2	16.4	10.1	15.6	11.7	9.9%	6.4%	8.6%
	CBD	37.2	26.5	16.5	10.1	15.6	11.7	9.9%	6.4%	8.6%
	P-Spline	36.8	26.5	16.5	10.1	15.6	11.7	9.9%	6.4%	8.5%
	CMI	37.8	27.1	17.0	10.2	15.7	11.9	9.8%	6.4%	8.4%
BVG 2010: 2007	*LC*	34.2	23.6	14.3	9.5	14.6	10.6	10.6%	6.9%	9.5%
	CBD	34.5	23.8	14.4	9.5	14.6	10.6	10.5%	6.9%	9.5%
	P-Spline	34.4	23.8	14.4	9.5	14.6	10.6	10.5%	6.8%	9.4%
	CMI	35.1	24.2	14.7	9.6	14.7	10.7	10.4%	6.8%	9.3%
VZ2010:2012*	*LC*	35.5	24.7	15.1	9.8	15.0	11.0	10.2%	6.7%	9.1%
	CBD	35.9	25.0	15.3	9.8	15.0	11.1	10.2%	6.7%	9.0%
	P-Spline	35.7	24.9	15.3	9.8	15.0	11.1	10.2%	6.7%	9.0%
	CMI	36.6	25.4	15.7	10.0	15.1	11.2	10.0%	6.6%	8.9%
EVK2000: 1996	*LC*	33.7	24.0	15.0	9.3	14.7	11.0	10.8%	6.8%	9.1%
	CBD	34.1	24.0	15.0	9.3	14.6	10.9	10.7%	6.8%	9.1%
	P-Spline	33.7	24.0	15.1	9.2	14.6	11.0	10.8%	6.8%	9.1%
	CMI	34.3	24.4	15.4	9.3	14.7	11.1	10.7%	6.8%	9.0%

Source: Author's calculations.
* Figures are for 2012

Change in liability value

The graphs below show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. The results of all models converge reasonably well. The standard table for annuity providers (ERM/F 2000, Figure 5.43) seems quite conservative, resulting in even a possible overprovisioning for longevity. The generational tables for pensioners (BVG 2010 and VZ 2010, Figures 5.44, 5.45 and 5.46) seem to sufficiently account for future improvements in mortality overall, with little expected shortfall in provisions. The older static tables (EVK 2000, Figure 5.47) which do not account for future improvements, however, result in a significant shortfall in funding of 12-15%.

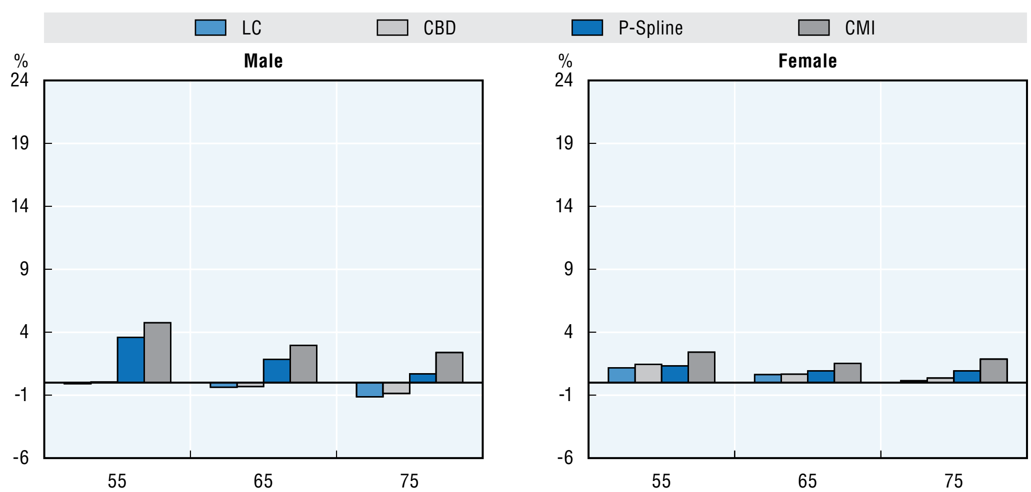
Figure 5.43. **Potential shortfall from ERM/F 2000 table for annuitants in Switzerland**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153369

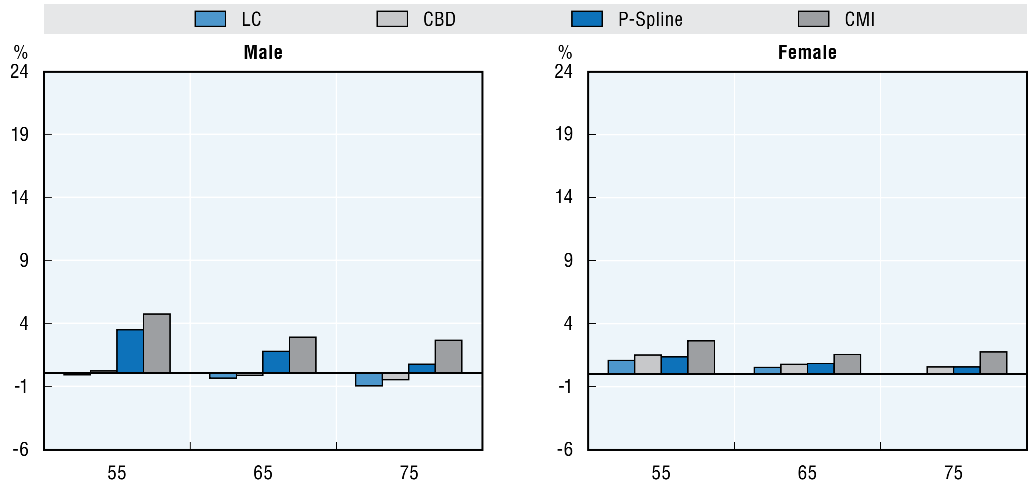
Figure 5.44. **Potential shortfall from BVG 2010 table for pensioners in Switzerland**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153370

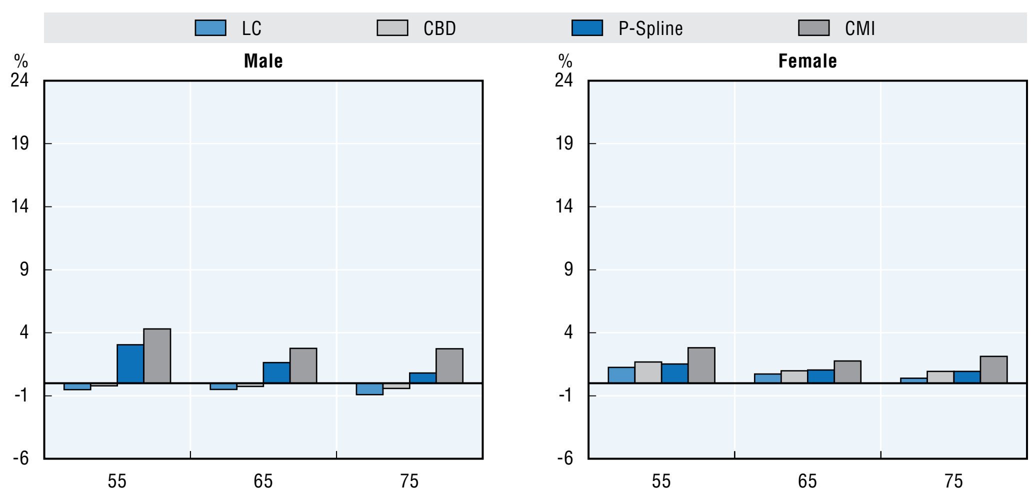
Figure 5.45. **Potential shortfall from VZ 2010 table with Menthonnex improvements for pensioners in Switzerland**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153385

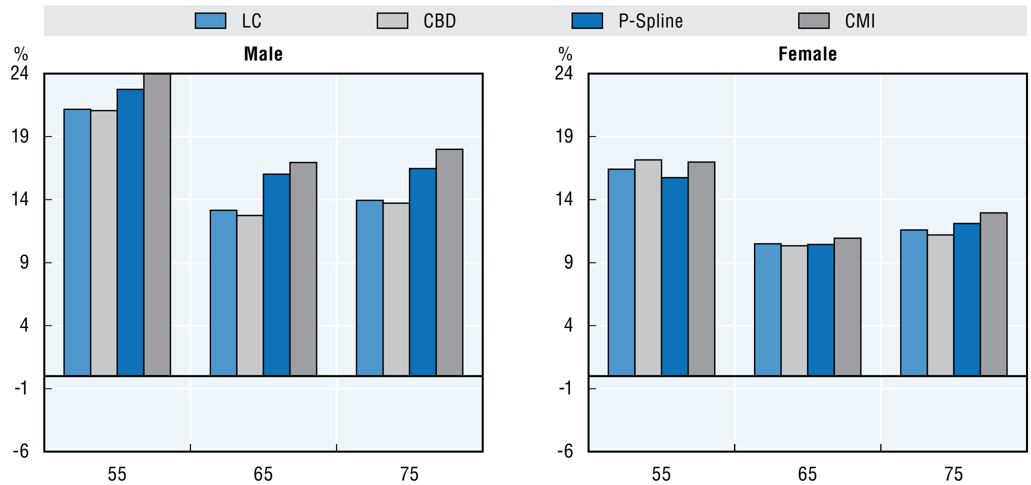
Figure 5.46. **Potential shortfall from VZ 2010 table with Nolfi improvements for pensioners in Switzerland**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153392

Figure 5.47. **Potential shortfall from EVK2000 table for pensioners in Switzerland**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153407

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, with the gender gap decreasing over the last decade. The standard table referenced by annuity providers appears rather conservative compared to experience and the estimations of the projection models.

The newer generational tables used by pension funds incorporating mortality improvements significantly reduces the exposure to a potential shortfall compared to using static tables which do not account for future development in mortality. These newer tables represent a solid benchmark for funds to refer to in adjusting the tables for their own use, as is the common practice in Switzerland.

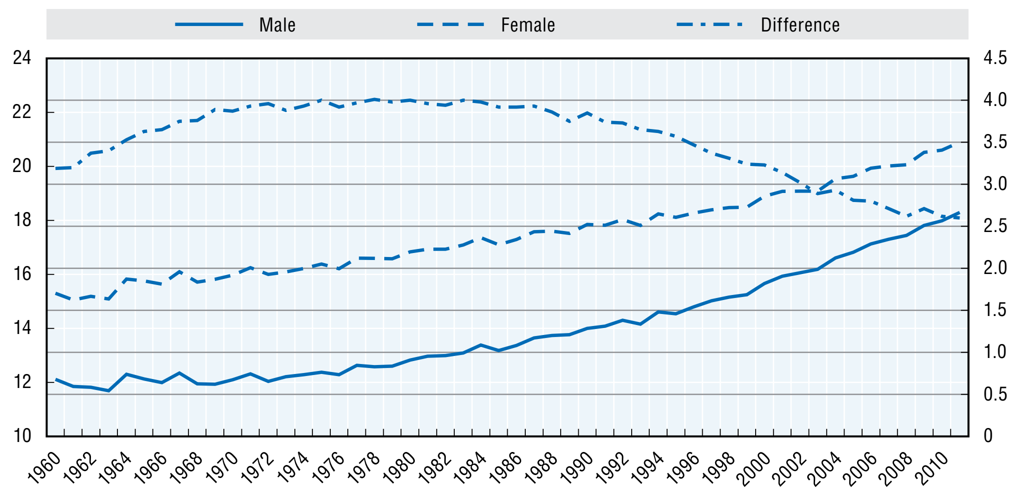
United Kingdom

The assessment for the United Kingdom relied on UK HMD data from 1960 to 2011.

Historical life expectancy at age 65

Figure 5.48 below shows the evolution in period life expectancy at age 65 for males and females. The life expectancy for males seems to have been increasing at an accelerating rate since 1960, while the growth for females appears to have been increasing at a steadier rate, though has picked up in more recent years. This has resulted in a convergence in life expectancy for 65 year old males and females since around 1990, with the difference (shown on the right axis) peaking at around 4 years and decreasing to about 2.5 years currently.

Figure 5.48. **Life expectancy at age 65 in the United Kingdom**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153413

Historical and future mortality improvements

Table 5.42 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it becomes clear in looking at the historical improvements (HMD) that higher improvements have been shifting to the older age groups for both genders, with improvements for males being overall higher than those for females.

Assumptions commonly used by the industry continue these high improvements over the next decade, though at a somewhat lower rate than recently observed, before converging to the long term improvement rate as indicated.[6] The stochastic models project higher rates at ages under around 65 and lower rates at the older ages than those assumed by the industry tables, which likely is an outcome of the fact that these models do not account for the cohort effect which has been observed in the United Kingdom population. The P-spline seems to project forward the high improvements experienced in the last decade, reflecting the model's sensitivity to the most recent data, whereas the CMI model continues higher improvements over the next decade, moving towards a lower rate in the 2020s. The results of the CMI model tend to be somewhat more conservative than those assumed by the industry despite the fact that these latter assumptions are based on the

CMI model. This is likely a result of the fact that the CMI projection used for this study is based on more recently updated data. A long term improvement of 1.6% has been assumed for the CMI model for the United Kingdom.

Table 5.42. **Evolution of annual mortality improvements in the United Kingdom***

	HMD		PCMA2000-CMI -> 1.75%		SAPS1-CMI -> 1.5%		LC		CBD		PS		CMI	
Males	1990-2000	2000-2010	2011-2021	2021-2031	2011-2021	2021-2031	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.7%	2.1%	1.6%	1.1%	1.5%	0.9%	2.4%	2.1%	2.2%	2.0%	2.3%	2.3%	2.1%	1.7%
60-64	3.1%	3.0%	1.7%	1.2%	1.6%	0.9%	2.5%	2.1%	2.1%	1.9%	2.9%	2.9%	2.5%	1.8%
65-69	3.2%	3.3%	1.9%	1.5%	1.8%	1.3%	2.4%	2.1%	2.0%	1.8%	3.3%	3.4%	2.9%	2.0%
70-74	2.4%	3.7%	2.5%	1.4%	2.3%	1.2%	2.2%	1.9%	1.9%	1.7%	3.7%	3.7%	3.1%	2.1%
75-79	2.1%	3.4%	2.6%	1.6%	2.4%	1.3%	1.9%	1.6%	1.8%	1.6%	3.7%	3.7%	3.3%	2.2%
80-84	1.6%	2.8%	2.7%	1.8%	2.6%	1.6%	1.5%	1.3%	1.6%	1.4%	3.2%	3.3%	3.1%	2.3%
85-89	1.0%	2.1%	2.4%	1.8%	2.2%	1.6%	1.2%	1.0%	1.5%	1.3%	2.5%	2.6%	2.5%	2.2%
90-94	0.5%	1.4%	1.6%	1.8%	1.4%	1.5%	0.8%	0.7%	1.3%	1.1%	1.9%	1.9%	1.9%	1.8%
95-99	0.1%	0.8%	1.4%	1.4%	1.2%	1.2%	0.4%	0.4%	1.1%	0.9%	1.0%	1.1%	1.2%	1.3%
100-104	-0.1%	0.4%	1.0%	1.0%	0.9%	0.9%	0.2%	0.2%	0.8%	0.7%	0.3%	0.4%	0.9%	1.0%
105-110	-0.2%	0.1%	0.7%	0.8%	0.6%	0.6%	0.0%	0.0%	0.6%	0.5%	-0.1%	-0.1%	0.6%	0.7%
	HMD		PCFA2000-CMI -> 1.75%		SAPS1-CMI -> 1.5%		LC		CBD		PS		CMI	
Females	1990-2000	2000-2010	2011-2021	2021-2031	2011-2021	2021-2031	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.2%	1.8%	1.7%	1.1%	1.8%	1.3%	1.8%	1.6%	1.9%	1.8%	1.8%	1.8%	1.8%	1.7%
60-64	2.9%	2.3%	1.7%	1.3%	1.8%	1.5%	1.8%	1.5%	1.8%	1.7%	2.3%	2.3%	2.2%	1.8%
65-69	2.5%	2.7%	1.8%	1.4%	1.9%	1.6%	1.9%	1.6%	1.8%	1.6%	2.8%	2.8%	2.5%	2.0%
70-74	1.6%	3.0%	2.1%	1.3%	2.3%	1.5%	1.9%	1.6%	1.7%	1.5%	3.2%	3.1%	2.8%	2.1%
75-79	1.3%	2.7%	2.3%	1.3%	2.4%	1.6%	1.9%	1.6%	1.6%	1.4%	3.2%	3.2%	2.9%	2.2%
80-84	1.1%	2.0%	2.4%	1.4%	2.5%	1.6%	1.7%	1.4%	1.5%	1.3%	2.7%	2.8%	2.6%	2.2%
85-89	0.7%	1.6%	1.8%	1.4%	2.0%	1.6%	1.4%	1.1%	1.4%	1.2%	2.2%	2.2%	2.2%	2.0%
90-94	0.4%	1.1%	1.2%	1.3%	1.4%	1.5%	0.9%	0.8%	1.3%	1.1%	1.7%	1.7%	1.7%	1.7%
95-99	0.1%	0.6%	1.0%	1.0%	1.1%	1.2%	0.5%	0.5%	1.1%	0.9%	1.1%	1.1%	1.2%	1.2%
100-104	0.0%	0.3%	0.7%	0.7%	0.9%	0.9%	0.3%	0.2%	0.9%	0.7%	0.5%	0.5%	0.9%	1.0%
105-110	-0.1%	0.1%	0.5%	0.5%	0.6%	0.6%	0.1%	0.1%	0.7%	0.5%	-0.1%	-0.1%	0.6%	0.7%

Source: Author's calculations.
**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153695

Life expectancy and annuity values[7]

Tables 5.43 and 5.44 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

The figures given for each of the projection models applied are shown for the population as well as adjusted to the different initial mortality rates for the standard tables.

The SAPS2 mortality table is an update to the SAPS1 table. This new table indicates that female pensioner life expectancy has not increased quite as much as expected, while male life expectancy has somewhat surpassed expectations except at the older ages.

Table 5.43. **United Kingdom males**

Mortality tables		Life Expectancy 2012			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
PCMA 2000 (1.75% long term improvement)		33.8	24.1	14.7	9.2	14.5	10.6	10.9%	6.9%	9.4%
SAPS1-S1PMA (1.5% long term improvement)		32.5	22.8	13.9	8.9	14.1	10.2	11.3%	7.1%	9.8%
SAPS2-S2PMA (1.5% long term improvement)		33.0	23.0	13.8	9.0	14.2	10.2	11.1%	7.0%	9.8%
Modelled Mortality										
Population	*LC*	29.2	19.6	11.6	8.1	12.9	9.0	12.4%	7.8%	11.1%
	CBD	29.3	19.7	11.9	8.0	12.8	9.1	12.5%	7.8%	11.0%
	P-Spline	32.4	21.8	12.7	8.8	13.6	9.6	11.4%	7.3%	10.4%
	CMI	31.1	21.3	12.7	8.5	13.5	9.6	11.8%	7.4%	10.4%
Adjusted										
PCMA/PCFA 2000: 2000	*LC*	31.9	22.1	13.2	8.9	13.9	9.9	11.3%	7.2%	10.1%
	CBD	32.5	22.6	13.8	8.9	14.0	10.1	11.2%	7.1%	9.9%
	P-Spline	35.2	24.5	14.6	9.5	14.7	10.6	10.5%	6.8%	9.4%
	CMI	34.2	24.1	14.6	9.3	14.6	10.6	10.8%	6.9%	9.5%
SAPS1: 2003	*LC*	31.2	21.3	12.7	8.7	13.6	9.6	11.5%	7.3%	10.4%
	CBD	31.8	21.8	13.2	8.7	13.7	9.9	11.5%	7.3%	10.1%
	P-Spline	34.3	23.5	13.8	9.3	14.4	10.2	10.7%	7.0%	9.8%
	CMI	33.2	23.0	13.8	9.1	14.2	10.2	11.0%	7.0%	9.8%
SAPS2: 2007	*LC*	31.4	21.5	12.8	8.7	13.7	9.7	11.5%	7.3%	10.3%
	CBD	31.8	21.8	13.1	8.8	13.8	9.9	11.4%	7.3%	10.1%
	P-Spline	34.5	23.6	13.9	9.4	14.4	10.3	10.6%	6.9%	9.7%
	CMI	33.5	23.2	13.9	9.1	14.3	10.3	10.9%	7.0%	9.7%

Source: Author's calculations

Table 5.44. **United Kingdom females**

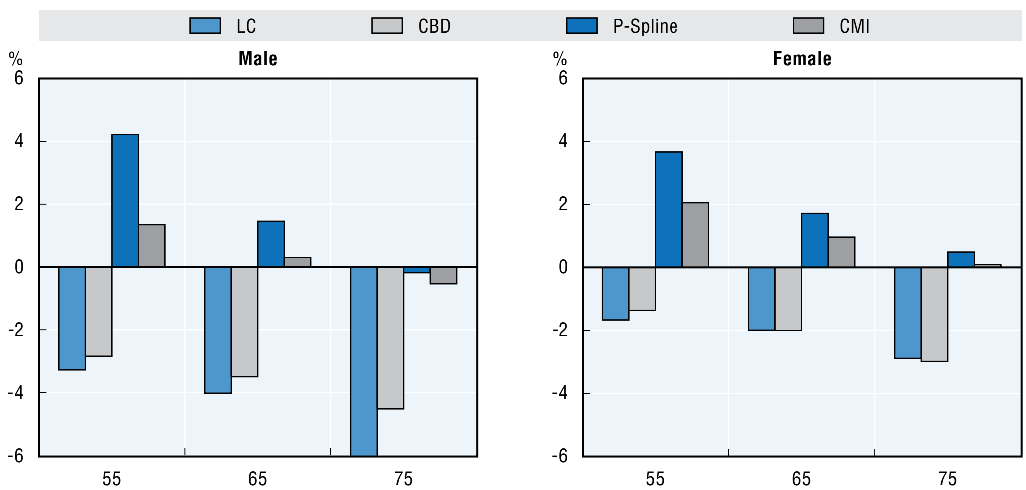
Mortality tables		Life Expectancy 2012			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
PCFA 2000 (1.25% long term improvement)		35.1	25.2	15.8	9.6	15.0	11.2	10.5%	6.7%	8.9%
SAPS1-S1PMA (1.5% long term improvement)		34.8	24.9	15.6	9.4	14.9	11.1	10.6%	6.7%	9.0%
SAPS2-S2PFA (1.5% long term improvement)		34.8	24.7	15.2	9.5	14.8	11.0	10.6%	6.7%	9.1%
Modelled Mortality										
Population	*LC*	32.1	22.4	13.8	8.8	14.0	10.2	11.3%	7.1%	9.8%
	CBD	32.2	22.3	13.7	8.8	13.9	10.1	11.3%	7.2%	9.9%
	P-Spline	34.5	24.0	14.5	9.4	14.5	10.6	10.7%	6.9%	9.5%
	CMI	33.9	23.7	14.5	9.2	14.4	10.5	10.9%	6.9%	9.5%
Adjusted										
PCMA/PCFA 2000: 2000	*LC*	34.2	24.2	15.1	9.4	14.7	10.9	10.6%	6.8%	9.2%
	CBD	34.5	24.4	15.2	9.4	14.7	10.9	10.6%	6.8%	9.2%
	P-Spline	36.7	25.9	15.9	9.9	15.3	11.3	10.1%	6.5%	8.9%
	CMI	36.1	25.7	15.9	9.8	15.2	11.2	10.2%	6.6%	8.9%
SAPS1: 2003	*LC*	33.6	23.8	14.8	9.2	14.6	10.8	10.8%	6.9%	9.3%
	CBD	33.9	24.0	15.0	9.3	14.6	10.8	10.8%	6.9%	9.2%
	P-Spline	35.7	25.2	15.4	9.7	15.0	11.1	10.3%	6.7%	9.0%
	CMI	35.4	25.3	15.7	9.6	15.0	11.2	10.4%	6.7%	9.0%
SAPS2: 2007	*LC*	33.4	23.6	14.6	9.2	14.5	10.7	10.9%	6.9%	9.4%
	CBD	33.6	23.7	14.7	9.2	14.5	10.7	10.9%	6.9%	9.4%
	P-Spline	35.7	25.1	15.3	9.7	15.0	11.0	10.3%	6.7%	9.1%
	CMI	35.2	24.9	15.3	9.5	14.9	11.0	10.5%	6.7%	9.1%

Source: Author's calculations.

Change in liability value

The graphs in Figure 5.49, 5.50 and 5.51 below show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. The results of the P-spline give the most conservative results for both genders, which is logical given the observation above that the model projects forward continuously the very high improvements of the last decade. The stochastic models consistently demonstrate an overprovisioning for longevity, one reason likely being that they do not account for the higher improvements of the 'golden cohort' in the United Kingdom. The results of the updated CMI model remain very similar to what is assumed in the industry tables which are based on the same type of model. Overall the results for males are more dispersed than those for females, where the variation of actual provision to expected provisions is quite close.

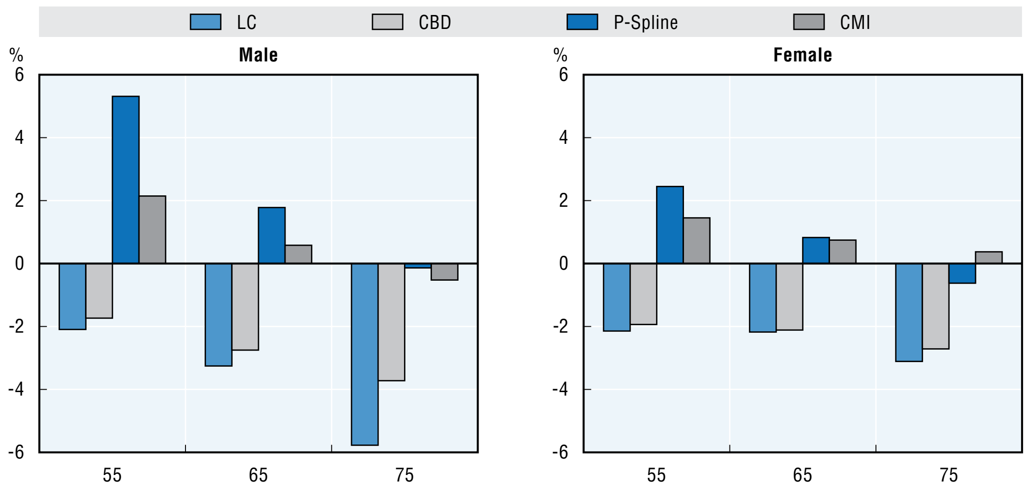
Figure 5.49. **Potential shortfall from the PCM/FA tables for annuitants in the United Kingdom, assuming a 1.75% long term improvement for males and 1.25% for females**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153426

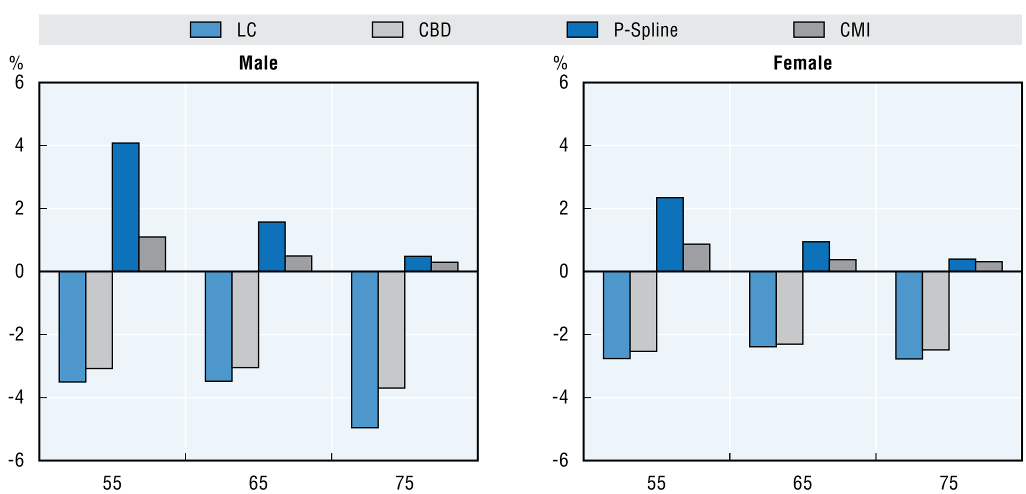
Figure 5.50. **Potential shortfall from the SAPS1 tables for pensioners in the United Kingdom assuming a 1.5% long term improvement**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153435

Figure 5.51. **Potential shortfall from the SAPS2 tables for pensioners in the United Kingdom assuming a 1.5% long term improvement**



Source: Author's calculations.

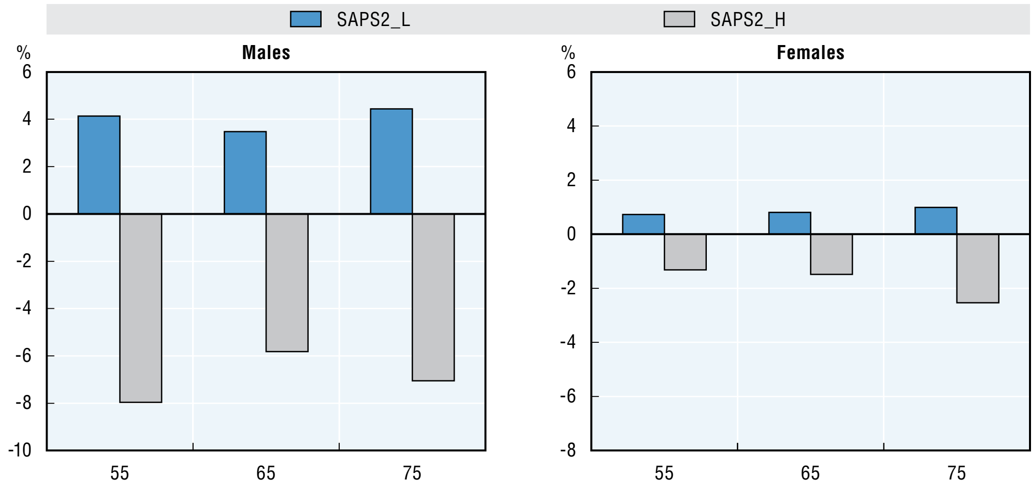
StatLink http://dx.doi.org/10.1787/888933153449

Given the results shown here the mortality assumptions assumed for both annuitants and pensioners seem to be adequate.

Impact of socio-economic variables

As part of the study to develop the SAPS tables for all pensioners, the CMI also produces tables varying by income level. The graphs in Figure 5.52 below show the change in liabilities due to the different mortality level of pensioners with high income (SAPS2_L) and low income (SAPS2_H) relative to the total pensioner population. High income is defined as an annual income greater than 14,750 for males and 5,500 for females, and low income is less than 1,700 for males and 850 for females.

Figure 5.52. **Impact of high (SAPS2_L) and low (SAPS2_H) income on liability value in the United Kingdom**



Source: Author's calculations based on (CMI, 2014)

StatLink http://dx.doi.org/10.1787/888933153457

The influence of income on mortality is more evident for males than females, with high income pensioners potentially increasing necessary provisions by up to nearly 5%, whereas the impact for females is only around 1%. Low income pensioners suffer even greater in terms of higher mortality, however, decreasing the liability value by over 7% for males and 2% for females.

Main conclusions

Life expectancy at age 65 for males and females has been increasing steadily over the last several decades, though the two genders have been converging since the 1990s. Looking at the pattern of mortality improvements in the 1990s and 2000s, high mortality improvements seem to be shifting to higher ages, which would not be well captured by the stochastic models which lack a parameter to capture this cohort effect. As a result these models tend to indicate an overprovisioning for longevity. As the United Kingdom bases their mortality improvement projections on the CMI model, these results are very much in line with the results of the CMI model here, with differences likely coming from the length of historical data used in the calibration as well as differences in the long term improvement assumption.

The United Kingdom has been at the forefront of developing models and studies to understand the trends in longevity, and the results of this study confirm that the provisioning for expected future improvements in mortality in the United Kingdom does indeed seem to be adequate. Tables are also regularly updated by the CMI, which can be taken as good practice in the provisioning of pension and annuity liabilities.

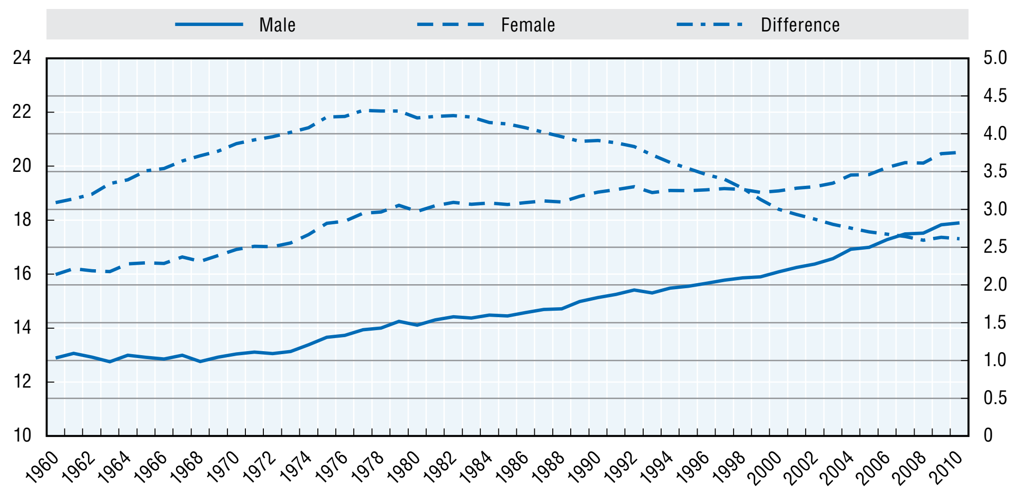
United States

The assessment for the United States relied on HMD data from 1960 to 2010.

Historical life expectancy at age 65

Figure 5.53 below shows the evolution in period life expectancy at age 65 for males and females. The number of years 65 year old males can expect to live has been increasing rather steadily from 1970, whereas the trend slowed somewhat for females in the 1980s and 90s. This slowdown resulted in a convergence of life expectancies for males and females, with the difference (shown on the right axis) peaking at just over 4 years around 1980, decreasing to around 2.5 years recently. This convergence, however, seems be stabilizing somewhat in recent years.

Figure 5.53. **Life expectancy at age 65 in the United States**



Source: Human Mortality Database.

StatLink http://dx.doi.org/10.1787/888933153468

Historical and future mortality improvements

Table 5.45 shows the annualized improvement to mortality rates for age groups of five years and demonstrates the progression of these improvements across ages from one decade to the next. From the left, it becomes clear in looking at the historical improvements (HMD) that higher improvements have been shifting to the older age groups for both genders, with a more marked acceleration for women across all age groups shown from the 1990s to 2000s. The Scale AA improvements, which are most commonly used in practice, and the Scale BB improvements which have been updated based on more recent data, seem to not sufficiently reflect the fact that mortality improvements have been increasing. Scale AA in particular seems to be underestimating experienced improvements for women. The MP2014 scale, however, reflects the recent higher improvements while assuming a convergence to a lower long term average. The outputs from the Lee-Carter (LC) and Cairns-Blake-Dowd (CBD) models seem to be largely in line with the updated Scale BB improvements. The P-spline seems to project forward the high improvements experienced in the last decade, reflecting the model's sensitivity to the most recent data, whereas the CMI model continues somewhat higher improvements over the next decade, moving towards a lower rate in the 2020s. A long term improvement of 1.25% has been assumed for the CMI model for the United States.

Table 5.45. **Evolution of annual mortality improvements in the United States***

Males	HMD		ScaleAA		ScaleBB		Scale MP2014		LC		CBD		PS		CMI	
Age Range	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	2.0%	0.8%	1.7%	1.7%	0.4%	0.4%	1.0%	1.0%	1.7%	1.7%	1.6%	1.6%	0.9%	0.9%	0.8%	1.2%
60-64	2.1%	1.9%	1.5%	1.5%	0.9%	0.9%	1.0%	1.1%	1.7%	1.7%	1.5%	1.5%	1.8%	1.7%	1.1%	1.0%
65-69	1.9%	2.3%	1.4%	1.4%	1.4%	1.4%	1.4%	1.0%	1.6%	1.6%	1.4%	1.4%	2.4%	2.4%	1.5%	0.9%
70-74	1.6%	2.6%	1.5%	1.5%	1.5%	1.5%	1.9%	1.0%	1.5%	1.5%	1.3%	1.3%	2.7%	2.7%	1.9%	1.0%
75-79	1.4%	2.3%	1.3%	1.3%	1.5%	1.5%	2.1%	1.1%	1.3%	1.3%	1.2%	1.2%	2.8%	2.9%	2.1%	1.2%
80-84	0.9%	2.4%	0.8%	0.8%	1.5%	1.5%	2.1%	1.1%	1.0%	1.0%	1.0%	1.0%	2.8%	2.8%	2.1%	1.4%
85-89	0.0%	2.2%	0.6%	0.6%	1.4%	1.4%	2.0%	1.1%	0.7%	0.7%	0.9%	0.9%	2.5%	2.5%	1.9%	1.5%
90-94	-0.5%	1.4%	0.3%	0.3%	0.9%	0.9%	1.8%	1.0%	0.3%	0.3%	0.7%	0.7%	1.8%	1.9%	1.5%	1.3%
95-99	-0.9%	1.1%	0.2%	0.2%	0.4%	0.4%	1.4%	0.8%	0.0%	0.0%	0.6%	0.6%	0.8%	0.9%	1.0%	1.0%
100-104	-1.1%	0.7%	0.0%	0.0%	0.2%	0.2%	1.0%	0.6%	-0.1%	-0.1%	0.4%	0.4%	0.0%	0.0%	0.7%	0.7%
105-110	-0.7%	0.3%	0.0%	0.0%	0.0%	0.0%	0.6%	0.4%	-0.2%	-0.2%	0.3%	0.3%	-0.4%	-0.4%	0.5%	0.5%
Females	HMD		ScaleAA		ScaleBB		Scale MP2014		LC		CBD		PS		CMI	
Age Range	1990-2000	2000-2010	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030	2010-2020	2020-2030
55-59	1.1%	1.5%	0.6%	0.6%	0.7%	0.7%	0.9%	1.0%	1.2%	1.2%	1.5%	1.5%	1.4%	1.4%	0.7%	1.1%
60-64	0.9%	2.2%	0.5%	0.5%	1.1%	1.1%	1.5%	1.0%	1.1%	1.1%	1.4%	1.4%	2.1%	2.1%	1.1%	0.9%
65-69	0.6%	2.1%	0.5%	0.5%	1.2%	1.2%	1.9%	1.1%	1.1%	1.1%	1.3%	1.3%	2.2%	2.2%	1.5%	0.9%
70-74	0.5%	2.0%	0.6%	0.6%	1.2%	1.2%	2.0%	1.1%	1.2%	1.2%	1.2%	1.2%	2.1%	2.2%	1.8%	1.2%
75-79	0.2%	1.7%	0.7%	0.7%	1.2%	1.2%	2.0%	1.1%	1.3%	1.3%	1.1%	1.1%	2.2%	2.2%	1.8%	1.5%
80-84	0.0%	1.9%	0.7%	0.7%	1.2%	1.2%	2.0%	1.1%	1.2%	1.2%	1.0%	1.0%	2.3%	2.3%	1.7%	1.5%
85-89	-0.4%	1.7%	0.4%	0.4%	1.2%	1.2%	2.1%	1.1%	1.0%	1.0%	0.9%	0.9%	2.3%	2.3%	1.6%	1.4%
90-94	-0.8%	1.3%	0.3%	0.3%	0.9%	0.9%	2.0%	1.0%	0.6%	0.6%	0.8%	0.8%	1.8%	1.9%	1.3%	1.2%
95-99	-1.0%	0.9%	0.1%	0.1%	0.4%	0.4%	1.6%	0.8%	0.3%	0.3%	0.7%	0.7%	1.0%	1.1%	1.0%	1.0%
100-104	-1.0%	0.6%	0.0%	0.0%	0.2%	0.2%	1.2%	0.6%	0.1%	0.1%	0.5%	0.5%	0.2%	0.2%	0.7%	0.7%
105-110	-0.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.7%	0.4%	0.0%	0.0%	0.4%	0.4%	-0.4%	-0.4%	0.5%	0.5%

Source: Author's calculations.

**Statlinks file shows a coloured heat map of the improvements shown in the table*

StatLink http://dx.doi.org/10.1787/888933153700

Life expectancy and annuity values

Tables 5.46 and 5.47 below show the values for the cohort life expectancy, the annuity value based on a 4.5% nominal discount rate, and the annuity payment as a per cent of the initial investment (net of margins and fees).

The figures given for each of the projection models are shown for the general population as well as adjusted to the different initial mortality levels for the standard mortality tables.

It can be noted that even though the IRS Static table intends to capture the impact of future mortality improvements, it falls well short of the other generational tables as well as the projection models. The updated RP2014 table and MP2014 scale result in a significant upward revision of life expectancy for pensioners. However, as a basis for the projection models, the new table results in slightly lower life expectancies likely due to the higher proportion of blue collar workers used to establish the base mortality of the RP2014 compared to the RP2000.

Table 5.46. **United States males**

Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
GAM-94 Generational		29.4	20.1	12.3	8.1	13.0	9.4	12.3%	7.7%	10.6%
RP 2000 Generational Scale AA		29.1	19.2	11.4	8.1	12.8	8.9	12.3%	7.8%	11.2%
IRS Static		28.2	18.9	11.4	7.9	12.7	9.0	12.7%	7.9%	11.1%
RP 2000 Generational Scale BB		30.1	20.1	12.1	8.3	13.0	9.3	12.0%	7.7%	10.8%
RP 2014-MP 2014		30.9	21.2	13.2	8.5	13.4	9.8	11.8%	7.4%	10.2%
Modelled Mortality										
Population	*LC*	27.4	18.6	11.3	7.5	12.4	8.9	13.2%	8.0%	11.3%
	CBD	27.4	18.6	11.5	7.4	12.3	8.9	13.4%	8.1%	11.3%
	P-Spline	30.3	20.8	12.5	8.2	13.2	9.5	12.2%	7.6%	10.6%
	CMI	28.4	19.8	12.2	7.7	12.8	9.3	13.0%	7.8%	10.8%
Adjusted										
GAM-94: UP94 *1988*	*LC*	29.7	20.2	12.2	8.3	13.1	9.4	12.1%	7.6%	10.7%
	CBD	30.0	20.4	12.6	8.2	13.1	9.5	12.2%	7.6%	10.5%
	P-Spline	32.7	22.3	13.4	8.9	13.9	10.0	11.2%	7.2%	10.0%
	CMI	30.8	21.4	13.0	8.4	13.5	9.8	11.8%	7.4%	10.2%
RP 2000 / IRS: *1992*	*LC*	30.1	20.0	11.9	8.4	13.1	9.2	11.9%	7.6%	10.8%
	CBD	30.2	20.2	12.2	8.4	13.1	9.3	11.9%	7.6%	10.7%
	P-Spline	33.4	22.4	13.3	9.1	13.9	9.9	10.9%	7.2%	10.1%
	CMI	31.6	21.5	13.0	8.7	13.6	9.8	11.5%	7.3%	10.2%
RP 2014: *2006*	*LC*	29.8	20.0	12.1	8.3	13.0	9.3	12.1%	7.7%	10.7%
	CBD	30.1	20.2	12.4	8.3	13.1	9.5	12.0%	7.6%	10.6%
	P-Spline	33.0	22.2	13.4	9.0	13.8	10.0	11.1%	7.3%	10.0%
	CMI	31.1	21.3	13.0	8.5	13.5	9.8	11.7%	7.4%	10.2%

Source: Author's calculations.

Table 5.47. **United States females**

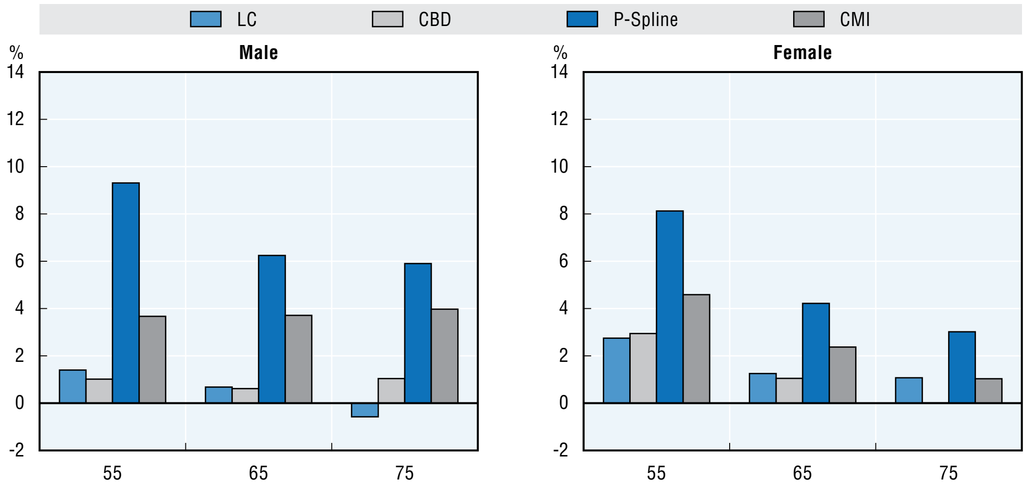
Mortality tables		Life Expectancy 2010			Annuity factors			Annuity payment		
		55	65	75	55	65	75	55	65	75
GAM-94 Generational		31.9	22.5	14.4	8.8	14.0	10.6	11.4%	7.1%	9.5%
RP 2000 Generational Scale AA		30.7	21.1	13.4	8.5	13.5	10.0	11.8%	7.4%	10.0%
IRS Static		30.0	20.8	13.4	8.3	13.4	10.0	12.0%	7.5%	10.0%
RP 2000 Generational Scale BB		32.4	22.4	14.2	8.9	13.9	10.4	11.3%	7.2%	9.7%
RP 2014-MP 2014		33.6	23.4	14.9	9.2	14.3	10.7	10.9%	7.0%	9.3%
Modelled Mortality										
Population	*LC*	30.8	21.6	13.7	8.4	13.6	10.1	11.9%	7.3%	9.9%
	CBD	30.8	21.3	13.4	8.4	13.5	9.9	11.9%	7.4%	10.1%
	P-Spline	33.2	23.1	14.3	9.0	14.1	10.5	11.2%	7.1%	9.6%
	CMI	31.7	22.3	13.9	8.6	13.9	10.2	11.6%	7.2%	9.8%
Adjusted										
GAM-94: UP94 *1988*	*LC*	32.9	23.1	14.6	9.0	14.2	10.7	11.1%	7.0%	9.4%
	CBD	33.0	23.0	14.5	9.1	14.2	10.6	11.0%	7.0%	9.5%
	P-Spline	35.0	24.3	15.1	9.5	14.6	10.9	10.5%	6.8%	9.2%
	CMI	33.7	23.5	14.7	9.2	14.4	10.7	10.9%	7.0%	9.4%
RP 2000 / IRS: *1992*	*LC*	32.5	22.5	14.2	8.9	14.0	10.4	11.2%	7.2%	9.6%
	CBD	32.5	22.4	14.0	8.9	13.9	10.3	11.2%	7.2%	9.7%
	P-Spline	35.1	24.2	15.1	9.5	14.5	10.8	10.5%	6.9%	9.3%
	CMI	33.8	23.5	14.7	9.2	14.3	10.6	10.9%	7.0%	9.4%
RP 2014: *2006*	*LC*	32.5	22.3	14.1	9.0	13.9	10.4	11.2%	7.2%	9.6%
	CBD	32.6	22.3	14.1	9.0	13.9	10.4	11.2%	7.2%	9.6%
	P-Spline	34.9	23.9	14.9	9.5	14.4	10.8	10.6%	6.9%	9.3%
	CMI	33.5	23.1	14.5	9.1	14.1	10.5	10.9%	7.1%	9.5%

Source: Author's calculations.

Change in liability value

The graphs below show the change in liability value based on the annuity values for the standard mortality tables and the adjusted model outputs presented in the section above. The results of the P-spline model tend to be outliers for both genders, which is logical given the observation above that the model projects forward continuously the very high improvements of the last decade. The table used for annuitants has a potential shortfall of around 1-3% (GAM94, Figure 5.54). The older tables used for pensioners demonstrate a larger expected shortfall of around 4-5% (IRS and RP2000 Scale AA, Figures 5.55 and 5.56). However the more recently updated interim improvements of Scale BB shown in Figure 5.57 significantly reduces the potential shortfall and bring the liabilities more in line with what could be expected based on the projection models. Using the new RP2014 table and MP-2014 scale shown in Figure 5.58 corrects the shortfall in the older tables coming from the use of lower improvement assumptions and results in little to no residual risk.[8]

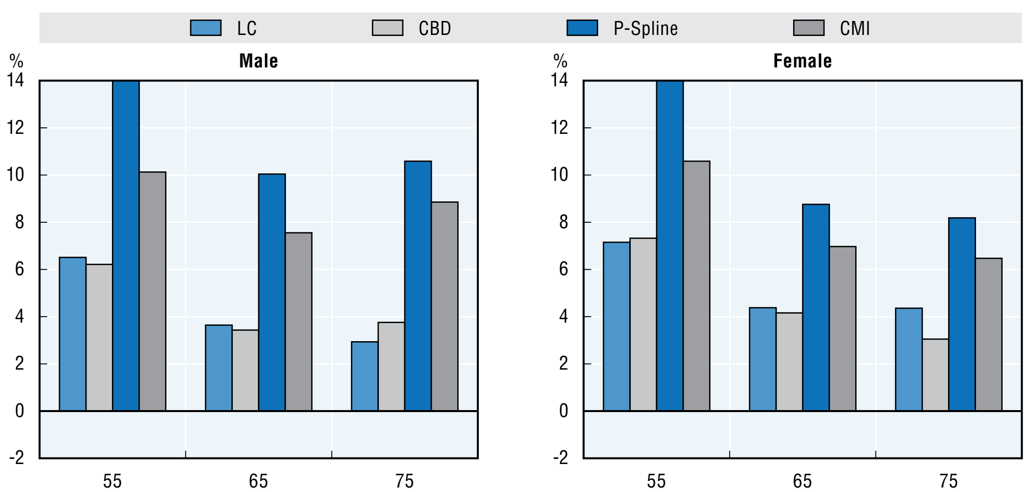
Figure 5.54. **Potential shortfall of GAM 94 with Scale AA improvements for annuitants in the United States**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153477

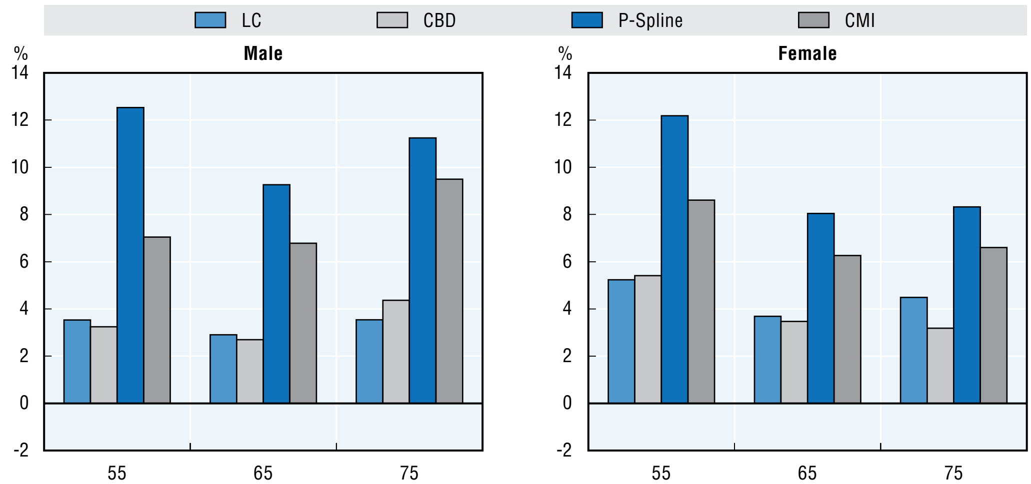
Figure 5.55. **Potential shortfall of the IRS static table for pensioners in the United States**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153481

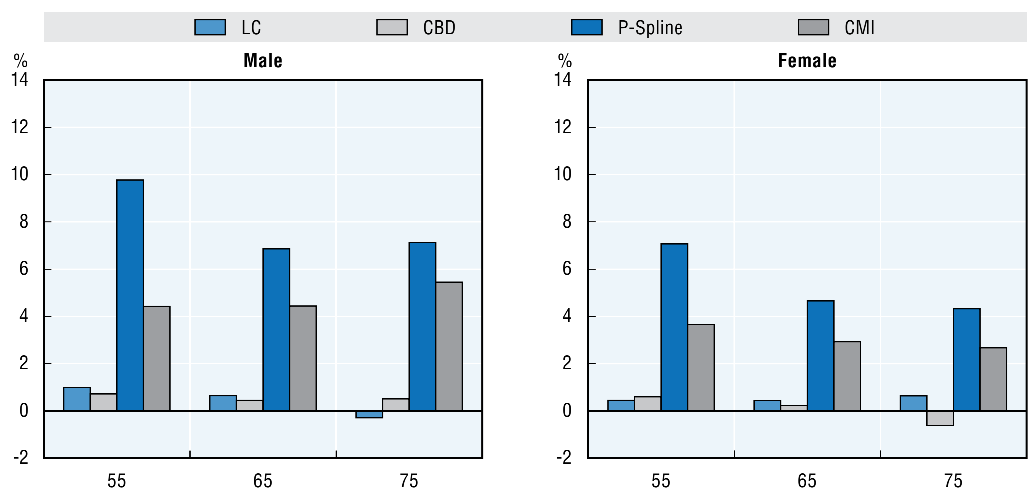
Figure 5.56. **Potential shortfall of the RP2000 table with Scale AA improvements for pensioners in the United States**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153491

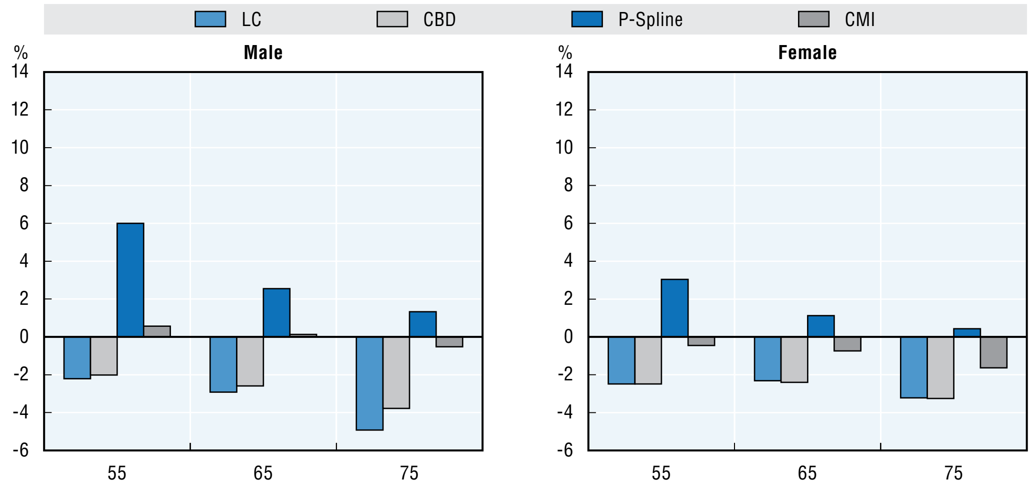
Figure 5.57. **Potential shortfall of the RP2000 table with Scale BB improvements for pensioners in the United States**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153506

Figure 5.58. **Potential shortfall of the RP2014 table and MP-2014 scale for pensioners in the United States**



Source: Author's calculations.

StatLink http://dx.doi.org/10.1787/888933153513

Impact of socio-economic variables

As part of the development of the RP2014 tables for pensioners, the impact on mortality of the type of employment (blue collar vs. white collar) and income level were found to be significant. Figure 5.59 shows the increase of liabilities due to both of these variables relative to the RP2014 generational table. For males, the sub-population of white collar workers represent an increase of around 5% of liabilities relative to the total population of pensioners. The impact of salary level is much more significant, however, with those having a salary in the top quartile increasing liabilities by 6-9% due to their lower mortality, all else equal.

Figure 5.59. **Impact of socio-economic variables on liabilities for United States pensioners**

Source: Author's calculations. based on (SOA, 2014)

StatLink http://dx.doi.org/10.1787/888933153525

While the difference is still significant, females seem to be overall less impacted by these socio-economic variables, with those in white collar positions or having salaries in the top quartile both representing a similar increase of liabilities of 2-4%.

Main conclusions

Life expectancy at age 65 for males has been increasing steadily over the last few decades, reducing the gap in life expectancy relative to females, though this difference seems to be stabilizing somewhat in recent years. Mortality improvements for both genders have accelerated in the past decade compared to the 1990s. The projection models overall are in line with historical improvements, though the P-spline model appears to be overly sensitive to the very high improvements of the past decade, resulting in rather elevated projections of life expectancy.

Comparing model outputs to calculations based on assumed tables, a shortfall of provisioning for longevity seems likely in most cases, especially for the regulatory static table (IRS). The most recent update of the pensioner table (RP2014), however, seems to correct for the shortfall predicted from the older table. Given the significance of the difference in mortality for white collar and higher income pensioners, attention should be paid to the socio-economic profile of the population for which the standard tables are being used, and adjustments to the level of mortality considered accordingly.

Notes

1. Figures are shown for age groups of five years, ages 55-110. It should be noted, however, that limited data is available at the very high ages and the improvements at these ages for the historical data are heavily dependent on the methodology used to extrapolate the mortality to these ages.
2. All annuities are calculated assuming a discount rate of 4.5%, and annuity values for age 55 are assumed to begin payments at age 65.
3. Analysis of the subset of Chilean annuitant data implied a slightly higher margin for the mortality table for females which could also be considered in the assessment of the potential shortfall, but this level of margin was not confirmed.
4. Only the DAV2004 R table used by annuity providers is assessed in this note as the assumptions for the Heubeck 2005 G used by pensions plans are not available.
5. Figures as of 2012 for the VZ 2010
6. Note that the CMI improvements shown here are only illustrative of what is used in practice.
7. Figures are shown as of 2012.
8. This analysis was performed on the draft version of the RP2014 and relies on the assumption that the current level of mortality was accurately assessed and reflects that the mortality improvement assumptions embedded in the table are in line with future expectations; concerns have been raised regarding the appropriateness of the methodology used to set the base assumptions, but this has not been taken into account here.

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Mortality Assumptions and Longevity Risk
Implications for Pension Funds and Annuity Providers

Chapter 6

Policy options for managing longevity risk

This chapter discusses how pension funds and annuity providers can manage longevity risk and how the regulatory framework can support this effort. Regulators should enable and encourage the management of longevity risk as they have an interest to ensure that pension funds and annuity providers will be able to meet future payment obligations to retirees.

The first step in managing longevity risk is to ensure that pension funds use appropriate and up to date mortality tables that incorporate expected future improvements in mortality and life expectancy and are based on the relevant populations. For the unexpected future improvements in mortality and life expectancy, regulators may want to facilitate capital market solutions to hedge or mitigate this risk using standardised index based longevity hedges that would promote transparent and liquid secondary markets. Governments could also provide a reliable longevity index and mortality projections. Finally governments could assist by establishing capital and funding requirements as well as accounting standards that ensure appropriate valuations and reflect the risks faced.

This chapter discusses how pension funds and annuity providers can manage longevity risk and how the regulatory framework can support this effort.[1] Previous chapters showed that if the assumptions on mortality improvements embedded in the mortality tables commonly used for the valuation of pension and annuity liabilities are not adequate, pension funds and annuity providers face an increased likelihood that they will not be able to meet future payment obligations.

Therefore, the first consideration in managing longevity risk is to ensure that mortality assumptions used account for the expected improvements in mortality and life expectancy. Moreover, mortality tables should also be based on relevant mortality experience and be regularly updated based on this experience.

Secondly, once pension funds and annuity providers have ensured the adequacy of their mortality assumptions and have aligned them with current expectations about future mortality improvements, they then need to address the potential financial impact of unexpected increases in longevity beyond the current expectations and determine if and how to mitigate this risk.[2] The financial impact of these unexpected improvements in mortality can also be quite significant, and pension funds and annuity providers must then decide how much of this risk they are willing or able to bear. The risk beyond their capacity must be transferred or mitigated in some manner. The regulatory framework should encourage the recognition of this risk as well as enable the effectiveness and availability of mechanisms for reducing longevity risk exposure in order to encourage the management of longevity risk and ensure the sustainability of pension funds and annuity providers.

Therefore, the regulation needs to ensure that longevity risk is recognised and provide a framework that encourages and facilitates the active management of the risk. This should be done based around two main objectives. The first objective is to ensure that pension plans and annuity providers have addressed the costs of aligning with the current expectations of life expectancy by using mortality assumptions which are based on relevant and recent mortality data and account for the future expected trend in mortality. Secondly, incentives for the management of this risk also need to be put in place, with regulation encouraging and facilitating the measurement and mitigation of longevity risk coming from the uncertainty around these assumptions. The latter objective, however, is not possible unless the first objective is met. Longevity risk will not be able to be accurately measured or appropriately managed unless the mortality assumptions are in line with reasonable expectations. The mortality assumptions used must therefore be the first focus of policymakers.

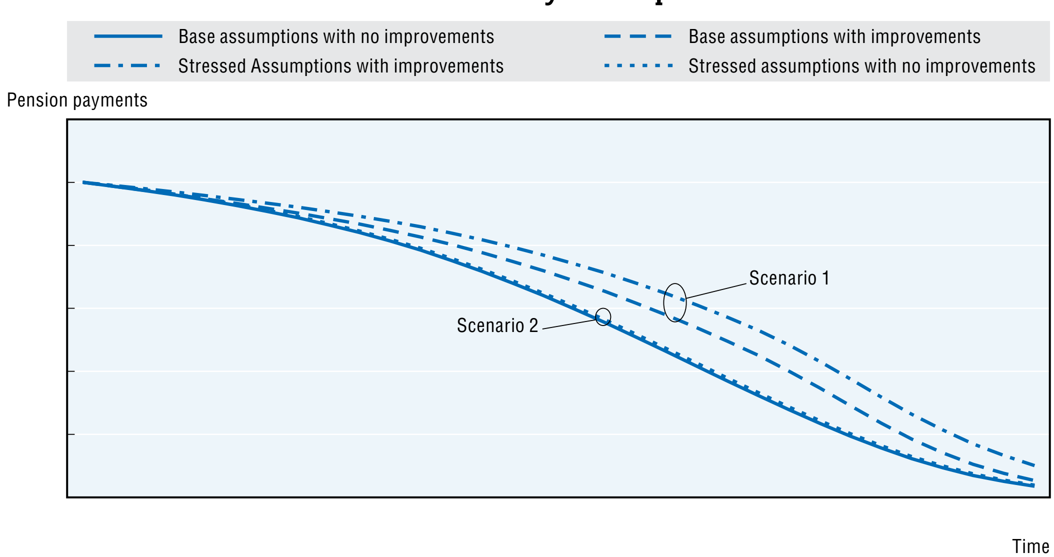
Establish mortality tables which adequately reflect current and future expectations of mortality

Mortality tables used for the valuation of pension and annuity liabilities should reflect reasonable expectations with respect to current and future mortality. The importance of starting with reasonable mortality assumptions can be illustrated with a simple example. Imagine a pension fund that has up-to-date mortality assumptions that account for the expected improvement in mortality wants to assess the financial impact of overestimating its mortality assumptions by 25%. This overestimation would mean a realised life expectancy higher than provisioned for and an increase in the amount of future pension payments to be made. The expected pension payments and the increase in these payments due to an overestimation in mortality are shown for Scenario 1 in the figure below, which clearly demonstrates the significant financial impact this longevity risk could have.

Now imagine that the pension fund's starting mortality assumptions fail to include mortality improvements. As demonstrated in the previous section of the document, not accounting for future improvements has a significant impact on the present value of expected payments and can result in an underestimation of these liabilities by over 10%. However, Scenario 2 shows that not only are the expected future pension payments underestimated, but the estimated financial impact of overestimating these assumptions by 25% is unrealistic compared to the actual financial impact shown by the difference between the two lines in Scenario 1.

The use of unreasonable mortality assumptions therefore not only increases the probability that future payments are not properly reserved for, but also that the fund is underestimating its exposure to longevity risk and will not take appropriate actions to manage this risk. The fund in Scenario 2 is not likely to deem its exposure to longevity risk significant enough to consider mitigation, when in reality its actual exposure to longevity

Figure 6.1. **Illustration of expected pension payments using different mortality assumptions**



risk is much greater than the fund in Scenario 1. Furthermore, even if it did want to hedge its risk, any solution to do so with a third party is likely to be more expensive than the pension fund is willing or able to pay, as the price to hedge the longevity would be based on the assumptions accounting for mortality improvements in Scenario 1.

This example illustrates the importance of setting reasonable mortality assumptions in order to avoid a significant shortfall in provisions for future pension payments as well as to have the ability to make appropriate decisions regarding the management of the risk. The regulatory framework therefore needs to set the standards for assumption setting in order to subsequently further the goal of the recognition and the active management of longevity risk.

In order to accomplish this goal, there should be clear guidelines regarding the data used as the basis for mortality assumptions. Moreover, assumptions in mortality tables should include expected mortality improvements.

As a starting point, assumptions should be based on mortality data of the country in which they are used. Figures 3.1 and 3.2 in Chapter 3 demonstrated that life expectancy and the evolution of mortality can vary significantly from one country to the next. Mortality assumptions for pensioners and annuitants based on one country's population cannot be assumed to accurately reflect the mortality in another country. This difference stems not only from the social and economic environment in a given country, but also the structure of the pension system itself, which would be reflected in the magnitude of the differences in mortality for the subpopulations of pensioners and annuitants compared to the general population. This is because the proportion of the population covered by private pensions and whether or not the system is mandatory is related to the level of anti-selection experienced, in other words the extent to which individuals with lower mortality and higher life expectancy choose to insure their own longevity. This anti-selection will be larger where private pensions represent a small proportion of retirement income and where this type of longevity protection is voluntary, as the individuals most likely to elect this type of coverage tend to be of a higher socio-economic status than the general population. Income and socio-economic status are correlated with having a higher life expectancy, resulting in a gap between the mortality of the general population and that of the pensioners and annuitants.

With that said, ideally the initial mortality assumptions should be based not only on the mortality experience of the country in question, but also of the subpopulation of pensioners and annuitants themselves, where available, or adjusted to reflect the characteristics of the particular population for which the tables are being used. These adjustments could reflect, for example, the expected mortality of the specific industry in which the pensioners are employed or the socio-economic characteristics of the individuals insured.

Expected improvements in mortality must also be taken into account. The highest assessed shortfall in provisions is for tables which do not account for these improvements. Figures 3.1 and 3.2 in Chapter 3 showed that future mortality improvements are expected to add at least two years to life expectancy on average, with each additional year of life expectancy not provisioned for translating to an expected shortfall in reserves of 3-5%.[3]

Finally, mortality tables should also be regularly updated and based on the most recent experience to ensure that assumptions accurately represent the current mortality level and monitor whether or not experience has been in line with expectations. Encouraging frequent review will also help to avoid significant one-off increases in reserves driven by the update of assumptions as these changes in expectations could be implemented more gradually.

To facilitate the assessment of mortality assumptions, policymakers should also ensure that accurate and timely mortality data are publically available. National statistical institutes should regularly publish population estimations and death statistics so that the mortality of the general population may be assessed. This data should be as granular as possible – by individual age and gender at a minimum – in order to provide a benchmark or basis for mortality assumptions. Data including socio-economic indicators could also be quite useful to assess the general differences in mortality within the same country. Having readily available data allows for academic studies regarding mortality patterns and trends which could lead to a better understanding overall of the potential future evolution of mortality and its drivers. The data and studies can furthermore be used to inform the setting of mortality assumptions by providing a credible basis for model inputs and measuring mortality improvements. The data should be released in a timely manner, as a significant time-lag results in more uncertainty around the current assumptions.

To go even further, cooperation with industry bodies to organise the collection of mortality data from pension plans and insurance companies could allow for the assessment of the mortality for these specific populations. This could lead to the development of more appropriate mortality assumptions for these sub-populations, particularly for smaller plans or portfolios which do not have sufficient experience of their own on which to base assumptions. However this initiative can be costly to organise in the private sector, and as there is a clear benefit that this type of data is made available, the organization of the data collection in the public sector may be more efficient.

Assess the potential impact of unexpected improvements in life expectancy

The risk of having insufficiently provisioned for future improvements in mortality and life expectancy stems from having unreasonable starting mortality assumptions and from the uncertainty surrounding future improvements. The discussion above highlighted the importance of establishing reasonable mortality assumptions for the valuation of and provisioning for future pension and annuity payments.

Once adequate mortality assumptions have been established which reasonably reflect recent mortality experience and the expectations regarding its future improvement, the remaining longevity risk coming from the unexpected increases in life expectancy can be assessed. While the central mortality assumptions can reasonably be estimated using deterministic models, stochastic models are typically more useful for the assessment of the unexpected longevity risk as they are capable of providing probability distributions around the expected value of future mortality rates. Such distributions allow pension funds and annuity providers to quantify the likelihood that their current provisions could be insufficient and what the financial impact of that shortfall could be.

Two stochastic models, the Lee-Carter (LC) model and the Cairn-Blake-Dowd (CBD) model, were implemented in this study for the quantification of the potential shortfall in provisions due inadequate mortality assumptions. These two models can also be used here to demonstrate the potential impact of the additional longevity risk to which pension funds and annuity providers are exposed coming from unexpected improvements in future mortality.

Table 6.1 below shows the financial impact of unexpected improvements in life expectancy at the 95% confidence level as a percentage of liabilities for each age and gender for several countries based on these two stochastic models. This level of confidence means that there should be only a 5% chance that future mortality experience will result in a financial loss greater than the figures given in the table. Therefore, if a pension fund or annuity provider wants to be 95% sure to be able to meet its future payment obligations, it should have this additional amount of funds, or capital, available to cover the excess longevity risk. These figures are based on the population mortality for each country as an illustration of the potential impact. Adjusting the figures to be based on a lower level of mortality, for example to the mortality of a specific insured population, would slightly reduce the magnitude of the results.

The results of this risk assessment are quite dependent on the model being used. We can observe that the Cairns-Blake-Dowd model generally results in a larger estimation of

Table 6.1. **Financial impact of unexpected improvements in life expectancy at the 95% level of confidence as a percentage of pension liabilities**[1]

		Male		Female	
Country	Age	LC	CBD	LC	CBD
Canada	55	2.3%	3.4%	2.3%	2.7%
	65	1.4%	2.2%	1.6%	2.0%
	75	1.4%	2.6%	1.9%	2.5%
Chile	55	6.8%	8.2%	5.4%	6.3%
	65	4.7%	5.2%	4.1%	4.7%
	75	6.1%	5.5%	5.0%	6.2%
France	55	5.3%	6.9%	4.0%	4.9%
	65	3.3%	4.3%	3.1%	3.7%
	75	3.4%	4.8%	3.7%	4.7%
Germany	55	4.3%	6.0%	3.4%	4.3%
	65	2.6%	3.6%	2.4%	3.0%
	75	2.3%	3.8%	2.5%	3.5%
Israel	55	4.7%	5.6%	3.4%	4.5%
	65	3.1%	3.9%	2.5%	3.4%
	75	3.2%	4.6%	2.8%	4.5%
Japan	55	5.1%	6.6%	3.2%	4.0%
	65	3.6%	4.6%	2.7%	3.3%
	75	4.2%	5.5%	3.6%	4.4%
Netherlands	55	4.1%	6.9%	3.9%	4.5%
	65	2.4%	4.4%	2.9%	3.2%
	75	2.0%	5.1%	3.4%	4.1%
Spain	55	7.2%	8.7%	3.7%	5.1%
	65	4.8%	5.7%	2.8%	4.0%
	75	5.2%	6.7%	3.4%	5.3%
Switzerland	55	3.7%	5.5%	3.3%	4.6%
	65	2.3%	3.6%	2.4%	3.4%
	75	2.2%	4.0%	2.7%	4.2%
UK	55	4.6%	6.9%	4.6%	5.4%
	65	3.0%	4.7%	3.3%	3.9%
	75	3.1%	5.5%	3.8%	4.9%
US	55	3.0%	4.0%	3.3%	3.5%
	65	1.7%	2.4%	2.1%	2.4%
	75	1.5%	2.6%	2.4%	2.7%

Source: OECD Calculations

Notes: 1. The table shows the percentage increase in liabilities that can be expected at the 95% confidence level. These calculations are based on 1 000 simulations of future mortality using the two stochastic mortality projection models (Lee-Carter and Cairns-Blake-Dowd), and assuming a discount rate of 4.5% to calculate the annuity value. The calculation for age 55 is based on a deferred annuity commencing payments age 65; calculations for ages 65 and 75 are calculated as commencing immediately.

StatLink http://dx.doi.org/10.1787/888933153712

longevity risk than the Lee-Carter model. This is driven by the tendency of the Lee-Carter model to produce narrower confidence intervals, and has been mentioned as a disadvantage for the use of this model for risk assessment in Chapter 4. Nevertheless, considering the results of the two models here provides a reference for the potential magnitude of the longevity risk coming from unexpected improvements in life expectancy.

Assessing longevity risk using probability distributions from stochastic models provides a way to quantify the risk at a given confidence level. The results from this type of analysis can provide a basis for the pension fund or annuity provider to make a decision regarding its ability to retain the risk or the need to mitigate the risk. This will ultimately be affected by capital constraints – i.e. are there sufficient assets to meet future payment obligations if longevity experience turns out to be at the 95th percentile of what we expect today – or internal risk appetite limits, for example the decision of management to limit the possible losses from changes in longevity experience to a certain amount.

The potential role that regulation can play in encouraging the management of longevity risk

Policymakers can ensure that the regulatory framework encourages the pension or annuity provider not only to assess and evaluate longevity risk, but also facilitates the availability and effectiveness of methods to hedge the excess risk if necessary. Incentives for the management of longevity risk can be addressed through capital and funding requirements as well as through accounting standards. Unless these regulatory standards consistently recognise the existence of longevity risk, pension funds and annuity providers will have little incentive to recognise and manage the risk to which they are exposed.

As such, capital and funding requirements should be reflective of and reactive to the risk profile of the liabilities in order to account for the specific exposure to longevity risk.

Risk-based requirements aim to reflect the underlying risk profile of the concerned entity and would therefore compel it to measure the longevity risk to which it is exposed. Changes to this exposure should have a direct impact on the capital required to support the pension or annuity liabilities. This would provide an incentive to assess how much risk can be retained given any protection mechanisms in place and whether to mitigate excess risk in order to achieve a target level of capitalization or funding, or at least not fall below any minimum limits imposed.

Any measure taken to reduce the exposure to longevity risk should therefore be reflected in the capital requirements. For example, any reduction in risk from business diversification or from directly hedging longevity risk should result in a reduction of the capital requirements. Otherwise the entity will not realise any benefit from the reduction of its risk, even if internal risk measures consider the risk reduction prudent or necessary.

Interactions between risks, and in particular the diversification between risks, should be recognised if such diversification of exposures can reduce the overall risk profile of the pension fund or annuity provider. For example mortality-contingent insurance business which provides payments upon death could offset some of the longevity risk from annuity liabilities, since if longevity increases significantly it could also be expected that mortality claims would decrease. While this offset is only partial due to differences in the age groups and populations covered by the two lines of business, diversification of business mix should be taken into account in assessing the risk profile and therefore the capital or funding requirements of an entity.

Capital requirements should also account for instruments purchased explicitly to hedge longevity risk such as reinsurance or a longevity swap. For example, consider the calculation of capital requirements which is based on a simple formula of a percentage of reserves. As the purchase of a longevity swap would not necessarily impact the value of reserves, it would also not impact the capital requirement. The reduction in risk achieved will therefore not be recognised by regulation and the entity will not be able to use the instrument to manage their longevity risk. Indeed, the entity would be penalised for purchasing such an instrument in the short-term compared to another entity which has not hedged its longevity risk.

Capital and funding requirements need to reflect the full potential impact of longevity risk so that these requirements are reactive to risk mitigating measures which decrease the risk of insolvency. Risk-based requirements for which an explicit charge is imposed for longevity risk and which account for risk diversification would force pension sponsors and annuity providers to address the risk and actively assess their exposure to it.

In addition to capital and funding requirements, however, accounting standards should ensure the appropriate valuation of longevity hedging instruments. If longevity hedges are not appropriately reflected in the balance sheet, pension funds and annuity providers will not be able to use these instruments to hedge their longevity risk.

For example, in some countries insurance companies are not allowed to value longevity instruments at a higher value than the purchase price. Thus, if mortality improves at a higher rate than expected and the pension fund can expect a positive return from a longevity swap, they would not be allowed to recognise this increase in the value of their assets to offset the resulting increase in liabilities. Moreover, for participating policies where annuitants are entitled to a certain part of the annuity provider's unrealised gains, the increase in fair value of the longevity swap could only be partly used to offset the increase in liabilities as a portion of the gains would be paid to the policyholders.

If instruments to hedge longevity cannot be used to offset the increase in liabilities due to decreasing mortality rates, no benefit from the reduction of risk from the hedge will be realised.

External solutions for mitigating longevity risk

The measurement of longevity risk discussed above is the key to determining whether or not the mitigation of the risk is necessary. Once the financial impact of an unexpected increase in longevity has been determined and assessed given the business mix and risk diversifications, the pension fund or annuity provider can then take an informed decision regarding its capacity to retain the longevity risk of its liabilities and its ability to continue managing it internally given the protection mechanisms in place, such as a capital buffer. If the entity is not capable or willing to fully bear this longevity risk, external solutions to mitigate the risk need to be available as an alternative solution.

There are several financial arrangements that allow pension funds and annuity providers to either transfer or hedge longevity risk. For those looking to reduce their exposure to longevity risk, the traditional solution has been to transfer the risk to insurance or reinsurance entities. Several different types of structures for this arrangement are possible. The first type is referred to as a bulk annuity, where both investment and longevity risk are transferred to the third party, 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.

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 maximise 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 derivatives

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.

A forward contract is the simplest form of a longevity derivative, and is defined as an agreement to exchange a fixed sum defined at the inception of the contract with a floating amount to be determined based on future mortality experience. These floating amounts can be based on a realised mortality rate ($q_{x,t}$) or survival rate (${}_tp_x$) and are referred to as q-forwards and s-forwards, respectively. The fixed amounts are typically based on the expected mortality or survival plus a risk premium. These contracts require no upfront funding and there is no exchange of payments until the maturity of the contract, at which time the payment is the net amount of the fixed and floating payments. With a q-forward, the party agreeing to pay the floating payment benefits if mortality is lower than expected, whereas the party with the fixed payment gains with an s-forward if longevity is higher than expected. Longevity forward contracts can be used as building blocks to construct a more complete hedge of longevity risk by combining them with different ages and durations.

As s-forwards are based on cumulative survival probabilities over *n* years, they are likely to be a better match to hedge pension and annuity liabilities compared to q-forward contracts which are based on one year probabilities of death (i.e. mortality rates) and therefore are subject to significantly more volatility.

Box 6.1. **Hypothetical examples of q-forward and s-forward contracts**

q-forward contract

Consider a 5-year q-forward contract on a population aged between 58 and 60 years at January 1 2010. The cash flows at maturity depend on the average mortality rates of the three ages in 2015, i.e. the average mortality rate of the ages between 63 and 65. The maturity date is January 1 2015 and the notional amount is 1 million. Let q(x,t) be the one-year death probability of an x-year old person in the year t. The relevant one-year death probabilities in 2010 are given in the table below:

Age	q(x,2010)
63	1.80%
64	2.00%
65	2.20%
Average	2.00%

Thus, the average one-year death probability for the given population is 2.00%. Assume that an expected decrease of the mortality rate in the population in question of 1.50% per year, i.e. the best estimate of the one-year death probability is 98.5% of the rate in the previous year. Consequently, the best estimate of q(63,2011), the one-year death probability of a person aged 63 in the year 2011, is 1.773% = 1.80% • 0.985. Therefore, the best estimate of the mortality rate of our group in 2015 is 1.85% = 2.00% • $(0.985\%)^5$.

To determine the fixed payment the forward mortality rate is needed. Assume that the risk premium is equivalent to a decrease of the mortality rate of 1.00% in addition to the expected decrease of 1.50%, equating to an overall improvement in mortality of 2.5% per year to be used for calculating the fixed rate. Therefore, the forward mortality rate of the group in 2015 is 1.76% = 2.00 • $(0.975\%)^5$. Thus, the fixed rate is 1.76% in our q-forward and the risk premium is equal to 0.09% because 1.85% – 1.76% = 0.09%.

The price of the q-forward at any time is the net value of the present values of the two expected payments, in other words the difference between the present value of the fixed payment and floating payment. At inception, the present value of both payments is the same (ignoring any bid-offer spread) and the present value of the fixed payment is calculated by:

PV = 1 000 000 • 1.76% / $(1 + 3\%)^5$ = 15 182, where we have assumed a risk-free interest rate of 3%.

The cash flows (or settlements) at each year of the contract are shown in the table below and are calculated as the difference between the realised and fixed mortality rates multiplied by the notional amount. The final payments depend on the outcome of the realised mortality rate. The pension fund or annuity provider receives payments if the realised mortality rate is below the fixed rate and makes payments otherwise.

Realised mortality rate	Fixed mortality rate	Notional	Settlement
1.56%	1.76%	1 000 000	200 000
1.66%	1.76%	1 000 000	100 000
1.76%	1.76%	1 000 000	0
1.86%	1.76%	1 000 000	- 100 000
1.96%	1.76%	1 000 000	- 200 000

Box 6.1. **Hypothetical examples of q-forward and s-forward contracts** *(cont.)*

s-forward contract

Consider next an s-forward contract with a term of three years and a notional amount of 1 million, based on males aged 65 years at inception of the contract (1 January 2011). Thus, the underlying survival rate is the three-year survival probability of a person aged 65 at inception; i.e. the probability that a person aged 65 survives three more years. Let q(x,t) be the one-year death probability of a person aged x in the year t, i.e. the probability that an x-year old person dies in the year t, and let p(x,t) be the corresponding one-year survival probability such that p(x,t) = 1 – q(x,t).

Assume an expected mortality improvement of 2% for each year and age. Thus, if the one-year death probability of a person aged 65 in the year 2010 is 1.80%, the best estimate of the one-year death probability of a person aged 65 for the year 2011 is 1.76% = 0.98 • 1.80%. The table below shows the best estimate of the one-year death probabilities. The one-year death probabilities relevant for the s-forward are in bold.

Age x	q(x,2010)	q(x,2011)	q(x,2012)	q(x,2013)
65	1.80%	**1.76%**	1.73%	1.69%
66	1.90%	1.86%	**1.82%**	1.79%
67	2.00%	1.96%	1.92%	**1.88%**

The corresponding one-year survival probabilities can be found in the next table. The three-year survival probability can be calculated as the product of these one-year survival probabilities, such that: 0.9664= 0.9824 • 0.9818 • 0.9812. Therefore, the best estimate of the three-year survival probability is 96.64%. This means that 96.64% of the given population (males aged 65 years) is expected to survive to the end of the year 2013.

Age x	p(x,2010)	p(x,2011)	p(x,2012)	p(x,2013)
65		**98.24%**		
66			**98.18%**	
67				**98.12%**

Ignoring the risk premium for simplicity, the fixed payment is based on a survival rate of 96.64%. The table below shows the net settlement of this s-forward, where the exact cash flow depends on the realised survival rate. If the realised survival rate is above the fixed one, the pension fund or annuity provider will receive the net payment.

Realised survival rate	Fixed survival rate	Notional	Settlement
96.44%	96.64%	1 000 000	- 200 000
96.64%	96.64%	1 000 000	0
96.84%	96.64%	1 000 000	200 000

Source: LLMA 2010a, 2010b

One of the more commonly used longevity derivatives is a longevity swap, which is essentially a series of forward contracts combined. 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 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 6.2 provides an example of the structure and payments for a bespoke longevity swap based on survival rates.

Box 6.2. **Hypothetical example of a longevity swap**

Consider a hypothetical example of a homogeneous pension plan with 100 000 members aged 65 years as of January 1st. 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 January 1st. 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.

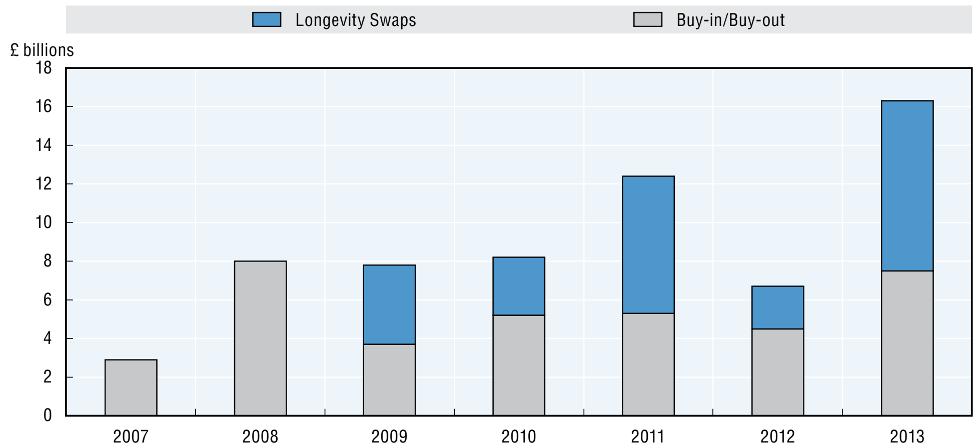
Date	Actual Pension Payment	Predefined cash flow	Payment to the pension plan
Feb. 1st	1 000 000	950 000	50 000
March 1st	950 000	930 000	20 000
April 1st	900 000	910 000	-10 000
May 1st	900 000	890 000	10 000

Longevity swaps have been increasing dramatically in popularity compared to bulk annuity structures since 2009, as shown Figure 6.2 below for the United Kingdom. The year 2013 saw swaps transactions surpassing buy-ins and buy-outs in the United Kingdom.

Longevity swap deals totalled over GBP 70 billion at the end of the third quarter of 2014, with the transactions listed in the Table 6.2 below. The vast majority have been bespoke transactions based on the actual mortality of the pensioners, though two notably large index-based transactions (Aegon with Deutche Bank and Delta Lloyd with RGA Re) have been based on Dutch population indices.

Insurers and reinsurers are capable of taking on longevity risk for bespoke transactions because this type of risk forms a core part of their business and expertise. However, they may be limited in their capacity to absorb longevity risk. While exposure to longevity risk can be partially offset by the exposure to mortality risk coming from life insurance products sold by insurers, the life insurance and annuity portfolios often cover different population

Figure 6.2. **Volume of longevity transactions in the United Kingdom**



Source: Hymans Robertson (2014)

StatLink http://dx.doi.org/10.1787/888933153532

Table 6.2. **Longevity Swap Transactions as at Q3 2014**

Organization	Date	Provider	Value (GBP bn)
Delta Lloyd	Q3 2014	RGA Re	12
Pheonix Group	Q3 2014	Pheonix Life	0.9
AXA France	Q3 2014	Hannover Re	EUR 0.75 bn
BT Pension Scheme	Q3 2014	Prudential	16
Aviva	Q1 2014	Swiss Re/Munich Re/SCOR	5
BAE Systems	Q4 2013	Legal & General	1.7
AstraZeneca	Q4 2013	Deutsche Bank/Abbey Life	2.5
Carillion	Q4 2013	Deutsche Bank/Abbey Life	1
Aegon	Q4 2013	Societe General CIB/SCOR	1.4
Bentley	Q2 2013	Deutsche Bank/Abbey Life	0.4
BAE Systems	Q1 2013	Legal & General	3.2
LV	Q4 2012	Swiss Re	0.8
Azko Nobel	Q2 2012	Swiss Re	1.4
Aegon	Q1 2012	Deutsche Bank	12
Pilkington	Q4 2011	Legal & General	1
British Airways	Q4 2011	Goldman Sachs/Rothesay Life	1.3
Rolls Royce	Q4 2011	Deutsche Bank/Abbey Life	3
ITV	Q3 2011	Credit Suisse	1.7
Pall	Q1 2011	JP Morgan	0.1
BMW	Q1 2010	Deutsche Bank/Abbey Life	3
Berkshire	Q4 2009	Swiss Re	1
RSA Insurance	Q3 2009	Goldman Sachs/Rothesay Life	1.9
Babcock	Q3 2009	Credit Suisse	1.2
Canada Life	Q3 2008	JP Morgan	0.5
Lucida	Q1 2008	JP Morgan	0.1

Source: Artemis

StatLink http://dx.doi.org/10.1787/888933155985

groups so this arrangement is not a perfect hedge and there is residual longevity exposure. Furthermore, with the trend towards risk based requirements and the increased emphasis on enterprise risk management, the capacity for the (re)insurance industry to absorb the increasing demand for longevity protection is limited. These capacity constraints therefore need to be addressed in order to ensure a supply of longevity protection sufficient to meet the demand. Given the potentially limited capacity of the insurance market to absorb longevity risk, another solution may have to be found.

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 seems to be 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. 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. 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.

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.

The main sources of basis risk stem from the structural risk coming from the structure of the instrument itself, sampling risk due to the natural volatility in mortality experience, and the demographic risk reflecting the inherent underlying differences in dynamics of mortality of the index and hedged populations (LLMA, 2012). This latter risk is typically driven primarily by geographic and socio-economic differences, which were previously demonstrated to have a significant impact on life expectancy.

Pension funds or annuity providers can reasonably manage many aspects of basis risk. Structural risk can be reduced with careful analysis and matching of the age and gender profile of the portfolio with the one the hedge references. More granular hedge references enable a better match to be achieved. This risk would further be reduced with the emergence of a more liquid market as the hedge could be adapted to the evolving demographic profile over time.

The risk stemming from underlying volatility, also referred to as idiosyncratic risk, can be mitigated by pooling underlying portfolios. This implies that basis risk in general is likely to be much larger for small pension schemes or portfolios as the mortality experience is subject to more volatility than large ones, making indexed based solutions less effective for a small group of lives where this idiosyncratic risk, or individual differences, are not sufficiently diversified as with a large pool of lives. Index-based transactions may therefore be more effective in transferring the systemic longevity risk, which comes from the overall shifts in longevity trends 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.

Demographic basis risk remains the most challenging component to mitigate and quantify, however, primarily due to the lack of data with which to assess such differences. As discussed previously, there is some evidence that insurers and pensioners not only experience lower mortality than the general population but also experience higher improvements, with these differences driven primarily by differences in socio-economic profiles. Thus if a longevity swap is indexed to the evolution in the mortality of the general population, the floating payments received may not be sufficient to cover the higher increase in longevity for the pensioners or annuitants being hedged. This component presents one of the largest obstacles to the demand for index-based longevity protection.

The development of capital market solutions for hedging longevity risk does seem to be a promising way forward in order to ensure the continued capacity for pension funds and annuity providers to mitigate the risk. However, this misalignment of incentives between those needing to hedge longevity risk and the capital markets investors who can provide additional capacity will need to be overcome. This will involve addressing the risk constraints of the capital markets investors through the use of index-based instruments, as well as facilitating the recognition and assessment of the residual basis risk for those using these instruments to hedge their risk.

Index-based instruments offer a solution to the constraints of capital markets investors in supplying longevity protection, and the further development of these instruments could be facilitated by additional standardization and transparency in the market. However, on the demand side, the measurement of the residual basis risk from using index-based longevity instruments to hedge their risk remains a challenge for pension funds and annuity providers, particularly for the risk relating to socio-economic differences. This poses a problem not only for assessing the residual longevity exposure which is retained, but also in determining the appropriate level of risk reduction which should be reflected through the capital and funding requirements. This measurement then needs to be facilitated through the increased availability of data, particularly by socio-economic groups, and clear rules communicated as to the level of capital or funding relief which can be realised from index-based longevity hedges.

As policymakers have an interest in the continued availability of longevity risk protection and alternative solutions to mitigate the risk, the additional capacity that the capital markets can offer should be acknowledged and the development of this market facilitated. This involves addressing this misalignment of incentives on both sides of the market. On the supply side, the transparency and standardization of longevity hedge instruments could be facilitated to address the constraints of capital markets investors. For pension funds and annuity providers seeking to mitigate their longevity risk, the measurement of the residual basis risk retained could also be facilitated and the recognition of it clear and consistent for capital and funding requirements.

More transparency and standardization in the pricing of longevity instruments would aid potential investors in becoming comfortable with investing in longevity risk and allow for the further development of index-based instruments. 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 (Blake et al., 2010). A longevity bond is an index-based longevity hedging instrument where the third party issuing the bond assumes longevity risk. These bonds have no principle re-payment, but pay regular coupons which are linked to a longevity index which would typically be 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 case that mortality improvements have been higher than expected.

A longevity bond would allow prices to become publicly available as a reference point for other transactions, establishing a 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 (re)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 (re)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. While some argue that the government could hedge some of its exposure to increases in systemic longevity through adjustments to the state pension (Blake et al, 2010), governments are currently proving that these types of adjustments – such as increasing retirement age or decreasing pension levels – are very slow and unpopular to implement. However if insurance companies are not able to insure the longevity risk of

Box 6.3. **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. 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:

$$S(0) = 1$$

$$S(1) = S(0) * (1 - q(65,2003))$$

$$S(2) = S(1) * (1 - q(66,2004))$$

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

Therefore, the following coupon payments would have been £50 million. S(t) with t=1,2,…,25 and the issue price of £540 million determined by the projected coupons based on survival rates, calculated by the UK Government Actuary Department, which were discounted at LIBOR minus 35 basis points.

Here a hypothetical scenario describes the coupon payment in the first three years. The table below shows a possible development of the mortality rates, where the ones 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 = 0.9795 • 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

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.

The current lack of demand for these bonds and the extent to which these instruments are effective in hedging longevity risk must also be considered, as attempts thus far to issue a longevity bond have not succeeded. Reasons for the lack of interest by pension funds and annuity providers include the significant upfront capital required and the basis risk involved, the latter of which seems to be one of the main reasons for the failure (Biffis and Blake, 2014). The bond structure is capable of providing longevity risk protection to several entities seeking to hedge their pension funds and annuity portfolios, therefore the reference index on which the coupons is based is typically more generic than the reference population which could be used for an index-based swap. As such, a longevity hedge using longevity bonds would expose the pension fund or annuity provider to arguably more structural basis risk than a longevity swap, where the reference index can be tailored more specifically to the population being hedged. Overall, a longevity swap based on survival rates can provide a better hedge for the longevity risk of pension and annuity portfolios at a much lower upfront cost.

There is some evidence that the private markets are beginning to develop products and structures to hedge longevity risk, with a handful of index-based longevity swaps having already succeeded in being transacted. Progressively innovative structures have aimed to resolve the tension between the interests of the hedging party and the investor and create standardised instruments which can be easily customised to provide attractive investments which offer effective longevity hedges which minimise basis risk for the subscriber.

The Pall Pension Fund longevity swap with J.P. Morgan in 2011 was the first public index-based swap, and the first transaction to cover the longevity risk for future pensioners, whose younger ages mean more uncertainty around future longevity experience. This was clearly a big step in demonstrating the possibility to hedge the longevity risk for a larger portion of the exposure for pension funds or insurance companies.

The index-based longevity swap transacted between Aegon and Deutche Bank in 2012 provided an excellent example of how an innovative structure can help to bridge the conflicting interests of the two counterparties, and was the first transaction directly targeting capital market investors. To limit the duration of risk exposure for the investors, payments will only be exchanged for twenty years. However a lump sum will be paid at the end of the contract reflecting the evolution in mortality up to that point, effectively covering the risk of deviations from the current expected mortality beyond that point. This structure allows Aegon to partially hedge the long tail of their liabilities while restricting the time horizon on which the investor is exposed to the risk. Furthermore payments to cover the longevity risk would only be triggered when longevity would exceed a pre-specified reduction in mortality set beyond current expectations. This reduced the cost of the swap for Aegon as it was not priced 'at the money' and provided an effective source of capital relief for the tail longevity risk.

The year 2013 saw an additional push towards the standardization and transparency of these types of transactions with the development of products meant to be highly customisable. Deutche Bank launched its Longevity Experience Option, a product with specified attachment and detachment points for specified cohorts over a ten year duration for which pricing is publically available. Aegon completed a second index-based longevity transaction, this time with Société Générale, with the longevity risk being passed on to reinsurers. More recently, Delta Lloyd conducted a large six-year longevity swap with RGA Re based on a Dutch population index, allowing the insurer to manage its economic capital position (Artemis, 2014).

This evolution in the structures being used to hedge longevity risk indicate a strong potential for index-based instruments to be used more widely to achieve an effective reduction in longevity risk for pension funds and annuity providers while attracting a wide investor base in the capital markets. Perhaps, then, all that is needed is an additional nudge towards the more rapid development of the market by taking smaller steps to facilitate the standardization and transparency of these instruments.

A regular and reliable publication of a longevity index could further this standardisation 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.

Finally, to further the aim of transparency, regulation could consider bringing in standardised swaps traded on the capital markets into exchanges or electronic trading platforms, where appropriate, to be centrally cleared (consistent with the FSB's OTC derivative reform agenda) so as to limit the opaqueness of these over-the-counter (OTC) transactions and keep tabs on the accumulation of longevity risk in the capital markets.

Concluding remarks

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 in both cases. The improvement in mortality and life expectancy is a phenomenon globally observed and cannot be ignored when setting mortality assumptions for the future. Pension funds and annuity providers must actively assess and monitor mortality experience, keeping assumptions up-to-date and recognizing the risk to which they are exposed.

The analysis included in this publication has shown that failure to account for future improvements in mortality can result in an expected 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 provider to the need for a significant increase in reserves.

Beyond ensuring that mortality assumptions used for the valuation of pension and annuity liabilities reflect reasonable expectations, regulatory frameworks should also encourage pension funds and annuity providers to recognise and assess the risk to which they are exposed through capital and funding rules. Funding and capital requirements along with accounting standards should reflect any actions taken to mitigate longevity risk, which would provide incentives for the active management of this risk.

Effective options for pension funds and insurers to mitigate longevity risk, when necessary, should also be available. With the potentially limited capacity for insurers and reinsurers to accept this risk, capital market solutions seem to be a promising alternative option for hedging the risk that pension plans and annuity providers are not willing or able to retain via a capital buffer. However several issues need to be addressed to facilitate both the supply and demand of index based longevity hedging instruments which could be traded on the capital markets. Investors have a need for standardisation and transparency with respect to the pricing of the instruments, and additional benchmarks may be necessary to facilitate this.

Demand for protection against longevity risk will only increase as individuals are expected to live longer, and the sustainability of pension funds and annuities 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 the risk and mitigate it if needed will allow continued protection to be offered in the future.

To summarise, the main policy options discussed are[4]:

- The regulatory framework should ensure that pension funds and annuity providers use appropriate mortality tables to account and provision for expected future improvements by establishing clear guidelines for the development of mortality tables used for reserving for annuity and pension liabilities.
  - Mortality tables should include the expected future improvements in mortality.
  - Mortality tables should be regularly updated to accurately reflect the most recent experience and avoid significant increases in reserves.
  - Mortality tables should be based on the mortality experience of the relevant population.
- Governments should facilitate the measurement of mortality for the purposes of assumption setting and the evaluation of basis risk of index-based hedging instruments.
  - Accurate and timely mortality data should be publicly available.
  - Mortality data by a socio-economic indicator should be made publically available.
- The regulatory framework should provide incentives for the active management of longevity risk.
  - Capital and funding requirements should be reflective of the risks faced in order to account for the specific exposure to longevity risk and allow institutions mitigating their longevity risk to adjust their requirements accordingly. These requirements could be based on results from stochastic models which provide probability distributions.
  - Accounting standards should ensure the appropriate valuation of longevity hedging instruments.
- Governments could encourage the development of a market for alternative instruments to hedge longevity in order to ensure a complementary solution for pension funds and annuity providers to mitigate the risk they are not able or willing to retain. This could be accomplished by facilitating transparency and standardization of index-based longevity hedges.
  - A reliable longevity index could be developed to provide price reference and encourage liquidity and standardization.
  - Over-the-counter standardised transactions could be brought into exchanges or electronic trading platforms and centrally cleared.
  - The issuance of longevity indexed bond could be considered, though with care, as it would also increase the exposure of the government to longevity risk which many governments already have significant exposure to.

Notes

1. There are different approaches to address the management of longevity risk that may be country specific. Consequently, discussions about managing longevity risk should keep different country contexts in mind. One example could be the existence of pension protection funds which can be used to offset the financial impact of longevity risk in the event that it materialises in the future. The approach presented in this section is preventative as the focus is on addressing the management of longevity risk directly in order to avoid excessive adverse financial impacts from materialising.

2. Mitigating or hedging a risk is the act or method of reducing the risk of financial loss of an investment. In what follows, the text refers to hedging longevity risk as reducing the longevity risk to which pension funds and annuity providers are exposed.
3. Based on the analysis in Chapter 3.
4. These policy options elaborate in more detail existing recommendations relating to managing longevity risk, such as those of the Joint Forum Paper. For example, the option suggesting specifically that future improvements should be accounted for, that tables are regularly updated, and that the relevant experience be used as a basis for setting assumptions develops in more detail the Joint Forum's Recommendation 4 to "Review longevity risk rules and regulations … pertaining to the measurement, management and disclosure of longevity risk". Additionally, the policy option saying that policymakers should facilitate the measurement of mortality for the purposes of assumption setting by ensuring that accurate and granular mortality data is publically available – a recommendation completely in line with Recommendation 8 of the Joint Forum to "Collect adequate data" goes further than the recommendation 2 of the Joint Forum to "Understand longevity risk exposures…to ensure that holders of longevity risk…have the appropriate knowledge, skills, expertise and information to manage it". Moreover, the final policy option in this paper that policy makers could encourage the development of the longevity transfer market goes hand and hand with Recommendation 3 of the Joint Forum to "Assess relevant policies…with regard to where longevity risk should reside" and simply takes a position that longevity risk should be more broadly shared across society in order to ensure the continued capacity of pension funds and annuity providers to manage and insure longevity risk.

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