Koninklijk Actuarieel Genootschap

# PROJECTIONS LIFE TABLE AG2020

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# CONTENTS

# 1 PREFACE

For decades, life expectancy has increased steadily in the Netherlands as well as in the neighbouring countries. This trend has had a large impact on society. It is important for pension funds and life insurers to understand the development of life expectancy in order to be able to estimate future cashflows and thus to set provisions.

Every two years The Royal Dutch Actuarial Association (Koninklijk Actuarieel Genootschap or 'AG') publishes a new Projections Life table, providing an insight into the expected development of life expectancy in The Netherlands, based on the most recent information at the time.

Before you is the publication of the new Projections Life Table AG2020. The underlying model is a fully transparent model with a limited number of parameters, making it easy to explain and exactly reproducible. This complies with AG's aim to make knowledge available to and applicable by the financial sector.

Since the publication of AG2018 various analyses have been conducted that have led to further improvements of the model. The changes from AG2018 will be explained both substantively and numerically.

The impact of Covid-19 on life expectancy is as yet hard to predict because of the limited availability of data and the uncertainty in how the pandemic will develop in the future. Therefore, only a number of sensibility analyses have been carried out.

I want to thank the members of AG Mortality Research Committee (Commissie Sterfte Onderzoek or 'CSO') and the Projections Life Tables Working Group for their efforts and all the work that they have done over the past two years.

**Wies de Boer AAG**
Chair AG Mortality Research Committee

# 2 JUSTIFICATION

**Mortality Research Committee**

Monitoring the development of mortality in the Netherlands and developing projections of this has traditionally been an important task of the Royal Dutch Actuarial Association. An expression of this is the long series of period and projections life tables the Association has published. In 2011, the Board of the Association set up the Mortality Research Committee and assigned it the task of publishing a new Projections table every two years, which was to serve as the basis for estimating the future life expectancy of the population of the Netherlands. In 2014, a model was implemented which, in addition to the mortality projections, also reflects the uncertainty in the projection of this model (a so-called stochastic model). This resulted in the publication of Projections Life Table AG2014. Projections Life Table AG2016 is based on the same model as Projections Life Table AG2014, with a number of changes to the data used and the method of estimation. In particular, the correlation between the development of mortality amongst men and women was modelled. After the publication of Projections Life Table AG2016 a number of aspects have undergone further research, but this has not led to any model adjustments. Thus, AG2018 was based on the same model as AG2016. In the past two years further analyses have been performed, that have led to some model adjustments. These adjustments have made the model more robust and this model is the basis for AG2020.

The committee consists of members with an academic background, members from the pensions and insurance sector with a technical background and members from these sectors with a managerial background. Mid 2020, the Mortality Research Committee consists of the following members:

B.L. de Boer AAG, chair
drs. C.A.M. van Iersel AAG CERA, secretary
prof. dr. B. Melenberg
drs. J. de Mik CFA AAG
drs. E.J. Slagter FRM
prof. dr. ir. M.H. Vellekoop, vice chair
ir. R.E.J.M. Waucomont AAG
M.A. van Wijk MSc AAG
ir. drs. M.R. van der Winden AAG MBA

**AG Projections Life Tables Working Group**

The Mortality Research Committee set up the Association's Projections Life Tables Working Group at the end of 2012 with the task of supporting the Committee in the development of projection tables. Mid 2020, the Working Group consists of the following members:

M.J.A. Klein MSc AAG, chair
F. van Berkum PhD
F.J. Cuijpers MSc AAG
ir. drs. J.H. Tornij
J.I. Tol MSc AAG
Drs. B.G. ter Veer AAG
W. van Wel MSc
K. Wittekoek MSc

In performing its task, the Working Group has carried out various analyses to obtain Projections Life Table AG2020. These analyses have deepened the Working Group's insights and resulted in model adjustments. The Mortality Research Committee has validated the Projections Life Table AG2020 as set by the Working Group.

# 3 SUMMARY

By publishing Projections Life Table AG2020 AG presents its most recent estimation of future mortality of the Dutch population to date. This estimation is based on mortality data from both the Netherlands and European countries of similar prosperity. Projections Life Table AG2020 replaces Projections Life Table AG2018.

The most important features of the Projections Life Table AG2020 are:

- Projections Life Table AG2020 can be used to estimate mortality levels far into the future. Expected future developments in mortality can be factored into calculations of life expectancy and provisions.
- In addition to historical mortality in the Netherlands, Projections Life Table AG2020 also uses mortality data from selected European countries with similar prosperity levels. This combination of data leads to a stable model less sensitive to random aberrations in the Dutch data for any one year.
- Projections Life Table AG2020 is based on a stochastic model, enabling pension funds and life insurers to also estimate the uncertainty of the forecast.

After the publication of AG2018 various analyses were conducted in preparation of Projections Life Table AG2020. These were partly driven by questions and suggestions from the profession. With the analyses further refinements of the model were tested. The selection of the AG2020 model was based on a number of science-based statistical model selection criteria. Model outcomes must be plausible as well as explicable. Stability and robustness of the model are important factors too. Finally, coherence is an important criterion, meaning that future mortality in the Netherlands and the selected European countries will not diverge significantly.

All this has resulted in two model adjustments, which are explained in detail in chapter 6. Both adjustments relate to the modelling of the Dutch deviation from the European countries:

1. Constants are added to the modelling of the Dutch deviation for both men and women. This means that the time series that describe the differences between the Netherlands and other countries converge to non-zero numbers.

2. The modelling of the Dutch deviation no longer used data from 1970 onwards, but instead data from 1983 onwards. Dutch data from 1970 is still used in the modelling of the European mortality trend.

The changes of Projections Life Table AG2020 as compared to Projections Life Table AG2018 are caused by (1) the two aforementioned model adjustments and (2) the addition of new mortality data from The Netherlands and Europe.

Table 3.1 lists the effects of the new projections table. It shows that life expectancy at birth is reduced by about one year for both men and women. The remaining life expectancy at age 65 drops by about six months. Model change is the main cause of the downward adjustment of the prognosis. The impact of adding new mortality data is much smaller.

| Cohort life expectancy in 2021 | At birth | | At age 65 | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| **AG2018** | **90.2** | **92.7** | **20.5** | **23.3** |
| Model change | -0.8 | -0.6 | -0.5 | -0.2 |
| Adding new data | -0.1 | -0.4 | 0.0 | -0.2 |
| **AG2020** | **89.3** | **91.7** | **20.0** | **22.9** |

**Table 3.1** Cohort life expectancy in 2021

The conclusion is that life expectance is still expected to rise in the future, but at a lower rate compared to Projections Life Table AG2018.

For a variety of model funds, chapter 7 presents calculations of the impact of the implemented changes on provisions and premium levels.

For an average fund, the provision will drop by around 2 per cent at a 1% interest rate. Table 3.2 breaks down the impact of replacing AG2018 by AG2020 for an average model portfolio into two steps.

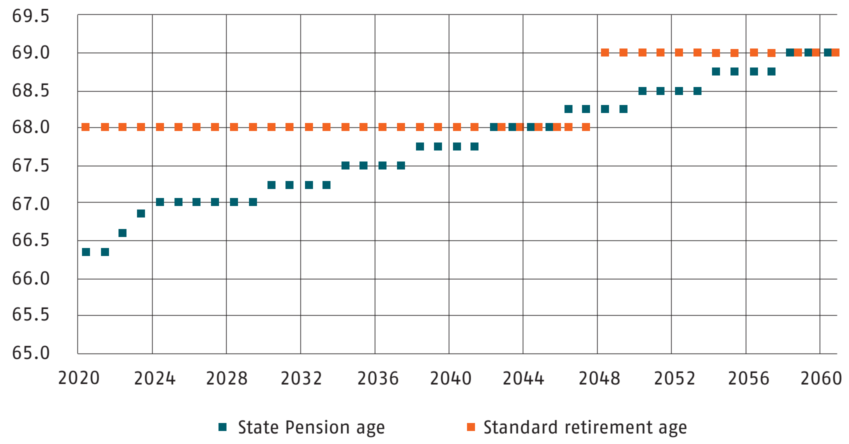
| Impact TP 1% interest | Average | |
|---|---|---|
| | Male | Female |
| Model change | -1.6% | -1.4% |
| Data update | -0.5% | -0.8% |
| **Total** | **-2.1%** | **-2.2%** |

**Table 3.2** Impact on technical provision for an average model portfolio at a 1% interest rate

It shows that more than two thirds of the reduction in technical provision is explained by the model change.

The impact on the premium exceeds that of the provision. This is related to a longer average projection horizon. The premium drops by 2.5 to 3 per cent at a 1% interest rate.

The expected development of the State Pension retirement age and standard retirement age using the latest insights based on Projections Life Table AG2020 and the Outline agreement of June 5th, 2019 is summarised in graph 3.1 We wish to emphasise that the actual increase of the State Pension retirement age and standard retirement age is linked to the estimates of Statistics Netherlands (Centraal Bureau voor de Statistiek, CBS) and these values are to be regarded as indicative.




**Graph 3.1** Development of State Pension retirement age and standard retirement age based on AG2020. Adjustment of the State Pension retirement age is done in three-month steps. According to the AG2020 projections the State Pension retirement age increases to 67 years and 3 months in 2030 and to 68 year in 2042.

The impact of Covid-19 on life expectancy is as yet hard to predict. The outbreak was in 2020 and that means that only limited date are available. Future developments related to this virus are uncertain and at this time it is not clear if there will be a lasting effect. For this reason, the 2020 effects have not been included in the projections. To provide some insight into the possible impact on life expectancy, two sensitivity analyses were performed:

- An analysis only including excess mortality until mid 2020.
- Another analysis assuming that there will be an equal excess mortality in the second half of 2020.

In the first analysis the average life expectancy at birth is about six months lower than the AG2020 prognosis. In the second analysis the average life expectancy decreases by more than a year. The effect is stronger for men than for women.

# 4 INTRODUCTION PROJECTIONS LIFE TABLE AG2020

**Through the publication of Projections Life Table AG2020, AG presents an assessment of the expected development of survival rates and life expectancy in the Netherlands. This assessment is based on the most recent mortality data from The Netherlands and from European countries of similar prosperity. The result is a forecast of mortality probabilities by age for each future year for men and women.**

**This introduction describes why the forecast is made, how the model works and what activities were performed since the release of Projections Life Table AG2018.**

## 4.1 Why does AG develop a projection model for mortality probabilities?

Every two years AG publishes a projection model to forecast the development of mortality rates in the Dutch population. This model is relevant to, among others, pension funds and life insurance companies. The projection model can be used for the determination of the provisions held by pension funds and insurers, taking into account fund or portfolio specific mortality experience if desired. Pension benefits, in general, are paid as long as a participant or insured person lives and therefore it is important to know how long this person is expected to survive.

AG combines expertise from science and the pensions and insurance industry to develop this mortality forecast. The AG model is fully transparent and only uses publicly available data. Based on the model documentation and the data used, the model can be copied and its results reproduced. AG has developed this model for the whole industry and it therefore contributes to market uniformity.

## 4.2 How does the model work?

The projections are based on a stochastic model. This makes it possible to give an impression of the uncertainty in the development of life expectancy.

The model estimates parameters that best describe the historical development of European mortality in countries with a prosperity level similar to that of the Netherlands. Based on these parameters a forward projection can be made for these countries. The size of the dataset makes this projection stable. In addition, parameters are estimated that describe the historical aberration between mortality in The Netherlands and these European countries.

From 1970 onwards a decreasing difference in mortality probabilities between European countries is clearly discernible. Also, the development of period life expectancy has shown a similar upward trend for decades. See graphs 5.1 and 5.2 in chapter 5.

The current view is, that life expectancy will continue to rise. The evolution of life expectancy is the balance of all (positive and negative) circumstances that impact life expectancy. Implicit in our projections is the assumption that, as in the past, new developments will keep occurring that bring about further increases in life expectancy. This may be, for instance, medical or technological developments or developments related to lifestyle and environment. Mortality developments observed in the past also had multiple causes, such as changes in smoking behaviour, improvements in the treatment of cardiovascular diseases and an increased regard for a healthy lifestyle.

The covid-19 outbreak may also impact life expectancy. At this time, it is hard to gauge these effects, because much is still unclear. Although 2020 will show a significant excess mortality, it is unclear what the effects will be in subsequent years. The absence or availability of a vaccine is of great importance to this. Chapter 8 explores the possible effects of covid-19 by calculating a number of sensitivity analyses. Because of the fact that extrapolation techniques had to be used to obtain data points that were not yet available, these sensitivity analyses are not part of the AG2020 model.

## 4.3 What happened since the release of Projections Life Table AG2018?

A number of analyses were conducted to explore further model refinements. The analyses conducted were in part prompted by questions and suggestions from the profession after the publication of AG2018. The analyses have led to two adjustments. Firstly, constant terms were added to the projection of the Dutch deviation from Europe. Also, the sample length for the Dutch deviation was shortened. As a result, the projection model AG2020 is further improved and meets the standards set by the Mortality Research Committee for a good model.

## 4.4 Publication of Projections Life Tables on the AG website

AG published Projections Life Table AG2020, including the technical specifications of the projection model, on its website. Refer to www.ag-ai.nl/ActuarieelGenootschap/Publicaties. Also listed there are Excel files with the data sets that can be used to reproduce the estimations of the model's parameters.

# 5 DATA

## 5.1 Dutch and European data are input for the Projection model AG2020

The current Projection model AG2020 uses similar data as Projection model AG2018. This implies that, additional to mortality in the Netherlands, data are used on the mortality developments in a number of other European countries. Since 1970 a decrease in the differences in mortality probabilities between these European countries is clearly discernible. Also, the period life expectancies in these countries have shown similar upward trends for decades. Please refer to graphs 5.1 and 5.2.

In view of these apparent similarities, as of Projection model AG2014 the choice was made to expand the basis for the Dutch projections to the developments in these European countries. This prevents the forecast from being solely dependent on Dutch data that may include specific historical fluctuations that may not be indicative of future developments. The view is, that the long term increase of life expectancy in the Netherlands can be more accurately predicted by including a broader European population, as this vastly expands the number of observations: from just over 100,000 deaths annually in the Netherlands to over 2,000,000 deaths per year for the included European countries, rendering the model more robust. Consecutive projections are expected to be more stable than when using only Dutch data.

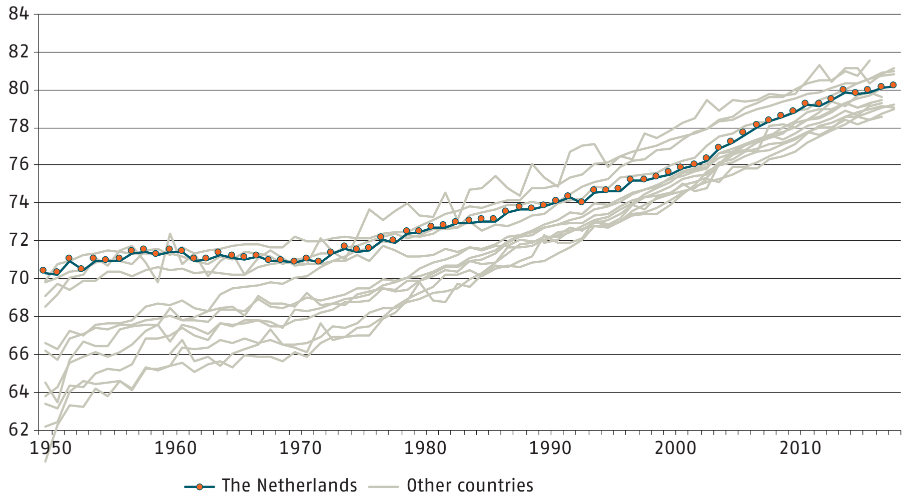
## 5.2 European mortality data: countries with an above-average GDP

The projection model uses European mortality data from countries with an above-average Gross Domestic Product (GDP). GDP is seen as a measure for a country's prosperity. A positive correlation exists between prosperity and ageing: the higher the prosperity level, the older people get. The Netherlands is a high prosperity country with a GDP above the European average. Based on this criterion, the following European countries have been included: Belgium, Denmark, Germany, Finland, France, Ireland, Iceland, Luxembourg, Norway, Austria, United Kingdom, Sweden and Switzerland. In this publication the aforementioned countries together are referred to as "Europe" or "Western Europe".

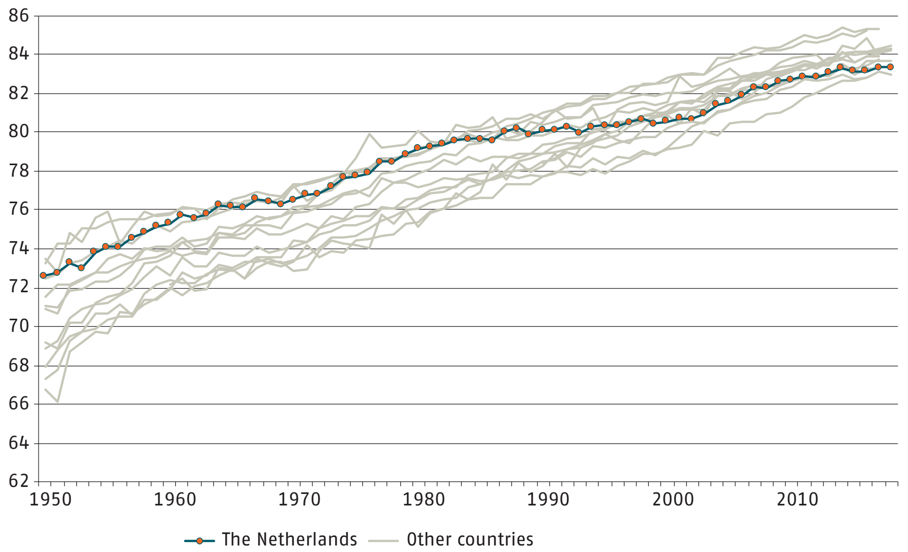
The selection of countries was first performed for the publication of the Projection model AG2014. As time passes, other countries may also meet the above-average GDP selection criterion, or countries may cease to do so. In the creation of AG2020 the criterion still generates the same set of countries.

## 5.3 Data range

Graphs 5.1 and 5.2 show the historical development of life expectancy at birth in the Netherlands and the selected European countries since 1950. The graphs show that in the first part of this period life expectancies are quite far apart, for men in particular. From 1970 onwards a stable development can be seen in life expectancies of both men and women. For the estimation of the European leg of the model, including the Netherlands, we use data from the observation period 1970 through 2018. For the Dutch deviation we use data from 1983 through 2019.




**Graph 5.1** Period life expectancy at birth male



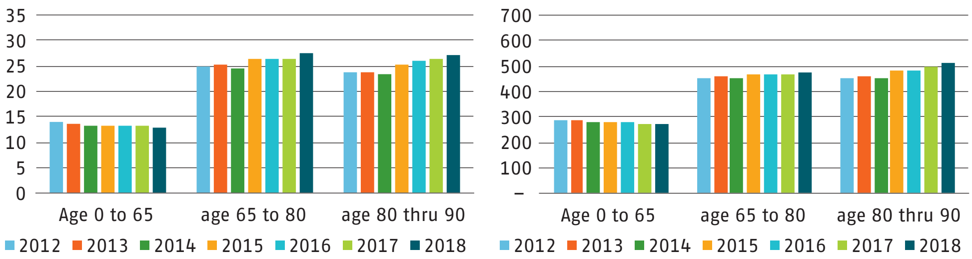

**Graph 5.2** Period life expectancy at birth females

Graphs 5.1 and 5.2 show that life expectancy in the Netherlands after 1970 has risen less than the average over the selected European countries. This is true in particular for women, since the early eighties. The difference between Dutch and European women is even more apparent when looking at the underlying mortality probabilities. Chapter 6 will explore this further and also explain what the effect of this lagging (compared to other European countries) is on the Projection model AG2020.

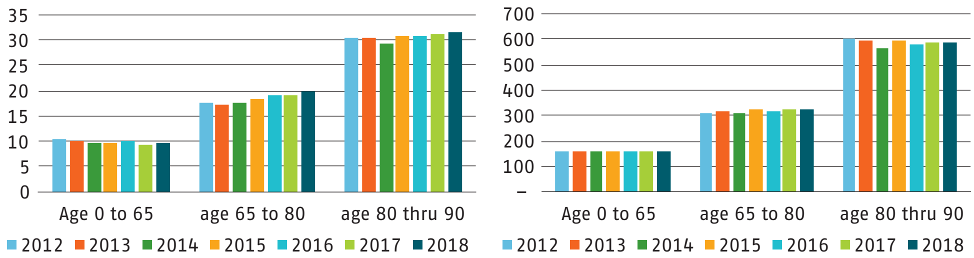
## 5.4 Observed mortality has increased in recent years

In the publication of Projection model AG2020, attention was given to excess mortality in the years 2016 and 2017 as a result of, among other causes, a wave of influenza in the 2016/2017 season. This led to mortality higher than was to be expected based on Projection model AG2016, in particular for higher ages. This was true for the Netherlands as well as for the selection of European countries.

For observation years 2017 and 2018 mortality continues to be higher than expected for higher ages in particular. This too can be partly attributed to the flu season 2017/2018. Mortality caused by influenza has been above average in recent years not only in the Netherlands, but also in other European countries[1,2]. A strong increase or decrease of mortality in the Netherlands often coincides with a strong increase or decrease in other European countries. This can be seen in the bar charts in graphs 5.3 and 5.4. These represent the numbers of deaths per year in The Netherlands and in Europe. Mortality in 2018 in the over 65 age group is shown to be higher than in previous years. For men this shows in The Netherlands and in Europe, for women it is most prominent in The Netherlands.




**Graph 5.3** Number of deaths male (x1,000) in The Netherlands (left) and in Europe (right) in the years 2012 – 2018




**Graph 5.4** Number of deaths female (x1,000) in The Netherlands (left) and in Europe (right) in the years 2012 – 2018

## 5.5 Data sources: Human Mortality Database, Eurostat and CBS

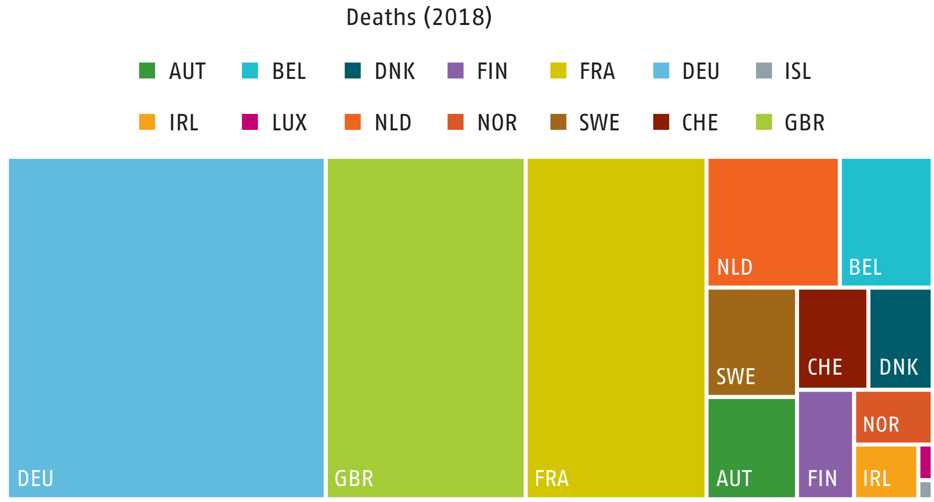
The data were obtained from the Human Mortality Database (HMD), supplemented with data from Eurostat for years and countries missing in HMD. The 2019 data for the Netherlands was obtained from CBS. The Eurostat data were adapted as required to ensure consistency with HMD. This applies to the 2018 mortality probabilities for the overseas territories of France, see appendix C.

1 – CBS (2018), 'Meer sterfgevallen in wintermaanden', CBS. URL visited May 18th, 2020.

2 – EuroMOMO (2020), Graphs and Maps, EuroMOMO. URL visited May 18th, 2020.

The information from these sources is regularly supplemented and sometimes also adjusted retroactively for prior years. The data set used, in the shape of mortality frequencies and exposure for both the Netherlands and the complete group of Western European countries can be found on the AG website and totals more than 115 million deaths.

The graph below shows the spread of these deaths across the countries.




**Graph 5.5** Spread by country of deaths (male plus female) in 2018

# 6 THE PROJECTION MODEL

**Every two years the Mortality Research Committee, in collaboration with the Working Group, estimates a new projection model, that can be used to determine a best estimate of future mortality probabilities and also to generate stochastic scenarios. In the analyses that precede this, considerations are made whether it is wise to implement model changes. This was not the case when moving from AG2016 to AG2018. The Committee has decided to make some changes for AG2020. These changes are described and explained in this chapter.**

**First, the starting points of the approach are discussed, indicating why adjustments in some areas are desirable. Then the new choices are detailed and the consequences of these changes for the mortality forecast clarified.**

## 6.1 Model assumptions unchanged

As in previous years, the forecast is based on the best possible projection of past trends. Again, explicit consideration is given to the fact that mortality *probabilities* cannot be observed, as we only observe mortality *frequencies* in a limited sample. The best way to take account of the uncertainty that this entails is to estimate the parameters using a statistical model.

The uncertainty in future projections can be visualised by defining stochastic scenarios for future mortality alongside the best estimate mortality probabilities. This offers insurers and pension funds the option to supplement the stochastic scenarios for quantities such as interest, inflation and share prices in their asset and liability management with stochastic scenarios for mortality. This feature makes the Dutch approach stand out from that in many other countries, where the actuarial societies only supply mortality tables.

The fundamentals are unchanged for AG2020:

**The projections are based on publicly available mortality data in the Netherlands and a number of similar countries in Europe.**
Chapter 5 discussed the details of the dataset used. As in previous years, the Committee promotes that the parameter calibration can be replicated by everyone. To that end, Appendix A provides a comprehensive description of the estimation procedure. All required datasets can be found on the AG website.

The model again builds on the fact that mortality developments in the selected group of European countries clearly shows a linear trend for hazard rates on a logarithmic scale, as we will show later in this chapter. This naturally leads to the use of a random walk with drift model. If we then compare the Dutch hazard rates to the European rates at the same logarithmic scale, we see annual fluctuations occurring, but there seems to be no divergence. Therefore, for the Dutch deviation a first-order autoregressive process was selected again.

**Males and females are modelled jointly, not separately.**
Dependencies between developments for men and women and between developments in the Netherlands and elsewhere in Europe are explicitly included in the modelling. There are four stochastic processes that describe the annual changes in mortality probabilities. Two pertain to the dynamics in Europe (one for men and the other for women) and the other two generate the Dutch deviation from the European trend for both sexes. Any dependencies between these four processes are allowed for by estimating all mutual correlations during the calibration.

**For high ages the common closing method of Kannisto is used.**
The relatively small numbers of observations available for higher aged persons make that data less reliable for estimating mortality probabilities. The difference between observed mortality frequencies and estimated mortality probabilities could be large here. Therefore, as with AG2018, mortality probabilities over age 90 are determined by extrapolation of mortality probabilities for lower ages, assuming that the development in higher ages corresponds to Kannisto's parameterisation[3].

**The measurement noise, the difference between observed mortality frequencies and the underlying mortality probabilities, has a Poisson distribution.**
As before, the basis for AG2020 is a Li-Lee[4] model that combines linear specifications for hazard rates in the European countries and the Dutch deviation. Contrary to that model we model measurement noise explicitly[5] and allow for dependencies between different stochastic drivers.

## 6.2 Adjusted model assumptions

### 6.2.1 Motivation for adjustments

During the construction of the previous projections table in 2018 and in the subsequent discussions in the actuarial field a variety of pros and cons of the approach were brought forward. Below we discuss a number of items that were frequently mentioned.

**Are the time series for the difference between The Netherlands and other European countries expected to converge to zero?**
AG2018 explicitly assumes that the time series that describe the expected value of the difference between the logarithmic hazard rates in The Netherlands and in other selected European countries converges to zero[6]. The parameter driving the speed of convergence also drives the stability of the model. During the 2016 and 2018 calibrations it soon turned out that, although the model is stable, the values of this parameter for both men

3 – See Kannisto, V. (1992). Development of the oldest – old mortality, 1950-1980: evidence from 28 developed countries. Odense University Press.

4 – See Li, N and Lee, R. (2005). Coherent Mortality Forecasts for a Group of Populations: An Extension of the Lee-Carter Method. Demography 42 (3), pp. 575 - 594

5 – See Brouhns, N., Denuit, M. and Vermunt, J.K. (2002). A Poisson log-bilinear regression approach to the construction of projected lifetables. Insurance: Mathematics & Economics 31(3), pp. 373-393.

6 – Please note that this does not imply that the deviation between the Netherlands and the other countries also converges to zero, because in addition to this time series the model includes a constant difference that does not vary over time (denoted as $\alpha_x$ in the model specification).

and women is close to the critical threshold for stability[7]. This begs the question if a more stable model would be found if we allow the expected values of these time series to converge to non-zero values.

**How much history should be included in the creation of the projections?**
If convergence to other values is allowed, the question is raised whether these values are constant over time and, more specifically, if they are unchanged since 1970. This question touches upon the choice of historical dataset used for the calibration and that is a subject that the actuarial field has had questions about at earlier projections publications.

The choice to start the datasets in 1970 was driven by the relatively stable pattern in the European mortality characteristics since that year. The effects of negative factors such as smoking, aids and the rise of obesity on the one hand and positive developments such as the successful battle against cancer and cardiovascular diseases on the other have yielded an all but constant trend in the logarithmic hazard rates within the selected group of European countries. The observed fluctuations in the Dutch deviation from this trend since 1970 are more ambiguous. Periods of increase and decrease emerge that make convergence (in expected value) to zero less likely if we only look at recent data. It may therefore make sense to exclude some data after 1970 from the estimation of the expected value of the long-term difference between the Netherlands and other European countries.

### 6.2.2 Adjustments made

In light of the above considerations the Committee has decided to implement two adjustments.

**The European dataset starts in 1970, the Dutch deviation dataset starts in 1983.**
The choice of 1983 as the starting point for the Dutch calibration data and leaving the starting point for the European data unchanged, is the result of an extensive analysis of the time series involved. The Working Group also analysed several alternatives, including specifications that also adjusted the calibration period for Europe, specifications with different calibration periods for men and women, excluding any dependencies between European changes and the Dutch deviation. The Committee's deliberations around the model choice included statistical model selection criteria such as log-likelihood, AIC and BIC values[8] and the long-term robustness and stability of fitted models and plausibility of the projections. As a matter of fact, entering the start of the calibration period as a free parameter in the model selection procedures almost invariably led to 1983 as preferred option, based on the time series for women. That made the case for this choice.

**The time series describing the differences between the Netherlands and the other countries converge to values no longer assumed to be zero.**
These limits are now new parameters included in the calibration, because new constant terms are added to the autoregressive processes describing the Dutch deviation. This leads to a change in the expected value of the difference in the longer term. Because the variance of the time series does not move to zero over time, there will always be fluctuations around this expected value. Dutch mortality probabilities will continue to fall in terms of expected value, as the Dutch deviation is added to the falling European trend.

7 – The autoregressive parameter values for men and women were 0.975 and 0.993 respectively. The critical threshold for these parameters is 1.

8 – The Akaike Information criterion (AIC) and the Bayesian Information Criterion (BIC) are quantities that measure the plausibility of a fitted model with a log-likelyhood term, but seek to avoid unnecessary complexity by introducing a "penalty term" that increases as more parameters get used in the model.

## 6.3 Effects of adjustments made

The adjustments discussed impact several properties of the model.

**The times series for the Dutch deviation are more stable**

The parameter estimates that determine the speed of the convergence (in expected value) for the Dutch deviation time series are now considerably further away from the critical threshold. The introduction of two new constants and the new data points since 2017 also change the estimates of the European trend somewhat, but not by much.

**The model's consistency improves**

An important property of any projection model is time consistency. This means that in a scenario where observed mortality exactly matches a projection, a re-estimate of the model should yield unchanged parameters. In practice minor aberrations will always occur, because after adding new data points there are more observations, altering the estimators' uncertainty. Adding the two additional parameters (constants) leads to a stronger form of time consistency, that no longer depends on the method applied to rescaling. Moreover, a projection for only the European countries (without adding the Dutch data separately[9]) then equals the projection for those countries in case the Dutch data are added. This implies that all other European countries in our peer group would find the same European projection as the Netherlands, if they were to apply the AG2020 methodology.

## 6.4 Parameter estimates

Chapter 7 discusses the model results. In this paragraph we discuss the estimation results of AG2020, that drive those model results. The details of the applied estimation procedure are found in Appendix A. The underlying one year mortality probabilities are determined by modelling hazard rates, namely the European hazard rates, $\mu_x^{g,EU}(t)$, for year $t$, age $x$ and gender $g$, and the hazard rate of the Dutch deviation from Europe, $\mu_x^{g,NL}(t)$, for year $t$, age $x$ and gender $g$. We model the logarithm of the hazard rates as follows:

$$\ln\left(\mu_x^{g,EU}(t)\right) = A_x^g + B_x^g K_t^g$$

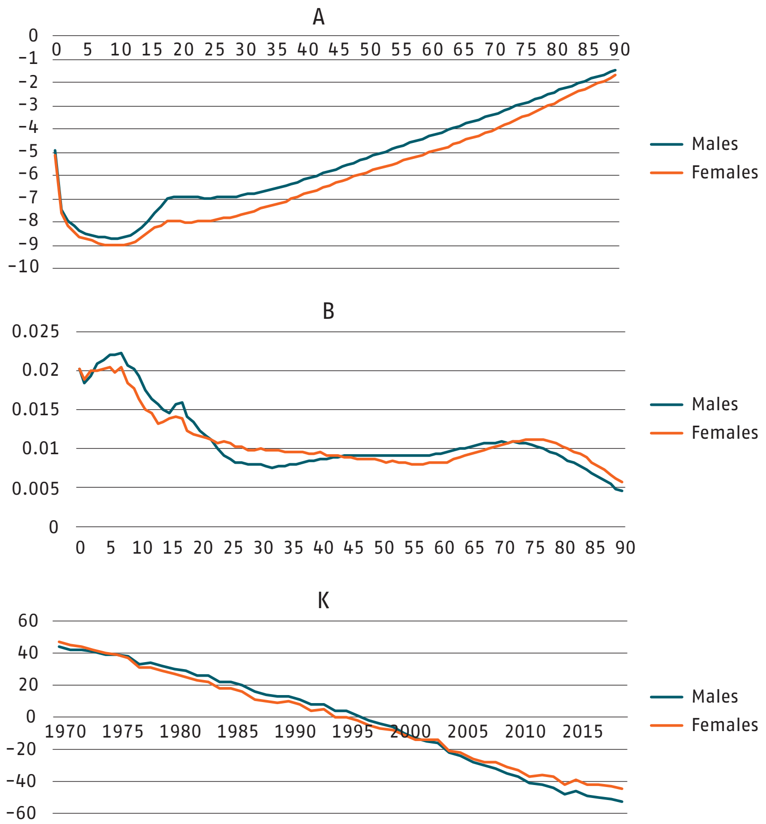
$$\ln\left(\mu_x^{g,NL}(t)\right) = \alpha_x^g + \beta_x^g \kappa_t^g$$

The hazard rates for the Netherlands, denoted by $\mu_x^g(t)$, then follow from the equation

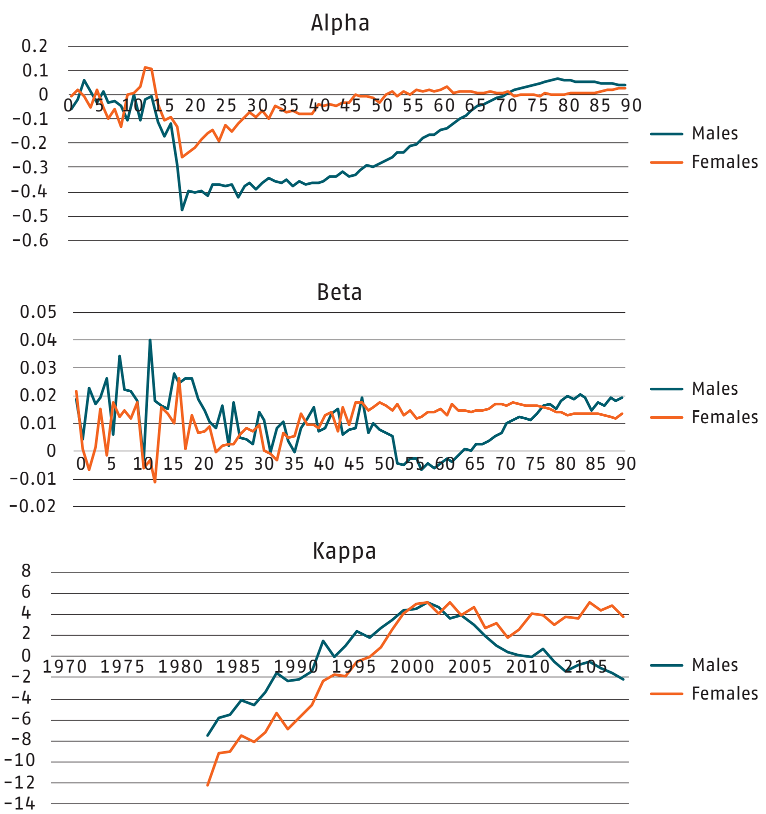
$$\ln\left(\mu_x^g(t)\right) = \ln\left(\mu_x^{g,EU}(t)\right) + \ln\left(\mu_x^{g,NL}(t)\right).$$

Graph 6.1 shows the parameter estimates of the hazard rates on a logarithmic scale. The top three graphs (graph 6.1a) show the parameters for Europe and the bottom three graphs (graph 6.1b) show the parameters for the Dutch deviation. The first graph shows the constant age specific effect ($A_x^g$ and $\alpha_x^g$ respectively). The product of the values in the second and third graphs yields the age specific time effect ($B_x^g K_t^g$ and $\beta_x^g \kappa_t^g$): the third graph shows the average annual improvement over all ages ($K_t^g$ and $\kappa_t^g$), while the second graph is age specific ($B_x^g$ and $\beta_x^g$) and represents the degree of change for that age. The interpretation of each of the graphs is linked to the chosen normalisation, but the resulting hazard rate estimates do not depend on this normalisation.

9 – We speak of adding the Dutch data "separately", because when using European data only, the Dutch data points are in fact included in the aggregated data set.




**Graph 6.1a** AG2020 model parameter estimates: parameters for the group of European countries




**Graph 6.1b** AG2020 model parameter estimates: parameters for the Dutch deviation

The results for Europe in graph 6.1a show that for all ages shown the trend in the hazard rates is downward for both men and women. The $B_x^g$ values are positive while the time series $K_t^g$ are descending. The trend for lower ages is in general more severe (downward) than for higher ages, because the values in the middle graph are generally higher for lower ages.

The results for the Dutch deviation in graph 6.1b show a more varied picture. For women we see in the third graph an upward timeseries until the year 2002 and a more or less flat development after that. The age specific effects for women in the second graph are positive for most ages. This means that for these ages the difference in logarithmic hazard rates between the Netherlands and Europe, or $\ln\left(\mu_x^{v,NL}(t)\right) = \ln\left(\mu_x^{v}(t)\right) - \ln\left(\mu_x^{v,EU}(t)\right)$, increases until 2002 and is more or less stationary after that. For men we see in the same graph a time series that goes up until 2002 and drops thereafter. For men too the age specific effects in the middle graph are positive for most ages. For these ages the difference in logarithmic hazard rates between the Netherlands and Europe, $\ln\left(\mu_x^{m,NL}(t)\right) = \ln\left(\mu_x^{m}(t)\right) - \ln\left(\mu_x^{m,EU}(t)\right)$, increases until 2002 and decreases after that.

To estimate future hazard rates the time effects in Europe ($K_t^g$) are modelled as a random walk with drift. The time effects of the Dutch deviation ($\kappa_t^g$) are modelled by a first order autoregressive AR(1) model (including the new constant terms $c^g$). This leads to the following equations, with parameters $\theta^g$, $a^g$ and $c^g$ and noise terms $\epsilon_t^g$ and $\delta_t^g$:

$$K_t^g = K_{t-1}^g + \theta^g + \epsilon_t^g$$

$$\kappa_t^g = a^g\,\kappa_{t-1}^g + c^g + \delta_t^g$$

Table 6.1 shows the parameter estimates. The value of $\theta^g$ is the estimated drift of the time effects in Europe. The values $c^g$ and $a^g$ are the estimated constant term and the estimated AR(1) term of the time effects in the Dutch deviation.

| | **Male** | **Female** |
|---|---|---|
| $\theta$ | -1.9639 | -1.8603 |
| $c$ | 0.1951 | 0.4071 |
| $a$ | 0.9347 | 0.9484 |

**Table 6.1** Time series parameter estimates

The future time effects $K_t^g$ and $\kappa_t^g$ can be estimated using these estimated models. Combined with the age dependent quantities $A_x^g$, $\alpha_x^g$, $B_x^g$ and $\beta_x^g$ (which are considered constant over time) these will produce estimates of both the future European hazard rates and the Dutch deviation from Europe.

For Europe we find that the hazard rates continue to drop. For identical values of the age specific effects as shown in the middle graph of graph 6.1a the hazards rates for men decrease slightly more than those for women, the $\theta$ value for men being more negative than for women.

For the Dutch deviation we observe that the logarithmic hazard rates of that deviation converge to limit values $\alpha_x^g + \beta_x^g\,\kappa_\infty^g$. The limit values of the AR(1) processes $\kappa_\infty^g$ are positive for men and women. This leads to positive limit values for the logarithmic hazards rates of the Dutch deviation, for higher ages in particular. This means that, certainly in the longer term, the estimated mortality probabilities at higher ages for Dutch men and women will exceed those of the European peer group. As a result, the estimated future life expectancies of Dutch men and women will grow at a slower pace than those of European men and women. This is confirmed in graphs 7.2 and 7.3 in the next chapter, that show the development of period life expectancy at birth and at age 65 for The Netherlands and the European group of countries.

# 7 RESULTS

**This chapter presents the results of Projections Life Table AG2020. The results are compared to those of Projections Life Table AG2018. For a number of example funds the effect on the level of the provisions is evaluated. With the aid of these example funds it is possible to assess the impact for other pension funds. In addition, the AG2020 forecast is confronted with historical developments and compared to the latest forecast by Statistics Netherlands (CBS 2019-2060).**

## 7.1 Definitions of life expectancy

A classic definition of life expectancy is the so-called period life expectancy. This period life expectancy is based on mortality probabilities in a certain period, such as one calendar year, and assumes that mortality probabilities will be constant in the future. In period life expectancy current mortality rates are used for mortality rates needed one or two years from now. So, period life expectancy does not allow for expected future developments in the mortality probabilities. This definition is commonly used to compare developments over time, but must never be used to estimate how long people are expected to live.

The second definition however, the cohort life expectancy, does take into account expected future mortality developments. When calculating cohort life expectancy at birth, mortality probabilities are required for a new-born, a one-year-old a year from now, a two-year-old two years from now and so on. In cohort life expectancy, for probabilities you need in one- and two-years' time, you use mortality probabilities projected one and two years into the future. So, cohort life expectancy is based on expected developments in mortality probabilities in future calendar years. To evaluate cohort life expectancy, you need a forward projection of mortality probabilities.

In case of an expected decrease in mortality probabilities, cohort life expectancy is therefore higher than period life expectancy.

## 7.2 Observations with respect to Projections Life Table AG2018

Tables 7.1 and 7.2 present the AG2018 forecast of period life expectancies in the years 2017, 2018 and 2019 and how these relate to the realised life expectancies in these years. Also the table shows the forecast of life expectancies for 2019, 2020 and 2021. In this case, period life expectancies are used, as these can be compared across observation years.

| | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | **Realised** | **AG2018** | **AG2020** | **Realised** | **AG2018** | **AG2020** |
| 2017 | 80.1 | 80.1 | | 83.3 | 83.3 | |
| 2018 | 80.2 | 80.3 | | 83.3 | 83.5 | |
| 2019 | 80.5 | 80.4 | 80.4 | 83.6 | 83.6 | 83.6 |
| 2020 | | 80.6 | 80.5 | | 83.8 | 83.7 |
| 2021 | | 80.8 | 80.7 | | 84.0 | 83.8 |

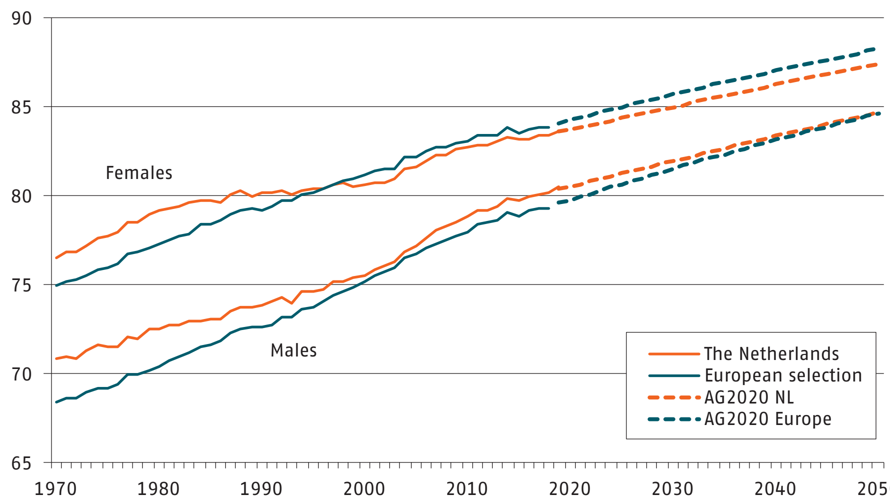
**Table 7.1** Period life expectancy at birth

| | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | **Realised** | **AG2018** | **AG2020** | **Realised** | **AG2018** | **AG2020** |
| 2017 | 18.6 | 18.5 | | 21.1 | 21.2 | |
| 2018 | 18.6 | 18.6 | | 21.0 | 21.3 | |
| 2019 | 18.8 | 18.8 | 18.7 | 21.2 | 21.4 | 21.3 |
| 2020 | | 18.9 | 18.8 | | 21.5 | 21.4 |
| 2021 | | 19.0 | 18.9 | | 21.6 | 21.5 |

**Table 7.2** Period life expectancy at age 65

In general, the observed life expectancies are slightly below the AG2018 forecast.

Graph 7.1 shows the development of period life expectancy at birth for the period until 2050. The graph is based on realised mortality rates until 2019 and AG2020 projections thereafter.




**Graph 7.1** Period life expectancy in the Netherlands and selected European countries

Graph 7.1 demonstrates that period life expectancy for Dutch women, as in the previous projections, is still below life expectancy of women in selected European countries. Life expectancy of Dutch men on the other hand is, as before, higher than life expectancy of men in selected European countries. For men this difference is diminishing over time, while the difference for women is roughly stationary.

## 7.3 From AG2018 to AG2020

To further clarify the differences between the old and the new projections tables, cohort life expectancy is used. Cohort life expectancy includes all future mortality developments. Below the step-by-step impact on cohort life expectancy for starting year 2021 of each added set of data points is shown.

| Cohort Life expectancy in 2021 | At birth | | At age 65 | |
|---|---|---|---|---|
| | Males | Females | Males | Females |
| AG2018 | 90.2 | 92.7 | 20.5 | 23.3 |
| Model change | -0.8 | -0.6 | -0.5 | -0.2 |
| Add EU2017 | -0.1 | -0.0 | 0.0 | 0.0 |
| Add NL2018 | -0.1 | -0.4 | -0.1 | -0.3 |
| Add EU2018 | 0.0 | -0.1 | -0.0 | -0.0 |
| Add NL2019 | 0.1 | 0.1 | 0.1 | 0.1 |
| AG2020 | 89.3 | 91.7 | 20.0 | 22.9 |

**Table 7.3** Cohort life expectancy in 2021

Table 7.4 lists the future cohort life expectancies for starting years 2021, 2046 and 2071.

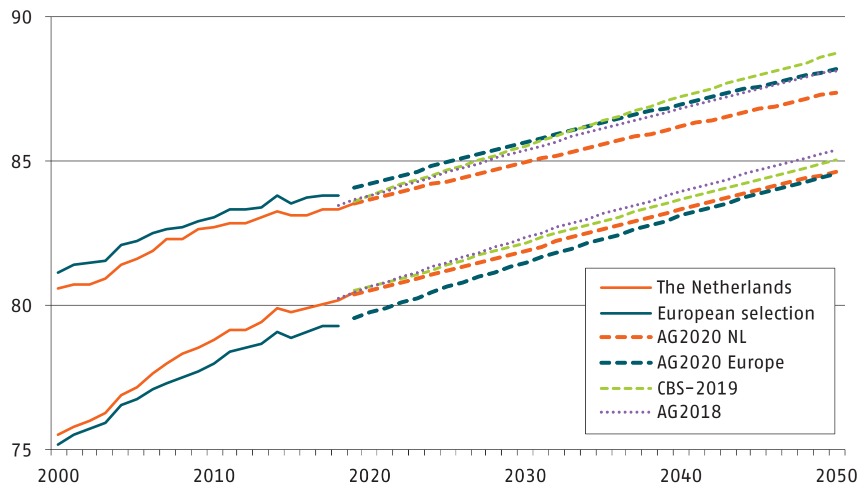
| Starting year | At birth | | | At age 65 | | |
|---|---|---|---|---|---|---|
| | Males | Females | Difference | Males | Females | Difference |
| 2021 | 89.3 | 91.7 | 2.4 | 20.0 | 22.9 | 2.9 |
| 2046 | 91.6 | 93.8 | 2.2 | 22.7 | 25.3 | 2.6 |
| 2071 | 93.3 | 95.3 | 2.0 | 24.9 | 27.3 | 2.4 |

**Table 7.4** Future cohort life expectancy based on AG2020

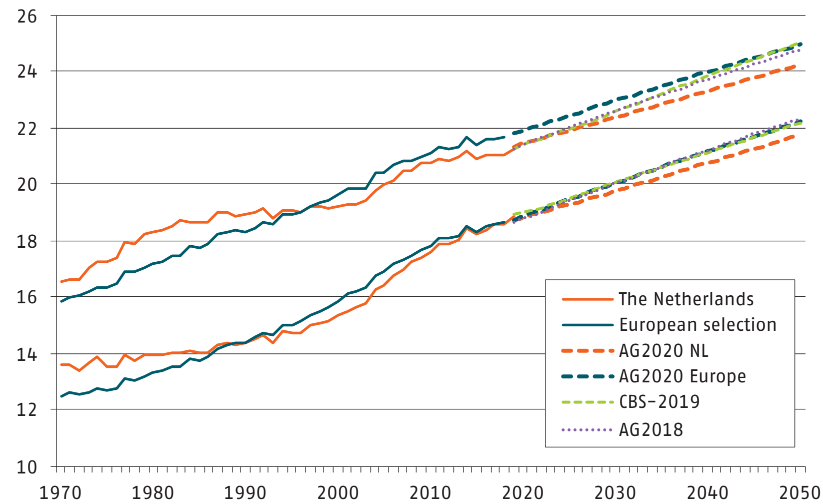
These numbers demonstrate that according to the forecast life expectancies for men and women will continue to rise, slightly faster for men than for women, thus reducing the gap in life expectancies between the men and women.

## 7.4 Projections in perspective

Graph 7.2 compares the developments in period life expectancy at birth for AG2018, AG2020 and CBS2019-2060. It is apparent that the AG2020 forecast is adjusted downwards. The trend in the AG2020 forecast for Dutch men converges to the trend for met in the forecast for the selected European countries. The trend in the AG2020 forecast for women diverges slightly from the trend for European countries, which widens the gap in period life expectancy through time.




**Graph 7.2** Development of period life expectancy at birth




**Graph 7.3** Development of period life expectancy at age 65

Graph 7.3 shows the development of period life expectancy at age 65. For both men and women, the downward adjustment compared to AG2018 is clearly visible. There is a minor divergence between the different forecasts of period life expectancy.

Table 7.5 lists cohort life expectancies for AG2018, AG2020 and CBS2019-2060. The differences in cohort life expectancy at age 65 between AG2020 and CBS2019-2060 have increased since AG2018.

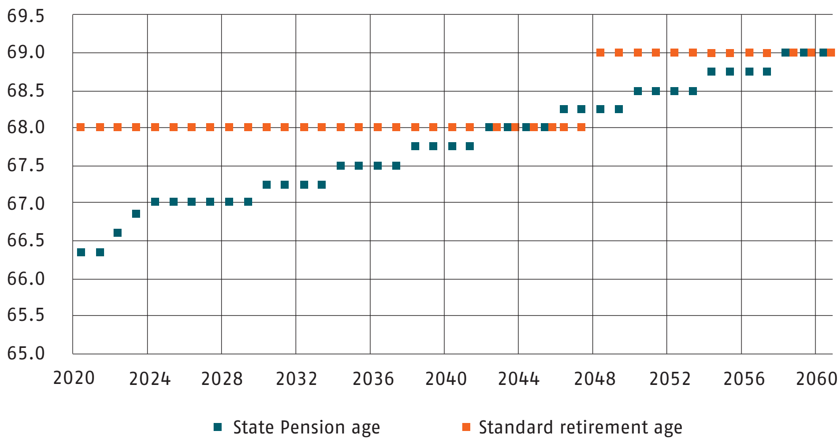
| Year 2021 Projection | At birth | | At age 65 | |
|---|---|---|---|---|
| | Males | Females | Males | Females |
| AG2018 | 90.2 | 92.7 | 20.5 | 23.3 |
| AG2020 | 89.3 | 91.7 | 20.0 | 22.9 |
| CBS2019 | Not available | | 20.5 | 23.3 |

**Table 7.5** Life expectancies for AG2018, AG2020 and CBS2019

## 7.5 Link between life expectancy at age 65 and 1st and 2nd pillar retirement age

The Raising of the State Pension Retirement Age and Standard Pension Retirement Age Act (Wet Verhoging AOW- en Pensioenrichtleeftijd) of July 12th, 2012 links the first pillar (State pension) retirement age and the standard retirement age in the second pillar (employers' pension schemes) to period life expectancy.

The development of the State Pension retirement age and the standard retirement age using the latest views based on Projections Life Table AG2020 and the adjustments from the Outline agreement of June 5th, 2019 is summarised in graph 7.4. However, the actual adjustment of the State Pension age is linked to the CBS estimates, so the values shown are to be considered as indicative.




**Graph 7.4** Development of State Pension retirement age and standard pension age based on AG2020

**Raising the State Pension retirement age**

Raising the State Pension age is done in three-month steps. The adjustments depend on the level of the average remaining period life expectancy at age 65, as estimated by CBS.

The Pensions agreement of June 5th, 2019 stipulates that the State Pension age will be set to 67 years in 2024. Also, the link to life expectancy is adjusted to curb the rise of the State Pension age: the adjustments to the State Pension age after 2024 are based on 2/3rds of the expected rise in remaining life expectancy at age 65. Because the State Pension age is adjusted in 3-month steps, a minimum increase of 4.5 months in remaining life expectancy is required for a further adjustment (taking into account 2/3rds).

According to Projections Life Table AG2020 the State Pension age will increase to 67 years and 3 months only in 2030, because that is when the remaining life expectancy is expected to be up 4.5 months from the 2024 reference value of 20.64, mentioned in the bill "Adjustment Link State Pension and standard retirement age". Table 7.6 shows the expected State Pension age development in full year steps.

| Expected State Pension retirement age | CBS2019 | AG2020 |
|---|---|---|
| 68 | 2037 | 2042 |
| 69 | 2051 | 2058 |
| 70 | Unknown | 2075 |
| 71 | Unknown | 2095 |

**Table 7.6** Expected years in which the State Pension retirement age will have risen by a full year according to the latest CBS and AG projections

**Raising the Standard retirement age**
The raising of the standard retirement age (in one-year steps) in the second pillar is based on the same formula as for the State Pension retirement age. By law however, expected increases in life expectance are to be anticipated sooner: it is to be based on the remaining life expectancy of a 65-year-old that is expected to occur ten years after the calendar year of the adjustment. An adjustment to the standard retirement age must be published at least one year before it is implemented. For instance, an adjustment of the standard retirement age in 2022 must be published before January 1$^{st}$, 2021. This will be based on the remaining life expectancy of a 65-year-old in 2032.

The mitigation of the link to life expectancy introduced in the Pensions agreement means that the standard retirement age will only reach 69 in about 25 years' time.

## 7.6 Effects on provisions

To plot the effects of Projections Life Table AG2020 on the technical provisions of pension portfolios six fictitious example funds have been constructed. Three of the funds have male participants and three have female participants. For both sexes a young, an old and an average fund has been constructed. An additional model portfolio was designed to assess the impact om pension premiums. See Appendix B for a description of the model portfolios.

Besides an old age pension (OAP) the example funds contain a deferred survivor's pension (SP) and a survivor's pension in payment. For male portfolios spouses receiving survivor's benefits are assumed to be females. For female portfolios the opposite applies. The benefits used are a retirement benefit commencing at age 65 and an "undetermined partner" type survivor's benefit with a partner frequency of 100%.

A fixed age gap of 3 years is assumed between male and female partners, the male partner being assumed older than the female. The model portfolios have a weighted (by provision) average age of 45 (young), 55 (average) and 65 (old). The effects are shown for interest rates 3 and 1%, so that the effects can be compared to the previous publication (AG2018).

| Impact Technical Provision | | | | | | |
|---|---|---|---|---|---|---|
| | Males | | | Females | | |
| **3% interest rate** | **Young** | **Average** | **Old** | **Young** | **Average** | **Old** |
| OAP (65) | -2.4% | -2.2% | -2.1% | -2.2% | -1.9% | -1.6% |
| Deferred SP | 1.1% | 0.7% | 0.1% | 1.9% | 0.8% | -0.3% |
| SP in payment* | -1.2% | -1.1% | -1.4% | -1.0% | -1.3% | -1.7% |
| Total | -1.7% | -1.6% | -1.6% | -1.8% | -1.7% | -1.6% |
| **1% interest rate** | **Young** | **Average** | **Old** | **Young** | **Average** | **Old** |
| OAP (65) | -3.0% | -2.8% | -2.5% | -2.7% | -2.4% | -2.0% |
| Deferred SP | 0.4% | 0.0% | -0.4% | 1.0% | 0.0% | -1.0% |
| SP in payment* | -1.6% | -1.5% | -1.7% | -1.5% | -1.8% | -2.1% |
| Total | -2.2% | -2.1% | -2.0% | -2.4% | -2.2% | -2.0% |

**Table 7.7** Impact on model portfolio provisions of a transition from AG2018 to AG2020 (difference AG2020 minus AG2018 expressed as percentage of AG2018). The separate percentages as listed for OAP and SP do not add up to the percentages in the total lines. This is caused by the difference in the provisions for the separate benefits.
* The impact on the provisions of survivor's pensions in payment refer to the gender of the surviving partner.

Table 7.7 indicates that the differences between model funds, in terms of provision, are limited. For an average portfolio the provision will be reduced by about 2% at 1% interest. For women the impact is higher (average reduction of 1.2 and 1.6% respectively). Compared to the effects at 3% interest rate, the lower interest rate exacerbates the impact at 1% interest.

Table 7.8 lists the impact of AG2018 to AG2020 on pension scheme contributions for the model portfolios.

| Impact Contributions | | |
|---|---|---|
| **3% interest rate** | **Males** | **Females** |
| OAP (68) | -2.9% | -2.5% |
| OAP + 70% deferred SP accrual | -1.9% | -2.0% |
| OAP + 70% deferred SP risk | -2.4% | -2.3% |
| **1% interest rate** | **Males** | **Females** |
| OAP (68) | -3.5% | -3.0% |
| OAP + 70% deferred SP accrual | -2.4% | -2.6% |
| OAP + 70% deferred SP risk | -3.1% | -2.9% |

**Table 7.8** Impact on model portfolio contributions of a transition from AG2018 to AG2020 (difference AG2020 minus AG2018 expressed as percentage of AG2018)

The impact on contributions exceeds the impact on provisions due to the longer average projection horizon and shows a decrease of 2.5 to 3 per cent at 1% interest rate.

In table 7.9 the impact on provisions of AG2018 to AG2020 for an average model portfolio is split into 2 steps.

| Impact Provision 1% interest rate | Average | |
|---|---|---|
| | Males | Females |
| Model change | -1.6% | -1.4% |
| Data update | -0.5% | -0.8% |
| Total | -2.1% | -2.2% |

**Table 7.9** Impact on provisions for model portfolio "average" at 1% interest rate

The table shows that more than 2/3rds of the decrease in provisions is explained by the model change.

Table 7.10 shows the provision effect on the separate benefits for various ages. As with the impact on the provisions of the model fund, the impact of the new table is more severe at lower ages. For SP in payment the impact increases for higher ages.

| Impact Technical Provision | | | | | | |
|---|---|---|---|---|---|---|
| | Males | | Females | | Males | Females |
| **3% interest rate** | **OAP** | **Latent SP** | **OAP** | **Latent SP** | **SP in payment*** | **SP in payment** |
| 25 | -2.6% | 2.1% | -2.6% | 5.3% | -0.5% | -0.5% |
| 45 | -2.5% | 1.1% | -2.3% | 2.0% | -0.9% | -0.9% |
| 65 | -1.8% | 0.5% | -1.4% | -1.1% | -1.8% | -1.4% |
| 85 | -1.9% | -1.1% | -1.4% | -2.2% | -1.9% | -1.4% |
| **1% interest rate** | **OAP** | **Latent SP** | **OAP** | **Latent SP** | **SP in payment*** | **SP in payment** |
| 25 | -3.2% | 1.1% | -3.1% | 3.9% | -1.0% | -1.0% |
| 45 | -3.1% | 0.3% | -2.8% | 0.8% | -1.5% | -1.4% |
| 65 | -2.3% | -0.2% | -1.8% | -2.0% | -2.3% | -1.8% |
| 85 | -2.1% | -1.3% | -1.5% | -2.5% | -2.1% | -1.5% |

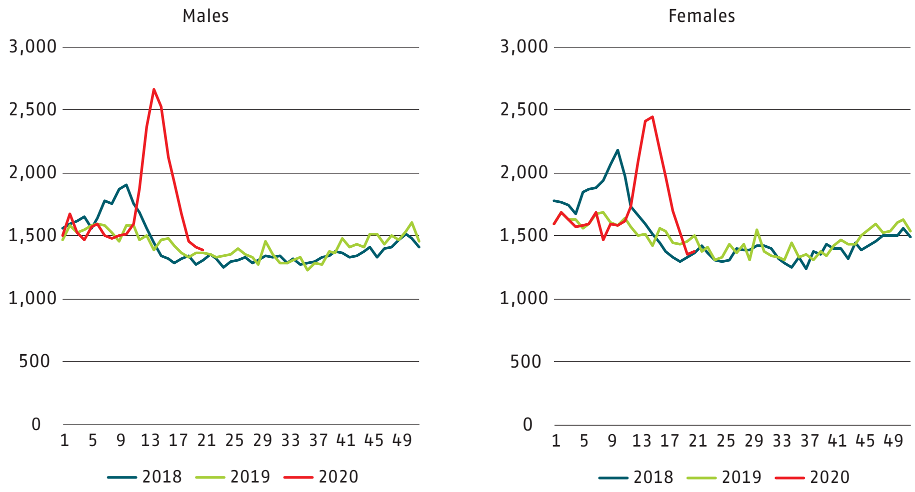
**Table 7.10** Impact on provisions by age and gender of the transition from AG2018 to AG2020 (difference AG2020 minus AG2018 expressed as a percentage of AG2018)
* The effect on the provisions of survivor's pensions in payment refer to the gender of the surviving partner.

# 8 THE IMPACT OF THE COVID-19 PANDEMIC

**The AG2020 forecast is based on European data until 2018 and Dutch data until 2019. This means that the effects of the Covid-19 pandemic are not included in the estimations of mortality probabilities and life expectancies. In this chapter we discuss the possible impact of the pandemic on the forecast and we argue why the Committee feels that AG2020 at this time is the best possible estimation of future mortality.**

## 8.1 Effects in the Netherlands already observed

At the time of writing this publication (August 2020) the spread of Covid-19 in Europe has been pushed back after the spike early in the year as a result of all the measures taken. A resurgence of the number of cases is however visible, giving rise to new localised restrictions. The World Health Organisation (WHO) warns that the worldwide pandemic is far from over. At the presentation of this report more weeks will have gone by and the situation may be quite different again.




**Graph 8.1** Mortality in the Netherlands by week in 2018, 2019 and 2020

It is already apparent that in the first half of 2020 Covid-19 has caused more deaths than the previous years' average. Graph 8.1 demonstrates this[10]. We observe that in years with an influenza epidemic the number of deaths exceed historical averages as well. During the flu epidemic of 2017/2018 for instance, the National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en milieu, RIVM) reported an excess mortality of over 9,000 cases[11]. The effect of the influenza epidemic in the spring of 2018 shows clearly in the graph.

## 8.2 Possible long-term effects

Actuarial forecasting has a number of specific properties and targets that sets them apart from other forecasts. For one, the extended time horizon adds to the importance of distinguishing between incidental and structural effects. It is also upon the actuary to make every estimation as objective as possible and to justify any subjective assumptions as clearly as possible.

At this time, predictions about the impact of the Covid-19 virus on future mortality rates and life expectancies are highly speculative. There are many uncertainties around the spread of the virus, in addition to which very little reliable data about the impact to date is available. Moreover, data from different countries is often incompatible because of variations in dealing with Covid-19, in areas such as testing policy, prevention measures and the available health care capacity.

In years to come the full impact of Covid-19 on long-term life expectancy will emerge. At this point in time it is difficult to assess if the Covid-19 related excess mortality will be structural. If a vaccine is found offering permanent protections, the number of victims will drop sharply from then on. If persons dying from corona in general had a lower life expectancy than their peers, the impact will be further reduced. It may also be the case that elderly person who survive the virus have an above average resilience and therefore have a higher life expectancy. However, if there is permanent damage to the lungs or other organs after recovering from the infection, this could indicate a lower remaining life expectancy. And if the care for patients with other afflictions is impaired because hospitals get overwhelmed, that too will have a major impact on mortality.

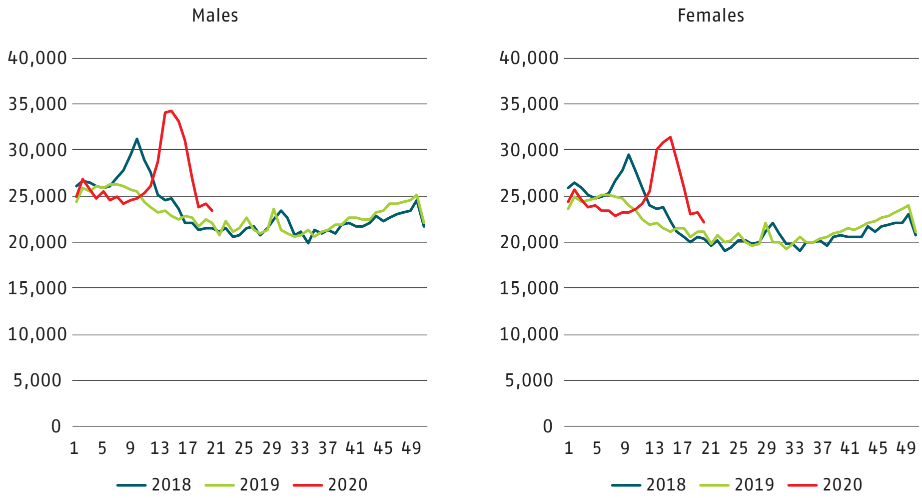
All in all, very little can be said about the consequences for life expectancy in 2021 and beyond.  Therefore, the choice was made not to make adjustments to the AG2020 forecast, which is based on data until January 1st, 2020, for the time being. In the Committee's opinion this forecast represents the best possible estimate at this point in time. Nonetheless, in the following paragraphs the results of a sensitivity analysis is presented to get a first impression of the impact of excess mortality in 2020 on life expectancies in 2021.

## 8.3 Sensitivity analysis

For the projections life table AG2020 the Dutch deviation from a European trend is estimated, which is why we include observed excess or below-average mortality in other countries in this sensitivity analysis. Due to limited availability of data the sensitivity analysis only includes data from Germany, France, the UK, Belgium and the Netherlands. On aggregate, these countries represent 83% of the European exposures normally used. The aggregated weekly mortality in these countries can be found in graph 8.2 for 2018, 2019 and the first 21 weeks of 2020.

10 – Data source: The Short-term Mortality Fluctuations in the Human Mortality Database, www.mortality.org. The Dutch data in that database are provided by CBS.

11 – Data source Reukers et al. (2019), Annual report Surveillance of influenza and other respiratory infections in the Netherlands: Winter 2018/2019, RIVM.




**Graph 8.2** Aggregated weekly mortality in Germany, France, the UK, Belgium and the Netherlands in 2018, 2019 and the first 21 weeks of 2020

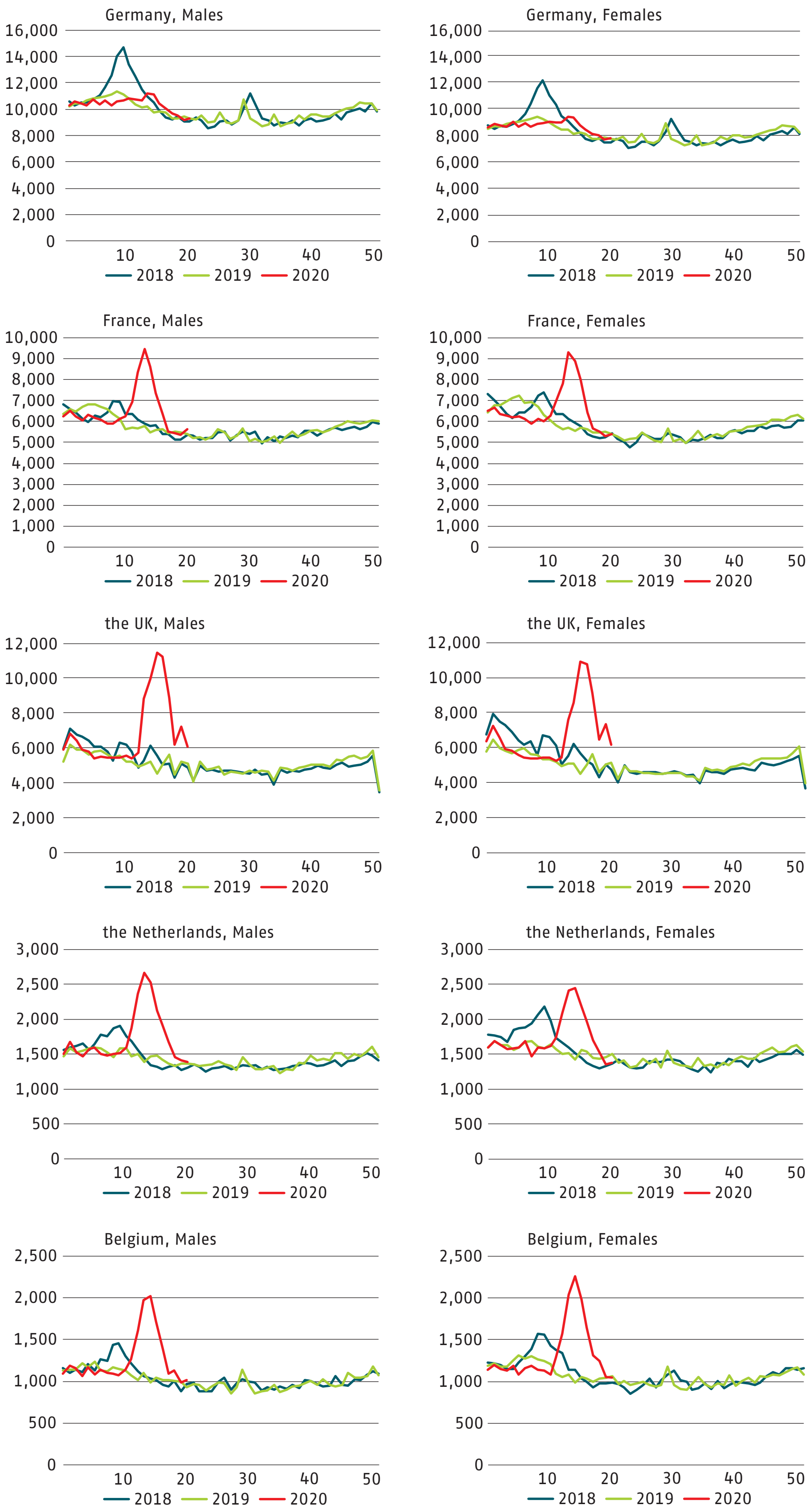
Graph 8.3 presents the same information broken down by country, showing major differences in terms of excess mortality and below average mortality. The German data shows large excess mortality observed in 2018 due to the influenza wave in that year, while 2020 to date shows no notable excess mortality due to Covid-19. Other countries do show clear Covid-19 related excess mortality. Note also that in France and the UK there was hardly any excess mortality in 2018 caused by influenza.

The sensitivity analysis for the impact of Covid-19 was done by augmenting the AG2020 data for Europe (through 2018) and the Netherlands (through 2019) with so called *virtual data points* extending to the end of 2020. The data to do this are not available or not complete yet, so extrapolation was used as required to determine excess or under-mortality compared to the AG2020 mortality forecast. Weekly CBS mortality data[12] up to and including week 21 was used, plus preliminary data from the Short-term Mortality Fluctuations dataset in the Human Mortality Database (as shown in graph 8.3). Two possible assumptions in the extrapolation were analysed:

- *Current observed excess mortality*
  The assumption that mortality in the Netherlands and in Europe in the remainder of 2020 (i.e. from week 22 onwards) will develop according to the AG2020 forecast from earlier chapters and no further excess or below-average mortality will occur.
- *Double the observed excess mortality*
  The assumption that for the weeks after week 21 in 2020 the same total excess or below-average mortality will be recorded (in number of deaths) as in the period up to week 21. This effectively doubles excess mortality in 2020.

In addition to virtual data points for deaths virtual data points for exposures were construed, using population and migration data from Eurostat and projections based on AG2020. Having added the virtual exposures and deaths, the usual calibration method for the model can be applied. In time, the virtual data point now surrounded by much uncertainty will be replaced by actual data points.

12 – A special query was submitted to CBS to be able to use more detailed mortality data by age and by week. We thank the CBS staff involved for their help and quick delivery of the data.




**Graph 8.3** Mortality by country and by week in Germany, France, the UK, Belgium and the Netherlands in 2018, 2019 and 2020

## 8.4 Results of the sensitivity analysis

Table 8.1 lists the results of the sensitivity analysis under the assumptions outlined in the previous paragraph. The numbers are cohort life expectancies at birth and at age 65 in 2021 after recalibration of the model with the new, virtual data points. Adding that new data, representing excess mortality for many ages, will shift both the European trend and the Dutch deviation, leading to new life expectancy best estimates.

| Cohort life expectancy in 2021 | At birth | | At age 65 | |
|---|---|---|---|---|
| | Males | Females | Males | Females |
| AG2020 | 89.3 | 91.7 | 20.0 | 22.9 |
| Current excess mortality | 88.6 | 91.3 | 19.6 | 22.7 |
| Double excess mortality | 87.9 | 91.0 | 19.2 | 22.5 |

**Table 8.1** Cohort life expectancies in 2021 based on AG2020, the current excess and below average mortality in 2020 and doubled excess and under-mortality in 2020

| Difference relative to AG2020 Cohort life expectancy 2021 | At birth | | At age 65 | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Current excess mortality | -0.68 | -0.41 | -0.44 | -0.19 |
| Double excess mortality | -1.37 | -0.73 | -0.87 | -0.33 |

**Table 8.2** Difference in cohort life expectancies in 2021 relative to AG2020, based on the current excess and below average mortality in 2020 and doubled excess and below average mortality in 2020

The effect observed in graphs 8.1 and 8.2 that a relatively high number of men die of Covid-19 clearly returns in table 8.1 The effect for men exceeds women by 50 to 150 per cent. We also note that doubling the excess and under-mortality observed to date also doubles the drop. For women this factor is a bit smaller.

The sensitivity of the pension scheme provisions can be tentatively assessed by looking at the cohort life expectancies for 65-year-olds. We see that these drop by 2.2 and 0.8% for men and women respectively under the first assumption and by 4.3 and 1.5% under the second. In reality the effects on provisions will be mitigated by interest and by survivor's pensions.

## 8.5 Future forecasts

CBS and RIVM are working to increase the availability of reliable data on the impact of Covid-19. The Committee, in collaboration with the Working Group, will continue its efforts to include new data in future forecasts. We stress again that calculations around the impact of Covid-19 are currently of a highly speculative nature. Much will depend on the effects turning out to be structural or only temporary. The sensitivity analyses given above need to be assessed in this context.

This being the case, the Committee is of the opinion that the AG2020 forecast as outlined in previous chapters provides the best possible assessment at this moment. For this reason too, only the model parameters and mortality probabilities for that forecast are published; the sensitivity analysis is not part of the AG2020 model. In the course of 2021 an update will be published if and when new developments give cause to do so.

# APPENDICES

# APPENDIX A

## Projection model AG2020

Technical specifications

## 1 Definitions

The Projections life table shows per gender for the ages $x \in X = \{0, 1, 2, .., 120\}$ and years $t \in T = \{2020, 2021, \dots, 2191\}$ the best estimate for one-year mortality probabilities $q_x(t)$. This is the probability that a person alive at 1 January of year t and born on 1 January of year $t - x$, will have deceased before 1 January of year $t + 1$.

The mortality probabilities are not modelled directly; instead, we specify the corresponding force of mortality (or hazard rate) $\mu_x(t)$. We assume that $\mu_{x+s}(t + s) = \mu_x(t)$ for all 0 ≤ s < 1. It follows, that

$$q_x(t) = 1 - e^{-\int_0^1 \mu_{x+s}(t+s)ds} = 1 - e^{-\mu_x(t)}.$$

Any dynamic model specified in terms of force of mortality $\mu_x(t)$ can be redefined in terms of one-year mortality probabilities using the formula above.

## 2 Dynamic model

For ages up to and including 90, $(x, t) \in \tilde{X} \times T$ with $\tilde{X} = \{0,1,2, \dots, 90\}$, the Li-Lee[13] model is used for both genders $g \in \{M, V\}$:

$$\ln\left(\mu_x^g(t)\right) = \ln\left(\mu_x^{g,EU}(t)\right) + \ln\left(\mu_x^{g,NL}(t)\right)$$

$$\ln\left(\mu_x^{g,EU}(t)\right) = A_x^g + B_x^g K_t^g$$

$$\ln\left(\mu_x^{g,NL}(t)\right) = \alpha_x^g + \beta_x^g \kappa_t^g$$

with dynamics for each gender, age $x \in X^0$ and year $t \geq 2020$ given by the time series

$$K_t^g = K_{t-1}^g + \theta^g + \epsilon_t^g$$

$$\kappa_t^g = a^g \kappa_{t-1}^g + c^g + \delta_t^g.$$

[13] Li, N. and Lee, R. (2005) Coherent Mortality Forecasts for a Group of Populations: An Extension of the Lee-Carter Method. *Demography* 42(3), pp. 575-594.

with dynamics for each gender, age $x \in X^0$ and year $t \geq 2020$ given by the time series

$$K_t^g = K_{t-1}^g + \theta^g + \epsilon_t^g$$

$$\kappa_t^g = a^g \kappa_{t-1}^g + c^g + \delta_t^g.$$

Here, $\mu_x^g(t)$ is the force of mortality for the Dutch population (of gender $g$), $\mu_x^{g,EU}(t)$ is the force of mortality for a peer group of Western European countries and $\mu_x^{g,NL}(t)$ is the quotient of the two (i.e. the Dutch deviation from the peer group). This means that a random walk with drift model is assumed for the time series of the peer group and a first order autoregressive model with constant term for the time series of the Dutch deviation.

The stochastic variables $Z_t = (\epsilon_t^M, \delta_t^M, \epsilon_t^V, \delta_t^V)$ are independent and identically distributed (i.i.d.) and have a four-dimensional normal distribution with mean (0,0,0,0) and a given 4x4 covariance matrix $C$.

## 3 Closure of the table

For ages over 90, $(x,t) \in \tilde{X} \times T$ with $\tilde{X} = \{91,92,\dots,120\}$, Kannisto's closing method is used, which is based on a logistic regression derived from the table for the ages $y \in X^{Kan} = \{80,81,\dots,90\}$ (with $y_k = 79 + k, k = 1,\dots,11$). Hence, the regression is based on $n = 11$, the average of those ages is $\bar{y} = \frac{1}{n}\sum_{k=1}^{n} y_k = 85$ and the squared sum of deviations is $\sum_{k=1}^{n}(y_k - \bar{y})^2 = 110$.
Closure using Kannisto means that for $x \in \tilde{X}$ and every $t$

$$\mu_x(t) = L\left(\sum_{k=1}^{n} w_k(x)\ L^{-1}\left(\mu_{y_k}(t)\right)\right).$$

Here, $L$ and $L^{-1}$ are the logistic and inverse logistic functions respectively

$$L(x) = \frac{1}{1+e^{-x}}, \quad L^{-1}(x) = -\ln\left(\frac{1}{x} - 1\right)$$

and the regression weights are given by

$$w_k(x) = \frac{1}{n} + \frac{(y_k - \bar{y})(x - \bar{y})}{\sum_{j=1}^{k}(y_j - \bar{y})^2} = \frac{1}{11} + \frac{(y_k - 85)(x - 85)}{110}.$$

Whenever a mortality probability is required for an age exceeding 120, that probability is assumed equal to the mortality probability at age 120.

## 4 Best estimates for mortality probabilities and life expectancies

Because we identify the *best estimate* future values of the time series as the *most likely* results, these will match the series for $K_t^g$ and $\kappa_t^g$ obtained by entering $(\epsilon_t^M, \delta_t^M, \epsilon_t^V, \delta_t^V) = (0,0,0,0)$ for every $t$. The covariance matrix $C$ is not required to generate best estimates but is required to perform simulations that can serve to analyse the uncertainty around the best estimates.

If we want to determine the remaining life expectancy of a person at 1 January of year $t$ under the assumption that this person was born on 1 January of year $t-x$ (with $x \in X$ and $t \in T$) and if we assume that, on average, a person who dies in any calendar year is alive for half of that calendar year, then we will find for that person the so-called *cohort life expectancy*:

$$e_x^{coh}(t) = \tfrac{1}{2} + \sum_{k=0}^{\infty}\prod_{s=0}^{k}\big(1 - q_{x+s}(t+s)\big).$$

Please note that with the formula above we 'move diagonally across the table of projections'. The probability that that person is alive at time $t+k$ is the product of survival probabilities $1 - q_{x+s}(t+s)$ for each year $s$ between $0$ and $k$, with the person not only ageing a year, but also moving to a new column in the mortality table. This effect is not included in the *period life expectancy*:

$$e_x^{per}(t) = \tfrac{1}{2} + \sum_{k=0}^{\infty}\prod_{s=0}^{k}\big(1 - q_{x+s}(t)\big)$$

which suggests that today's (time $t$) mortality probabilities will not change over time. This creates a false image of life expectancy and while this period life expectancy is often denoted as 'the life expectancy', this is actually incorrect.

## 5 Data set used for calibration

The parameter values in the model above were determined with the maximum likelihood method. Mortality data and exposures were used from Western European countries and from the Netherlands. Throughout it was assumed that for given exposures $E_{x,t}$ the observed instances of death $D_{x,t}$ are Poisson distributed[14] and that the expected value of $\frac{D_{x,t}}{E_{x,t}}$ equals the force of mortality $\mu_x(t)$ to be modelled. In this paragraph we leave gender and EUR/NL indicators out of the notation.

Appendix C to this publication lists the exact data sources. The data from the Human Mortality Database (HMD) has been supplemented with some data from the Eurostat database (EUROS). For Dutch 2019 data the CBS database (Statline) was used.

In the last two databases mentioned we find the required death frequencies per gender, but not the exposures. However, these can be derived from other quantities that are given:

- $P_{x,t}$ : the population at 1 January of year $t$ aged between $x$ and $x+1$.
- $C_{x,t}$ : the number of people that have died within year $t$, who would have been between $x$ and $x$+1 years old at 31 December of year $t$.

Conversion to exposures is done using the method laid down in the HMD protocol[15]. For $x > 0$ this gives:

$$E_{x,t} = \tfrac{1}{2}\big(P_{x,t} + P_{x,t+1}\big) + \tfrac{1}{6}\Big(\tfrac{1}{2}C_{x,t} - \tfrac{1}{2}C_{x,t+1}\Big),$$

and for $x = 0$:

$$E_{x,t} = \tfrac{1}{2}\big(P_{0,t} + P_{0,t+1}\big) + \tfrac{1}{6}\Big(\tfrac{1}{2}C_{0,t} - \tfrac{1}{2}C_{0,t+1}\Big).$$

In the French Eurostat data a correction was made for mortality in overseas territories, to match French HMD data for earlier years.

[14] Brouhns, N., Denuit, M. and Vermunt, J.K. (2002) A Poisson log-bilinear regression approach to the construction of projected lifetables. *Insurance: Mathematics and Economics* 31, pp. 373-393.

[15] See http://www.mortality.org/Public/Docs/MethodsProtocol.pdf

# 6 Calibration method

The following steps are completed for both genders $g \in \{M, V\}$ separately:

- We take the exposures $E_{x,t}^{g,EU}$ and observed mortality rates $D_{x,t}^{g,EU}$ for the relevant Western European countries, with $x \in X^o = \{0,1,\dots,90\}$ and $t \in T^o = \{1970,1971,\dots,2018\}$. Each time, the sum of all exposures and the sum of all deaths in the countries concerned is taken, including the Netherlands. The parameters $A_x^g$, $B_x^g$ en $K_t^g$ are then set so as to maximise the Poisson likelihood function for the observed deaths given the exposures, i.e. we solve

$$\max_{\{A_x^g, B_x^g, K_t^g\}} \prod_{x \in X^o} \prod_{t \in T^o} \frac{\left(E_{x,t}^{g,EU} \mu_x^{g,EU}(t)\right)^{D_{x,t}^{g,EU}} \exp\left(-E_{x,t}^{g,EU} \mu_x^{g,EU}(t)\right)}{D_{x,t}^{g,EU}!}$$

  with $\mu_x^{g,EU}(t) = e^{A_x^g + B_x^g K_t^g}$. To obtain a unique specification of the three vectors, we normalise by imposing that the sum of the elements of $K_t^g$ over $t \in T^o$ equals $0$ and the sum of the elements of $B_x^g$ over $x \in X^o$ equals $1$.

- Data after 2018 is not available for all relevant countries. Hence, the values of $K_t^g$ in the previous step are determined until 2018. Then linear extrapolation is performed for:

$$K_{2019}^g = K_{2018}^g + \frac{K_{2018}^g - K_{1970}^g}{2018 - 1970}.$$

- The maximum likelihood is now applied to the Dutch data to determine $\alpha_x^g, \beta_x^g$ and $\kappa_t^g$ with

$$\max_{\{\alpha_x^g, \beta_x^g, \kappa_t^g\}} \prod_{x \in X^o} \prod_{t \in T^*} \frac{\left(E_{x,t}^{g,NL} \mu_x^g(t)\right)^{D_{x,t}^{g,NL}} \exp\left(-E_{x,t}^{g,NL} \mu_x^g(t)\right)}{D_{x,t}^{g,NL}!}$$

  with $\mu_x^g(t) = \mu_x^{g,EU}(t) e^{\alpha_x^g + \beta_x^g \kappa_t^g}$, $T^* = \{1983,\dots,2019\}$ (now starting in 1983 and including the year 2019) and $X^o = \{0,1,\dots,90\}$ as before. Again normalisation is done by setting the sum of the elements in $\kappa_t^g$ over $t \in T^*$ and $\beta_x^g$ over $x \in X^o$ to 0 and 1 respectively.

In this last step two time series $\{ (K_t^M, K_t^V) \mid t \in \{1970,\dots,1982\}$ and four time series $\{ (K_t^M, \kappa_t^M, K_t^V, \kappa_t^V) \mid t \in T^* \}$ are used to estimate the parameters $(\theta^M, \theta^V, a^M, a^V, c^M, c^V)$ and matrix $C$. Under the assumption that the variables $Z_t = (\epsilon_t^M, \delta_t^M, \epsilon_t^V, \delta_t^V)$ are independent and identically distributed following a four-dimensional normal distribution with mean (0,0,0,0) and covariance matrix $C$, we can set the estimators $(\theta^M, \theta^V, a^M, a^V, c^M, c^V)$ and $C$ so as to maximise the likelihood for these time series.

We use the equation $Y_t = X_t \Psi + Z_t$ with the following matrices voor t = 1970,…,1982

$$Y_t = \begin{bmatrix} K_{t+1}^m - K_t^m \\ K_{t+1}^v - K_t^v \end{bmatrix}, \qquad X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}, \qquad Z_t = \begin{bmatrix} \epsilon_t^m \\ \epsilon_t^v \end{bmatrix},$$

and the following matrices for t = 1983,…, 2018

$$Y_t = \begin{bmatrix} K_{t+1}^m - K_t^m \\ K_{t+1}^v - K_t^v \\ \kappa_{t+1}^m \\ \kappa_{t+1}^v \end{bmatrix}, \qquad X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & \kappa_t^m & 0 & 0 & 0 \\ 0 & 0 & 0 & \kappa_t^v & 0 & 0 \end{bmatrix}, \qquad Z_t = \begin{bmatrix} \epsilon_t^m \\ \epsilon_t^v \\ \delta_t^m \\ \delta_t^v \end{bmatrix}.$$

Next, $C$ and $\Psi$ are determined by optimising the log likelihood for the time series:

$$\arg\max_{C,\Psi} -\frac{1}{2}\mathrm{tr}\left[\tilde{C}^{-1}\sum_{t=1970}^{1982}(Y_t - X_t\Psi)(Y_t - X_t\Psi)'\right] - \frac{13}{2}\ln\left(\left|\tilde{C}\right|\right) - \frac{1}{2}(13\times 2)\ln(2\pi)$$

$$-\frac{1}{2}\mathrm{tr}\left[C^{-1}\sum_{t=1983}^{2018}(Y_t - X_t\Psi)(Y_t - X_t\Psi)'\right] - \frac{36}{2}\ln(|C|) - \frac{1}{2}(36\times 4)\ln(2\pi).$$

With $\tilde{C}$ the 2 x 2 submatrix consisting of the first two rows and first two columns of $C$.

## 7 Simulation of the time series

To be able to simulate scenarios for the time series $Z_t = (\epsilon_t^M, \delta_t^M, \epsilon_t^V, \delta_t^V)$ samples from a normal distribution with mean (0,0,0,0) and covariance matrix $C$ must be generated. This can be done by multiplying a (row) vector $\tilde{Z}_t$ of four independent standard normally distributed variables by a matrix H that meets $H^T H = C$, ergo by $Z_t = \tilde{Z}_t H$. Therefore, the list of parameters in the publication and the accompanying Excel spreadsheet include not only the covariance matrix $C$, but also a Cholesky matrix $H$.

## Parameter values

### Males

| x | A(x) | B(x) | alpa(x) | beta(x) |
|---|---|---|---|---|
| 0 | -4,914247095 | 0,020169298 | -0,061680987 | 0,018886773 |
| 1 | -7,487155801 | 0,018317373 | -0,017252908 | 0,004099924 |
| 2 | -7,941834928 | 0,019345023 | 0,057295702 | 0,022429227 |
| 3 | -8,186430736 | 0,020784116 | 0,013244777 | 0,016754881 |
| 4 | -8,374880309 | 0,021425724 | -0,029991152 | 0,019048939 |
| 5 | -8,476949363 | 0,022008088 | 0,014339758 | 0,026278493 |
| 6 | -8,557811710 | 0,022015266 | -0,032015052 | 0,005834950 |
| 7 | -8,624966357 | 0,022176933 | -0,027489103 | 0,034217140 |
| 8 | -8,660755925 | 0,020698951 | -0,048115755 | 0,022155714 |
| 9 | -8,711960709 | 0,020136833 | -0,106869702 | 0,021642261 |
| 10 | -8,733735230 | 0,019197474 | -0,000151698 | 0,018258148 |
| 11 | -8,665863521 | 0,017463483 | -0,102689736 | -0,003440330 |
| 12 | -8,592044684 | 0,016264352 | -0,017825042 | 0,040250803 |
| 13 | -8,464788667 | 0,015750435 | -0,005829345 | 0,018162686 |
| 14 | -8,246014647 | 0,014976607 | -0,111718271 | 0,016121966 |
| 15 | -7,981876456 | 0,014648749 | -0,173385320 | 0,015071023 |
| 16 | -7,606717723 | 0,015684493 | -0,117746820 | 0,028026921 |
| 17 | -7,332487713 | 0,015802693 | -0,287722410 | 0,024556552 |
| 18 | -7,024088136 | 0,014119887 | -0,474947955 | 0,026336764 |
| 19 | -6,954331184 | 0,013444357 | -0,394614193 | 0,026151343 |
| 20 | -6,933547621 | 0,012336411 | -0,399550396 | 0,018785886 |
| 21 | -6,925472332 | 0,011660137 | -0,398210124 | 0,014413243 |
| 22 | -6,937719802 | 0,011049754 | -0,416603752 | 0,010545512 |
| 23 | -6,948672419 | 0,009962205 | -0,368977474 | 0,008007554 |
| 24 | -6,962163789 | 0,009148673 | -0,367798075 | 0,016246053 |
| 25 | -6,962823982 | 0,008559407 | -0,378984285 | 0,002139667 |
| 26 | -6,954782388 | 0,008262343 | -0,368721498 | 0,017363750 |
| 27 | -6,943317944 | 0,008230282 | -0,420934567 | 0,004739583 |
| 28 | -6,920957040 | 0,007945164 | -0,376475483 | 0,004289316 |
| 29 | -6,887736743 | 0,007992853 | -0,362100822 | 0,002299198 |
| 30 | -6,854287037 | 0,007959857 | -0,387613277 | 0,013781927 |
| 31 | -6,812716797 | 0,007673834 | -0,362608547 | 0,010925476 |
| 32 | -6,769259411 | 0,007612844 | -0,345478142 | -0,000454407 |
| 33 | -6,719395625 | 0,007857925 | -0,358816830 | 0,008326944 |
| 34 | -6,660912180 | 0,007774203 | -0,364247114 | 0,010848107 |
| 35 | -6,594615977 | 0,007893596 | -0,349700281 | 0,003630588 |
| 36 | -6,524762786 | 0,008022308 | -0,374401012 | -0,000653025 |
| 37 | -6,450773587 | 0,008303332 | -0,358144471 | 0,008273432 |
| 38 | -6,371476884 | 0,008403313 | -0,368695079 | 0,011513432 |
| 39 | -6,283660062 | 0,008492422 | -0,359983863 | 0,015750531 |
| 40 | -6,192101202 | 0,008681686 | -0,361814406 | 0,007242108 |
| 41 | -6,104125568 | 0,008768747 | -0,356241024 | 0,008308809 |
| 42 | -6,009114203 | 0,008965052 | -0,338132646 | 0,013388011 |
| 43 | -5,913209828 | 0,008949958 | -0,335384147 | 0,015304740 |
| 44 | -5,819974999 | 0,009018261 | -0,319006077 | 0,006012250 |
| 45 | -5,720352330 | 0,009065768 | -0,339408904 | 0,007460733 |
| 46 | -5,626542554 | 0,009093567 | -0,333210712 | 0,008456080 |
| 47 | -5,529596076 | 0,009033748 | -0,308723225 | 0,019223465 |
| 48 | -5,436690864 | 0,009069069 | -0,292838523 | 0,006749232 |
| 49 | -5,336595794 | 0,009061882 | -0,294232056 | 0,010194992 |
| 50 | -5,236324063 | 0,009192646 | -0,283659832 | 0,007768840 |
| 51 | -5,145693527 | 0,009056994 | -0,268592977 | 0,006376597 |
| 52 | -5,049982729 | 0,009061124 | -0,257983295 | 0,005535926 |
| 53 | -4,957473481 | 0,009010183 | -0,236293964 | -0,004257372 |
| 54 | -4,860015030 | 0,009032334 | -0,236957779 | -0,004863678 |
| 55 | -4,768241800 | 0,009054346 | -0,212288231 | -0,002466806 |
| 56 | -4,677326159 | 0,009053090 | -0,207578578 | -0,002900097 |
| 57 | -4,583652176 | 0,009169516 | -0,178818718 | -0,006794076 |
| 58 | -4,492893343 | 0,009225685 | -0,167982499 | -0,004325915 |
| 59 | -4,402615671 | 0,009281159 | -0,166169224 | -0,006264570 |
| 60 | -4,305724324 | 0,009455223 | -0,143832733 | -0,004454817 |
| 61 | -4,216542674 | 0,009551577 | -0,137917760 | -0,002891537 |

| t | K(t) | kappa(t) |
|---|---|---|
| 1970 | 43,476185931 | |
| 1971 | 42,122441005 | |
| 1972 | 41,978359231 | |
| 1973 | 40,463659479 | |
| 1974 | 38,764418114 | |
| 1975 | 38,797540416 | |
| 1976 | 37,626343923 | |
| 1977 | 33,190494724 | |
| 1978 | 33,736509869 | |
| 1979 | 31,589061411 | |
| 1980 | 30,017109167 | |
| 1981 | 28,436663031 | |
| 1982 | 26,234007199 | |
| 1983 | 25,539808825 | -7,508551396 |
| 1984 | 22,001744120 | -5,775936278 |
| 1985 | 22,268630138 | -5,513230507 |
| 1986 | 19,926084064 | -4,176363486 |
| 1987 | 16,111413341 | -4,517362620 |
| 1988 | 14,205387761 | -3,401389850 |
| 1989 | 12,853301267 | -1,513635659 |
| 1990 | 12,954772747 | -2,350282504 |
| 1991 | 10,980823111 | -2,092044054 |
| 1992 | 8,028399951 | -1,473669332 |
| 1993 | 8,167355017 | 1,452052922 |
| 1994 | 3,860040059 | 0,016951602 |
| 1995 | 3,614301706 | 1,086927833 |
| 1996 | 1,200483546 | 2,444378659 |
| 1997 | -2,339111165 | 1,819678635 |
| 1998 | -4,376249094 | 2,754911459 |
| 1999 | -6,442564497 | 3,464564130 |
| 2000 | -9,901733972 | 4,324305008 |
| 2001 | -13,163761756 | 4,544153834 |
| 2002 | -14,810741948 | 5,139510536 |
| 2003 | -16,289954432 | 4,735066130 |
| 2004 | -22,397375637 | 3,561568490 |
| 2005 | -24,302158998 | 3,881898661 |
| 2006 | -28,096128459 | 2,937742850 |
| 2007 | -30,347393341 | 1,945874821 |
| 2008 | -32,442640494 | 0,963668304 |
| 2009 | -34,842262645 | 0,497186342 |
| 2010 | -37,288138880 | 0,108889433 |
| 2011 | -41,327808021 | -0,022136235 |
| 2012 | -42,312308562 | 0,731567789 |
| 2013 | -43,663982904 | -0,547213307 |
| 2014 | -48,135457772 | -1,467150243 |
| 2015 | -45,954852024 | -0,856360901 |
| 2016 | -48,710865025 | -0,492023484 |
| 2017 | -50,210041959 | -1,035881715 |
| 2018 | -50,789807569 | -1,486140883 |
| 2019 | -52,753682434 | -2,181524983 |

| | |
|---|---|
| theta | -1,963874502 |
| a | 0,934675399 |
| c | 0,195144902 |

## Males (continued)

| | | | | |
|---|---|---|---|---|
| 62 | -4,124464377 | 0,009750249 | -0,118218649 | -0,003744388 |
| 63 | -4,034069282 | 0,009938037 | -0,095871564 | -0,001392907 |
| 64 | -3,943735779 | 0,010125965 | -0,083178243 | 0,000953250 |
| 65 | -3,850953621 | 0,010340278 | -0,063880893 | -0,000018845 |
| 66 | -3,764213716 | 0,010397380 | -0,048322981 | 0,002337368 |
| 67 | -3,673176648 | 0,010657144 | -0,036561550 | 0,002744688 |
| 68 | -3,580337801 | 0,010720739 | -0,023786796 | 0,003339603 |
| 69 | -3,489956549 | 0,010790110 | -0,009558107 | 0,005400278 |
| 70 | -3,395647914 | 0,010893725 | -0,005934639 | 0,006679891 |
| 71 | -3,302593836 | 0,010788303 | 0,005897955 | 0,010243789 |
| 72 | -3,206945685 | 0,010821448 | 0,020278906 | 0,010919021 |
| 73 | -3,111678463 | 0,010712752 | 0,026821564 | 0,012174736 |
| 74 | -3,015503686 | 0,010598003 | 0,036294191 | 0,011461389 |
| 75 | -2,920026164 | 0,010428394 | 0,043259083 | 0,010957659 |
| 76 | -2,824051589 | 0,010199171 | 0,048880542 | 0,013486331 |
| 77 | -2,727658786 | 0,009916626 | 0,050756964 | 0,016369490 |
| 78 | -2,629435852 | 0,009580390 | 0,057888895 | 0,017075031 |
| 79 | -2,532037041 | 0,009340889 | 0,064717543 | 0,015174385 |
| 80 | -2,425940773 | 0,008997338 | 0,060180724 | 0,017882098 |
| 81 | -2,326830029 | 0,008492667 | 0,060306215 | 0,019689929 |
| 82 | -2,226286810 | 0,008113684 | 0,052877216 | 0,018925341 |
| 83 | -2,126831856 | 0,007697536 | 0,052808724 | 0,020534275 |
| 84 | -2,027723639 | 0,007307280 | 0,054035264 | 0,019174043 |
| 85 | -1,929639254 | 0,006808047 | 0,054901697 | 0,014515450 |
| 86 | -1,829141169 | 0,006355261 | 0,046369021 | 0,017739692 |
| 87 | -1,734530589 | 0,005895089 | 0,047438243 | 0,016254307 |
| 88 | -1,640108832 | 0,005414308 | 0,049618098 | 0,019323274 |
| 89 | -1,548025676 | 0,004916550 | 0,043107542 | 0,017938924 |
| 90 | -1,450435481 | 0,004580025 | 0,041504950 | 0,019442034 |

## Females

| x | A(x) | B(x) | alpa(x) | beta(x) |
|---|---|---|---|---|
| 0 | -5,150375131 | 0,020290890 | -0,007029546 | 0,021649904 |
| 1 | -7,637374567 | 0,018957943 | 0,022488271 | 0,000861945 |
| 2 | -8,187142677 | 0,019944707 | -0,004037867 | -0,006534060 |
| 3 | -8,427428764 | 0,020076227 | -0,049761923 | 0,001033341 |
| 4 | -8,618596243 | 0,020198009 | 0,020434402 | 0,014963483 |
| 5 | -8,747552361 | 0,020401466 | -0,051342702 | -0,001748524 |
| 6 | -8,809028460 | 0,019807786 | -0,097470586 | 0,017266357 |
| 7 | -8,927076448 | 0,020358655 | -0,060397932 | 0,012178637 |
| 8 | -8,964071698 | 0,018330369 | -0,128656579 | 0,014410851 |
| 9 | -9,006928213 | 0,017723333 | -0,002504341 | 0,011862470 |
| 10 | -9,017531975 | 0,016342220 | 0,010302964 | 0,017226136 |
| 11 | -8,998895882 | 0,015067238 | 0,031766065 | -0,006223224 |
| 12 | -8,925216420 | 0,014591694 | 0,114042715 | -0,003225829 |
| 13 | -8,838398510 | 0,013261162 | 0,108307853 | -0,011260058 |
| 14 | -8,669303950 | 0,013371109 | -0,042225395 | 0,015579106 |
| 15 | -8,460957004 | 0,013811463 | -0,104580324 | 0,013345226 |
| 16 | -8,261761026 | 0,014107371 | -0,089306381 | 0,010074683 |
| 17 | -8,152773244 | 0,013917980 | -0,134454949 | 0,025990661 |
| 18 | -7,985500797 | 0,012230750 | -0,258738458 | 0,000558742 |
| 19 | -7,976281040 | 0,011735842 | -0,240152153 | 0,013051336 |
| 20 | -7,982874093 | 0,011595404 | -0,218250647 | 0,006641284 |
| 21 | -7,995775065 | 0,011471043 | -0,184626800 | 0,007368164 |
| 22 | -7,997129705 | 0,011144318 | -0,159356651 | 0,008984157 |
| 23 | -7,984760418 | 0,010774176 | -0,143124619 | -0,000269570 |
| 24 | -7,970731110 | 0,010954855 | -0,192734685 | 0,001979090 |
| 25 | -7,933405992 | 0,010703583 | -0,122575306 | 0,002365326 |
| 26 | -7,892071369 | 0,010285376 | -0,148696734 | 0,002452919 |
| 27 | -7,849041941 | 0,010245108 | -0,117431769 | 0,006065697 |
| 28 | -7,796117833 | 0,009913338 | -0,090494244 | 0,008389016 |
| 29 | -7,731513466 | 0,009749204 | -0,074405613 | 0,007324214 |
| 30 | -7,662350107 | 0,010040815 | -0,094121879 | 0,009580362 |
| 31 | -7,603159363 | 0,009802443 | -0,065253720 | 0,000298826 |
| 32 | -7,519104119 | 0,009845926 | -0,101526901 | -0,001167743 |
| 33 | -7,436442855 | 0,009719975 | -0,044762649 | -0,003359710 |
| 34 | -7,354363698 | 0,009580589 | -0,058321563 | 0,006642930 |
| 35 | -7,265747384 | 0,009656270 | -0,074677087 | 0,005059493 |
| 36 | -7,179410832 | 0,009668237 | -0,066510710 | 0,005370429 |
| 37 | -7,094791168 | 0,009524070 | -0,081850199 | 0,013168477 |
| 38 | -7,002217871 | 0,009419542 | -0,076109782 | 0,009449084 |
| 39 | -6,904005125 | 0,009240751 | -0,078023888 | 0,009244756 |
| 40 | -6,811131129 | 0,009477688 | -0,039823056 | 0,008180005 |
| 41 | -6,714887832 | 0,009105325 | -0,046441613 | 0,012837006 |
| 42 | -6,617057957 | 0,009166864 | -0,042298921 | 0,013859566 |
| 43 | -6,512520819 | 0,009102111 | -0,044179858 | 0,006921276 |
| 44 | -6,419963208 | 0,008985680 | -0,032175507 | 0,015785246 |
| 45 | -6,322772709 | 0,008813964 | -0,032237268 | 0,009690380 |
| 46 | -6,226719244 | 0,008695300 | -0,001866612 | 0,017512317 |
| 47 | -6,130688191 | 0,008716784 | -0,004971971 | 0,017481954 |
| 48 | -6,036041149 | 0,008721339 | -0,003608409 | 0,014601320 |
| 49 | -5,945804828 | 0,008668793 | -0,012796525 | 0,015577874 |
| 50 | -5,852244883 | 0,008552960 | -0,030055298 | 0,017637747 |
| 51 | -5,771602173 | 0,008252527 | 0,002861113 | 0,016563692 |
| 52 | -5,682285768 | 0,008371414 | 0,015472459 | 0,014761469 |
| 53 | -5,605734753 | 0,008199932 | -0,006272620 | 0,016958671 |
| 54 | -5,521634295 | 0,008116420 | 0,013398969 | 0,012641382 |
| 55 | -5,438019081 | 0,007962599 | 0,001523622 | 0,014880324 |
| 56 | -5,357659504 | 0,007997843 | 0,017004797 | 0,011884091 |
| 57 | -5,271080981 | 0,008013016 | 0,013750651 | 0,012545522 |
| 58 | -5,187843958 | 0,008215957 | 0,023243993 | 0,014051093 |
| 59 | -5,102438821 | 0,008164111 | 0,013041512 | 0,013794288 |
| 60 | -5,007354346 | 0,008262882 | 0,020768175 | 0,015306331 |
| 61 | -4,924586734 | 0,008290081 | 0,031936334 | 0,012726450 |

| t | K(t) | kappa(t) |
|---|---|---|
| 1970 | 46,443547782 | |
| 1971 | 44,471629664 | |
| 1972 | 43,327019192 | |
| 1973 | 41,660918476 | |
| 1974 | 39,381135782 | |
| 1975 | 38,665594506 | |
| 1976 | 37,018092861 | |
| 1977 | 31,050839538 | |
| 1978 | 31,101343275 | |
| 1979 | 28,644090426 | |
| 1980 | 26,522094554 | |
| 1981 | 25,284413053 | |
| 1982 | 22,911576391 | |
| 1983 | 21,965766035 | -12,182077758 |
| 1984 | 17,401663616 | -9,107373962 |
| 1985 | 17,999822961 | -9,017950669 |
| 1986 | 15,639881731 | -7,537467674 |
| 1987 | 11,042560333 | -8,154380859 |
| 1988 | 9,518026690 | -7,244710013 |
| 1989 | 8,714522543 | -5,315386972 |
| 1990 | 9,491921333 | -6,833543225 |
| 1991 | 7,376801288 | -5,742029142 |
| 1992 | 3,908865215 | -4,641483540 |
| 1993 | 4,565580874 | -2,345124671 |
| 1994 | 0,089720167 | -1,705713306 |
| 1995 | -0,219117452 | -1,799475083 |
| 1996 | -1,976072741 | -0,498611998 |
| 1997 | -4,822142499 | -0,080727218 |
| 1998 | -6,726188501 | 0,863259755 |
| 1999 | -7,761709860 | 2,617134765 |
| 2000 | -11,028433009 | 4,039466040 |
| 2001 | -13,766270494 | 5,022504204 |
| 2002 | -14,076832750 | 5,207000343 |
| 2003 | -14,578547677 | 4,054161382 |
| 2004 | -21,652898016 | 5,098749152 |
| 2005 | -22,626834125 | 3,951637700 |
| 2006 | -26,018638484 | 4,655571626 |
| 2007 | -27,997713848 | 2,718299013 |
| 2008 | -28,574217537 | 3,122560658 |
| 2009 | -31,109061816 | 1,836345383 |
| 2010 | -33,050415314 | 2,602194755 |
| 2011 | -36,876779375 | 4,000537606 |
| 2012 | -36,134453048 | 3,845051374 |
| 2013 | -37,385435373 | 3,075406101 |
| 2014 | -42,130971463 | 3,761709043 |
| 2015 | -38,757291346 | 3,691545491 |
| 2016 | -41,771743749 | 5,087346672 |
| 2017 | -42,303058544 | 4,303013712 |
| 2018 | -42,852601260 | 4,853281111 |
| 2019 | -44,712937698 | 3,799280203 |

| | |
|---|---|
| theta | -1,860336002 |
| a | 0,948362701 |
| c | 0,407085135 |

## Females (continued)

| | | | | |
|---|---|---|---|---|
| 62 | -4,835237420 | 0,008564139 | 0,009268202 | 0,016859767 |
| 63 | -4,747370045 | 0,008783489 | 0,014163951 | 0,014546230 |
| 64 | -4,653696310 | 0,009092804 | 0,012199687 | 0,014455649 |
| 65 | -4,559169236 | 0,009321450 | 0,013571625 | 0,014034158 |
| 66 | -4,465944888 | 0,009464935 | 0,010033251 | 0,014771114 |
| 67 | -4,370147703 | 0,009830266 | 0,008582280 | 0,014347647 |
| 68 | -4,270066983 | 0,009970655 | 0,016120870 | 0,015276989 |
| 69 | -4,165762721 | 0,010264091 | 0,005918858 | 0,017105557 |
| 70 | -4,058853639 | 0,010466384 | 0,004038155 | 0,016901286 |
| 71 | -3,954223434 | 0,010625314 | 0,011377505 | 0,016449025 |
| 72 | -3,840389190 | 0,010836106 | -0,005358449 | 0,017318044 |
| 73 | -3,727955245 | 0,010963486 | -0,002208638 | 0,016905426 |
| 74 | -3,614478311 | 0,011117096 | -0,000279989 | 0,016418250 |
| 75 | -3,497944354 | 0,011166712 | 0,000859698 | 0,016551020 |
| 76 | -3,378078623 | 0,011089826 | -0,005090291 | 0,016553728 |
| 77 | -3,262353787 | 0,011097543 | 0,006016531 | 0,015536144 |
| 78 | -3,140271088 | 0,010870527 | 0,001774057 | 0,015472706 |
| 79 | -3,017350692 | 0,010680633 | -0,001164659 | 0,014152608 |
| 80 | -2,887136728 | 0,010333531 | 0,000610293 | 0,014264055 |
| 81 | -2,764598872 | 0,009953575 | 0,005741326 | 0,012984545 |
| 82 | -2,638989916 | 0,009653314 | 0,008187557 | 0,013549905 |
| 83 | -2,514836713 | 0,009258029 | 0,008948685 | 0,013341375 |
| 84 | -2,392969365 | 0,008909070 | 0,008289548 | 0,013196283 |
| 85 | -2,272646472 | 0,008310668 | 0,007463393 | 0,013303707 |
| 86 | -2,152074884 | 0,007850544 | 0,015693869 | 0,013288149 |
| 87 | -2,036494542 | 0,007246365 | 0,021718461 | 0,012635765 |
| 88 | -1,922923940 | 0,006743933 | 0,018720546 | 0,012215514 |
| 89 | -1,809435457 | 0,006175802 | 0,024905793 | 0,011427925 |
| 90 | -1,699907845 | 0,005644883 | 0,026357353 | 0,013291042 |

## Covariance and Cholesky matrices

| **Covariance matrix C** | | | | |
|---|---|---|---|---|
| | epsilon males | delta males | epsilon females | delta females |
| epsilon males | 2,293141130 | 0,428910558 | 2,585390765 | -0,464480172 |
| delta males | 0,428910558 | 0,878152988 | 0,476758077 | 0,532030561 |
| epsilon females | 2,585390765 | 0,476758077 | 3,360968811 | -0,544232019 |
| delta females | -0,464480172 | 0,532030561 | -0,544232019 | 1,079121574 |

| **Cholesky matrix C** | | | | |
|---|---|---|---|---|
| | epsilon males | delta males | epsilon females | delta females |
| epsilon males | 1,514312098 | 0,283237886 | 1,707303777 | -0,306726845 |
| delta males | 0,000000000 | 0,893268877 | -0,007629322 | 0,692856586 |
| epsilon females | 0,000000000 | 0,000000000 | 0,667850595 | -0,022864533 |
| delta females | 0,000000000 | 0,000000000 | 0,000000000 | 0,710258531 |

# APPENDIX B

## Model portfolios Technical provisions

To evaluate the impact on the technical provisions of model portfolios six model portfolios were used. The portfolios differ in gender (male and female) and average age (young, average and old). The model portfolios have a weighted (by provision) average age of 45 (young), 55 (average) and 65 (old).

The model portfolios contain the benefits lifelong old age pension (OAP) and lifelong Survivor's pension (SP).

Listed under male are the benefits accrued by male participants (including widows) and under females the benefits accrued by female participants (including widowers).

| | Males Young | | | Males Average | | | Males old | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | OAP (65) | SP (def) | SP (i.p.) | OAP (65) | SP (def) | SP (i.p.) | OAP (65) | SP (def) | SP (i.p.) |
| 30 | 15,000 | 10,500 | - | 1,500 | 1,050 | - | 500 | 350 | - |
| 40 | 25,000 | 17,500 | 150 | 8,500 | 5,950 | 1,000 | 3,000 | 2,100 | - |
| 50 | 10,000 | 7,000 | 450 | 15,000 | 10,500 | 2,000 | 7,000 | 4,900 | 200 |
| 60 | 7,500 | 5,250 | 450 | 15,000 | 10,500 | 2,000 | 15,000 | 10,500 | 5,000 |
| 70 | 3,500 | 2,100 | 600 | 8,500 | 5,100 | 500 | 15,000 | 9,000 | 10,000 |
| 80 | 1,500 | 750 | - | 3,500 | 1,750 | 150 | 15,000 | 7,500 | 5,000 |
| 90 | - | - | - | 500 | 200 | - | 10,000 | 4,000 | 2,000 |

**Table B.1** Accrued rights per type of benefit for model portfolio males

| | Females Young | | | Females Average | | | Females old | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | OAP (65) | SP (def) | SP (i.p.) | OAP (65) | SP (def) | SP (i.p.) | OAP (65) | SP (def) | SP (i.p.) |
| 30 | 7,500 | 5,250 | 50 | 2,500 | 1,750 | - | 750 | 525 | - |
| 40 | 20,000 | 14,000 | 150 | 7,500 | 5,250 | 100 | 1,000 | 700 | - |
| 50 | 15,000 | 10,500 | 250 | 12,500 | 8,750 | 250 | 5,000 | 3,500 | 250 |
| 60 | 5,000 | 3,500 | 50 | 10,000 | 7,000 | 250 | 10,000 | 7,000 | 500 |
| 70 | 1,000 | 600 | - | 7,500 | 2,250 | 100 | 12,500 | 3,750 | 1,000 |
| 80 | - | - | - | 5,000 | 1,000 | - | 10,000 | 2,000 | 500 |
| 90 | - | - | - | 1,000 | 100 | - | 5,000 | 500 | 250 |

**Table B.2** Accrued rights per type of benefit for model portfolio females

**Modelportfolio premium level**
For the effect on premium levels a single model portfolio was used. Table B.3 lists the accrual by age in any year.

| | Males | | Females | |
|---|---|---|---|---|
| age | OAP (68) | SP (def) | OAP (68) | SP (def) |
| 30 | 600 | 420 | 400 | 280 |
| 40 | 750 | 525 | 500 | 350 |
| 50 | 800 | 560 | 550 | 385 |
| 60 | 600 | 420 | 400 | 280 |

**Table B.3** Rights accrual per type of benefit for model portfolio premium levels

For the survivor's pension risk premium 40 years of service are assumed (in service at age 28, retirement at age 68). For schemes with old age pension and risk only survivor's pension this means assuming 40 service years for all participants. For funds with survivor's pension accrual, the survivor's pension risk premium is based on future service years (68 minus current participant age minus 1).

**Actuarial assumptions**
The technical provisions and premiums for these portfolios are calculated using the following assumptions:

- Life tables: Projections Life Table AG2018 and Projections Life Table AG2020, starting year 2021
- Age corrections and/or experience mortality: none
- Discount rate: 1% and 3%
- Retirement age: 65 for provisions and 68 for premiums
- For deferred survivor's pensions the following applies:
  - Undetermined-partner system prior to retirement age with a 100% partner frequency, determined-partner system after that.
  - 3 years age difference between man and woman (man older than woman)
  - Different genders for participant and spouse.
- Lump sum rates for old age pension and survivor's pension in payment are set by taking the average of in advance and in arrears payments.

# APPENDIX C

## Literature and data used

**This report makes use of the data as was available in the Eurostat, CBS (Statline) and HMD databases at the end of June 2020.**

[1] CBS data from Statline for 2019:
Exposures-to-Risk (P-values);  version of June 10$^{th}$, 2020.
https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37325/table?ts=1530795309853
Observed Deaths (C-values and D-values); version of June 10$^{th}$, 2020:
https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37168/table?ts=1530802763004

[2] Eurostat data (data until 2018):
Exposures to Risk (demo_pjan) version of February 24$^{th}$, 2020:
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_pjan&lang=en
Observed Deaths (demo_mager en demo_magec) version of March 2$^{nd}$, 2020:
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_mager&lang=en
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_magec&lang=en

[3] HMD-database:
http://www.mortality.org/

Table C.1 shows for each geographical area and each year which data source was used as input for the AG2020 model. The Eurostat data definition for France was changed at the end of 2012: since that time it includes data from overseas territories. This was compensated for in the French Eurostat data using the difference between populations according to both definitions (the P values) as observed at January 1$^{st}$, 2013 and the difference in mortality for each age (the C values) observed in 2012.

| GEO | 2013 through 2016 | 2017 | 2018 | 2019 | HMD-version |
|---|---|---|---|---|---|
| Austria | HMD | HMD | ***EUROS*** | | 2018.09.03 |
| Belgium | HMD | HMD | HMD | | 2019.09.06 |
| Denmark | HMD | HMD | HMD | HMD | 2020.03.20 |
| Finland | HMD | HMD | HMD | | 2019.12.02 |
| France (metropolitan) | HMD | HMD | ***EUROS*** | | 2019.11.01 |
| Germany (until 1990 former territory of the FRG) | HMD | HMD | ***EUROS*** | | 2018.12.17 |
| Iceland | HMD | HMD | HMD | | 2020.04.02 |
| Ireland | HMD | HMD | ***EUROS*** | | 2019.10.01 |
| Luxembourg | HMD | HMD | ***EUROS*** | | 2019.12.10 |
| Netherlands | HMD | HMD | HMD | **CBS** | 2020.04.03 |
| Norway | HMD | HMD | HMD | | 2019.11.21 |
| Sweden | HMD | HMD | HMD | | 2020.01.09 |
| Switzerland | HMD | EUROS | EUROS | | 2020.05.08 |
| United Kingdom | HMD | ***EUROS*** | ***EUROS*** | | 2018.05.28 |

**Table C.1** Data sources AG2020

To generate the 2020 virtual data points in the Covid-19 impact sensibility analysis the weekly mortality data from CBS up to and including week 21 plus preliminary data from the Short-term Mortality Fluctuations dataset in the Human Mortality Database were used.

In addition, the most recent population and migration data from Eurostat were used to derive virtual exposures in 2020.

**Literature**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V. Kannisto. (1992). Development of the oldest – old mortality, 1950-1980: evidence from 28 developed countries. Odense University Press.

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Reukers et al. (2019), Annual report Surveillance of influenza and other respiratory infections in the Netherlands: winter 2018/2019, RIVM.

CBS (2018), 'Meer sterfgevallen in wintermaanden', CBS. URL visited May 18th, 2020.

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# APPENDIX D

## Glossary

### State Pension retirement age
Age at which a person becomes eligible to receive State Pension retirement benefit (AOW).

### Best estimate
In this publication: the most likely value for a quantity subject to chance, such as a mortality probability, the value of a product or portfolio etc.

### Cohort life expectancy
Life expectancy based on a projections life table allowing for expected future mortality developments in the following calander years. To calculate cohort life expectancy at birth, mortality probabilities are needed for a newborn today, a 1-year-old in one-year's time, a 2-year-old in two years' time and so on.

### Eurostat database
The database of Eurostat (the European Union's bureau of statistics) offers a wide range of data, for use by governments, companies, the education sector, journalists and the broader public.

### Human Mortality Database (HMD)
International database containing population and mortality data from over 40 countries worldwide.

### Survivor's pension in payment (SP in payment)
An insurance where the surviving spouse (the co-insured) of the main insured person gets periodic payments after the main insured person is deceased.

### Kannisto closure of the table
A method to obtain mortality probabilities for high ages from mortality probabilities of lower ages through extrapolation.

### Deferred survivor's pension (deferred SP)
An insurance – linked to old age pension – in which a provision is formed to pay out periodic benefits to the survivor after the main insured person is deceased, as long as the survivor lives.

### Old age pension (OAP)
An insurance where the insured participant (main insured person) receives periodic benefit payments after reaching the retirement age for as long as that person lives.

## Period life expectancy
Life expectancy based on mortality probabilities in a certain period, usually one calender year. This expectancy assumes that mortality probabilities are stationary over time. To calculate period life expectancy current probabilities are used as the probabilities needed for 1 or 2 years from now. Thus, period life expectancy does not account for expected future developments in mortality. This definition is often used to compare developments in time, but must not be used to estimate the expected longevity of individuals.

## Projection period
The number of future years over which -within the model- mortality levels are stated.

## Projections life table
Mortality table in which mortality rates are given for each future year. This provides a mortality probability for each combination of age and observation year. This offers the possibility to calculate a remaining life expectancy for every age and every (future) starting year.

## Statline
Statline is the public database of Statistics Netherlands (CBS). It provides statistics on economics, the Dutch population and our society.

## Stochastic model
Model in which future mortality probabilities are not fixed but are defined by means of probability distributions.

## Stochastic projections life table
Projections life table that results from using a stochastic model and hence assumes different values in different realisations of the random variables (as can be seen in the simulations).

# PROJECTIONS LIFE TABLE AG2020