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Netspar DESIGN PAPERS

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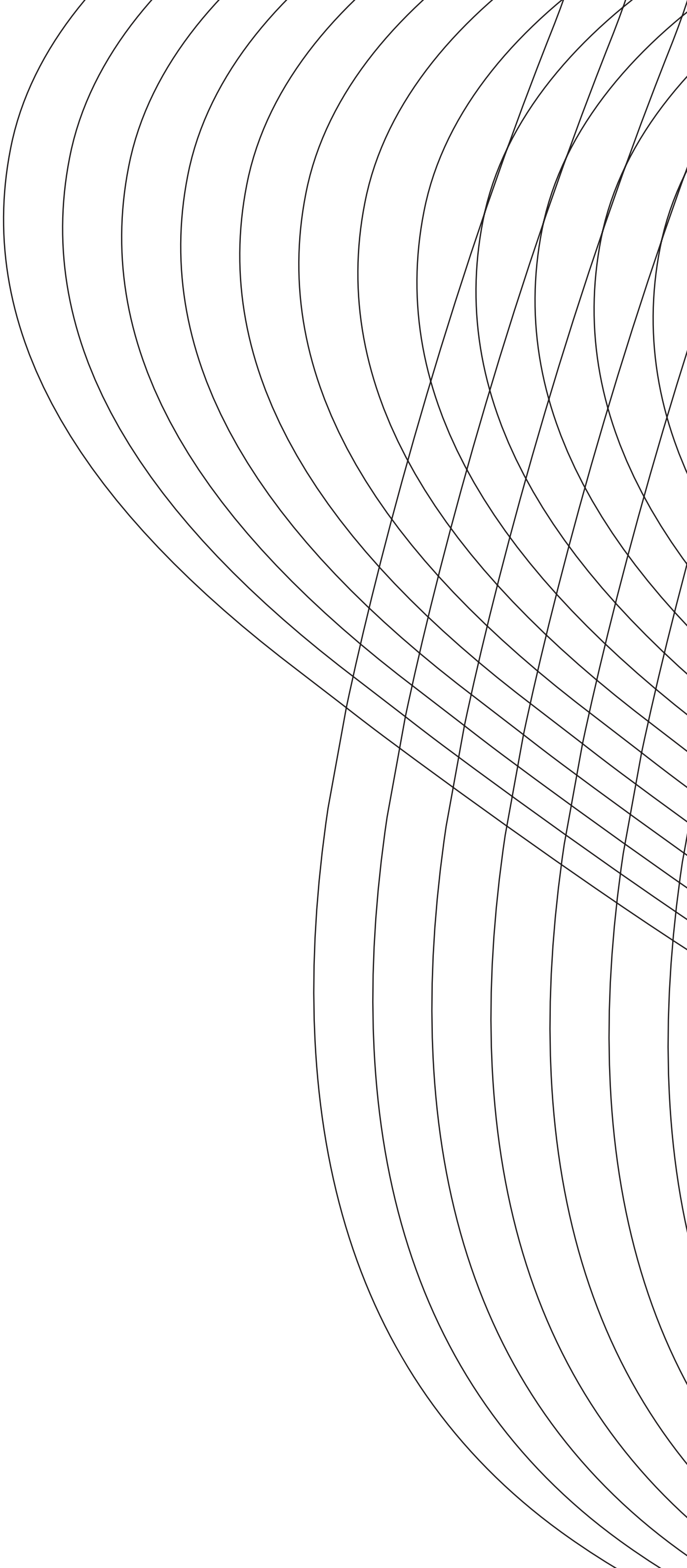
The longevity risk of the Dutch Actuarial Association's projection model



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PREFACE

Netspar seeks to stimulate debate on the effects of aging on the behavior of men and women, (such as what and how they save), on the sustainability of their pensions, and on government policy. The baby boom generation is approaching retirement age, so the number of people aged 65 and over will grow fast in the coming decades. People generally lead healthier lives and grow older, families have fewer children. Aging is often viewed in a bad light since the number of people over 65 years old may well double compared to the population between 20 and 65. Will the working population still be able to earn what is needed to accommodate a growing number of retirees? Must people make more hours during their working career and retire at a later age? Or should pensions be cut or premiums increased in order to keep retirement benefits affordable? Should people be encouraged to take personal initiative to ensure an adequate pension? And what is the role of employers' and workers' organizations in arranging a collective pension? Are people able to and prepared to personally invest for their retirement money, or do they rather leave that to pension funds? Who do pension fund assets actually belong to? And how can a level playing field for pension funds and insurers be defined? How can the solidarity principle and individual wishes be reconciled? But most of all, how can the benefits of longer and healthier lives be used to ensure a happier and affluent society?

For many reasons there is need for a debate on the consequences of aging. We do not always know the exact consequences of aging. And the consequences that are nonetheless clear deserve to be made known to a larger public. More important of course is that many of the choices that must be made have a political dimension, and that calls for a serious debate. After all, in the public spectrum these are very relevant and topical subjects that young and old people are literally confronted with.

For these reasons Netspar has initiated Design Papers. What a Netspar Design Paper does is to analyze an element or aspect of a pension product or pension system. That may include investment policy, the shaping of the payment process, dealing with the uncertainties of life expectancy, use of the personal home for one's retirement provision, communication with pension scheme members, the options menu for members, governance models, supervision models, the balance between capital funding and pay-as-you-go, a flexible job market for older workers, and the pension needs of a heterogeneous population. A Netspar Design Paper analyzes the purpose of a product or an aspect of the pension system, and it investigates possibilities of improving the way they function. Netspar Design Papers focus in particular on specialists in the sector who are responsible for the design of the component.

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THE LONGEVITY RISK OF THE DUTCH ACTUARIAL ASSOCIATION'S PROJECTION MODEL

Abstract

Accurate assessment of the risk that arises from further increases in life expectancy is crucial for the financial sector, in particular for pension funds and life insurance companies. The Dutch Actuarial Association presented a revised projection model in 2010, while in the same year two fundamentally different approaches were published by other institutions. This situation invites study of the consequences that the choice of projection model has on estimates of future life expectancy, which is the purpose of this paper. We firstly compare the three approaches against theoretical findings in the international literature. Secondly, we compare their outcomes in terms of period and cohort survival. In addition, we estimate the impact of each model on the present value of future pension payments. Our results indicate that, even in the short term, remarkable differences in life expectancy occur that also translate into different pension values. The literature review suggests that there is currently no blueprint for mortality projections; that calls for the application of various approaches to discount the uncertainty of the individual models. Instead of relying on extrapolation methods only, the pension sector should also take expert-driven forecasts into account as well as approaches that model causal influences on mortality. The model of the Actuarial Association could be improved by taking cohort influences into account as well as the estimate of uncertainty

bounds around the outcome measure. Also, the consistency of the projection in terms of the age and gender dimensions but also other countries should be enhanced.

1. Background

Projections of survival and longevity play a central role in almost all actuarial calculations related to pension and life insurance, such as the market value of liabilities of pension funds and the indexation of pensions, and in the discussion of retirement age. Given the large effect of changes in survival on the future size and age composition of the population, an accurate estimate of future survival is also central to the projection of future healthcare costs and other government spending.

The uncertainty about the survival of present and future pension recipients is an important source of uncertainty for the actuarial sector (Actuarieel Genootschap 2007). This uncertainty, termed as "macro longevity risk", can be broken down into process risk (referring to the stochastic nature of an individual lifespan in general) and model risk (related to the appropriate choice of a parsimonious statistical model to estimate the "real" distribution of future survival prospects) (Pitacco, Denuit et al. 2009; De Waegenaere, Melenberg et al. 2010).

This paper focuses on the model risk, as we aim to assess the consequence of the choice of projection model on longevity. We compare the "forecast tables" prepared by the Dutch Actuarial Association ("Actuarieel Genootschap" or AG), to give the insurance sector insight into the expected future trends in survival and life expectancy in the Netherlands (Actuarieel Genootschap 2007), against two other national projections. For comparison we used the projection by Janssen and Kunst (2010), which is part of the Public Health Forecast – Volksgezondheid Toekomst Verkenningen (VTV), and that by Statistics Netherlands (CBS) in the context of the national population forecast (Van Duin and Garssen 2010; Van Duin, de Jong et al. 2011). We evaluate the different projections of short-term and long-term trends in period life expectancy, future survival of currently living cohorts, and implications for the value of pension annuities.

Structure of the paper

We firstly review the international literature on mortality projections, thereby placing the AG approach and its alternatives in a broader scientific context. Next, we describe the three projections and compare the methods and outcomes. We close the paper with suggestions and considerations for the next AG projection model[1].

1 The AG projection was evaluated by an external expert committee (Van de Poel, Palm and Nijman) in 2010. Chapter 6 refers to this evaluation.

2. Literature review

Any projection model has to consider two fundamental questions: (1) what is the forecast object, and (2) how is that to be forecasted.

Model life expectancy or mortality rates?

For mortality projections the exceptionally high dimensionality of age-specific mortality is a major challenge (Booth and Tickle 2008). A straightforward solution is the projection of a measure of centrality only. Oeppen and Vaupel suggest extrapolating life expectancy linearly (2001) since this fits better in any country than modeling age-specific mortality rates (White 2002). Nonetheless, linear extrapolation of life expectancy has two drawbacks. First, for many applications the age profile of mortality is more relevant; for instance, the calculation of pension plan or healthcare expenditures requires information by age. Second, there are notable exceptions from the general linear and converging international trend (Meslé and Vallin 2006). The Netherlands is one of these exceptions.

Competing philosophies of forecasting

There are several philosophies to model and forecast the age distribution of death. Booth and Tickle (2008) distinguish *extrapolation*, *expectation*, and *explanation* approaches. Extrapolation covers all attempts that project future rates based on extrapolation of historical data. Expectation involves either the forecaster or consulted experts making assumptions about future levels or trajectories of mortality, often based on biomedical considerations. The practice of building scenarios, assuming upper limits of life expectancy, convergence to low-mortality groups, or including theoretical knowledge on human aging are examples of the expectation approach. Explanation also relies on external knowledge, by including determinants of mortality such as smoking and obesity in the projection model.

2.1 Extrapolation

Linear extrapolation methods represent the most straightforward way of projecting age-specific mortality rates. They can be classified according to the three dimensions of the Lexis surface, which assigns a period, an age, and a cohort to every death event (Tabeau, Jeths et al. 2001). Booth and Tickle (2008) refer to this as zero-factor, one-factor, two-factor, and three-factor models.

Zero-factor models

Zero factor approaches are characterized by the non-use of a function for one of the three Lexis dimensions. The use of constant reduction factors for projecting separate death probabilities for each age and gender, as commonly done by actuaries (Pitacco, Denuit et al. 2009), is a typical example. The reduction factor is either an average of past improvements or derived via a model (Renshaw and Haberman 2006). The robustness of the results depends on the appropriate choice of the historical reference period (Booth, Maindonald et al. 2002). Using separate factors may yield inconsistent future age profiles or need additional assumptions to assure consistency (Ediev 2009).

One-factor models

One-factor models usually reduce the roughly one hundred dimensions of age by applying a mortality law and then extrapolating its parameters to the future (Booth and Tickle 2008). The use of mortality laws solves the problem of inconsistent future age profiles that zero-factor models often suffer from and reduces the number of parameters noticeably. However, since they model mortality for each single period separately it is less clear how this could be used to forecast mortality over time (Pitacco, Denuit et al. 2009). Typical problems are the interdependence of parameters and fluctuations in yearly estimates. For these reasons law-based estimates are rarely used (De Waegenaere, Melenberg et al. 2010).

Two-factor models

Two-factor models are probably most commonly used to forecast mortality. The most prominent two-factor model has been proposed by Lee and Carter (1992), today sometimes referred to as the golden standard of forecasting (Li and Chan 2007). This approach factorizes the surface of mortality rates into its principal components: a vector representing the age profile, a vector for the time trend, and finally a vector expressing the average age-specific deviations of mortality change over the entire fitting period. By estimating and projecting the time trend as random walk with drift, it explicitly models mortality over time as a stochastic process and produces uncertainty bounds around the estimate. Several extensions and modifications have been suggested meanwhile, as for instance by Lee and Miller (2001) and Lee and Li (2005). The Lee-Carter model is comparably simple and at the same time explains a large proportion of the variance in death rates (Booth and Tickle 2008). Its original version faced the drawback of assuming fixed age-specific levels of improvement of survival for an entire period. This is very unlike as in the past an aging of mortality decline was observed (Horiuchi and Wilmoth 1997). To relax this, the Cairns-Blake-Dowd projection model was developed (Cairns, Blake et al. 2006). The CBD model allows modeling two time indices: the intercept indicating the general trend in mortality and the slope term representing changing age-specific dynamics (Cairns, Blake et al. 2007). Age is modeled as a continuous variable. A limitation is that the logit transformation of the death probability allows using the approach only for older persons (aged 40+).

Three-factor models

Three-factor models include an additional term to allow for cohort effects. As the cohort is a linear combination of age and period, further constraints are necessary to provide a unique solution. Renshaw and Haberman (2006) suggested an age-period cohort (APC) variant of the Lee-Carter model that seems to be superior to the two-factor model (Booth and Tickle 2008). Likewise, a cohort extension for the CBD model has been proposed (Cairns, Blake et al. 2007). In a systematic comparison Haberman and Renshaw (2011) concluded that the additional cohort parameter can provide better projections, although it should only be included if cohort effects are indicated.

The development from zero-factor up to three-factor models demonstrates the general trend in this field to achieve progress by including more parameters in the equations. Despite this trend there is a consensus that simpler methods often produce more robust and reliable outcomes, which is also confirmed by back-testing different models against historical data (Booth, Hyndman et al. 2006; Dowd, Cairns et al. 2010).

Coherence more important than goodness of fit

Recently a tendency for coherent approaches can be witnessed. Coherence among subgroups defined by age, gender, and country/region is thereby enhanced at the cost of the model fit to group-specific data. Examples are the extension of the Lee-Carter model to estimate trends in several countries at once (Li and Lee 2005) and the product ratio method to forecast the geometric mean of subpopulation rates (Hyndman, Booth et al. 2011). King and Soneij (2011) used a Bayesian hierarchical forecasting model to include prior information in the forecasting model, such as smooth age and time patterns and smoking and obesity prevalence.

Misleading cause-of-death information

All-cause mortality projections based on different causes of death are intended to increase the transparency of the models, but they actually lead to new and more serious problems. First, there is a systematic bias in the cause information due to misdiagnosis and multi-morbidity especially at older ages (Oeppen 2008). In addition, the international classification of causes of death (ICD) and coding practices have changed over time, which may lead to inconsistent time series. A methodological problem is that, over time, diseases with a recently stagnating decline or increase in death rates gain weight, leading to potentially absurd patterns in the long run (Caselli, Vallin et al. 2006). Cause-of-death projections tend to be too pessimistic and exceptionally sensitive to the length of the reference period (Wilmoth 1995). There is consensus that projections based on causes of death generally perform worse than the direct projection of all-cause mortality (McNown and Rogers 1992; Wilmoth 1995; Caselli, Vallin et al. 2006; Willets 2006; Booth and Tickle 2008).

2.2 Expectation

Expectation is used by many statistical institutions, which calculate a best guess and add a high and a low variant as deterministic scenario (Cruijsen and Eding 2001). An elaborate method to include opinions of experts via a Delphi method to forecast life expectancy has been proposed by Lutz et al. (1997).

Here, probability distributions for the estimates are derived from expert discussions in order to simulate point and interval trajectories of future mortality in a probabilistic manner.

Other ways to incorporate theoretical knowledge have been developed, for example by Olshansky, Goldman et al. (2009) and Bongaarts (2004), that model alternative possible trajectories of mortality decline. Olshansky modeled ageing-related intrinsic mortality (i.e. total mortality minus accidents, homicide and suicide) either as a fixed pattern shifting to later ages or as a slowing rate of aging due to biomedical interventions.

There is consensus that expectation approaches rarely provide a better fit to historical data than extrapolation methods. Contrary to extrapolation approaches, scenario-based forecasts are able to project the future to be different from what has been observed in the past. For instance, they take into account that mortality related to certain diseases or unfavorable lifestyle factors can change, either because of a change in the prevalence of the diseases or lifestyle factors, or in their consequences for mortality. Unfortunately experts tend to be too conservative about future trends and to underestimate possible changes (Ahlberg and Vaupel 1990).

2.3 Explanation

To this date, a sufficient explanation of life expectancy trends has not been found. King and Soneji (2011) argue that despite this drawback at least some causal empirical regularities from health and demography literature can be used, such as obesity and smoking patterns. However, this requires estimates on the effect of a certain risk factor on mortality and the delay between exposure and death. Forecasts for different populations are dependent on the validity of these estimates. Also, in addition to the projection of mortality, a projection of the risk factors is necessary. Another problem is that the quality of risk factor data is generally lower than that of mortality data. Nonetheless, explanatory forecasts seem to be valuable for certain applications. In particular, information on smoking is considered useful (Rostron and Wilmoth (2011). Wang and Preston (2009) found that adding a smoking-specific cohort term to a Lee-Carter model explains 20 percent more of the variation between countries.

2.4 General considerations: Historical period and uncertainty

Next to the decision for a certain projection philosophy, two important decisions must be made: first, the selection of the data to which the model is fitted and, second, how the uncertainty of this data is incorporated in the model.

Choice of historical period

Mainly for the extrapolation approach, but also for expectation and explanation, the period selected for the forecast strongly influences the outcome (Janssen and Kunst 2007). The original Lee-Carter method suggests using about ten to twenty years as reference. Lee and Miller (2001) found that extension of the historical period to the second half of the twentieth century improves the forecast. Pitacco, Denuit et al. (2009) demonstrated for Belgian data that the Lee-Carter method performs worse for shorter reference periods (30 and 40 years) and best when choosing 50 years. To increase robustness, Janssen and Kunst (2007) recommend using a reference period that is at least as long as the projection horizon. However, in their view the presence of an abrupt trend change calls for a shorter period, which indicates that there is a trade-off between having at least as many years of sample data as the length of projection and using the most recent (preferably linear) robust trend only. Booth et al. argue that in particular for the Lee-Carter method, but also in general, the observations for the model fit show a more or less stable linear trend and are free of trend breaks (Lee and Miller 2001; Booth, Maindonald et al. 2002). To reduce subjective influences, they suggest using a statistical goodness-of-fit criterion for selecting the reference period, which is supported by comparable analyses of Ediev (2009). However, using the most recent linear period also involves the risk of extrapolating unusual temporary trends far into the future. Some researchers argue that choosing the right model will solve the problem of selecting the best reference period (Pitacco, Denuit et al. 2009).

Dealing with uncertainty

Several forecasting experts agree that projections should generally assign a probability to each possible outcome (Goldstein 2004; Booth and Tickle 2008). This could be derived from ex-post errors observed in the historical data or from ex-ante errors based on expert judgments or prior distributions (Booth and Tickle 2008). Some argue that approaches should be favored that produce individual sample paths to allow for bootstrapping (Cairns, Blake et al. 2008). Using the percentiles of the bootstrapping re-sampling procedure has the advantage of obtaining confidence intervals without assuming a prior distribution (Pitacco, Denuit et al. 2009).

2.5 Conclusions of the review

In recent years an exponential increase in proposed methods and extensions to forecast mortality has been witnessed, in an effort to tackle the most serious problems of classic approaches. Within the paradigm of extrapolation, much progress has been achieved in providing less restrictive models than the original Lee-Carter model. However, this necessarily leads to more complex models that present new challenges. As indicated above, two new streams for modeling future death rates have meanwhile emerged, namely explanation and expectation, in addition to the prior idea of extrapolation.

The literature review outlines important considerations for mortality forecasting.

- For countries where a linear-like pattern prevails for life expectancy and the logarithm of death rates, the Lee-Carter model provides a useful benchmark even though recent alternatives, such as the Cairns-Blake-Dowd model, are to be recommended. It is unclear which model should be preferred in countries with distinct non-linear patterns of mortality such as the Netherlands.
- For long-term projections consistency and coherence are important, such as non-crossing trajectories for gender-specific and age-specific mortality. For short-term projections, taking non-linear trends into account may be more relevant. For this purpose, a trade-off between model fit and compatibility to generally observed trends and consistency has to be reflected in the model.
- Cause-of-death specific information does not improve the forecast of all-cause life expectancy. Not only data problems but also methodological problems remain unsolved, although promising methods have been published (Oeppen 2008; Hyndman 2010). Three-factor models (Renshaw and Haberman 2006) can be applied to capture the variation that is indirectly induced by specific cause-of-death trends.

The literature review has, however, also shown that there is no blueprint for mortality projections. Given the relevance of mortality projections as a "primary source of risk" for the insurance and pension sector (Cairns, Blake et al. 2006), it is unfortunate that no standard approach or set of generally agreed guidelines exists. It is even more disturbing that, in the past, increases of life expectancy were not only underestimated by *any* projection (Keilman 1997; Oeppen and Vaupel 2002) but that their accuracy also did not improve over the past three decades (Keilman 2008). Also, the seemingly reasonable tendency to use more parameters and/or more data to reduce model and parameter risk is not a guarantee for better projections. As Caselli, Vallin et al. (2006) pointed out: *"More complex data or more sophisticated methods are not themselves a guarantee for better results. Numerous experiences of this nature have ended up more as a disappointment than anything else."* It is recommended that important decisions be based on more than one approach (Seematter-Bagnoud and Paccaud 2010).

3. Dutch projections

3.1 The AG 2010 projection

In 2007 the Dutch Actuarial Association presented its first projection of future life expectancy, based on the extrapolation approach (Actuarieel Genootschap 2007). This was refined in 2010 (Actuarieel Genootschap 2010).

Motivation for a new forecasting approach in 2010 and its innovations

The 2007 forecasting model of the AG (2005–2050) extrapolated mortality, based on the 1988–2005 period and assuming a constant mortality reduction factor. Deviations of more than half a year between the 2007 AG forecast of life expectancy at birth and the realized life expectancy during the 2001–2008 period occurred, which is substantial for such a short time after the projection had been published. According to the AG, the deviation was due to two reasons. First, the reference period for the extrapolation (1988–2005) was characterized by a much lower average increase in life expectancy than observed since 2001. Second, the 2007 projection relied on 5-year period tables instead of single calendar years, so that short-term fluctuations – and thus also trend reversals – appear with a certain delay and more moderately.

To overcome these problems and achieve greater flexibility, several changes were made in the 2010 projection. First, a short-term trend was added in the model, based on a shorter and more recent reference period (2001–2008), and for the long-term trend the reference period was extended by three years, now including the years 1988 through 2008. Second, the AG decided to use two-year period tables, as a compromise between five-year averaging with too little fluctuation and a single year with too much fluctuation. As a result of these two innovations, the recent steeper increase in life expectancy gained more weight in the projection than before. Finally, the projection horizon was extended by ten years to 2060 to fulfill the special needs of pension and life insurance companies. To produce a smooth pattern of mortality over age, graduation techniques were applied (Actuarieel Genootschap 2007).

Tests using the same data as in the 2007 approach showed that the 2010 approach anticipated the increase in life expectancy better, with a deviation of only about 0.1 years. In addition the long-term mortality improvement was larger, as life expectancy at birth in 2050 was, according to the 2010 projection, three years longer compared to the 2007 projection (85.5 years for men and 87.3 years for women) (AG Prognosetafel Model 2010-2060).

Approach of the 2010 forecast

To project future mortality risk, the AG first constructed the goal table for the last year of the projection (2060) by applying separate mortality reduction factors for each single age and gender, based on the two reference periods. The two age-specific reduction factors, RF^{ST} for the short and RF^{LT} for the long-term trend, were computed as follows:

$$RF_x^{ST} = \left(\frac{q_x(2007,2008)}{q_x(2001,2002)} \right)^{\frac{1}{6}} \tag{1}$$

$$RF_x^{LT} = \left(\frac{q_x(2007,2008)}{q_x(1987,1988)} \right)^{\frac{1}{20}} \tag{2}$$

The last observed value $q_x(2008)$ was then multiplied 52 times by the long-term reduction factor RF^{LT} to construct the goal table for 2060. In addition to this long-term trend, the rate of reduction of the death probability RF^{ST}, based on observations for 2001–2008, was included as multiplier for the mortality risk of the last observed period. In this way the annual mortality risk decreases by the short-term reduction factor until it finally reaches the value of the goal table in 2060. The influence of the steeper short-term trend thus decreases exponentially over time. The whole procedure fixes the start and end points of the projection as the linear extrapolation of log death rates, at the same time allowing a non-linear trajectory towards the goal table. This is performed separately for each single year of age. To produce a smooth pattern of mortality over age, graduation techniques were applied (Acturieel Genootschap 2007).

3.2 The VTV forecast

Rijksinstituut voor Volksgezondheid en Milieu (RIVM) has published a public health forecast termed *Volksgezondheid Toekomst Verkenning* (VTV) every five years since 1993 (Luijben and Kommer 2010). In 2010 it added a projection of life expectancy prepared by Janssen and Kunst (2010) based on an approach that they had developed earlier (Janssen and Kunst 2007). We refer to this as the "VTV projection". This method includes both extrapolation and explanation elements.

The VTV started from separate mortality projections for non-smokers and smokers. These were combined to obtain a projection of overall life expectancy.

To project future non-smoking-related mortality it was assumed that, over the long term, the mortality rates for each gender in the Netherlands parallel the common trends for both genders in ten other European countries. For this purpose the Li and Lee method for coherent forecasting was used (Li and Lee 2005), which is a variant of the Lee-Carter model (Lee and Carter 1992). Assuming that all eleven countries follow a common trend in age- and gender-specific mortality on a long-term basis, this yielded a constant ratio between the mortality rates between countries and both genders. At the same time, country-specific deviations were allowed for the short run.

To project smoking-related mortality, smoking patterns were first extrapolated based on the model of the smoking epidemic, which postulates that smoking mortality follows a bell-shaped pattern that echoes the same pattern of smoking prevalence just three decades earlier, plus additional assumptions. More details on this approach can be found in Janssen and Kunst 2010. Adding the projected smoking-related and non-smoking-related mortality yielded the total projected mortality and in turn projected life expectancy.

Similar to the AG, the VTV approach combines a non-linear short-term trend and a linear long-term trend to account for short-term and long-term differences. However, this method differs fundamentally as it first eliminates irregularities in the trend by excluding smoking-related effects, which are an important determinant for mortality and responsible for non-linear cohort-driven short-term trends. Second, the long-term trend pattern is obtained by using the average of several countries as reference, instead of projecting it strictly for the Netherlands.

3.3 The CBS projection

Statistics Netherlands (*Centraal Bureau voor de Statistiek*, CBS) has the oldest tradition when it comes to projections of Dutch life expectancy, since this is a crucial component of the projection of Dutch population. The CBS projection is the most complex of all three attempts, including elements of extrapolation, explanation, and expectation.

Two aspects make the CBS approach fundamentally different from the AG and VTV methods. Firstly, the CBS projection follows a "two-step" approach. The first step is to split mortality up into several causes of death by age groups; these were projected separately for the sample years (2018, 2034, 2050, and 2060). To decide whether to apply a linear extrapolation of the logarithm of the death probability or to include expert knowledge, trends in cause-specific mortality from 1970 to 2009 and in determinants were examined. As a second step, the specific age profile for each of the sample years was recovered by applying the Brass logit method (Brass 1974), while the intermediate calendar years were subsequently interpolated. CBS mentions three reasons for this two-step approach: (1) it allows using information on specific determinants for a specific cause of death, (2) it allows modeling non-linear trends that may occur when trend reversals occur for different causes at a different time, and (3) it allows evaluation and update of projections per cause of death in a specific age range (De Jong and Van der Meulen 2005).

Secondly, since 1999 CBS makes stochastic projections, which included information – partly based on past experiences from prior projections – on future uncertainty of the current projection (De Beer and Alders 1999). This is done via bootstrapping by assuming a confidence interval of ten years for the projected life expectancy at the end of the 50-year projection horizon, based on the literature and own simulations. It was assumed that uncertainty in the future level of mortality is mostly inherent and that therefore more advanced projection methods do not lead to more accurate long-term forecasts.

Two constraints were introduced to ensure consistency. First, male mortality has to be higher than female mortality and, second, age-specific mortality has to increase monotonically. Both indicators served as a plausibility check to evaluate the outcomes of the prognosis, but they are not included in the model equations.

CBS projects a different pattern for future life expectancy in the short term compared to the long term by using a mix of extrapolations based on different reference periods and assumptions about future risk factors and medical developments.

4. Comparison of AG approaches and outcomes with other Dutch projections

4.1 Comparison of approaches

The three Dutch projection approaches differ fundamentally in terms of design. The most important differences are the underlying model(s), the role of causal modeling and expert expectations, the choice of reference period, and the modeling of non-linear future trends in overall mortality. The outcome measures, including whether or not uncertainty estimates are given, are listed in Table 1 and summarized below.

Model to forecast mortality

The approaches have in common that they model age-specific mortality rates or risks instead of aggregate measures, but the underlying statistical models differ. The AG uses separate age-specific extrapolations to construct a goal table at the end of the projection horizon. CBS first disaggregates overall mortality into broad cause-of-death groups, and then separately projects age groups for specific sample years. It uses a relational model to restore the full age structure and interpolation methods to restore the full time series. Contrary to both AG and CBS, the VTV projection extrapolates non-smoking-related mortality for all ages and both genders, based on a single model that includes information from other countries to ensure robustness.

Role of expert opinions and causal modeling

Another crucial difference is that the AG approach is based on "pure" extrapolation of historical mortality trends, while the other projections combine this with expert expectations and/or causal modeling that relate smoking to mortality. In the

CBS projection, expert knowledge on risk factors and medical developments relevant for each cause of death is used to adjust (generally reduce) the length of the historical period on which the trend extrapolations are based, or to adjust (generally reduce) the strength of the extrapolated mortality reduction. In both the CBS and VTV projections, sub-forecasts of smoking are made, which are in turn used to project future smoking-related mortality.

Length of reference period

Regarding the length of the historical period, the AG uses for the long-term trend a 20-year reference period to project mortality about 50 years ahead. In addition, it includes the last eight years to reflect recent changes. CBS utilizes about 50 years to project about 40 years ahead, although it uses much shorter reference periods for several causes. VTV bases its projections on a historical period of 36 years (to project 40 years ahead). Contrary to both AG and CBS, it does not include the most recent years, since lung-cancer information for all eleven European countries after 2006 was not available.

Inclusion of non-linear trends

To account for non-linear regularities, AG models a short-term trend, which converges exponentially to the goal table. Also CBS and VTV model non-linear patterns by taking into account cohort and period effects in smoking-related mortality, building on a hypothetical model of the smoking epidemic (see Lopez, Collishaw et al. 1994). In addition, the CBS projection includes opinions about reasonable levels and trends for certain disease groups, based on the scientific literature. The VTV forecasting model allows for non-linear short-term deviations from the long-term common trend across eleven countries (VTV).

Table 1. Features of Dutch forecasting approaches, with problematic components in bold type and favorable ones in italics, based on literature review

Feature	AG 2010	VTV 2010	CBS 2010
Reference period	1988–2008 and 2001–2008	1970–*2006*	1970–2009
Extrapolation	*separate* for age and gender	**coherent** for countries and gender	*separate* for age, gender and cause-of-death
Causal modeling		smoking-related mortality	smoking-related mortality
Role of expert opinion			*expectation about future trends and levels*
Non-linear trends	*short-term trend converging to goal table*	**cohort smoking patterns**	*expert judgments* and **cohort smoking pattern**
Outcomes	mortality by age and gender, life expectancy	mortality by age, gender and smoking, life expectancy + variants	mortality by age, gender, cause of death, life expectancy
Uncertainty	*no*	*no*	yes, but external model

Outcomes

The AG presents age-specific mortality rates and life expectancy for males and females by age and gender, but it does not specify the uncertainty of the estimates. VTV adds the dimension of smoking/non-smoking-related mortality and provides life expectancy estimates for different variants (based on models both with and without smoking-related mortality and both with and without other countries). CBS offers the greatest variety of published outcome measures, as it presents cause-specific death rates next to the usual indicators and identifies uncertainty bounds. None of the projections provide information on population subgroups, such as educational or income groups, or socio-demographic characteristics other than age and gender.

Table 1 summarizes the findings of this chapter and additionally marks problematic components in red and favorable ones in green, based on the literature review. We consider the less up-to-date reference period of the VTV somewhat problematic, as well as the separate modeling of age and gender in AG and CBS and the expert-based approach of CBS. Estimating the short-term trend via experts (CBS) or solely on the recent strong increase in life expectancy (AG) seems to us less convincing than taking possible (smoking-related) cohort effects into account (CBS and VTV). Also the absence of uncertainty in the AG and VTV outcomes are drawbacks worth mentioning.

4.2 Comparison of projected outcomes

In Table 2 we compare period life expectancy at birth and age 65, the respective gender gap at these ages for the projected years 2020 and 2050, and the increase since 2010. The table presents outcomes for the year 2050 rather than 2060, the final year of the AG and CBS projections, to allow for comparison with the VTV projection. The figures do include the period up to 2060 when available.

Large differences concerning pace of increase in the short and long term

There is no general low or high approach, but the AG projection of a 3.0-year increase of male life expectancy at birth within one decade and of 6.7 years up to 2050 is by far the most optimistic for males. VTV and CBS project a total increase of about 5 years. In the short term VTV is quite pessimistic for both genders by modeling an increase of 1.0 years for males and only 0.7 years for females

Table 2. Projected life expectancy by the AG, VTV and CBS model in 2020 (upper panel), 2050 (lower panel) and differences to 2010

Indicator	AG 2020	dif 2010	VTV 2020	dif 2010	CBS 2020	dif 2010
LE at birth males	81.8	3.0	79.7	1.0	80.6	1.9
LE at birth females	84.9	2.2	83.5	0.7	84.1	1.3
LE age 65 males	19.7	1.7	18.1	0.2	19.0	1.0
LE age 65 females	22.4	1.2	21.0	-0.2	21.8	0.6
gender gap at birth	3.1	-0.9	3.7	-0.2	2.9	-1.0
gender gap at age 65	2.7	-0.5	2.9	-0.4	2.5	-0.7

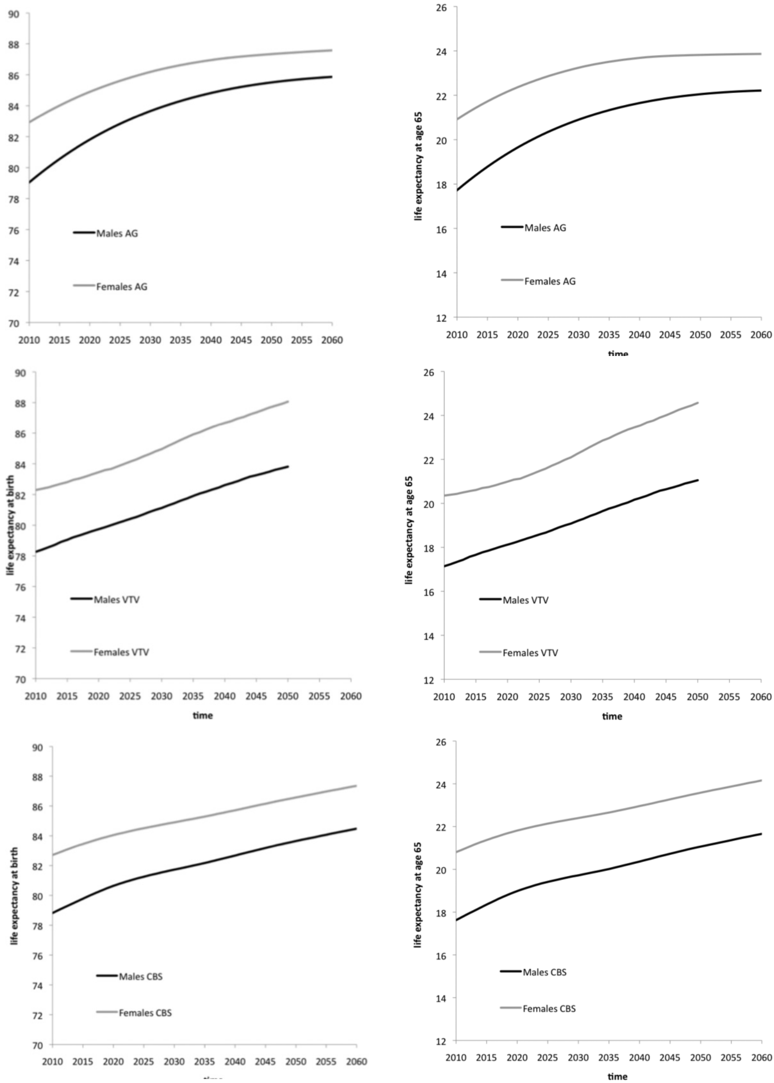
Indicator	AG 2050	dif 2010	VTV 2050	dif 2010	CBS 2050	dif 2010
LE at birth males	85.5	6.7	83.8	5.0	83.7	4.9
LE at birth females	87.3	4.6	88.1	5.3	86.6	3.8
LE age 65 males	22.0	4.1	21.1	3.1	21.1	3.1
LE age 65 females	23.8	2.6	24.6	3.4	23.6	2.4
gender gap at birth	1.8	-2.1	4.2	0.3	2.9	-1.0
gender gap at age 65	1.8	-1.5	3.5	0.3	2.5	-0.7

Source: CBS, AG and VTV

up to 2020. In the long run, however, VTV projects for females the highest increase: of 5.3 years up to a level of 88.1 years in 2050. AG is slightly less optimistic, with an increase of 4.6 years, and CBS projects an increase of 3.8 years. In general, AG is more optimistic in the first ten years but more pessimistic in the following thirty years, which is the reverse from the VTV approach (at least for females). CBS is slightly more positive for the short term but not as much as AG.

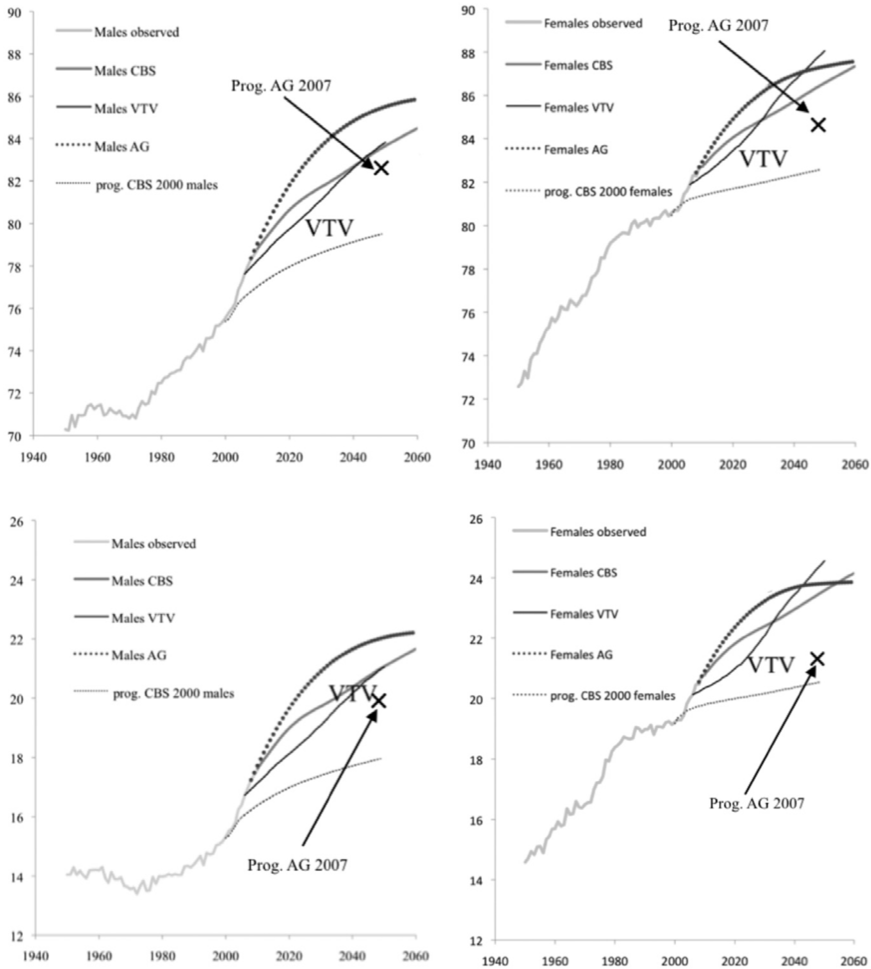
Figures 1 and 2 compare the trajectories of the projected life expectancies. The AG forecast predicts a strong slowdown of the increase in life expectancy in the longer term, with near-stagnation at the end, while VTV projects the most linear pattern. The CBS prognosis foresees initially a faster pace of increase, but later a more or less linear trend, comparable to the VTV projection. The projected changes in gender differences converge strongly in the AG forecast, while in the CBS forecasts male and female life expectancies are more or less parallel for the

Figure 1. Comparison of Dutch life expectancy according to forecasts by AG, VTV and CBS at birth (left panels) and age 65 (right panels)



Source: AG, VTV and CBS

Figure 2. Comparison of Dutch life expectancy according to CBS, AG and VTV forecasts for male (left) and female (right) life expectancy at birth (upper panel) and at age 65 (lower panel)



Source: CBS, AG and VTV

entire projection period. VTV first shows a small convergence until about 2025, with divergence after that.

Figure 2 presents the trajectories for the three projections, and in addition, projected life expectancy in 2050 according to the 2007 AG and 2000 CBS projection. The latter were lower than all three 2010 projections, especially for women.

Note the clear exponential slope of the AG projection caused by the specific inclusion of the short-term reduction factor in the model. Until about 2040 (women) and 2060 (men), AG gives by far the most optimistic projection of life expectancy. The almost linear pattern of the VTV projection converges to that of CBS for males and even overtakes the other two trend lines for females. The VTV projection stops in 2050, but the linear increases suggest that for a longer horizon this projection would similarly catch up with the very optimistic AG trend for males.

The results of model choice become especially visible when comparing the trends projected by VTV and CBS. Although both CBS and VTV model the effect of smoking, which diminishes over time, the short-term patterns differ remarkably. Initially the CBS projection is more optimistic, but later VTV is more optimistic, due to the inclusion of past mortality data from other countries in its projection and the conservative assumptions about future medical improvements in the CBS projection.

4.3 Implications for the value of pension annuities

This section aims to assess possible consequences of the different projections of period life expectancy and underlying age-specific mortality rates for the actuarial sector. We have estimated survival trajectories for cohorts and assessed the present value of future pension annuities, according to the procedure introduced by De Waegenaere, Melenberg et al. (2010).

We first present cohort survival of the age 65 cohort in 2010, based on projected future age-specific mortality. This interprets the projected survival trends shown in Figures 1 and 2 in a different perspective, since all period life tables of the years 2010–2060 are used to construct the expected survival of the cohorts.

Next we present pension annuities, which were estimated as follows. Let $l_c(x,t)$ be the probability to survive to age x, for a cohort at age c in the present year t, calculated by using the mortality risk of adjacent period life tables as follows.

$$l_c(x,t) = 1 \cdot \prod_{x=c}^{\omega} 1 - q(x, t + (x-c)) \,, \tag{5}$$

The present value of all future pension payments $a_c(t)$ for this cohort in year t is calculated as

$$a_c(t) = \sum_{x=66}^{\omega} \frac{l_c(x,t)}{(1+r)^{x-c}} \,, \tag{6}$$

where ω is the highest age in the life table used, and r the interest rate to discount future payments. The denominator in (6) serves to allocate at the same time a higher weight to survival probabilities that are nearer in time, which accentuates the short-term and mid-term period of each projection approach, at least for elderly persons. Long-term projections still matter for calculating the pension of cohorts that are comparably young in the present year since their first payment starts far into the future[2].

2 To calculate the cohort survival rates, the values from the three projections were extended to such age when every cohort is extinct. For that extension we kept the mortality rates constant from the last year of the end of the projection, which is 2050 for VTV and 2060 for AG and CBS. In addition, we extended the mortality rates to age 130 by applying linear interpolation.

Table 3. Cohort survival at age 65 in 2010 for AG, VTV and CBS

	Males			Females		
Age	**AG**	**VTV**	**CBS**	**AG**	**VTV**	**CBS**
65	1.00	1.00	1.00	1.00	1.00	1.00
70	0.93	0.92	0.93	0.96	0.95	0.95
75	0.85	0.81	0.83	0.90	0.87	0.89
80	0.72	0.65	0.70	0.81	0.75	0.79
85	0.54	0.46	0.50	0.67	0.59	0.64
90	0.29	0.25	0.28	0.45	0.38	0.41
95	0.08	0.10	0.09	0.18	0.18	0.18
100	0.01	0.03	0.01	0.03	0.05	0.03
105	0.00	0.00	0.00	0.00	0.01	0.00
E65	**19.56**	**18.60**	**19.22**	**22.51**	**21.44**	**21.99**

Source: own calculations

Table 3 shows the different survival trajectories $l_{65}(x,2010)$ for a cohort aged 65 in 2010 and their remaining cohort life expectancies according to the AG, VTV and CBS data. For both males and females, AG shows by far the most optimistic scenario, while VTV represents the most pessimistic one. At age 80, which is only 15 years in the future, quite large differences are already present, with 72% of males surviving in the AG setting versus 65% according to the VTV table (respective values for females are 81% and 75%). Although these differences in survival disappear at higher ages, they have high relevance through the discounting factor mentioned above. Hence, not only the level of life expectancy but also the pattern of mortality over age is important for pension calculations.

We calculated the total present value of future pensions for cohorts at age 65, 55, 45, 35, and 25 in 2010, applying an interest rate in (8) of r=0.03 (Table 4). While the total present value is substantially influenced by this discount rate, the relative difference remains about the same. A person aged 65 in 2010 would, based on CBS, receive a total pension with a present value

Table 4. Discounted present value of all future pension payments for a person aged 65, 55, 45, 35, and 25 in 2010 with a constant annual interest rate of 3.0%

age 2010	males					females				
	CBS	AG	diff to CBS	VTV	diff to CBS	CBS	AG	diff to CBS	VTV	diff to CBS
65	13.95	14.18	1.6%	13.52	-3.1%	15.53	15.83	1.9%	15.17	-2.3%
55	10.05	10.44	3.9%	9.83	-2.2%	11.23	11.53	2.7%	11.28	0.5%
45	7.57	7.96	5.2%	7.52	-0.7%	8.40	8.60	2.3%	8.67	3.1%
35	5.78	6.08	5.3%	5.77	-0.2%	6.38	6.47	1.4%	6.62	3.9%
25	4.39	4.61	5.0%	4.36	-0.7%	4.82	4.87	0.9%	4.99	3.5%

Source: own calculations

of € 13.95 (standardized as € 1.00 for every survived year above age 65). This would be € 14.18 for AG and € 13.52 by using the VTV projection (Table 4). Compared to the CBS values for males, pension funds would thus have to reserve 1.6% more if they were to follow the AG forecast scenario and 3.1% less in the VTV case. For younger ages, such as age 35, the difference between CBS and AG in male annuities more than doubles to 5.3% and declines in the VTV scenario. The differences in pensions for women are relatively smaller. For younger ages the VTV scenario now is most expensive, with differences of up to 3.9%, while the AG is more expensive for persons aged 45 to 55 years (2.7% and 2.3% respectively).

These calculations demonstrate how the model risk directly affects the reserves that are needed for future pensions. Although the three projections arrive at comparable levels of life expectancy at the end of their projection horizon, the trajectory towards that horizon influences substantially the outcomes relevant for the insurance sector. It is to be noted that the differences between the three approaches do not increase with time, but that they are especially large in the short term. Hence, the model risk is not just relevant in the distant future but already within the next several years.

5. Evaluation of AG approach with insights from other Dutch projections and international context

The AG describes the main task of an actuary by saying: "*Providing insight and advice, and assessing risk issues in the area of finance contribute to a significant degree to managing risks and promoting the financial stability of our society.*" (Actuarieel Genootschap 2007). One of the central aspects of this assessment of risk issues is the estimation of possible risks arising from uncertainty about longevity.

Based on comparison with two other Dutch mortality projections and on literature review, we will shed more light on the risk arising from use of the present AG model.

Separate versus simultaneous modeling of time trends over age
The AG projection represents an extrapolation approach, where the time trends of more than one hundred ages are separately modeled. CBS models ages separately but projects only seven broad age groups. The VTV projection is largely based on a coherent two-factor Lee-Carter model fitting the time and age trends simultaneously for several countries. Separate extrapolations for each single age allow for flexibility concerning the correlation structure between them and the possibility of using different periods and models for different ages (Ediev 2009). However, this enhanced flexibility can lead to irregular age patterns and inconsistency. Ediev (2009) shows that various methods and measures need to be implemented to solve the most serious problems of the direct and separate estimation of mortality. This ensures that the long-term trend is consistent and in line with previous knowledge and other studies, while in the AG approach coherent or non-coherent outcomes are

due to chance. Although the AG uses smoothing techniques and manual correction of implausible situations (higher female than male mortality), these tools are not part of the projection model and can lead to new problems. The strong convergence of life expectancy of males and females (Table 2 and Figure 1) in the AG projections illustrates such a possible inconsistency. While separate modeling of different ages is applied in the AG approach to solve the problem of fixed progress of age-specific mortality in the Lee-Carter method, a safer approach would be to use either the CBS model approach or an extension of the Lee-Carter model.

Isolated national projection versus multi-country approach
In addition to potential inconsistencies in age- and gender-specific estimates, both the AG and CBS projections have the risk of lack of coherence. Since the Netherlands is one of the few countries with a deviating trend in life expectancy and with an abrupt trend change, a pure national-driven forecast may be dangerous in the long term. Hence, we recommend examining the trends and forecasts observed in neighboring countries and using these as a potential consistency check for the Dutch projection. Using a multi-country model to achieve long-term coherence, as in the VTV projection, may be too optimistic. However, clearly diverging forecasts require further explanation, which is not done in the case of the AG projection, where life expectancy is assumed to level off at the end of the projection period. In the report that describes the AG projection model, forecasted life expectancies were compared with other European countries. While the female life expectancy forecast in 2030 is in line with other projections, the male life expectancy is 3.7 years higher than the EU27 average, which calls for explanation (Actuarieel Genootschap 2010).

Avoiding trend breaks versus sufficiently long reference period
The historical period used to project life expectancy was 20 years for AG, 36 years for VTV, and 39 years for CBS. None of the projections followed the suggestion of Janssen and Kunst (2007) to use a reference period at least as long as the projected series, although they also remark that abrupt trend changes should be taken into account. It is noteworthy that VTV did not include the most recent years because data on smoking were not available for that period. Booth et al. (2002) and Ediev (2009) argue that in the case of trend changes also much shorter series may be used, as long as they provide linear patterns. Unfortunately, only in the recent decade (2001-2010) does life expectancy follow such a linear pattern (probably shorter for age-specific trends) in the Netherlands, which may not be a sustainable basis for extrapolation. The decision of the AG to use separate reference periods relates to diagnosed trend breaks before 1988 and in 2001. An alternative to this separate projection would be to use several time parameters in one model as in the CBS model or the extension of the Lee-Carter model including higher order variants.

Pure deterministic projection techniques are outdated
The AG does not provide any measure of uncertainty. In the literature there is increasing consensus on the need to provide this information along the projected life expectancies, especially for typical users of actuarial estimates such as life insurance companies and pension funds. Depending on the preferred projection approach, views still differ whether uncertainty should be based solely on an ex-post, ex-ante time-series approach, or on expert-based scenarios. However, given that AG uses a pure extrapolation approach, there is consensus that uncertainty based on an ex-ante time series approach should be included in the

life expectancy projections. CBS provides an ex-post estimation of uncertainty that is not directly linked to the forecasting model. This is debatable, but there is some support for such a procedure in the presence of recent trend changes (Booth and Tickle 2008). The VTV projections do not provide information on uncertainty, although the Lee-Carter variant used by VTV might allow the estimation of uncertainty. Neither the AG nor the CBS and VTV models are able to produce individual sample paths.

Summarizing, the literature indicates that the AG approach suffers major disadvantages, as it is prone to inconsistent and implausible forecasts for age, gender and possibly time-specific trends. Furthermore it does not account for potential cohort effects, such as caused by smoking patterns, nor for other irregularities in the data, plus it does not specify the degree of uncertainty. Nevertheless, a projection based on a purely extrapolative approach could give an important alternative view of future life expectancy and thereby complement the more expert-based CBS approach and the more explanation-based VTV method. In that sense, considering all three approaches provides a useful overview of possible future trends in the Netherlands, as suggested by Seematter-Bagnoud and Paccaud (2010), who argued using several forecasts in the absence of a single best-practice approach. However, the literature review also suggests that the three approaches are far from representing the full scope of possible *model risk*. For this purpose the projections considered should be complemented by the very optimistic Andreev and Vaupel approach (2006) and likely by the more pessimistic approach of King and Soneji (2011), who take the smoking and obesity epidemics into account.

6. Suggestions for the next AG projection

The report by the "Commission of Experts" (Van de Poel, Palm et al. 2010) evaluated the AG projection and gave some suggestions for the next projection. We will briefly discuss these and add further suggestions, based on the comparison between the AG and the two other projections and our literature review.

Firstly, the commission pointed out the importance of explanations of past changes in mortality in the modeling process. We acknowledge the importance of explanations of recent mortality trends, but with the proviso that the projection model should not be based on cause-of-death data (as in the CBS projection). We consider it most useful that extrapolations are checked for their consistency with multiple dimensions of past trends (not only trend in life expectancy, but also age-specific reductions in mortality and cohort effects if relevant), and for their consistency with explanations of past trends.

Secondly, the commission pointed at the importance that the model match the "best practice" on the basis of the scientific literature. While this report has shown that there is no projection blueprint, in our view some crucial points to consider have been presented in the current paper, including consistent modeling across age and gender, modeling time trends in coherence with other countries, and cohort effects. In addition, it is suggested that specification of the model should be based on statistically sound arguments, and next to back-testing the projections should also be judged against scientific insights in the development of mortality and its determinants. In our view, this could include what-if scenarios, for instance to assess the effect of plausible future mortality trajectories that reflect potential developments in aging process, healthcare provision, medical technology, and health behavior that differ in their effects on mortality by age and gender from those used in the current projection model.

Finally, according to the Commission the model should provide uncertainty as an outcome. We agree and wish to add that this preferably should take into account the considerable uncertainty involved in selecting the modeling approach, which goes beyond uncertainty as provided for instance by a Lee-Carter model. A comparison of multiple projection models and of multiple assumptions within an approach could shed light on this uncertainty. The analyses in this report contribute to this assessment.

Considering the great need within the actuarial field for uncertainty estimates, a stochastic model is indispensible. More specifically, a stochastic two- or three-factor time-series model would seem a promising candidate. The model should be flexible enough to capture current cohort effects, such as those due to smoking, but also future cohort effects that arise from other causes. At the same time some consistency should be implemented, though without too strong assumptions about relations between subgroups.

Based on our comparison of the outcomes of three projections and the literature review in the current paper, we add that important decisions and policy measures should not be based on a single projection only. Even a more sophisticated extrapolation approach should not be the sole approach but should be complemented with other approaches that consider information on developments in healthcare, as done by CBS and VTV, and approaches, similar to Olshansky, Goldman et al. (2009) and Bongaarts (2004), that model alternative possible trajectories of mortality decline.

In summary, based on our literature review and comparison of the three projections for the Netherlands, which show that the projections of future mortality and life expectancy vary substantially between the approaches, including in the short term, we recommend the following:

- basing important decisions not on a single projection model but using complementary projections, based on different approaches, including a stochastic two- or three-factor time-series model, to replace the current AG model;
- presenting uncertainty estimates and communicating about uncertainty, including uncertainty regarding the choice of approach; and
- carefully monitoring current developments in mortality, healthcare, and other important determinants so that changes can be quickly recognized.

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The longevity risk of the Dutch Actuarial Association's projection model

Accurate assessment of the risk that arises from further increases in life expectancy is crucial for the financial sector, in particular for pension funds and life insurance companies. The Dutch Actuarial Association presented a revised projection model in 2010, while in the same year two fundamentally different approaches were published by other institutions. In this paper Frederik Peters, Wilma Nusselder, Johan Mackenbach (all Erasmus MC) firstly compare the three approaches against theoretical findings in the international literature. Secondly, they compare their outcomes in terms of period and cohort survival. In addition, they estimate the impact of each model on the present value of future pension payments.