Assessing the Accuracy of National Population Projections: A Case Study of Norway

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Abstract

Few producers of official population projections provide regular evaluations of past projection inaccuracies. This paper assesses deviations between the projected and registered total population for Norway (1996–2018), as well as deviations in the age structure, total fertility rate and number of births, period life expectancy at birth and number of deaths, and net international migration. Projected life expectancy was consistently lower than the real development. Few systematic deviations were observed for fertility up to 2009, but thereafter fertility has been consistently overprojected. However, the deviations between projected and realised trends in births and deaths have been relatively small as compared to those for net international migration. The projections produced between 1996–2005 underestimated long-term population growth due primarily to the unforeseen increase in immigration following EU expansion in 2004. More recent projections contain no consistent under- or overprojection of net migration and the deviations for the total population have been moderate.

Keywords: Accuracy, Errors, Fertility, Methods, Migration, Mortality, Population Projections

Introduction

Knowledge of how the population will develop and change is of crucial importance for planners, policy makers and societies at large. Such information can inform decisions on investments in health and social care systems, pension funds, education and infrastructure planning as well as policies designed to influence future population trends (e.g. pro-natalist policies or the strengthening/relaxing of barriers to immigration). The size and composition of future populations depends on developments in the three main demographic components: fertility, mortality and international migration. Thus, a population projection involves calculations, based on assumptions about these components, that seek to capture the future course of population change (United Nations 2018).

Despite their utility, population projections are inherently uncertain. Natural stochastic temporal fluctuations, errors in base populations, limited knowledge of underlying demographic dynamics (i.e. fertility, mortality and migration processes), the emergence of unforeseen social, political, health and economic changes, and the mis-specification of projection models, all contribute to inaccuracies in projected populations (de Beer 2000, National Research Council 2000, Keyfitz & Caswell 2005, Wilson 2007).

There is a small but growing literature on the accuracy of past population forecasts (e.g. Chi & Wang 2018, Keilman 2007, 2008, Keilman & Pham 2004, Keyfitz 1981, Khan & Lutz 2008, National Research Council 2000, Shaw 2007, Wilson 2007). Yet, producers of official population projections very rarely provide regular evaluations of past projection inaccuracies, at least beyond the short-term (e.g. one to two years after the projection start year). As noted by Wilson (2007), evaluations of the accuracy of past projections can reveal the existence of systematic errors, identify errors that could be used directly to generate predictive intervals in probabilistic projections, and provide a rough idea of the accuracy of current projections assuming the scale of errors in past projections are broadly similar. Providing users with information on the accuracy of past projections may be one way to increase the transparency of our work, while also emphasising the general utility of population projections by reminding end users that projections represent conditional computations (i.e. a computation of how the population would look if certain assumptions hold) as opposed to the forecasts for the future that they are often mistaken for (Keilman 2008, Smith et al. 2006).

In the case of Norway, the official national population projections are conducted and published by the national statistical office, Statistics Norway. In this paper, we provide an assessment of the short-, medium- and long-term accuracy of the national population projections produced between 1996–2018, comparing projected changes in the population size and composition against registered demographic data. Beyond an examination of the accuracy of the total population projections, we assess several key demographic characteristics: age structure and the support burden of the elderly in Norway, total fertility rate (TFR) and number of births, period life expectancy at birth and the number of deaths, and finally, net international migration and the number of immigrants and descendants of immigrants residing in Norway. Beyond this, we identify the contribution of births, deaths and international migration to the deviations observed between the projected and registered populations, using a decomposition method adapted from Wilson (2007). In doing so, we identify the existence of a systematic underestimation in life expectancy, reveal the durations at which large component-specific discrepancies' start to emerge, highlight the effect of the unforeseen consequences of certain events (e.g. the large increase in immigration that followed EU expansion in 2004) and identify an apparent tendency to project fertility at similar levels as those observed immediately prior to the production of the projections.

Background

Demographers rely on a certain degree of continuity to inform their projections of future population trends. For instance, due to demographic momentum, forecasters can be confident that societies in many Western and East Asian contexts will get older, because it is already written into the age structure of today's population (Lutz & Goldstein 2004). With that said, any set of projections will inevitably be proven wrong as a forecast of future population trends. After all, demographers have a limited understanding of the complex social behaviours that underpin future population trends, and even when an understanding of certain mechanisms exists, the emergence of unforeseen external events can produce significant and unexpected changes in demographic behaviour and outcomes. Indeed, few foresaw the sudden increase in the number of births after the Second World War (the post-war baby boom), nor its abrupt end two decades later (the baby bust) (United Nations 2018), while at present we remain unsure even of the short-term effects of the COVID-19 pandemic on population dynamics. From this perspective, it seems appropriate to agree with the following statement from Keyfitz (1981, p. 579): *"[d]emographers can no more be held responsible for inaccuracy in forecasting population 20 years ahead than geologists, meteorologists, or economists when they fail to announce earthquakes, cold winters, or depressions 20 years ahead. What we can be held responsible for is warning one another and our public what the error of our estimates is likely to be"*.

Statistics Norway regularly compares the projected population with the registered population as new population data become available. When a new population projection is produced, it is compared with earlier projections, with a focus on the results pertaining to individual components as well as the specific population estimates that result from the different models (e.g. life expectancy at birth and the old age dependency ratio). Short-term evaluations are made every year and published in Statistics Norway's report *'Økonomisk utsyn'*.[1] Yet, aside from these short-run checks, few longer-term evaluations of the Norwegian national population projections have been undertaken. Two notable exceptions include Texmon and Keilman (1991) and Rogne (2016), the latter of which evaluated the accuracy of the projections made between 1996 and 2014. According to a recent survey of national statistical offices, the situation in other European contexts appears to be no better (Gleditsch et al. 2021a).

Evaluating past projection errors, by comparing previous projections to actual trends (termed ex post error analysis), can provide important information about the overall scale of errors and their main sources, and can help in identifying instances of systematic under- or overprojection in the demographic components. Previous examples of such work (for instance Keyfitz 1981, Stoto 1983, Keilman 1997, 2008, National Research Council 2000, Keilman & Pham 2004, Wilson 2007, Khan & Lutz 2008, Rogne 2016) have shown how projection accuracy tends to be better for shorter rather than longer projection

1 Unfortunately, the publications are only available in Norwegian. However, the graphs and tables should be understandable, see https://www.ssb.no/nasjonalregnskap-og-konjunkturer/artikler-og-publikasjoner/arkiv-for-okonomisk-utsyn.

durations, and for larger rather than smaller populations (and population subgroups). In addition, large differences in the accuracy of the three projection components have also been identified. Being aware of differences in the relative accuracy of each component is important because projections can appear reasonably accurate purely by chance, for instance, when errors in the assumptions for fertility, mortality and migration work in opposite directions (Keilman 2007).

Statistics Norway's projection data and methods

Statistics Norway employs a cohort-component method to project the national population for Norway, with two types of input: i) updated figures for the national population by sex and one-year age groups; and ii) assumptions about future developments in the demographic components (fertility, life expectancy and migration). The results of the population projection are largely dependent on the assumptions used for the different components. With projections inherently uncertain, it can be useful to formulate a range of possible scenarios for the future development of the population. As such, several alternative projections are developed, with different combinations of assumptions.[2] Here, we assess the accuracy of the medium (main) alternatives of the twelve most recent projections (1996–2018) that may be evaluated.[3] This medium alternative has been labelled in past projections as either M1 or MMMM, and signals that the medium assumption has been used for all components, i.e. medium fertility, medium life expectancy and medium immigration, as well as medium internal migration.[4] Internal migration is not relevant for our analyses of the national population. These medium level assumptions are those that the producers consider to be the most plausible future scenario. Since 1996, the national population projections have been produced at varying intervals. Between 1996 and 2008, projections were produced every three years, then every year until 2012. Since 2012, the projections have been produced biennially, with the most recent projection undertaken in 2020. No reasons have been provided for the varying intervals.

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2 For instance, the low national growth alternative is calculated by employing the low fertility, low life expectancy and low immigration assumptions. Alternatively, the weak ageing alternative is based on the high fertility, low life expectancy and high immigration alternatives.

3 The most recent projection was produced June 2020, and only has a 6-month observation window for evaluation and is therefore not included here. In short, the short-term discrepancies are minor overall: The population in Norway on January 1 2021 was only 792 lower than projected in the main alternative, which corresponds to a deviation of 0.01% of the total population and around 3% of the population growth. However, there are larger discrepancies for individual components: We greatly underestimated both immigration and emigration, each by around 10 000. However, since the discrepancies were approximately equal we only underestimated net migration by 495. We overestimated the number of births by 1 600, whereas the number of deaths were overestimated by 224.

4 For emigrations, the default is the medium alternative. It is thus not indicated by a separate letter.

Data input

The Norwegian national population projections use aggregated individual-level data on population size and age structure, births, deaths and international migration from Statistics Norway's population statistics (BESTAT), which are retrieved from the National Population Register, administered by the Norwegian Tax Administration. The population statistics include persons who are registered as residents in the National Population Register. This includes persons who reside permanently in Norway, as well as persons who plan to reside in Norway for six months or longer and hold a valid residence permit. Since 1956, citizens of the other Nordic nations (Denmark, Finland, Iceland and Sweden) have gained residency automatically in Norway. Freedom of movement was granted to all citizens from the EU and EFTA countries in 1994, with additional Eastern European countries joining the agreement following EU expansion in 2004. Beyond this, the population statistics include persons who have moved abroad but have not officially registered this move. Some groups are not included in the population register and thus not considered in the projections, even though they, at least temporarily, live in Norway (Syse et al. 2020). These groups include persons on short-term work contracts or people who reside in Norway without a resident permit. In addition, people who have applied for asylum in Norway, but who have not had their application processed, are not registered as immigrants even if they reside in the country. For example, among the many asylum seekers who arrived in the last months of 2015, only a small number were included in the immigration figures for 2015 and the population figures at the start of 2016. In other words, it is the *de jure* population and not the *de facto* population that is projected.[5]

Projection methods

The cohort-component method is used for projecting the national population of Norway (cf. Syse et al. 2020). It calculates the next year's population by starting with the population in the current year and adding births, deducting deaths and emigrations, and adding immigrations. This is done for both sexes by one-year age groups. When the following year's population has been calculated, it is used as the basis for calculating the population the year after. The cohort-component method is a common method for projecting populations and is used by most agencies that project populations at a national or international level (Gleditsch et al. 2021a). Most of the assumptions that are used in the cohort-component method are stated as rates, probabilities or proportions by sex and one-year age groups. This applies to the assumptions about future fertility, mortality, and emigration. For immigration, the total assumed number of immigrations is distributed by age and sex based on the age and sex distribution observed in previous years of immigrations.

The methods used for determining the assumptions regarding the individual components have changed over time and details of the methods currently employed can be

5 For more details on criteria for residency and emigration, please refer to the English publication by Zhang (2008) and the English abstract in the report on this topic by Pettersen (2013).

found in Syse et al. (2020). Statistics Norway does not currently use a model for projecting future fertility. Instead, in consultation with fertility experts, a long-term level for the Total Fertility Rate (TFR) is set based on analyses of historical-trends and theoretical assumptions about a range of variables assumed to affect the future number of births, whereas the short-term TFR is usually obtained by a gradual extrapolation towards the long-term level.[6] It is assumed that long-term fertility will fluctuate around this fixed assumption. The assumptions for TFR are used to create age-specific fertility rates based on the current age schedule. Since the 2014 projection, the fertility of different groups of immigrant women by country group (cf. Appendix) and length of stay in Norway are also separately projected, along with the levels for the general population.

For the mortality component, assumptions are currently made about age-and sex-specific death probabilities, based on a stochastic forecasting model. Currently, a product-ratio version of the Lee-Carter model is employed, where the trend in mortality for the selected time period, represented by two estimated time series, is extended using an autoregressive integrated moving average (ARIMA) model (Li & Lee 2005, Hyndman et al. 2013). Some discretionary adjustments are also included to avoid unrealistic cross-overs between future male and female life expectancies in the short-term (cf. Syse et al. 2020).[7]

The approaches taken to project migration have changed several times during the past two decades. Immigration is currently modelled separately based on assumptions made about the economic development in Norway relative to various country groups (cf. Appendix), the sex and age distribution among potential immigrants from each country group and other important determinants of immigration (cf. Cappelen et al. 2015, Skjerpen & Tonnessen 2020). This econometric approach to the prediction of immigration was partially implemented from 2005 and became fully implemented in 2008. Emigration probabilities are calculated based on previous rates by sex, age, country group of origin and immigrant background. Prior to 2005, net migration was set at a long-term level in consultation with experts. Up until 2011, assumptions were made about future net migration. In the current national projections, assumptions are made separately for gross immigrations and gross emigrations, with net migration then calculated by deducting annual emigration from annual immigration.

Methods

The majority of the analyses presented in this paper are based on simple comparisons of projected and registered population components. Where relevant, we calculate the per-

6 Total fertility rate (TFR) is a measure of the number of children a woman will have if, throughout her life, she follows the age-specific pattern of fertility (the average number of children at each age) for a given year, and she does not die before the end of her fertile period.

7 Life expectancy at birth is a measure of how long you can expect to live if you follow the sex- and age-specific mortality patterns (the probability of dying at each age) for a given year.

centage error (PE). This measure indicates how many percentage points higher/lower the projected population has been than the registered one. It may be calculated for the total population or for specific subgroups (such as age groups). PE is defined as:

$$PE_{s,t,g} = \frac{P^{proj}_{s,t,g} - P^{reg}_{s,t,g}}{P^{reg}_{s,t,g}} \times 100$$

where P denotes the total population, s indicates start year (the year in which the projection is produced), t indicates duration (the number of years after the start year) and g indicates the specific population subgroup. Projected and registered populations are denoted by the superscripts *proj* and *reg*, respectively.

Decomposition of errors

As part of the assessment of the accuracy of the projections, we need to know more about the projection errors for specific components. This is done by comparing the the projected population to the registered population, using a decomposition method adapted from Wilson (2007). Decomposing the projection errors requires data on projected and registered numbers of births, deaths and net migrations. In addition, we need the population for each year and the registered start population, as well as the start population used in the projections.[8] Due to the fact that the start population is taken directly from the population register, there are no errors in the start population. However, very small errors in the registers in the form of inconsistencies between the changes in the population stock and the sums of the change components do occur. They can also be calculated directly. We correct for these small *Errors in the Registers* (ER) in the calculation of the other components (this is where our approach differs slightly from the method used by Wilson (2007), where the corresponding measure does not account for the peculiarities of Norwegian register data inconsistencies). ER is given by:

$$ER_{s,t} = P^{reg}_{s,t=0} + \sum_{r=0}^{t-1} B^{reg}_{s,r} - \sum_{r=0}^{t-1} D^{reg}_{s,r} + \sum_{r=0}^{t-1} N^{reg}_{s,r} - P^{reg}_{s,t}$$

where P is the population on January 1. The s denotes the start year of the projection (i.e. the year the projection is produced) and t denotes duration, where $t=0$ is the start year. For example, if $s = 2002$, and $t = 1$, this indicates the 2002 projection for 2003. The summing

8 The start population is the population on January 1st of the first year of the projection, i.e. 2020 for the 2020 population projections. This is also called the base population or the initial population.

index is given by r, B is the number of births, D is the number of deaths and N is the net migration. From this, we calculate the Percentage Error due to errors in the Registers (PER). This can be interpreted as the percentage error in the projected total population that we would see if there were only errors in the registers – that is, if the projection was accurate for all components:

$$PER_{s,t} = \frac{ER_{s,t}}{P_{s,t}^{reg}} \times 100$$

Calculations for the Percentage Errors of the various components – Births (PEB), Deaths (PED) and Net migration (PEN), respectively, where we correct for inconsistencies in the registers – are given by the following equations:

$$\mathrm{PEB}_{s,t} = \frac{\mathrm{P}_{s,t=0}^{reg} + \sum_{r=0}^{t-1} B_{s,r}^{proj} - \sum_{r=0}^{t-1} D_{s,r}^{reg} + \sum_{r=0}^{t-1} N_{s,r}^{reg} - P_{s,t}^{reg} - ER_{s,t}}{P_{s,t}^{reg}} \times 100$$

$$\mathrm{PED}_{s,t} = \frac{\mathrm{P}_{s,t=0}^{reg} + \sum_{r=0}^{t-1} B_{s,r}^{reg} - \sum_{r=0}^{t-1} D_{s,r}^{proj} + \sum_{r=0}^{t-1} N_{s,r}^{reg} - P_{s,t}^{reg} - ER_{s,t}}{P_{s,t}^{reg}} \times 100$$

$$\mathrm{PEN}_{s,t} = \frac{\mathrm{P}_{s,t=0}^{reg} + \sum_{r=0}^{t-1} B_{s,r}^{reg} - \sum_{r=0}^{t-1} D_{s,r}^{reg} + \sum_{r=0}^{t-1} N_{s,r}^{proj} - P_{s,t}^{reg} - ER_{s,t}}{P_{s,t}^{reg}} \times 100$$

The absolute value of the percentage errors due to the registers, births, deaths and net migration is summed to the Register and Component Absolute Percentage Error (RCAPE):

$$RCAPE_{s,t} = \left|\mathrm{PER}_{s,t}\right| + \left|PEB_{s,t}\right| + \left|PED_{s,t}\right| + \left|PEN_{s,t}\right|$$

Using this calculation, the errors are first decomposed to the individual components, which roughly constitute a projection. More specifically, we account for errors in the registers, as well as in the number of births, deaths and net migrations. These are first summed over time to a total measure of the error in each component and then the absolute values of these component errors are summed up to the RCAPE aggregate measure. RCAPE can be interpreted as the error one would find if the error in all components pointed in the same direction. Thus, it sums up the accuracy of all the components in a single number. This measure is analogous to the SCAPE measure used by Wilson (2007).

Results

Evaluating the accuracy of the 1996-2018 national population projections

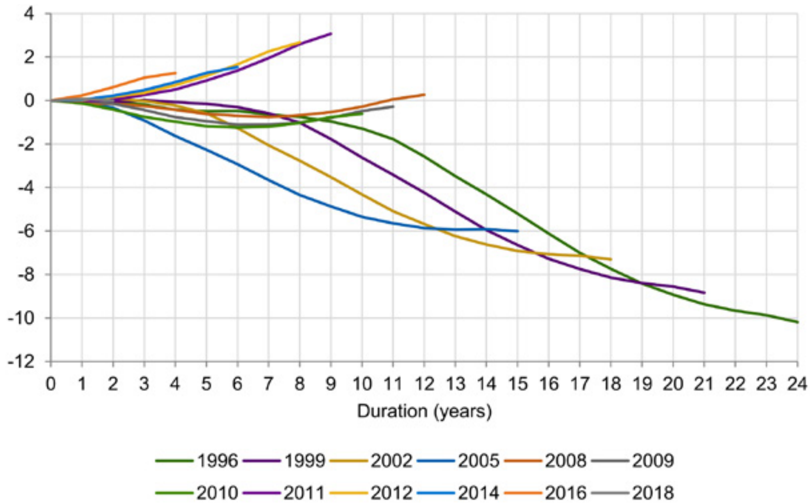
An assessment of the accuracy of the projections includes examining the projected and the registered population. This includes the overall population, age structure, fertility, mortality and net migration. The following section starts with an assessment of the projected total population and age structure before examining the accuracy of each demographic component.

Total population

A simple comparison of deviations between the projected and registered total population will be sensitive to the size of the population, which varies over time, and errors tend to increase over time. Consequently, it can be more informative to examine errors as a percentage of the registered population. Figure 1 details the percentage errors for all projections between 1996 and 2018, comparing the projected total population size with the actual population size for the available years after each projection (e.g. up to 24 years for the 1996 projection and up to two years for the 2018 projection). The estimates are shown in Appendix Table A1. Older projections appear to have underestimated population growth, though the deviations between the projected and registered population were relatively small in the period up to 2005 and the expansion of the EU. For the projections produced in 2008–2010, there is no persistent underestimation of the population growth, with percentage errors never exceeding ± 1.25 percent. The 2011 projection is reasonable in the first four years, before it appears to substantially overproject population growth. A similar tendency is also observed in the short-run for the population projections from 2012–2016. So far, the 2018 projection is performing relatively well, with errors of less than 0.10 percent.

In general, the population projections tend to perform poorly during times of significant demographic change. A common challenge when making population projections relates to the decision of whether to treat shifts in demographic trends as short-term fluctuations or long-term changes. While the first alternative might lead to 'assumption drag', i.e. an overreliance on outdated core assumptions, the second alternative, if it is later proven to be wrong, may be disruptive to long-term policy planning (Ascher 1979). It appears that both projections of fertility and net migration have been affected by assumption drag in the past. However, as we show below, the opposite may have been the case for fertility projections in more recent years.

Figure 1. *Percentage errors between registered and projected total population figures (the medium alternative) by duration (in years) since production*



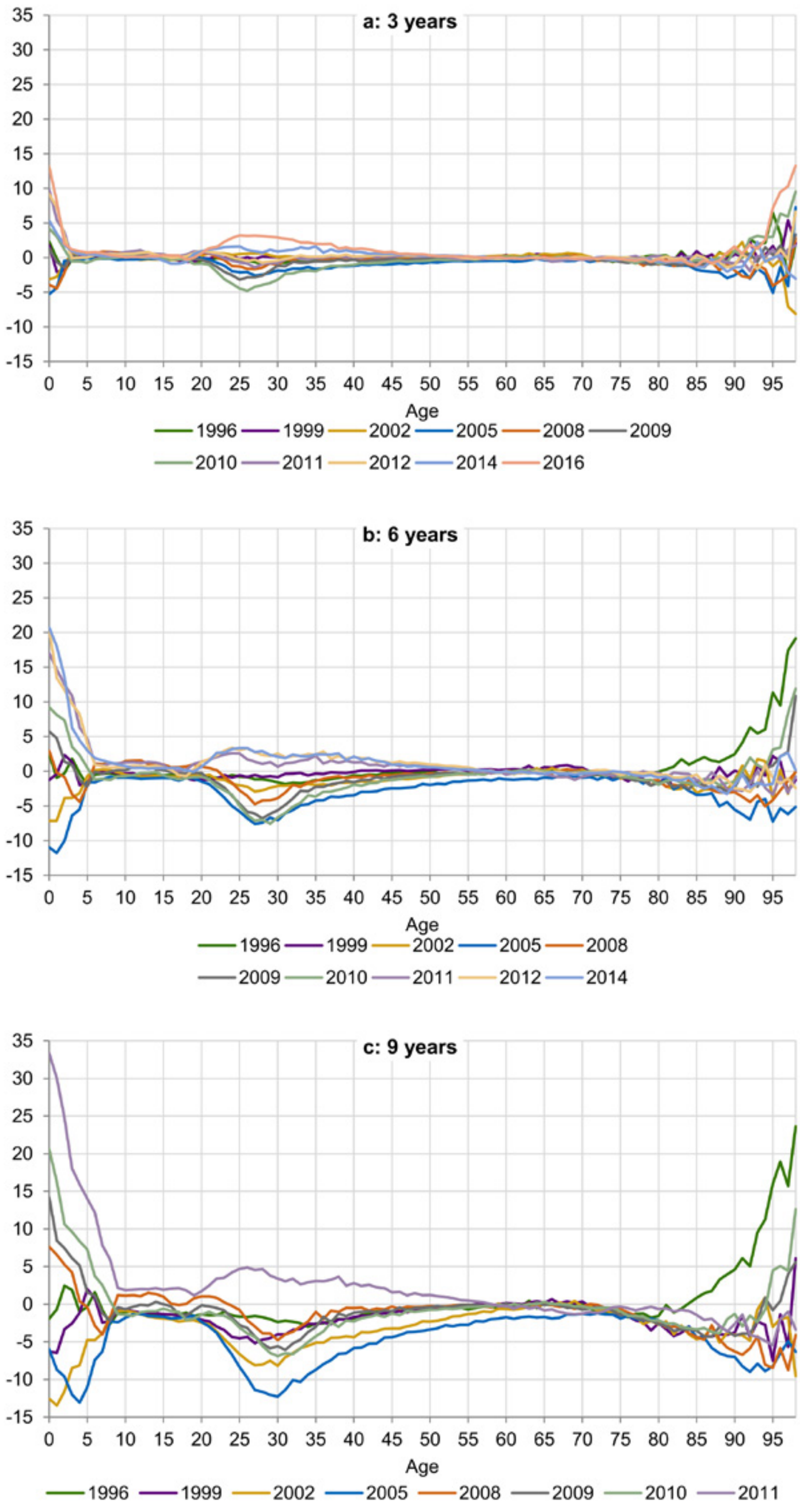
The underlying figures are presented in Table A1.

Age structure of the population

The age structure of the population is perhaps the most important aspect of population projections in terms of its role in determining the relative size of the working-age population and the degree to which investments in welfare services, such as kindergartens, schools and nursing homes, are required.

According to Keilman (1997), a pervasive feature of projections in industrialized countries has been to overestimate future fertility and underestimate future mortality, a scenario that leads to the assumption of too many births and too few elderly and thus an incorrect estimation of both the size and age structure of the future population. Texmon and Keilman (1991) have observed the same issue when examining older Norwegian projections. In Figure 2, percentage errors for one-year age groups are plotted after three (a), six (b) and nine (c) years, respectively. The figure shows ages up to 98 years, and the figures are not adjusted for errors in total population, so an error of 0 percent means that the projection was accurate for the given age group in that year. Negative numbers mean that too few individuals were projected in the given age group. It is worth noting that in the oldest age groups there are very few people, so large percentage errors do not necessarily reflect large errors in absolute terms. Note that while errors in the number of young children are primarily affected by projection errors in TFR, they are also affected by projection errors in the number of immigrant women of childbearing age as well as childhood immigrants.

Figure 2. *Percentage errors between registered and projected figures for one-year age groups in the projections, 3, 6 and 9 years after start year*



Age is shown on the x-axes, whereas the percentwise errors are shown on the y-axes. The underlying figures are available on request.

From Figure 2, we can see that there has been no systematic overprojections of births (or young children) in the projections produced between 1996 and 2009. Rather, too few births were projected in 2002, 2005 and to a lesser extent in 1999. More recently, the population projections have overprojected the number of births, primarily due to a pronounced decline in fertility since 2009, from a TFR of 1.98 to 1.53 in 2019, leading to an overprojection of the number of children. Although the overall reasons for declining fertility are difficult to determine, the data indicate that the overestimation of the number of births in the last projections has been due to an increase in maternal age (postponement of births) and fewer women having three or more children (Syse et al. 2020).

In addition to errors in fertility, the earlier projections (1996, 1999, 2002 and 2005), as well as those undertaken in 2009 and 2010, underestimated the number of people aged 20 and older. The projections made since 2011 have tended to slightly overestimate the number of people aged 20 and older. As discussed below, this is largely due to discrepancies between projected and realised net migration. There is also a tendency to underestimate the number of people in older age groups in the longer-term (Figure 2c) – especially those aged between 75 and 90 years of age.

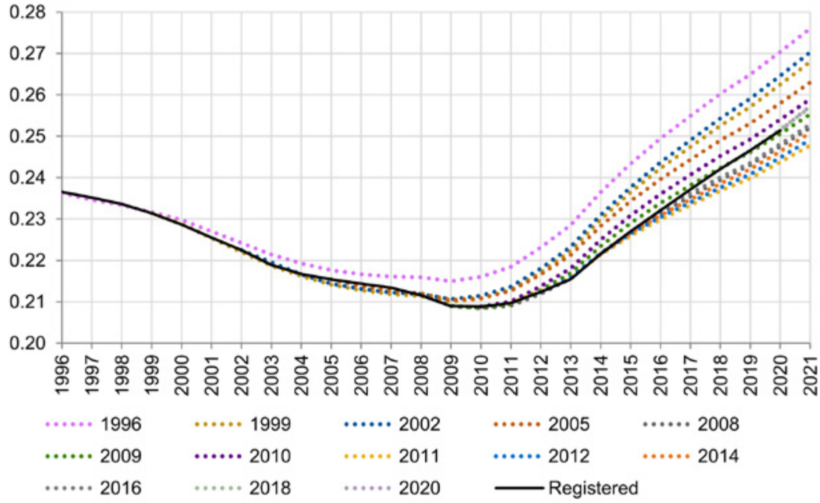
The old age dependency ratio is a measure that indicates the ratio of the number of elderly (67 years and older) to the number of people in working ages (20–66). It thus provides a rough approximation of the 'burden' associated with the elderly relative to the 'productive' population (a higher ratio indicates an increased burden). The ratio does not account for the actual employment rates of these groups, nor the share of older people who are truly dependent, in need of care, or contribute to care-related activities. In the context of population ageing, itself driven by strong and persistent increases in life expectancy and the ageing of the large post-war cohorts, the dependency ratio has become an increasingly important focus for academics and policy makers alike. When we compare the projected and registered old-age dependency ratios (Figure 3), the projections from 1996–2005 assumed a high dependency ratio in the intermediate-term (i.e. five to ten years from the publication year) with a fairly rapid onset. However, the ratio did not increase as soon in reality as it was projected to do. Again, this is largely a result of the fact that these earlier projections underestimated net migration (see below), with high immigration working to postpone the process of population ageing in Norway. In projections produced after 2008, there has not yet been a consistent over- or underestimation of the projected old-age dependency ratio.

Fertility and the number of births

The number of births is affected by the fertility level, the proportion of immigrant women, as well as the composition of the population of immigrant women in terms of their country group of origin and their length of stay. The number of births is also impacted by the total number of women and the age structure of the female population, which is also impacted by net migration and the age distribution among women who migrate. Thus, immigration not only influences the number of children born per woman, but also, and more importantly, the number of resident women who may have children (Tonnessen 2014).

It appears that there has been a strong tendency to project fertility at similar levels as

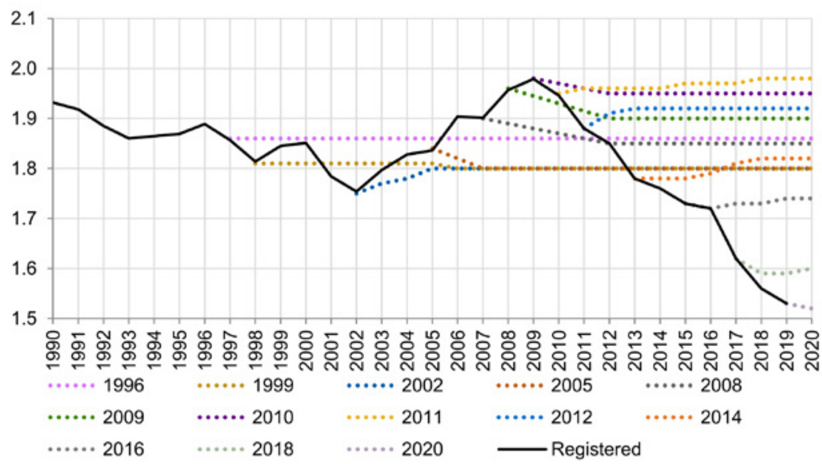
Figure 3. *Projected and registered old age dependency ratios*



Old age dependency ratio is defined as the ratio of the number of elderly (67+ years) to the number of people in working ages (20–66 years). The underlying figures are available on request.

those observed in the year prior to the production of the fertility projections. In other words, the current levels of fertility have largely been extended into the future. When looking at the projected and registered TFR between 1996 and 2009 (Figure 4), we find no consistent under- or overprojection during this period. However, since 2009, the year in which period fertility started to shift downwards, recent projections have consistently overprojected the TFR. This tendency to project fertility at similar levels as those observed immediately prior to the production of the projections constitutes the opposite of an assumption drag, namely a tendency to treat short-term fluctuations as persistent changes in levels (Ascher 1979, Shaw 2007).

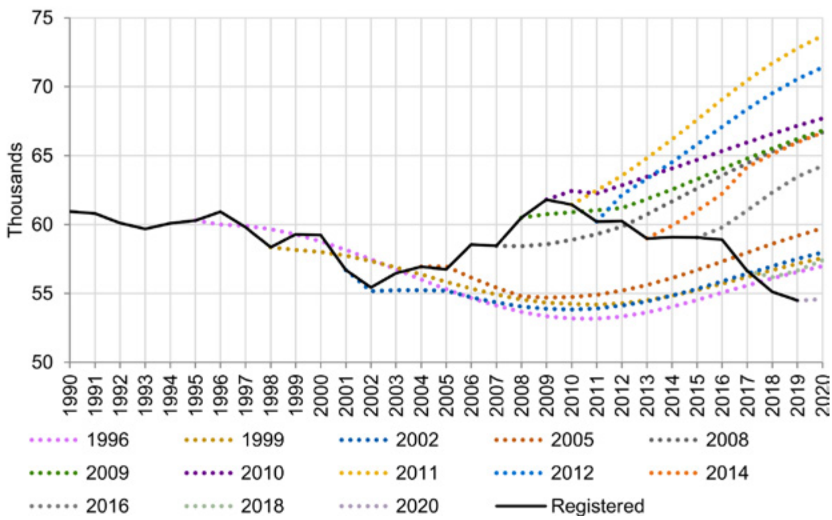
Figure 4. *Projected and registered total fertility rate (TFR)*



The underlying figures are available on request.

When it comes to the projected and registered number of births (Figure 5), we observe some interesting distinctions. The projections produced between 1996 and 2005 performed relatively poorly in terms of the accuracy of their short-term projections of the number of births, but much better in the longer term. The underprojection of the number of births after 2005 in these projections are due in part to the large increase in net migration during this period, a process that contributed to an increase in the number of women of childbearing age, and due to the strong increase in fertility (TFR increased from 1.75 in 2002 to 1.98 in 2009). However, at the same time, the fertility of immigrants has also decreased (Tonnessen 2014, 2020). Thereafter, the fall in fertility due to the postponement of childbirths and fewer women having more than two children has contributed to the clear overprojection of the number of births in the projections made since 2009. However, this decline in the TFR since 2009 has resulted in smaller errors for the projected number of births produced between 1996 and 2005 for more recent years.

Figure 5. *Projected and registered number of births*

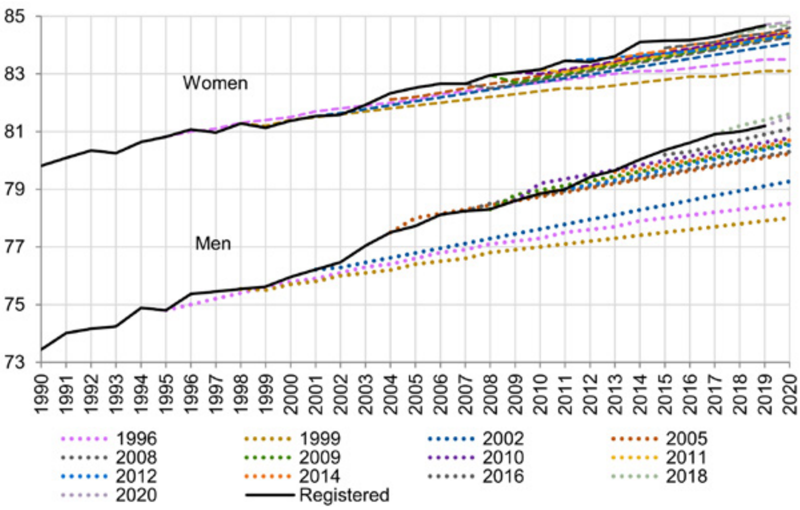


The underlying figures are available on request.

Life expectancy and the number of deaths

The underestimation of life expectancy is a common occurrence across many national contexts, with people tending to live longer than demographers have assumed in their population projections (Keilman 2008, Keilman & Pham 2004, Syse & Pham 2014). As can be seen in Figure 6, the problem persists in recent projections for Norway, though the size of discrepancies between projected and registered life expectancy have become somewhat smaller in recent years. This is in part due to an adjustment of start dates for the historical time series included in the modelling – from 1950, to 1968 for the 2014 projection, to 1990 for the 2016 and 2018 projections. Of course, it is also worth noting that the time horizon for evaluation is rather short for the latest projections.[9]

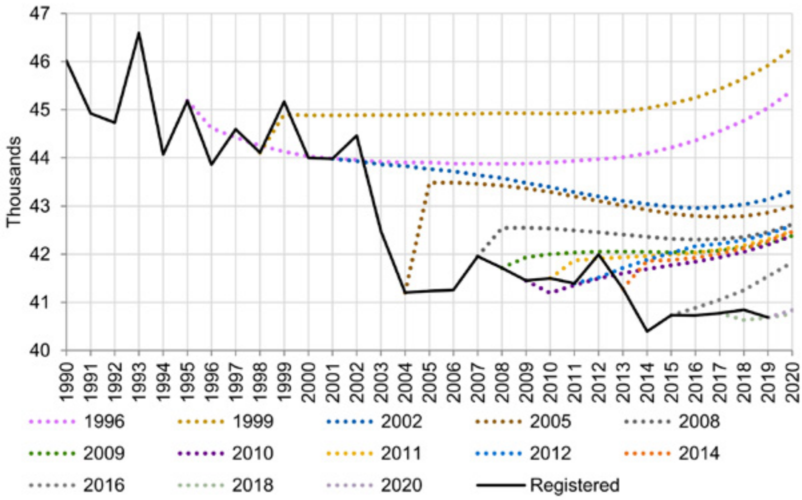
Figure 6. *Projected and registered life expectancy at birth for men and women*



The number of deaths is affected by the age-specific probabilities of death (which are converted and summed to the life expectancy), but also by the age structure of the population. When there are more elderly people there are also more deaths, but a strong increase in the life expectancy (especially in older ages) can pull in the opposite direction. From the projected and registered number of deaths shown in Figure 7, there has generally been an overprojection in the number of deaths, which itself results from an underprojection of life expectancy. Thus, while the errors are relatively small in absolute terms, it appears that the projections have not predicted the persistent downward trend in registered deaths, with the particularly sharp decline observed between 2002 and 2004 leading to large deviations between the projected and registered trends. This is also in part evident in Figure 2, in the relatively marked percentwise errors for the highest age groups.

9 Life expectancy is somewhat lower in the projections than in the population statistics (maximum 0.5 years) because the projections use age at the end of the year and not age at the event, and due to characteristics of the model used to project life expectancy.

Figure 7. *Projected and registered number of deaths, men and women combined*



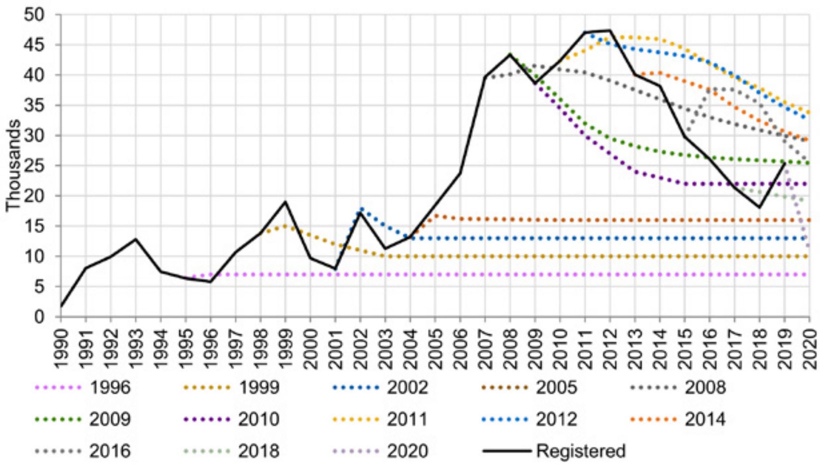
The underlying figures are available on request.

Net international migration

Net migration in recent decades can be divided into two periods; before and after the EU expansion in 2004. Figure 8 shows that up to 2004, we observe a slight increase in net migration, with specific peaks occurring as a result of refugee inflows. During this period, long-term constant levels of net migration were projected, which were at about the same level as the registered net migration in the previous years. Prior to 2005, the deviations in these projections were relatively small. However, the scale of the increase in labour immigration that resulted from the EU expansion in 2004 was not anticipated in the projections produced between 1996 to 2005 and led to considerable underestimation of net migration in these projections in the short and medium term.

In contrast, projections from 2011 and onwards have estimated higher levels of net migration and, at least in the short-term, these projections have proven to be too high. This is seen especially in the case for the 2016 projections, where *ad hoc* assumptions of high net migration resulting from the refugee crisis were applied, but since the expected migrants did not arrive, or in many cases were denied residency, increasing levels of net migration did not occur. However, for projections produced after 2005, we find no consistent under- or overprojection of net migration.

Figure 8. *Projected and registered net migration*



The underlying figures are available on request.

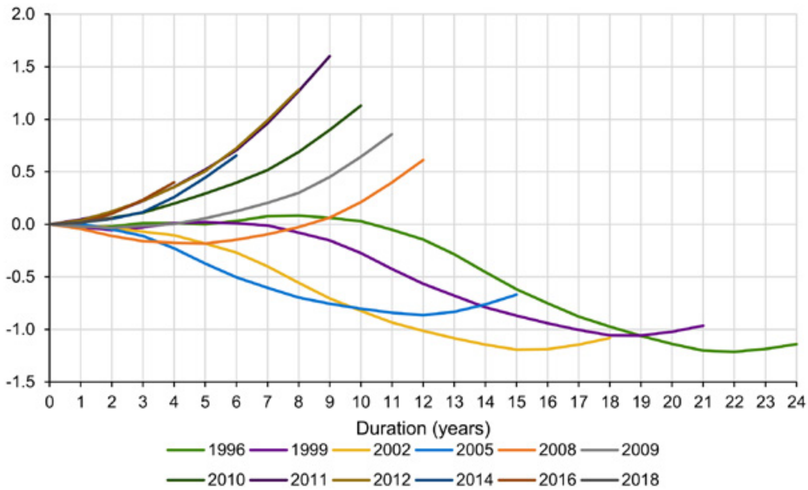
How much do the errors in each component contribute to the total error?

To be able to compare the contribution of each component to the total error in the projections, we decompose the errors into errors that can be attributed to discrepancies in the number of births (PEB), number of deaths (PED) and net migration (PEN). The errors are portrayed in Figures 9–11, whereas the corresponding estimates are shown in Appendix Tables A2–A4.

These component measures (PEB, PED and PEN) show us the contribution of each component to the total error. For example, percentage error attributed to the number of births (PEB) shows how many percentage points the total error would be in the projection if the number of deaths and net migration were accurate, but not the number of births. Because the errors are cumulative, components that are too high one year and equally too low the next, or vice versa, will sum to zero over time, meaning that the component errors can be interpreted as cumulative deviations from the long-term trend, rather than errors due to short-term fluctuations. In addition, the individual components do not take into account possible interaction between the components, such as the fact that higher net migration usually contributes to an increase in births over time.

Figure 9 illustrates that the percentage errors attributed to errors in the number of births (PEB) contribute relatively little to the total percentage error in the projections – mostly less than one percentage point after durations of up to ten years. In particular, the projections from 1996, 1999 and 2008 were close to the registered numbers of births. This is in part because these projections assumed fairly accurate levels of fertility in the short- to intermediate term (TFR of 1.86, 1.80 and 1.85, respectively), but also due to the fact that these projections were quite accurate when projecting net migration on an intermediate term basis. The errors in the number of births are particularly pronounced when too high or too low levels of TFR have been projected medium-term or when net migration trends have been inaccurately projected.

Figure 9. *Percentage error attributed to deviations in the number of births (PEB) by duration (years) for projections produced in different years*

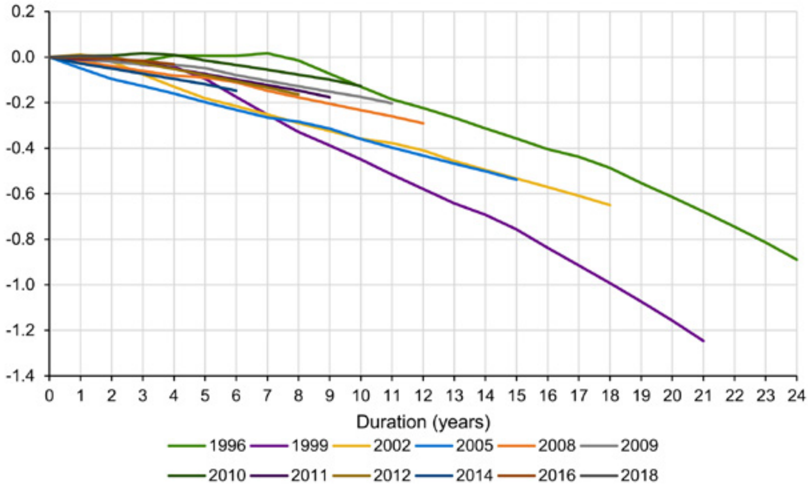


The underlying figures are available on request.

Errors in the projected number of deaths have very little significance for the total population errors, as is shown in Figure 10. Errors in the number of deaths contribute less than half a percentage point when examining durations of up to ten years. However, as mentioned earlier, we have consistently underestimated the increase in life expectancy and thus projected too many deaths in total in all projections, as is indicated by negative trajectories in Figure 10.

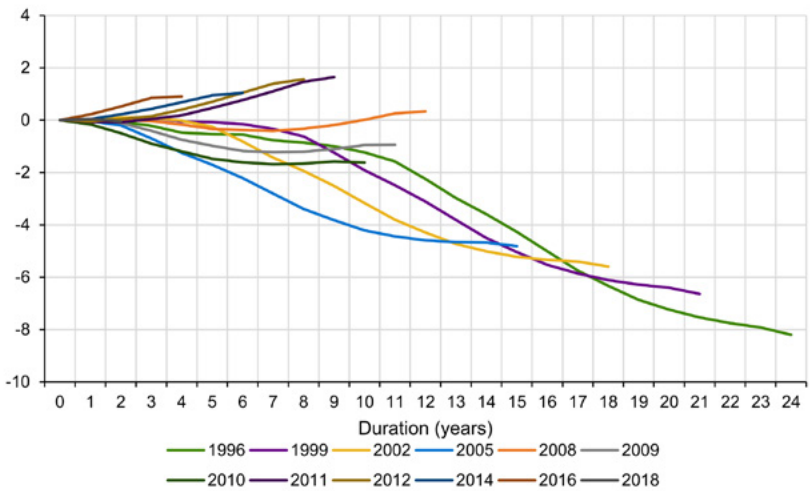
As mentioned earlier, and shown in Figure 11, migration projections contribute most to the total errors in the projections, up to more than four percentage points after ten years. Earlier projections (those produced before 2011) mainly underprojected net migration, although the errors in some projections were small for a long period of time. In the more recent projections (2011, 2012, 2014 and 2016) this is no longer the case. The figure also illustrates that the 2008 projection has been quite accurate when projecting net migration. As previously mentioned, the underprojection of immigration in the projections produced up to, and including 2005, can be attributed to the high number of labour immigrants following the EU expansion in 2004, as well as the low projection of net migration from other country groups.

Figure 10. *Percentage error attributed to deviations in the number of deaths (PED) by duration (years) for projections produced in different years*



The underlying figures are presented in Table A3.

Figure 11. *Percentage error attributed to deviations in net migration (PEN) by duration (years) for projections produced in different years*



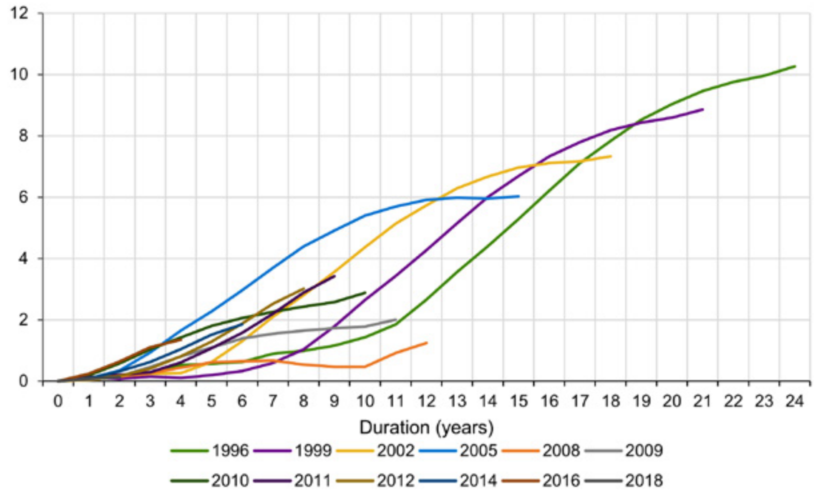
The underlying figures are presented in Table A4.

Overall accuracy

Figure 1 illustrated the percentage errors in the projections examined in this study. Calculations of percentage errors for the entire population combined gives a measure of accuracy that is easy to calculate and interpret. However, the number provides little information about the *causes* of the errors. Furthermore, errors in different components can net each other out. As an example, overprojection of both fertility and mortality can result in very small percentage errors but will in turn result in a projected population that is younger than the registered one.

To compensate for this, we also calculate the 'register and component absolute percentage error' (RCAPE). RCAPE can be interpreted as the error one would find if the error in all components pointed in the same direction. Thus, it sums up the accuracy of all the components to a single number. Figure 12 (and Appendix Table A5) compares RCAPE by duration and shows that the 2008 projection is the most accurate one for all components overall in the intermediate term, i.e. five to ten years from the publication year. This is mainly because the migration projections were quite accurate, but also that the projection of the total number of births so far has been quite accurate (see above). In the projections from 1996 and 1999, the errors were also small for a long time, but they increased sharply after immigration increased from around 2005. The 2002 projection held up well for the first five years, but thereafter the errors have increased markedly. There are relatively pronounced errors in the 2005 and 2010 projections, both short- and long-term, whereas the errors in the 2009 projection appear more moderate. Again, it is mainly migration that causes the errors in these projections. So far, the projection errors from the 2011 and 2012 projections appear moderate in the short-term, but the errors have increased in recent years. As for the projections from 2016 and 2018, only short-term errors can be assessed. These are rather marked for the 2016 projection, mostly due to this projection missing the mark on short-term net migration following the refugee crisis. So far, but with only two years of observation time, the 2018 projection is remarkably accurate, and the errors are minor. However, the COVID-19 pandemic was not accounted for in the production of this projection. During the current health crisis, and subsequent economic crisis, most borders have been closed, and international travel is very difficult. This has had, and will continue to have, effects on all forms of migration, from labour, student, refugee to family unification migration. In addition, quarantine regulations make it difficult to work cross-nationally, and most schools and universities have been physically closed. For the coming years, migration is thus likely to be much lower than what was assumed in 2018, and we thus expect the errors to increase in the years to come. In addition, the short and longer-term effects of this crisis on fertility and mortality are difficult to predict.

Figure 12. *Register and component absolute percentage error (RCAPE) by duration (years) for projections produced in different years*



The underlying figures are presented in Table A5.

Discussion

Errors in projections emerge from a wide range of sources. These sources include, but are not limited to, natural stochastic temporal fluctuations, errors in base populations, limited knowledge of underlying demographic dynamics (i.e. fertility, mortality and migration processes), the emergence of unforeseen social, health, political and economic changes as well as mis-specification of projection models. As such, there will always be discrepancies between the projected and the registered total population, as well as for different population subgroups. While fertility proved to be the most difficult component to project during the post-war period, we find net international migration to be the main source of errors in more recent population projections (1996–2016). Indeed, for the projections produced in 1996, 1999, 2002 and 2005, we observe an underprojection of long-term population growth due to the unforeseen increase in immigration driven by the EU expansion in 2004. However, for projections produced after 2005, we find no consistent under- or overprojection of net migration. For fertility, the deviations between projected and registered TFRs over the period 1996–2009 do not point systematically in one direction and, compared to net migration, the errors in the number of births have been relatively minor. With that said, our assessment does identify an overestimation of TFR since 2009, driven largely by a persistent decline in fertility levels observed over the last decade. Indeed, there is a tendency to project fertility at similar levels as those observed immediately prior to the production of the fertility projections. For life expectancy at birth, better than expected mortality rates have led to a systematic underestimation of life expectancy, though errors in the number of deaths are far smaller than those observed for net migration over the same period. Taken together, the discrepancies between the projected and registered total populations appear moderate for the period studied.

Historically, methodological studies of projections in individual countries have focused almost exclusively on mortality (see e.g. Lee & Carter 1992, Li & Lee 2005, Hyndman et al. 2013, Janssen 2018). This might seem surprising as, at least for Norway, the mortality component contributes relatively little to the overall inaccuracy of projections. However, mortality is the only component for which many countries find that the errors are systematic (Keilman 1997), and as such they might be perceived to constitute a more profound problem than the non-systematic errors observed for net migration and fertility. Studies evaluating the methodological approaches and developments in fertility projections have been rarer, although notable exceptions exist (Hyndman & Ullah 2007, Bohk-Ewald et al. 2018). For some countries, as was the case for Norway prior to the EU expansion, the impact of this component is substantial, as the effect of even a small change in fertility can have cumulative effects, across generations, that will play out over many decades (United Nations 2013). Recently, methodological advances have taken place also in the projections of international migration (e.g., Bijak 2011, Cappelen et al. 2015, Disney et al. 2015, Raymer & Wiśniowski 2018). This appears warranted, as projections of net migration tend to result in rather pronounced inaccuracies. As we have shown, net migration is the source of the largest share of the errors in the Norwegian population projections in recent decades.

It is important to note that population projections may be used to amend policies to avoid or prepare for certain future population developments, for instance in anticipation of strong population ageing. If medium- and long-term inaccuracies are a result of policy changes that seek to adjust population development, deviations between the projected and registered population size and structure are clearly less attributable to the producers of projections. With that said, when planning is informed by projection results, knowledge of the reliability of projections, and the errors therein, becomes even more important. As an example, trends and estimates of past, present and future migration may be used to inform changes in policies that impact subsequent migration flows, but also to prepare societies for the more diverse populations that may result from such flows. Indeed, recent history has shown us that after particularly large increases in immigration, policies are often put in place to reduce subsequent entries – as was the case in the aftermath of the relatively large asylum-related flows of 2015–2016 in Norway. If the projected migration figures are inaccurate, policy adjustments and preparations might be unjustified, for instance, in unduly restricting access to future immigrants or in affecting the support (e.g. in education and language course opportunities) offered to already resident immigrants. Errors in the projection of net migration might also result in misinformed immigration debates in the public sphere.

Statistics Norway's most recent population projections, carried out in 2020, estimate that the Norwegian population will continue to grow. [10] However, the projected growth is weaker than what was postulated in 2018, corresponding to a 7 percent reduction in the projected total population in 2060 and accompanied by a larger decrease in the younger half of the population than the older half (Syse et al. 2020). Such a reduction among persons in prime working ages would normally result in a lower total GDP, but not necessarily in GDP per capita. It would also have implications for the per capita income of the oil fund, where one could expect an increase in the per capita income. However, the expenses for pensions (OECD 2019a) and health and care services (OECD 2019b) might become slightly higher since life expectancy is assumed to increase more than previously projected (Syse et al. 2020, European Commission 2016). Furthermore, a systematic overprojection of the number of deaths, which itself results from an underprojection of projected life expectancy, will result in a stronger than projected ageing of the population and thus a larger total number of elderly people. Thus, while the errors are relatively small in absolute terms, it might have profound consequences for elderly individuals, communities and welfare systems, since older individuals use more services and rely more on public welfare than many other population subgroups.

To summarize, Stoto's (1986) two main messages from near 40 years ago still appear to be valid: First, simple projection techniques may give as accurate results are more complex methods. Second, knowledge of past population projection errors may be valuable in helping estimate the accuracy of future projections. The latter argument is recently emphasized in a regional study by Chi and Wang (2018), where they assess factors that affect projection accuracy for population figures in various US counties. They conclude that the counties whose populations are more predictable tend to be desirable places, in terms of, for instance, employment, income and education. They further argue that an improved understanding of factors that affect population accuracy may aid users in utilising the projections knowledgeably. We believe this to be a valid argument also at national levels. Beyond the publication of regular reviews of past projections, Statistics Norway's StatBank contains projected figures from previous projection rounds starting in 1996.[11] Making historical projections publicly available allows users and the scientific community to independently assess the accuracy of past projections. It also enables policy makers and planners to adjust previously laid plans if the inaccuracies warrant such adjustments.

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10 An updated population projection will be published 5th July 2022.

11 All projections from 1996 onwards can be found under 'older projections' at https://www.ssb.no/en/statbank/list/folkfram.

Concluding remarks

Regardless of the methods used to make projections, responsible agencies need to make choices and assumptions about the type of method to be used, the base period and the selection of indicators and explanatory variables. Additionally, assumptions must be made concerning continuations of past trends or future changes in the population. Ideally, decisions and assumptions underlying the choice and application of methods should be made explicit, as this will allow users to evaluate their usefulness (de Beer 2011). In other words, projections should be transparent. It is perhaps unfortunate, therefore, that most agencies only evaluate the accuracy of their short-term projections, that the evaluations are mostly informal and only performed prior to the production of a new round of projections. Indeed, few agencies regularly report the accuracy of their past projections to users (Gleditsch et al. 2021a).

Providing users with regular accounts on the accuracy of past projections is one way to increase transparency. Furthermore, by reporting on the short-, medium- and long-term discrepancies between projected medium alternatives and registered population figures in Norway, we have identified the existence of a systematic underestimation in life expectancy, revealed the durations at which large component-specific discrepancies start to emerge, highlighted the effect of the unforeseen consequences of certain events (e.g. the large increase in immigration that followed EU expansion in 2004) and identified the apparent tendency to project fertility at similar levels to those observed immediately prior to the production of the projections. Such information is useful for identifying the areas where adjustments to our current models and assumptions are most necessary. The information can also be useful for policymakers, government officials and businesses that frequently use the projections and need to take the uncertainty of projection results into account.

Furthermore, the information on the inaccuracies reported here may also be used to argue for the use of multiple scenarios and/or prediction intervals, i.e. the relevance of providing users with several alternatives to convey the message of the inherent uncertainty that is associated with projection work and its results. By providing measures of accuracy of past projections along with alternative future scenarios, we remind ourselves and our users of Stoto's (1983) important message: Although population projections are important tools for planning and policy analyses, they can never exactly foretell the future.

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Appendix

Concepts

In both Statistics Norway's official statistics and in the population projections immigration is defined as the number of migrations to Norway during a single-year period, irrespective of the immigrants' country of birth or citizenship. For example, during a calendar year, immigration to Norway typically includes 8 000-10 000 Norwegian citizens. *Emigration* is defined as the number of migrations out of Norway during a period, irrespective of the country of birth or citizenship. *Net migration* corresponds to the difference between the number of immigrations to and emigrations from Norway during a single year. As mentioned, individuals who both immigrate and emigrate (or vice versa) during a single year are not counted toward the total number of immigrations and emigrations that year in the projections.

Start year (also denoted 'jump-off year') is the year in which the projection is produced and the first year for which fertility, mortality and migration are projected. *Start population*, on the other hand, is the population on January 1st of the start year. This is also called the *initial population* or the *base population*. *Duration* is the number of years after the start year, e.g., the time that has elapsed since the projection was produced. *Total fertility rate* (TFR) is a measure of the number of children a woman will have if, throughout her life, if she follows the age-specific pattern of fertility (the average number of children at each age) for a given year, and she does not die before the end of her fertile period. *Life expectancy* at birth is a measure of how long you can expect to live if you follow the sex- and age-specific mortality patterns for a given year.

Country Groups

Statistics Norway divide immigrants according to three country of origin groups based on 'country of birth' and not, for example, citizenship or previous country of residence. Even though there is substantial heterogeneity within each country group of origin, there are also certain similarities. Over the years, several versions of country groupings have been used (cf. Gleditsch et al. 2021b). However, since 2010 the country group breakdown has remained generally unchanged.[11] In this grouping, *Country Group 1* comprises all the Western European countries, i.e. countries that were part of the 'old' EU (pre-2004) and/or the EFTA, as well as the US, Canada, Australia and New Zealand. On average, nationals from these countries display relatively similar demographic behaviour for fertility and emigration. Moreover, few or no restrictions apply in terms of opportunities for living and/or working in Norway. *Country Group 2* comprises the eleven new EU countries in

11 Croatia was switched from Country Group 3 to Country Group 2 upon gaining EU membership in 2013.

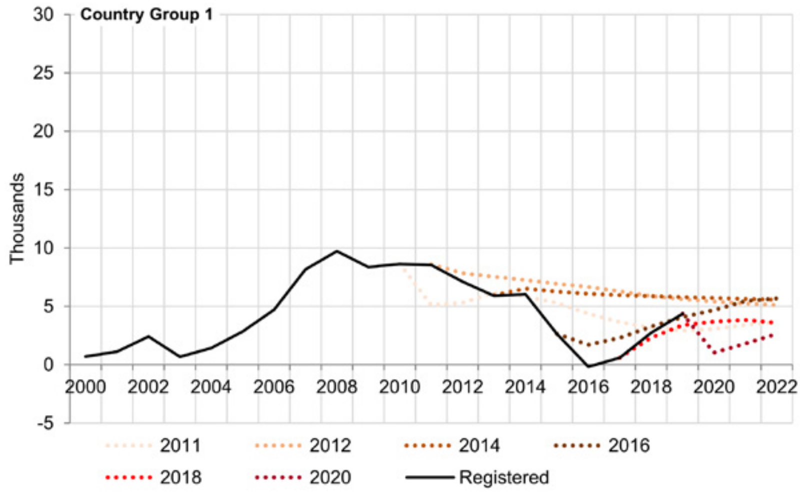
Eastern Europe (EU members in 2004 or later): Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. Migration from these countries was a major contributor to the immigration peak in Norway from 2007 to 2016. Moreover, among all of the EU countries, these are the 11 countries where the income differences are greatest relative to Norway, while the expected demographic development in these countries also differs from other parts of the EU. As with all EU citizens, persons from this country group have the right to live, work and study in Norway. Country Group 3 comprises 'the rest of the world', e.g. the rest of Eastern Europe, Africa, Asia (including Turkey), South and Central America and Oceania (excluding Australia and New Zealand). Nationals from these countries must apply for a permit to live and work in Norway. While a large share of immigrants from these countries arrive as refugees or asylum seekers, or as family members of such immigrants, this country group is particularly heterogeneous, and forecasters have primarily grouped these countries for the sake of simplicity.

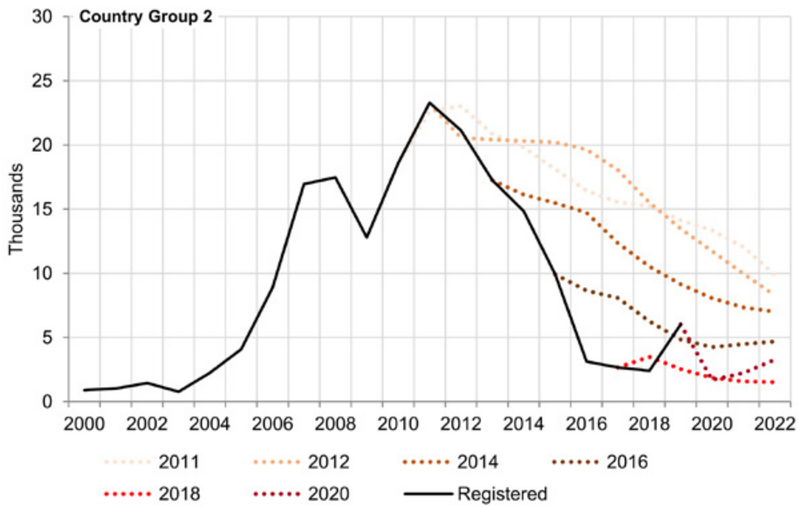
Migration

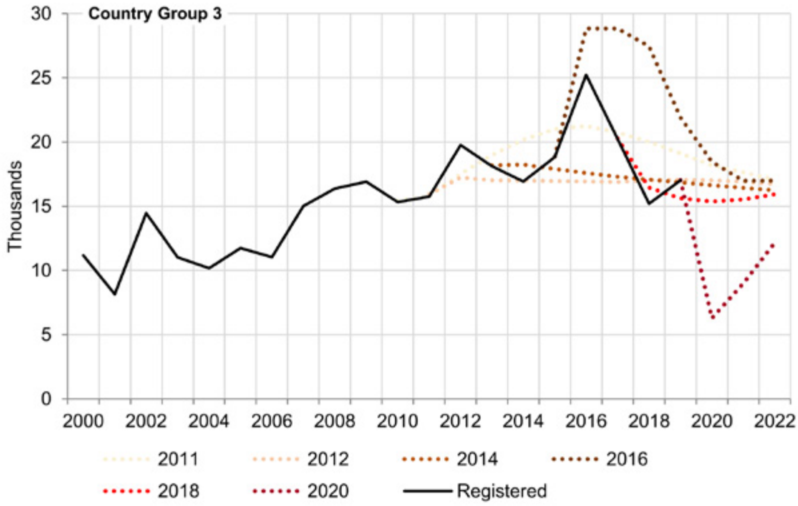
Since 2005, net migration to Norway has been higher than previous years and although net migration increased from all country groups, immigration from Eastern European EU countries has contributed the most to the increase. In the 2008 projections, net migration was projected at a much higher level than previous projections due to the recently observed increase in immigration from these countries. In 2009 and 2010 it was assumed that economic development in Norway would be weaker in the future and that unemployment rates would be higher. As a result, it was assumed that the economic differences between Norway and 'the rest of the world' would be reduced and that net migration would decline, especially from Eastern European EU countries. In reality, however, registered net migration continued at approximately the same level in the years that followed, which resulted in underprojections of net migration in the 2009 and 2010 projections.

Figures for projected net migration from the various country groups are only available from the projections starting in 2011 and are shown in Figure A1. When looking at net migration from Country Group 1 (Western European countries, United States, Canada, Australia and New Zealand), the discrepancies are small in absolute terms, though there seems to be a tendency of overprojecting net migration in the projections between 2011 and 2016. For Country Group 2 (new EU countries in Eastern Europe), there has been a consistent overprojection of immigration, while a small overprojection of emigration numbers has also occurred, which in turn worked to reduce the error in projected net migration for this country group. For Country Group 3 (the rest of Eastern Europe, Africa, Asia (including Turkey), South and Central America and Oceania except Australia and New Zealand), the differences between registered and projected net migration numbers are small, except for the 2016 projection which grossly overestimated net migration.

Figure A1. *Net migration from Country Groups 1, 2 and 3 in projections from 2011 onwards*







Net migration results from subtracting emigration from immigration from 2011 onwards. Prior to this, assumptions were made only for net migration. Country Group (CG) 1 comprises all Western European countries, i.e. those part of the 'old' EU (pre-2004) and/or the EFTA, as well as the US, Canada, Australia and New Zealand. CG2 comprises the 11 new EU countries in Eastern Europe (post-2004): Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. CG3 comprises 'the rest of the world'.

Additional tables

Table A1. *Percentage errors between registered and projected total population figures (the medium alternative) by duration in years since production (cf. Figure 1)*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1996	-0.01	-0.06	-0.18	-0.43	-0.49	-0.48	-0.65	-0.76	-0.97	-1.29	-1.78	-2.58	-3.49	-4.32	-5.20	-6.12	-7.01	-7.73	-8.42	-8.93	-9.37	-9.66	-9.87	-10.19
1999	-0.11	-0.07	0.02	-0.08	-0.15	-0.31	-0.59	-1.02	-1.77	-2.63	-3.41	-4.24	-5.11	-5.96	-6.64	-7.28	-7.75	-8.14	-8.40	-8.56	-8.84			
2002	0.07	0.09	-0.02	-0.23	-0.59	-1.27	-2.06	-2.77	-3.52	-4.32	-5.09	-5.68	-6.24	-6.62	-6.91	-7.07	-7.13	-7.30						
2005	-0.08	-0.34	-0.92	-1.63	-2.26	-2.94	-3.66	-4.35	-4.87	-5.35	-5.65	-5.87	-5.94	-5.92	-6.01									
2008	-0.13	-0.15	-0.25	-0.43	-0.63	-0.70	-0.77	-0.68	-0.54	-0.28	0.06	0.26												
2009	0.00	-0.15	-0.44	-0.77	-0.95	-1.11	-1.11	-1.02	-0.80	-0.48	-0.28													
2010	-0.13	-0.42	-0.75	-0.98	-1.19	-1.24	-1.21	-1.03	-0.77	-0.62														
2011	-0.02	0.03	0.25	0.51	0.92	1.38	1.95	2.59	3.07															
2012	0.01	0.17	0.35	0.71	1.13	1.67	2.25	2.67																
2014	0.03	0.22	0.48	0.84	1.27	1.54																		
2016	0.23	0.61	1.06	1.26																				
2018	0.07	0.00																						

Table A2. *Percentage error attributed to deviations in the number of births (PEB) by duration in years from January 1 in projection year (cf. Figure 9)*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1996	-0.02	-0.02	0.01	0.01	0.00	0.03	0.08	0.08	0.06	0.03	-0.05	-0.14	-0.28	-0.45	-0.62	-0.75	-0.88	-0.97	-1.06	-1.14	-1.20	-1.21	-1.19	-1.14
1999	-0.03	-0.05	-0.03	0.01	0.02	0.01	-0.01	-0.08	-0.15	-0.27	-0.42	-0.57	-0.68	-0.79	-0.87	-0.94	-1.00	-1.06	-1.06	-1.02	-0.96			
2002	-0.01	-0.03	-0.07	-0.10	-0.18	-0.27	-0.40	-0.56	-0.70	-0.82	-0.93	-1.01	-1.08	-1.14	-1.19	-1.19	-1.15	-1.08						
2005	0.00	-0.05	-0.11	-0.23	-0.37	-0.50	-0.60	-0.70	-0.75	-0.80	-0.84	-0.86	-0.83	-0.76	-0.67									
2008	-0.04	-0.11	-0.16	-0.18	-0.18	-0.15	-0.09	-0.03	0.06	0.21	0.40	0.61												
2009	-0.02	-0.03	-0.02	0.00	0.06	0.12	0.20	0.30	0.45	0.64	0.86													
2010	0.02	0.06	0.11	0.20	0.29	0.40	0.52	0.69	0.90	1.13														
2011	0.05	0.11	0.22	0.36	0.52	0.71	0.96	1.27	1.60															
2012	0.04	0.12	0.23	0.35	0.51	0.72	0.99	1.28																
2014	0.02	0.05	0.12	0.26	0.44	0.65																		
2016	0.02	0.10	0.23	0.40																				
2018	0.02	0.06																						

Table A3. *Percentage error attributed to deviations in the number of deaths (PED) by duration in years from January 1 in projection year (cf. Figure 10)*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1996	-0.02	-0.01	-0.02	0.01	0.01	0.01	0.02	-0.01	-0.07	-0.13	-0.19	-0.22	-0.27	-0.31	-0.36	-0.40	-0.44	-0.49	-0.55	-0.61	-0.68	-0.75	-0.81	-0.89
1999	0.01	-0.01	-0.03	-0.04	-0.10	-0.17	-0.25	-0.33	-0.39	-0.45	-0.52	-0.58	-0.64	-0.69	-0.76	-0.84	-0.91	-0.99	-1.07	-1.16	-1.25			
2002	0.01	-0.02	-0.08	-0.13	-0.18	-0.21	-0.25	-0.29	-0.32	-0.36	-0.38	-0.41	-0.46	-0.49	-0.53	-0.57	-0.61	-0.65						
2005	-0.05	-0.10	-0.13	-0.16	-0.20	-0.23	-0.27	-0.28	-0.31	-0.36	-0.40	-0.43	-0.47	-0.50	-0.54									
2008	-0.02	-0.04	-0.06	-0.08	-0.09	-0.11	-0.15	-0.18	-0.20	-0.23	-0.26	-0.29												
2009	-0.01	-0.02	-0.03	-0.03	-0.05	-0.08	-0.10	-0.13	-0.15	-0.18	-0.20													
2010	0.01	0.01	0.02	0.01	-0.01	-0.03	-0.06	-0.08	-0.10	-0.13														
2011	-0.01	-0.01	-0.02	-0.05	-0.07	-0.10	-0.12	-0.15	-0.18															
2012	0.01	0.00	-0.03	-0.05	-0.08	-0.11	-0.13	-0.16																
2014	-0.03	-0.05	-0.07	-0.10	-0.12	-0.15																		
2016	0.00	-0.01	-0.02	-0.03																				
2018	0.00	0.00																						

Table A4. *Percentage error attributed to deviations in the number of net migrations (PEN) by duration in years from January 1 in projection year (cf. Figure 11)*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1996	0.03	-0.06	-0.21	-0.48	-0.53	-0.55	-0.77	-0.86	-0.99	-1.23	-1.58	-2.25	-2.98	-3.59	-4.26	-5.01	-5.74	-6.33	-6.86	-7.23	-7.54	-7.75	-7.92	-8.20
1999	-0.09	0.00	0.09	-0.05	-0.08	-0.15	-0.33	-0.62	-1.24	-1.92	-2.48	-3.11	-3.81	-4.50	-5.04	-5.53	-5.86	-6.11	-6.28	-6.40	-6.64			
2002	0.02	0.10	0.09	-0.02	-0.25	-0.81	-1.43	-1.94	-2.52	-3.17	-3.80	-4.29	-4.73	-5.01	-5.22	-5.34	-5.40	-5.59						
2005	-0.04	-0.20	-0.69	-1.25	-1.70	-2.21	-2.81	-3.39	-3.82	-4.21	-4.44	-4.59	-4.66	-4.67	-4.81									
2008	-0.07	-0.01	-0.03	-0.17	-0.33	-0.37	-0.41	-0.32	-0.19	0.02	0.25	0.34												
2009	0.03	-0.10	-0.40	-0.75	-0.97	-1.17	-1.22	-1.21	-1.11	-0.95	-0.94													
2010	-0.16	-0.50	-0.90	-1.20	-1.48	-1.62	-1.68	-1.66	-1.57	-1.62														
2011	-0.06	-0.08	0.04	0.19	0.47	0.76	1.10	1.47	1.64															
2012	-0.04	0.04	0.15	0.40	0.70	1.05	1.40	1.56																
2014	0.04	0.22	0.44	0.68	0.95	1.04																		
2016	0.22	0.53	0.84	0.91																				
2018	0.05	-0.05																						

Table A5. *Register and component percentage error (RCAPE) by duration in years from January 1 in the projection year (cf. Figure 12)*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1996	0.07	0.11	0.27	0.53	0.57	0.62	0.90	0.99	1.16	1.43	1.85	2.65	3.57	4.40	5.28	6.21	7.11	7.84	8.53	9.04	9.46	9.76	9.96	10.27
1999	0.12	0.07	0.15	0.11	0.20	0.33	0.59	1.03	1.79	2.65	3.43	4.27	5.15	6.00	6.68	7.33	7.80	8.18	8.43	8.59	8.86			
2002	0.04	0.15	0.24	0.26	0.62	1.30	2.09	2.80	3.56	4.37	5.14	5.74	6.30	6.67	6.96	7.12	7.17	7.33						
2005	0.09	0.35	0.94	1.65	2.28	2.96	3.69	4.39	4.91	5.40	5.70	5.91	5.98	5.95	6.03									
2008	0.13	0.16	0.26	0.44	0.62	0.65	0.67	0.54	0.47	0.47	0.92	1.25												
2009	0.06	0.16	0.46	0.80	1.09	1.39	1.54	1.65	1.72	1.78	2.00													
2010	0.19	0.58	1.04	1.42	1.80	2.06	2.26	2.43	2.58	2.88														
2011	0.12	0.21	0.29	0.61	1.07	1.58	2.19	2.88	3.42															
2012	0.09	0.17	0.41	0.81	1.29	1.88	2.52	3.01																
2014	0.09	0.32	0.63	1.04	1.52	1.85																		
2016	0.24	0.64	1.10	1.35																				
2018	0.08	0.13																						