FINAL REPORT

RESTRICTED

Contract number: HPSE-CT-2001-00095

Project number: SERD-2000-00172

Title: CHANGING POPULATION OF EUROPE: UNCERTAIN FUTURE

Project coordinator: Statistics Netherlands

Partners: University of Joensuu
Statistics Norway
Statistics Finland

Reference period: from 1 September 2001 to 1 September 2004

Starting date: 1 September 2001 Duration: 3 years

Date of issue of this report: 28 January 2005

Project financed within the Key Action Improving the Socio-economic Knowledge Base

Statistics Netherlands
Division of Social and spatial statistics
Department of Demography

P.O.Box 4000
2270 JM Voorburg
The Netherlands

Changing population of Europe: uncertain future

Final report

January 2005

CHANGING POPULATION OF EUROPE: UNCERTAIN FUTURE

FINAL REPORT

Abstract

Forecasts of the age/sex composition of the population in 18 countries of the European Economic Area (EEA) omitting Liechtenstein, but including Switzerland have been compiled up to 2050. The principal innovative aspect is that forecast uncertainty is quantified: predictive intervals are computed, that specify the probability that the future population will be between x and y million, and likewise for all age groups, at each year in the future. The statistical dependency across countries is taken into account. The traditional approach (applied by the UN, Eurostat and most national agencies) is merely to run deterministic variant projections, for example assuming high fertility, life expectancy and net migration levels, without attaching probability content to them. The project has demonstrated that for the countries considered:

1. Long-term stochastic population forecasts by sex and age may significantly differ from latest population scenarios of Eurostat and the UN, and from national population forecasts both in terms of how the most likely future demographic development is assessed, and how forecast uncertainty is taken into account.
2. The parameter values of the predictive distributions of future fertility, mortality and migration can be successfully derived from a methodology that combines the findings of three different methods: analysis of observed errors in past forecasts, model-based estimates of forecast errors, and elicitation of expert opinions.
3. In spite of the lack of internationally consistent data series on international migration, the production of multi-national stochastic population forecasts is feasible.
4. Ageing is certain, and a modest population growth for the group of countries as a whole to the horizon 2050 is likely. However, the speed of population ageing is quite uncertain.

The outcomes justify that the reasons and consequences of the discrepancies between latest, official national population forecasts produced by statistical agencies and those produced by this project should be critically evaluated. Secondly, it is recommended that both Eurostat and those national statistical agencies that have not (yet) produced stochastic population forecasts by sex and age should start to do so. Thirdly, due to the bigger than generally expected uncertainty of future demographic trends, the development and implementation of new criteria for the evaluation of policy reforms (e.g. intergenerational robustness) should be encouraged. Finally, producers of forecasts, decision-makers within governmental agencies, and the public need to be further educated about the magnitude of demographic uncertainty.

1. Executive summary

The overall goal of the project was to develop and implement stochastic forecasting for both producers and users of population forecasts to more adequately quantifying uncertainty of future demographic trends for countries of the European Economic Area. Due to its size and the absence of long-term demographic time series Liechtenstein had to be omitted. Switzerland was selected as an appropriate alternative. Hence the following 18 countries are covered: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom (in the remainder of this report, this group of European countries will be indicated as EEA+).

In the original work programme the following three more detailed research objectives were distinguished:

1. to extend existing stochastic methods to all EEA+ countries, in order to produce stochastic population forecasts of each EEA+ country separately, broken down by age and sex to the horizon 2050;
2. to study the feasibility of making long-term internationally consistent stochastic population forecasts for a selected number of relatively data rich EEA+ countries (taking into account the correlation structure of forecast errors across countries);
3. to explore the feasibility of making sub-national stochastic population forecasts in general and functional stochastic population forecasts for the elderly in particular.

Due to the lack of sufficiently comprehensive and long time series on both observed and projected regional demographic trends, the latter research objective had to be relaxed somewhat. Instead it was decided that additional research efforts would be devoted to examine inter-country correlation in forecast errors, so that internationally consistent stochastic population forecasts could be produced for all countries considered.

The production of any national stochastic population forecast by sex and age requires the specification of four types of assumptions:

1. *The (future) form of probability distribution of forecast errors for fertility, mortality, and international migration.* Generally normality in the log-scale is assumed for each demographic component for each forecast year, so first and second moments of all processes (by sex and age) are needed to fully specify the predictive distribution for the population.

2. *First moments* (or point forecasts).
3. *Second moments* (both variances and autocovariances).
4. *Correlation between components.* Generally, forecast errors of female and male mortality are correlated. Even though there are probably correlations between fertility, mortality, and migration, the correlations of forecast errors of these processes are normally to be expected of secondary importance.

For the compilation of internationally consistent population forecasts also assumptions are needed on the correlation across countries.

In this project both point forecasts and key-assumptions concerning the uncertainty around these "best guesses" have been assessed on the basis of three types of analyses:

- An analysis of errors of past forecasts;
- Model-based estimates of errors;
- Elicitation of expert's opinions.

Most of these analyses focused on the total fertility rate (TFR), the life expectancy at birth, and the level of net migration. Other relevant and meaningful demographic indicators such as the average age at motherhood or the gross migration flows, or more detailed sex and age specific rates and numbers were basically applied during the phase of preparing all model parameters needed to run the software PEP (Program for Error Propagation).

The analysis of errors of past forecasts was preceded by the execution of a data collection programme on historical national population forecasts. Useful information was received from 14 countries (Austria, Belgium, Denmark, Finland, France, Germany (mostly West Germany), Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland, and the United Kingdom).

The principal outcomes of this empirical analysis can be summarized as follows. The TFR-forecasts made since the 1960s indicate that these predictions have been wrong by 0.3 children per woman for forecasts 15 years ahead, and by 0.4 children per woman 25 years ahead. TFR-predictions were too high on average, mainly as a result of the sharp fall in fertility in the 1960a and 1970s. The absolute TFR-errors show a distribution that is close to an exponential distribution. The commonly assumed normal distribution fits the somewhat less well. Absolute TFR-errors in the following countries were moderately correlated: Denmark, Finland, the Netherlands, Norway, Switzerland and the United Kingdom.

Absolute errors in life expectancy forecasts for men and women increase by 0.2 years per year for forecast horizons 10-25 years, and somewhat slower for shorter durations. The forecasts have been too low on average: forecasters in the 14 countries have been too pessimistic in the past, and predicted too slow increases in life expectancy. The under-prediction amounts to 1.0-1.3 and 3.2-3.4 years of life expectancy at forecast horizons of 10 and 20 years ahead, respectively. The distributions of the absolute errors are close to a normal one, in particular for men. Errors for men and women are strongly correlated, with a correlation coefficient around 0.7. Correlations across countries are different for men and women. For women, low-mortality countries move together, with a correlation coefficient equal to 0.8-0.9. For men, there is no systematic correlation pattern across countries.

Net migration forecasts for Austria, West Germany, Luxembourg, Portugal and Switzerland were clearly less accurate than the average for the 14 countries, for different reasons: large unforeseen immigration flows after the fall of the Berlin Wall (Germany, Austria), small population size combined with large migration flows that are inherently difficult to predict (Luxembourg), or simply inaccurate migration statistics (Portugal). Net migration levels have been consistently under-predicted in historical forecasts. The error distribution of the absolute error in net migration is generally exponential, although for low probabilities the errors are more extreme than an exponential distribution would predict. There is no systematic pattern in cross-country correlations.

In the second analysis, aimed at estimating model-based forecast errors, both simple (e.g. assuming constant TFR or constant increase in life expectancy) and more advanced models have been used. With respect of the TFR, the naïve, constant level model produced predictions in 2050 with 80% prediction intervals between 1.6 to 2.2 children per woman. The ARCH model, that takes into account the diminishing volatility in the TFR during the 20th century, showed 95% prediction intervals with a width ranging from a low 1.0 (Greece) and 1.3 (Portugal), to a high 2.9 (Austria, Germany) and 3.4 children per woman (Sweden).

A possible explanation for the large uncertainty in Sweden is the baby boom around 1990, caused by a change in legislation for maternity leave. Greece had a baby boom in the 1960s and 1970s that was much less pronounced than that in most other countries. Fertility fell more or less regularly after 1950, and hence the narrow interval in 2050. Ten years ahead 95% prediction intervals appeared to be 0.6 (Greece) to 1.2 (Sweden) children per woman wide. ARCH models estimated on the basis of long data series (1990-2000) tended to result in prediction intervals in 2050 that on average were slightly narrower than those for short data series (1950-2000). Finally, comparisons of cross-country correlations in the observed data series and those computed across countries between residuals from the time series models showed that the models had removed a large part of the original cross-country correlations.

The constant increase model predicts that between 2000 and 2050, life expectancy at birth for men will rise by well over 4 (Denmark) to almost 10 years (Finland and Germany). For women the future gains in longevity are generally expected to be slightly lower. The respective 80% prediction intervals are almost 11 years. The GARCH models forecast long-term increases from 6-13 years. Across countries and sexes, the average annual increase amounts to 0.2 years. This is line with historical developments. Long-range (fifty years) 95% prediction intervals are 4-14 years wide, with men and women from England and Wales at the lower end of the spectrum, and Danish men and women at the upper end. Ten years ahead 95% intervals are between 1 (men In France, women in England and Wales) and 4 (Denmark, both men and women) years wide.

Similarly to the exercise for the TFR, two sets of prediction intervals have been constructed: one based upon the available annual series on life expectancy of the period 1900-2000 (for 11 countries), another one using the series since 1960 (for 18 countries). The differences, particularly for men, appeared to be small. Comparisons of cross-country correlations in the observed data series and those computed across countries between residuals from the time series models showed that the models had removed a large part of the original cross-country correlations, but not all. The relatively high cross-sex correlations in the observed data series, on the contrary, appeared to be still present in the residuals from the time series models.

Assuming constant net migration levels as from 2000 would result in a cumulated net migration for the period 2000-2050 for the EEA+ of well over 57 million persons. Ten years 80% prediction intervals of net migration per 1000 inhabitants (population 2000) ranged between 2 (France) and 24 (Portugal). Net migration modeled as an autoregressive process led to more reasonable intervals, whilst a linear trend model showed relatively narrow intervals. The predictions compiled by the latter two more advanced models indicate that the total net migration level in 2050 of the EEA+ may range between 600 000 and 2 million. Cumulated net migration for the period 2000-2050 could amount to between 30 and 70 million persons.

Inspection of observed cross-country correlations revealed a cluster of Central European countries (Austria, Switzerland, and Germany) and the Benelux countries, a South European cluster (Portugal, Italy, and Greece), and a North-West European cluster (Denmark, Iceland, Norway, and the UK). The countries in these three clusters are positively correlated. There are also two clusters (Finland/Sweden and France/Portugal) with negative correlations. Probably this is explained by counter cyclical economic developments, which induce labour migration between the two countries in each pair. Inspection of the residuals from the AR(1) model - the time series model that was judged as giving the most realistic prediction intervals – showed that just a limited number of bilateral correlations remained.

The third analysis, aiming at developing and applying methods of systematically elicitation of expert's opinions, comprised two parts. In the first part an extensive literature study was executed to collect and globally assess principal methods for the elicitation of expert's opinions. Thereafter, the utility was tested of expert meetings, a survey and the application of an argument-based approach. Three expert meetings were organised, each one following a different procedure. An important part of the meetings was dedicated to background variables and determinants of the demographic component in question.

The survey was part of a larger survey conducted by Eurostat. Forecasters from 29 European national statistical offices were asked to provide the width between their lowest and highest variants of the total fertility rate, life expectancy at birth of men and women and net migration, and to make an estimate of the probability of this interval. It appeared that in spite of all recent efforts to harmonise national population forecasts, a wide range of opinions exists on the nature and content of projection variants.

The argument-based approach was successfully applied to forecast future fertility levels for the Netherlands. A distinction was made by birth order, all from a cohort perspective.

Based on the experiences of this first part, it was concluded that any assessment on future demographic uncertainty should focus on argued views of experts, preferably with some practical experience in stochastic population forecasting. In order to systematically elicit the opinions of these experts, they should be provided with quantitative information from time series models and from analyses of past forecast errors, and a number of concrete questions.

During the second part of the analysis, a series of one day, in depth interviews was organised with four very experienced, international demographers. They were provided with different sets of point forecasts for the period 2000-2050, and forecasts on 80% prediction intervals (based on results of the analyses on past forecast errors and model-based errors). The primary task of the invited experts was to suggest revisions to point forecasts and prediction intervals, to give arguments for the suggested revisions, and to assess the uncertainty they foresee for the future as compared to the past.

The experts either gave their own point forecasts, or chose one of the alternatives presented to them in the material. The experts on mortality and migration gave 80% prediction intervals around these forecasts, based on their insights in future as compared to past uncertainty. The first fertility expert labelled his upper and lower bounds for future fertility as 'expert margins', which in his view do not represent any level of uncertainty. The second fertility expert gave his views on the proposed point forecast, prediction intervals and future as compared to past uncertainty.

The experts provided numerous useful justifications and insights with regard to the most likely demographic future developments and the uncertainty around these trends that could not be derived from experiences in the past or from available literature.

The mortality expert pointed out that there are medical breakthroughs to be expected, not apparent in the past, which possibly have an effect on the trends in the future. He therefore made suggestions how to adjust the upper limit of the predictive distribution in light of this knowledge. He expressed that forecasting is more difficult now than in the past due to the uncertainty of when, and how medical advances will materialise in the coming decades.

One of the fertility experts had problems with the fact that statistical models were chosen which did not include our present knowledge of key factors determining fertility levels. According to his opinion variances based on historical forecasts cannot be used for prediction intervals of expected futures. The other fertility expert, on the other hand, confirmed that the past is a good guideline for assessing future uncertainty, and that a volatile past is a good predictor of a volatile future in fertility levels. All under the condition that sensible models were used in the past for forecasting and that present knowledge is incorporated.

Finally, the international migration expert pointed out that in general and for the EEA as a whole the future is less uncertain than the past for migration, because experience has learned that sharp changes in net migration tend to fade out fairly soon.

The principal assumptions concerning future fertility, mortality and migration trends and patterns are summarised in the table. It shows long-term, national point forecasts and 80% prediction intervals for the total fertility rate, life expectancy at birth, and crude net migration rate (expressed in 1,000 population in 2000).

With respect of fertility all countries except Portugal are categorised in two clusters. For the Northern EEA+ cluster (Belgium, Denmark, Finland, France, Iceland, Ireland, Luxembourg, Netherlands, Norway, Sweden, and the United Kingdom) a point forecast for the TFR in 2049 of 1.8 children per woman is assumed. For the Mediterranean and the German-speaking cluster (Austria, Germany, Greece, Italy, Spain and Switzerland) a long-term level of 1.4 children per woman is expected. For Portugal an intermediate level of 1.6 children per woman is assumed. The 80% intervals in 2049 range from about 1.1 children to 2.8 children per woman for the Northern cluster, and from 0.9 to 2.2 children per woman for the other cluster.

With respect of the timing of children, it is assumed that in all countries considered the mean age at motherhood will continue to increase, and eventually converge to a level of 31 years.

These key-assumptions on fertility are mainly based on time-series models applied to long series of observations. Expert judgement is mainly included to adjust the prediction intervals based on time-series models and past forecast errors for the short and medium term. The basic reason is that the models applied do not take into account the relatively low volatility of the TFR during the last one or two decades sufficiently. Therefore, the 80% prediction intervals for the short and medium term are expected to smaller than predicted by the models. This is in line with the fertility experts' views.

The point forecasts of mortality are primarily based on recently observed age specific mortality patterns, combined with the results of a fairly simple extrapolation of recently observed declines in these age-specific mortality rates. It is assumed that the initial rates of decline for each country will change linearly over time towards an average, European rate of improvement by the year 2030. For some countries this implies a catching up, for other countries a slowing down of recent improvements in mortality rates. The resulting expected gains in life expectancy at birth for men during the period 2002-2049 vary between 6.5 (Netherlands) to well over 10 years (Luxembourg, Portugal and Spain). For women slightly lower improvements are expected, varying from 5.7 (Netherlands) to 9.6 (Ireland).

The 80% prediction intervals are mainly based on time-series models. However, in the final assumptions these intervals are about 50 per cent wider than the model-based intervals. This is mainly motivated by expert's views that states that it is not unlikely that unprecedented medical breakthroughs will happen. The assumed intervals in 2049 range from 7.4 years for Austrian females to almost 12 years for males in Luxembourg.

An important topic in establishing stochastically sound, future mortality levels is the degree of cross-sex correlation. It is assumed that the correlation between male and female life expectancy is 0.85.

Forecasting international migration was seriously hampered by the data situation. Available international time-series are rather short, and in some cases of poor quality. This implies that more than for fertility and mortality expert knowledge is to be involved, and that prediction intervals are wide. Starting point for the point forecasts is a linear trend model. A significant upward linear trend was detected in many countries. However, it is very uncertain whether these linear, rising trends will persist in the future. For this reason several arguments are used to adjust the linear trend estimates downwards. Eventually it is assumed that for the total of the 18 countries net migration per thousand population in 2000 will rise to a level of around 3.5 in 2049. This is considerably less than the 5 per thousand according to the linear trend model. Next, long-term country-specific assumptions on crude net migration rate are made, that varied from 1.5 (Finland, France, Iceland) to 6 (Luxembourg).

With respect of the 80% prediction intervals the results from an AR(1)-model were taken as the starting point. The key motivation for determining whether to deviate from the AR(1)-results is that intervals should be smaller for countries with good registrations. This implies that intervals are smallest in the Nordic countries and broadest in the Southern European countries. To make consistent assumptions clusters of countries are made.

Subsequently, the key-assumptions concerning fertility and migration have been translated into more detailed quantitative model input (i.e. age specific fertility rates and net migration numbers by sex and age). Furthermore, for all components additional assumptions were made with respect of correlation of forecast errors over age and time, and across countries (the latter correlations are relevant for the results published for the EEA+ as a whole, and not for the forecasts of the individual countries).

Table. Summary of assumptions for the TFR, life expectancy at birth and net migration in 18 European countries: point forecasts and 80% intervals in 2049

	TFR			***Net migration (per 1,000 population in 2000)***		
	Point forecast	Lower limit	Upper limit	Point forecast	Lower limit	Upper limit
Austria	1.40	0.89	2.20	3.5	-1.0	8.0
Belgium	1.80	1.14	2.84	2.0	-0.6	4.6
Denmark	1.80	1.15	2.82	2.0	-0.6	4.6
Finland	1.80	1.15	2.82	1.5	-1.1	4.1
France	1.80	1.15	2.83	1.5	-3.0	6.0
Germany	1.40	0.88	2.21	3.5	-1.0	8.0
Greece	1.40	0.90	2.18	4.5	-3.2	12.2
Iceland	1.80	1.14	2.85	1.5	-3.6	6.6
Ireland	1.80	1.15	2.83	3.5	-2.3	9.3
Italy	1.40	0.89	2.20	4.5	-1.3	10.3
Luxembourg	1.80	1.14	2.84	6.0	-1.7	13.7
Netherlands	1.80	1.15	2.82	3.0	0.4	5.6
Norway	1.80	1.16	2.80	3.5	0.9	6.1
Portugal	1.60	1.02	2.51	4.5	-3.2	12.2
Spain	1.40	0.89	2.21	4.5	-1.3	10.3
Sweden	1.80	1.12	2.89	3.0	0.4	5.6
Switzerland	1.40	0.90	2.18	3.5	0.9	6.1
United Kingdom	1.80	1.16	2.80	3.5	-1.0	8.0

	Life expectancy at birth, males			***Life expectancy at birth, females***		
	Point forecast	Lower limit	Upper limit	Point forecast	Lower limit	Upper limit
Austria	84.4	80.3	88.8	88.7	85.1	92.5
Belgium	84.2	79.4	89.2	88.3	84.1	92.9
Denmark	83.2	78.3	88.3	87.3	82.5	92.4
Finland	84.7	80.0	89.4	88.7	84.9	93.4
France	85.5	80.6	90.6	89.7	85.5	94.1
Germany	84.9	79.8	90.5	89.1	84.7	94.0
Greece	82.8	78.2	87.2	86.9	83.1	91.0
Iceland	85.9	81.8	90.2	89.9	85.1	95.7
Ireland	84.7	80.1	89.6	89.9	85.5	95.1
Italy	85.7	81.4	90.4	89.8	85.8	94.3
Luxembourg	85.2	79.9	91.8	89.4	84.7	95.3
Netherlands	82.5	78.1	87.1	86.4	82.4	91.0
Norway	83.7	79.3	88.2	87.9	83.8	92.2
Portugal	84.2	79.1	89.6	88.4	84.1	93.3
Spain	85.9	81.1	91.4	90.1	85.9	94.9
Sweden	84.7	80.3	89.4	88.7	84.2	94.3
Switzerland	85.3	81.1	89.6	89.4	85.7	93.8
United Kingdom	83.4	78.7	88.3	87.5	83.3	92.2

Two sets of stochastic population forecasts are produced. First, stochastic population forecasts by sex and single years of age (0,1,…,99, 100+) are made for the period 2003-2050 for each of the 18 EEA+ countries considered individually. In the second run, stochastic population forecasts by sex and age are compiled for the whole EEA+ region.

The national stochastic population forecasts have been compiled by using PEP (Program for Error Propagation), a software package developed by Alho (1998). This programme calculates the probability distribution of the future population size and structure by means of Monte Carlo simulations (a total of 3,000 simulation rounds has been used). The respective model equations combine the widely used cohort-component projection model and the so-called scaled model for error (Journal of Official Statistics 13(1997), 203-225.). For a detailed description of PEP, one may visit http://joyx.joensuu.fi/~ek/pep.

For each country, the main characteristics of the model (as used in these forecasts) are qualitatively as follows:

- Uncertainty in age-specific mortality and age-specific fertility is treated in the relative (logarithmic) scale, for net-migration uncertainty is treated in the additive scale.
- Uncertainty is assumed to increase with forecast year. Any increasing pattern of error variances can be represented by a suitable choice of the scales of the model.
- Error increments of each age and sex group have a constant non-negative autocorrelation that can be chosen freely.
- Cross-correlation of errors across age are represented by an AR(1) process, whose correlation at lag = 1 is non-negative but otherwise it can be chosen freely.
- Correlation between error increments of males and females, in each age, can be chosen freely.
- Correlation between errors in male and female net migration can be chosen freely.
- Uncertainty in fertility, mortality, and migration were assumed to be independent of each other.
- A normal distribution was used to represent error increments for each age- and sex-group.

In general, the median is used as the principal location parameter of the predictive distribution, because this indicator is less sensitive for statistical outliers than for example the mean. The spread around the median is used to provide a realistic indication of forecast uncertainty.

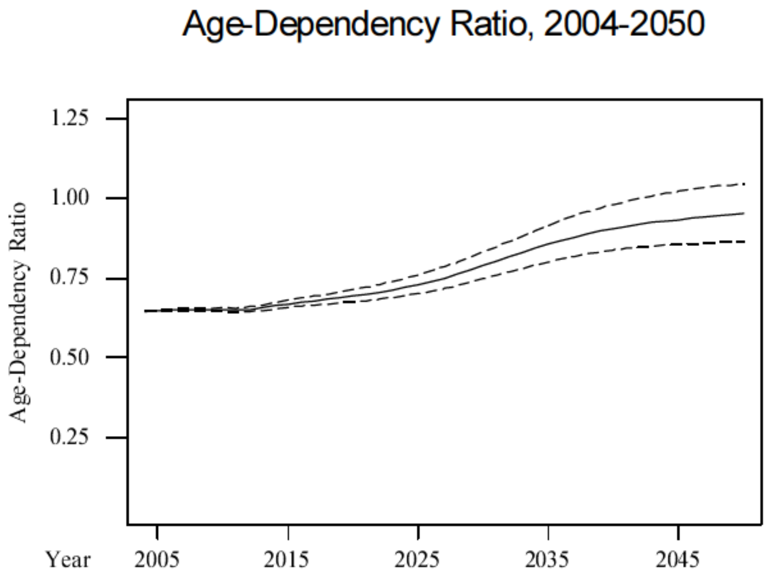
For the purpose of combining all country-specific forecasts to form a forecast for the EEA+ as a whole, PEP had to be expanded. The following, additional modules are developed and implemented:

1. cross-correlation of both the general fertility rate and life expectancies across countries is induced via post-processing of the simulation counts using the "method of seeds";
2. net migration numbers are generated in such a way that they are correlated across the countries according to the assumed cross-country correlation structures.

A selection of the outcomes of the two sets of stochastic population forecasts has been put on the web (http://www.stat.fi/tup/euupe/). Separate web pages are developed and implemented concerning the methodology used, and the assumptions applied. Furthermore, a guide for interpreting the results of the stochastic population forecasts is included.

Amongst others, these results show that a number of (generally) predicted demographic trends such as a future decline of both total and working age population are far from certain. In fact, EEA+ population size shows a moderate growth to 2050, with an expected growth rate of 0.2 per cent per year. However, future population ageing and for example the (generally) expected increases in age dependency ratios are fairly sure, although the speed of these developments is also quite uncertain (see figure).

Figure. Age-Dependency Ratio in EEA+, in 2004-2050



Part of the outcomes of the national stochastic population forecasts are used to compile stochastic forecasts for two important subgroups of the population aged 65+: the divorced elderly men, and the severely disabled elderly. Both applications are based on recently observed or projected prevalences. The results illustrate that stochastic calculations provide a new way to bring a wide range of relevant, population outcomes to the attention of policy and decision-makers.

Finally, additional research efforts have been put to the (classical) problems of dimension reduction and the estimation of lacking or inconsistent cells of internal migration and international matrices respectively by origin and destination.

The UPE project has demonstrated that for the 18 EEA+ countries considered:

1. Long-term stochastic population forecasts by sex and age may significantly differ from earlier population scenarios of Eurostat and the U.N., and from national population forecasts both in terms of how the most likely future demographic development is assessed, and how the uncertainty of forecasting is taken into account.
2. The parameter values of the predictive distributions of future fertility, mortality and migration can be successfully derived from a methodology that combines the findings of three existing methods: analysis of observed errors in past forecasts, model-based estimates of forecast errors, and elicitation of expert opinions.
3. In spite of the lack of internationally consistent data series on international migration, the production of multi-national stochastic population forecasts is feasible.

Four types of policy implications can be drawn from the UPE work. First, expected population growth in EEA+-countries is considerably stronger than indicated by latest UN- or Eurostat-forecasts. Life expectancy and net migration forecasts of the UPE project are respectively more optimistic and significantly higher than those produced by the official agencies. The reasons and consequences of these discrepancies should be critically evaluated by the statistical agencies.

Second, the UPE team recommends that both Eurostat and those national statistical agencies that have not (yet) produced stochastic population forecasts by sex and age should start to do so. The adoption of novel methods takes some experimenting, and we would expect that a number of choices the UPE project has made might not be favored by the official agencies. Yet, the agencies should seriously study our results, and determine how they could adopt similar techniques to give a better indication of forecast uncertainty.

Third, in recent years economists have increasingly been alerted to the fact that demographic developments cannot be forecast accurately. This has already led to the development and implementation of new criteria for the evaluation of policy reforms (e.g. intergenerational robustness).

Fourth, producers of forecasts, decision-makers within governmental agencies, and the public need to be further educated about the magnitude of demographic uncertainty. Many aspects of probabilistic thinking (e.g., cancellation of error) are not intuitive from every day experience, so a special effort is needed that the parties involved can develop a realistic appreciation of risk.

2. Background and objectives of the project

2.1 Background

Demographic trends in Europe continue to take forecasters by surprise. Over the last 2-3 decades, the rapid declines and thereafter persisting low levels of fertility in the Mediterranean and former socialist countries, the ongoing rather strong decrease of mortality rates in countries with relatively high life expectancies at birth (e.g. France, Italy and Sweden), or opposite, the significant increase of mortality rates in countries with relatively low life expectancies (e.g. Baltic States and Russia), and the considerable and for some countries even massive net migration flows (both in positive and negative numerical terms) have not been predicted.

Although there is some hope that more detailed or comprehensive demographic studies may help to understand better the causes of these errors after the fact, there appears to have been an element of genuine surprise in them. Therefore, there is no reason to believe that the future development of the vital rates would be less unpredictable. If population forecasts are to be used to formulate policies regarding the labour market, health care, economic development, or pension systems, then uncertainty involved should be quantified, and included in those forecasts.

Population projections are basically prepared by national statistical institutes, and by international organisations such as Eurostat and the United Nations. Almost all of these agencies apply the traditional, deterministic way to represent uncertainty: a medium variant or forecast is accompanied with various other, plausible combinations of variant assumptions concerning fertility, mortality and migration. In most cases at least the combinations resulting in relative low or high population growth are being compiled and published.

A number of problems are associated with such an approach (Lee, 1998). First, in publications generally no probability is given that the actual demographic variable of interest will fall within the range defined by the high and the low projection variants. And if confidence intervals are being requested, different replies are received from national population forecasters (Alders, 2002). Thus, policy makers and other users of demographic projections are either not or differently informed about the expected accuracy of the projections produced.

Secondly, the range implied by two particular variant projections may reflect uncertainty for some variables, but may be quite misleading for others. For example, according to the low and high (population growth) variants of the 1998-based population projections produced by Statistics Netherlands, the population size of those aged 65 and older in the Netherlands in 2050 would be between 3.52 and 4.17 million (Alders and De Beer, 1998). This high-low-range of 0.65 million persons constituted 17 per cent of the medium variant result. Similarly, total population size in 2050 had a range of 19 per cent. However, for the share of the elderly in the whole population, the high-low range was projected to amount 1.6 per cent only, surely much smaller than one would stochastically expect. This inconsistency is caused by the fact that the high projection variant results from combining high assumptions on fertility, life expectancy and net migration, and likewise for the low variant. This is only plausible if, unrealistically, a perfect correlation exists of annual fertility, mortality and migration levels. A third problem, related to the last one, is that if deterministically produced, national population projections are simply summed to get an aggregate (e.g. the projections of Eurostat for the European Union are obtained as the sum of country-specific projections), then the probability coverage of the aggregate will be consistent with that of the countries only if there is perfect correlation of the projection errors across countries. For instance, one would need high net migration to all countries simultaneously, which is unrealistic.

In order to avoid or solve these statistical problems and to provide users plausible indications of uncertainty around future “best guesses”, one needs to make stochastic population forecasts. Methodologies for such forecasts have been developed in Europe (Alho and Spencer, 1997; De Beer, 1997; Keilman, 1997) and the United States (Lee and Tuljapurkar, 1994), but several problems - both practical and theoretical - were not solved when the proposal of the project ‘Changing Population of Europe: Uncertain Future’ was drafted in 2000.

First of all, it appeared to be necessary to extend the empirical analysis on errors of official population forecasts by sex and age already made in such countries as Austria (Hanika et al., 1997), Finland (Alho, 1998), Germany (Lutz and Scherbov, 1998), the Netherlands (De Beer and Alders, 1999), and Norway (Keilman and Hetland, 1999) to other countries of the European Economic Area (EEA). Such a more comprehensive international analysis would, if sufficiently long observed and forecast data series exist, allow to prepare historically sound conclusions about:

1. Differences in forecast errors between the three components, fertility, mortality and migration;
2. Differences between forecasts made in different points in time;
3. The relationship between the size of forecast errors and the forecast lead time;
4. Differences in forecasts errors across countries.

Secondly, it was obvious that in order to respond to a similar list of topics by using time-series models, more internationally comparative research was needed. Actually, up to 2000 no pan-European study was executed to test the robustness of existing, univariate projection models, and to examine the respective model-based error structures of key demographic indicators such as the total fertility rate, life expectancy at birth and net migration. Furthermore, few national specialists had tested the feasibility of using naïve forecasts by comparing the implied errors against observed forecast errors for countries with a relatively good record of past forecasts (e.g. Austria, Denmark, the Netherlands, Norway).

Thirdly, no methods did exist (yet) to systematically elicit expert's opinions on uncertainty. Most of the above mentioned, first applications of stochastic population forecasting in Europe were heavily based upon expert's opinions, but none of the institutes involved explored existing methods of expert judgment in a consistent manner. Additionally, a new method or at least the development of a set of some basic rules of guidance was necessary to judgmentally combine or select relevant outcomes of the three, principal methods of making stochastic forecasts: analysis of observed errors in past forecasts, modeling expected errors in future forecasts by means of time-series methods, and elicitation of expert's opinions.

Fourthly, up to 2000 no attempts had been made to compile multinational stochastic population forecasts. Hence, the technically complex issues of making assumptions on cross-country international migration flows or future cross-country correlation structures in fertility and mortality had not been examined.

Finally, two meaningful extensions to the study were formulated in order to increase both the utility of the projections methodologies developed and the use of the projections results: the preparation of sub-national or regional stochastic population forecasts (including the modeling of interregional migration) and an illustration as to how uncertainty concerning the number of elderly in the future may affect social policy.

2.2 Objectives

The major goal of the UPE project was to develop and implement stochastic forecasting for both producers and users of population forecasts to more adequately quantifying uncertainty of future demographic trends for countries of the European Economic Area (EEA). Switzerland is also contained in the analyses, but due to its size and the absence of long-term demographic time series Liechtenstein is omitted. Hence the following 18 countries are covered: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

More detailed objectives were:

- to produce a stochastic forecast of the population in each country of the European Economic Area, broken down by age and sex, to the horizon 2050 (these forecasts will be computed on the basis of a consistent set of assumptions for each separate country). Switzerland is also contained in the analyses, but due to its size and the absence of long-term demographic time series Liechtenstein is omitted. Hence the following 18 countries are covered: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom
- to explore the feasibility to produce internationally consistent stochastic population forecasts, taking into account the correlation structure of forecast errors across countries (this part will be restricted to a selected number of relatively data rich EEA+ countries, but the methodology developed should be applied to all European countries in the future);
- to carry out a feasibility study aimed to examine whether sub-national stochastic population forecasts for selected EEA+ countries can be made on the basis of assumptions about the correlation of forecast errors between sub-national regions.

During the process of collecting historical series of official population projections for the countries considered it became clear that very few countries possess a series of official, regional population forecasts of sufficient length. In addition, it appeared that there is no international demographic database available comprising annual and regional time series of sufficient length on total fertility rate, life expectancy at birth, net internal migration and net international migration. Therefore, at the steering committee meeting in Warsaw in August 2003 it was decided to delete the international analysis of regional population forecast errors, and to suppress the above mentioned feasibility study on the compilation of regional stochastic population projections. Instead it was decided that additional research efforts would be devoted to examine inter-country correlation in forecast errors, so that internationally consistent stochastic population forecasts could be produced for all countries considered.

3. Scientific description of the project results and methodology

3.1 Introduction

The research project had four components that complemented each other. In the first component existing stochastic methods were applied to all countries considered, in order to compile long-term stochastic population forecasts by sex and age of each country individually. The computer program PEP (Alho 1998, Alho and Spencer 1997) was used for the calculation of these forecasts.

In the second component the feasibility of making multinational stochastic forecasts was studied. Originally this part of the project was restricted to selected EEA+ countries, based on the availability of data. During the project it was decided to expand the scope to all 18 countries considered. Therefore, the eventual aim was to develop methodologies and computer programs that could be successfully applied to all EEA+ countries.

The third component aimed to extend the analysis to a sub-national level. A natural candidate was NUTS 2 level, the regional level often used by policymakers of the European Commission. Also specific applications for the elderly were foreseen, in order to explore the feasibility of making functional stochastic population forecasts. Due the general lack of reliable and internationally consistent regional demographic time series and projections, the first part of this component of research had to be suppressed.

The fourth component cut through the three first ones, and it involved the specification of assumptions on the size of errors in forecasts of fertility, mortality, and migration. Empirical analysis of past forecast errors, model-based estimates of projection errors and the elicitation of experts' opinions should be used simultaneously as a basis for assessing the expected level of error in future forecasts.

The project was broken down into eight work packages. Apart from a work package needed for the co-ordination of the project (WP1), the following research modules were distinguished:

1. Analysis of past forecast errors (WP2);
2. Model-based estimates of errors (WP3);
3. Elicitation of expert's opinions (WP4);
4. Assumptions for national stochastic population forecasts (WP5);
5. Production and dissemination of stochastic national population forecasts (WP6);
6. Dimension reduction and imputation in migration modelling (WP7);
7. Stochastic multi regional forecasts with applications to the elderly (WP8).

This section attempts to describe the main features and the principal findings of the various analyses carried out in the different work packages. It summarises the data series and the methodologies used, and concludes with a list of innovations and recommendations for future research.

3.2 Analysis of past forecast errors (WP2)

3.2.1 General

During the last 4-5 decades the vast majority of national statistical offices within the EEA have produced a series of official, national population forecasts by sex and age. The objective of WP2 was to trace systematic patterns in errors observed for these historical population forecasts, specifically differences in forecast errors between fertility, mortality, and international migration.

The error structures of the following demographic key-indicators have been examined:

- total fertility rate (TFR);
- life expectancy at birth;
- net immigration (scaled to population size at 1 January 2000).

For each of these indicators, the accuracy and bias has been assessed, the statistical distribution of the errors, and the cross-country correlations. For the life expectancy at birth, also the correlation between men and women has been analysed.

In order to increase international comparability, observed values for the above mentioned indicators were taken, to the extent possible, from international sources. The following principal sources have been used:

- For the TFR: Chesnais (1992) and Council of Europe (2002).
- For the life expectancy at birth: Council of Europe (2002) and the Human Mortality Database of the University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany).
- For net immigration: Council of Europe (2002).

In few cases these international sources had to be supplemented with national sources. Occasionally, for Germany and the United Kingdom sub-national series have been applied, describing the situation for Federal Republic of Germany and England and Wales respectively.

Information on *forecast* values was collected from national sources. By means of a special request to the national statistical agencies concerned, sufficiently long and detailed historical time series have been received and stored for the following 14 countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland, and the United Kingdom. The oldest forecasts date back to the early 1950s.

Concerning *observed* variables, we only used annual time series. In contrast, forecast variables were not available as annual series in many cases, but only in the form of values for certain selected years, for instance every tenth year. In those cases we interpolated linearly between known values. This may have reduced the variability in the forecast errors somewhat, but not very much, because all forecast variables are smooth extrapolations of current trends.

In many cases, *variant* assumptions were used in a specific forecast. For example, the 1990 forecast of Norway includes a low, a medium, and a high assumption for fertility. Variant assumptions were also frequently made for the components of mortality and migration. In that case, we included all variants in our data set, because very few of the forecast reports contained a clear advice as to which of the variants the statistical agency considered as the most probable one at the time of publication[1]. Hence, it was left to the user to pick one of the variants. We may assume that all variants have been used, although the middle one probably more often than the high or the low one (in case there were three variants) [2].

- The (signed) annual, empirical errors, calculated as the difference between forecast and observed values, have been summarised in various ways:
- The mean error (ME). It reflects the tendency to over- or under-predict the variable of interest. Positive errors will cancel negative ones. Therefore, the mean error is not a good indicator of accuracy, but it yields useful information on bias.
- The standard deviation (SDE). It measures the variability in the errors around their mean value. It reflects uncertainty in the variable appropriately, provided that its expected value is predicted correctly.

---

[1] The 1980-based forecast of the Netherlands is one exception.

[2] For some countries, we had enough data to check the implications of this choice. For Norway, the standard deviation in the observed TFR-errors based on all forecast variants was very close to that based on main variants only. For Sweden, the all-variants standard deviations were approximately 10 per cent higher than those based on main variants.

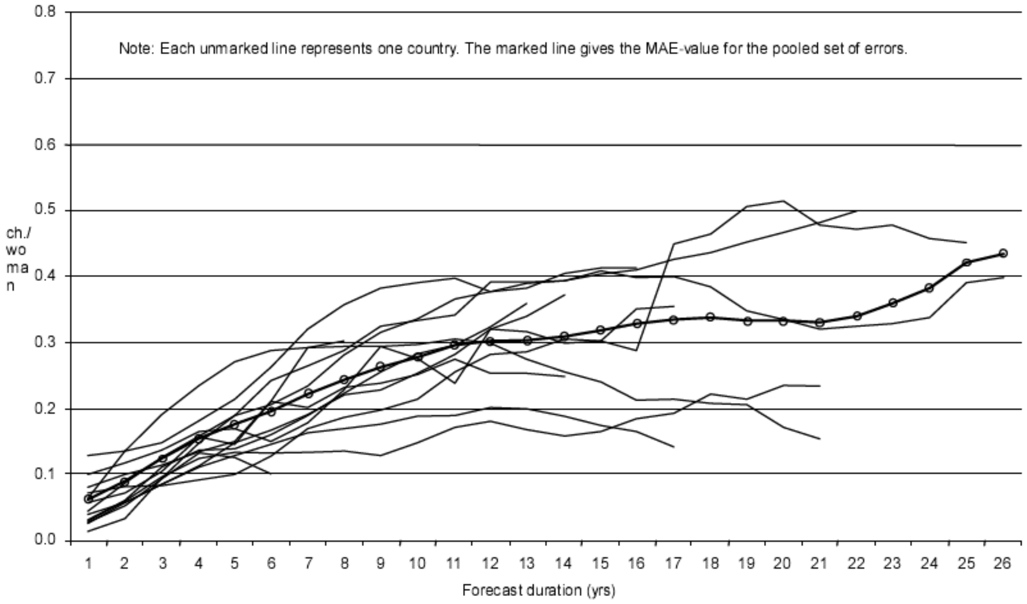
- The latter assumption may be relaxed by inspecting the Root Mean Squared Error (RMSE), which adds a bias component to the standard deviation.
- The mean absolute error (MAE). It summarises the errors disregarding sign and therefore yields useful information on accuracy.
- The standard deviation of the absolute error (SDAE).

In order to appropriately compare historical forecast errors over time and space, all of the analyses have been executed and presented by forecast duration or forecast lead time.

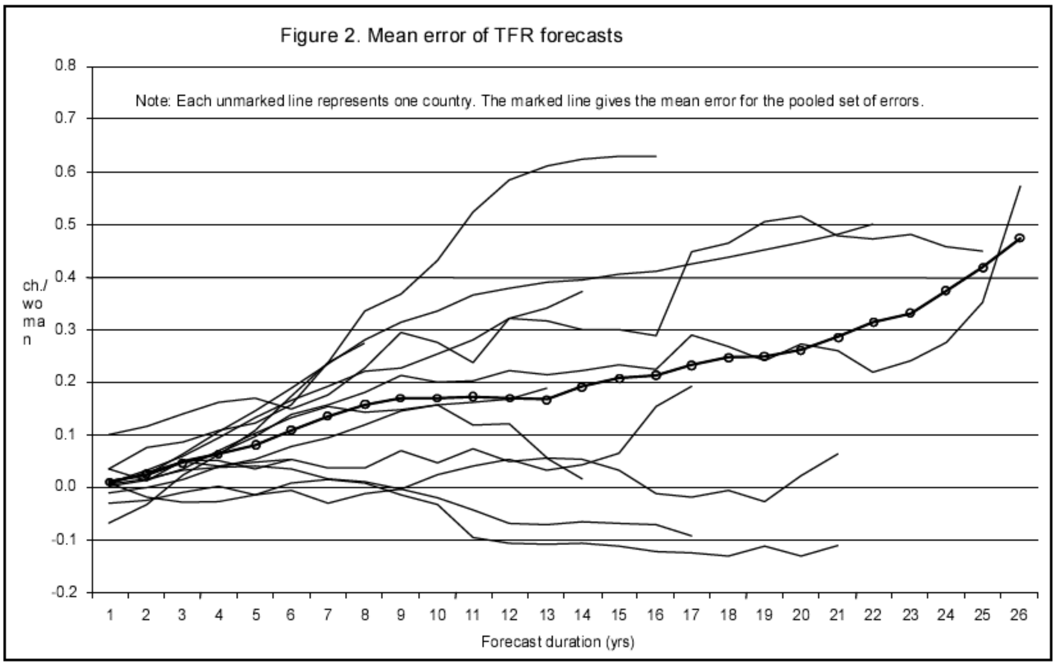
3.2.2 TFR

The mean absolute errors of TFR forecasts in the 14 countries considered indicate that on average these projections were wrong by 0.3 children per woman for forecasts 15 years ahead, and 0.4 children per woman 25 years ahead (figure 1).

Figure 1. Mean absolute error of TFR forecasts



The results for the mean errors confirm earlier findings that the TFR-forecasts were too high on average, mainly as a result of the sharp fall in fertility in the 1960s and 1970s (figure 2).



The TFR forecasts in 14 countries indicate that the absolute TFR-errors have a distribution that is close to an exponential distribution. The commonly assumed normal distribution fits the data somewhat less well. Thus the absolute errors in the TFR in our data set can be said to be characterized by two features: a set of normalization factors that increase with forecast duration, as plotted in Figure 1, combined with an exponential distribution for the probability that the normalized error exceeds a given value, as plotted in Figure 3. These two characteristics are to be used for forecast durations up to approximately 20 years and for probabilities not lower than about five per cent. For example, the probability is approximately 20 per cent that the absolute error 6 years ahead exceeds 1.5*0.2=0.3 children per woman. The value pair (20%, 1.5 children per woman) is read off from Figure 3, whereas the normalized value 0.2 children per woman at a forecast duration of 6 years is found in Figure 1. At 12 years ahead, the normalized value is 0.3. Hence there is a 20-per cent chance that the absolute error in the TFR will exceed 1.5*0.3=0.45 children per woman at that horizon.

Finally, it was found that the absolute TFR-errors in the following countries were moderately correlated: Denmark, Finland, Netherlands, Norway, Switzerland, and the UK.

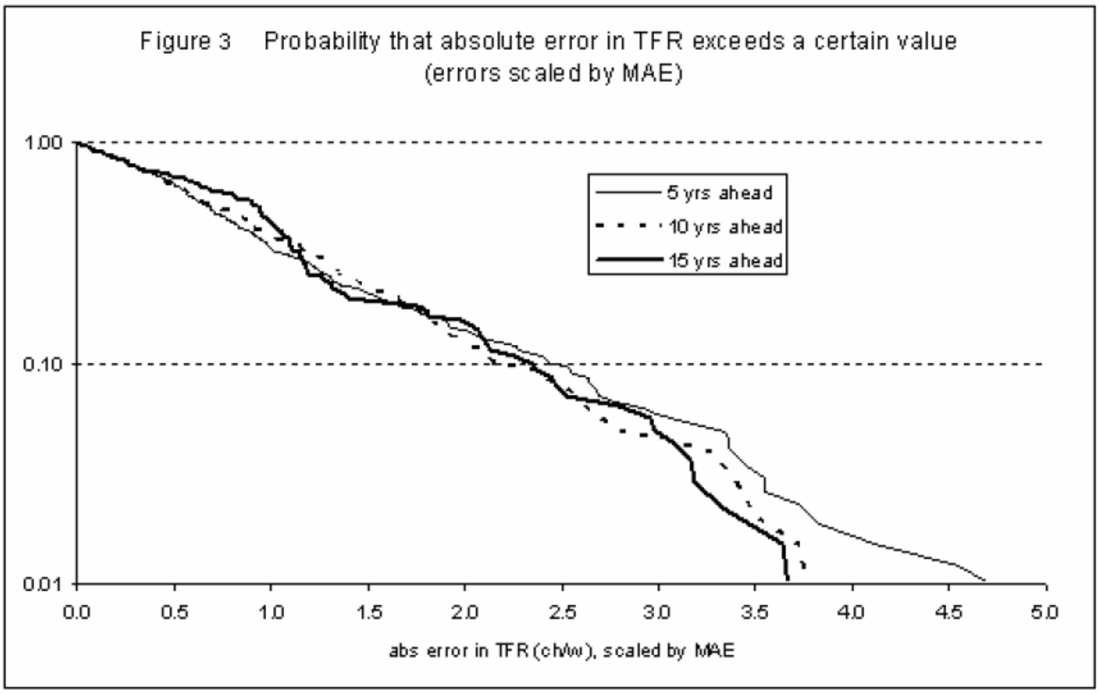


Figure 3 Probability that absolute error in TFR exceeds a certain value (errors scaled by MAE)

3.2.3 *Life expectancy at birth*

Absolute errors in life expectancy forecasts for men and women increase by 0.2 years per year for forecast horizons 10-25 years, and somewhat slower for shorter durations (figures 4-5).

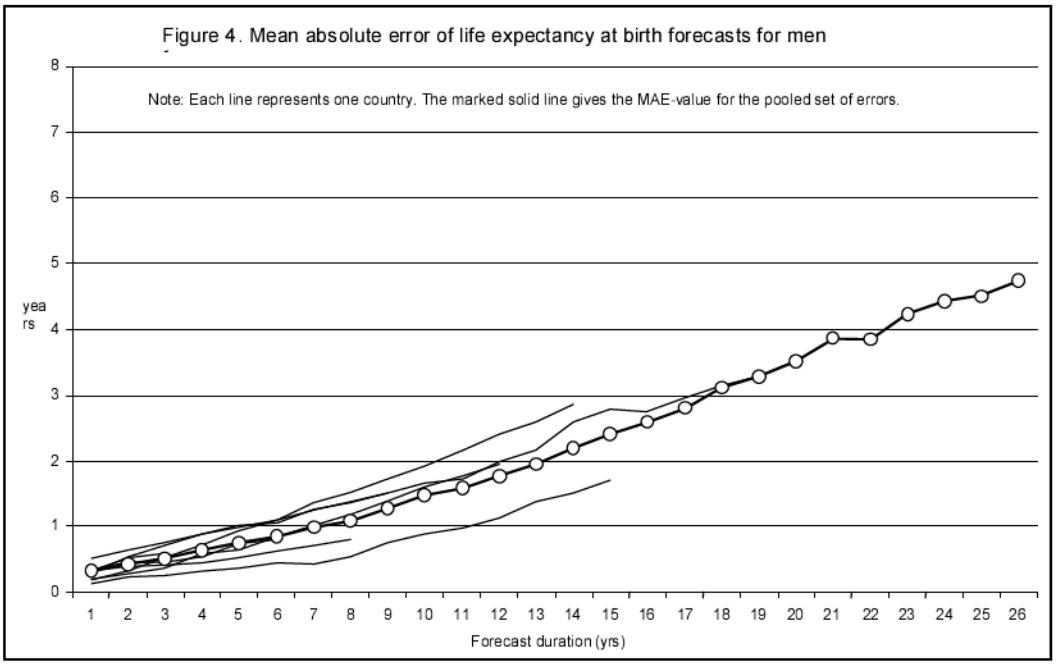
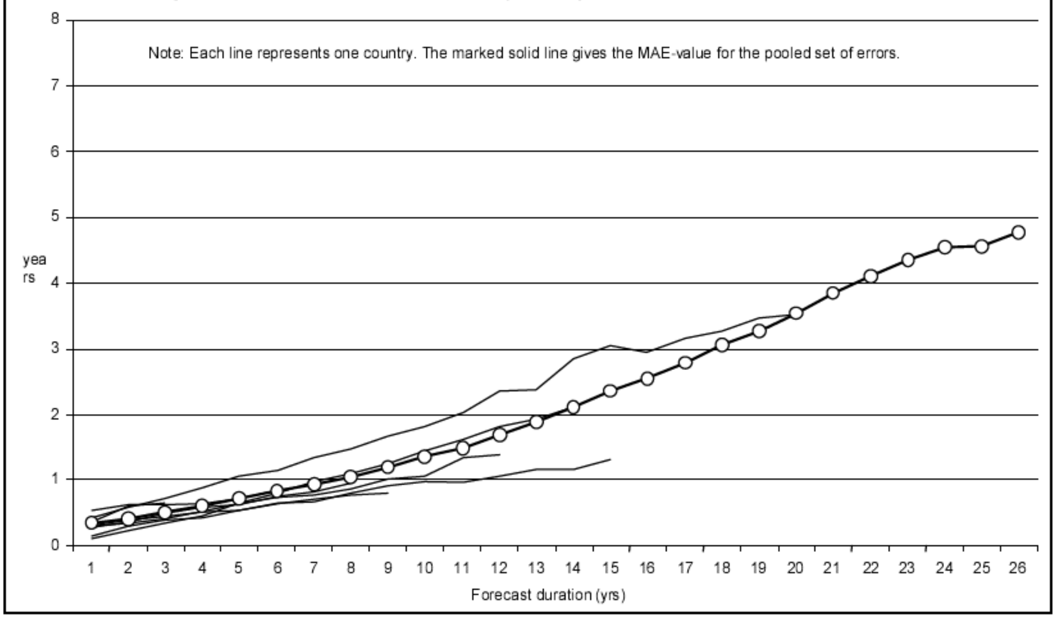


Figure 4. Mean absolute error of life expectancy at birth forecasts for men

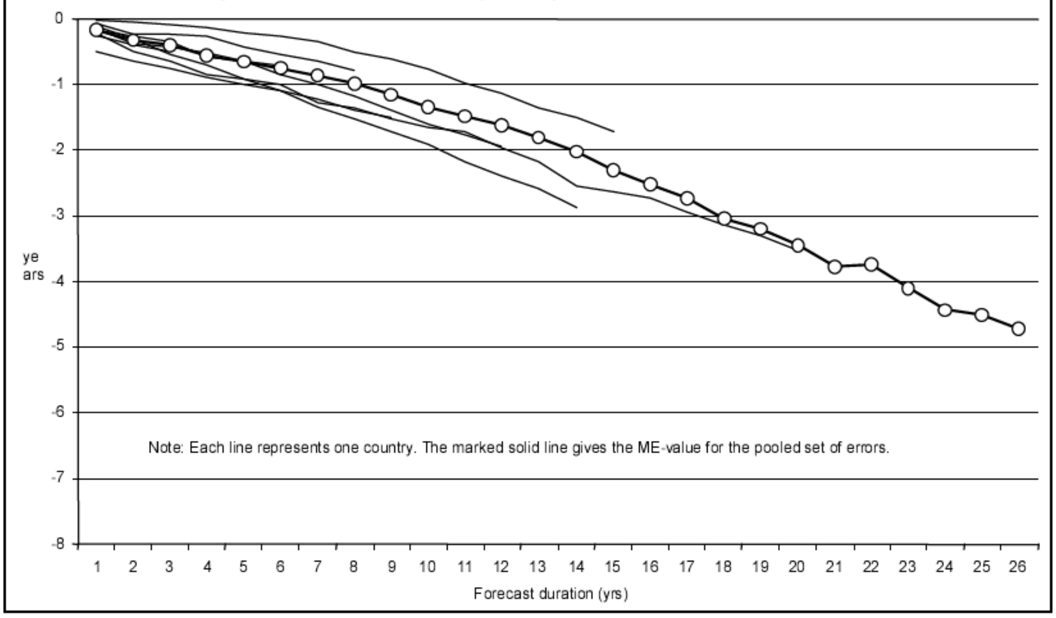
Note: Each line represents one country. The marked solid line gives the MAE-value for the pooled set of errors.

Figure 5. Mean absolute error of life expectancy at birth forecasts for women



The forecasts have been too low on average: forecasters in the 14 countries have been too pessimistic in the past, and predicted too slow increases in the life expectancy. The underprediction amounts to 1.0-1.3 and 3.2-3.4 years of life expectancy at forecast horizons of 10 and 20 years ahead, respectively (figures 6-7).

Figure 6. Mean errors of life expectancy at birth forecasts for men



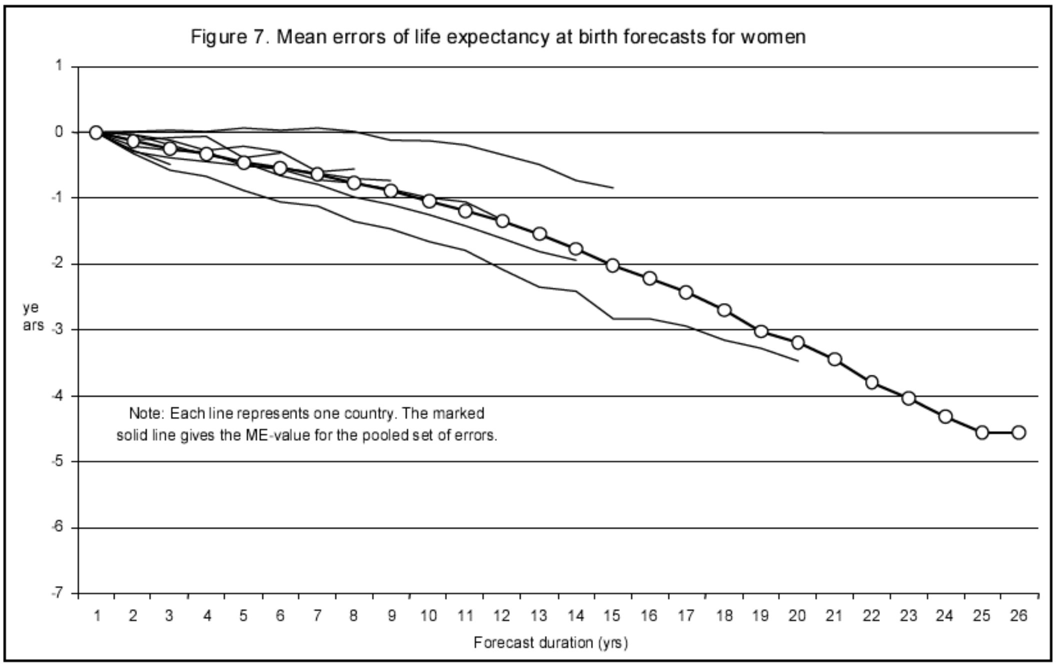


Figure 7. Mean errors of life expectancy at birth forecasts for women

The distributions of the absolute errors are close to a normal one, in particular for men. This implies that the distributions for life expectancy errors can be described by two parameters, as opposed to only one parameter for the TFR-errors. Figures 8 and 9 plot the distribution of the standardized errors, i.e. errors obtained after having subtracted the mean and divided by the standard error.

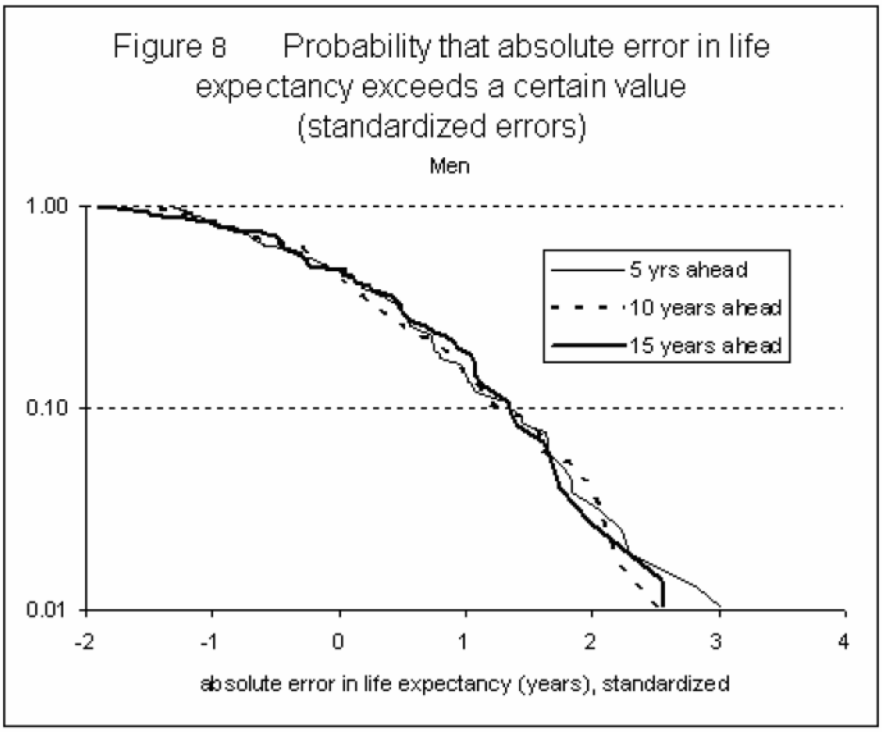


Figure 8 Probability that absolute error in life expectancy exceeds a certain value (standardized errors)

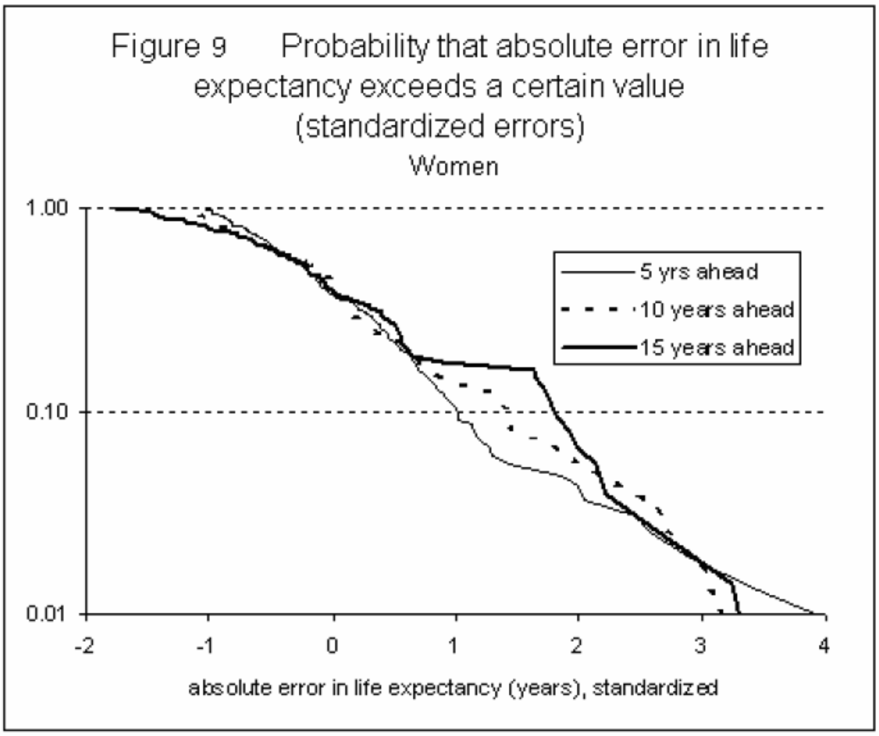


Figure 9 Probability that absolute error in life expectancy exceeds a certain value (standardized errors)

Women

The means and standard deviations increase with forecast lead time, as plotted in figure 10 (since there was very little difference between the sexes, only one plot for men and women is presented).

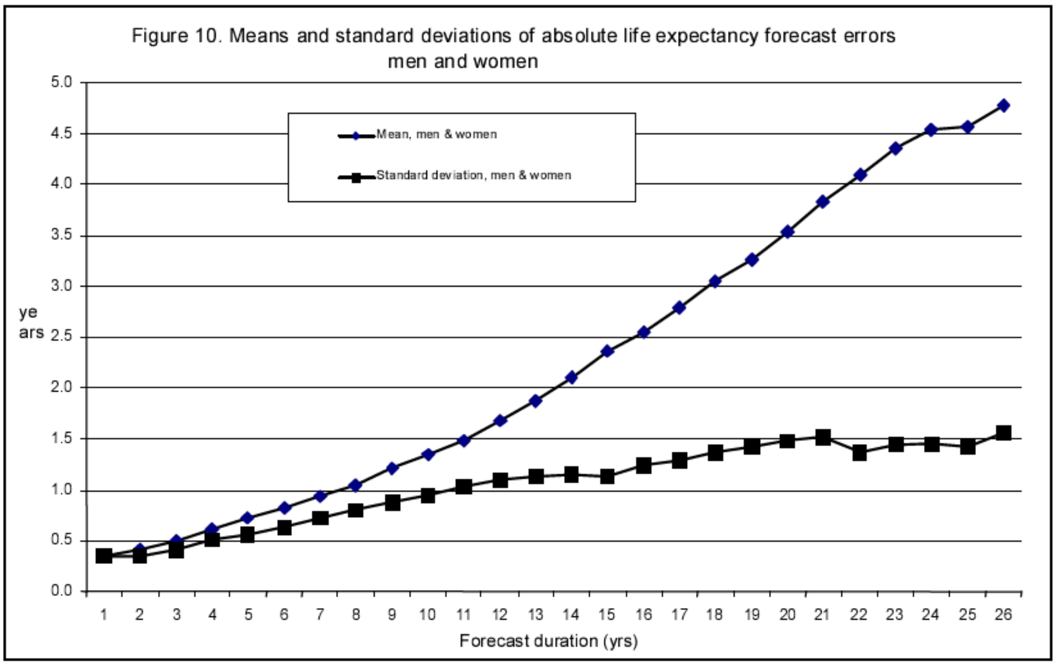


Figure 10. Means and standard deviations of absolute life expectancy forecast errors men and women

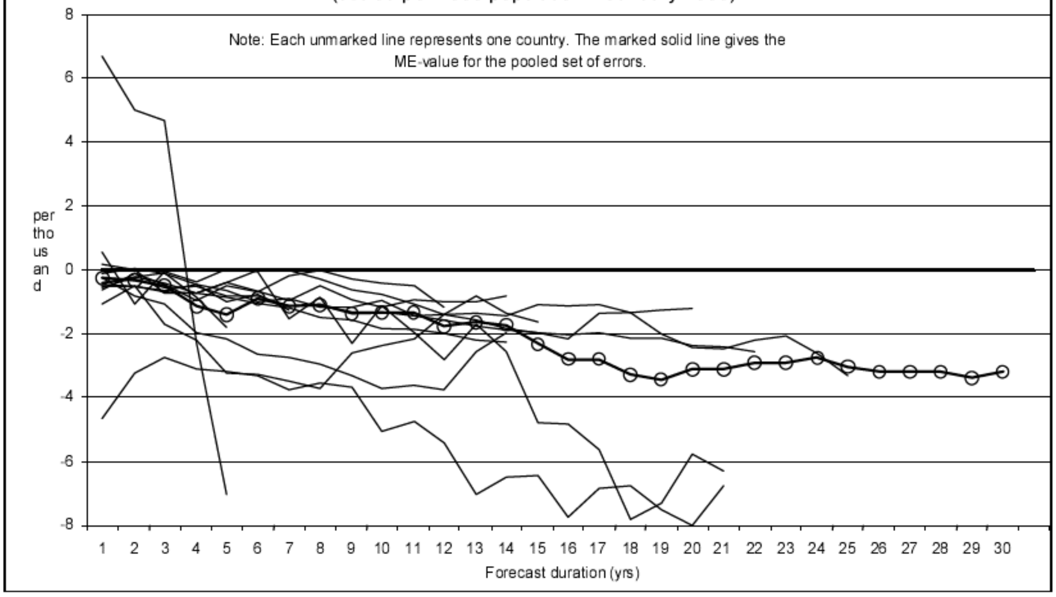
Assuming a normal distribution for the absolute errors at each forecast duration, one can use figure 10, combined with figures 8 and 9, for statements about the likelihood of errors of a certain magnitude in life expectancy forecasts. For example, one can read from figure 9 that the probability is 20 per cent that the standardized absolute error in female life expectancy will exceed 0.6 years. Figure 10 gives the two parameters that are necessary to recompute standardized errors to errors in the original scale. At 10 years into the future, figure 10 gives a mean error of 1.3 years and a standard deviation of 1.0 year. Thus the standardized error of 0.6 years mentioned earlier will translate into an unstandardized error of 1.3 + 1.0*0.6 = 1.9 years. In other words, there is a 20 per cent chance that the ten-year ahead life expectancy forecast for women will be wrong by at least 1.9 years.

Absolute errors in life expectancy forecasts are correlated across sexes with a correlation coefficient of about 0.7. Cross-country correlations for men are not systematic, but for women in Austria, Finland, France, Norway, Sweden, and Switzerland they increase with forecast lead time, from 0.8 for five years ahead, to over 0.9 for 15 years ahead.

3.2.4 Net migration

Net migration has been consistently underpredicted during the last 2-3 decades. The mean error in (scaled) net migration falls regularly to minus 3 per thousand after 20 years, and for longer forecast durations it stabilizes around that level. (figure 11).

Figure 11. Mean error in net migration forecasts
(scaled per 1000 population 1 January 2000)



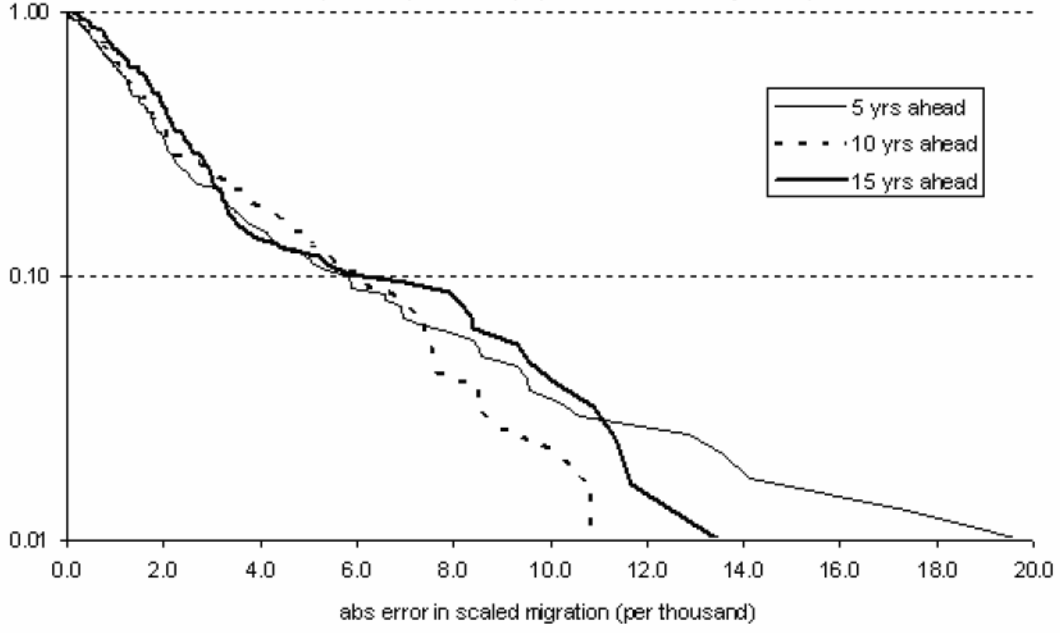
Note: Each unmarked line represents one country. The marked solid line gives the ME-value for the pooled set of errors.

International migration forecasts for Austria, West Germany, Luxembourg, Portugal, and Switzerland were clearly less accurate than the average for the 14 countries considered. There are different reasons for this empirical evidence: large unforeseen immigration flows after the fall of the Berlin Wall (Germany, Austria), small population size combined with large migration flows that are inherently difficult to predict (Luxembourg), or simply inaccurate migration statistics (Portugal).

There is a general belief among demographers that of the three components of population change at the national level, migration is the least predictable (Cruijsen and Keilman 1992, 332). The consequences for migration flows to industrialized countries brought about by economic, political, and demographic developments are much more difficult to foresee then those for births or deaths. This explains our finding that extreme migration errors are more likely than an exponential distribution would predict.

Figure 11 plots the empirical probability distributions for absolute errors in migration assumptions at forecast durations of five, ten, and fifteen years ahead. The pattern is that of a straight line for probabilities between 10 and 100 per cent. This suggests an exponential distribution. However, in the range between 0 and 10 per cent, the empirical pattern deviates from this straight line, in particular for the short term. In other words, the probability for extreme errors is larger than an exponential distribution would predict.

Figure 11 Probability that the absolute error in migration exceeds a certain value (scaled per 1000 population 1 January 2000)



3.3 Model-based estimates of forecast errors (WP3)

3.3.1 General

A number of recent stochastic population forecasts have used some form of time series analysis for one or more key indicators, when assessing the expected accuracy of predicted values for these indicators. Time series models were used to predict the TFR in stochastic forecasts prepared for the US (Lee and Tuljapurkar, 1994), Finland (Alho, 1998), the Netherlands (De Beer and Alders, 1999), and Norway (Keilman et al. 2001). One attractive property of time series models is that they not only give a prediction of future values of the variable in question, but also allows to computing prediction intervals.

A common finding with TFR- time series in industrialized countries is that these are non-stationary. As a consequence, long run prediction intervals, when unchecked, may become extremely wide. Therefore, adjustments are necessary. For instance, Lee and Tuljapurkar (1994) introduced upper and lower bounds to the TFR by a generalized logit-transformation. This way they constrained TFR-predictions to between 0 and 4 children per woman on average. Alho (1998) found that time-series based TFR-prediction intervals 50 years ahead were 15 per cent wider than those obtained based on the volatility in the historical TFR-observations, and he decided to rely on the latter type of intervals. De Beer and Alders (1999) initially found a 95-per cent prediction interval for the TFR in 2050 equal to [0.6 – 2.8] based on time series models. Next, an analysis of fertility by birth order led them to suggest that an interval of [1.1-2.3] would be more appropriate. Keilman et al. (2001) simulated predicted TFR-values, and rejected TFR-simulations that would fall outside the interval [0.5 – 4] in any year up to 2050.

An important question is how much of the data one should use in the modelling. Several issues are at stake here. First, Box and Jenkins (1970, 18) suggest at least 50 observations for ARIMA-type of time series models, although annual models (in contrast to monthly time series) probably need somewhat shorter series. Second, the quality of the data is better for the 20th century than for earlier years. This is particularly true for the denominators of the fertility rates, i.e. the annual numbers of women by single years of age. Third, one may question the relevance of data as long back as the early or mid 1800s. Current childbearing behaviour, mortality patterns and net migration levels are very different from those observed during the 19th century. Fourth, our ultimate goal is to compute long-term predictions of some 50 years ahead, which necessitates a long series.

The ultimate choice on the length of the demographic data series to be used is necessarily a subjective one, and therefore includes a good deal of judgement and arbitrariness. In this project a reasonable balance between conflicting goals has been achieved by selecting the

20th century as the basis for the time series models applied. For example, a fertility analysis only based on the period 1950-2000 would be unfortunate: it would include the baby boom of the 1950s and early 1960s, but not the low fertility of the 1930s, to which the boom was a reaction, at least partly. A base period stretching back into the 19th century would be hampered by problems of data quality, and it would also unrealistically assume that the demographic behaviour over such a long period could be captured by one and the same model.

By using the international data sources mentioned in section 3.2.1, the following annual data series have basically been applied:

- TFR: 1900/1901 to 2000 for Denmark, England and Wales (instead of the United Kingdom), Finland, France, Iceland, Netherlands, Norway, Sweden, and Switzerland; 1950/1951-2000 for Austria, Belgium, Italy, Luxembourg, and Spain; 1960-2000 for Germany, Greece, Ireland and Portugal.
- Life expectancy at birth: 1900/1901-2000 for Belgium, England and Wales (instead of the United Kingdom), France, Luxembourg, Netherlands, Norway, Sweden and Switzerland; 1906-2000 for Italy; 1921-2000 for Denmark; 1941-2000 for Finland; 1948-2000 for Austria; 1960-2000 for Greece and Spain; 1963-2000 for Germany; 1965-2000 for Portugal; 1970-2000 for Iceland; 1985-2000 for Ireland.
- Net migration: 1960-2000 for all countries but Spain (series starting in 1965).

3.3.2 TFR

During the 20th century the TFR of the 18 countries considered show a similar pattern, which reflects the (first) demographic transition, followed by the effects of the economic recession in the 1930s, the baby boom in the 1950s and 1960s, and the baby bust in the 1970s and 1980s (figure 12). Major events, such as the First World War, and the occurrence of the Spanish Influenza in 1918/1919 are clearly reflected in the most national series.

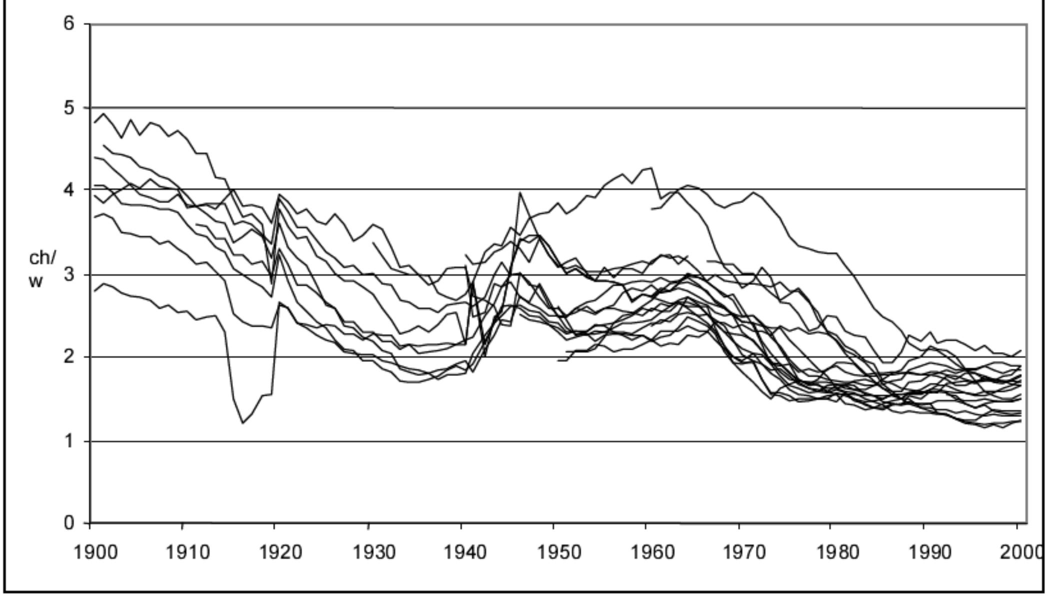


Figure 12. Total Fertility Rate

Most countries show a tendency towards lower variability in the TFR. However, traditional time series models of the ARIMA type assume homoscedasticity, i.e. constant residual variance. Therefore, such models could not be used.

The Autoregressive Conditional Heteroscedastic (ARCH) model introduced in Engle (1982) combines time-varying variance levels with an autoregressive process. This model and its generalizations (generalized, integrated, and exponential ARCH models, to name a few) have gained popularity in recent years (Bollerslev 1986). The model has already proven useful in analysing economic phenomena such as inflation rates, volatility in macroeconomic variables, and foreign exchange markets; see Bollerslev (1986) for a review.

Application to demographic time series is less widespread. Yet, given the varying levels of volatility in the TFR during the 20th century, an ARCH type of model was classified as promising candidate time series model to construct prediction intervals for the TFR.

Let Z_t be the logarithm of the TFR in year *t*. Then the model is:

$$\begin{aligned}
&Z_t = C + \phi Z_{t-1} + v_t + \eta_1 U_{1,t} + \eta_2 U_{2,t} + \eta_3 U_{3,t} + \eta_4 U_{4,t} + \eta_5 U_{5,t} \\
&v_t = \psi_1 v_{t-1} + \psi_2 v_{t-2} + \ldots + \psi_m v_{t-m} + \varepsilon_t \\
&\varepsilon_t = \left(\sqrt{h_t}\right) e_t \\
&h_t = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2
\end{aligned} \qquad (5.1)$$

where $e_t \sim N(0,1)$. This is the AR(*m*)-ARCH(*q*) model.

The maximum number of terms m included in the autoregressive expression of v_t was set equal to 10, but few of the ψ -estimates turned out to be significantly different from zero. In practice, m was restricted to 2. Similarly, estimates for α_i suggested that the order (q) of the CH-part of the model could be restricted to one.

For the nine countries with long time series on TFR, two sets of prediction intervals up to 2050 have been constructed: one based on the annual data series 1900-2000, and another one based on annual figures observed during the period 1950-2000. The first set of intervals appeared on average to be slightly narrower then those estimated by using the short data series.

The robustness of the prediction intervals was assessed by applying several, more simple time series models (e.g. a pure AR(m)-model) on long series of Denmark, Finland, Norway and Sweden. Based on these sensitivity tests it was concluded that the ARCH-model in expression (5.1) gives a useful and reliable description of the development in the TFR in the four countries in the previous century. Given the similarity of trends, it was assumed that this is also the case for the other countries.

Application of the ARCH-type of model to the annual TFR series of all 18 countries for the period 1950-2000 led to the conclusion that only for Belgium, Germany, and England and Wales the CH-part was needed. Obviously, in most countries the TFR level were less volatile during the second half of the 20th century than those observed during the first half.

Secondly, due to the recent strong fall in fertility, the constant term had to be omitted for Greece, Ireland, Italy, Portugal and Spain.

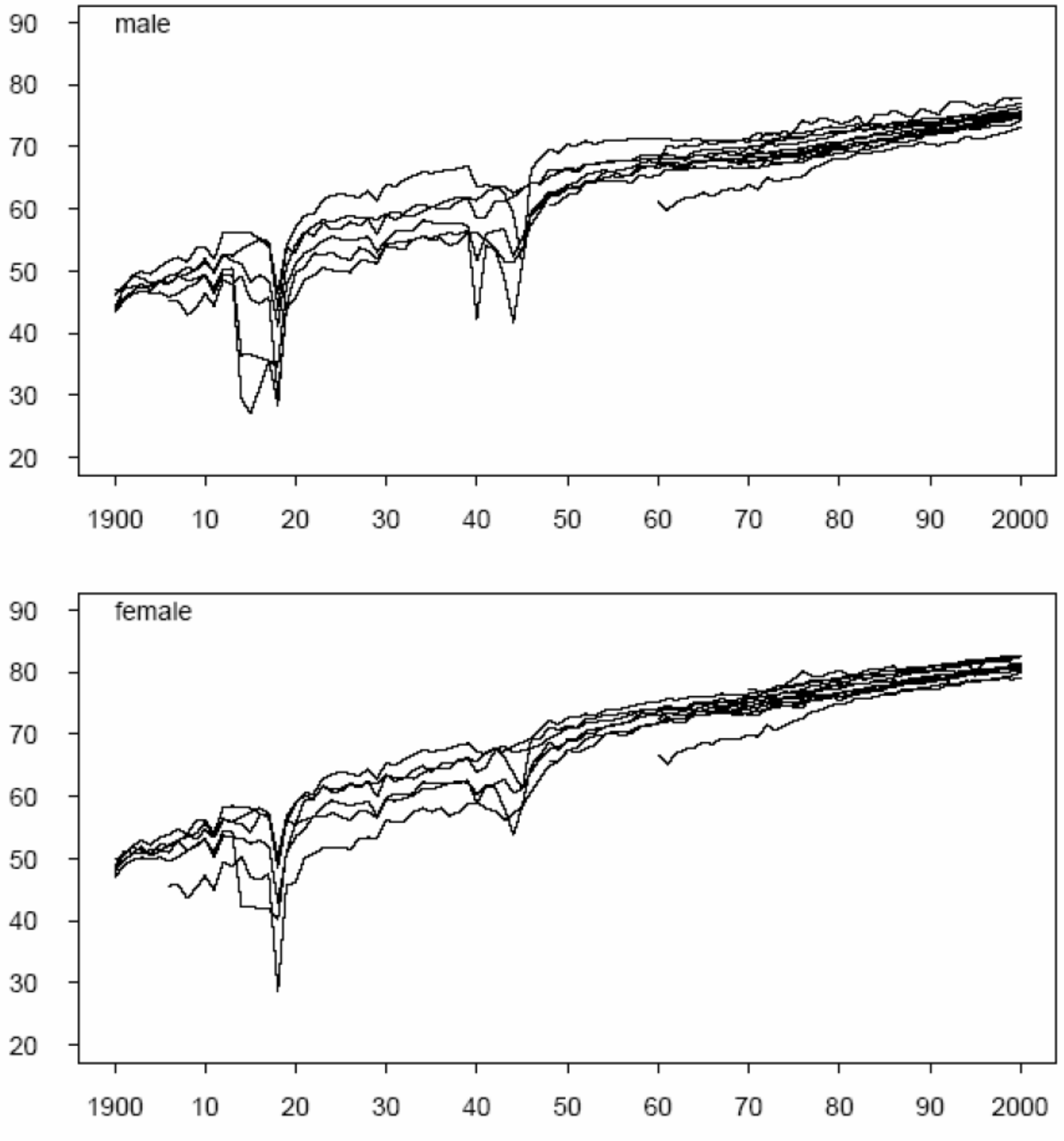
Finally, comparisons of cross-country correlations in the observed data series and those computed across countries between residuals from the time series models showed that the models had removed a large part of the original cross-country correlations.

In Annex 1 one can find plots for all 18 countries considered comprising point forecasts (i.e. expected values) and 67%, 80%, and 95% prediction intervals for the TFR based upon data series 1950-2000. The width of long-range 95 per cent prediction intervals varies a great deal, ranging from a low 1.0 (Greece) and 1.3 (Portugal), to a high 2.9 (Austria, Germany) and 3.4 (Sweden). A possible explanation for the large uncertainty in Sweden is the baby boom around 1990, caused by a change in legislation for maternity leave. Greece had a baby boom in the 1960s and 1970s that was much less pronounced than that in most other countries. Fertility fell more or less regularly after 1950, and hence the narrow interval in 2050. Ten years ahead 95 per cent intervals are 0.6 (Greece) to 1.2 (Sweden) children per woman wide.

3.3.3 Life expectancy at birth

Figure 13 plots the life expectancy at birth for men and women in the 18 countries, observed/estimated since 1900. Major interruptions caused by the First World War, the Spanish Influenza, and the Second World War are clearly visible. The time series show less variability in the second half of the 20th century than in the first half.

Figure 13. Life expectancy at birth



The time series models applied belong to the group of Generalized Autoregressive Conditional Heteroscedasticity (GARCH)-models, i.e. models that are slightly more general than the ARCH-models employed for the TFR. All models were estimated for men and women separately.

Let $e_{0,t}$ represent the life expectancy at birth in year t, and define $\nabla e_{o,t}$ as $e_{0,t}$ - $e_{0,t-1}$. The model is

$$\nabla e_{0,t} = C + \phi \nabla e_{0,t-1} + v_t + \sum_j \eta_j U_{j,t}$$

$$v_t = \psi_1 v_{t-1} + \psi_2 v_{t-2} + \ldots + \psi_m v_{t-m} + \varepsilon_t$$

$$\varepsilon_t = \left(\sqrt{h_t}\right) e_t, \text{ where } e_t \sim N(0,1), \text{ and}$$

$$h_t = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \gamma_j h_{t-j} \qquad (5.2)$$

This is the AR(m)-GARCH(p,q) regression model.

Similarly to the exercise for the TFR, two sets of prediction intervals have been constructed: one based upon the available annual series on life expectancy of the period 1900-2000 (for 11 countries), another one using the series since 1960 (for 18 countries). The differences, particularly for men, appeared to be small.

Comparisons of cross-country correlations in the observed data series and those computed across countries between residuals from the time series models showed that the models had removed a large part of the original cross-country correlations, but not all.

The relatively high cross-sex correlations in the observed data series, on the contrary, appeared to be still present in the residuals from the time series models. A multivariate GARCH-time series model for men and women simultaneously could possibly capture this correlation (Engle and Kroner, 1995; Kroner and Ng, 1998). However, a recent test of the available software for such multivariate GARCH models revealed considerable differences in the resulting parameter estimates across four software packages (Brooks, Burke and Persand, 2003).

In Annex 2 one can find plots for all 18 countries considered comprising point forecasts (i.e. expected values) and 67%, 80%, and 95% prediction intervals for the life expectancy at birth for the period 2001-2050 based on the data for the period 1960-2000. Between 2000 and 2050, life expectancy at birth for men and women is expected to rise by between 6 and 13 years. Across countries and sexes, the average annual increase amounts to 0.2 years. This is in line with historical developments (0.23 years for record life expectancy 1840-2000, Oeppen and Vaupel, 2002; 0.21 years for 21 industrialized nations 1955-1995, White, 2002), but it reflects a much stronger increase than that recently projected for 21 OECD countries to 2050 (0.09 years, Dang et al. 2001).

Long-range 95 per cent prediction intervals are 4-14 years wide, with men and women from England and Wales at the lower end of the spectrum, and Danish men and women a the upper end. Ten years ahead 95 per cent intervals are between 1 (men in France, women in England and Wales) and 4 (Denmark, both men and women) years wide.

3.3.4 Net migration

Net migration poses a greater challenge than total fertility or life expectancy, for two reasons:

- the observed trends are strongly volatile, due to political and economic developments, and changes in legislation;
- the data situation is problematic – time series of observed net migration are rather short, and the data quality may be questioned in some cases.

Three different models have been applied on the basis of the time series for each country, namely a linear trend model, a random walk with drift, and an autoregressive process of order 1 (AR(1)). Dummy variables are included in order to capture outliers caused by special political or economic events or the occurrence of a census.

Let Z_t be the net migration in year t. The three models are as follows.

Linear trend (LT)

$$Z_t = \eta_1 U_{t_1} + \ldots + \eta_n U_{t_n} + C + \beta t + \varepsilon_t , \tag{5.3}$$

where U_{t_i} is the dummy variable for year t_i, C is the constant, and β is the slope of the trend.

Random walk with drift (RWD)

$$Z_t = \gamma_1 U_{t_1} + \ldots + \gamma_n U_{t_n} + \mu + Z_{t-1} + a_t , \tag{5.4}$$

where U_{t_i} is the dummy variable for year t_i, and μ is the drift.

Autoregressive AR(1) process (AR(1))

$$Z_t = \lambda_1 U_{t_1} + \ldots + \lambda_n U_{t_n} + K + \phi Z_{t-1} + v_t \tag{5.5}$$

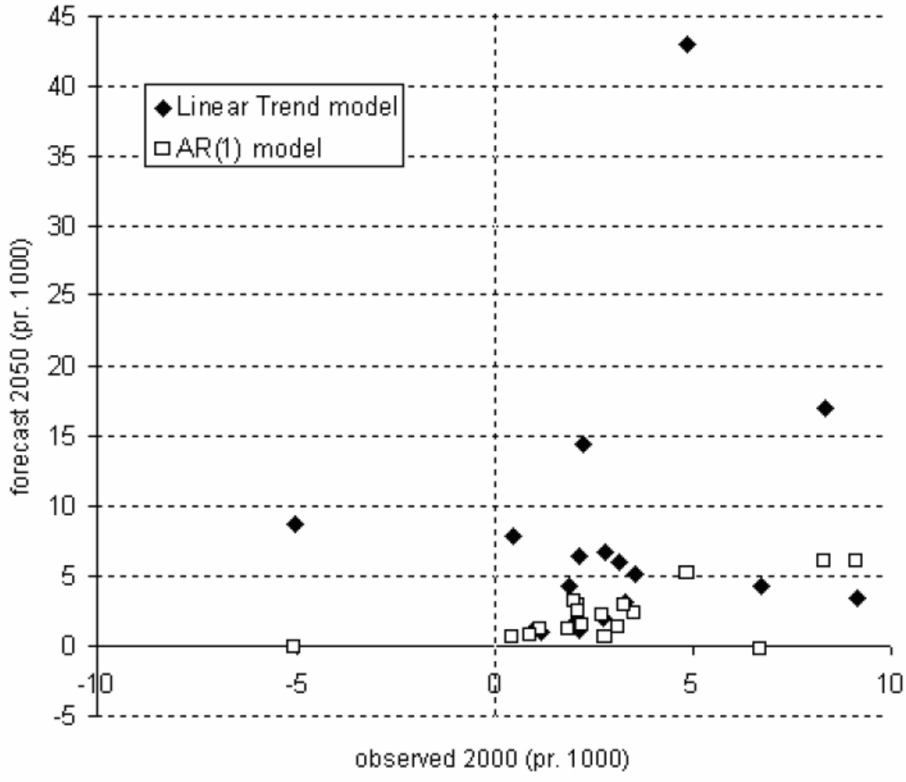
where U_{t_i} is the dummy variable for year t_i, K is a constant, and the autoregressive coefficient $\phi < 1$.

All 3x18 = 54 models estimated passed tests for independence and constant variance in the residuals (α=0.05), but the residuals were not normal in a number of cases, especially those resulting from the RWD-model. Furthermore, the RWD-model predicted much wider intervals than the historical data suggested (see Annex 3). For these two reasons the RWD-model was eventually qualified as not appropriate for stochastic forecasting.

The intervals for the AR(1)-model appeared to be somewhat wider than those for the LT-model. The reason is that prediction uncertainty for multiple steps ahead forecasts cumulates for AR(1), as opposed to LT, in which each forecast step starts from the trend line. Although the AR(1)-model fails to predict the trend in a number of cases (Finland, Greece, Italy, Luxembourg, Norway, Portugal, Spain, the UK), its prediction intervals look more reasonable than those for LT.

In order to compare the forecasts across countries, net migration predictions and prediction intervals in each country were scaled by the national population size as of 1 January 2000. Figure 14 plots the scaled LT forecasts and AR(1) forecasts in 2050 as a function of the scaled observed migration in 2000. The picture shows that the AR(1) model predicts 2050 values that are closer to observed 2000 values than LT does. AR(1) predictions for 2050 are generally in the order of magnitude of up to 5 per thousand, whereas half the LT predictions exceed this level. The reason is again the linear trend in the historical data, which is not picked up by AR(1).

Figure 14 Net migration predictions 2050 vs. observed 2000, scaled numbers
Each country is represented by one dot



A second cross-country comparison concerns the width of the prediction intervals. Figure 15 plots the width of the 95 per cent prediction interval in 2050, relative to the predicted value for 2050, for the LT and the AR(1) model. This figure shows that LT generally produces narrower intervals than AR(1). There are two reasons. First, LT-intervals for some countries are narrow because the model picks up a linear trend. The estimated trend is moderate for Denmark, Italy, Luxembourg, Netherlands, Norway, and Spain, while Finland, Greece, Portugal, and the UK show a strong trend. Second, AR(1)-intervals are wide because the *K*-estimate has a large standard error. This is the case for Finland, France, Greece, Italy, Portugal, and the UK.

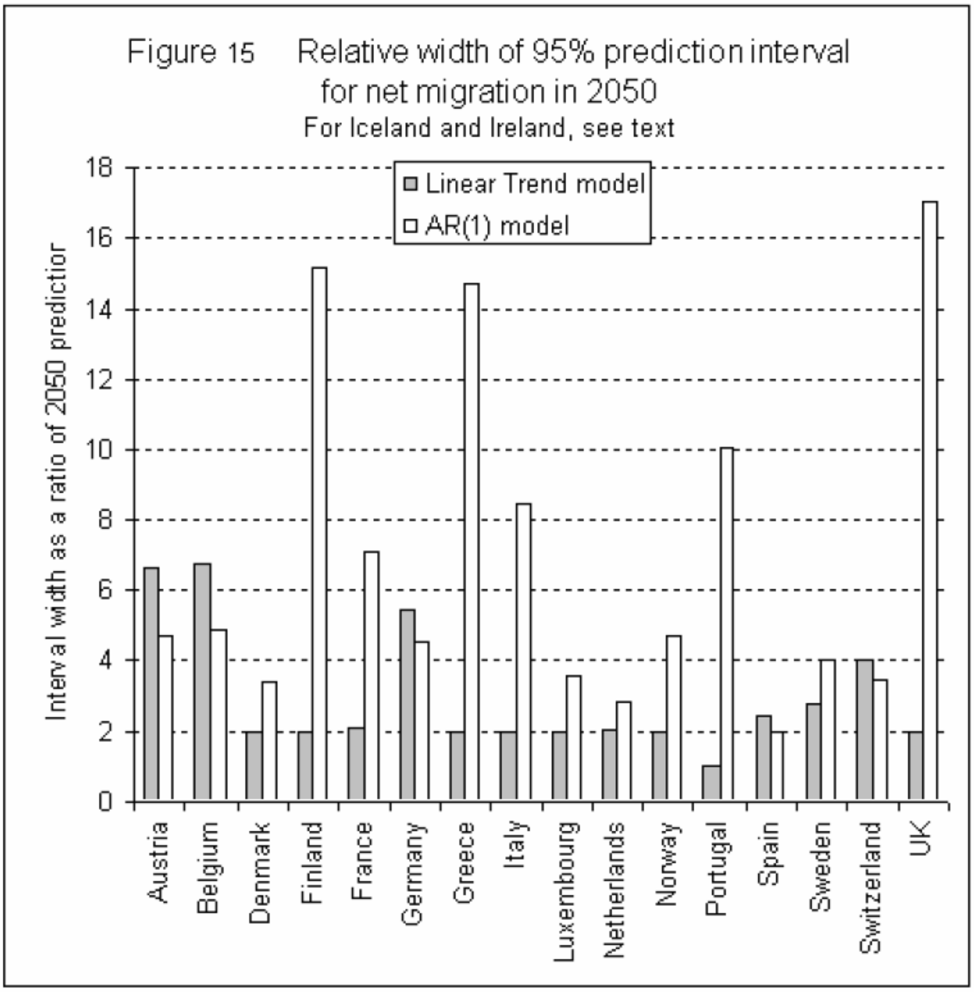


Figure 15 Relative width of 95% prediction interval for net migration in 2050

For Iceland and Ireland, see text

Inspection of observed cross-country correlations revealed a cluster of Central European countries (Austria, Switzerland, and Germany) and the Benelux countries, a South European cluster (Portugal, Italy, and Greece), and a North-West European cluster (Denmark, Iceland, Norway, and the UK). The countries in these three clusters are positively correlated. There are also two clusters (Finland/Sweden and France/Portugal) with negative correlations.

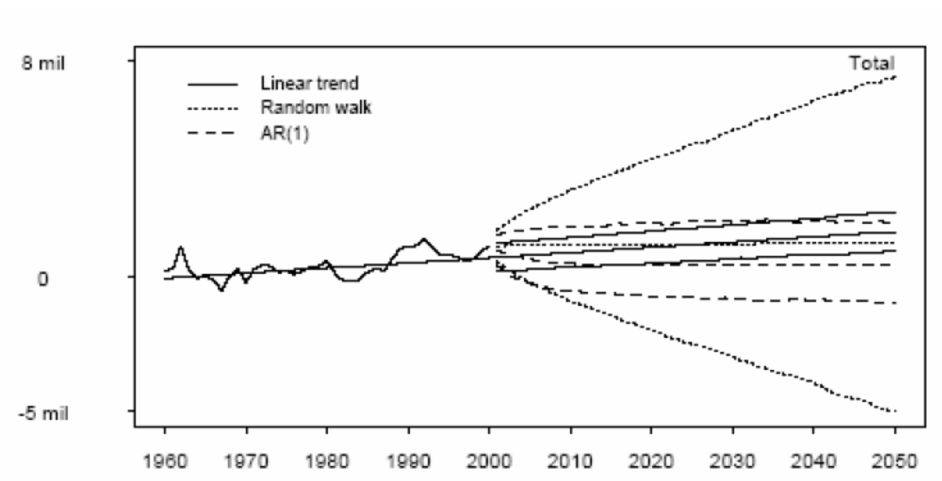
Probably this is explained by counter cyclical economic developments, which induce labour migration between the two countries in each pair.

Inspection of the residuals from the AR(1) model - the time series model that was judged as giving the most realistic prediction intervals – showed that just a limited number of bilateral correlations remained.

Finally, aggregated migration forecasts and prediction intervals were estimated for the whole European Economic Area, and compared with the simple sums across countries. Again the RDW-model appeared to produce very wide prediction intervals (figure 16). The AR(1) model predicted a net migration level for the EEA+ in 2050 considerably lower than the simple sums, whilst the linear trend model yielded the opposite. The latter model showed relatively narrow prediction intervals.

The predictions indicate that net migration to the total of the 18 countries involved may increase to between 600 000 and 2 million in the year 2050, depending on the particular time series model one adopts. Cumulated immigration for the period 2000-2050 could amount to between 30 and 70 million persons.

Figure 16. Forecasts and 95% prediction intervals for net migration to EEA+



3.4 Elicitation of expert's opinions (WP4)

3.4.1 General

The basic idea in the project 'Changing Population of Europe: Uncertain Future' (UPE) is that the past is the key source of information for the future. For the expected level of mortality, fertility and international migration in about 50 years from now, as well for the assessment of the uncertainty, the experience of the past is analysed and used. The probability of events that have not yet occurred however, cannot be based on an analysis of past events only. For example, the uncertainty of forecasts of mortality partly depends on the probability of medical breakthroughs that may have a substantial impact on survival rates. An argumentation for and assessment of the probability of the occurrence of such circumstances and/or events and their impact on demographic components is needed to determine the uncertainty of the forecast. Demographic experts have the task to point out these possibilities and assess how these factors and determinants influence the uncertainty of the future.

Generally the width of the interval between variants of population forecasts is based on either judgement or simple rules (e.g. fertility at replacement level or zero net migration). Usually no explicit arguments are given for the specification of the variants (in most cases national statistical offices publish low and high variants, next to the baseline or medium variant). Consequently, the width of the intervals between the low and high variant tends to vary strongly across countries. Even though analyses of historic errors and model-based estimates of errors are useful for specifying the width of forecast intervals, expert judgement is required since an assessment of the probability of events that have not yet occurred cannot be based on an analysis of past data only.

The aim of WP4 is to develop methods to systematically elicit experts' opinions on uncertainty. Three different types of research techniques have been applied:

- literature research (theories and methods);
- experimental testing (surveys and expert meetings);
- interviewing.

3.4.2 Literature research

An extensive literature study was executed to collect and review principal issues, theories and methods for the elicitation of experts' opinions. First the answers found on the following set of basic questions were reviewed:

- What is probability?
  Answer: "The probability a person assigns to an event represents his or her subjective degree of belief that the event will occur and is expressed on a continuous numerical scale with end-points of 0 and 1".
- Which heuristic principles reduce the complex task of assessing probabilities? Answer: availability, imaginability, adjustment and anchoring, representativeness.
- What are the most important risks connected to group decision-making? Answer: groupthink, polarisation, social loafing, conformity.

Thereafter, different approaches and methods to capture expert opinions were discussed. The pros and cons of the following instruments were presented:

- The in-depth interview
- The survey
- Open discussions
- Brainstorming
- The Nominal Group Technique
- Delphi method
- Group Delphi method
- Social Judgement Theory.

3.4.3 Experimental testing

Some of the methods listed in the previous section were assessed by a series of experiments. First of all, three expert meetings were organised, each one following a different procedure and attended by different groups of specialists. An important part of the meetings was dedicated to background variables and determinants of the demographic component in question. The outcomes showed considerable, subjective differences in prediction intervals for future fertility, mortality and international migration.

Secondly, a survey was conducted among national population forecasters of 29 European national statistical offices. They were asked to provide the width between their lowest and highest variants of the total fertility rate and to make an estimate of the probability of this interval. Again, a range of rather different forecast intervals was collected.

The last method assessed was the argument-based approach. Applied to Dutch fertility, a distinction was made by birth order, all from a cohort perspective (Alders and De Beer, 2004). The main objective was to provide arguments for a specific interval. The results of this approach were compared to results from time-series models and from analyses of past forecast errors. This information was pooled by Dutch national population forecasters to construct their forecast intervals.

3.4.4 Interviewing

Based on the outcomes of both the literature research and experimental testing it was decided to organise a restricted number of one-day argument-based interviews with very experienced, international demographers on the future course of fertility, mortality and international migration. In order to guide the experts in quantifying the uncertainty of future developments they were provided with quantitative information of empirical errors (WP2) and forecasts and prediction intervals resulting from time-series models (WP3). The experts were invited to explicitly give arguments to support their ideas or opinions.

The primary task of the experts was to suggest revisions to point forecasts and prediction intervals, give arguments for the suggested revisions, and assess the uncertainty they foresee for the future as compared to the past.

The mortality expert provided the following remarks/views:

1. The improvement in age-specific mortality has gradually shifted from young ages to older ages. During the past decade an acceleration of decline (especially in ages 80-100) has been observed in several countries, notably Japan, France, Switzerland, Italy, Spain and Germany. However, in some other countries such as the United States the progress has been nil, and in others such as the Netherlands, Denmark, Finland, Norway and the United Kingdom the progress has been slow. Overall, this may mean that extrapolations based on the continuation of past trends underestimate future gains in life expectancy.

2. For females the best practice value of life expectancy has increased, by 0.25 years per calendar year in the past 160 years It is not likely that life expectancy in EU/EEA countries will permanently increase at a slower pace. Corrective action would be taken on the part of the government, if a country would begin to fall too far behind. An example of this is Denmark, where committees have been appointed to investigate means of reducing hazardous behaviours (smoking, alcohol consumption; both factors

that can be influenced by education and regulation) and the inadequacy of past health investments. The effect of, e.g., reductions in the prevalence of smoking are expected to have a rapid effect on cardio-vascular morbidity, the major cause of death, although for other diseases, such as lung cancer the long latency time will attenuate the effect of behavioural changes. In summary, one would expect further increases at the past best practice rate. In 50 year's time this means an average increase of 12.5 years.

3. Life expectancy of individual countries has sometimes increased faster than the best practice life expectancy, sometimes slower. Countries close to the best practice level are expected to have slightly slower increase, and countries far from the best practice level are expected to have slightly faster increase. If a country deviates now by x years from the average of the European countries, then its life expectancy is expected to increase roughly by 12.5 - x/2 years in the next 50 years. This means that there is some degree of convergence in life expectancies across countries.
4. The empirically observed level of average uncertainty in Europe, which includes the effect of wars, epidemics, penicillin et cetera, is appropriate for the down side or lower limit of the prediction interval. However, possible future medical advances may bring unexpected gains in life expectancy. Examples include the cure of cancer, the prevention of Alzheimer's disease, improvement of cardio-vascular health through the rejuvenation of the heart via stem cell therapy, and improvement of pharmaceuticals based on genetic understanding. Even the possibility of slowing down the pace of ageing is considered feasible by some. The effect of possible acceleration in biomedical technologies is not reflected in the past developments. Thus, the upper limit should be about twice as far from the median as the lower limit, or 11 years above the median.
5. Forecasting life expectancy now is somewhat harder than forecasting it in the past has been, because of the uncertainty related to the prospects of medical advances. That is why the upper limit of the prediction interval is so much higher than the lower limit.
6. Correlation across sexes is high. It can be estimated from the past data by correcting for Poisson type observation error. Across all European countries, future life expectancies will be positively correlated. There are regions, such as the Nordic countries, that have an additional degree of positive correlation, beyond what all countries have. The order of magnitude of both types of correlations can be assessed by correcting estimates from the past data for Poisson type observation error.

In his view forecasting is more difficult now than in the past due to the uncertainty of when, and how medical advances will materialise in the coming decades. In tables 1 and 2 the suggestions of the expert have been translated in an expert point forecast and prediction interval for each country, for males and females separately, using the best practice experience of females. The tables show life expectancy at birth for each country as observed in the year 2000, together with the naive, time series and expert forecasts and their respective intervals.

Table 1. Life expectancy at birth of males for the base year 2000 and in 2050, according to three forecasts, with 80 % prediction intervals

	2000 base	2050								
		Naive forecast			Time-series forecast			Expert forecast		
		Point forecast	Lower limit	Upper limit	Point forecast	Lower limit	Upper limit	Point forecast	Lower limit	Upper limit
Austria	75.4	84.7	79.3	90.1	87.9	84.5	91.2	87.9	82.4	98.9
Belgium	74.6	81.4	76.0	86.8	86.0	83.6	88.4	87.5	82.0	98.5
Denmark	74.4	78.9	73.5	84.3	80.1	76.8	83.5	87.4	81.9	98.4
Finland	74.2	83.8	78.4	89.2	85.5	81.8	89.0	87.3	81.8	98.3
France	75.2	83.3	77.9	88.7	88.0	85.8	90.1	87.8	82.3	98.8
Germany	75.0	84.6	79.2	90.0	85.6	82.5	88.6	87.7	82.2	98.7
Greece	75.5	83.6	78.2	89.0	83.1	80.0	86.0	88.0	82.5	99.0
Iceland	78.0	83.4	78.0	88.8	86.4	79.9	92.8	89.2	83.7	100.2
Ireland	74.3	79.7	74.3	85.1	81.8	80.0	83.5	87.4	81.9	98.4
Italy	76.3	84.3	78.9	89.7	89.4	86.9	91.8	88.4	82.9	99.4
Luxembourg	74.8	83.4	78.0	88.8	87.6	84.3	91.0	87.6	82.1	98.6
Netherlands	75.5	80.4	75.0	85.8	82.6	80.0	85.1	88.0	82.5	99.0
Norway	76.0	81.8	76.4	87.2	83.9	81.6	86.1	88.2	82.7	99.2
Portugal	73.2	81.3	75.9	86.7	88.8	84.5	93.1	86.8	81.3	97.8
Spain	75.7	83.8	78.4	89.2	86.1	83.7	88.5	88.1	82.6	99.1
Sweden	77.4	84.3	78.9	89.7	87.5	85.6	89.4	88.9	83.4	99.9
Switzerland	76.9	86.1	80.7	91.5	88.4	85.6	91.2	88.7	83.2	99.7
UK	75.6	83.3	77.9	88.7	87.0	85.0	89.1	88.0	82.5	99.0

Table 2. Life expectancy at birth of females for the base year 2000 and in 2050, according to three forecasts, with 80 % prediction intervals

	2000 base	2050								
		Naive forecast			Time-series forecast			Expert forecast		
		Point forecast	Lower limit	Upper limit	Point forecast	Lower limit	Upper limit	Point forecast	Lower limit	Upper limit
Austria	81.2	89.1	83.7	94.5	93.1	90.1	96.1	93.6	88.1	104.6
Belgium	80.8	87.4	82.0	92.8	91.9	89.4	94.5	93.4	87.9	104.4
Denmark	79.1	83.4	78.0	88.8	86.1	82.5	89.7	92.6	87.1	103.6
Finland	81.0	89.0	83.6	94.4	92.5	89.5	95.3	93.5	88.0	104.5
France	82.7	90.1	84.7	95.5	94.8	91.9	97.6	94.4	88.9	105.4
Germany	81.0	89.3	83.9	94.7	92.9	89.0	96.8	93.5	88.0	104.5
Greece	80.6	88.5	83.1	93.9	89.2	86.6	91.8	93.3	87.8	104.3
Iceland	81.4	86.7	81.3	92.1	89.3	84.4	94.2	93.7	88.2	104.7
Ireland	79.2	85.7	80.3	91.1	88.1	86.5	89.8	92.6	87.1	103.6
Italy	82.6	90.2	84.8	95.6	95.5	93.3	97.5	94.3	88.8	105.3
Luxembourg	81.1	88.8	83.4	94.2	94.4	90.8	98.1	93.6	88.1	104.6
Netherlands	80.6	86.1	80.7	91.5	87.9	84.9	90.8	93.3	87.8	104.3
Norway	81.4	86.8	81.4	92.2	88.7	86.7	90.6	93.7	88.2	104.7
Portugal	80.0	87.9	82.5	93.3	97.4	93.5	101.0	93.0	87.5	104.0
Spain	82.5	90.4	85.0	95.8	94.4	90.9	97.9	94.3	88.8	105.3
Sweden	81.7	87.8	82.4	93.2	91.4	88.3	94.6	93.9	88.4	104.9
Switzerland	82.6	90.9	85.5	96.3	93.5	90.1	96.5	94.3	88.8	105.3
UK	80.3	86.5	81.1	91.9	89.0	87.6	90.2	93.2	87.7	104.2

The first fertility expert provided the following list of key factors of future reproductive behaviour:

1. Postponement of childbearing and recuperation of lost births at higher ages are the most important direct determinants of fertility developments. Postponement behaviour is clear and universal in Europe, but this is not the case for recuperation behaviour.

2. There is a North-South divide in Europe. The North, and especially the Scandinavian countries, is the forerunner. North European countries are the first to postpone childbearing (in the early 1970s visible in the data), and the first to recuperate. In the German speaking countries and in the South of Europe there is postponement too but there is a much weaker recuperation if at all (at least visible in the data we have up to now).

3. One can use the recent Eurobarometer data to look at the average ideal or desired family size as mentioned by the 1975 and 1980 female cohorts. If this is done, the difference between ideal size mentioned and realised in practice in the past should be used to scale the ideal sizes to expected realised sizes. In case the results do not come above the level

of two, the proposed margins have to be kept as they are, otherwise they may be adjusted upward or downward depending on the values found.

4. A number of explanatory factors account for the new pattern of family formation and for concomitant postponement. The general ones are:

- Increased female education and female economic autonomy;
- Rising and high consumption aspirations that created the need for a second income in households and equally fostered female labour participation;
- Increased investments in career developments by both sexes, in tandem with increased competition in the workplace;
- Rising "post-materialist" traits such as self-actualisation, ethical autonomy, freedom of choice and tolerance for the non-conventional;
- A greater stress on the quality of life with rising taste for leisure as well;
- A retreat from irreversible commitments and a desire for maintaining an "open future";
- Rising probabilities of separation and divorce, and hence a more cautious "investment in identity".

The first fertility expert had problems with the fact that statistical models were chosen which did not include our present knowledge of key factors determining fertility levels. In addition, he was arguing that we cannot use variances based on historical forecasts for prediction intervals of expected futures.

In his view cohort profiles of age specific fertility rates are the basis on which point estimates should be made. With graphs of cumulated fertility deficits of recent cohorts compared to a benchmark cohort, past and immediate future developments are more easily interpretable. Therefore, this expert did not choose any point forecast or prediction interval for the TFR suggested by the UPE team. Cohort profiles with primarily data from the Council of Europe and the latest cohort information from NIDI/Eurostat were used instead for the point estimates of completed fertility for the cohorts 1970 and 1980.

The expert provided point forecasts and "defendable margins" for the 1970 and 1980 female generations (see table 3). The point estimates for these generations are the same, the only difference is found in the expert margins. After generation 1980 it is all speculation, in his view, because we cannot use statistical knowledge on variances of the past to predict the future in fertility. For the long run, one can either hold the values constant and put quickly increasing intervals around them, or make scenarios.

Table 3. Total Cohort Fertility Rates with expert margins in 2025

	Cohort 1970			Cohort 1980		
	Point forecast	Expert margin low	Expert margin high	Point forecast	Expert margin low	Expert margin high
Austria	1.45	1.35	1.55	1.45	1.30	1.60
Belgium	1.75	1.65	1.85	1.75	1.60	1.90
Denmark	1.90	1.80	2.00	1.90	1.75	2.05
Finland	1.85	1.75	1.95	1.85	1.70	2.00
France	1.90	1.80	2.00	1.90	1.75	2.05
Germany	1.40	1.30	1.50	1.40	1.25	1.55
Greece	1.55	1.45	1.65	1.55	1.40	1.70
Iceland	2.20	2.10	2.30	2.20	2.05	2.35
Ireland	2.00	1.90	2.10	2.00	1.85	2.15
Italy	1.35	1.25	1.45	1.35	1.20	1.50
Luxembourg	1.80	1.70	1.90	1.80	1.65	1.95
Netherlands	1.80	1.70	1.90	1.80	1.65	1.95
Norway	1.95	1.85	2.05	1.95	1.80	2.10
Portugal	1.65	1.55	1.75	1.65	1.50	1.80
Spain	1.35	1.25	1.45	1.35	1.20	1.50
Sweden	1.90	1.80	2.00	1.90	1.75	2.05
Switzerland	1.45	1.35	1.55	1.45	1.30	1.60
United Kingdom	1.80	1.70	1.90	1.80	1.65	1.95

With the second fertility expert, an explicit discussion was hold about the 'Group' forecast. This expert expressed his general agreement with the two fertility clusters chosen. The lowest-low fertility cluster or German/Mediterranean group appeared to be coherent. The country that seems most odd in the other, "Nordic" cluster is the UK, given family policies and immigration patterns.

In his view the naive point forecast is an improbable candidate for a good forecast of future trends (although empirically it may not have performed terribly), because it ignores what demographers tend to know about systematic influences on fertility trends. Based on judgements of the graphs, the expert believes that it is hard to give a preference of the naive over the group forecast. In those countries where the two diverge, he considers the Group point forecast as more likely. He predicts a somewhat higher long-term fertility for the German/Mediterranean group based on the following arguments. First, there is a likely Easterlin effect for small cohorts entering labour/ housing/marriage markets. Secondly, an increase in the proportion of women who are childless or at low parities at fairly advanced ages will lead to even lower fertility. This lower fertility will be perceived as a problem and lead to policy reactions to counter the trend. For this reason, he predicts a long-term TFR's in the German/Mediterranean group of closer to 1.6 than 1.4.

Concerning the prediction intervals the second fertility expert stated that they have the right order of magnitude, with the narrower ones being somewhat more plausible. This is based on intuition rather than formal analyses of the patterns. However, in his view it is hard to imagine that that the appropriate 80% interval for Germany in 2010 —six years from today— ranges from about 0.8 to 2.5 children per woman. He is quite willing to bet that in six years the German TFR will be not more than 0.3 higher or 0.2 children per woman lower than the current level.

The international migration expert pointed out that in general and for the EEA as a whole the future is less uncertain than the past for migration, because experience has learned that sharp changes in net migration tend to fade out fairly soon. The expert provided the following list of principal factors determining migration developments in the coming 50 years (in descending order of magnitude):

1. The economic developments in countries of the EEA, and in the EEA area as a whole, are the most important condition or determinant driving migration. If the economic engine starts rolling again —and the recession is short/or over soon— the demand for labour will rise. The national economies in many countries cannot deliver all the demand for labour. People will come first from other EEA countries, but also and primarily from outside the present EEA to fill the gaps or seize opportunities that are there. However, demand will not be met completely, because rigid economies and wage systems will keep unemployment high. Business cycles will lead to fluctuations in migration flows.

2. The ageing of the EEA population is the second and very important force that induces a demand for labour migrants (Social and Health Care are examples in the 1990s in the United Kingdom and other countries where recruitment outside the EEA has taken place, i.e. nurses from Finland and South Africa).

3. The interaction between factors 1 and 2, and especially the developments and changes in pension systems.

4. Developments in the global South and East will continue to put (enormous) pressures on the gates of the wealthy EEA.

5. The expansion of the EU with 10 countries will have a temporary effect (immigration boom, fading out, followed by return). This observation is in support of the analysis of Kupiszewski on the experience and expectations based on the Polish German experience of the 1990s (Kupiszewski, 2002).

6. Historical ties and streams or destinations will keep relevance when living conditions can be improved by moving abroad. Examples are United Kingdom migration to

Australia, USA and Canada and Southern Europe. The last group for the wealthy and healthy.

Apart from this general list, he specified a number of country specific factors.

The migration expert chose in all but four countries the AR(1) interval (see table 4). Partly on the basis of the visual inspection of the graphs and partly based on the arguments given for the individual countries.

Table 4. Two point forecasts of net migration in 2050, with one 80% prediction interval, and population size per 1 January 2000 (x 1 000)

	Naive forecast	AR(1), point forecast	AR(1) lower limit 80% interval	AR(1), upper limit 80% interval	Population size in 2000
Austria	17	23	-7	65	8103
Belgium	12	13	-6	31	10239
Denmark	10	6	-1	12	5330
Finland	2	3	-8	19	5171
France	55	45	-111	90	58749
Germany	167	254	-92	662	82163
Greece	24	15	-48	94	10554
Iceland	2	0	-1	1	279
Ireland	-19	-1	-20	25	3777
Italy	181	71	-122	272	57680
Luxembourg	4	3	0	6	436
Netherlands	57	35	15	80	15864
Norway	10	11	5	37	4478
Portugal	50	53	-118	227	10198
Spain	364	237	91	374	39733
Sweden	25	19	-4	45	8861
Switzerland	24	20	-3	43	7164
UK	168	37	-43	373	60350

3.5 Assumptions for national stochastic population forecasts (WP5)

3.5.1 General

National population forecasts by age and sex are based on a base population by age and sex and assumptions about future changes in fertility, mortality, and international migration. In this project the base population of the countries considered refers to the situation at 1 January 2003. The stochastic forecasts of the population by sex and single years of age (0,1,…,99, 100+) cover the period 2003-2050, which implies that annual assumptions on fertility, mortality and international migration have been prepared for the period 2003-2049.

The stochastic population forecasts have been compiled by using PEP (Program for Error Propagation), a software package developed by Alho (1998). This programme calculates the probability distribution of the future population size and structure by means of Monte Carlo simulations (a total of 3,000 simulation rounds have been used). The respective model equations combine the widely used cohort-component projection model and the so-called scaled model for error (Alho and Spencer, 1997). For a detailed description of PEP, one may visit http://joyx.joensuu.fi/~ek/pep.

For each country, the main characteristics of the model (as used in these forecasts) are qualitatively as follows:

- Uncertainty in age-specific mortality and age-specific fertility is treated in the relative (logarithmic) scale, for net-migration uncertainty is treated in the additive scale.
- Uncertainty is assumed to increase with forecast year. Any increasing pattern of error variances can be represented by a suitable choice of the scales of the model.
- Error increments of each age and sex group have a constant non-negative autocorrelation that can be chosen freely.
- Cross-correlation of errors across age are represented by an AR(1) process, whose correlation at lag = 1 is non-negative but otherwise it can be chosen freely.
- Correlation between error increments of males and females, in each age, can be chosen freely.
- Correlation between errors in male and female net migration can be chosen freely.
- Uncertainty in fertility, mortality, and migration were assumed to be independent of each other.
- A normal distribution was used to represent error increments for each age- and sex-group.

The necessary input has been prepared in two steps. First an internationally consistent set of qualitative and quantitative key-assumptions on the future course of fertility, mortality and international migration was discussed and established. This set comprises point forecasts, 80% forecast intervals and future values of various types of correlations. These principal assumptions were mainly derived from the findings of work packages 2-4, although sometimes also the result of sex and age specific extrapolation (e.g. for mortality). Secondly, all necessary, more detailed assumptions have been prepared, such as future values of net migration by sex and age.

This section briefly explains for each demographic component the basic set of point forecasts, and 80% forecast intervals, and lists the key assumptions concerning correlations across countries, time, sex and age. Summarised justifications of the latter assumptions can be found in sections 3.7.3 and 3.8.2, as they were the outcomes of newly developed methods.

3.5.2 Fertility

Past trends, contemporary levels and recent explanatory research (including the list of key factors as specified by one of the experts) indicate that there is a clear geographic division in fertility levels in Europe. The Northern and Western EEA countries are experiencing levels of the completed fertility rate (CFR) and total fertility rate (TFR) of about 1.8 children per woman, whereas the Mediterranean and German-speaking countries are moving towards historically low levels of around 1.4 children per woman.

The Northern and Western cluster of countries comprises Belgium, Denmark, Finland, France, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Sweden, and the United Kingdom. The Mediterranean and German-speaking cluster consists of Austria, Germany, Greece, Italy, Spain and Switzerland. Portugal is the only EEA country that cannot be easily classified: its fertility trends and levels are somewhere in the middle.

For the period 2003-2049 it is assumed that these clusters will remain. The Northern and Western EEA countries will continue to achieve a TFR level of 1.8 children per woman. The TFR in Portugal will rise to a level of 1.6 children per woman, whereas the TFR of other EEA countries will persist or slightly increase to a level of 1.4 children per woman (see table 5).

These key-assumptions are basically motivated by the following reasons. The Northern and Western countries were the first to postpone childbearing, and the first to recuperate. In the Southern European and German-speaking countries there was also postponement but much less recuperation. In the latter countries one-child families became quite popular, and it is expected that this will remain due to relatively weak childcare and housing facilities.

Generally speaking, these assumptions are in line with the latest 1999-based fertility baseline scenario of Eurostat. The main difference is that Eurostat expected levels of 1.5 and 1.6 children per woman for the lowest-fertility countries, and 1.7 to 1.8 children per woman for the other countries (table 5). However, the provisional assumptions for the new, revised set of projections currently being prepared by Eurostat, show that assumptions for the lowest-fertility countries will be adjusted downwards. For example, the assumption for Italy will be adjusted from 1.5 to 1.4 children per woman in 2050. This is very close to the latest national forecast made by the national statistical agency of this country: 1.42 children per woman.

Table 5. Assumptions on the point forecast of TFR of 18 European countries

				Eurostat Baseline		
	Observation	Point forecast		1999 revision 1)		EUROPOP 2003 2)
	2002	2010	2049	2010	2050	2050
Austria	1.40	1.40	1.40	1.41	1.50	1.45
Belgium	1.62	1.65	1.80	1.68	1.80	1.70
Denmark	1.72	1.74	1.80	1.76	1.80	1.85
Finland	1.72	1.73	1.80	1.69	1.70	1.77
France	1.89	1.87	1.80	1.79	1.80	1.85
Germany	1.31	1.32	1.40	1.47	1.50	1.45
Greece	1.25	1.27	1.40	1.45	1.60	1.50
Iceland	1.93	1.91	1.80	:	:	:
Ireland	1.97	1.93	1.80	1.83	1.80	1.80
Italy	1.26	1.29	1.40	1.36	1.50	1.40
Luxembourg	1.63	1.66	1.80	1.75	1.80	1.80
Netherlands	1.73	1.74	1.80	1.79	1.80	1.75
Norway	1.75	1.76	1.80	:	:	:
Portugal	1.47	1.49	1.60	1.64	1.70	1.60
Spain	1.25	1.28	1.40	1.34	1.50	1.40
Sweden	1.65	1.68	1.80	1.61	1.80	1.85
Switzerland	1.40	1.39	1.40	:	:	
United Kingdom	1.64	1.67	1.80	1.75	1.80	1.75

1) Source: Eurostat (NewCronos)

2) Provisional assumptions presented at the Working Party on Population Projections (Luxembourg, July 2004)

With respect of the timing of childbearing it is assumed that the postponement, which is observed in all countries, will continue. The mean age at childbearing is expected to increase to 31 years in the long run. This value is slightly higher than recently observed in countries like Spain, Italy and the Netherlands. The speed at which countries reach this level is estimated from the increase in the mean age at childbearing as observed in the recent past. The increase is projected up to 31 years by using a log-linear model. The above mentioned countries will reach this level in just a few years, whereas Austria and the United Kingdom close the row only after 2020.

The long-term prediction intervals for fertility were mainly obtained by using the results of the time-series models as developed in work package 3. This was also supported by one of the consulted experts (the other expert did not express a preference). However, a few adjustments are made. There are several reasons for making these adjustments. First, the point forecast of the time-series models do not equal the final assumptions on the point forecast as specified in the previous section.

Second, the results of the time-series models suggest that the widths of the 80% intervals differ strongly for some countries. For example, the width of the 80% interval 50 years ahead ranges from 0.63 children per woman in Greece to 1.51 children per woman in Austria. These differences are hard to justify, especially for similar or neighbouring countries. Moreover, the experts who were consulted in the experts' elicitation process did not indicate that future developments in fertility in some countries are much more uncertain than in other countries. For this reason the country-specific intervals on the long run reflect the average of the historically measured level of volatility measured from countries with long data series. The time-series refer to log(TFR) rather than TFR. For each country the standard deviation of log(TFR) is about 0.35 children per woman in 2049. This does not imply that the intervals are equal for each country since the point forecasts differ between countries. For those countries with a point forecast of 1.8 children per woman in 2049 the 80% interval ranges from about 1.1 to 2.8 children per woman (table 6). For the cluster of Mediterranean and German-speaking countries the interval ranges from 0.9 to 2.2 children per woman, an interval that is 0.4 children per woman narrower than that of the former countries. It seems reasonable to assume a smaller interval for the latter countries since the point forecast is lower. For the cluster of Northern and Western EEA countries the lower limit of the 80% interval is about 0.7 children per woman less than the point forecast. Applying this difference to the Mediterranean/German-speaking countries would yield a lower limit of about 0.7 children per woman. According to the consulted experts as well as the results of the time-series models this value is unrealistically low. The lower limits are on average of the same order of magnitude as specified by the time-series models. The upper limits are somewhat higher.

With respect to short and medium forecast horizons the width of the intervals as specified by the time-series models as well as by the analysis of past forecast errors are adjusted downwards. This is motivated by the elicitation of experts' opinions. The first expert made clear that cohort analyses may predict the near future relatively precisely since fertility behaviour of women born in 1970 and 1980 respectively is to some extent already observed. Although this expert did not interpret his 'expert margins' as forecast intervals, it does however show that demographic knowledge can be incorporated to diminish the width of forecast intervals in the short run. The second expert also mentioned to have some troubles with the, in his opinion, rather wide intervals in the short run. For example, according to the analysis of past forecast errors the 80% interval in 2010 for Germany should be 1.7 children per woman wide.

Moreover, many European countries experience low volatility in most recent years. For these reasons a longer path or transition period from the recent low volatility to the higher past volatility was used.

The autocorrelation of error increments of each age specific fertility rate was assumed to be absent, whilst the cross-correlation of errors across age was set at a value of 0.95.

Finally, for the stochastic projections concerning EEA+ (or the so-called set of internationally consistent population projections) the cross-country correlations were implemented by the "method of seeds", that was specially developed for this purpose. The respective set of quantitative assumptions can be found in section 3.8.2.

Table 6. Summary of assumptions for TFR in 18 European countries: point forecast and 80% interval

	2010			2049		
	Point forecast	80% interval		Point forecast	80% interval	
		Lower limit	Upper limit		Lower limit	Upper limit
Austria	1.40	1.26	1.55	1.40	0.89	2.20
Belgium	1.65	1.47	1.85	1.80	1.14	2.84
Denmark	1.74	1.58	1.91	1.80	1.15	2.82
Finland	1.73	1.57	1.91	1.80	1.15	2.82
France	1.87	1.68	2.08	1.80	1.15	2.83
Germany	1.32	1.17	1.49	1.40	0.88	2.21
Greece	1.27	1.17	1.39	1.40	0.90	2.18
Iceland	1.91	1.69	2.15	1.80	1.14	2.85
Ireland	1.93	1.74	2.15	1.80	1.15	2.83
Italy	1.29	1.16	1.44	1.40	0.89	2.20
Luxembourg	1.66	1.48	1.86	1.80	1.14	2.84
Netherlands	1.74	1.58	1.92	1.80	1.15	2.82
Norway	1.76	1.55	2.01	1.80	1.16	2.80
Portugal	1.49	1.34	1.65	1.60	1.02	2.51
Spain	1.28	1.14	1.43	1.40	0.89	2.21
Sweden	1.68	1.44	1.95	1.80	1.12	2.89
Switzerland	1.39	1.28	1.52	1.40	0.90	2.18
United Kingdom	1.67	1.53	1.82	1.80	1.16	2.80

3.5.3 Mortality

With some interruptions life expectancy has been increasing in every country of the EEA during the last century. With regard to future developments the question is not if life expectancy will continue to increase but rather to what extent life expectancy will increase. Expert views range from very modest improvements in mortality with life expectancies slightly above present values to very steep improvements resulting in life expectancies well over hundred years.

A complicating factor when discussing possible improvements in mortality rates on the one hand and life expectancy at birth on the other is that the relationship between mortality rates and life expectancy is not linear. For example, a linear increase in life expectancy implies a more than linear decrease in mortality rates.

The assumptions for mortality were mainly based on an extrapolation of age-specific mortality rates. One of the advantages over extrapolating life expectancy is that in the latter case age-patterns have to be derived separately which is not very straightforward. In contrast to fertility there is no easy to interpret timing indicator for mortality, like mean age at childbearing is for fertility. Extrapolation of age-specific mortality rates directly takes into account different developments for different age groups.

In order to compile a consistent set of mortality forecasts of the 18 countries it is assumed that eventually for each country the rate of improvement of mortality rates will converge towards a European average rate of decline. Based on these considerations the forecasts of life expectancy at birth are based on past rates of decline of age-specific mortality rates in such a way that the rate of decline starts from its currently observed rate of decline. The initial rate of decline changes linearly over time towards an eventual rate of decline, which is to occur by the year 2030. The eventual rate of decline is empirically estimated from data from Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom during the latest 30-year period observed.

In some countries the extrapolation procedure would imply diverging developments of male and female life expectancies which is in contrast with observations in the last two or three decades. It seems plausible to assume that the gender gap in life expectancy will continue to decline as differences between men and women in life style habits like smoking are becoming smaller. For this reason a proportional adjustment was made such that the gender gap equals 4 years in the target year. Only in the case of Ireland the gender gap is assumed to equal 5 years due to strongly diverging trends in the recent past. The assumptions are summarised in table 7.

Table 7. Assumptions on life expectancy at birth in 18 European countries

				Eurostat Baseline		
	Observation	Point forecast		1999 revision[1]		EUROPOP 2003[2]
	2002	2010	2049	2010	2050	2050
Males						
Austria	75.8	78.1	84.4	76.1	81.0	83.9
Belgium	75.1	77.0	84.2	77.1	80.0	81.1
Denmark	74.8	77.0	83.2	76.0	79.0	80.9
Finland	74.9	77.0	84.7	75.7	80.0	81.9
France	75.8	78.0	85.5	76.8	80.0	83.2
Germany	75.4	78.0	84.9	76.6	80.0	83.5
Greece	75.4	77.5	82.8	77.7	81.0	80.0
Iceland	78.5	80.1	85.9	:	:	:
Ireland	75.2	76.8	84.7	75.8	79.0	81.1
Italy	76.8	79.4	85.7	77.4	81.0	84.9
Luxembourg	74.9	77.0	85.2	77.1	80.0	81.5
Netherlands	76.0	77.3	82.5	77.0	80.0	80.2
Norway	76.4	78.0	83.7	:	:	:
Portugal	73.8	76.2	84.2	73.8	78.0	81.8
Spain	75.8	78.4	85.9	75.9	79.0	81.1
Sweden	77.7	79.2	84.7	78.2	82.0	83.3
Switzerland	77.8	79.5	85.3	:	:	:
United Kingdom	75.9	77.4	83.4	77.0	80.0	84.0
Females						
Austria	81.7	83.3	88.7	82.1	86.0	87.7
Belgium	81.1	82.6	88.3	82.8	85.0	86.3
Denmark	79.5	81.0	87.3	80.0	83.0	83.7
Finland	81.5	83.2	88.7	82.5	85.0	86.5
France	83.0	84.3	89.7	84.2	87.0	89.4
Germany	81.2	83.2	89.1	82.3	85.0	87.8
Greece	80.7	82.1	86.9	82.4	85.0	84.9
Iceland	82.3	83.8	89.9	:	:	:
Ireland	80.3	83.0	89.9	81.0	84.0	85.4
Italy	82.9	84.6	89.8	83.4	86.0	90.1
Luxembourg	81.5	83.1	89.4	82.5	85.0	86.6
Netherlands	80.7	81.3	86.4	82.0	85.0	83.6
Norway	81.5	82.6	87.9	:	:	:
Portugal	80.5	82.3	88.4	80.7	84.0	87.7
Spain	83.5	84.6	90.1	83.3	85.0	87.7
Sweden	82.1	83.2	88.7	82.8	86.0	86.5
Switzerland	83.0	84.3	89.4	:	:	:
United Kingdom	80.5	81.7	87.5	81.7	85.0	88.1

1) *Source: Eurostat (NewCronos)*

2) *Provisional assumptions presented at the Working Party on Population Projections (Luxembourg, July 2004)*

The basic assumption of ongoing international convergence implies that it is expected that in countries with an exceptionally fast rate of decline in the past, the expected rate of decline will slow down to some extent. On the other hand, in countries with a modest rate of improvement in the past is expected to catch up to the European average rate of improvement. There are several reasons to justify the extrapolation procedure described above. First of all, it takes into account the country-specific developments. It has been noted that developments differ strongly between the European countries. For most countries there are no reasons that these developments will reverse in the next few coming years. For the long run however, countries adjust to the global European trend. This 'global' European trend incorporates all structural improvements that have been achieved in mortality. These assumptions imply that especially for males the differences between countries are becoming smaller. In 2002 the difference between the country with the lowest male life expectancy (Portugal) and the highest (Iceland) is about 4.7 years. This difference is assumed to decrease to 3.3 years (lowest for the Netherlands and highest for Spain). For females differences are only slightly decreasing.

Direct statistical analyses of life expectancy imply a faster improvement than analyses of age-specific mortality rates. Furthermore, the consulted mortality expert suggested that in the future even faster improvements in life expectancy are possible. In addition, the analysis of empirical errors showed that official mortality forecasts made in the past generally underestimated future rates of decline in mortality rates.

The annual increase in life expectancy at birth changes over time. Initially the gains in male life expectancy at birth are about 0.25 years per year, against 0.17 years for females. For males the gains gradually decline to about 0.15 years per years, almost equal to the gains for female life expectancy. These gains are smaller than estimated by the consulted mortality expert. The arguments to support his view are already summarised in section 3.4.3. Several other experts expressed similar, optimistic opinions. However, there are also many experts who are less optimistic regarding future gains in mortality. They argue that for a number of countries developments have been less favourable than the 'best practice' for many years and that there are little or no indications that they will catch up shortly. Another argument that is used is that it can be discussed whether medical breakthroughs can lead to an unexpectedly strong increase of life expectancy (see e.g. Alders and De Beer, 2002). Even in case of a significant improvement of medical technology, it will be questionable to what extent this future improvement will lengthen the life span of present generations. It should be kept in mind that the mortality forecasts are made for the period up to 2050, and thus primarily concern persons already born. Next, life table analyses show that reducing mortality rates for specific causes of death in general have a limited effect on life expectancy at birth. To illustrate, Mackenbach et al. (1999) have estimated that the gain in life expectancy after elimination of all neoplasms is less than four years.

That views on future mortality may shift over time is clearly illustrated by the Eurostat projections (table 7). The 2003-based forecasts on life expectancy at birth in the year 2050 are, with some exceptions, between one to four years higher than those used in the previous round. In addition, these new, revised projections have abandoned the notion of ongoing international convergence.

In the specification of forecast intervals for life expectancy at birth the model-based estimates played the leading role. As was already concluded the intervals based on historic mortality forecasts are of little use. These empirical intervals are excessively wide, because many of the historic forecasts simply assumed constant mortality.

Some adjustments were made to the model-based estimates of forecast intervals. There were several reasons for these adjustments. First of all, as was also indicated in the case of fertility, the point forecasts of the time-series models do not equal the final assumptions on the point forecasts as specified in the previous section. Second, the time-series results suggest that the widths of the 80% intervals differ strongly between countries. To illustrate, according to the time-series models the intervals for males in 2049 are smallest for Sweden (3.8 years) and broadest for Iceland (12.9 years) and Portugal (8.6 years). On average the intervals are about 6 years wide (leaving out Iceland results in an average of 5.5 years). For females the average width is almost equal. Although differences between countries in expected uncertainty may exist, these differences are hard to justify. Moreover, the expert who was consulted did not indicate that future developments in some countries are more uncertain than in other countries. The third reason for adjustment is that in the compilation of the stochastic population forecasts the variances of the future age-specific mortality rates are represented in terms of a model incorporating scales for error increments. These scales for error increments depend on age, in contrast with the scales for error increments for fertility. Therefore, the assumptions on the 80% prediction intervals life expectancy are a result of a model and are not prefixed.

This section discusses intervals for life expectancy since they are easier to interpret than the scales. For more details see Alho (2004).

With respect to the 80% intervals in 2050 it is assumed that these intervals are about 9 to 10 years wide on average, which is about 50 per cent wider than the average based on the time-series models (table 8). One of the motivations for this adjustment in a broader direction is the reaction of the elicited expert and other experts in literature who foresee much higher gains in life expectancy. The assumption on the 80% intervals implies that on average the upper limits of the 80% intervals for females are more or less equal to the point forecast of the mortality expert. For males the upper limits are about 1.5 years higher than the expert's point forecast. So, the point forecasts of the expert are not regarded as the most likely future by the forecasting team but they are not impossible either. It is assumed that the probability is about 10 per cent that on average female life expectancy at birth in 2050 is as high or even higher than the expert's view. These differences in the widths of the intervals reflect the past volatility.

The 80% intervals are asymmetric around the point forecast, especially for females, with the upper tails being longer than the lower tails. This can be justified by the expert's view.

An important topic in mortality is the assumed level of cross-sex correlations. As was indicated by the mortality expert correlation across sex is high. The statistical analyses done by Keilman and Pham (2004) have confirmed this. It is assumed that the correlation between male and female life expectancy is 0.85.

The autocorrelation of error increments of each age and sex group is expected to be low: a value of 0.05 was used. Cross-correlation of errors across age, on the contrary, are assumed to be high: a level of 0.95 was applied.

Finally, for the stochastic projections concerning EEA+ (or the so-called set of internationally consistent population projections) the cross-country correlations were implemented by the "method of seeds", that was specially developed for this purpose. The respective set of quantitative assumptions can be found in section 3.8.2.

Table 8. Summary of assumptions for life expectancy at birth in 18 European countries: point forecast and 80% interval

	2010			2049		
	Point forecast	80% interval		Point forecast	80% interval	
		Lower limit	Upper limit		Lower limit	Upper limit
Males						
Austria	78.1	76.9	79.2	84.4	80.3	88.8
Belgium	77.0	75.9	78.2	84.2	79.4	89.2
Denmark	77.0	75.8	78.2	83.2	78.3	88.3
Finland	77.0	75.9	78.2	84.7	80.0	89.4
France	78.0	76.8	79.2	85.5	80.6	90.6
Germany	78.0	76.9	79.2	84.9	79.8	90.5
Greece	77.5	76.3	78.6	82.8	78.2	87.2
Iceland	80.1	79.0	81.2	85.9	81.8	90.2
Ireland	76.8	75.7	78.0	84.7	80.1	89.6
Italy	79.4	78.3	80.5	85.7	81.4	90.4
Luxembourg	77.0	75.8	78.2	85.2	79.9	91.8
Netherlands	77.3	76.2	78.4	82.5	78.1	87.1
Norway	78.0	76.9	79.1	83.7	79.3	88.2
Portugal	76.2	74.9	77.3	84.2	79.1	89.6
Spain	78.4	77.2	79.5	85.9	81.1	91.4
Sweden	79.2	78.2	80.3	84.7	80.3	89.4
Switzerland	79.5	78.4	80.6	85.3	81.1	89.6
United Kingdom	77.4	76.3	78.5	83.4	78.7	88.3
Females						
Austria	83.3	82.3	84.3	88.7	85.1	92.5
Belgium	82.6	81.5	83.6	88.3	84.1	92.9
Denmark	81.0	79.9	82.2	87.3	82.5	92.4
Finland	83.2	82.2	84.2	88.7	84.9	93.4
France	84.3	83.3	85.3	89.7	85.5	94.1
Germany	83.2	82.2	84.2	89.1	84.7	94.0
Greece	82.1	81.2	83.1	86.9	83.1	91.0
Iceland	83.8	82.6	84.8	89.9	85.1	95.7
Ireland	83.0	81.9	84.0	89.9	85.5	95.1
Italy	84.6	83.6	85.6	89.8	85.8	94.3
Luxembourg	83.1	81.9	84.2	89.4	84.7	95.3
Netherlands	81.3	80.3	82.4	86.4	82.4	91.0
Norway	82.6	81.6	83.6	87.9	83.8	92.2
Portugal	82.3	81.3	83.3	88.4	84.1	93.3
Spain	84.6	83.7	85.6	90.1	85.9	94.9
Sweden	83.2	82.1	84.2	88.7	84.2	94.3
Switzerland	84.3	83.4	85.3	89.4	85.7	93.8
United Kingdom	81.7	80.6	82.6	87.5	83.3	92.2

3.5.4 International migration

Time series on net immigration are short and in some cases of dubious quality. This hampers the applicability of time-series models and enforces forecasters to incorporate expert knowledge, at least more than for fertility and mortality. The procedure to derive assumptions for the point forecast was as follows. The results from the linear trend model applied to the whole of the 18 countries (see section 3.4.3) was taken as a starting point. This initial assumption was modified (i.e. adjusted downwards) by using qualitative arguments. Finally, country-specific differences have been incorporated.

For many countries the time-series analysis indicated a significant upward linear trend in net migration. The linear trend model applied to the total of the 18 countries results in an increase of scaled net migration from almost 3 per thousand in 2000 to more than 5 per thousand in 2050. This level is even higher than the peak that was reached in 1992 of 3.6 per thousand. However, it does not seem plausible to assume such a strong continuation of past trends. At least a part of the trend is due to the increase in the number of asylum seekers in the 1980s and 1990s. In most recent years the number of asylum seekers is much lower than around 1992, which is at least partly due to restrictive migration policies in some countries. Although it is not unlikely that the number of asylum seekers as observed in 1992 will be seen again in the future, it does not seem very plausible that structurally higher levels will be obtained. This can be motivated by developments to receive refugees closer to the countries of origin, discussions about EU-regulated asylum policies (quotas), and by the rather abrupt changes in attitude, and accompanying unprecedented, restrictive policies, to asylum migration in countries like Denmark and the Netherlands.

With respect to labour migration the ageing problem is often mentioned as a pull factor for migration. Some developments may however temper this phenomenon, like increasing labour force participation of women and minority populations, and the export of labour. Moreover, in some sending countries, like in the new EU member states, ageing will even be more problematic than in the EEA.

Next to asylum and labour migration family related migration is a major source of migration. Family reunification and family formation are important motives for immigrants to enter the EEA. As migrant populations are growing in the countries of the EEA, family related migration is expected to remain important.

Based on these observations it is assumed that scaled net migration for the total EEA will increase, but not as much as estimated by the linear trend model. Instead a target level of 3.5 per thousand is assumed in 2049. This level takes into account some of the trend that is observed in historic data and is almost equal to the historic maximum that was reached in 1992.

The target level is used as a starting point for country-specific assumptions. Three, not very strict, clusters of countries are distinguished:

countries below average: Belgium, Denmark, Finland, France and Iceland

countries close to average: Austria, Germany, Ireland, Netherlands, Norway, Sweden, Switzerland and United Kingdom

countries above average: Greece, Italy, Luxembourg, Portugal and Spain.

The main assumptions are summarised in table 9. The country-specific assumptions are based on the clustering and the observations supplied by the migration expert.

With respect to the countries with target levels close to the average the following explanations are given. Net migration in Austria is assumed to increase to the average level. As noted by the migration expert Austria was the gateway to Europe from the East in 1990s. As a result Austria has a large foreign population which can attract new migrants. The high flows of Aussiedler and refugees, which made Germany the most important receiving European country around 1990, are probably over. Moreover, labour migration from Central and Eastern Europe is more balanced nowadays. The relatively high unemployment has a negative impact on net migration. For Ireland the future depends on whether the Celtic Tiger boom continues or will collapse. It is assumed that net migration will level off to the average level. In the Netherlands the economic situation as well as the restrictive policies in most recent years have led to decreasing migration numbers. In 2003 net migration was even negative. However, the Netherlands will remain attractive to immigrants due to large migrant populations in the Netherlands. Still a slightly lower level than the average is assumed (3 per thousand) which is partly due to limited absorbing capacity given the high population density. Norway and Sweden are still relatively generous in admission of asylum seekers, which will probably continue. Since the migration expert foresees more future restrictions in Sweden a somewhat lower target level is assumed for this country. Switzerland shows less enthusiasm for foreigners at present and will try to keep net migration below the high levels that they experienced in the past. The United Kingdom has become a country of immigration and will probably stay that way. Asylum seekers are expected to continue to come, and the labour market is easy to come into. According to the expert there will not be an increasing level of migration, but rather a continuing high level. Currently the level is about 3 per thousand, which is assumed to rise level of about 3.5 per thousand.

The assumptions for countries with target levels below average are motivated as follows. In Belgium net migration has been structurally lower than in neighbouring countries Germany and the Netherlands. However, an increase is foreseen, partly because of the important flow of labour elite migration focussed on its EU role. Although an increase will be assumed the target level (2 per thousand) will not be as high as for Germany and the Netherlands. Also for Denmark a level of 2 per thousand is assumed. Denmark has admitted a lot of asylum seekers around 1995, but there is a very clear backslash in recent years. Moreover, the observed levels are generally lower than in countries that are assumed to move to the European average. This also applies for Finland that has experienced relatively low levels of net migration in the past. Since the expert does not foresee large flows from Russia or other neighbouring countries (except from Estonia) a level of 1.5 per thousand is assumed, which is still well above recent levels. France is one of the countries for which the data quality was questioned by the migration expert. This has probably to do with the way France treats the francophone migrants in the statistics. Still, a rather low level of 1.5 per thousand is assumed. The continuing high unemployment discourages immigration. Moreover, since ageing is less than in countries like Germany, the demand for foreign labour is assumed to be less than in Germany. Net migration in Iceland is very volatile. One of the key issues is that net migration is highly influenced by the US military base in this country.

For the Southern European countries and Luxembourg future net migration is assumed to be higher than average. For all these countries but Luxembourg there are serious data problems, which makes it hard to make proper forecasts. Italy is one of the gateways to Europe for migrants from Africa and the Balkans (in particular Albania). At the moment it is unclear whether these migrants stay in Italy or move northwards. Italy seems rather relaxed about the inflows of migrants. Portugal on the other hand is the gateway for migrants from countries like Brazil, Angola and Mozambique. Spain has been recently confronted with massive immigration flows from Latin America. It is assumed that the Southern European countries will remain the main gateway to Europe, irrespective whether migrants move on to the north. A target level of 4.5 per thousand is assumed.

Luxembourg, currently by far the most affluent EU country, is a special case with very high net migration levels and a large non-native population. It is assumed that the target level is higher than in the Southern countries: 6 per thousand.

Table 9. Assumptions on the point forecast of net migration per 1,000 population in 2000 in 18 European countries

	Observation	Point forecast	Eurostat Baseline, 1999 revision[1]
	2000	2049	2050
Austria	2.14	3.5	2.5
Belgium	1.19	2.0	1.5
Denmark	1.89	2.0	1.9
Finland	0.47	1.5	1.0
France	0.94	1.5	0.9
Germany	2.03	3.5	2.4
Greece	2.26	4.5	2.4
Iceland	6.71	1.5	:
Ireland	-5.06	3.5	1.3
Italy	3.14	4.5	1.4
Luxembourg	8.33	6.0	4.6
Netherlands	3.60	3.0	2.2
Norway	2.17	3.5	:
Portugal	4.90	4.5	2.5
Spain	9.16	4.5	1.5
Sweden	2.77	3.0	2.3
Switzerland	3.31	3.5	:
United Kingdom	2.80	3.5	1.2

1) Source: Eurostat (NewCronos)

To specify forecast intervals for the net migration (scaled per 1,000 population in 2000) the intervals provided by the AR(1)-model are used as a starting point. It was concluded in work package 3 (see section 3.4.4) that, with respect to uncertainty, this model was to be preferred over the linear trend model and random walk model. Furthermore, the consulted migration expert expressed his preference of the results of this model. However, adjustments to the intervals provided by the model will be made. As already mentioned data series on international are rather short and in some cases of poor quality. For this reason, more than in the case of fertility and mortality, expert judgement will be incorporated. Another reason for making adjustments is that the point forecast is not equal to the point forecast of the AR(1)-model but is more or less a modification of the linear trend model (see previous section).

Assumptions will be specified for the standard deviation of net migration per thousand population in 2000. Table 10 shows the assumptions made for the standard deviation in the target year (2049) as well as the limits of the 80% interval, which are assumed to be symmetric around the point forecast.

The key motivation for determining whether to deviate from the AR(1)-results is that intervals should be smaller for countries with good registrations. To make consistent assumptions clusters of countries are made.

The cluster with the lowest standard deviations consists mainly of countries in the North(-West). For the Nordic countries, Denmark, Finland, Norway and Sweden, as well as for Belgium, the Netherlands and Switzerland a standard deviation of 2 per thousand is assumed. This implies a width of the 80% interval of 5.1 per thousand. This assumption is more or less consistent with the results of the AR(1)-model and/or the empirical results. For countries like Finland and Sweden this assumption is almost equal to the interval of the AR(1)-model. For Belgium, Denmark and the Netherlands the assumed interval is somewhat broader than that of the AR(1)-model but narrower, if not almost equal, than the empirical interval. For Norway the interval is smaller than the AR(1)-interval but broader than the empirical interval. Since all these countries have comparable registrations one single assumption was made for these countries.

For the second cluster of countries – Austria, France, Germany, Iceland, Ireland, Italy, Spain and United Kingdom – a standard deviation between 3.5 and 4.5 per thousand is assumed (table 10). For Austria (3.5 per thousand), Germany (3.5) and Ireland (4.5) this assumption is very much in line with the AR(1)-model. For Italy and Spain a somewhat broader interval than the AR(1)-interval is assumed, for reasons of data quality. Moreover, it takes into account the opinion of the migration expert that the future for Spain is more uncertain than compared to the past. For Italy it is rather uncertain whether Italy's relaxedness towards immigrants will remain. For the United Kingdom the interval is broader since it is rather uncertain whether the increase in the last decade will come to an end pretty soon. The assumption is more in line with the naïve interval, as preferred by the expert. Also for France a broader interval is assumed. In France migration numbers are estimated by using population growth and natural increase during the intercensus period. The migration expert was surprised of the low observed levels of migration that has probably to do with the way francophone migrants are treated in the statistics. For this reason a broader interval is assumed, which is equal to that of countries like Germany and the United Kingdom. For Iceland a broader interval than the AR(1)-interval is assumed, with the main reasons being the small population and migration numbers for Iceland as well as the uncertainty towards the future of the US military base.

The third cluster consists of Greece, Luxembourg and Portugal. For Greece and Portugal the data situation is known to be problematic. For instance, in Greece no data on emigration is collected. The figure for immigration is regarded as net migration (Eurostat, 2003). Although the data situation is also problematic in Italy and Spain a lower standard deviation is assumed for the latter countries, since compared to Greece and Portugal the past has shown less volatility (see results of AR(1)-model). Luxembourg is a specific case, due to its small population size and its relatively high net migration. As the past has shown large fluctuations Luxembourg is clustered with the countries with a relatively high uncertainty.

The cross-correlation in net migration errors between males and females is expected to be fairly high: a level of 0.9 was applied.

The autocorrelation of error increments is expected to vary by country: France got the lowest value (0.13), and Norway the highest (0.56). The cross-correlation of errors across age are assumed to be perfect.

Finally, for the stochastic projections concerning EEA+ (or the so-called set of internationally consistent population projections) cross-country correlations were implemented by a separate module applied outside the single state program PEP. The respective set of quantitative assumptions and its preparation can be found in sections 3.8.2 and 3.7.3.

Table 10. Summary of assumptions for net migration (per 1,000 population in 2000) in 18 European countries: point forecast and 80% interval

	2049			
	Point forecast	80% interval		Standard deviation
		Lower limit	Upper limit	
Austria	3.5	-1.0	8.0	3.5
Belgium	2.0	-0.6	4.6	2.0
Denmark	2.0	-0.6	4.6	2.0
Finland	1.5	-1.1	4.1	2.0
France	1.5	-3.0	6.0	3.5
Germany	3.5	-1.0	8.0	3.5
Greece	4.5	-3.2	12.2	6.0
Iceland	1.5	-3.6	6.6	4.0
Ireland	3.5	-2.3	9.3	4.5
Italy	4.5	-1.3	10.3	4.5
Luxembourg	6.0	-1.7	13.7	6.0
Netherlands	3.0	0.4	5.6	2.0
Norway	3.5	0.9	6.1	2.0
Portugal	4.5	-3.2	12.2	6.0
Spain	4.5	-1.3	10.3	4.5
Sweden	3.0	0.4	5.6	2.0
Switzerland	3.5	0.9	6.1	2.0
United Kingdom	3.5	-1.0	8.0	3.5

3.6 Production and dissemination of stochastic national population forecasts (WP6)

Two sets of stochastic population forecasts have been produced. First, stochastic population forecasts have been made for the period 2003-2050 for each of the 18 EEA+ countries considered individually, by using the key-assumptions specified in work package 5 and the software PEP (Program for Error Propagation, developed by Alho 1998). Population at 1 January was disaggregated by sex and single years of age (0,1,…,99, 100+).

In the second run, stochastic population forecasts by sex and age were compiled for the whole EEA+ region. In this set, the key-assumptions on the correlation of errors across countries and a modified, extended version of PEP have been applied, that were prepared and developed respectively in the work packages 7 and 8.

In order to produce these projections, first the most likely values or "best guesses"of the following set of detailed model parameters had to be specified for each country and each forecast year:

- age specific fertility rates;
- sex and age specific mortality rates;
- sex and age specific net migration numbers.

Recently observed, and smoothed patterns were used as a starting point for these forecasts. For mortality, age specific rates of decline were applied to generate future mortality rates. For fertility the assumed point forecasts on TFR's and the mean age at childbearing were used to generate future fertility rates. Future net migration numbers by sex and age were derived from assumed net migration levels and empirically calculated average patterns.

All point forecasts concerning fertility rates, mortality rates and net migration numbers have been put on the web (http://www.stat.fi/tup/euupe/).

To represent the uncertainty of forecasting, cohort-component book keeping was applied 3000 times, with stochastically varying values for the above mentioned set of model parameters. The respective method is based on the so-called scaled model for error (Alho and Spencer 1997). In general, the median was used as the principal location parameter of the predictive distribution, because this indicator is less sensitive for statistical outliers than for example the mean. The spread around the median was used to provide a realistic indication of forecast uncertainty.

For the purpose of combining all country-specific forecasts to form a forecast for the EEA+ as a whole, the following additional actions were executed:

- cross-correlation of both the general fertility rate and life expectancies across countries was induced via post-processing of the simulation counts using the “method of seeds”;
- the total numbers of net migrants were generated in such a way that they are correlated across the countries according to the assumed cross-country correlation matrix (see section 3.8.2).

A selection of the outcomes of the two sets of stochastic population forecasts has been put on the web (http://www.stat.fi/tup/euupe/). This database contains for the years 2010, 2020, 2030, 2040 and 2050 and for all 18 countries considered (including the EEA+), the results of all 3,000 simulation rounds concerning the population by sex and age groups (0,1-4, 5-9,…, 90-94, 95+). For the year 2050 also the simulated counts of the population by sex and single years of age were published.

Initially, it was planned to store all simulated counts of the population by sex and single years of age. However, this would lead to an unmanageable large number (3,000 by 202 matrices) of data files for many potential users. Therefore, it was decided to enter the bulk of the population projections’ data by 5-years age groups.

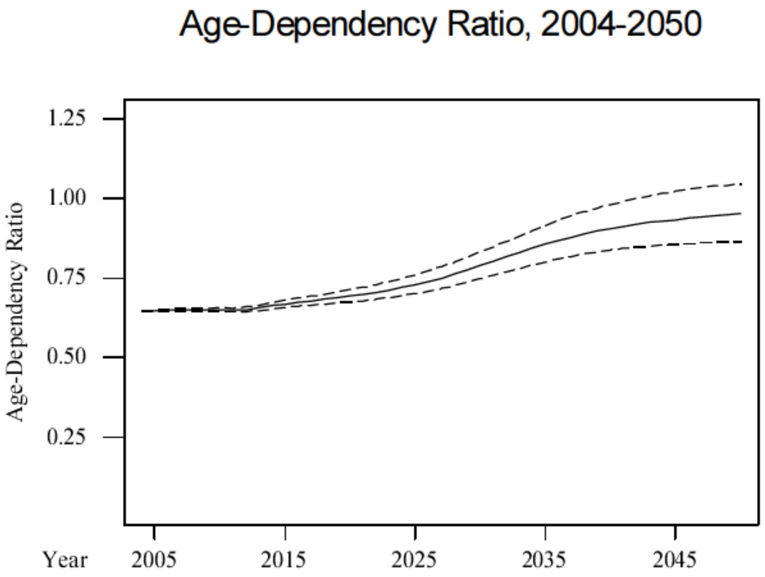
Apart from this, separate web pages were developed and implemented concerning the methodology used, and the assumptions applied. Furthermore, a guide for interpreting the results of the stochastic population forecasts was included.

Finally, a report was drafted summarising the principal outcomes of the two sets of stochastic population forecasts (deliverable 12 of the project). This report contains tables comprising the medians, and first and ninth deciles of the predictive distributions for all forecast years and all countries considered (including the EEA+ as a whole) with respect of the total population, the population aged 0-19, the population aged 20-64, and the population aged 65+.

Furthermore, it shows graphs on the medians, and 80% predictive prediction intervals of the age-dependency ratio (defined as the ratio of population aged 0-19 and 65+ to the population aged 20-64).

Amongst others, these results show that a number of (generally) predicted demographic trends such as a future decline of both total and working age population are far from certain. In fact, EEA+ population size shows a moderate growth to 2050, with an expected growth rate of 0.2 per cent per year. However, future population ageing and for example the (generally) expected increases in age dependency ratios are fairly sure, although the speed of these developments is also quite uncertain (see figure 17 and annex 5).

Figure 17. Age-Dependency Ratio in EEA+, in 2004-2050



3.7 Dimension reduction and imputation in migration modelling (WP7)

3.7.1 General

The analysis and projection of both internal and international migration is seriously hampered by a general lack of reliable and internationally comparable data series. In spite of various efforts to harmonise migration statistics (e.g. by means of international recommendations), national definitions and measurement systems continue to differ considerably throughout Europe.

In addition, migration is a highly dimensional demographic phenomenon. Migration flows need to be considered, not only by sex and age, but preferably also by region of origin (for arrivals/immigrants) and destination (for departures/emigrants). Hence, in a system of n regions/countries, there are $n(n-1)$ different flows to be measured, analysed and projected by sex, age and time.

Finally, even if all migration time series needed for making a consistent set of multi-national or multi-regional stochastic population forecasts would be available, the preparation of a generally agreed, fairly robust set of parameters for the compilation of stochastic population forecasts would be a major task due to the influence of all kinds of economic, political and cultural determinants on past and future migration patterns and levels.

Nevertheless, it is worth to examine the actual possibilities to increase the quality of internal and international migration databases, time series analysis and forecasting by using currently available stochastic methods. In the UPE project new attempts have been made to tackle two basic issues in multi-state stochastic projection modelling:

- can annual interregional migration patterns by sex, age, and origin and destination sufficiently be described, analysed and projected with a limited set of parameters?
- can the formulation of the uncertainty of future net migration, in particular its correlation across countries be improved by the application of imputation techniques and the use of auxiliary, symptomatic data?

3.7.2 Dimension reduction for internal migration

Over the past 25 years several demographers have applied curve fitting techniques on interregional migration flows by sex, age, origin and destination. For example, Rogers and Castro (1981) proposed a “double exponential”, parameterised curve to represent age dependency of migration intensities (see also Rogers, 1986). Capitilizing on the regularities of observed migration patterns, this procedure reduces the number of parameters to be estimated to approximately ten. A potential problem in this approach is that the parameters that provide the best fit may be unstable in the sense that different parameter combinations yield approximately a similar good fit to the data. If this is the case, the time series of past parameter values may be erratic and therefore not easy to interpret or to forecast into the future.

Van Imhoff et al. (1997) and Lin (1999) proposed an alternate approach that relies on log-linear models. The estimation theory of these models is well known (e.g., Bishop, Fienberg and Holland, 1975). The authors successfully selected and validated models that were able to accurately describe with a minimum set of parameters contemporary interregional migration patterns by sex, age, origin and destination at NUTS-2 level observed in Italy, the Netherlands and the United Kingdom.

In the UPE project first the application of log-linear models has been reviewed. Thereafter, the potential advantages of (the use of) log-bilinear models, introduced by Goodman (1991), were discussed. The latter models are closely related to the so-called Lee-Carter model for age-specific mortality (Lee and Carter, 1992), and more generally to factor analysis.

Due to the general lack of comprehensive and internationally consistent data series, the scope of this modelling exercise has been restricted to interregional migration flows by sex and age. The empirical part was limited to Finland.

After comparing different loadings of the (convential) log-linear model, it was concluded that these models might become too flexible when full interactions between sex and age are included. On the other hand they might become too restrictive if no interactions are included.

In finding a better compromise between the degree of flexibility and the number of model parameters to be estimated and projected, and capitalising on the generally observed regularities in sex and age structures of interregional migration flows, the application of a log- bilinear model was noted as a more promising one.

The utility of this approach has been further examined by discussing the basic features of two different kinds of bilinear models: one that allows for describing potential deviations from an average age- and sex-distribution and also takes account of annual changes therein, another one that additionally offers the possibility to describe the deviations from the mean in a more flexible way by the inclusion of two instead of one time-dependent model parameters under the restriction of orthogonality for the deviations. The latter model was also presented by using the terminology of factor analysis, so that the coefficients in the second linear term describing the sum of the deviations from the mean could be replaced by two orthogonal ”latent factors” that determine the deviations with two “loading factors”.

Thereafter, it was explained that more loadings could be added, though always under the restriction of orthogonality. Finally some suggestions were made on the estimation of model parameters.

The empirical part of this study considered two different data sets for Finland, one concerning male migration flows by age in a three regions setting, and one that used interregional migration flows by sex and age in a five regions setting. Both applications demonstrated that log-bilinear models can be implemented fairly easily i.e. with moderate computational burden.

In the first, simplest setting, the first three latent factors together explained more than 75% of the remaining variance, and changes over time were gradually. In the second case, the fractions of the remaining variance that is explained by the first three latent factors were considerably lower (37% for men, and 42% for women), partly as a result of a modification of the model structure by which the first term representing the overall mean interregional migration pattern over the regions is replaced by the average migration pattern over the sending regions, and consistently also the second term representing the (sum of the) deviations to the overall mean are replaced by the (sum of the) deviations to the average migration pattern over the sending regions.

The study concluded that further empirical research is needed to determine how stable the latent factors are over time.

3.7.3 On the correlation structure of international migration

In the first part of this study the methodology to prepare the input of internationally consistent, cross-country correlations on net migration (already presented as part of work package 5) has been developed. Starting point for the modelling of cross-country correlations of future international migration trends and patterns was the correlation matrix of observed net migration produced in work package 3 (see table 4 of Annex 4). The application of the correlation structure derived from the residuals of the estimates of the model that provided the best fit to past data, generally the linear model, was considered as not appropriate, due to its expected unprecedented long increase in net migration accompanied with relatively narrow prediction intervals.

Following the approach described and discussed in deliverable 15 of the UPE project, an eigenvalue analysis (or a factor analysis) of this matrix was executed. Based on the country-specific values of the first eigenvector, that explained 27% of the variance in net migration, it was concluded that, apart from France and Sweden, all other EEA+ countries seem to have a common variance component in net migration. The values of the second eigenvector, that explained 18% of the variance, indicated that Austria, France, Germany and Switzerland have tended to move together, into a direction opposite to Ireland, Portugal and Spain. In order to improve the interpretation of these associations, eventually the following three groups of countries were defined:

- GER: consisting of the ethnically related, German speaking countries Austria, Germany and Switzerland;
- MED: consisting of the Mediterranean countries Greece, Italy, Portugal and Spain that might share a similar future migration history;
- OTH: all other EEA+ countries.

The respective within and across group average correlations were:

GER	0.66		
MED	-0.01	0.45	
OTH	0.21	0.18	0.13
	GER	MED	OTH

Inclusion of both methodological (the highly simplified submodule of PEP that generates stochastic net migration forecasts needs somewhat higher correlations than generally observed) and substantive considerations (e.g. negative average correlation between GER and MED is partly caused by temporary, earlier migration flows from MED to GER), led to the application of a more simplified, assumed cross-country correlation structure (see section 3.8.2).

Using the latter structure, it was demonstrated that the variance components model can be used to impute values for net migration around a mean, and therefore can be viewed as an imputation model for net migration (PEP used it accordingly!).

In the second part of this study the use of imputation techniques for modelling the uncertainty of international migration has been conceptually examined. Starting point here was the idealised case that:

1. there would no international differences in the definition of migrants;
2. there would complete, comprehensive tables or matrices available on international migration flows by country of origin and destination;
3. individuals would be recorded as migrants independently from each other;
4. individuals would have the same probability of being recorded as migrant, provided that they have migrated;

5. being recorded as a migrant by one country would not influence the act of recording as a migrant by the other country.

Under these assumptions, the "true" international migration flows and its variance could be calculated by means of the classical capture-recapture estimates.

Subsequently the following less idealised, and increasingly more realistic cases were successfully examined, in the sense that either formulas for both the estimates and its variance either could be derived, or directions of using the capture-recapture techniques could be provided:

- migration data would originate from special sample surveys instead of data;
- international differences in the definitions of migrants would exist.

The third part of the study explored the possibilities for using auxiliary, symptomatic data in the assessment of data errors and in the formulation of forecast assumptions.

By visually comparing recently published estimates on the fraction of population foreign born and/or the fraction of foreign nationality on the one hand, and recently reported levels of crude net migration, it was observed that:

- for France, Norway and Spain fairly big discrepancies exist between the respective levels of these summary stock and flow indicators; as Norway possesses a reliable population register, it was concluded that for France either the net migration flow from outside the EEA+ has dramatically declined, or the number of in-migrants are underestimated, whereas for Spain the question arose whether the fluctuations in net migration over the past 5 years or caused by statistical revisions;
- for Austria, the Netherlands and the United Kingdom, both indicators turn out to be high.

A similar inspection with future crude net migration levels provided similar results, and therefore the assumed higher than average level of uncertainty for France and Spain were qualified as reasonable.

3.8 Stochastic multi-regional forecasts with applications to the elderly (WP8)

3.8.1 General

National population forecasts by sex and age are by far the most frequently used type of demographic projections. However, there is in many countries and organizations a more or less structural need for all kinds of more specific forecasts. For example, since the early 1980s the European Commission has commissioned already four times the compilation of long-term internationally consistent regional (NUTS-2 level) population and labour force projections by sex and age. Over the past 5-10 years also the need for more detailed projections on the future changes in the composition of the elderly population has become evident.

In order to satisfy these, also from a practical and methodological point of view more demanding and interesting user's needs, it was initially planned to explore the feasibility of making sub-national stochastic population forecasts in general, with applications of functional stochastic forecasts to the elderly. However, due to the lack of sufficiently comprehensive and long time series on both observed and projected regional demographic trends, this research objective had to be relaxed somewhat. Instead it was decided that additional research efforts would be devoted to examine inter-country correlation in forecast errors, so that internationally consistent stochastic population forecasts could be produced for all countries considered.

The primary problems in producing stochastic multi-state population forecasts are partly conceptual, and partly practical. The conceptual problems relate to the measurement of correlations. Although it seems natural to think that the TFR's in the countries considered would show a similar trend, the countries go through idiosyncratic periods, and therefore the correlation can be observed in a broad sense only, over long periods of time. For life expectancy (at birth) the situation is even more problematic, because while the TFR is the sum of age specific fertility rates, and thus behaves like an average, life expectancy is a highly non-linear function of age specific mortality rates. With two sexes involved the notion of cross-country correlation is further complicated. Therefore, it is much less clear in what way an association in mortality can be achieved via life expectancy. Net migration is conceptually somewhere in between fertility and mortality. Here the complicating factor is the possibility of a negative association between a pair of countries that might arise from the within EEA+ migration.

The practical problems relate to the general lack of empirical estimates on correlations. Especially for international migration this is partly due to the poor quality of the data series available, but also for the TFR's and life expectancies at birth, no one calculated and examined cross-country correlation structures until the UPE project started. On the other hand, even if empirical estimates would have been available, the tools for using them for the production of multi-national stochastic population forecasts were also lacking.

3.8.2 Cross-country correlations

Starting point for the analysis of cross-country correlations were the model-based estimates produced in work package 3 (see also Keilman and Pham, 2004). Although limited estimates of cross-country correlations have been made earlier (some from U.S. and the Nordic countries are reported in Alho and Spencer (2004), the estimates of the UPE project provide the first comprehensive look at the correlatedness of forecast errors in fertility, mortality and migration across countries. Following the approach described and discussed in deliverable 15 of the UPE project, an eigenvalue analysis (or a factor analysis) of the correlation matrix relating to the TFR, life expectancy at birth and net migration was executed.

For the TFR cross-country correlations were computed based on the residuals from an ARCH model, applied on data for the period 1950-2000. The respective 18x18 correlation matrix used is displayed as table 1 in Annex 4.

These empirical model-based estimates were applied, because although the ARCH models had an AR(1) structure, the estimates of first autocorrelations were in most cases over 0.95 and even the smallest one was 0.86 (for Sweden). Thus these models appeared to be very close to a process of independent increments that was programmed by PEP.

The proportions of the variance explained by the eigenvalues of the TFR appeared to be high: the first eigenvalue accounted for 30% of the total variance, the second 11%, and the third 9%. Further examination of the first and second largest eigenvalues resulted in a correlation matrix for the TFR, that suggests a contrast between the Mediterranean countries (MED = Greece, Italy, Portugal and Spain) and the other countries (OTH):

MED	0.30	
OTH	0.12	0.30
	MED	OTH

However, it was noted that these cross-country correlations are probably too low, leading to an under estimation of uncertainty. Furthermore, the correlation of fertility between Portugal and Spain amounted 0.58, a value well above the average correlation in the MED countries.

The study of cross-country correlations of life expectancy was based on the residuals from a GARCH model, applied on data for the period 1960-2000. The respective 18x18 correlation matrices for men and women can be found in Annex 4 (tables 2 and 3 respectively).

Similarly to fertility, such an analysis could be justified because the time series modeling was based on the first differences of the key indicator involved (in this case life expectancy). Again the proportions of the total variance explained by the three largest eigenvalues appeared to be high: 33%, 12% and 10% for men, and 30%, 13% and 9% for women. Further inspection of the eigenvalues revealed a contrast between Portugal and Spain (PS) and the rest (OTH). For men the corresponding correlations within and across groups were:

PS	0.74	
OTH	0.04	0.26
	PS	OTH

For women, slightly different correlations were estimated:

PS	0.62	
OTH	0.03	0.24
	PS	OTH

It was noted that the method applied did not account for correlations in the annual average gains in life expectancy. Therefore, especially the correlation among the OTH countries could be assumed to be higher than estimated. Furthermore, it was noted that the correlation between PS and OTH could be somewhat higher in the future due to (converging) changes in life styles.

The model for the estimation of cross-country correlation of forecast errors of net migration was based on (results of) a factor analysis of observed, past net migration time series and a judgmentally adjusted classification of the EEA+ into three regions: GER consisting of Austria, Germany and Switzerland; MED consisting of Greece, Italy, Portugal and Spain; and OTH consisting of Belgium, Denmark, Finland, France, Ireland, Iceland, the Netherlands, Norway, Sweden and the United Kingdom.

The model generated the following estimates of cross-country correlation:

GER	0.50		
MED	0.25	0.50	
OTH	0.25	0.25	0.25
	GER	MED	OTH

The implementation of the cross-country correlations in PEP was achieved in two different ways. For fertility and mortality, the use of the "model of seeds" has been applied, whereas for migration a special version of PEP was developed to bypass PEP's own generation of migration uncertainty.

3.8.3 Two applications for the elderly

Population ageing and a decreasing working age population are widely recognized as the most important future demographic trends. Its challenges and consequences for European public health and social security systems, in particularly the pension system, have been increasingly studied. However, the need for changes of our physical infrastructure (e.g. housing, transport, and communication systems) has just started to become apparent.

Some of the groups of the elderly are particularly vulnerable to the effects of population ageing. In this project, the following two groups were considered as to being confronted with potentially higher than average risks: the divorced elderly men and the severely disabled (in the sense that they are severely hampered in executing daily activities) elderly people.

Both characteristics of the elderly ("being male and divorced" and "being severely disabled") can be viewed as being functions or *functionals* of population counts measured via their prevalences. Simulated values of the prevalences have been applied, pathwise and in a multi-country setting, to the population counts that resulted from the internationally consistent set of stochastic population forecasts by sex and age. Hence, both the future population numbers and the future prevalences of interest were treated as being stochastic. The method of calculation is analogous in structure to that of Alho and Vanne (2001). Both applications were restricted to four continental countries: Belgium, France, Germany and the Netherlands. The time horizon used was 2001-2031.

The methodological contribution of these applications basically lies in the multi-country setting in which both the populations and the prevalences may be correlated across countries.

The point forecasts of the prevalence of being male and divorced were obtained from the EU funded project FELICIE (contractnr. QLK6-CT-2002-02310, Deliverable 2.2; authors: Murphy and Kalogirou, 2004). Due to the use of somewhat different assumptions concerning mortality (less optimistic) and net migration (lower levels), the median of the FELICIE predictions turned out to be considerably lower than that of the UPE forecasts.

The uncertainty in the prevalence of being divorced was assumed to come from two primary sources. First, the recording of divorces might not be fully accurate, especially in countries that do not have a continuously updated population register. Second, the expected trends in the future incidence of divorce and remarriage might be wrong. Obviously, the magnitude of the first source of forecast errors would depend on the particular characteristics of the nuptiality registration system of a country, and therefore it would not be the same across countries. However, similar to fertility and mortality, the future trends in divorce and remarriage could be influenced by cross-national cultural factors, so that forecasts errors could be correlated.

In the absence of any quantitative information on the uncertainty of the forecast of prevalence of being divorced (the FELICIE project only produced point forecasts), a sensitivity analysis was carried out. The basic assumptions were:

- errors in the forecasts of prevalence are independent of errors in the forecasts of population by sex and age;
- errors in the forecasts of prevalence in different ages within a country are the same.

In the sensitivity analysis the relative error and cross-country correlation parameters both were given three values:

- the relative error in the forecast of prevalence (i.e., the error in the log-odds of forecasted prevalence) was given values 5%, 15% and 30%; the same value was used for all ages;
- cross-country correlation in the forecasts of prevalence was given values 0.0, 0.3 and 0.5.

The sensitivity analysis suggests that probably the major source of uncertainty in the total number of divorced males is, at least initially, in the forecast of prevalence (assumption 3). The effect of cross-country correlation (assumption 4) depends on the relative error: the greater the relative error, the larger the effect of the correlation. As the forecast period increases, the uncertainty in the size of the total elderly population increases rapidly, and appears to take a larger share of the total uncertainty in the population of elderly divorced. If relative error is 15% and cross-country correlation is 0.3, the two components of uncertainty are approximately equal after a period of 25-30 years.

These calculations demonstrate that the uncertainty of a functional forecast evolves in a complex manner over the forecast period. Without stochastic tools such as those used in our project, it would be difficult to disentangle the various effects.

The second application examined changes in the predictive distribution of the severely disabled elderly population for the same group of four continental countries and the same projection period. Recent estimates for the prevalence of disability were taken from the European Community Household Panel. After some averaging to reduce irregularities in the empirical estimates (the data were considered by five year age-groups until 85+; values for Belgium and the Netherlands were averaged, similarly values for France and Germany were averaged) they were applied as point forecasts to the stochastic population numbers by age and sex.

In this case there were two sources of uncertainty in the forecasts of prevalence. First, there is a standard error that is due to the use of survey data. Second, there are annual fluctuations. In this application, the following assumptions were made:

1. errors in the forecasts of prevalence are independent of errors in the forecasts of population by age and sex;
2. empirically estimated standard errors for the logs-odds of prevalence were used for each country; this uncertainty was the same for Belgium and the Netherlands on one hand, and for France and Germany on the other; across age and across the pairs of countries this source of uncertainty was independent;
3. on top of standard errors mentioned above, annual fluctuations occur in the log-odds of the prevalence that had an empirically estimated standard deviation of 14%; these fluctuations are independent across age, sex, and country.

The results of these functional stochastic population forecasts demonstrate that the size of severely disabled elderly population will increase dramatically in the four countries, from the current value of about 4.5 million, to 8.9 million in 2016, and to 11.8 million in 2031. At the same time the interquartile range increases from [8.8, 9.1] million in 2016 to [11.3, 12.4] million 2031. (These ranges comprise the middle 50% of the probability mass.) The UPE team believes that these estimates are of the correct order of magnitude. However, it should also be said that, although these projections incorporate empirical estimates of uncertainty in both the total elderly population of the four countries (including cross-country correlation) and in the estimated prevalence, they assume that there is no trend in the age-specific prevalence of disability. Thus, there may be room for refinement.

4. Conclusions and policy implications

4.1 Introduction

Population forecasts are indispensable for preparing new EU social, economic, monetary and regional policies. In particular policies that concern gender and age related issues such as life long learning, a flexible workforce, active ageing and sustainable pension and health care systems and expenditure need internationally comparable demographic forecasts as input. Some other key topics in the social field such as equal opportunities and integration of migrants are increasingly studied with the help of forecasts. Important financial support programmes such as the regional structural funds are partly based upon future demographic indicators like population growth and population density.

Until now all these needs have been satisfied by means of compiling various sets of long-term population scenarios at national and regional level every five years. Over the years, the number of users within the European Union that applied these deterministic projections has increased. Currently the principal users are:

- DG ECFIN, especially for their studies on the financial implications of population ageing;
- DG EMPLOY for the ongoing research on future labour supply and labour demand, equal opportunities and social protection, and their annual report on the social situation of the population of the EU;
- DG REGIO for their regional reporting and support programmes;
- The European Parliament in assessing the sustainability of European Commission's and European Council's proposals and decisions in the social field.

DG REGIO has always stressed the uncertainty behind population projections. Already in 1997 it commissioned a study on the quality of the long-term population scenarios compiled since the early 1980's. The other principal users within the European Union have fairly recently become aware of the errors made in population forecasts: the EPC Working Group on Ageing organised in February 2004 a one-day workshop on the issue how to deal with uncertainty of future demographic trends, whilst DG EMPLOY requested during Summer 2004, by means of a call for tender, proposals for a study on the use of demographic trends and long-term population projections in public policy planning at EU, national, regional and local level. In the explanatory text of this call for tender it was explicitly mentioned that long-term demographic projections are subject to a high degree of uncertainty, and therefore one of the key research questions formulated was "How can policy-makers best handle the uncertainty inherent to demographic projections?"

The UPE project was designed to scientifically pave the way for answering such questions. The basic rationale behind the project was that stochastic forecasts assuming less than perfect correlation provide a better indication of forecast uncertainty than traditional scenario-based methods. The stochastic approach applies probability theory to derive a predictive distribution of future population. Instead of merely combining the fertility, mortality and migration input of a restricted number of deterministic projection variants, it uses the full range of possible demographic futures, adds quantitative probability distributions and also handles the complex interdependencies of forecast errors in time and space.

4.2 Conclusions

The findings and outcomes of the UPE project justify the following three conclusions

1. The UPE population projections by sex and age significantly differ from earlier population scenarios of Eurostat and the U.N., and from national population forecasts both in terms of how the most likely future demographic development is assessed, and how the uncertainty of forecasting is taken into account.

Although national population forecasters typically and increasingly do assess trends in other countries, recent past developments in the country in question still receive heavy attention. While this may improve accuracy in the very short term, in the longer run diverging trends lead to large differences in the demographic outlook that are incompatible with the shared economic, cultural, and social norms among the 18 EEA+ countries considered. In the UPE project an attempt was made to honor the recent developments in formulating the most likely future development for the first few forecast years. However, eventually and in particular for mortality, the demographic developments were assumed to conform to average trends of the area. This does not mean that a strong convergence hypothesis has been imposed, but it keeps the otherwise divergent trends in check. This corresponds to what Eurostat has applied during the compilation of the 1990-based, 1995-based and 1999-based long-term national population scenarios, and our experience suggests that this practice should be continued.

However, our assessment of the most likely future trends differs from the past practice of Eurostat and the U.N along with many national statistical agencies. A key question regarding fertility is whether the low levels of the past decade or two in the Mediterranean and German speaking countries will continue, or whether this is a temporary phenomenon related to the timing of births. Along with Eurostat, and as opposed to the U.N., the UPE team concluded that while some recuperation is likely, there is no evidence that fertility will rise significantly from the current levels. Although the current levels are the lowest in recorded history, the causes of the decline are poorly understood, and one cannot rule out the possibility that there are even further declines. Therefore, the UPE team expects that the total fertility rate will most likely remain close to recently observed levels, and the average at motherhood will further increase.

As regards mortality, the UPE project shows that virtually all, official national and international population forecasts over the past 4-5 decades have considerably underestimated the gain in life expectancy at birth. Most demographic forecasters simply do not (or can not) believe that the decline in age specific mortality will persist, and therefore generally expect a slowdown of improvement in life expectancy, eventually leading to stagnation. This erroneous assumption has lead to a systematic underestimation of the surviving populations, especially in the oldest ages. The UPE team expects that it is more likely that current rates of decline will continue, thus leading to a larger future population than predicted by the official agencies. It also notes that even more optimistic forecasts would be obtained if, instead of mortality, life expectancy would be taken as the variable to be predicted.

As regards migration, similar conclusions can be drawn. Net migration flows have been continuously underestimated, and also latest forecasts of Eurostat, the U.N. and of several national agencies still assume fairly moderate levels of future net migration. In contrast to mortality, this is a more recent phenomenon, covering the past two decades or so. (There is considerable variability in this respect among the EEA+ countries.) Data on migration are also much worse that data on fertility and mortality, so an assessment of past trends is on a weaker ground. The UPE team assumes that the level of migration, primarily, form outside the EEA+ will exceed the current levels to some extent. However, we have not simply assumed that the observed increasing trend will continue. Instead, country-specific target levels of migration have been specified on a judgmental basis. The consequence is that our forecasts of net migration are considerably higher than those made by official agencies.

Although net reproduction of all EEA+ countries is well below replacement, both *the declining mortality and increasing net-migration will lead to a much less bleak outlook on the total population of Europe than has been previously thought*. However, *aging will continue to be a major challenge*, as net-migration can only partially offset the joint effects of post-war baby-boom and the decline of mortality.

Past population scenarios of Eurostat and the U.N., together with forecasts of most national statistical agencies have tried to handle the uncertainty of forecasting by presenting alternative variants. Although this approach can be helpful in some planning connections, it has been conclusively demonstrated in the literature that it is not possible to give a logically consistent description of the uncertainty using those tools. The UPE project has used a stochastic approach instead. In this approach the forecaster recognizes that the most likely future development, or the point forecast, is not likely to be exactly correct, and uses probability theory to describe the level of uncertainty around the most likely development. A probability distribution incorporating of these two components is called a predictive distribution. In theory, it has been known how to formulate a predictive distribution for 50 years or so, but for both technical and substantive reasons, it has only been possible to produce stochastic of the type considered here until recently. The phenomenal increase in the speed of computing has largely removed the technical obstacles during the past decade.

2. The parameter values of the predictive distributions of future fertility, mortality and migration can be successfully derived from a methodology that combines the findings of three existing methods: analysis of observed errors in past forecasts, model-based estimates of forecast errors, and elicitation of expert opinions.

Earlier studies on stochastic population forecasting have heavily relied on only one of the methods mentioned (Alho 1998, De Beer and Alders 1999, Hanika et al. 1997, Keilman and Hetland 1999, Lee and Tuljapurkar 1994, Lutz and Scherbov 1998). The UPE project has demonstrated that by means of an overarching argument-based approach, the outcomes of the three methods can be optimally applied for assumptions making. Problems due to the limited availability of historical population forecasts and a general lack of reliable, internationally comparable data series on international migration can be solved by a creative mixture of both simple and advanced time series models, estimation techniques and expert knowledge.

3. The production of multi-national stochastic population forecasts has appeared to be feasible

In the UPE project the stochastic population forecasts are produced with the program PEP (Program for Error Propagation). The program simulated alternative paths of future development for age-specific mortality, fertility and net-migration. These are combined into a forecast of population using the classical cohort-component book-keeping equations. This is repeated many this, in our application 3,000 times. Thus, we have 3,000 alternative forecasts of the population of each country available, by age and sex. Summary statistics can be computed from the simulated values to approximate the parameters of the underlying predictive distribution. A selection of the results is available at www.stat.fi/tup/euupe/. This is the first time full stochastic cohort-component forecasts have been produced for all EEA+ countries (excluding the countries that joined in 2004).

While most technical issues had already been overcome before UPE started its work, it was not previously known how the results might be combined into an aggregate forecast for the whole EEA+ area. The problem is caused by the fact that the countries are neither independent of each other, nor perfectly correlated with each other. For this purpose special approximative procedures were developed that induce the desired correlations across the simulation runs of the different countries. As far as we know this is the first time a stochastic multistate forecast has been produced that allows for intermediate assumptions concerning cross-country correlations of the vital rates.

Given that the technical issues of producing stochastic forecasts in the EEA+ setting had been overcome, the substantive issue was to specify the level of uncertainty. When probabilities are used in this manner, they must be interpreted as “subjective probabilities”, i.e., as probabilities that express a degree of belief as opposed to relative frequency. However, subjective probabilities are meaningful to forecast users only if they can be given an interpretation in terms of something the users can relate to. Providing such a motivation is a new task that does not arise in the production of conventional forecasts or scenarios.

The goal of the UPE project was to anchor all uncertainty statements to empirical analyses. Two sources of statistical information are generally available: past forecasts, whose accuracy can be determined for those years we know the true values, and statistical time-series models that provide estimates of forecast uncertainty as a by-product of model fit. (The so-called GARCH models were used.) Considerable judgment is required in deciding what data to use, how to conduct the empirical analyses, and what scales of measurement to consider. In the case of fertility and mortality, past experience with such assessments provided a good starting point. However, for migration we had to rely on judgment to a much larger extent.

The challenge in the UPE work was that we had to be able to carry out the uncertainty analyses in a comparable manner for all EEA+ countries. This was not fully feasible, because many countries neither have sufficient numbers of forecasts nor time-series of sufficient length, to allow for a statistically stable estimation of the level of uncertainty. However, the necessity could be turned into a virtue. Having data from all the countries available, albeit of a varying quality, we could formulate average estimates for EU/EEA as a whole that we think are superior to those that one would obtain from any individual country, even if the country would have excellent past data. Thus, just as in the formulation of point forecasts, in formulating assumptions about uncertainty we used average values of the region as a whole to keep the possibly divergent country-specific values in check.

The empirical estimates of the level of forecast uncertainty derived in this manner are higher than forecast users generally expect. Even professionals not specializing in the field tend to disregard past errors as being caused by idiosyncratic developments and remember those forecasts that were reasonably correct. This implies that *the uncertainty of future population developments is generally underestimated.*

4.3 Policy implications

There are four types of policy implications that can be drawn from the UPE work. First, the predicted population growth in EEA+-countries is considerably stronger than indicated by latest UN- or Eurostat-forecasts. Life expectancy and net migration forecasts of the UPE project are more optimistic and significantly higher than those produced by the official agencies. The reasons and consequences of these discrepancies should be critically evaluated by the statistical agencies.

Second, the UPE project has demonstrated that stochastic forecasts can be produced, in practice, for all countries considered. Thus, both Eurostat and national statistical agencies could do the same. The adoption of novel methods takes some experimenting, and we would expect that a number of choices the UPE project has made might not be favored by the official agencies. Yet, the agencies should seriously study our results, and determine how they could adopt similar techniques to give a better indication of forecast uncertainty.

Third, in recent years economists have increasingly been alerted to the fact that demographic developments cannot be forecasted accurately. This has major implications on how such issues as pension systems and the provision of health care for the elderly are studied. The recognition of uncertainty leads to new criteria for the evaluation of policy reforms. In particular, a reform must be sufficiently robust so that unexpected demographic developments do not undermine its foundations or, say, put different cohorts in inequitable position relative to taxes and benefits. Policies that adjust to demographic shocks typically do so by shifting part of the risk to the citizens. Thus, the latter also need to understand the risks, so they can prepare for a range of surprises that have a good chance of materializing. Examples of work along these lines exist already.

Fourth, both forecast producers, decision makers within governmental agencies, and the public need to be educated about the magnitude of demographic uncertainty. Many aspects of probabilistic thinking (e.g., cancellation of error) are not intuitive from every day experience, so a special effort is needed that the parties involved can develop a realistic appreciation of risk.

5. Dissemination and/or exploitation of results

During the project four different methods have been applied to present, to discuss and to promote the use of the outcomes of the study:

1. oral presentations to both scientific audience and government officials;
2. reports and articles in scientific and popular press;
3. creation of a comprehensive information base on the web (including a users' guide, principal data series used, extracts of the assumptions applied and a selection of forecast results);
4. networking and actively responding to actual users' needs in the field of stochastic forecasts.

The oral presentations have been numerous because the UPE partners are partly involved in academic teaching activities, partly active in applied research projects including the production of deterministic demographic projections, and also frequently requested by policy-makers and decision makers to provide guidance on the use of (stochastic) demographic forecasts. The most prominent and substantial contributions were provided at:

- the Eurostat Working Party on Demographic Projections. Luxembourg, 16-17 September 2002.
- the Seminar "How to deal with uncertainty in population forecasting?", organised by the Vienna Institute of Demography, 12-14 December 2002.
- the CEPS/ENEPRI Conference on Ageing and Welfare Systems: What have we learned? Brussels, 24-25 January 2003.
- the Seminar "Demographic and Economic Analysis" at Stanford University, 28-29 May 2003.
- the European Population Conference in Warsaw, 26-30 August 2003.
- the Seminar "Projection Methods of Future Mortality", organised by the Continuous Mortality Investigation Bureau and the Government's Actuary Department; Edinburgh, 6 October 2003.
- the Workshop on Population Projections organised by the EPC Working Group on Ageing. Brussels, 5 February 2004.

In addition several oral presentations were given to students and already graduated persons (e.g. at the Max Planck Institute in Rostock and the Department of Economics, University of

Oslo), and to national users' groups of interest (e.g. the Finnish Actuarial Society, and the Finnish Centre for Pensions).

The written output of the project actually comprises:

- a set of 2 interim reports and 10 deliverables produced for the European Commission.
- 14 research papers or working documents submitted to the organisers and distributed among the participants of the above mentioned meetings (see annex 5).
- 6 articles already accepted and (being) published in scientific journals and books (see annex 5).
- a significant number of working papers that present the technical details of the procedures use and empirical estimates obtained; most of these latter documents have not been polished for outside readership. However, they provide source materials for approximately 4 articles to be submitted to scientific journals during 2005 (e.g., Journal of Official Statistics, Demographic Research, International Journal of Forecasting). Part of the research (notably migration modelling) requires further study, but may lead to submissions to publication in 2006. Part of the research on how to create correlated simulation data will appear in Alho and Spencer (2004).

The information base can be found at www.stat.fi/tup/euupe/. This site is open to everyone. It is the first time that stochastic forecasts have been made available in this form.

In order to diminish the gap between producers and consumers of stochastic population forecasts in Europe, the UPE team has actively sought for an intensive and efficient co-operation with users, in particular with those in demand for detailed population age structures. Obviously, making all simulated counts available to every conceivable user would be impracticable due to large amount of generated data files. An alternative, more appropriate way of servicing appeared to be the provision of the program PEP with the required input data, so that users themselves can produce identical results in their own computers.

During the studies two related projects have been supported in this way. First, as a participant in another EU supported research project titled DEMWEL, Alho has assisted representatives of the economic research institutions (from Belgium, Denmark, Finland, France, Germany, the Netherlands, Spain and the U.K.) to produce stochastic forecasts of their own country. The results of the stochastic simulations are combined in each country with economic models of various types to investigate ageing related phenomena in each country. Second, Keilman has used UPE produced input data and PEP in a collaboration with the Bank of Norway. The purpose of that project is to analyse the long-term obligations in Norway, and the uncertainty involved, in connection with public old-age pension system.

There are three primary areas of further research that the UPE project points to. First, one cannot overemphasize the importance of establishing an up-to-date high quality, international demographic database. Although the New Cronos database of Eurostat has been created with this intention in mind, it does not currently function sufficiently well in that capacity. Deficiencies noted in the course of UPE work include lacking data from even rather recent years, differences in age classifications (in the oldest ages) from country to country, and problems in population numbers that appear to be the result of defective imputation of the effect of net-migration after census years. In addition, reliable and internationally comparable time series on international and interregional migration flows by country/region of origin and destination barely exist. Finally, key-assumptions and main results of official, national population forecasts are not (yet) systematically collected and archived. As national statistical agencies may have other priorities and Eurostat may have to rely on them as the source of official figures, it would be desirable that some demographic research institution would be funded to take up the task of providing estimates for the lacking or defective data. Frequently, the legal or other constraints that national agencies may have, do not have importance from a scientific perspective, and the use of an institution as data producer that is free of such constraints could lead to data that are of higher quality and more dependable for research purposes.

Secondly, if more and better international data series become available, the analysis on both historical population projection errors and model-based projection errors can be enhanced and improved. More specifically, the empirical errors of the subsequent rounds of long-term national and regional population scenarios by sex and age commissioned by the European Commission can be examined. Furthermore, the errors of various other time series models currently in use (i.e. the extrapolation of cumulated age and cohort specific fertility rates, or the linear regression of sex and age specific mortality rates) should be studied. Finally, the correlation across countries and also the correlation between the demographic components need further research.

Thirdly, the work of the UPE project should be extended to the new member states that joined the EU in 2004, and in the short run, should also include the three EU candidate countries Bulgaria, Romania and Turkey. Most probably the data problems will exceed those encountered by the UPE project. In particular, even the establishment of the jump-off population is difficult due to significant, undocumented migration. However, especially for fertility and mortality, a lot of evidence could be borrowed from the UPE results for the EEA+. Furthermore, for all countries mentioned except Turkey, the recently compiled set of long-term national population scenarios by sex and age could serve as input for the point forecasts needed.

In addition, the production of sub-national stochastic population forecasts is an area that should be seriously looked into. The original project proposal of the UPE project comprised a feasibility study for making such a product, but it was soon discovered that the data problems were insurmountable and efforts were directed elsewhere. The UPE project did make progress in the dimension reduction of models of sub-national population flows, however. This effort should be continued and tested with other regional data series. Also, by developing ways to handle cross-country correlations in fertility, mortality and migration, the UPE work can also provide a basis for the representation of such cross-correlations for sub-national areas.

Finally, the production of other, relevant national stochastic forecasts should be seriously considered. In particular, the compilation of national stochastic labour force forecasts by sex and age seems to be feasible. Internationally consistent time series on labour force participation rates by sex and age are available since early 1980s, the majority of countries posses series of historical forecasts, and there is a fairly large group of international experts to be consulted for an argument based approach. And last but not least, the applications of the UPE project for the elderly demonstrate that the methodology including the software is now being operational to producing these related, stochastic projections.

6. Acknowledgements and references

6.1 Acknowledgements

The UPE-team gratefully acknowledges the kind help of many persons who provided the requested data series and publications concerning historical population forecasts at the national level: Alexander Hanika (Vienna), Leila Bellamammer (Brussels), Anna Quist (Copenhagen), Ossi Honkanen and Timo Nikander (Helsinki), François Clanché (Paris), Bettina Sommer and Dieter Emmerling (Wiesbaden), Helen Cahill and Francis McCann (Dublin), Federico Geremei (Rome), Jean Langers (Luxembourg), Rob Broekman, Hans Sanders, and Taeke Gjaltema (Voorburg, NL), Maria José Carrilho (Lisbon), Margarita Cantalapiedra (Madrid), Jan Qvist and Åke Nilsson (Stockholm and Örebro), Anne-Christine Wanders and Stéphane Cotter (Neuchâtel), Tony Whiffen and Chris Shaw (London).

Special thanks go to the four international demographic experts that actively participated in the Work package 'Elicitation of expert's opinions' (WP4).

6.2 References

Alders, M. (2002). *Changing population of Europe: uncertain future – Elicitation of experts' opinions*. Presentation of results of a survey among forecasters of European national statistical offices (Powerpoint), Eurostat Working Party "Demographic Projections" 16-17 September 2002, Luxembourg.

Alders, M. and J. de Beer (1998). Kansverdeling van de bevolkingsprognose. *Maandstatistiek van de bevolking* 46 (4): 8-11.

Alders, M. and J. de Beer (2002). *An expert knowledge approach to stochastic mortality forecasting in the Netherlands*. Paper for the Meeting on stochastic models for forecasting mortality, National Social Insurance Board, 29-30 January 2002, Stockholm, Sweden.

Alders, M. and J. de Beer (2004). Assumptions on fertility in stochastic population forecasts. *International Statistical Review 72:* 65-79.

Alho, J.M. (1998). *A stochastic forecast of the population of Finland*. Reviews 1998/4. Helsinki: Statistics Finland.

Alho, J.M. (2004). Second moments of fertility, mortality , and net migration. A report on work package 8 of the project Changing Population of Europe: Uncertain Future.

Alho, J.M. and B.D. Spencer (1997). The practical specification of the expected error of population forecasts. *Journal of Official Statistics* 13: 203-225.

Alho, J.M. and R. Vanne (2001). *On predictive distributions of public net liabilities*. A paper presented at the International Meeting on Age Structure Transitions and Policy Dynamics: The Allocation of Public and Private Resources Across Generations. Tapei 6.-8.12.2001.

Alho, J.M. and B.D. Spencer (2004). *Statistical demography and forecasting*. New York: Springer (in press).

Bishop, Y.M.M., S.E. Fienberg and P.W. Holland (1975). *Discrete multivariate analysis*. Cambridge MA: The MIT Press.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics* 31: 307-327.

Box, G.E.P. and G.M. Jenkins (1970). *Time series analysis: Forecasting and control.* San Francisco: Holden Day.

Brooks, C., S.P. Burke, and G. Persand (2003). Multivariate GARCH models: Software choice and estimation results. *Journal of Applied Econometrics* 18: 725-734.

Chesnais, J.-C. (1992). *The Demographic Transition: Stages, Patterns, and Economic Implications: a longitudinal study of 67 countries covering the period 1720-1984.*. Oxford: Clarendon Press.

Council of Europe (2002). *Recent demographic developments in Europe 2002*. Strasbourg: Council of Europe Publishing.

Cruijsen, H. and N. Keilman (1992). The future of national population forecasting. Pp. 323-342 in N. Keilman and H. Cruijsen (eds.). *National Population Forecasting in Industrialized Countries*. Amsterdam and Berwyn, PA: Swets and Zeitlinger Publishers.

Dang, T., P. Antolin, and H. Oxley (2001). *The fiscal implications of ageing. Projections of age-related spending*. OECD Economics Department Working Papers 305.

De Beer, J. (1997). The effect of uncertainty of migration on national population forecasts: the case of the Netherlands. *Journal of Official Statistics* 13: 227-243.

De Beer, J. and M. Alders (1999). *Probabilistic population and household forecasts for the Netherlands*. Paper presented at the joint ECE-Eurostat Work Session on Demographic Projections, Perugia, Italy, 3-7 May 1999. Internet www.unece.org/stats/documents/1999.05.projections.htm

Engle, R. (1982). Autoregressive conditional heteroskedasticity with estimates of the variance of U.K. inflation. *Econometrica* **50**: 987-1008.

Engle, R.F. and K. Kroner (1995). Multivariate simultaneous generalised ARCH. *Econometric Theory* 11: 122-150.

Eurostat (2003). *Demographic statistics: Definitions and methods of collection in 31 European countries*. Eurostat Working Paper published under theme Population and social conditions, 3/2003/E/n° 25.

Goodman, L. (1991). Measures, models, and graphical displays in the analysis of cross-classified data (with discussion). *Journal of the American Statistical Association* 86: 1085-1138.

Hanika, A., W. Lutz and S. Scherbov (1997) Ein probabilistischer Ansatz zur Bevölkerungsvorausschätzung für Österreich. Statistische Nachrichten, 984-988.

Human Mortality Database of the University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded on 16 June 2003).

Keilman, N. (1997). Ex-post errors in official population forecasts in industrialized countries. *Journal of Official Statistics* 13: 245-277.

Keilman, N. and H. Cruijsen (1992). *National Population Forecasting in Industrialized Countries*. Amsterdam and Berwyn, PA: Swets and Zeitlinger Publishers

Keilman, N., and A. Hetland (1999). *Simulated confidence intervals for future period and cohort fertility in Norway*. Paper presented at the joint ECE-Eurostat Work Session on Demographic Projections, Perugia, Italy, 3-7 May 1999.

Keilman, N., D. Q. Pham, and A. Hetland (2001). *Norway's uncertain demographic future.* Social and Economic Studies 105. Oslo: Statistics Norway. Internet www.ssb.no/english/subjects/ 02/03/sos105_en (30 April 2002).

Keilman, N., and D.Q. Pham (2004). Time series based errors and empirical errors in fertility forecasts in the Nordic Countries. *International Statistical Review 72*: 5-18.

Kroner, K.F. and V.K. Ng (1998). Modelling asymmetric co-movement of asset returns. *Review of Financial Studies* 11: 817-844.

Kupiszewski, M. (2002). How trustworthy are forecasts of international migration between Poland and the European Union? *Journal of Ethnic and Migration Studies* 28(4): 627-645.

Lee, R.D. and L.R. Carter (1992). Modeling and forecasting the time series of U.S. mortality. *Journal of the American Statistical Association* 87: 659-671.

Lee, R. and S. Tuljapurkar (1994). Stochastic population forecasts for the United States: Beyond High, Medium, and Low. *Journal of the American Statistical Association* 89: 1175-1189.

Lee, R. (1998). Probability approaches to population forecasting. In: W. Lutz, J.W. Vaupel, D.A. Ahlburg (eds.), *Frontiers of Population Forecasting*. A supplement to Volume 24, Population and Development Review (Population Council, New York), pp. 156-190.

Lin, G. (1999). Assessing structural change in the U.S. migration patterns: a log-rate modeling approach. *Mathematical Population Studies*7: 217-238.

Lutz, W. and Scherbov S. (1998). Probabilistische Bevölkerungsprognosen für Deutschland. *Zeitschrift für Bevölkerungswissenschaft* **23**: 83-109.

Mackenbach, J.P., A.E. Kunst, H. Lautenbrach, Y.B. Oei, and F. Bijlsma (1999). Gains in life expectancy after elimination of major causes of death: revised estimates taking into account the effect of competing causes. *Epidemiological Community Health* 53: 32-37.

Murphy, M. and S. Kalogirou (2004). *Population projections of those aged 75 and over by marital status, age and sex for the nine FELICIE countries over the next three decades: synthetic report*. The Department of Social Policy, London School of Economics.

Oeppen, J. and J. Vaupel (2002). “Broken limits to life expectancy”. *Science* 296(10), 1029-1030.

Rogers, A. (1986). Parametrized multistate population dynamics and pojections. *Journal of the American Statistical Association* 81: 48-61.

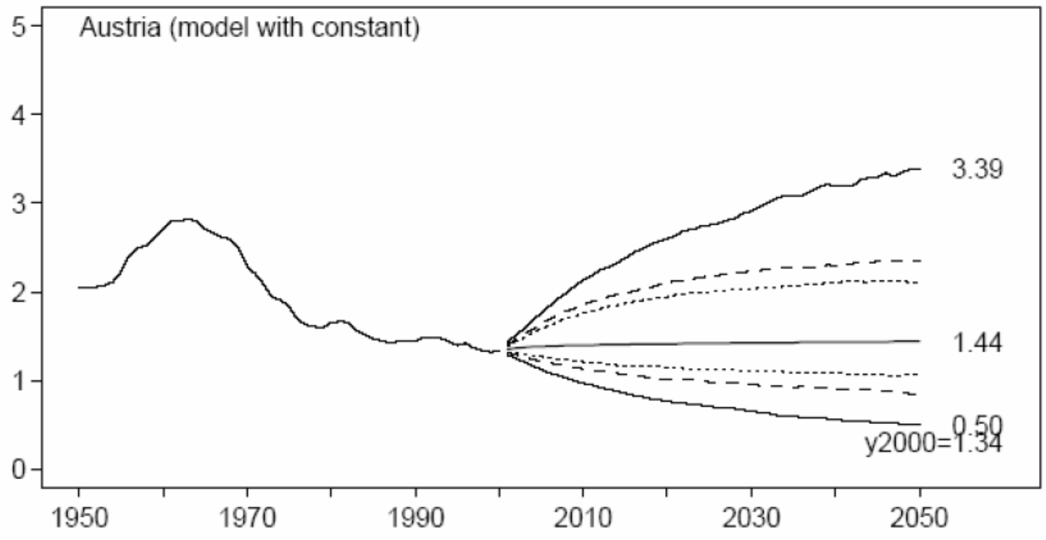
Rogers, A. and L.J. Castro (1981). *Model migration schedules*. PP-81-30. Laxenburg: I.I.A.S.A.

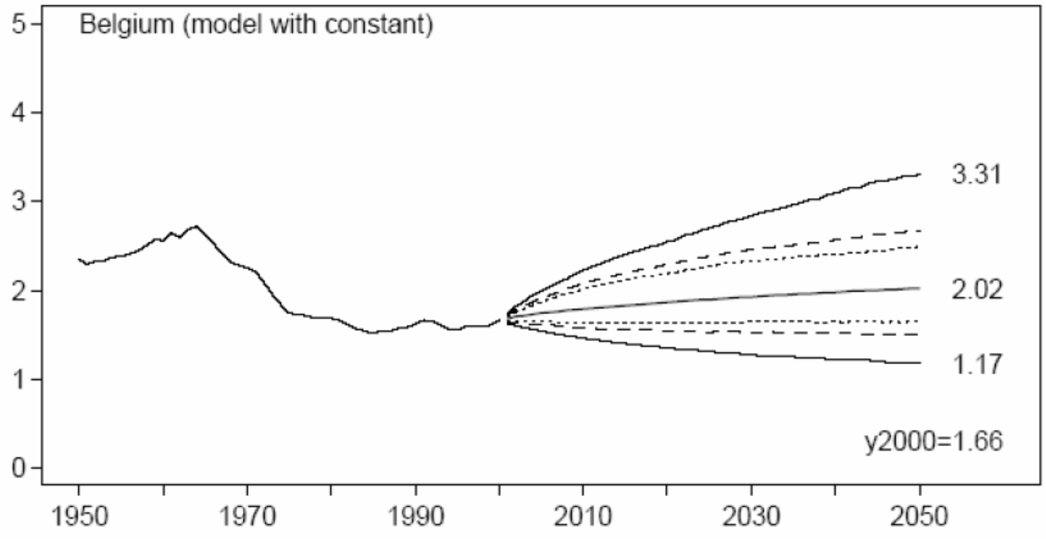
Van Imhoff, E., N. van der Gaag, L. van Wissen and P. Rees (1997). The selection of internal migration schedules for European regions. *International Journal of Population Geography* 3: 137-159.

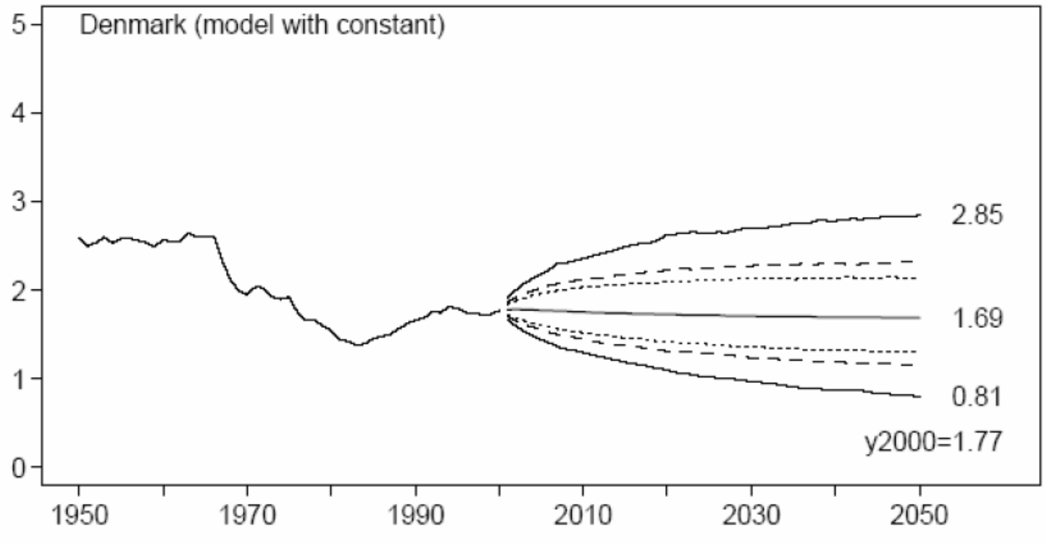
White, K. (2002). “Longevity advances in high-income countries 1955-96”. *Population and Development Review* 28: 59-76.

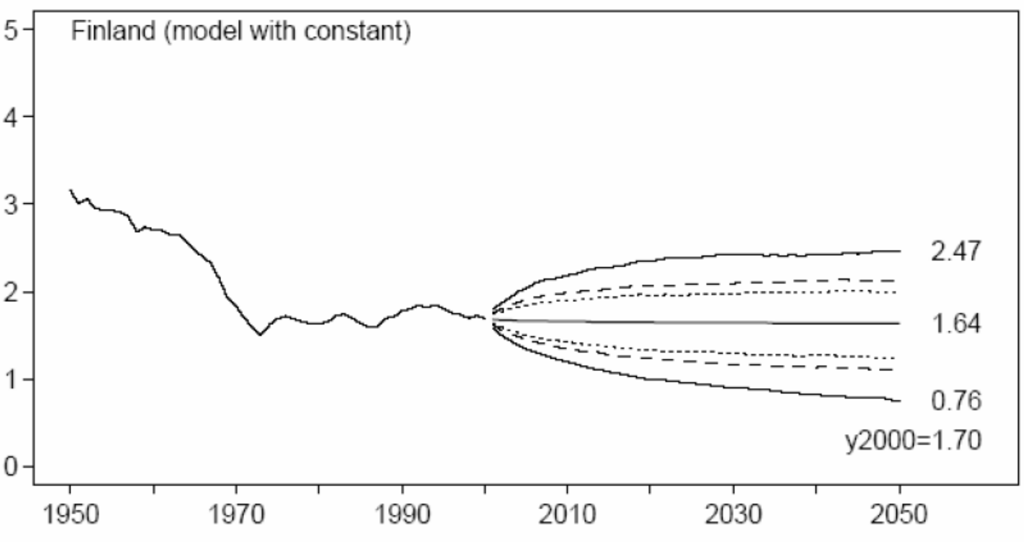
7. Annexes

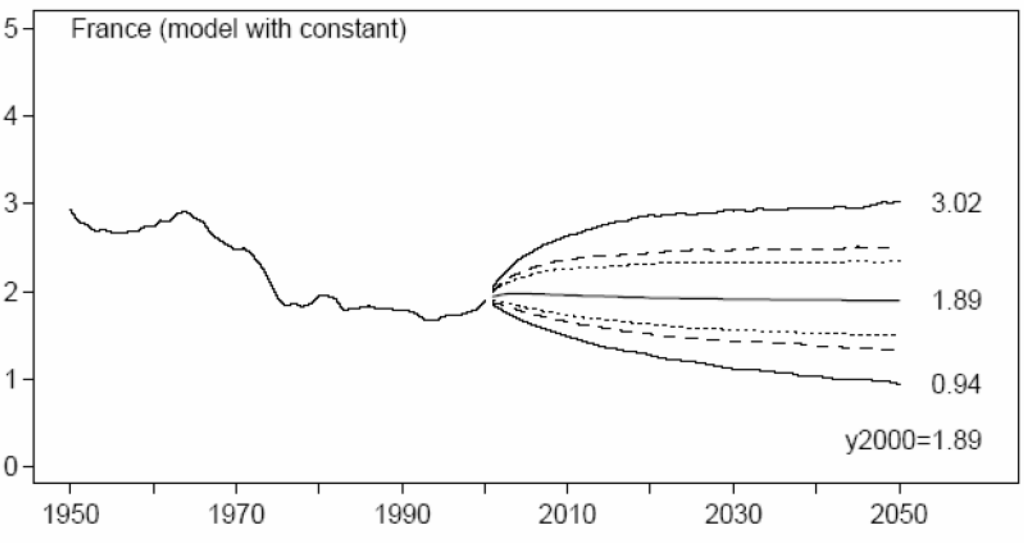
Annex 1: Forecasts and model-based 67%, 80%, and 95% prediction intervals for the TFR. Data 1950-2000. Observed values for the year 2000 are indicated as "y2000"

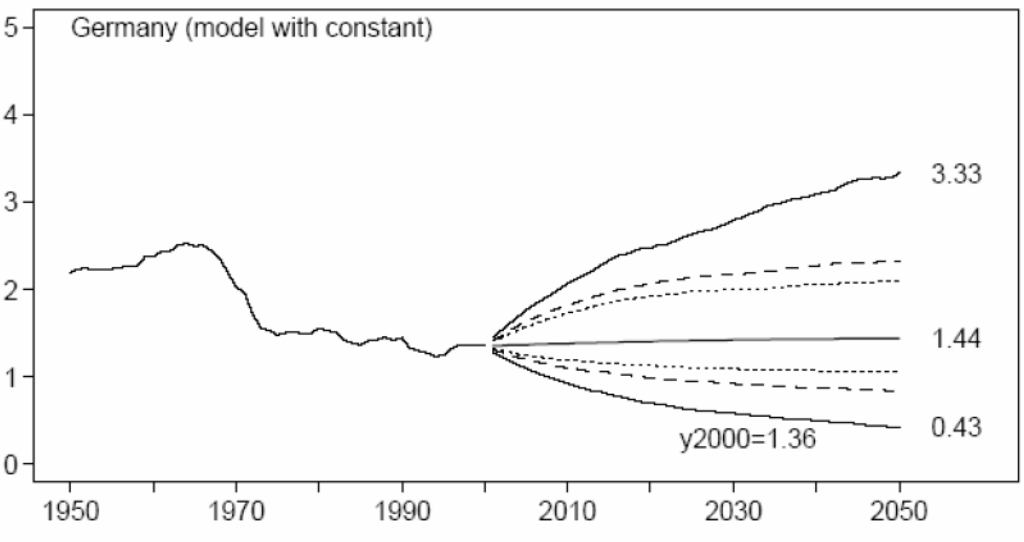

Austria (model with constant)
5
4
3
2
1
0
3.39
1.44
0.50
y2000=1.34
1950
1970
1990
2010
2030
2050

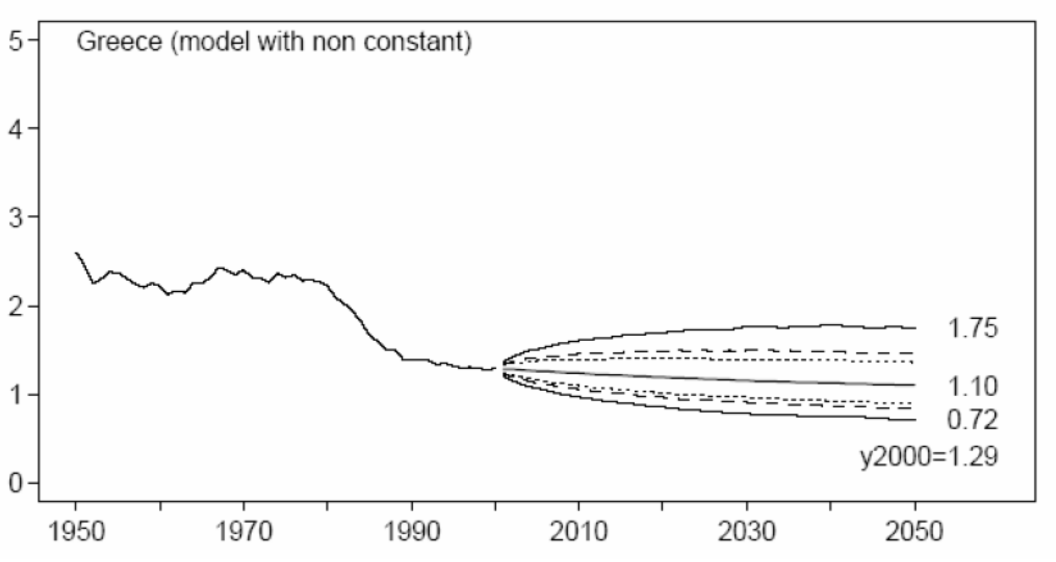

Belgium (model with constant)
5
4
3
2
1
0
3.31
2.02
1.17
y2000=1.66
1950
1970
1990
2010
2030
2050

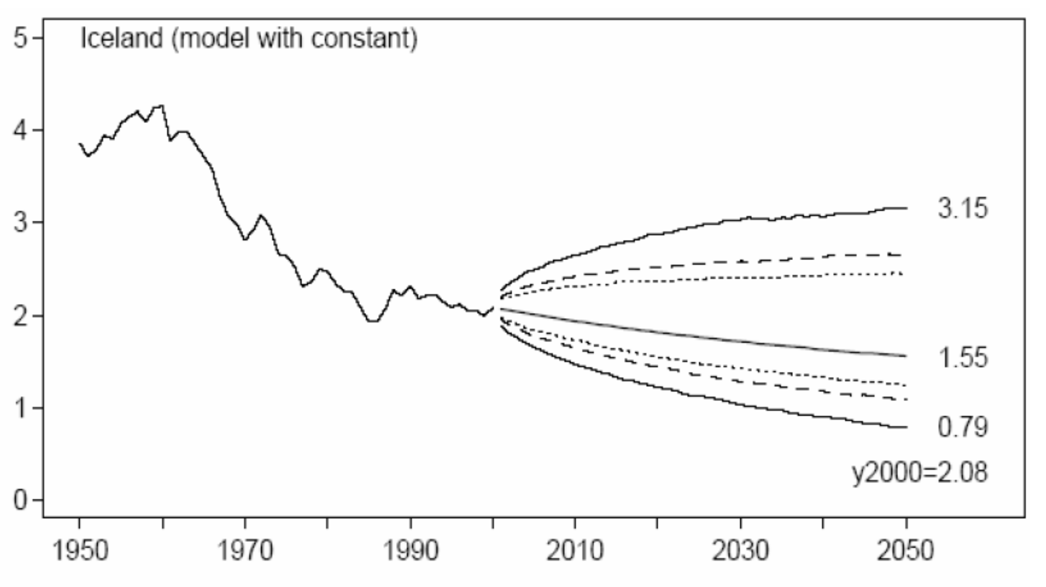

Denmark (model with constant)
5
4
3
2
1
0
2.85
1.69
0.81
y2000=1.77
1950
1970
1990
2010
2030
2050

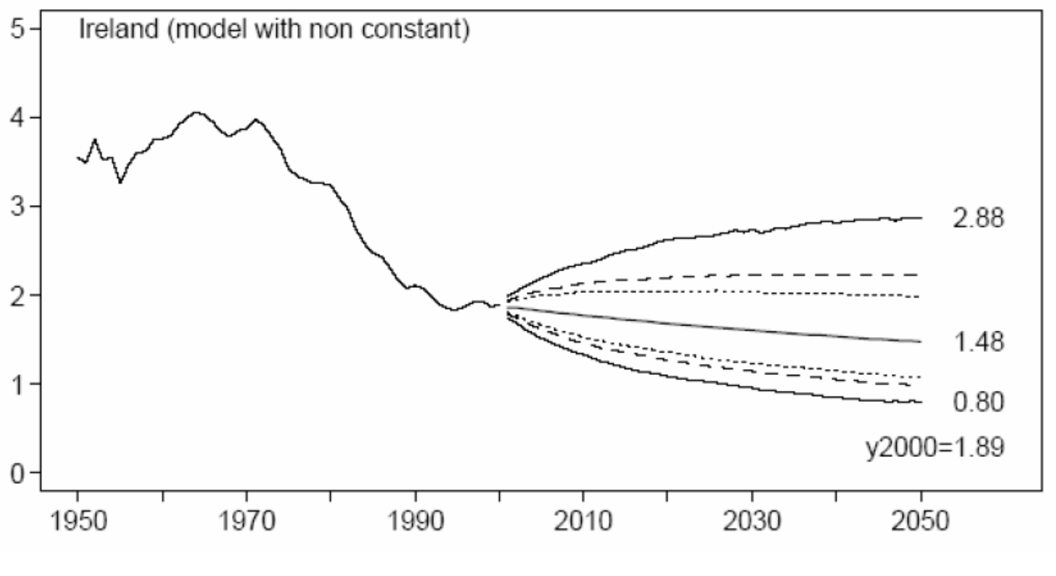

Finland (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.47
1.64
0.76
y2000=1.70

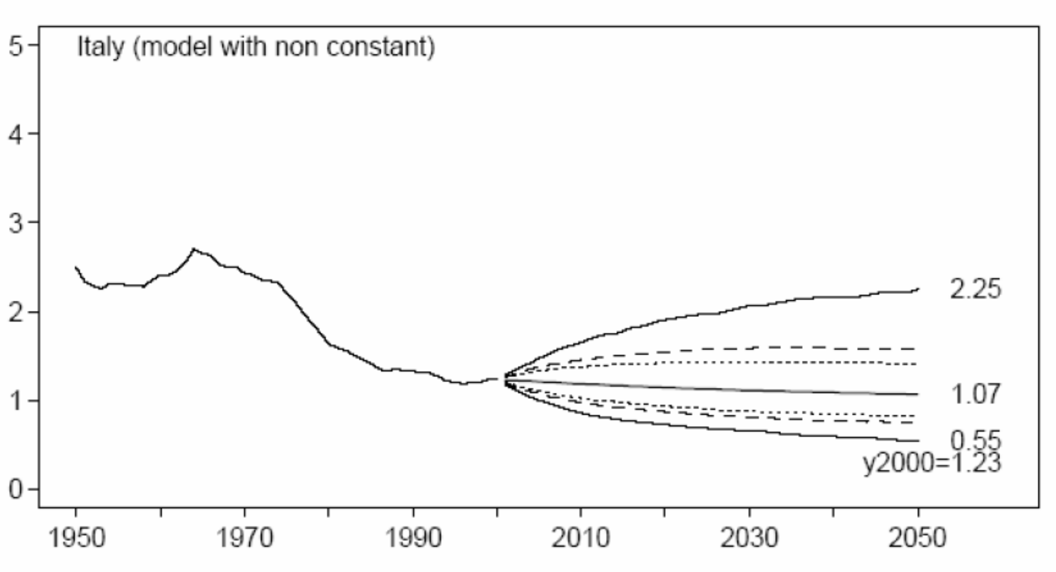

France (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
3.02
1.89
0.94
y2000=1.89

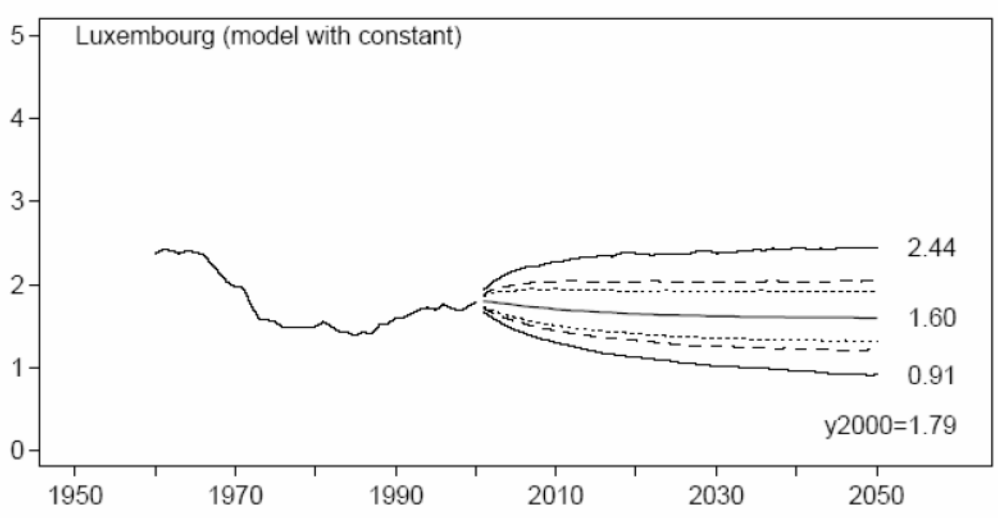

Germany (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
3.33
1.44
0.43
y2000=1.36

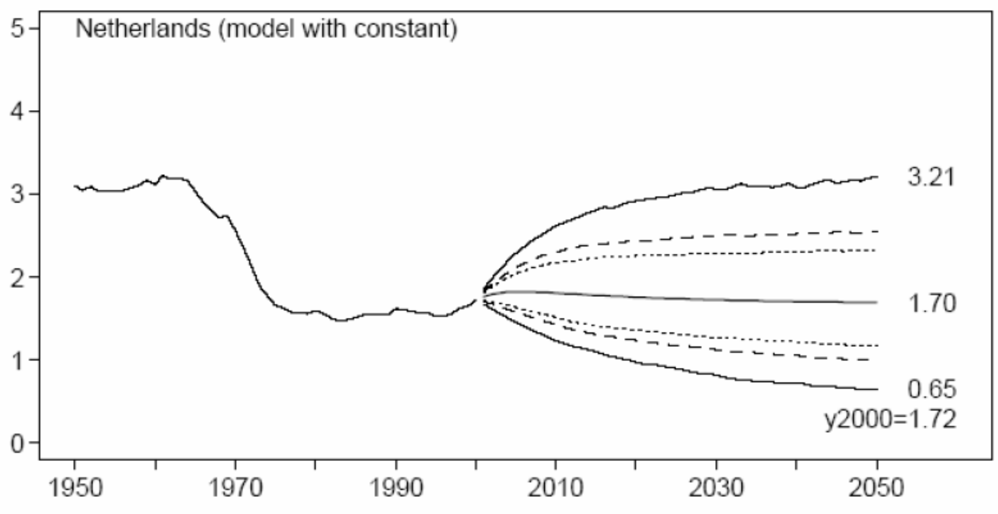

Greece (model with non constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
1.75
1.10
0.72
y2000=1.29

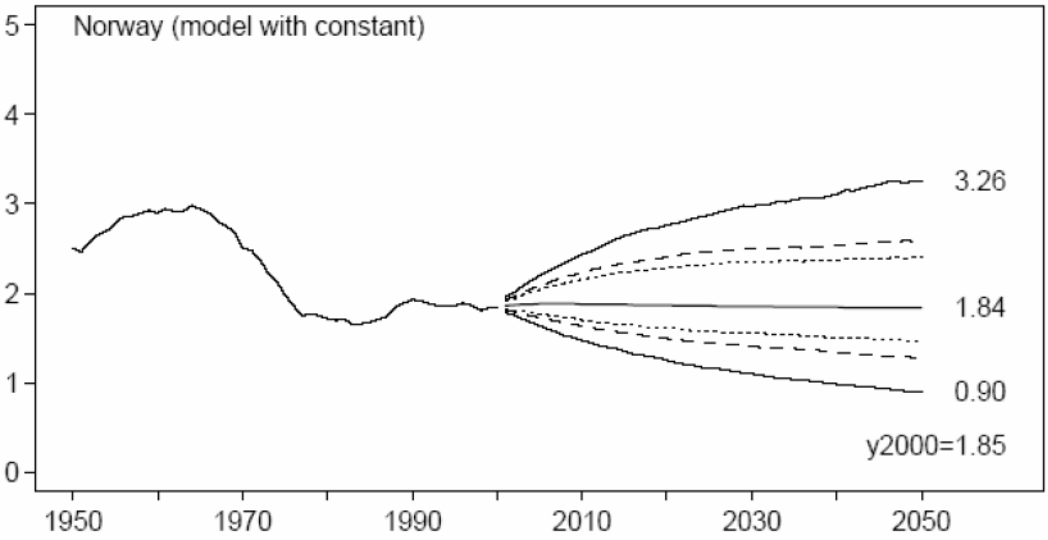

Iceland (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
3.15
1.55
0.79
y2000=2.08

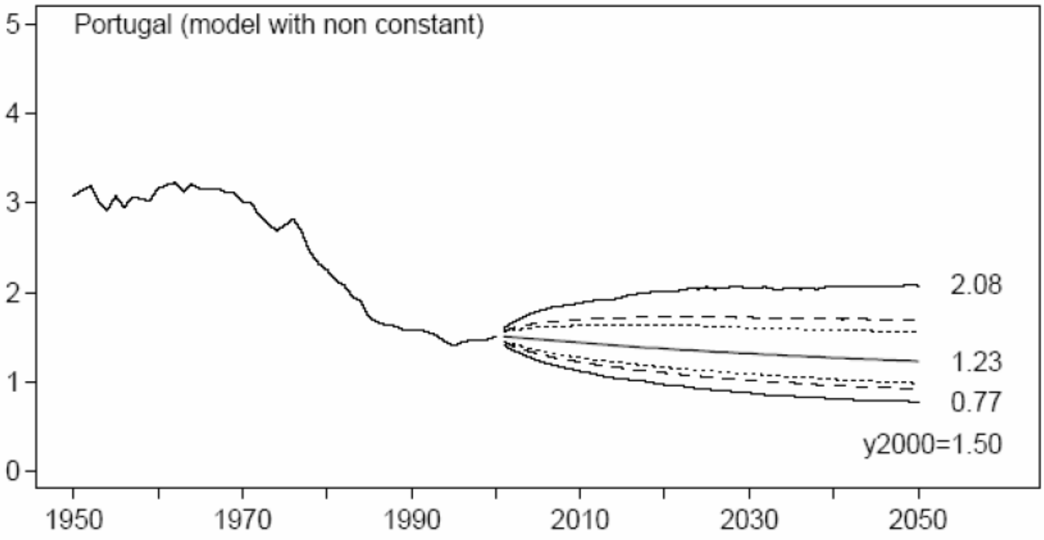

Ireland (model with non constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.88
1.48
0.80
y2000=1.89

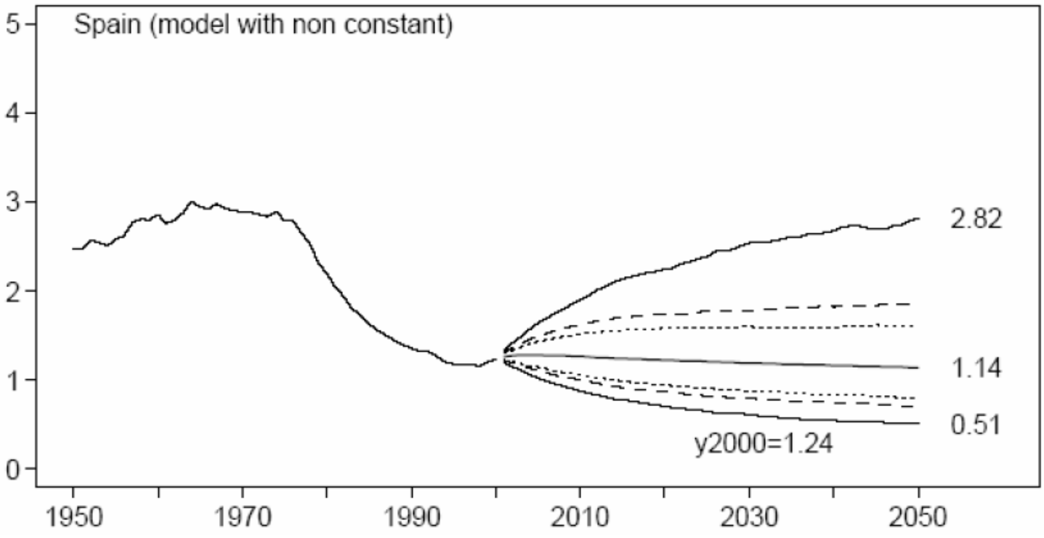

Italy (model with non constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.25
1.07
0.55
y2000=1.23

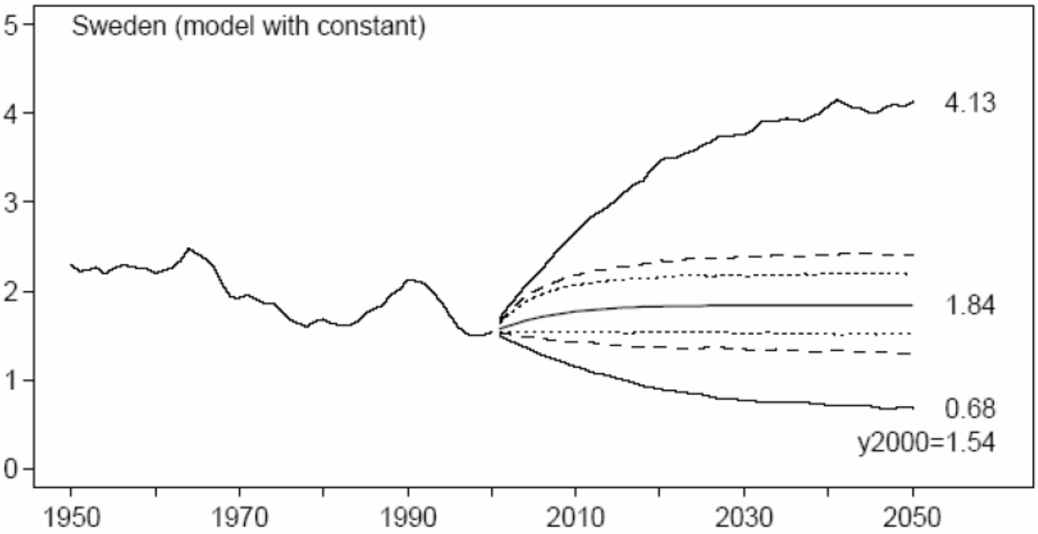

Luxembourg (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.44
1.60
0.91
y2000=1.79

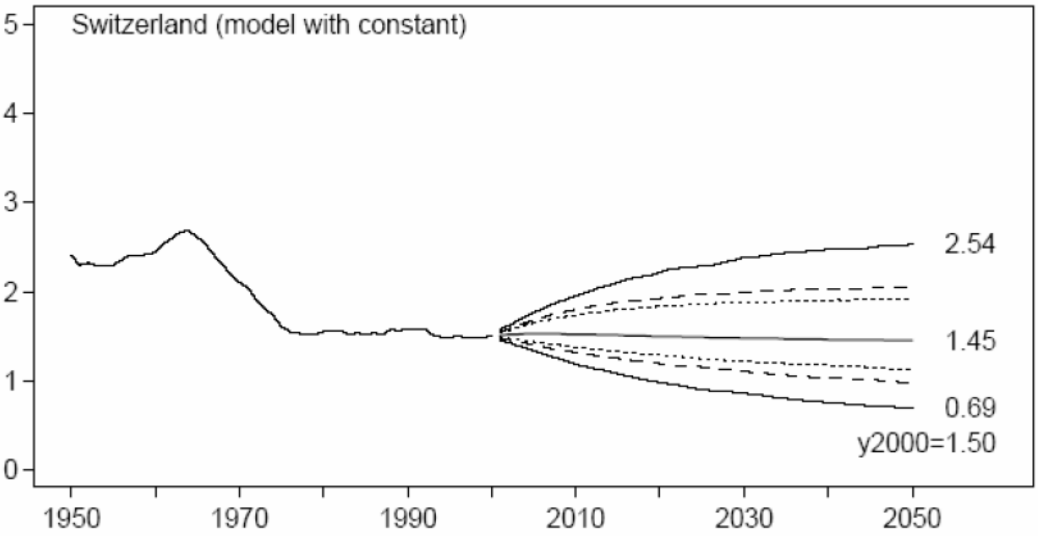

Netherlands (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
3.21
1.70
0.65
y2000=1.72

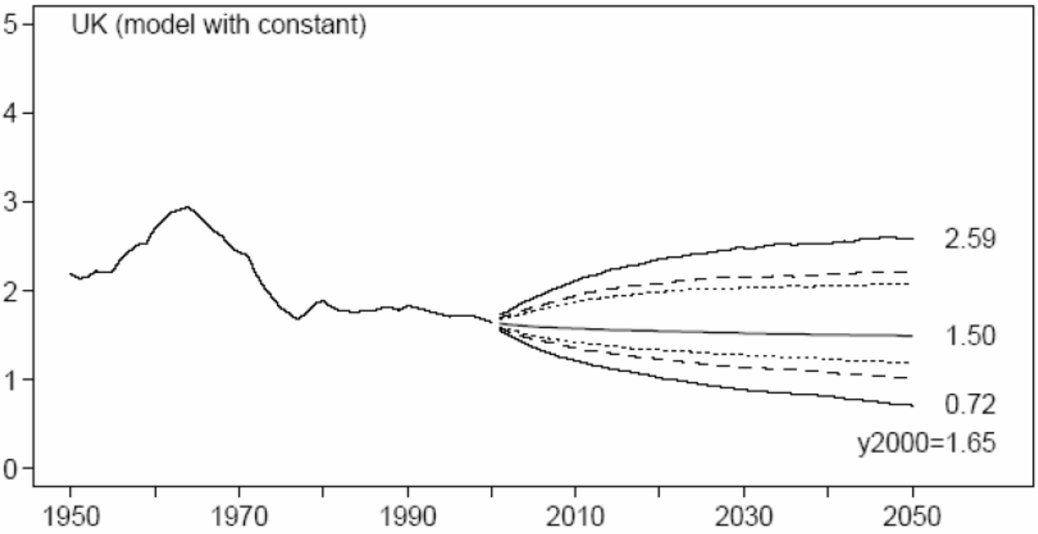

Norway (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
3.26
1.84
0.90
y2000=1.85


Portugal (model with non constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.08
1.23
0.77
y2000=1.50

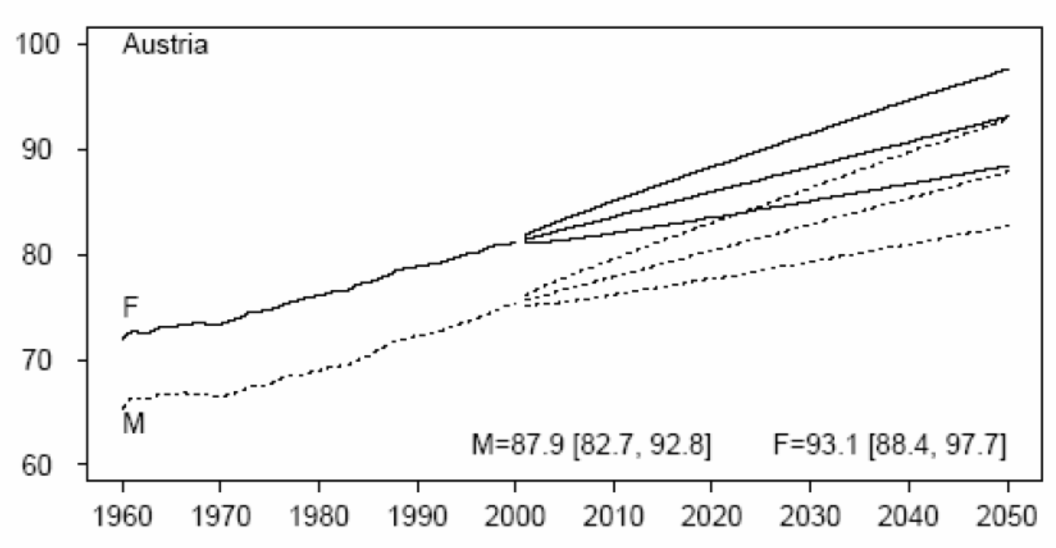

Spain (model with non constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.82
1.14
0.51
y2000=1.24

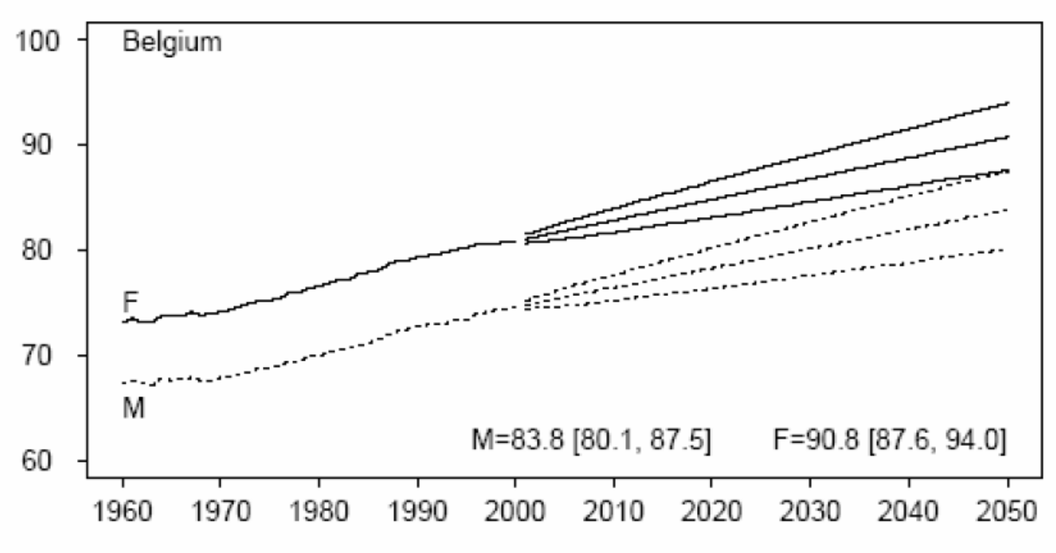

Sweden (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
4.13
1.84
0.68
y2000=1.54

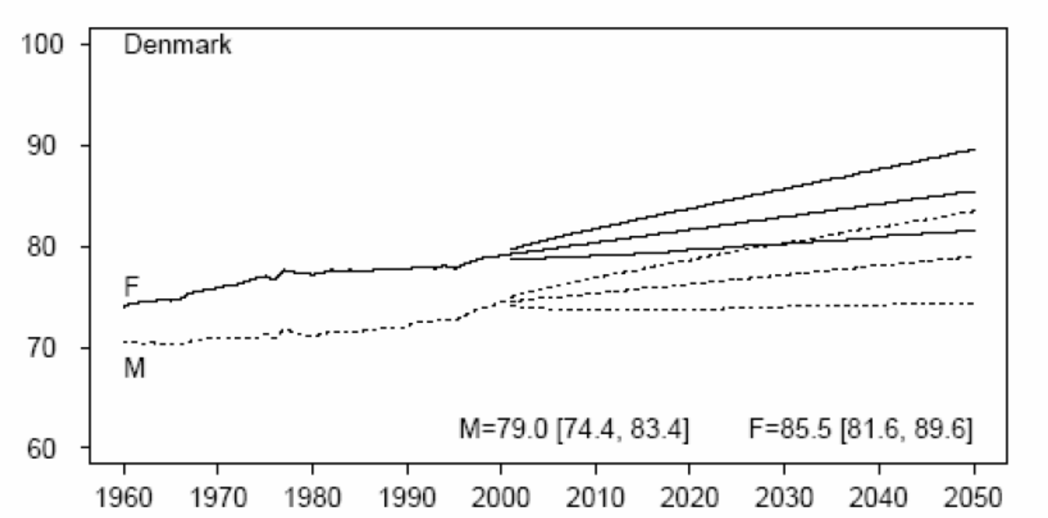

Switzerland (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.54
1.45
0.69
y2000=1.50

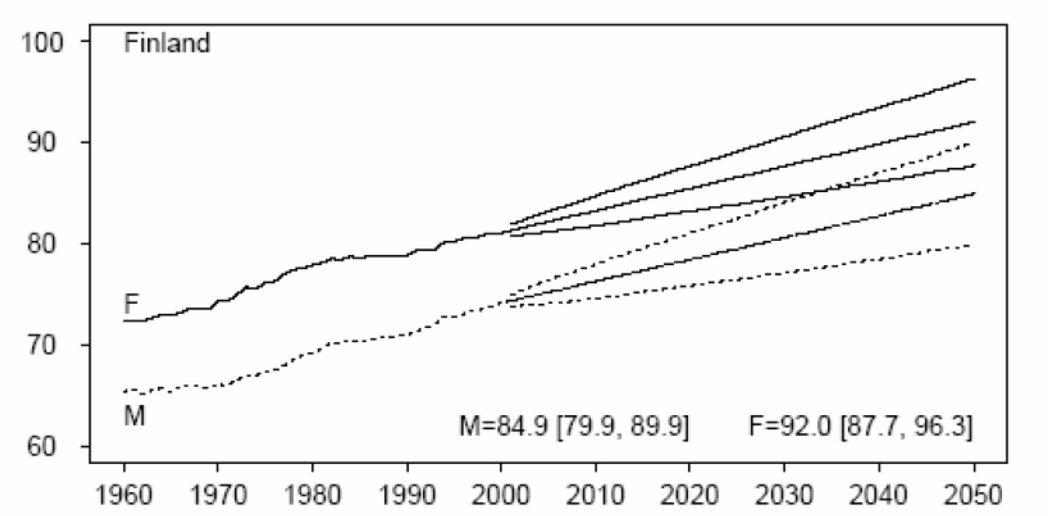

UK (model with constant)
5
4
3
2
1
0
1950
1970
1990
2010
2030
2050
2.59
1.50
0.72
y2000=1.65

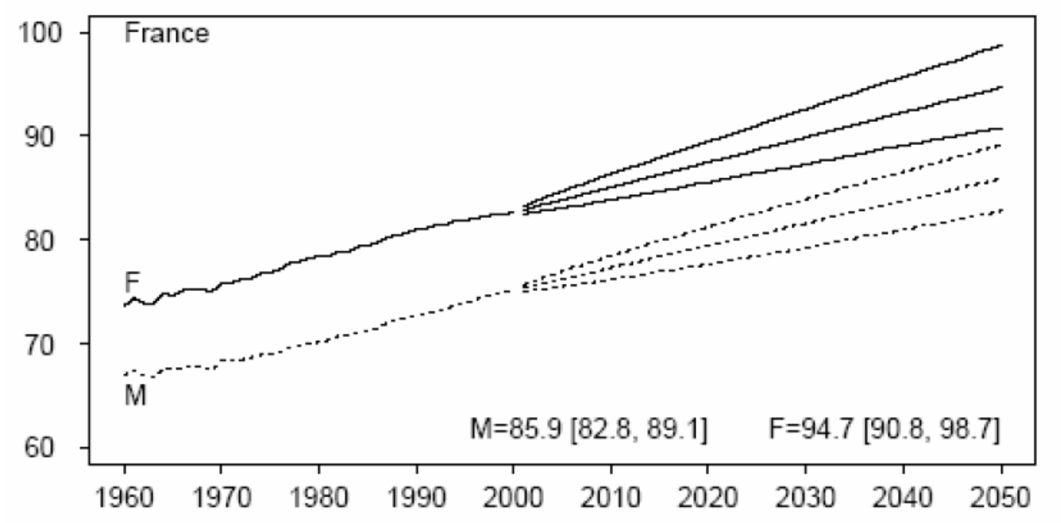
Annex 2: Forecasts and model-based 95% prediction intervals for the life expectancy at birth for men (M) and women (F). Data 1960-2000. Values written in each graph indicate the predicted life expectancy for 2050, and the 95% prediction interval bounds in 2050 in brackets.

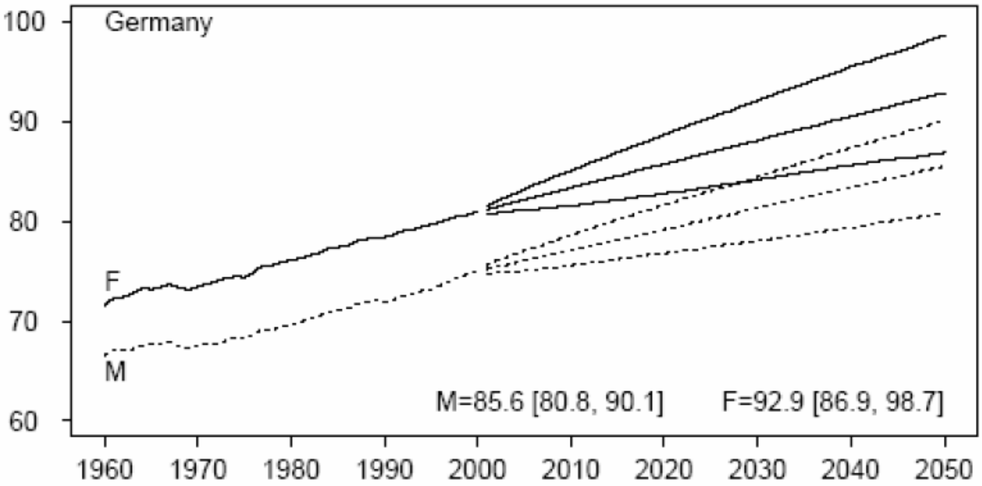


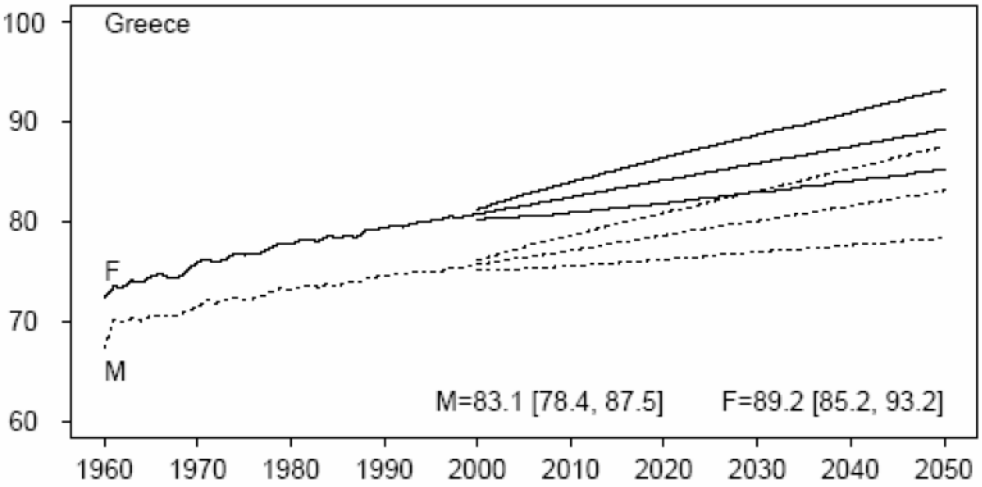


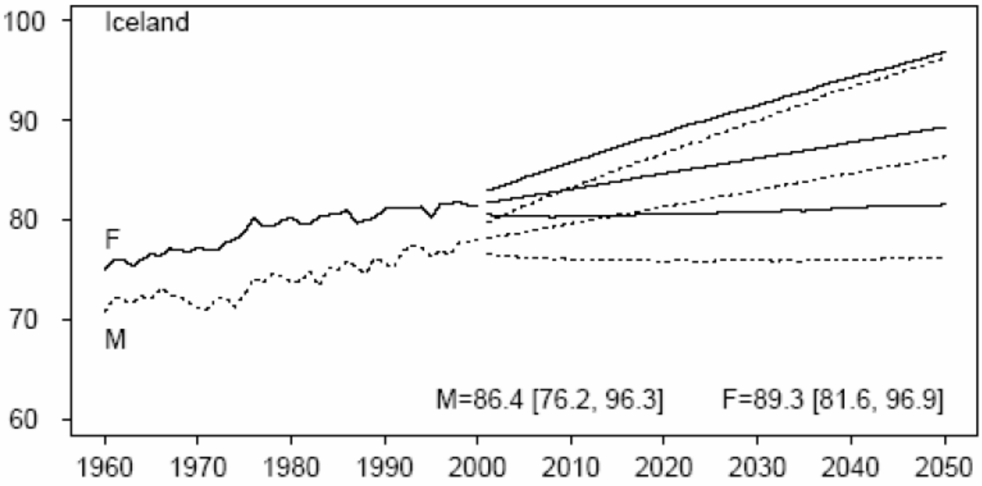

Denmark
100
90
80
70
60
F
M
M=79.0 [74.4, 83.4]
F=85.5 [81.6, 89.6]
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

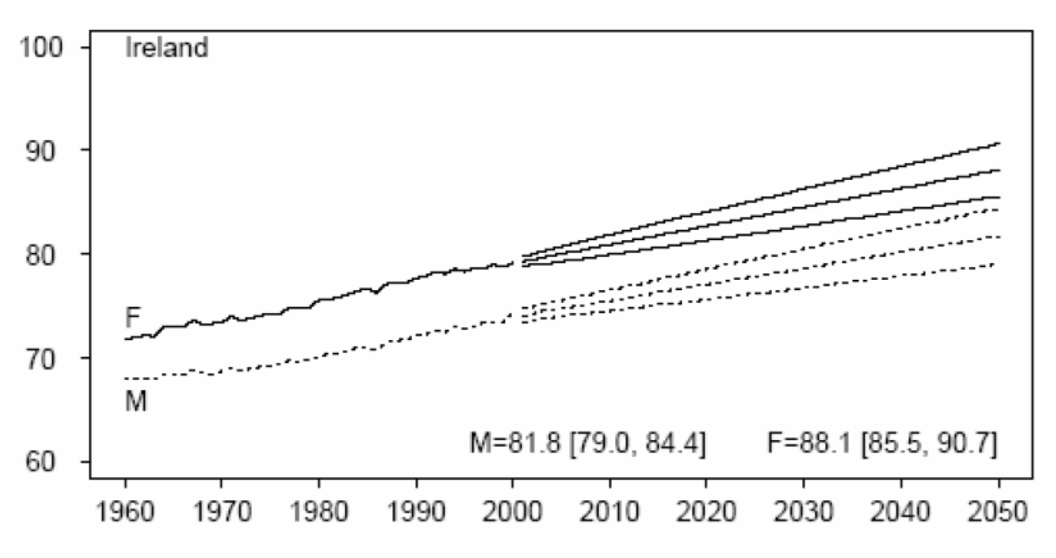

Finland
100
90
80
70
60
F
M
M=84.9 [79.9, 89.9]
F=92.0 [87.7, 96.3]
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

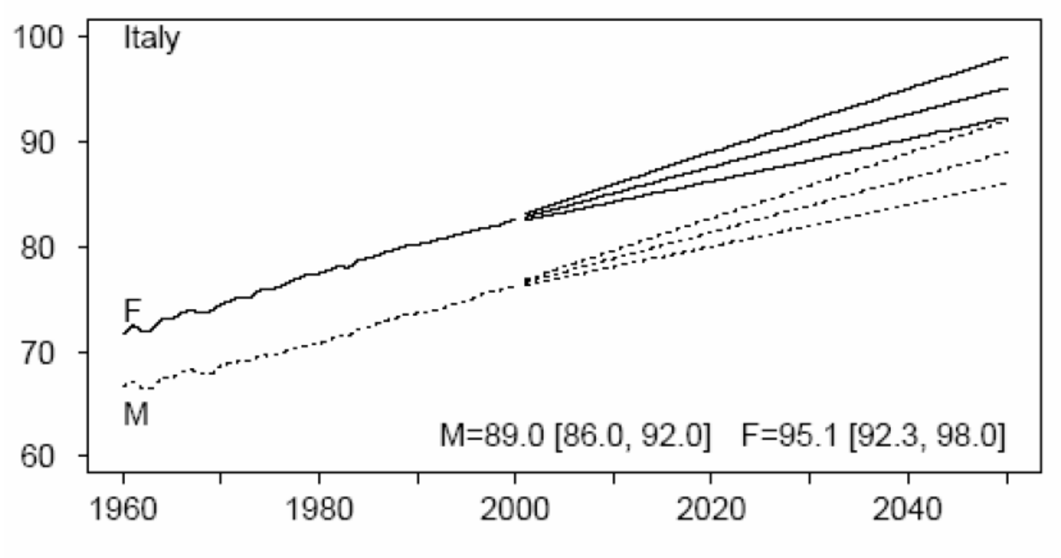

France
100
90
80
70
60
F
M
M=85.9 [82.8, 89.1]
F=94.7 [90.8, 98.7]
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

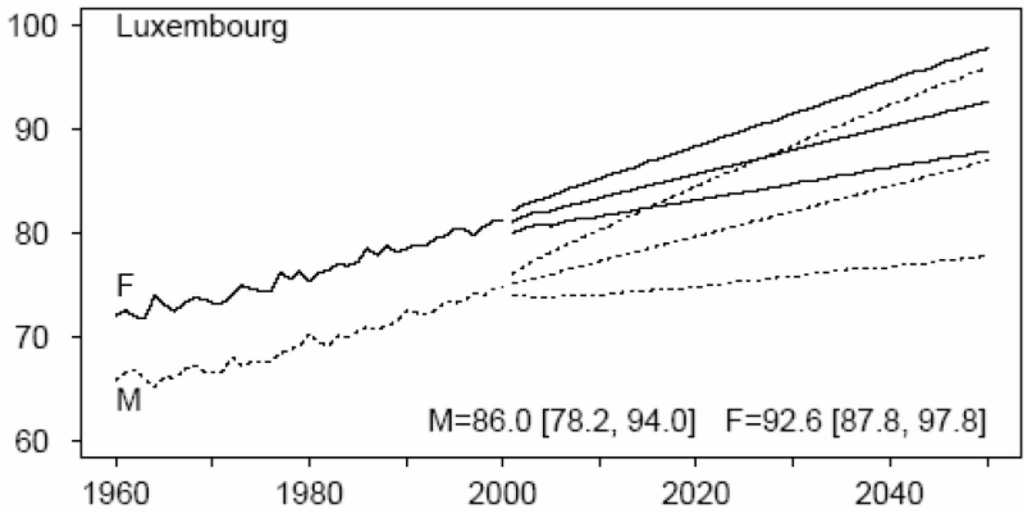

Germany
F
M
M=85.6 [80.8, 90.1]
F=92.9 [86.9, 98.7]
100
90
80
70
60
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

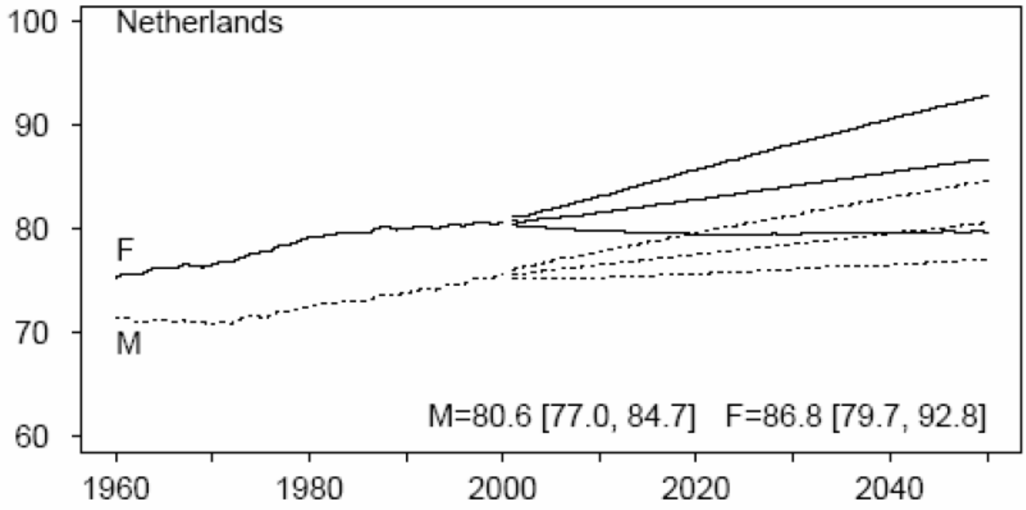

Greece
F
M
M=83.1 [78.4, 87.5]
F=89.2 [85.2, 93.2]
100
90
80
70
60
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

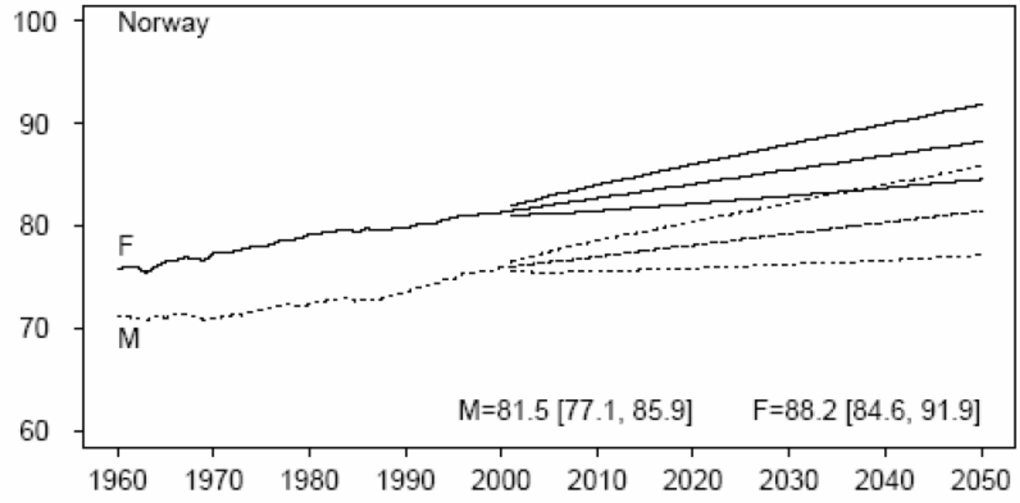

Iceland
F
M
M=86.4 [76.2, 96.3]
F=89.3 [81.6, 96.9]
100
90
80
70
60
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

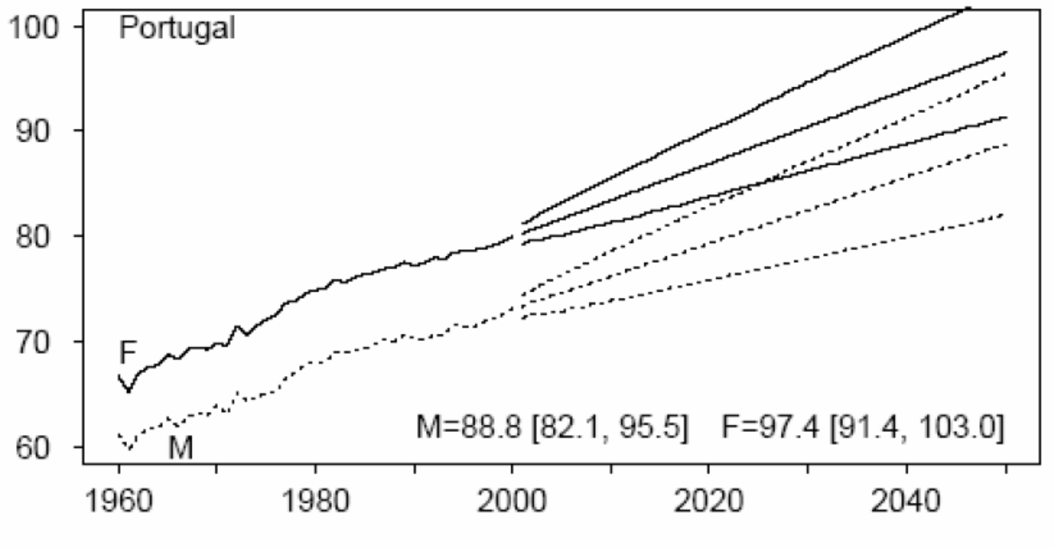

100
90
80
70
60
Ireland
F
M
M=81.8 [79.0, 84.4]
F=88.1 [85.5, 90.7]
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

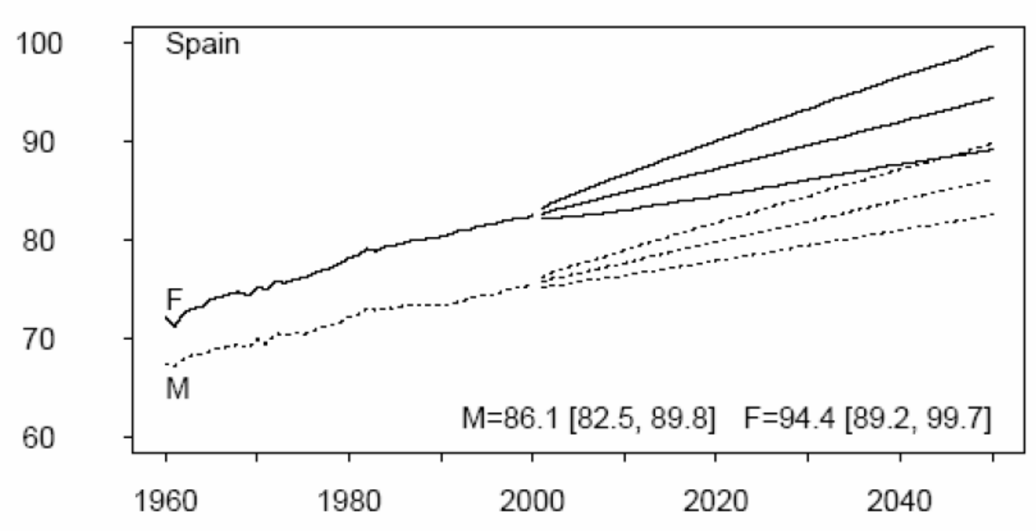

100
90
80
70
60
Italy
F
M
M=89.0 [86.0, 92.0]
F=95.1 [92.3, 98.0]
1960
1980
2000
2020
2040

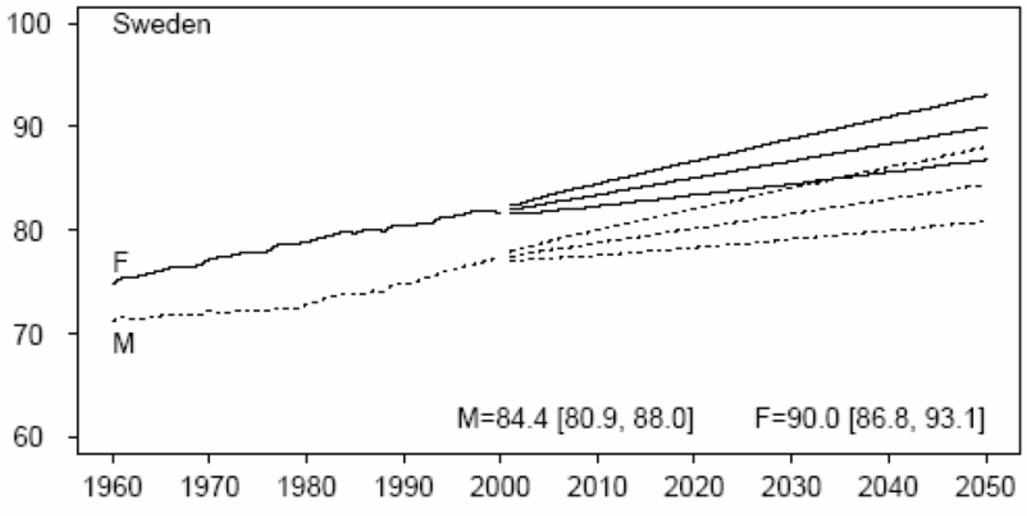

100
90
80
70
60
Luxembourg
F
M
M=86.0 [78.2, 94.0]   F=92.6 [87.8, 97.8]
1960
1980
2000
2020
2040

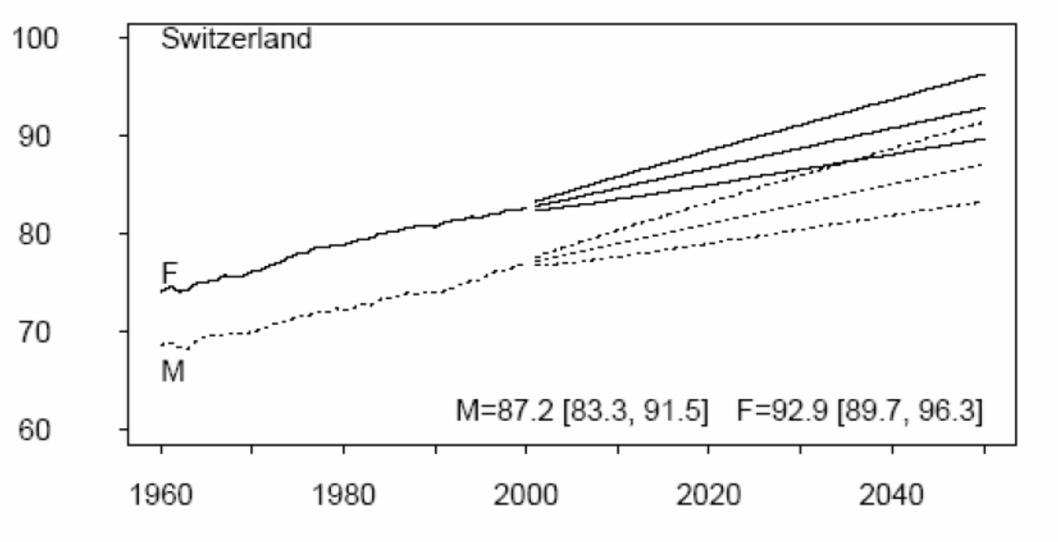

100
90
80
70
60
Netherlands
F
M
M=80.6 [77.0, 84.7]   F=86.8 [79.7, 92.8]
1960
1980
2000
2020
2040

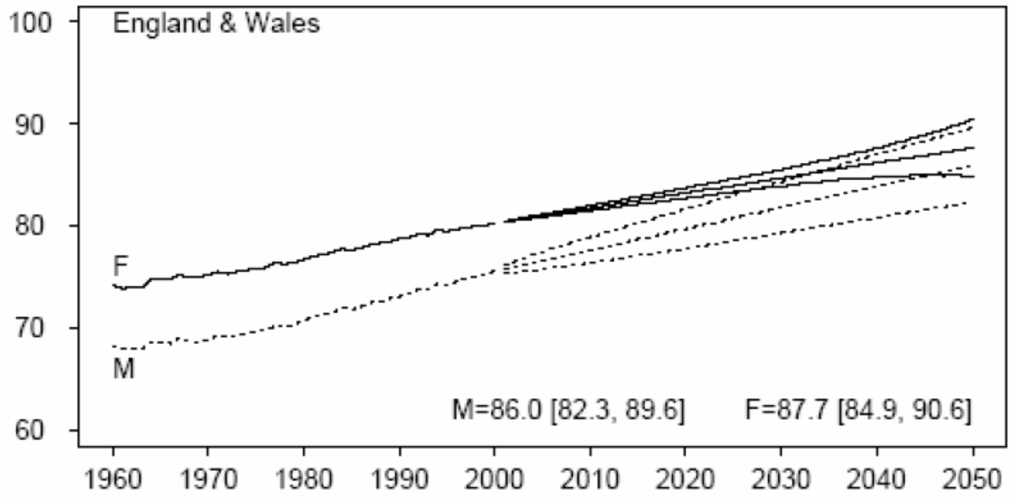

100
90
80
70
60
Norway
F
M
M=81.5 [77.1, 85.9]
F=88.2 [84.6, 91.9]
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050


Portugal
100
90
80
70
60
F
M
M=88.8 [82.1, 95.5]
F=97.4 [91.4, 103.0]
1960
1980
2000
2020
2040

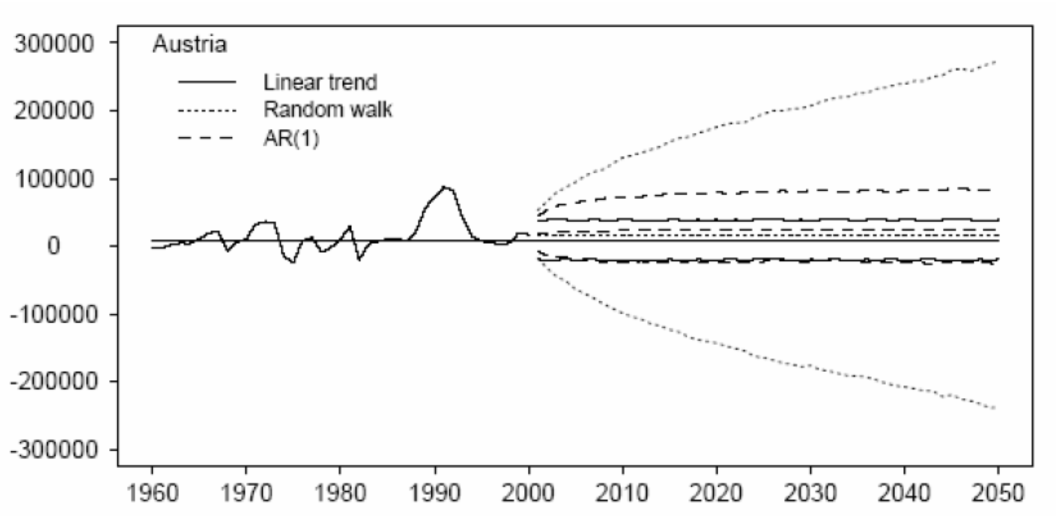

Spain
100
90
80
70
60
F
M
M=86.1 [82.5, 89.8]
F=94.4 [89.2, 99.7]
1960
1980
2000
2020
2040

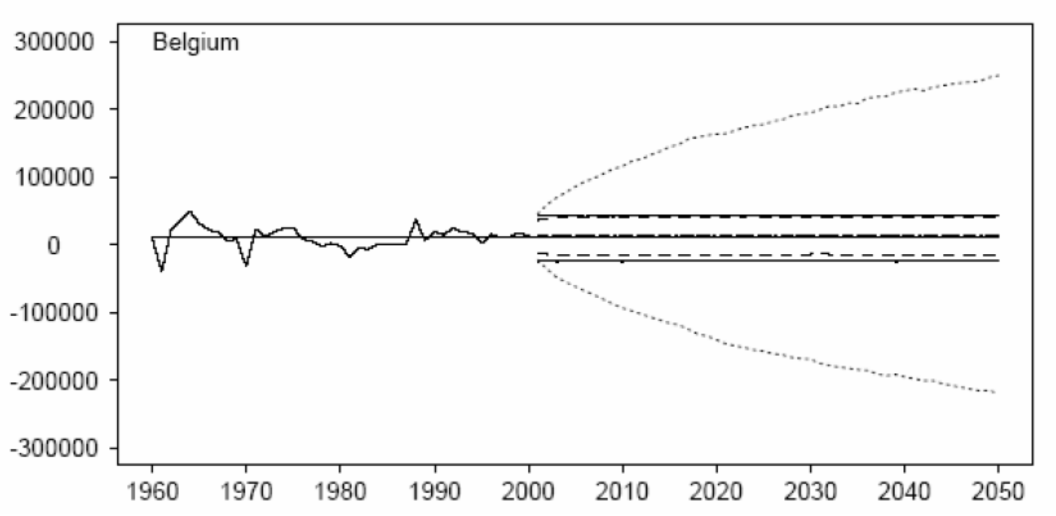

Sweden
100
90
80
70
60
F
M
M=84.4 [80.9, 88.0]
F=90.0 [86.8, 93.1]
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

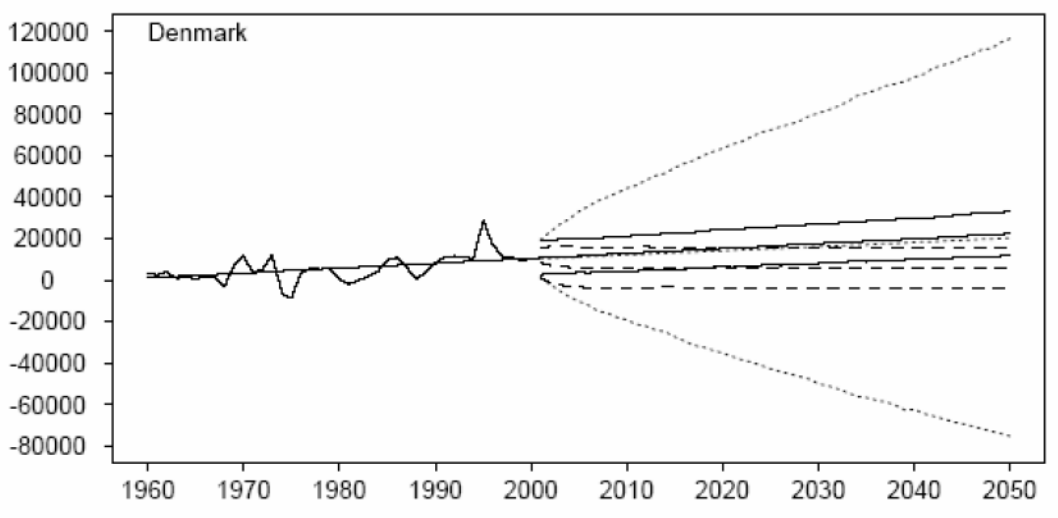

100
90
80
70
60
Switzerland
F
M
M=87.2 [83.3, 91.5]   F=92.9 [89.7, 96.3]
1960
1980
2000
2020
2040

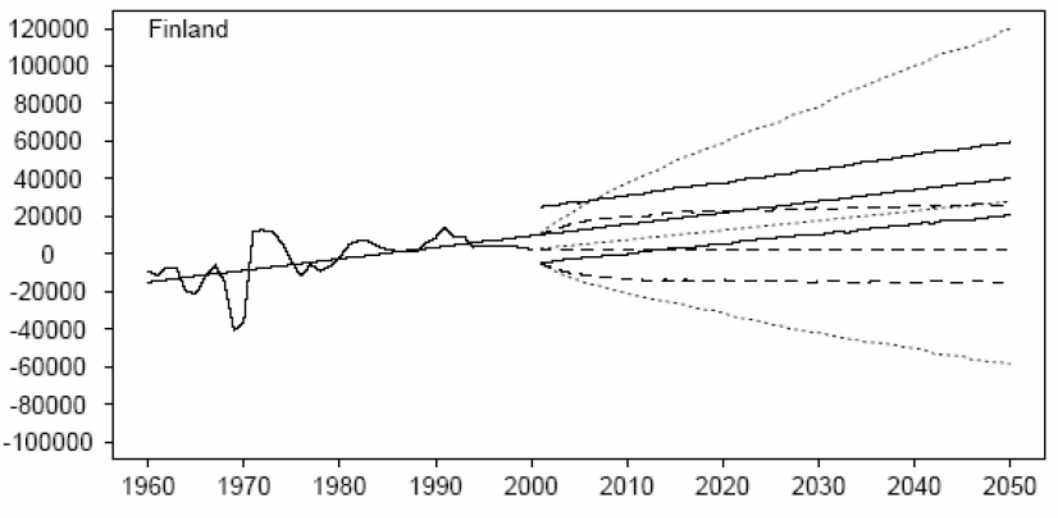

100
90
80
70
60
England & Wales
F
M
M=86.0 [82.3, 89.6]   F=87.7 [84.9, 90.6]
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

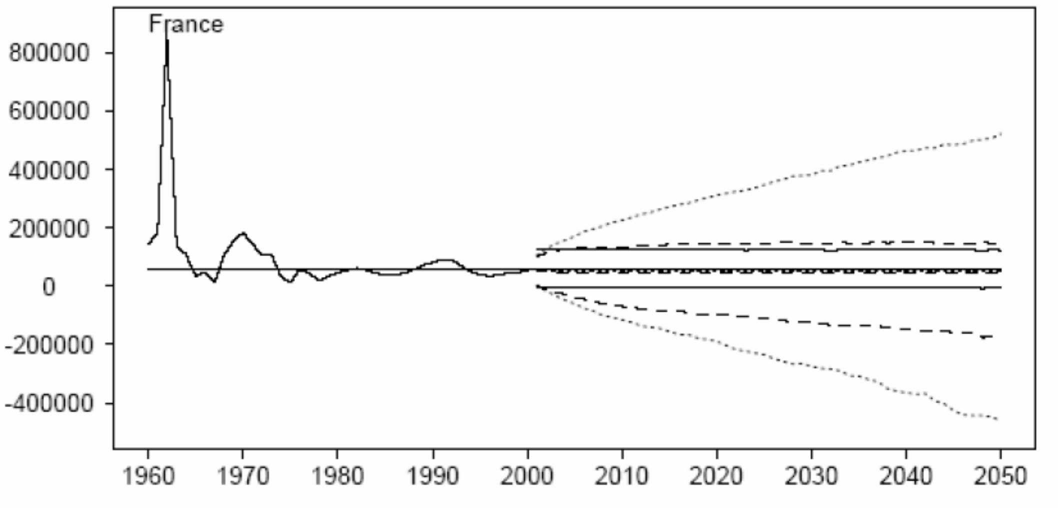
Annex 3: Forecasts and model-based 95% prediction intervals for net migration. Data 1960-2000.

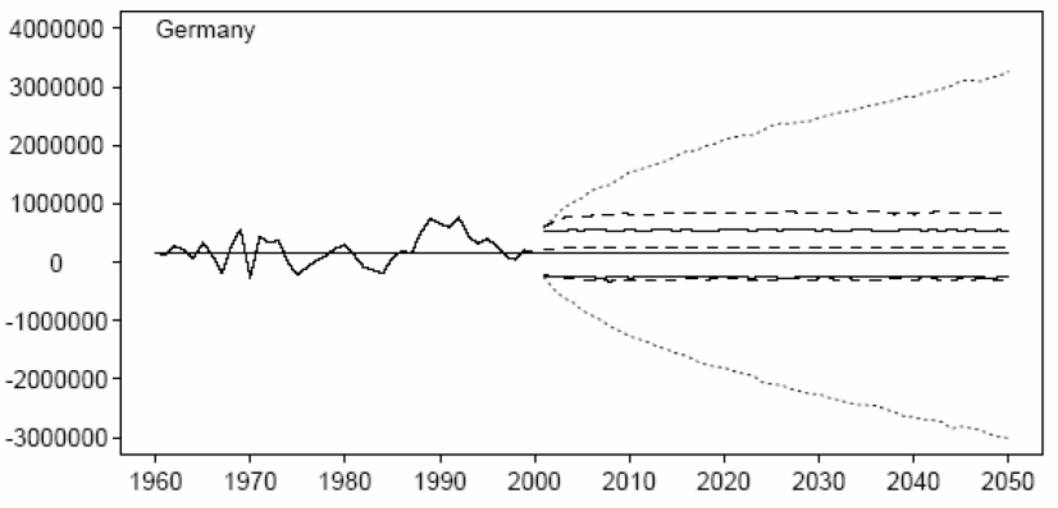


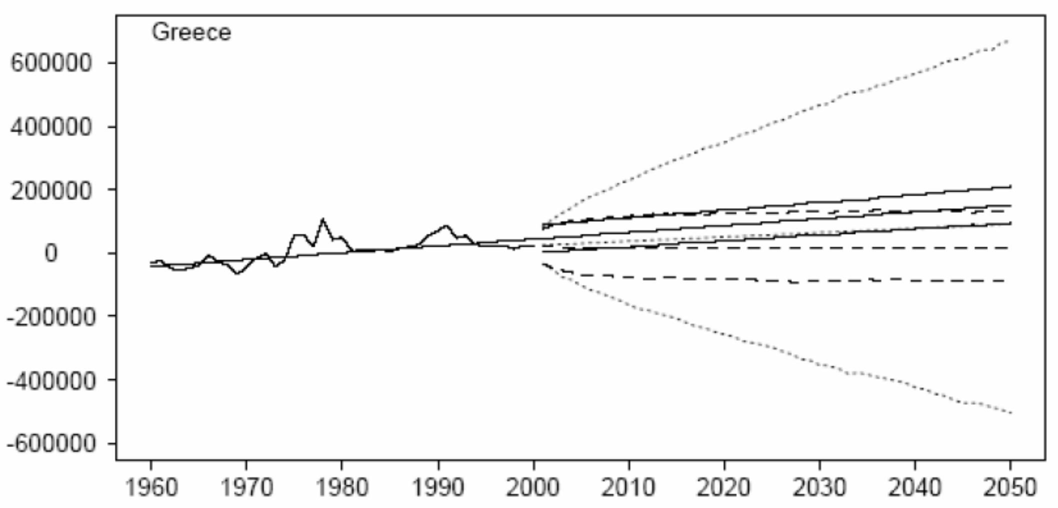


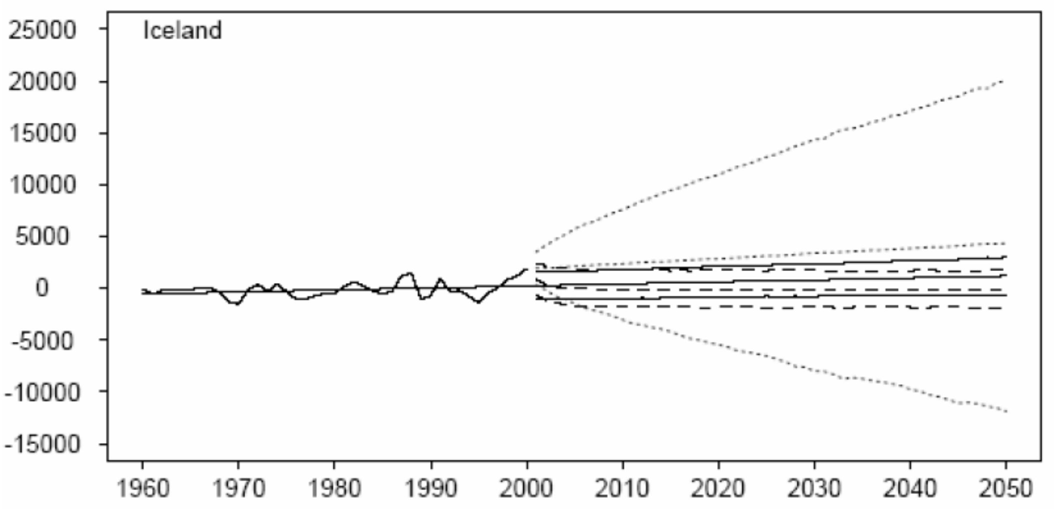

Denmark
120000
100000
80000
60000
40000
20000
0
-20000
-40000
-60000
-80000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

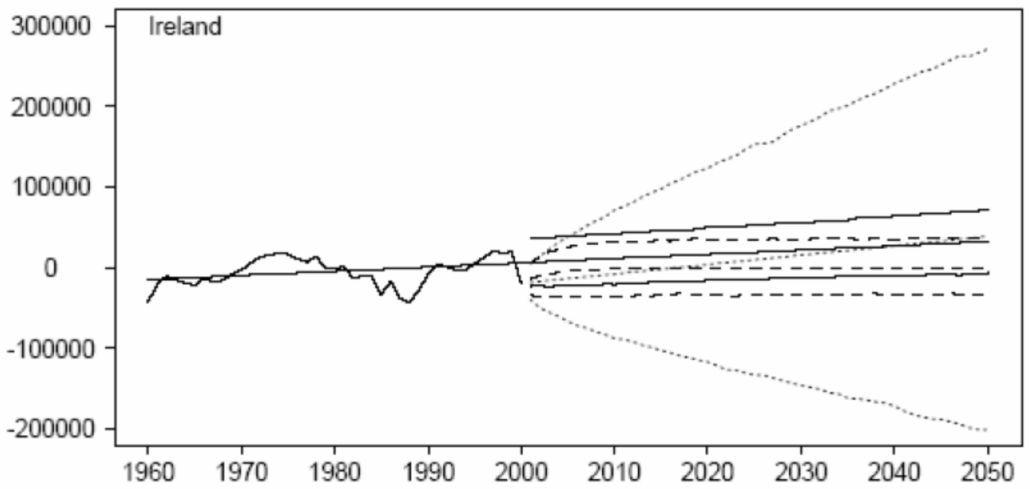

Finland
120000
100000
80000
60000
40000
20000
0
-20000
-40000
-60000
-80000
-100000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

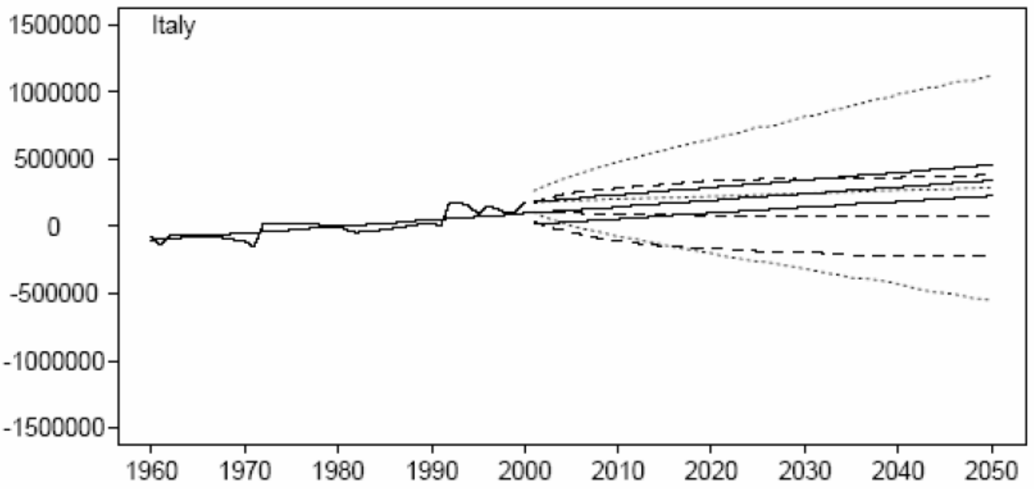

France
800000
600000
400000
200000
0
-200000
-400000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

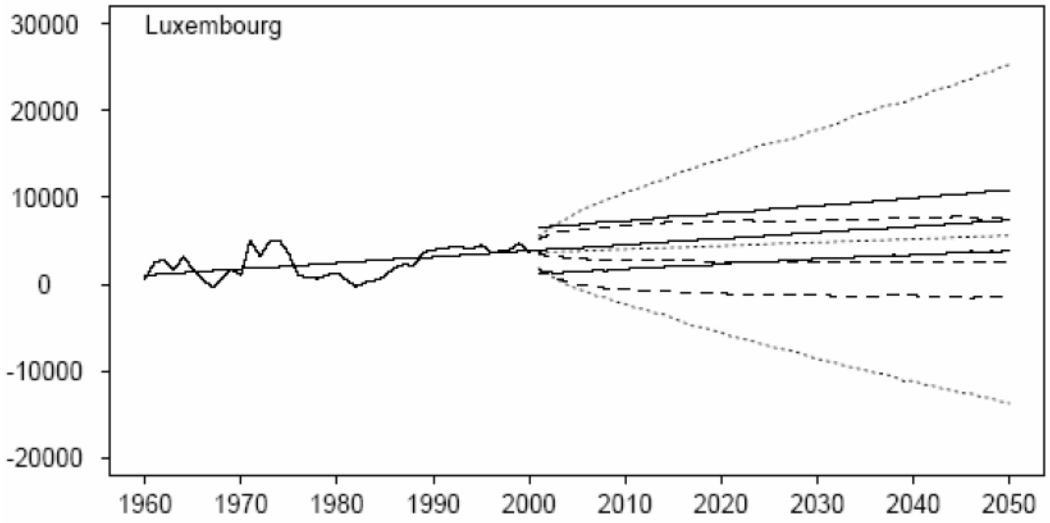

Germany
4000000
3000000
2000000
1000000
0
-1000000
-2000000
-3000000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

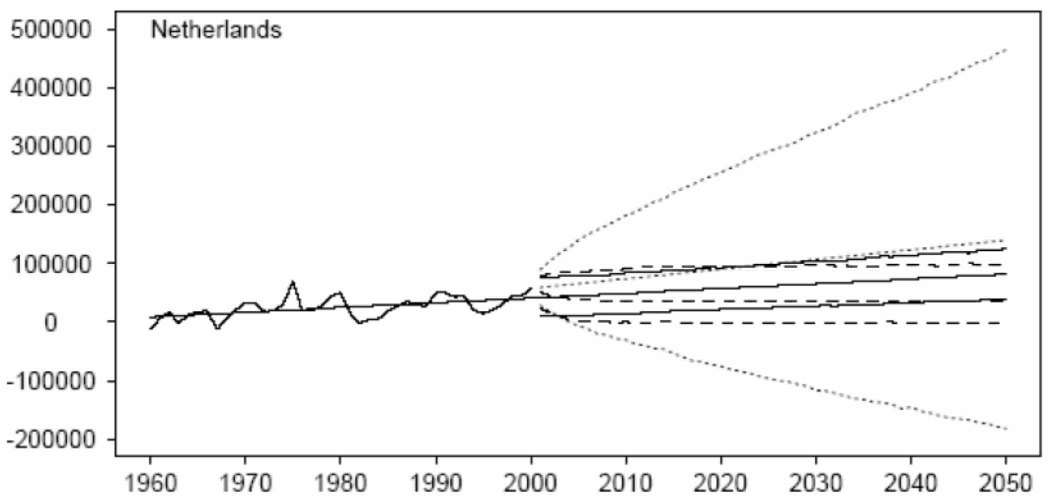

Greece
600000
400000
200000
0
-200000
-400000
-600000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

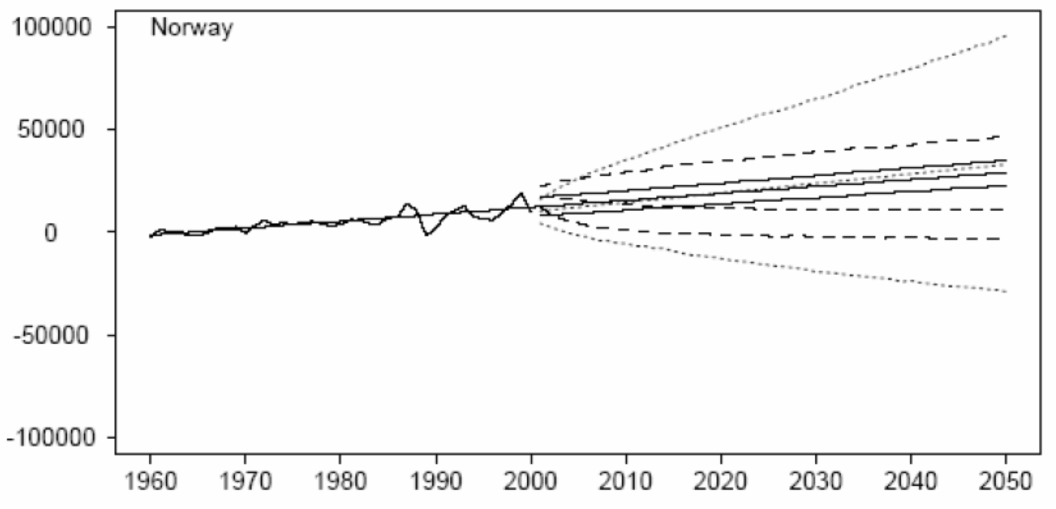

Iceland
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

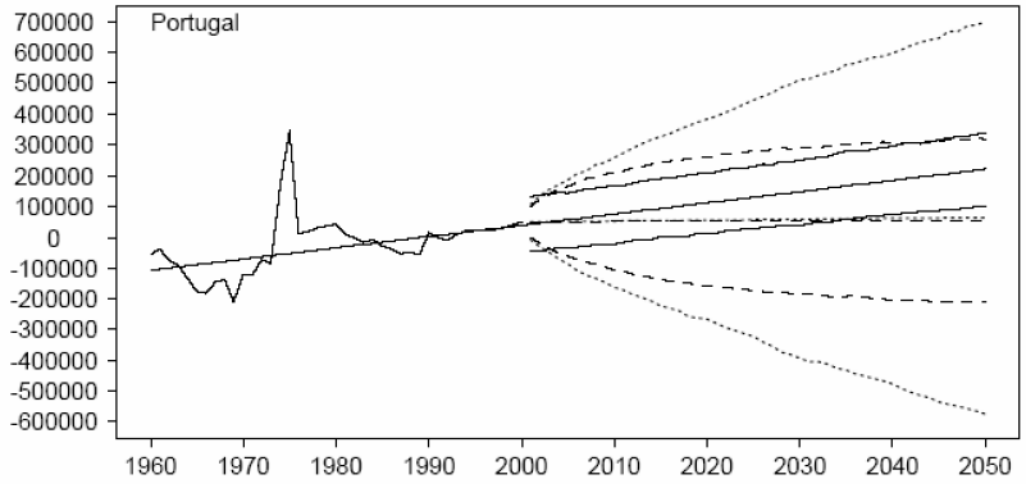

Ireland
300000
200000
100000
0
-100000
-200000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

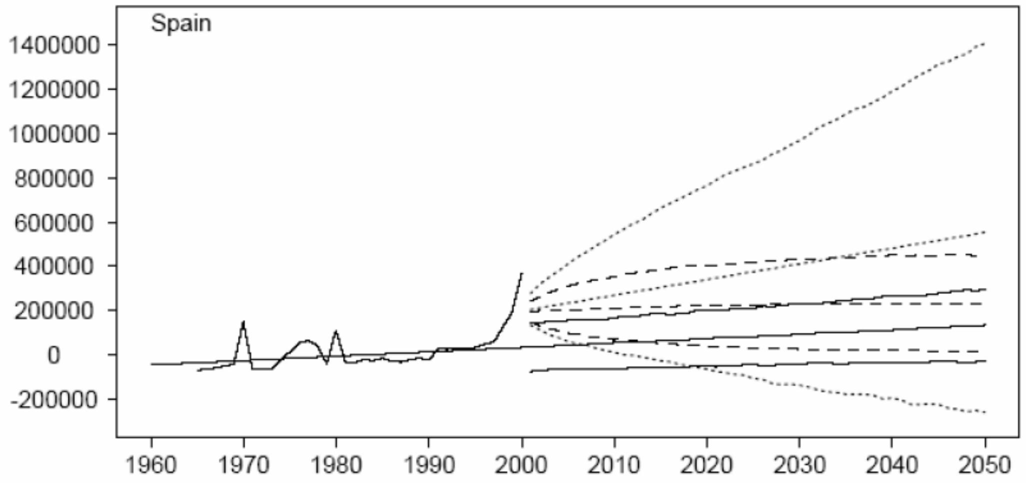

Italy
1500000
1000000
500000
0
-500000
-1000000
-1500000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

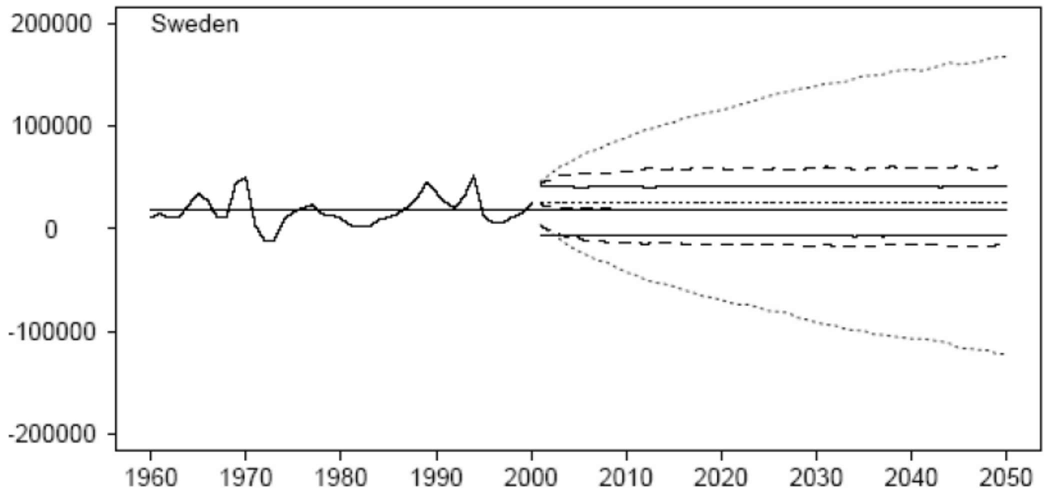

Luxembourg
30000
20000
10000
0
-10000
-20000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

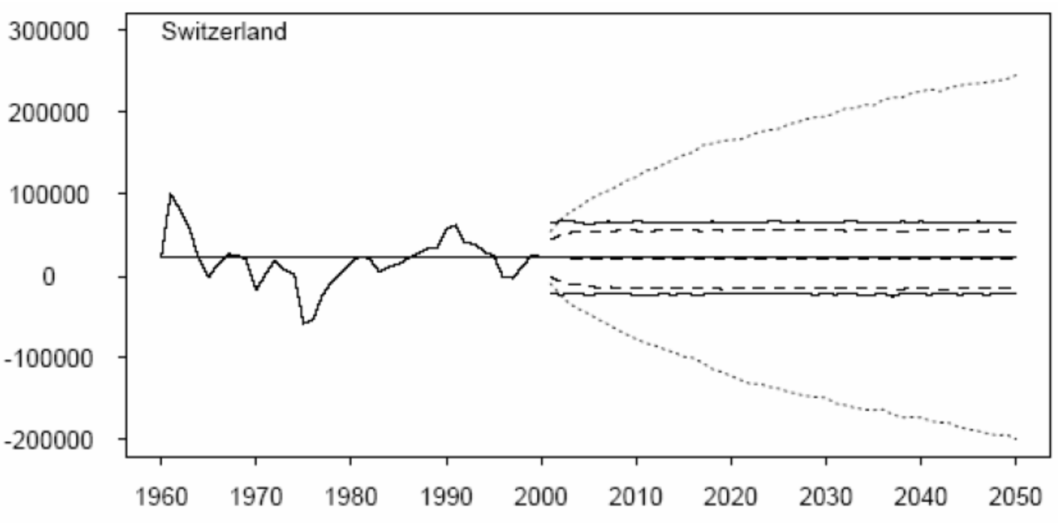

Netherlands
500000
400000
300000
200000
100000
0
-100000
-200000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

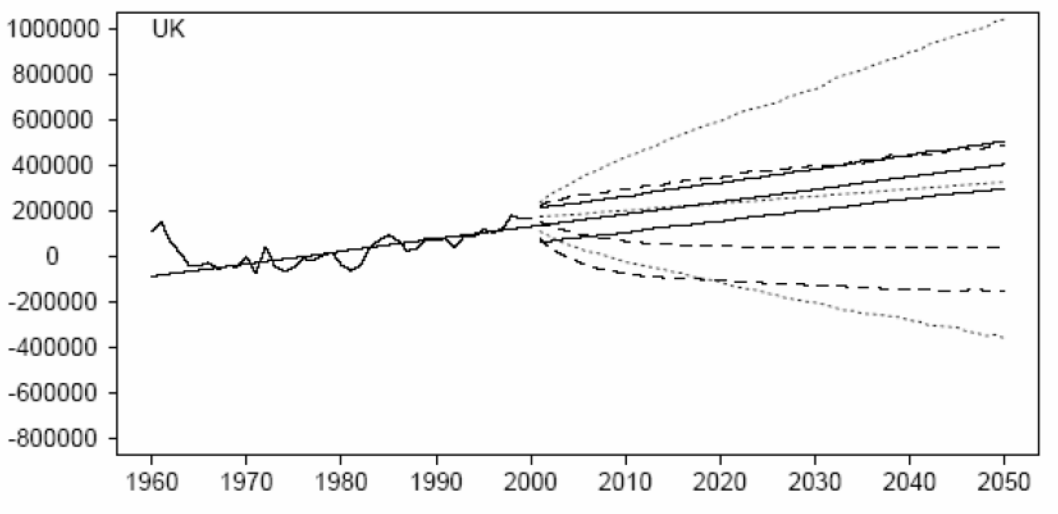

Norway
100000
50000
0
-50000
-100000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050


Portugal
700000
600000
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
-400000
-500000
-600000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050


Spain
1400000
1200000
1000000
800000
600000
400000
200000
0
-200000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050


Sweden
200000
100000
0
-100000
-200000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050


Switzerland
300000
200000
100000
0
-100000
-200000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050


UK
1000000
800000
600000
400000
200000
0
-200000
-400000
-600000
-800000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

Annex 4. Correlation structures across countries used for the assumptions concerning stochastic population forecasts for the EEA+

Table 1. Correlations for residuals, TFR time series, data 1950-2000

	A	B	Dk	SF	F	D	EL	Is	IRL	I	Lux	Nl	N	P	E	S	CH
Austria	1																
Belgium	0.333	1															
Denmark	0.247	0.086	1														
Finland	0.250	0.148	0.230	1													
France	0.408	0.540	0.192	-0.051	1												
Germany	0.419	0.437	0.105	0.378	0.291	1											
Greece	0.034	0.047	-0.105	0.250	-0.128	0.081	1										
Iceland	0.205	0.166	0.348	0.126	0.102	0.117	0.069	1									
Ireland	0.134	0.430	0.087	-0.032	0.440	0.242	-0.011	0.119	1								
Italy	0.136	0.271	0.122	0.283	0.226	0.180	0.239	0.263	0.231	1							
Luxembourg	0.525	0.476	0.293	0.400	0.342	0.531	0.104	0.124	0.106	0.151	1						
Netherlands	0.325	0.444	0.032	0.173	0.331	0.488	-0.040	0.048	0.305	0.084	0.253	1					
Norway	0.438	0.335	0.405	0.148	0.289	0.230	-0.107	0.436	0.140	0.272	0.327	0.294	1				
Portugal	0.161	0.321	0.005	0.095	0.095	0.250	0.103	0.153	0.176	0.162	0.279	0.17	-0.076	1			
Spain	0.152	0.262	0.181	0.211	0.096	0.195	0.247	0.121	0.336	0.440	-0.008	0.154	0.055	0.579	1		
Sweden	0.262	0.373	0.382	0.348	0.337	0.247	0.112	0.248	0.128	0.236	0.363	0.227	0.343	0.094	0.260	1	
Switzerland	0.535	0.633	0.299	0.240	0.573	0.364	-0.078	0.206	0.366	0.239	0.474	0.230	0.508	0.064	0.249	0.451	1
England & Wales	0.347	0.435	0.277	0.103	0.277	0.329	-0.001	0.284	0.400	0.122	0.303	0.331	0.467	-0.014	0.038	0.390	0.592

Table 2. Correlations for residuals across countries, life expectancy time series, data 1960-2000. Men

	A	B	Dk	SF	F	D	EL	Is	IRL	I	Lux	NI	N	P	E	S	CH
Austria	1																
Belgium	0.326	1															
Denmark	0.114	0.348	1														
Finland	0.289	0.315	0.340	1													
France	0.477	0.712	0.287	0.374	1												
Germany	0.477	0.611	0.080	0.161	0.601	1											
Greece	-0.238	-0.028	0.025	-0.099	0.046	-0.044	1										
Iceland	0.453	-0.039	0.021	0.355	0.048	0.211	-0.100	1									
Ireland	0.100	0.527	0.287	0.241	0.482	0.414	-0.111	-0.001	1								
Italy	0.280	0.569	0.143	0.355	0.632	0.511	0.034	0.218	0.253	1							
Luxembourg	-0.015	0.077	0.056	0.062	-0.064	-0.200	-0.123	0.015	-0.010	-0.181	1						
Netherlands	0.315	0.665	0.288	0.315	0.678	0.549	-0.029	-0.219	0.539	0.295	0.002	1					
Norway	0.192	0.460	0.311	0.499	0.387	0.305	-0.046	0.176	0.528	0.324	0.096	0.371	1				
Portugal	-0.211	-0.040	-0.017	0.346	-0.060	-0.180	-0.036	0.087	-0.023	-0.021	0.216	0.024	-0.12	1			
Spain	0.004	-0.069	0.063	0.453	0.084	0.119	-0.001	0.140	-0.001	0.035	0.012	-0.029	0.013	0.621	1		
Sweden	0.203	0.451	0.295	0.508	0.497	0.459	-0.097	0.142	0.471	0.470	0.001	0.303	0.451	0.057	0.180	1	
Switzerland	0.335	0.495	0.259	0.384	0.441	0.414	-0.215	0.270	0.247	0.727	-0.048	0.311	0.371	0.076	0.019	0.339	1
England & Wales	-0.019	0.537	0.320	0.177	0.454	0.383	-0.02	-0.152	0.811	0.259	-0.047	0.579	0.527	0.032	0.008	0.395	0.289

Table 3. Correlations for residuals across countries, life expectancy time series, data 1960-2000. Women

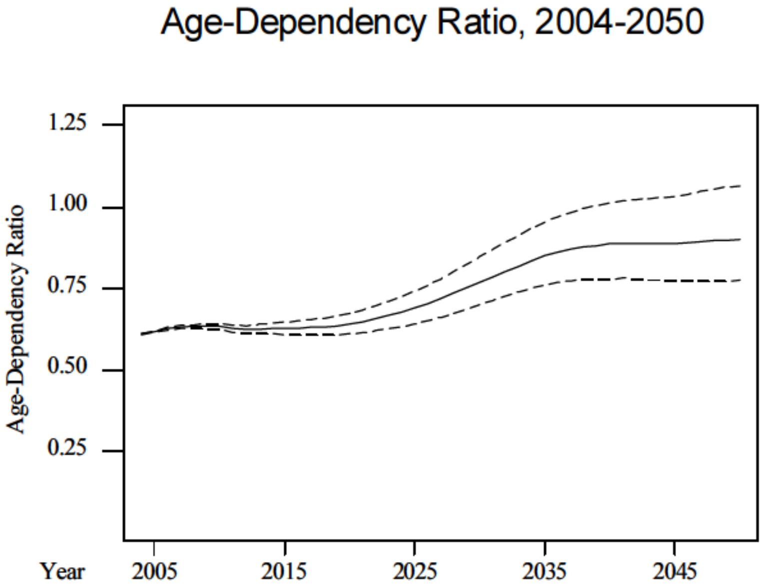
	A	B	Dk	SF	F	D	EL	Is	IRL	I	Lux	Nl	N	P	E	S	CH
Austria	1																
Belgium	0.440	1															
Denmark	0.099	0.128	1														
Finland	0.190	0.257	0.315	1													
France	0.603	0.642	0.311	0.141	1												
Germany	0.618	0.509	0.256	0.233	0.606	1											
Greece	-0.067	-0.114	-0.059	0.037	0.079	-0.109	1										
Iceland	-0.026	-0.122	0.030	0.083	0.104	-0.026	-0.089	1									
Ireland	0.086	0.442	0.095	-0.018	0.414	0.220	-0.152	0.103	1								
Italy	0.396	0.558	0.164	0.102	0.719	0.460	0.257	-0.139	0.232	1							
Luxembourg	0.331	0.507	0.104	0.114	0.250	0.158	-0.130	-0.041	-0.006	0.216	1						
Netherlands	0.450	0.510	0.399	0.169	0.544	0.472	-0.088	-0.042	0.394	0.316	0.235	1					
Norway	0.068	0.171	0.240	0.366	0.443	0.191	0.012	0.274	0.344	0.305	0.199	0.218	1				
Portugal	-0.142	0.012	-0.069	0.419	-0.127	-0.042	-0.070	-0.177	-0.017	-0.022	-0.057	0.073	-0.043	1			
Spain	-0.071	0.065	-0.160	0.350	0.010	0.002	0.014	-0.108	0.237	-0.005	-0.195	0.067	0.269	0.742	1		
Sweden	0.105	0.105	0.335	0.390	0.364	0.427	0.265	-0.120	0.117	0.307	-0.085	0.127	0.462	0.006	0.126	1	
Switzerland	0.291	0.579	0.450	0.455	0.555	0.483	-0.198	0.165	0.367	0.500	0.299	0.532	0.424	0.128	0.080	0.372	1
England & Wales	0.096	0.460	0.147	0.202	0.312	0.231	-0.087	-0.080	0.727	0.207	-0.028	0.338	0.343	0.113	0.294	0.233	0.374

Table 4. Correlations for observed net migration, data 1960-2000

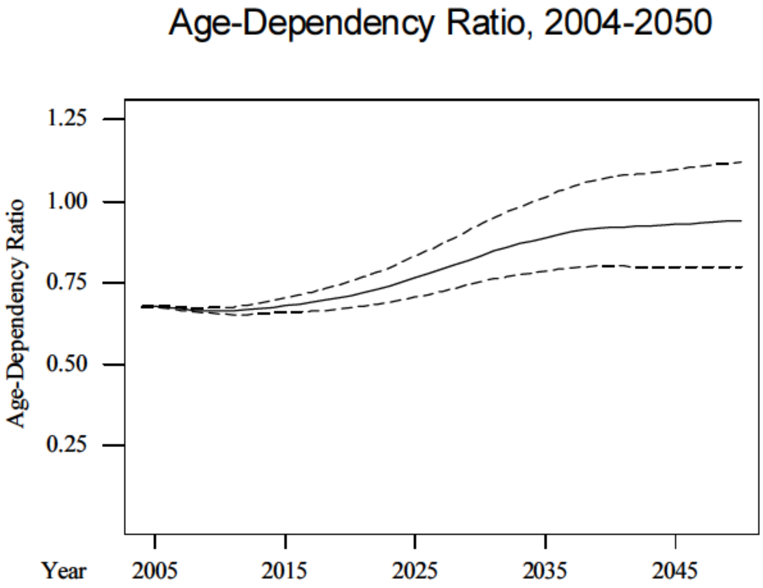
	A	B	Dk	SF	F	D	EL	Is	IRL	I	Lux	Nl	N	P	E	S	CH
Austria	1																
Belgium	0.239	1															
Denmark	0.304	-0.135	1														
Finland	0.381	0.267	0.147	1													
France	0.347	-0.191	0.140	-0.276	1												
Germany	0.706	0.422	0.321	0.245	0.307	1											
Greece	0.285	0.060	0.100	0.437	-0.421	0.215	1										
Iceland	0.063	0.316	-0.294	0.471	-0.236	-0.024	0.064	1									
Ireland	-0.090	0.017	0.157	0.158	0.024	-0.147	0.151	-0.197	1								
Italy	0.194	0.265	0.482	0.457	-0.348	0.278	0.504	0.017	0.360	1							
Luxembourg	0.390	0.504	0.386	0.477	0.174	0.547	0.157	0.048	0.405	0.536	1						
Netherlands	0.243	0.219	0.023	0.133	0.025	0.308	0.516	0.048	0.271	0.336	0.538	1					
Norway	0.085	0.098	0.332	0.475	-0.209	0.096	0.318	0.527	0.059	0.613	0.310	0.254	1				
Portugal	-0.249	0.064	-0.160	0.385	-0.505	-0.248	0.569	0.068	0.461	0.484	0.286	0.533	0.292	1			
Spain	-0.061	-0.343	0.348	-0.134	0.005	-0.180	0.344	-0.255	0.383	0.420	0.112	0.408	0.287	0.350	1		
Sweden	0.213	0.045	0.071	-0.504	0.214	0.273	0.084	-0.346	-0.371	0.013	0.027	0.238	-0.169	-0.188	0.243	1	
Switzerland	0.630	0.123	0.268	0.371	0.157	0.644	0.088	0.313	-0.414	0.120	0.193	-0.046	0.246	-0.346	-0.255	0.147	1
England & Wales	0.239	-0.013	0.679	0.363	-0.186	0.220	0.395	0.055	0.010	0.642	0.350	0.187	0.527	0.143	0.406	0.121	0.311

Annex 5. Age-dependency ratio for 18 EEA+ countries, 2004-2050

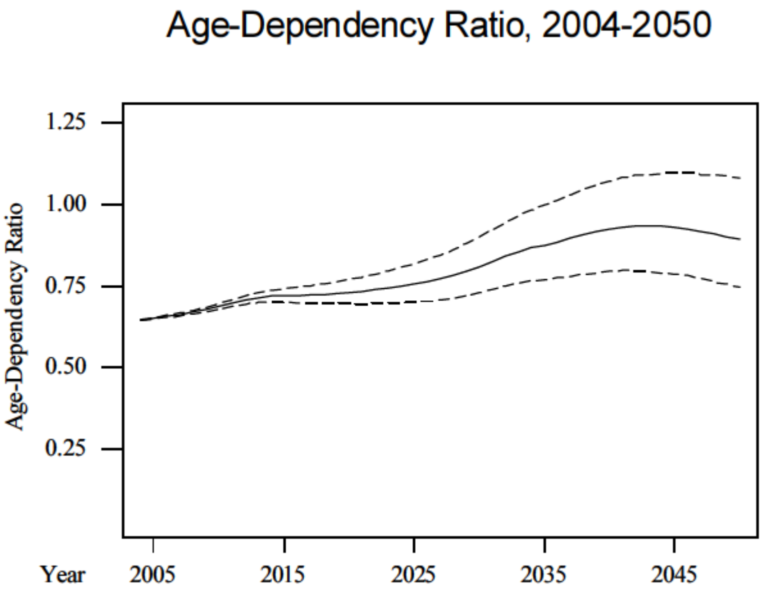
AUSTRIA



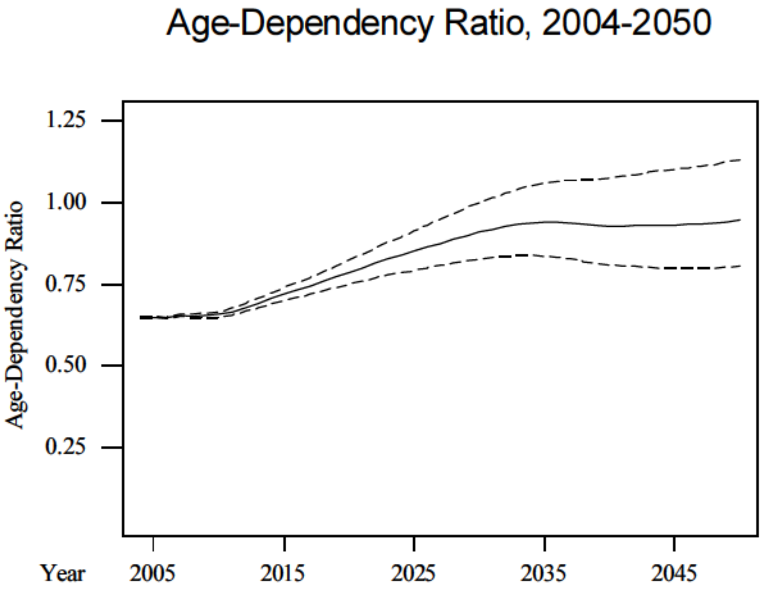
BELGIUM



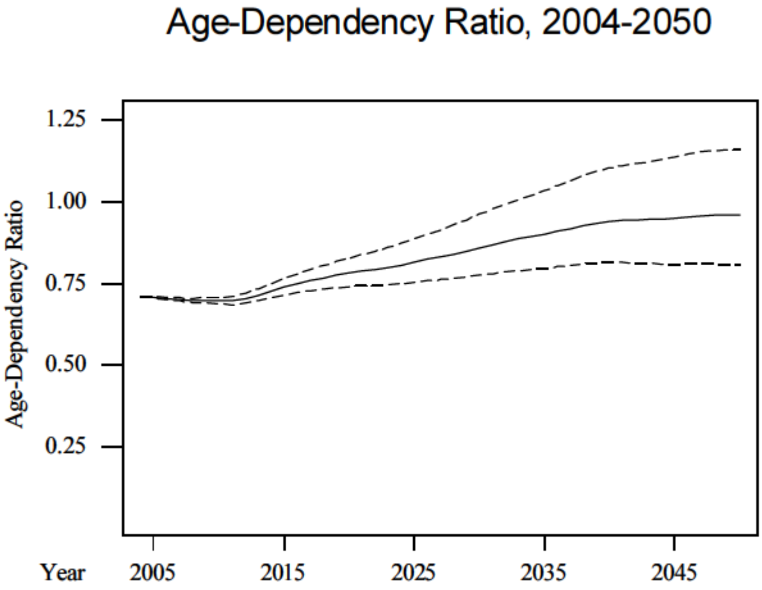
DENMARK



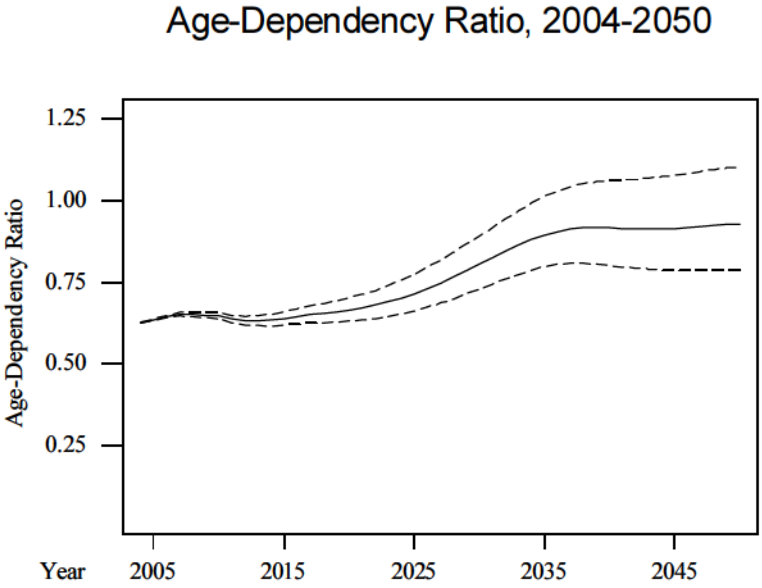
FINLAND



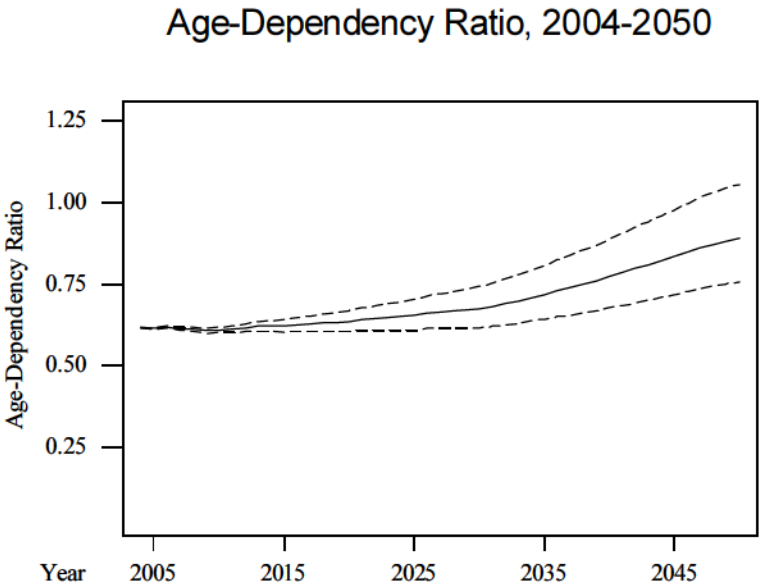
FRANCE



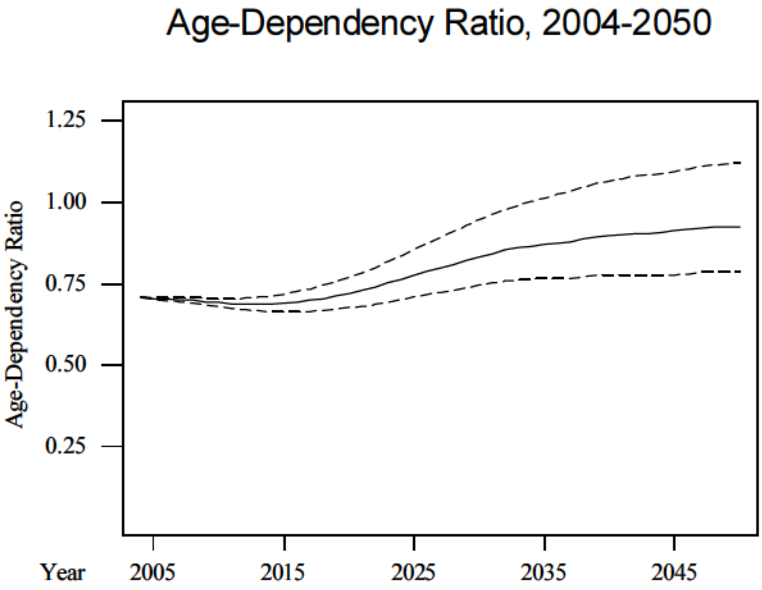
GERMANY



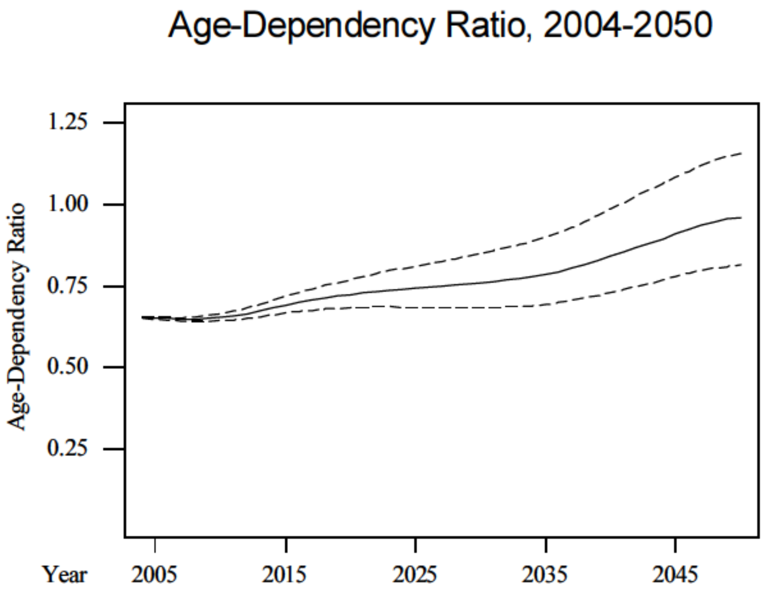
GREECE



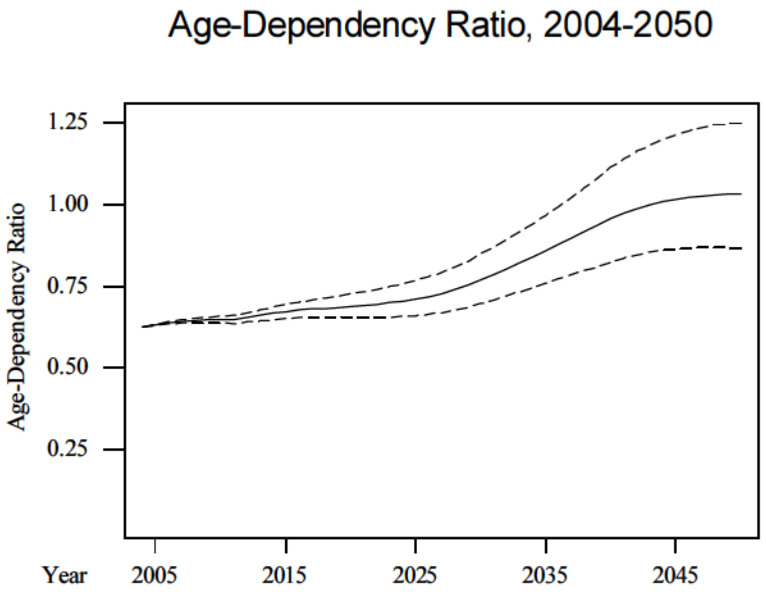
ICELAND



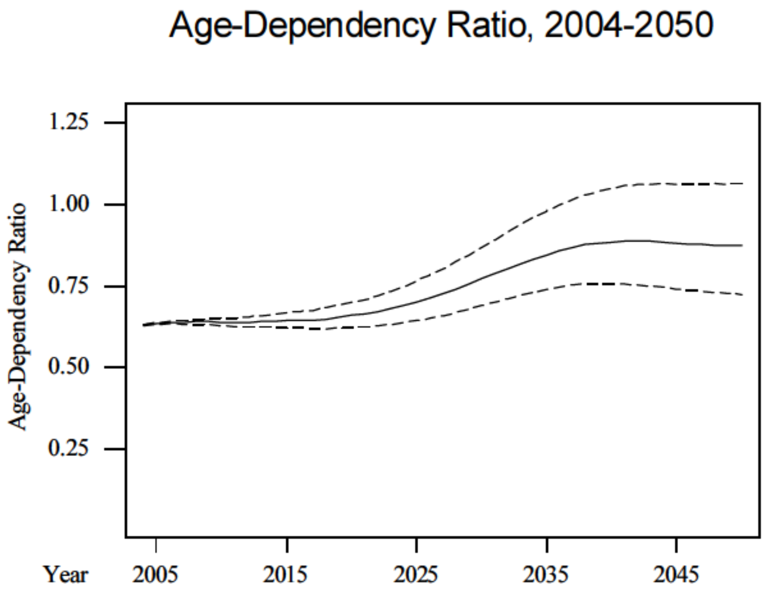
IRELAND



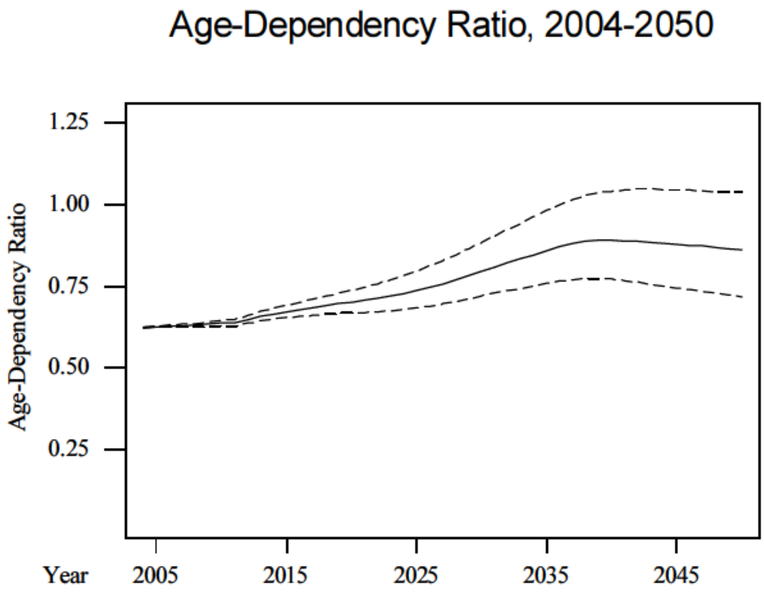
ITALY



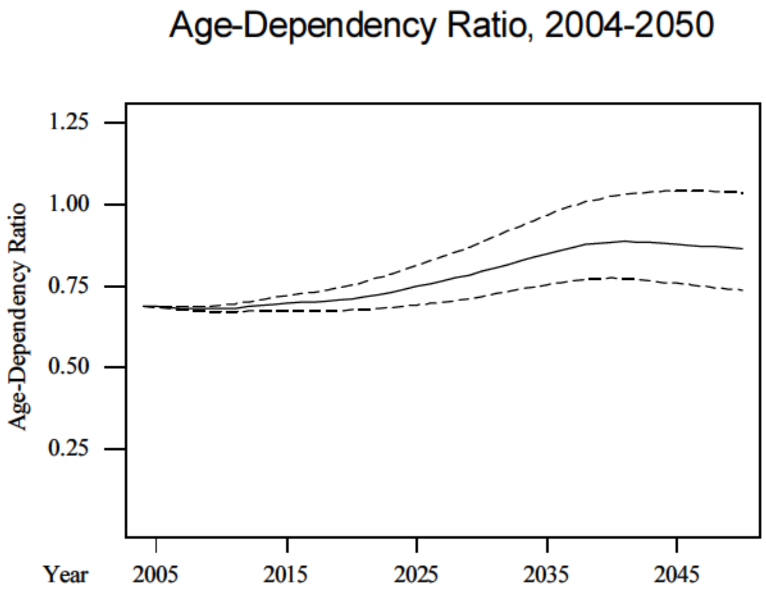
LUXEMBURG


Age-Dependency Ratio, 2004-2050

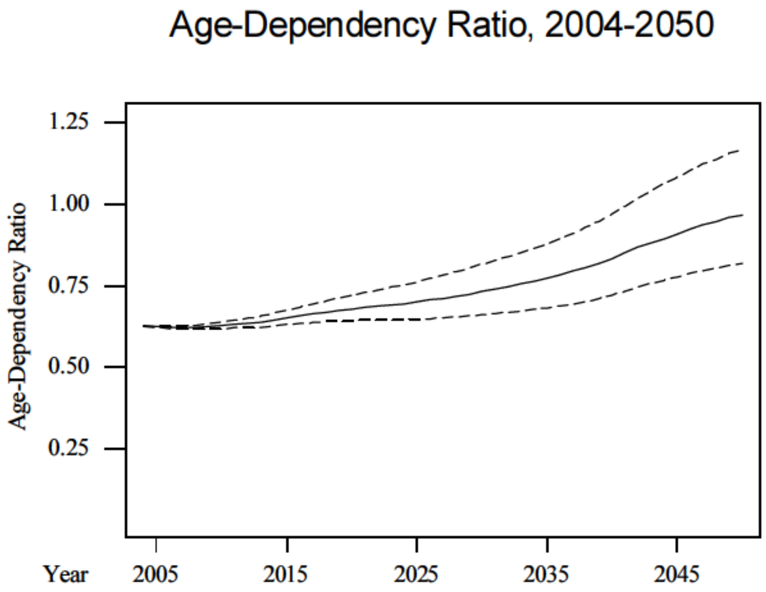
NETHERLANDS


Age-Dependency Ratio, 2004-2050

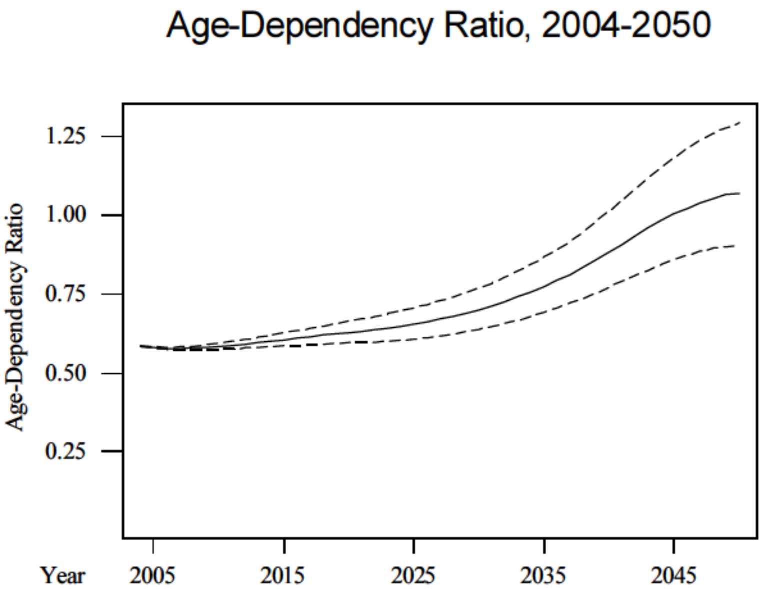
NORWAY



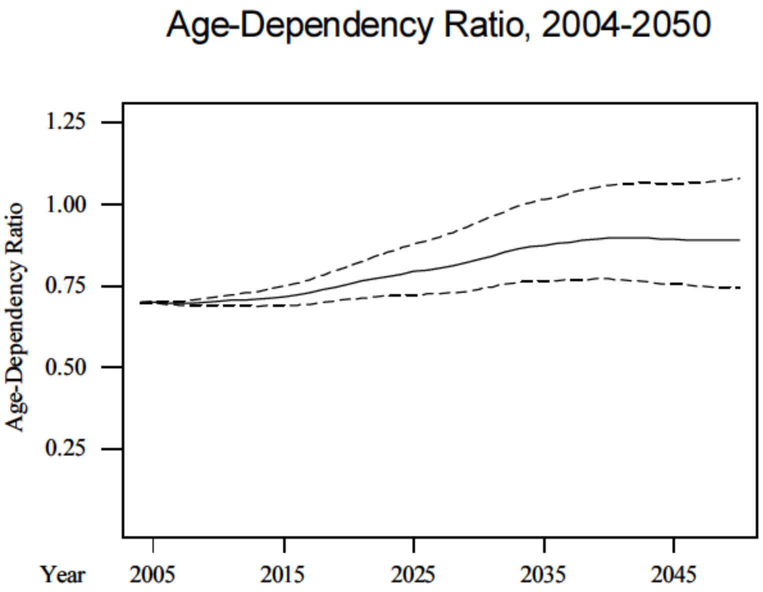
PORTUGAL



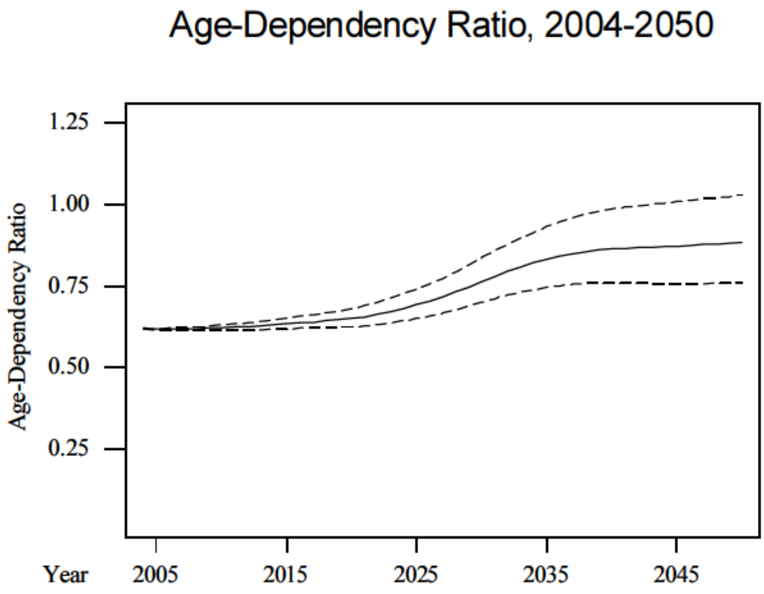
SPAIN



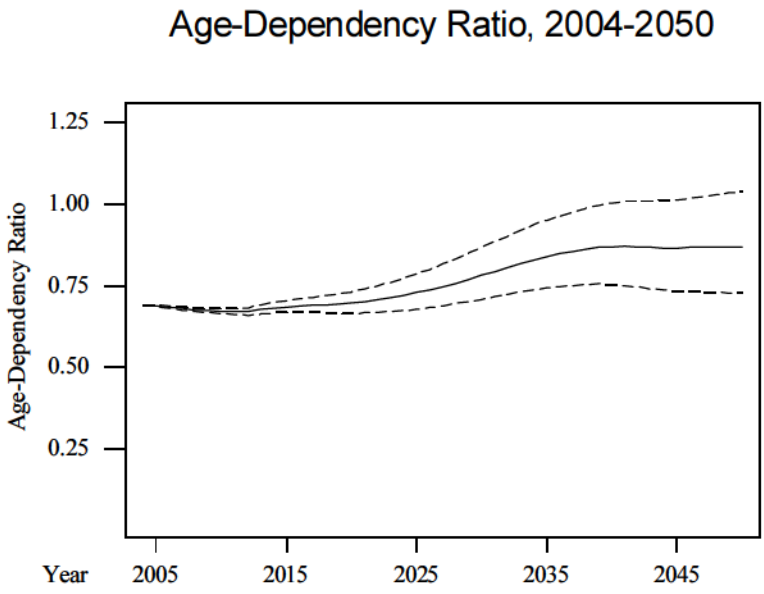
SWEDEN



SWITZERLAND



UNITED KINGDOM



ANNEX 6. Output of the project

Publications

Alders, M. and J. de Beer (2004). Assumptions on fertility in stochastic population forecasts. *International Statistical Review 72:* 65-79.

Alho, J.M., J. Lassila and T. Valkonen (2005) Demographic uncertainty and evaluation of sustainability of pension systems, in Holtzmann R. and E. Palmer (eds.) *Non-financial defined contribution (NDC) pension schemes: concept, issues, implementation, prospects*. World Bank, Washington D.C. (in press).

Alho, J.M. and B.D. Spencer (2004). *Statistical demography and forecasting*. New York: Springer (in press).

Keilman, N., and D.Q. Pham (2004). Time series based errors and empirical errors in fertility forecasts in the Nordic Countries. *International Statistical Review 72*: 5-18.

Keilman, N., and D.Q. Pham (2004). *Emprical errors and predicted errors in fertility, mortality and migration forecasts in the European Economic Area*. Discussion Papers 386. Oslo: Statistics Norway.

Presentations

Alders, M. and J. de Beer (2002). An expert knowledge approach to stochastic mortality forecasting in the Netherlands. Meeting on stochastic models for forecasting mortality, National Social Insurance Board, 29-30 January 2002, Stockholm, Sweden.

Alders, M. (2002). Changing population of Europe: uncertain future – Elicitation of experts' opinions. Presentation of results of a survey among forecasters of European national statistical offices (Powerpoint), Eurostat Working Party "Demographic Projections" 16-17 September 2002, Luxembourg.

Alders, M. (2002). Presentation at the Seminar "How to deal with uncertainty in population forecasting?", organised by the Vienna Institute of Demography, 12-14 December 2002

Alho, J.M. (2002). Remarks on the Use of Probabilities in Demography and Forecasting. Meeting on stochastic models for forecasting mortality, National Social Insurance Board, 29-30 January 2002, Stockholm, Sweden.

Alho, J.M. (2002). Presentation at the Eurostat Working Party "Demographic Projections" 16-17 September 2002, Luxembourg.

Alho, J.M. (2002). Presentation at the Seminar "How to deal with uncertainty in population forecasting?", organised by the Vienna Institute of Demography, 12-14 December 2002.

Alho, J.M. (2003). Presentation at the CEPS/ENEPRI Conference on Ageing and Welfare Systems: What have we learned? Brussels, 24-25 January 2003.

Alho, J.M. (2003). Presentation at the Seminar "Demographic and Economic Analysis" at Stanford University, 28-29 May 2003.

Alho, J.M. (2004). Presentation at the Workshop on Population Projections organised by the EPC Working Group on Ageing. Brussels, 5 February 2004

Keilman N. (2002). Presentation at the Eurostat Working Party "Demographic Projections" 16-17 September 2002, Luxembourg.

Keilman N. (2002). Presentation at the Seminar "How to deal with uncertainty in population forecasting?", organised by the Vienna Institute of Demography, 12-14 December 2002.

Keilman N. (2003). Presentation at the Seminar "Demographic and Economic Analysis" at Stanford University, 28-29 May 2003.

Keilman N. (2003). Presentation at the European Population Conference in Warsaw, 26-30 August 2003

Keilman N. (2003). Presentation at the Seminar "Projection Methods of Future Mortality", organised by the Continuous Mortality Investigation Bureau and the Government's Actuary Department; Edinburgh, 6 October 2003.

Keilman (2004) Presentation at the Seminar "Probabilistic Projection and Microsimulation: Methodologies for demographic, family and related issues", Population Studies Centre, University of Waikato, Hamilton, New Zealand, 6-8 December 2004.

Deliverables

1. Statistics Netherlands (2002) *First semi-annual report* (Status: abandoned)
2. Statistics Netherlands (2002) *Second semi-annual report* (Status: completed and accepted as first interim report)
3. Statistics Netherlands (2003) *Third semi-annual report* (Status: abandoned)
4. Statistics Netherlands (2003) *Fourth semi-annual report* (Status: completed and accepted as second interim report)

5. Statistics Netherlands (2004) *Fifth semi-annual report* (Status: abandoned)
6. Statistics Netherlands (2005) *Final report* (Status: completed)
7. Observed error structures for total fertility rate, life expectancy at birth and net migration at national level (Status: merged with deliverable 9 and submitted as Keilman, N., and D. Q. Pham (2004). *Empirical errors and predicted errors in fertility, mortality and migration forecasts in the European Economic Area*; completed and accepted)
8. Observed error structures for indicators of regional differences in fertility, mortality, international migration and internal migration (Status: abandoned)
9. Expert-based estimates of forecast intervals for fertility, mortality, and migration at national level (Status: merged with deliverable 9 and submitted as Keilman, N., and D. Q. Pham (2004). *Empirical errors and predicted errors in fertility, mortality and migration forecasts in the European Economic Area*; completed and accepted)
10. Expert-based estimates of forecast intervals for fertility, mortality, and migration at national level (Status: submitted as Alders, A., L. Heering, and M. Reinink (2004). *Changing population of Europe: uncertain future – Elicitation of experts' opinions*; completed and accepted)
11. Assumptions on the values of parameters of the probability distributions of the total fertility rate, life expectancy at birth of men and women, and net migration numbers, to the horizon 2050 for all EEA countries (Status: submitted as Alders, M. (2004). *Changing population of Europe: uncertain future – Assumptions for national stochastic population forecasts*; completed and accepted)
12. Report describing forecast intervals of total population size and selected age categories for all EEA countries (Status: submitted as Alho, J.M., and T. Nikander (2004). *Uncertain population of Europe – Summary results from a stochastic forecast*; completed)
13. Database containing simulations of one-year age groups by gender for all EEA (Status: submitted as Alho, J.M., and T. Nikander (2004). *A forecast of the population of Europe 2004-2050*; completed)
14. Report on the parsimonious representations of internal migration (Status: submitted as Alho, J.M., and T. Nikander (2004). *Dimension reduction for internal migration*; completed)

15. Report on the imputation methods for migration specification with applications (Status: submitted as Alho, J.M. (2004). *On the correlation structure of international migration*; completed)
16. Report describing approximate calculations for the multi state stochastic model (Status: submitted as Alho, J.M. (2004). *Second moments of fertility, mortality, and net migration*; completed)
17. Report on the functional forecasts of the elderly (Status: submitted as Alho, J.M.(2004). *The divorced and the disabled among the elderly*; completed)