PRELIMINARY VERSION

# Assumptions for long-term stochastic population forecasts in 18 European countries

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## 1. The UPE project

Demographic trends in Europe continue to take forecasters by surprise. During the last three decades, few predicted the rapid declines and thereafter persisting low levels of fertility in the Mediterranean and former socialist countries. Similarly, the ongoing rather strong decrease in death rates in countries where life expectancy at birth was already high (e.g. France, Italy and Sweden) was not foreseen by many. Finally, considerable and sometimes even massive migration flows came unexpected.

Although there is some hope that more detailed or comprehensive demographic studies may help improve our understanding the causes of these errors after the fact, there appears to have been an element of genuine surprise in the demographic trends mentioned above. Therefore, there is no reason to believe that these developments will be easier to predict in the near future than they were in the past. 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.

This was the purpose of the UPE project (”Uncertain Population of Europe”[1]): to compute stochastic population forecasts for 18 European countries, which we shall denote as EEA+ countries. The group consists of the 15 members of the European Union prior to the joining of the new member states in 2004 (i.e. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Spain, Sweden, the United Kingdom) plus Norway, Iceland, and Switzerland. Except for Switzerland, these countries made up the so-called European Economic Area, hence EEA+. We have quantified uncertainty of the demographic forecast by applying the cohort-component book-keeping model for each country 3 000 times, with a deterministic jump-off population, and probabilistically varying values for age- and sex-specific mortality, age-specific fertility, and net migration by age and sex. Starting point was the population as of 1 January 2003, by country, one-year age group, and sex. The forecast horizon was 2050. The method is based on the so-called scaled model for error, implemented in the program PEP – “Program for Error Propagation” (Alho and Spencer 1997).

For each year, three main sets of assumptions were required:

1. Country-specific point predictions for age-specific rates of fertility, age- and sex-specific rates for mortality, and numbers of net immigration broken down by age and sex. Assumptions of this kind

[1] The project was funded by the EU Commission (Contract HPSE-CT-2001-00095). It was carried out by Juha Alho of Joensuu University, Finland, Timo Nikander of Statistics Finland, and the three authors. The views expressed here are those of the Project Team and they do not necessarily reflect the views of the Commission, or the views of the national statistical agencies in the two countries.

are the same as those that statistical agencies formulate when they compute their deterministic population forecasts.
2. Country-specific uncertainty parameters for fertility and mortality rates, and for migration numbers.
3. Interregional correlations for fertility, mortality, and migration.

We have derived these forecast assumptions from three separate sources.
1. Time series analyses of age-specific and total fertility; age- and sex-specific mortality and life expectancy at birth; and net migration by age and sex, relative to total population size.
2. Analyses of historical forecast errors for total fertility, life expectancies, and net migration.
3. Interviews with subject experts for fertility, mortality, and migration.
The purpose of the present paper is to report on the assumption making process. This process included many steps, and the current paper cannot describe all of these. More information can be found at the UPE web site http://www.stat.fi/tup/euupe/, and in a project report that is available from the authors upon request. The web site contains also forecast results for each of the 18 countries in the form of age and sex detail for ten-year intervals to 2050.

The UPE project is the first attempt to combine information from those three sources in a systematic and balanced way. It shows that the three approaches are truly complementary. Earlier stochastic forecasts also combined elements of the three approaches, but one of those three was often the dominant approach. Lee and Tuljapurkar (1994) modelled the time series of the level parameter for US-fertility obtained by means of the Lee-Carter method as an ARIMA (1,0,1)-process with a constrained mean, subjectively chosen equal to 2.1. Alho (1998) compared prediction intervals for the Total Fertility Rate (TFR) in Finland obtained by means of an ARIMA(1,1,0)-model with those that result from the errors of so-called naïve forecasts, i.e. forecasts that assume that the current TFR-level is a reasonable forecast of the future TFR. He used a similar method for mortality. He also combined errors of naïve forecasts with time series analysis and expert judgement in his crude assessments of forecast uncertainty for twelve large world regions (Alho 1997). De Beer and Alders (1999) modelled the life expectancy of the Netherlands as a random walk with drift, and compared the resulting prediction intervals with those obtained from a time series of historical forecast errors for the life expectancy. Lutz et al. (2001) chose a certain level for the variance in the TFR in a target year. The variance was larger for regions with high fertility than for low fertility regions. As to mortality, they generally assumed that life expectancies would increase between zero and four years with 80 per cent probability. These subjectively chosen distributions were combined with a moving average time series process for the error in the TFR or the life expectancy increase. At the same time, the authors aimed at producing prediction intervals that were at least as large as those published by the NRC-panel for major world regions (NRC 2000). Keilman et al. (2002) modelled the log of the TFR in Norway as an ARIMA (1,1,0)-model, but obtained unreasonably large prediction intervals for the TFR in the long run. In their simulations, they rejected TFR-values larger than four children per woman. Their simulations for the life expectancy were based on a complicated multivariate ARIMA-model, the predictions of which were checked against observed errors in historical Norwegian life expectancy forecasts.

The current paper presents the approach that we followed for the point predictions and the prediction intervals for fertility, mortality, and migration assumptions. We report the intervals in the form of 80 per cent prediction intervals. In our view, 80 per cent intervals give a better impression of forecast uncertainty than the more usual 95 per cent intervals, which reflect extremes. Cross-national correlations are mentioned only briefly. Alho (2005) gives a more extensive report on the latter topic. Finally, we assumed independence across the components of fertility, mortality, and migration.

In practice, we derived initial guesses for point predictions of model parameters and for uncertainty parameters from time series analyses. These were adjusted, where necessary, based on historical forecast errors. We made further adjustments, sometimes of considerable magnitude, to reflect expert views.

## 2. Data issues

*2.1 Principal data series needed*

Since we have applied the cohort-component approach, we needed long time series for age-specific fertility, mortality, and net migration for each country. This required the following basic annual data:

- population at 1 January by sex and single years of age (0, 1,…, 100+);
- live births by sex;
- live births by single years of age of the mother (age at last birthday; 15, 16,…, 49);
- deaths by sex and single years of age (age at 31 December; 0, 1,…, 101+);
- net migration by sex and single years of age (idem).

In addition, we needed internationally comparable time series for as many years as possible for the TFR, the life expectancy at birth by sex, and net migration. To facilitate comparisons across countries, we scaled net migration for each country by the population size at 1 January 2000. Finally, it was decided to start the projection period in 2003, and therefore the initial population was defined as the population officially estimated at 1 January 2003.

*2.2. Principal, contemporary measurement problems*

We have assumed that population statistics in all 18 countries are based on the *de jure* concept, which covers all persons who have legal and/or usual residence in the country, even if they are temporarily abroad. The *de jure* population concept should be distinguished from the *de facto* population concept, which includes all persons who are actually present in the country at a given moment in time, regardless of whether they have legal and/or usual residence there. The latter population concept includes, for instance, all non-resident tourists and persons without a legal residence permit; at the same time it disregards residents who are abroad, such as tourists and persons who have not reported emigration. These examples show that it is important in a multi-country project to use one concept, in order to avoid double counts and missing persons.

Countries that use population register information for producing annual population statistics seem to follow the *de jure* population concept (Eurostat 2003). In our group of 18 countries, the national statistical offices of the following 13 countries use information from population registers: Austria, Belgium, Denmark, Finland, Germany, Iceland, Italy, Luxemburg, Netherlands, Norway, Spain, Sweden, and Switzerland. The majority of these countries use also the outcomes of population censuses, roughly once per decade. The five countries without a register (France, Greece, Ireland, Portugal, and the United Kingdom) rely on the outcomes of population censuses, combined with information from vital registration systems or sample surveys to measuring migration flows. All countries that carry out population censuses report that they follow the respective United Nations regulations, which recommend counting based on the *de jure* population concept.

However, in practice, countries may encounter various types of problems when attempting to accurately and timely determine or update the population age and sex structure according to the *de jure* concept. Most of these problems are caused by international migration, either directly or indirectly. Below we shall briefly mention problems connected to (1) the residence status of persons who experience a vital event or migration, (2) measurement and definition of international migration, (3) regularization of illegal or undocumented migrants, and (4) post-census adjustments of population statistics. We will not discuss the accuracy of stock data for the oldest old, or measurement problems for vital events connected to different age definitions (age at last birthday, age as of 31 December/1 January etc.)

First, all countries draw up a birth certificate when a child is born and a death certificate when a person dies. Yet, not all live births and deaths among the resident population will be counted. Births and deaths of residents who are temporarily abroad are either not registered at all, or only r with significant delays. At the same time, births and deaths to non-residents may be included in a country's population statistics. We know that one-half of the 18 countries systematically base their vital statistics on the *de jure* concept: Belgium, Denmark, Finland, Iceland, Luxembourg, the Netherlands, Norway, and Sweden. Hence the remaining nine countries work (or have worked until recently) with a mixture of *de jure/de facto* vital statistics measurement systems: Austria, France, Germany (births only), Greece, Ireland, Italy, Portugal, Spain, and the United Kingdom (Eurostat 2003). At least four of these (France (births only), Ireland, Portugal and the United Kingdom) handle this problem in a symmetric way: *de jure* births/deaths occurring abroad are excluded, whilst *de facto* births/deaths occurring in the country are included. Thus, the errors compensate to a certain extent. In the remaining countries, there may be structural underestimations or overestimations in annual numbers of live births and deaths.

Second, a more significant measurement problem relates to a range of difficulties in estimating *de jure* international migration flows in a consistent manner. For instance, Poulain et. al. (1990) have extensively documented that definitions of immigration and emigration vary substantially within Europe. Until now, only the statistical agencies in the Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) have succeeded in establishing a mutual, international consistent system of migratory flows occurring within their region. Furthermore, in spite of ongoing national and international efforts, a few EU countries do not measure international migration flows on an annual basis. France, Greece (emigration only), Ireland, Portugal, and the United Kingdom lack a population registration system, and therefore have to estimate annual migration flows by using various indirect sources. Only when outcomes of a new population census become available one can try to make improved re-estimations.

A third problem is connected to unreported emigration in countries with a population register. For example, the annual number of persons that left the Netherlands without reporting their move to the population register of the municipality where they had lived increased over the past twenty years from less then 5000 to well over 35000. Meanwhile annual registered emigration remained more or less constant at a level of around 65000 persons.

Fourth, measuring international migration accurately is difficult due to increasing numbers of illegal or undocumented migrants. Contemporary regularization programmes in Greece, Italy, Portugal, and Spain show that millions of persons can enter and stay in the European Union for years without a legal residence permit. They are able to do so in spite of the extension and reinforcement of border controls and the development and implementation of much more strict rules and higher penalties on hiring illegal or semi-legal employment. In addition, rules for asylum seekers, seasonal workers, and migration due to family reunion and/or family formation have become more restrictive. This may have led to more illegal migrants. Hence, the *de jure* population has become increasingly different from the *de facto* population.

Measuring international migration accurately is also difficult because whether a person is considered an international migrant or not depends on the intended length of stay in the country of destination. It is reasonable to assume that as a combined result of globalization and individualization, both the magnitude and the share of short-term migration due to asylum, study, work, or family formation have drastically increased over the past two to three decades, at the cost of the number and proportion of those that still express the intention to migrate more or less permanently. This implies that increasing numbers of international migrants tend to shift from one category to another over their life courses. However, migration measurement systems only record the current reason for migration; they are not able to capture these predominantly longitudinally driven moves.

These four groups of problems connected to international migration imply that it is difficult to compare demographic data across countries and over time. However, very little is known about the magnitude of the errors involved. Section 2.3 gives numerical examples for a few selected countries. A systematic investigation of the consequences of these measurement problems for population forecasts was beyond the scope of the UPE project, and thus we have not quantified these errors. This means that the prediction intervals are too narrow by this error source alone, although we do not know by how much.

### *2.3 Data availability and data quality*

National statistical agencies possess the longest demographic time series. However, as already mentioned in the previous section, national series may have different practices for calculating or estimating rates and summary indicators. Furthermore, national historical series are not always easily available or well-documented.

Over the past two to three decades, internationally harmonized demographic time series have become available. Examples are the well-known international demographic databases of the United Nations (Population Division), the Council of Europe (CoE), and the Statistical Office of the European Communities (Eurostat). The CoE and Eurostat have been substantially supported by the work of the European Demographic Observatory ("Observatoire Demographique Europeenne" or ODE) in Paris. The latter centre has successfully implemented an internationally accepted standardized system of calculating age specific fertility and mortality rates, TFRs and life expectancies (SYSCODEM; see for a detailed description, Eurostat 2005). Another important international database is the Human Mortality Database of the University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany).

On international migration, unfortunately no comprehensive, internationally harmonised database exists. The international migration database compiled by Eurostat since the beginning of the 1990s has recently been closed, due to a large number of inconsistencies and missing data.

We have used the following main data sources in the UPE project:

- TFR: Chesnais (1992) and Council of Europe (2002).
- 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).
- Net migration: Council of Europe (2002).

In a few cases these international sources have been supplemented with information from 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. Country-specific details are contained in Keilman and Pham (1994).

Some time series are very long (e.g. TFRs for Finland since 1776, life expectancies for France since 1806), others are short (e.g. life expectancies for Ireland since 1985). For all 18 countries considered, the annual series for net migration start in 1960.

In order to generate the detailed set of quantitative assumptions on age-specific fertility and mortality, we constructed a separate international database covering the period 1990-2003, mainly using figures taken from Eurostat's database NewCronos (as available during Spring 2004). The same source supplied us with data on net migration by age and sex for countries with a population register. Finally, NewCronos, combined with demographic now-casts for 2003, gave us also figures for the initial population at 1 January 2003 (Eurostat 2004).

With respect to the key-indicators, one may state that the time series on net migration are by far the weakest. Annual figures for migration have been generally estimated based on the difference between total population growth and natural growth. Thus, they include measurement errors connected to all three components of change. The ongoing practice of different definitions and measurement systems on international migration and/or the application of different post census re-estimation procedures and population counts obviously have lead to a considerable number of international inconsistencies and fairly strong trend shifts. The most striking examples are:

- After the population census of 1999, France re-estimated for the period 1995-1999 an average annual crude net migration level of around -0.2 per 1000 population in 2000, whereas all other EU countries reported crude net migration levels during the second half of 1990s of at least 1.5. Since the year 2000, France assumes a crude net migration level close to 1 per thousand, more or less similar to the levels provisionally estimated before the census of 1999.
- Italy reported before its latest population census held in October 2002 a cumulated total net migration of almost 1.5 million persons for the period 1991-2001; however, based on the census 2002 counts, the cumulated total net migration for this period amounted to no more than 0.7 million persons.
- Spain reported for the period 2000-2002 a cumulated net migration of almost 1.5 million persons, which is nearly twice the cumulated sum during the period 1990-1999. The main explanation is that the country executed several regularization programmes for illegal immigrants.
- The 2002 issue of "Recent demographic developments in Europe" reports "observed" net migration to Portugal in multiples of 1000 for each year since 1992 (Council of Europe 2002). The 1998-issue reports net migration for the years 1991-1997 even in multiples of 5000. For the years 1993-1997, there is little agreement between the two time series of net migration numbers.
- Some countries show large differences between pre-census round 2000/2001 population figures by sex and age, and census outcomes. In a few cases (e.g. France, Italy, and the United Kingdom), relative deviations amount to well over 5%. Especially for the age groups 20-30 and 80+ the latest census results reveal that pre-census estimates were too high.

## 3. Historical forecast errors

We collected information on errors in historical forecasts by the national statistical agencies of the following 14 countries: Austria, Belgium, Denmark, Finland, France, Germany[2], Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland, and the United Kingdom. Most of the forecasts stem from the period 1960-2000, although some early ones date back to the 1950s. We have used both published and unpublished sources. We selected the Total Fertility Rate (TFR), life expectancy at birth, and net migration, i.e. the difference between immigration and emigration, as indicators for the three demographic components of change. Details of the data collection process and the quality of the data are given in Keilman and Pham (2004).

The data set is restricted to forecasts produced by statistical agencies. An important reason for this choice has been the fact that the forecasts were made with a single methodology, namely the cohort component method of population forecasting. Indeed, this is the standard forecasting methodology among population forecasters (Keilman and Cruijsen 1992). A second reason is that the forecasts were produced in stable institutional settings. Thus, we have a relatively homogeneous data set, which provides a meaningful basis for error analysis.

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[2] More precisely, the Federal Republic of Germany (FRG) between 1952 and 1989, and the reunified Germany from 1990 onwards. For fertility and mortality, we have forecast errors for the (former) FRG for the period 1952-2002. For migration, we have errors for the FRG in forecasts made between 1952 and 1989, and for Germany in forecasts made since 1990. All errors apply to the period from the launch year up to 2002.

We computed annual forecast errors as the simple difference between forecast value and corresponding observed value for each of the three indicators. Thus, a positive error indicates that the forecast was too high; a negative error mirrors too low a forecast.
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 publication2. 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).[3]

Figure 3.1 plots the mean absolute error (MAE) and the mean error (ME) in the TFR. The means are computed across countries, forecast periods, and forecast variants, but controlling for forecast duration. The MAE reflects forecast accuracy. It tells us how far off the forecast was, irrespective of the sign of the error. The ME reflects forecast bias. Figure 3.1 shows that the TFR forecasts in the 14 countries made since the 1950s were wrong by an average of 0.3 children per woman for a forecast horizon of 15 years ahead, and by 0.4 children per woman for 25 years ahead. They differ from the actual TFR by 0.06 already in the first year. In the very long run, all forecasts were too high, since the ME coincides with the MAE; for short and medium term forecasts, there was some compensation of positive and negative errors, since the ME is lower than the MAE. Figure 3.1 reflects the well-known fact that fertility was over-predicted in many European countries in the late 1960s and the 1970s, when actual fertility fell rapidly.

Figure 3.2 shows the MAE and the ME for the life expectancy. There are hardly any differences between the means for men and women. Therefore, we have plotted the curves for only one sex. Life expectancy has systematically been under-predicted, by more than 2 years for forecasts 15 years ahead, and 4.5 years at 25 years ahead. Nearly all forecasts had too low life expectancy, and hence too high mortality, since the curves for the MAE and the ME are almost perfectly symmetric around zero.

Errors in scaled net migration are summarized in Figure 3.3. A number of historical projections have ignored migration, in particular the earliest ones. It is reasonable to assume that many users will have considered them as the statistical agency’s best guess regarding the country’s future population. Therefore, we have assumed that the implicit forecast hypothesis for international migration was a net migration level of zero. Hence, the signed error was simply equal to minus the observed net migration in those cases.

Net migration levels have been consistently under-predicted in historical forecasts. In a number of cases, the reason is that migration was omitted from the forecast, while actual net migration was positive. In other cases, the net migration assumption was simply too low. We found two distinct groups of countries. One group consists of Austria, West Germany, Luxembourg, Portugal, and Switzerland. The countries in this group have mean errors well above the average. The forecasts of Austria, Germany, and, to some extent, Switzerland were less accurate than the average, because of large immigration flows after the fall of the Berlin Wall in 1989. Luxembourg is a small country in which the level of migration in itself is high. Hence large migration forecast errors occur frequently. The large errors for Portugal are explained by the fact that migration statistics are not as reliable as those in other EEA countries; see Chapter 2. Countries in the other group, which consists of Belgium, Denmark, Finland, France, Italy, Netherlands, Norway, Sweden, and the United Kingdom, show much smaller errors in their migration forecasts.

[3] 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.

In summary, then, historical forecasts in the region on average assumed too high levels of future fertility, and too low mortality and immigration levels. Both forecast bias (reflected by the Mean Error) and forecast inaccuracy (Mean Absolute Error) increased regularly with forecast duration.

## 4. Time series analysis

The purpose of the time series analysis was to compute expected values (point predictions) and prediction intervals to 2050 for fertility, mortality, and net migration in each country. We applied two types of time series analysis: 1. a simple one, in which we assumed constant levels for the TFR and net migration, or constant reductions in the age-specific death rates; 2. a more advanced one, using ARIMA- and ARCH-type of models (ARCH = Generalized Autoregressive Conditional Heteroscedasticity); this approach was used for the TFR, the life expectancy, and net migration. We will briefly present the main features of the time series analyses in terms of predicted values and 80 per cent intervals in 2050.

*4.1 Fertility*

Figure 4.1 plots the TFR in the 18 countries. Here our interest is in the overall trend. The countries show a similar pattern in 20th century TFR, which reflects the demographic transition, followed by the effects of the economic recession in the 1930s and the baby boom in the 1950s and 1960s. Major events, such as the First World War and the occurrence of the Spanish Influenza in 1918/1919, are clearly reflected in the series for most countries. In the 20th century, many countries show a tendency towards lower variability in the TFR. Inter-country differences have become quite small in the 1990s.

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 mid-1800s. Current childbearing behaviour is very different from that of women in 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 is necessarily a subjective one, which includes a good deal of judgement and arbitrariness. We believe that we strike a reasonable balance between conflicting goals by selecting the 20th century as the basis for our models. An analysis solely based on the last 50 years, say, 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 unrealistically assume that the same model could capture the demographic behaviour over such a long period.

We have long data series for nine countries: Denmark, Finland, France, Iceland, the Netherlands, Norway, Sweden, Switzerland, and England and Wales.[4] We have estimated time series models for the TFR based on a whole century of data for these nine. Time series models for the remaining nine countries were estimated based on annual TFR-data for the years 1950-200. This was the case for Austria, Belgium, Germany, Greece, Ireland, Italy, Luxembourg, Portugal, and Spain.

Traditional time series models of the ARIMA type assume homoskedasticity, i.e. constant residual variance. Given the tendency towards less variability in the TFR in recent decades, such traditional

[4] Available time series for the observed values of the TFR and the life expectancy are rather short for the United Kingdom (England, Wales, Scotland, and Northern Ireland). The situation is much better for England and Wales: annual TFR series are available since 1911, and annual life expectancy values since 1841. Thus we have assumed that variability and predictability of the fertility and mortality in the United Kingdom in the 20th century was the same as that in England and Wales.

models could not be used. The Autoregressive Conditional Heteroskedastic (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 decades (Bollerslev 1986). The model has already proven useful in analyzing 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 is an obvious candidate.

The ARCH-predictions for the TFR in the year 2050 for the nine countries with long data series vary from 1.3 children per woman for Switzerland to 1.9 children per woman for France and the Netherlands. The 80 per cent prediction intervals are between 1.1 (Switzerland) and 1.4 (Finland, Iceland, Norway) children per woman wide. However, when the ARCH-model is fitted to the shorter time series 1950-2000 in all 18 countries, the point predictions in 2050 show a much larger range: from 1.1 (Greece, Italy, Spain) to 2.0 (Belgium) children per woman. The widths of the 80 per cent prediction intervals range from 0.7 (Greece) and 0.8 (Portugal) to 1.7 (Austria, Germany) and 2.1 (Sweden) children per woman. For the nine countries involved, the prediction intervals based on short time series are (with the exception of Finland) at least as wide, and for the Netherlands and Sweden much wider, than the intervals based on long series.

The simple model that assumes a constant value for the TFR starting from 2000 produces predictions in 2050 with 80 per cent prediction intervals between 1.6 and 2.2 children per woman wide.

*4.2 Mortality*

Figure 4.2 shows the life expectancy at birth for men and women in the 18 countries. Major interruptions to the upward trend, caused by two world wars and by the Spanish Influenza are clearly visible. The time series show less variability in the second half of the 20th century than in the first half. In addition, differences between countries appear to become smaller. The series vary a great deal in length across the countries. For eleven countries, we have estimated time series models of the ARCH-type based on long series, most often for the period 1900-2000. In a second analysis, applied to all 18 countries, we used data for the period 1960-2000.

The time series models indicate that 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. Long-range (fifty years) 80 per cent prediction intervals are 3-9 years wide, with women from England and Wales at the lower end of the spectrum, and Danish men and women a the upper end. Differences between predictions based on long time series or short time series appear to be small, particularly for men.

The constant increase model assumes that the rate of decline during the past 30 to 35 years for age-specific mortality rates (as long as it is not negative) observed in each country will continue in the coming 50 years. The result is an exponentially declining trend for age-specific mortality, for most ages, for all countries. The constant increase model predicts that between 2000 and 2050, life expectancy at birth for men will rise by well over four (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 per cent prediction intervals are almost 11 years.

*4.3 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; see Chapter 2.

The variable of interest is the level of net immigration per 1000 inhabitants (population 2000). Figure 4.3 plots this variable for the period 1960-2000. Compared to the other countries, Portugal experienced extraordinarily high levels of emigration between 1964 and 1973, mainly due to labour migration to other European countries. The fall of the German Wall and the war in the former Yugoslavia induced large immigration flows into German speaking countries in the 1990s.

We modeled net migration in two ways: as an autoregressive process, and as a linear trend model. The predictions from 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. Country-specific predictions for 2050 are generally between zero and ten per thousand. This is somewhat higher than the bands plotted in Figure 4.3, because for many countries we identified a significant upward trend in net migration. The estimated trend is moderate for Denmark, Italy, Luxembourg, Netherlands, Norway, and Spain, while Finland, Greece, Portugal, and England and Wales show a strong trend. The autoregressive model led to reasonable 80 per cent prediction intervals: between 2.4 (Denmark) and 14.1 (Luxembourg) promille-points wide, although Portugal was the exception (33.9, due to a bad model fit).

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 ahead 80 per cent prediction intervals of net migration per 1000 inhabitants (population 2000) ranged between two (France) and 24 (Portugal).

## 5. Expert views

The basic idea in the UPE-project 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.

Following the statistical analyses described in Sections 3 and 4, and after some exploratory work on the topic of systematic elicitation of expert's opinions, a series of one-day, in-depth interviews were organised with four experts on European demographic developments: two on fertility, one on mortality, and one on international migration[5]. The purpose of those interviews was to obtain an independent assessment on future demographic uncertainty. We provided the experts with different sets of point forecasts for the period 2000-2050, and corresponding 80 per cent prediction intervals. We formulated those forecasts based on the results of the time series analyses and the analyses of historical forecast errors, but amended them in view of demographic and non-demographic factors that were omitted from these analyses. The primary task of the experts was to suggest revisions to point forecasts and prediction intervals, to give arguments for the suggested revisions, and to assess the uncertainty they would foresee for the future as compared to the past. Their role was solely advisory; they are in no way committed to the results of the UPE-project.

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 per cent 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

[5] One interview was done by Email.

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. Here we give a few examples.

*5.1 Mortality*

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 Netherlands, Denmark, Finland, Norway and the United Kingdom the progress has been slow.
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 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. For other diseases, such as lung cancer the long latency time will attenuate the effect of behavioural changes.
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. Thus, one may assume is some degree of convergence in life expectancies across countries.
4. The empirically observed level of *average* uncertainty in Europe, which includes the effects 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. Some consider even the possibility of slowing down the pace of ageing feasible. 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.

*5.2 Fertility*

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. 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 stronger focus 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";
- and rising probabilities of separation and divorce, and hence a more cautious "investment in identity".

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, provided that sensible models were used in the past for forecasting and that present knowledge is incorporated.

### *5.3 Migration*

The 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. He provided the following principal factors determining migration developments in the coming 50 years:

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 important force that induces a demand for labour migrants.
3. Developments in the global South and East will continue to put (enormous) pressures on the gates of the wealthy EEA.
4. The expansion of the EU with 10 countries will have a temporary effect (immigration boom, fading out, followed by return).
5. 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).

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

## 6. Synthesis

### *6.1 General issues*

Most demographic developments start smoothly, last long and therefore evolve gradually. Principal trends such as declining family size, increasing childlessness, later motherhood, increasing life expectancy and net immigration levels may easily last five decades or more. However, there were and there will be also in the future turning points. In addition, sudden trend shifts, short periods of acceleration or slowing down, and incidental distortions have been observed or may arise due to a significant change of "environmental" circumstances, including the introduction of new and more effective means of planning and control (e.g. the pill, medicines and therapies to combat major diseases, more restrictive legislation concerning asylum seekers).

Apart from the time dimension, most demographic trends do have also a spatial dimension. For example, the trend towards later motherhood has started in Scandinavia (females born in and around 1942), spread rapidly to Western and Central Europe, and reached Southern Europe for women born in the 1950s and 1960s. Due to various political, cultural and economic factors, still considerable international differences exist concerning fertility, mortality and migration levels and patterns. However, the overall trend within the group of 18 countries considered is not one of divergence, and sometimes even convergence. Fertility, in terms of the period TFR, has shown a few periods of short-lived divergence, but the overall pattern is stable; see Figure 6.1. For cohort fertility there is a clear tendency towards convergence for women born since 1945, but since generation 1960 differences do not diminish anymore (Figure 6.2). International differences in life expectancy at birth have become smaller, although for women the trend has stabilized in recent years (Figure 6.3). For the remaining life expectancy at age 60 in the old EU15, the international differences are stable for women since 1970; for men they have decreased since that year; see Figure 6.4. Finally, only a few countries among our group of 18 have experienced net out-migration in recent years; in the 1950s and 1960s there were many more.

Therefore, a key-question, to be answered by anyone involved in long-term population forecasting for several countries simultaneously, is the following: will the trends towards convergence between countries continue? In other words: does one expect demographic continuities in the short, medium or long run, or are there strong reasons for assuming discontinuities, leading to new, reversed trends? We have assumed that current trends in the demographic indicators that we have analysed, including the trends towards stable or smaller differences between countries, will last for a few decades more. However, as in the past, short periods of accelerating, stagnating or even reversing trends may occur. These discontinuities or changes in the speed of a trend are not predictable, and are therefore treated as random fluctuations around an expected value or median value.

The principal assumptions concerning future fertility, mortality and migration trends and patterns that we have adopted are summarised in table 6.1. We based these assumptions on information from our three sources: the analysis of historical forecast errors, time series predictions, and the views of the experts. The table shows long-term, national point forecasts and 80 per cent prediction intervals for the total fertility rate, life expectancy at birth, and crude net migration rate (expressed per 1,000 of population in 2000).

*6.2 Fertility*

With respect to fertility, we grouped all countries except Portugal in two clusters. For the Northern EEA+ cluster (Belgium, Denmark, Finland, France, Iceland, Ireland, Luxembourg, Netherlands, Norway, Sweden, and the United Kingdom), we assumed a point forecast for the TFR in 2049 of 1.8 children per woman. 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, we assume an intermediate level of 1.6 children per woman. This gives a coefficient of variation in 2049 of 0.11, slightly lower than the current value. The 80 per cent 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 to the timing of fertility, we assumed that the mean age at motherhood on a period basis would continue to increase in all countries, 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. We used the experts' views and adjusted 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 per cent prediction intervals for the short and medium term are expected to be smaller than those predicted by the models.

*6.3 Mortality*

The point forecasts of mortality are primarily based on recently observed age specific mortality patterns, combined with the results of a simple extrapolation of recently observed declines in these age-specific mortality rates. We have 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 international differences in life expectancy in 2049 imply a coefficient of variation of 0.012, both for men and women. This is just a little under the most recent values; compare Figure 6.3.The 80 per cent 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 the views of the expert, who stated that it is not unlikely that unprecedented medical breakthroughs will happen. The assumed 80 per cent intervals in 2049 range from 7.4 years for Austrian females, to almost 12 years for males in Luxembourg.

*6.4 International migration*

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. We detected a significant upward linear trend in many countries. However, it is very uncertain whether these linear, rising trends will persist in the future. For this reason, we used several arguments to adjust the linear trend estimates downwards. Eventually it is assumed that for the EEA+ countries as a whole, net migration per thousand population in 2000 will rise to a level of around 3.5 in 2049. This is considerably less than the five per thousand according to the linear trend model. Next, we made long-term country-specific assumptions on crude net migration rate, that varied from 1.5 (Finland, France, Iceland) to six (Luxembourg). With respect to the 80 per cent prediction intervals, we took the results from the autoregressive time series model as the starting point. We reduced these intervals 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, we clustered the 18 countries.

*6.5 Cross-national correlations*

We estimated cross-national correlations from correlation patterns in historical forecast errors and from the residuals of the time series models. We used an eigenvalue analysis (factor analysis) for the correlation matrices relating to the errors in total fertility and the life expectancy at birth, and to observed net migration. The analysis suggested for fertility a contrast between the Mediterranean countries (Greece, Italy, Portugal and Spain) and the other countries. For mortality, we found two groups of countries: Portugal and Spain on the one hand, and all other countries on the other. The factor analysis for net migration resulted in three regions: one consisting of Austria, Germany and Switzerland; a second one consisting of Greece, Italy, Portugal and Spain; and a rest group consisting of the remaining countries. Alho (2005) gives more details of the cross-national correlations. These correlations are relevant for the results published for the EEA+ as a whole, and not for the forecasts of the individual countries

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). The result was a large set of input parameters for the PEP-program, which simulated 3000 possible demographic futures for each country to 2050.

## 7. Conclusions

The UPE population forecasts by sex and age differ significantly from earlier population scenarios of Eurostat and the U.N., and from national population forecasts in terms of both 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. The UPE project attempted to acknowledge 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 one should continue with this practice.

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 two decades 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 age at motherhood will increase further.

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 did not or could not believe that the decline in age specific mortality would persist. Therefore, they generally expected a slowdown of the improvement in life expectancy, eventually leading to stagnation. This erroneous assumption has led 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 age specific mortality, life expectancy would be taken as the variable to be predicted.

As regards migration, we can draw similar conclusions. Net migration flows have been continuously underestimated. In addition, recent forecasts of Eurostat, the U.N. and of several national agencies still assume moderate levels of future net migration. In contrast to mortality, this is a more recent phenomenon, covering the past two decades or so. For a number of countries, the migration data are of much lower quality than data on fertility or mortality, so an assessment of past trends is on a weaker ground. The UPE team assumes that the level of migration, primarily, from 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, these variants do not give a logically consistent description of forecast uncertainty. 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 correct, and uses probability theory to describe the level of uncertainty around the most likely development. A probability distribution incorporating 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 forecasts 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.

A last conclusion is that 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. 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. A creative mixture of both simple and advanced time series models, estimation techniques, and expert knowledge, can solve problems caused by the limited availability of historical population forecasts and a general lack of reliable, internationally comparable data series on international migration.

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Table 6.1 Summary of assumptions for the TFR, life expectancy at birth and net migration in 18 European countries: point forecasts and limits of 80 per cent prediction 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 |

Figure 3.1 Errors in TFR forecasts

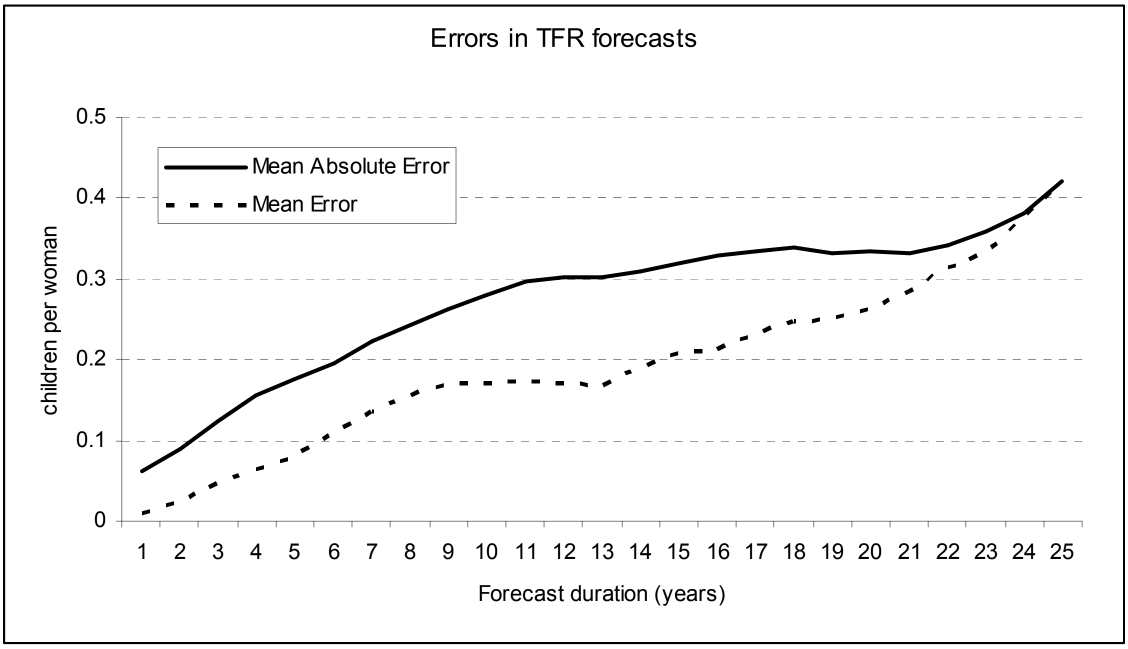



Figure 3.2 Errors in life expectancy forecasts

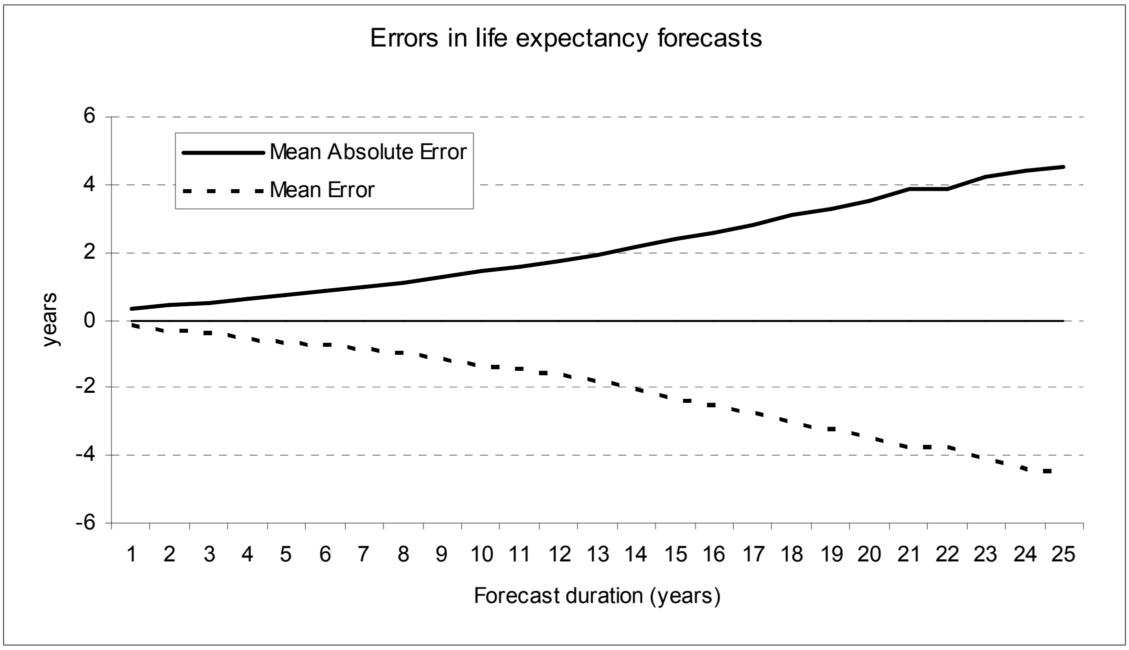


Figure 3.3 Errors in net migration forecasts

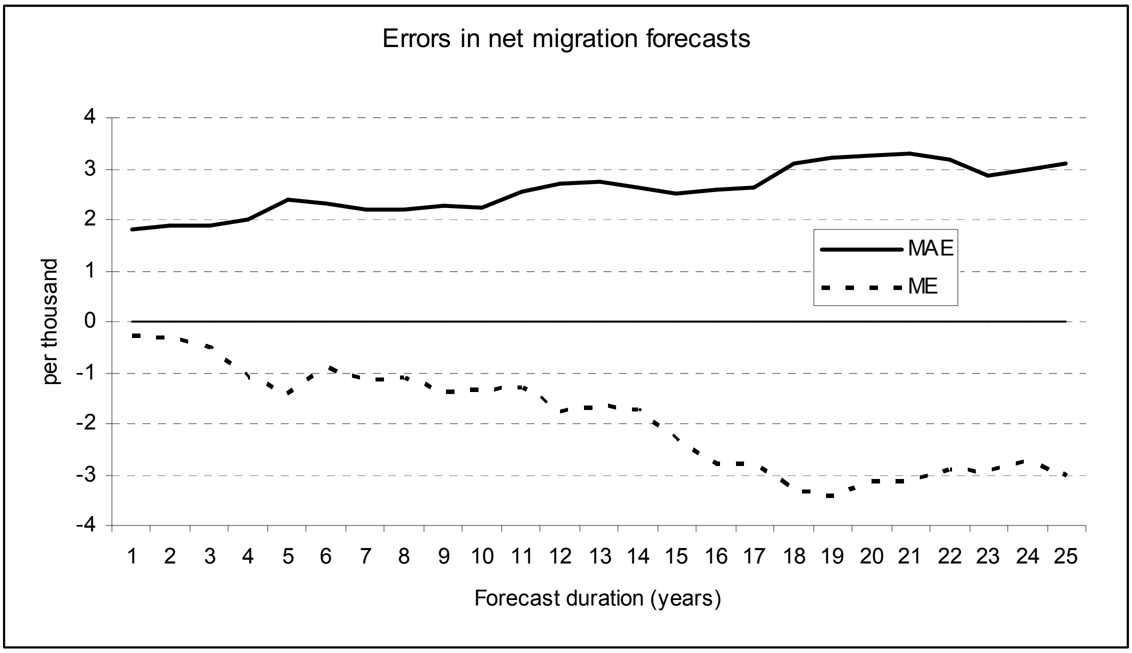


Figure 4.1 Total Fertility Rate in 18 European countries

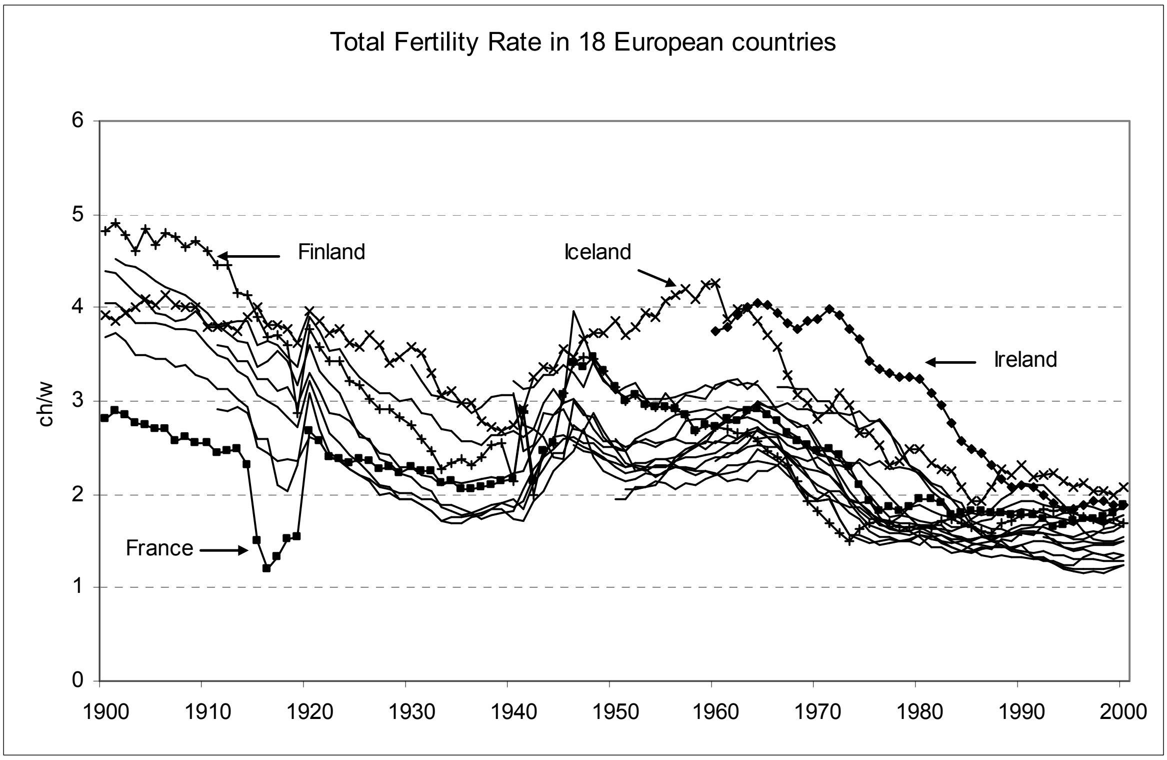
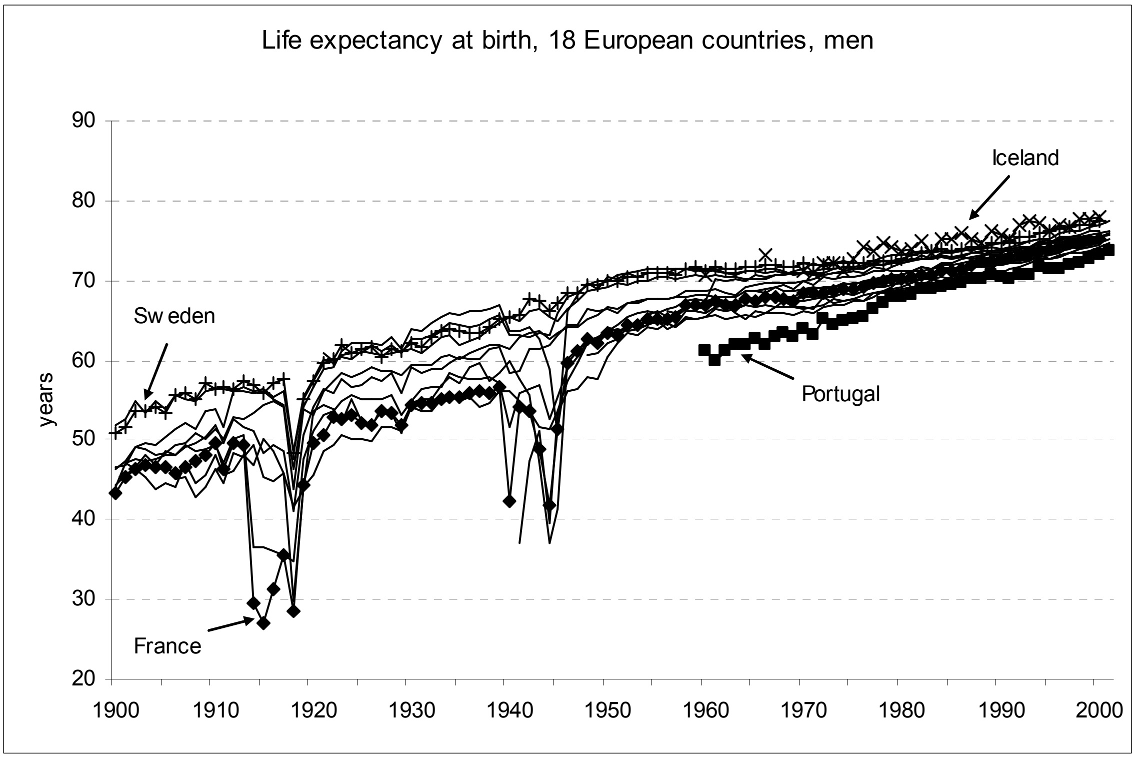


Figure 4.2 Life expectancy at birth, 18 European countries, men and women



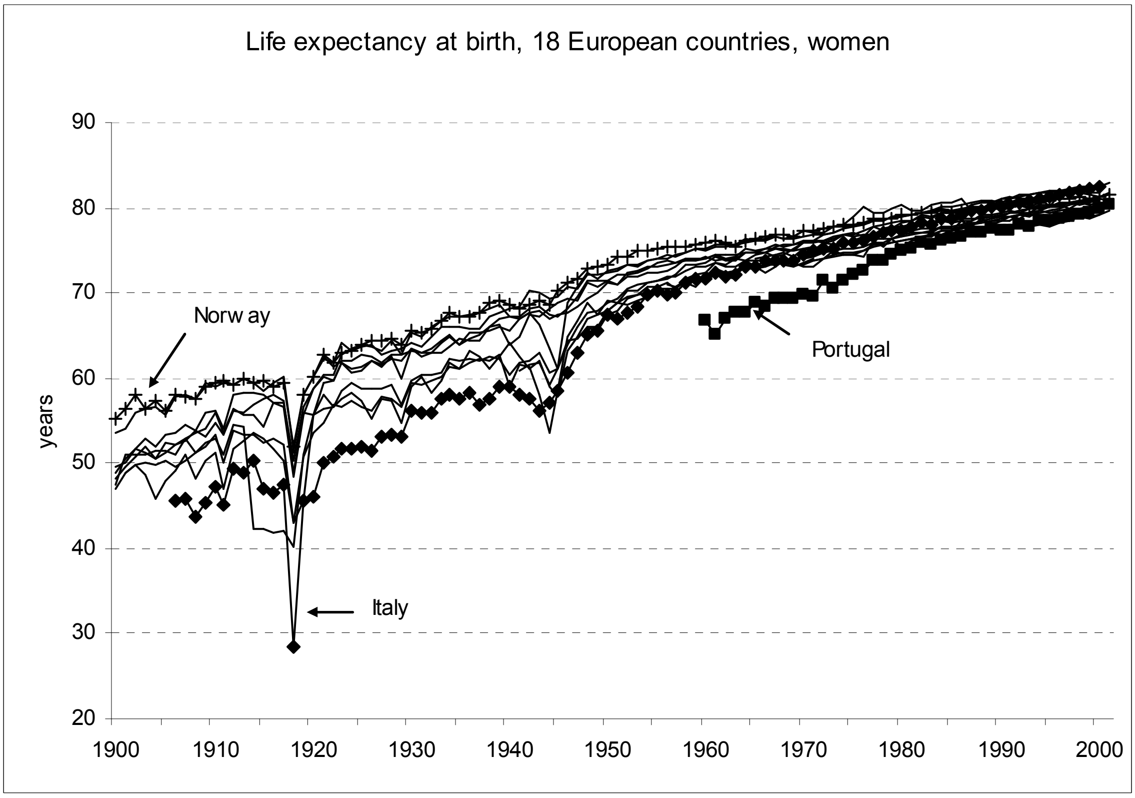



Figure 4.3 Net migration to 18 European countries

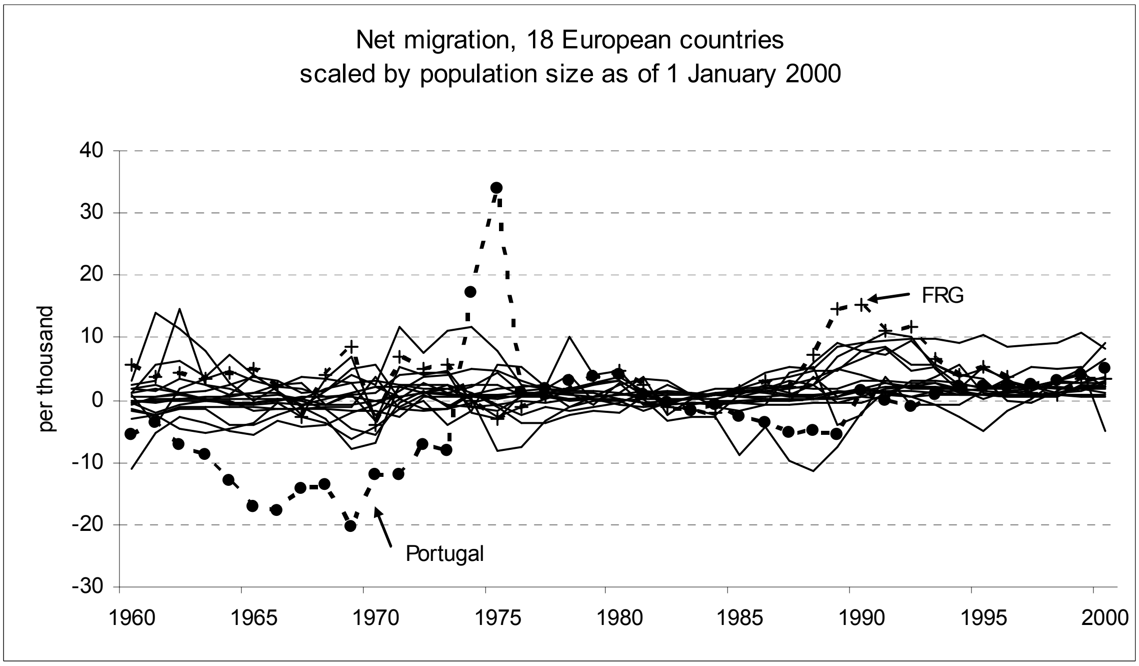


Figure 6.1 Coefficient of variation in TFR, 18 European countries

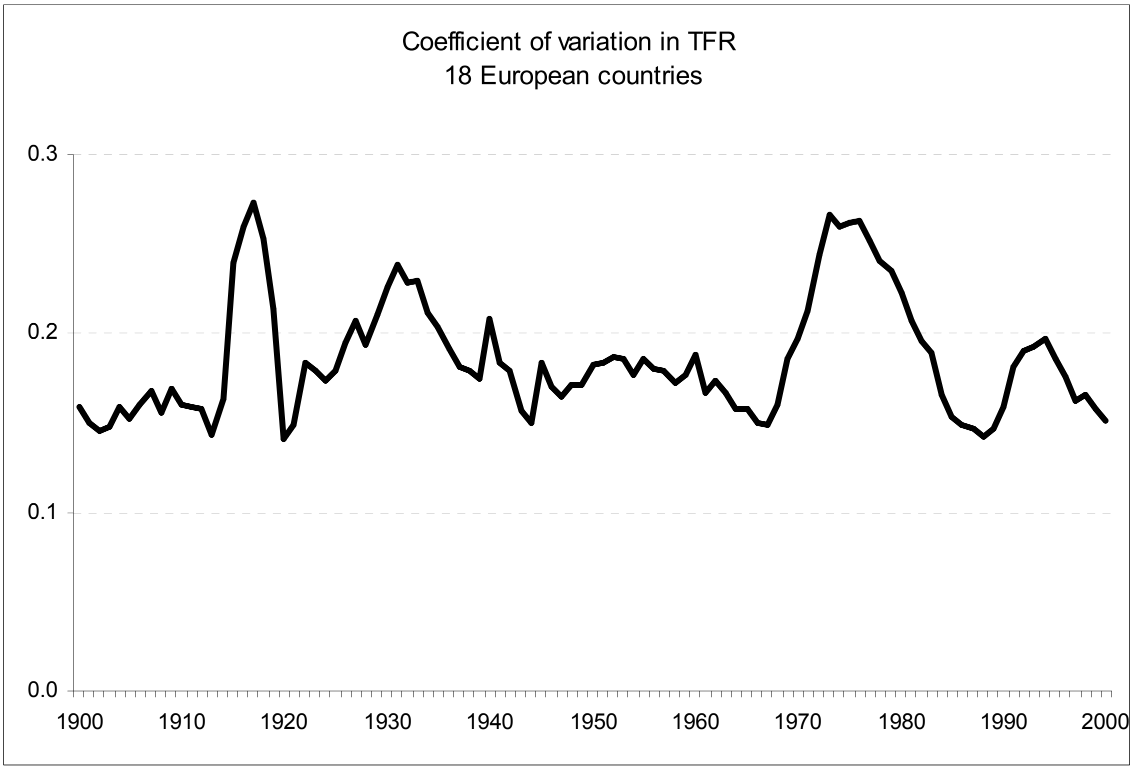



Figure 6.2 Coefficient of variation in Completed Cohort Fertility, 18 European countries

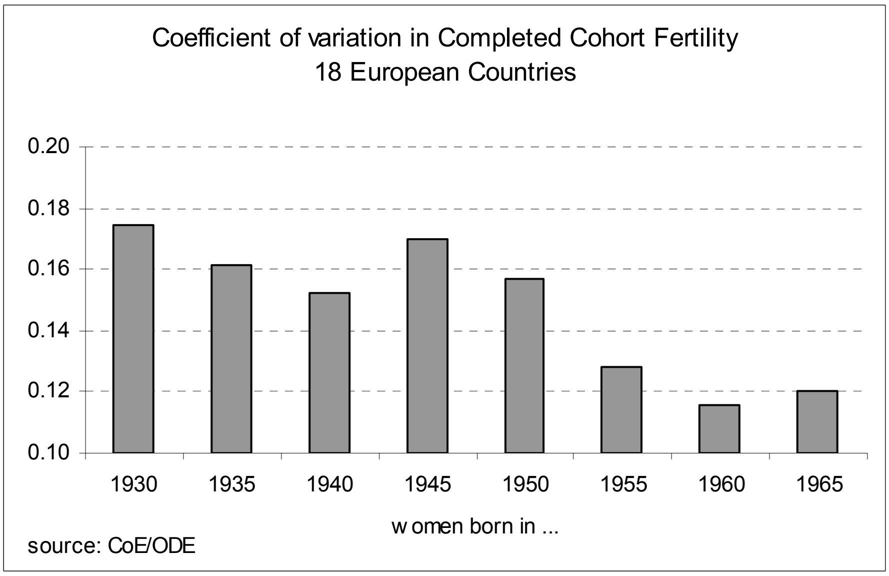


Figure 6.3 Coefficient of variation in life expectancy at birth, 18 European countries

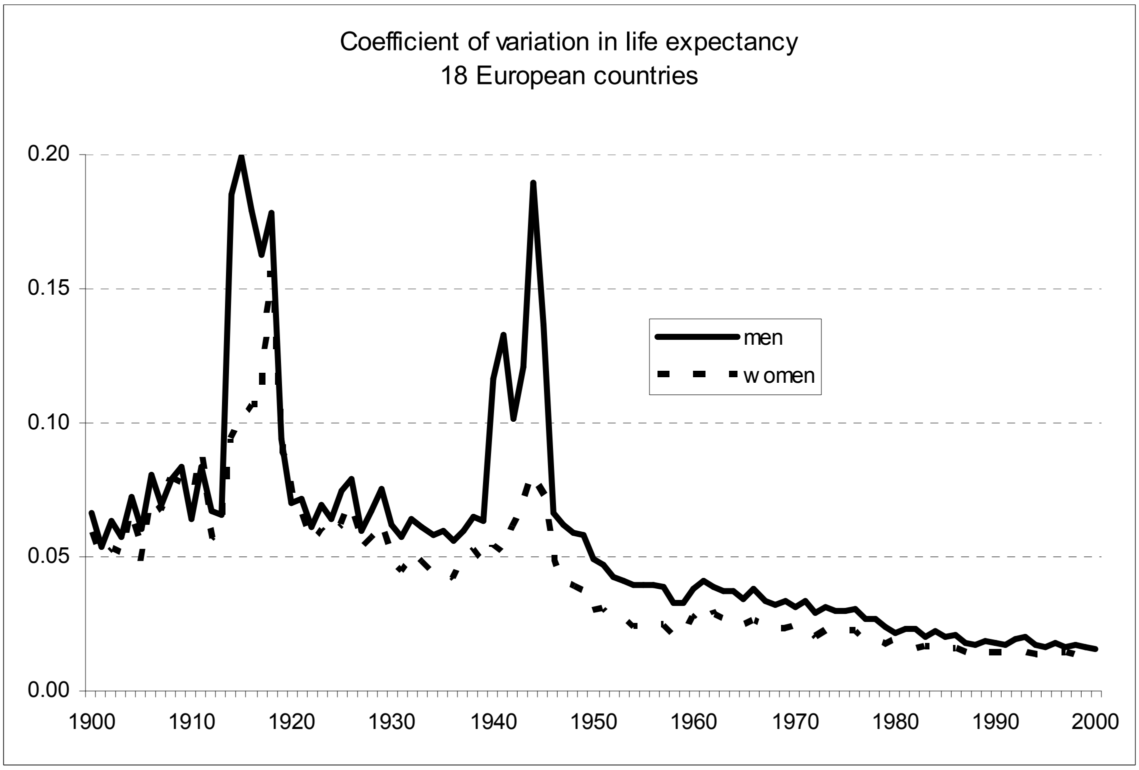



Figure 6.4 Coefficient of variation in remaining life expectancy at age 60, EU15