PLUREL

Driving forces and global trends

Module 1

PERI-URBAN LAND USE RELATIONSHIPS – STRATEGIES AND SUSTAINABILITY ASSESSMENT TOOLS FOR URBAN-RURAL LINKAGES, INTEGRATED PROJECT, CONTRACT NO. 036921

D1.2.1

Report on methods for demographic projections at multiple levels of aggregation

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SIXTH FRAMEWORK PROGRAMME

Contents

Abstract

This report describes methods of internal consistency in population projections at multiple levels of aggregation. The first step in the process is to make the initial assumptions used in the projections at different levels of aggregation consistent. This input-level consistency can be further enhanced by output-level analysis. Comparing the results at the relevant levels of aggregation ensures internal consistency at the output level. Thus, we are able to compare the differences in the age and sex distribution of the population and specific demographic indicators (such as the old age dependency ratio) over various regional levels.

In PLUREL, the national projections will be carried out using the probabilistic method while the regional projections will use deterministic or variant methods. The results at these two levels of aggregation cannot be directly compared one-to-one as there is no simple correspondence between the output variants and the probabilistic range. To avoid any problems arising from this, we develop an index representing the differences in the size and distribution of the population from the variant method to a given percentile in the probabilistic population estimate.

The report discusses various population projection techniques together with their strengths and weaknesses. The relative advantage of specific models for different purposes is discussed forming a selection of models to be used for the population projections in PLUREL: National (NUTS[1]-0), Regional (NUTS-2) and Case Study Projections (NUTS-5). We conclude that stochastic projections are best suited for national projections, while classic or multiregional cohort-component model projections are likely to be the best choice for the regional projections and for the detailed case study projections.

[1] NUTS (Nomenclature of Territorial Units for Statistics) defines the level of detail for the geographic units.

Introduction

This report presents a brief overview of different approaches for demographic projections along with detailed references to the key literature. It draws on a number of studies, notably reviews done by Wilson et al. (2002), Wilson and Rees (2005), Booth (2006), and Smith et al. (2001). Different methods of population projections are presented in order to compare the cohort-component and stochastic projection methods with other available population projection tools.

Identifying which projection model is optimal for a specific type of projection depends on several factors. Of crucial importance is whether the projections are to be carried out for larger geographical areas (including projections of nations and groups of countries) where uncertainty is lower, or smaller areas (including regional and peri-urban city projections) where migration makes future population developments more volatile and projections more difficult.

The length of the period for which one aims to project is also important for model selection. Other factors matter for model selection, including whether a model should cover certain complexities or specific dimensions, such as considering the change in size of population subgroups or the impact of policies.

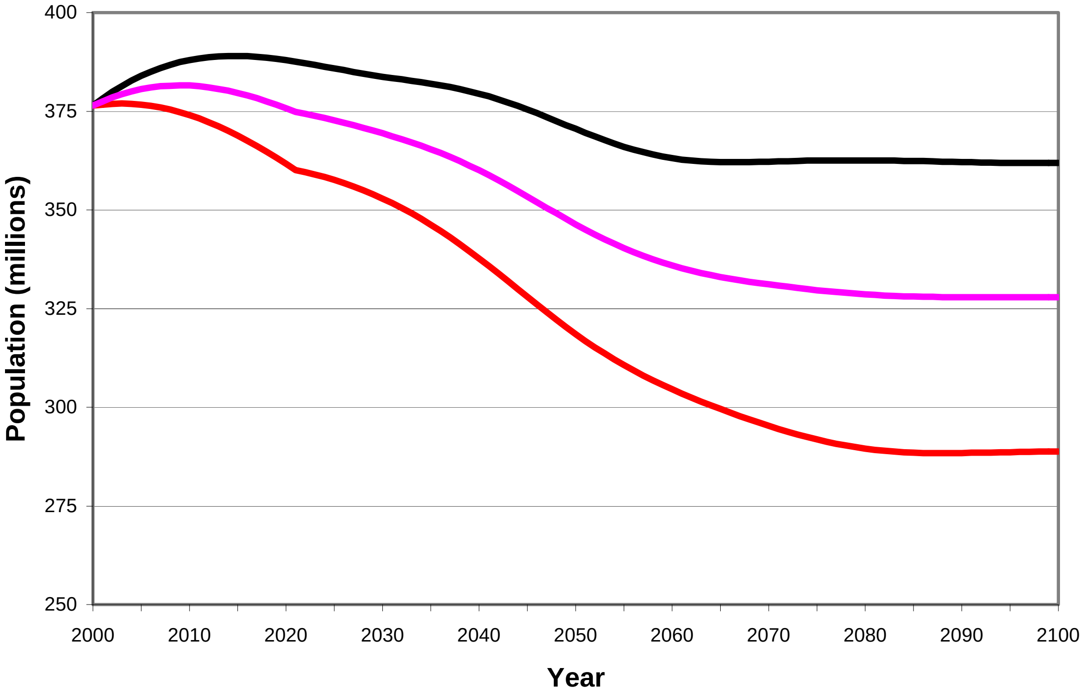
Assumptions for projections

Demographic components: Fertility
Fertility assumptions are usually expressed as period fertility, i.e., total fertility rate (TFR) which is the sum of age-specific fertility at one point in time. Assumed increases or reductions in TFR could either be caused by proportional shifts in fertility across the reproductive life span or changes in early or late childbearing patterns.

Population projections carried out by the UN and Eurostat predict that low-fertility European countries will experience increases in their TFR. The UN also predicts that European total fertility rates will uniformly converge to 1.85 children per woman, while Eurostat assumes fertility will increase to different levels, depending on recent nation-specific childbearing trends (Eurostat 2005; Lutz et al. 2006; UN 2005).

Assumptions about rising fertility in Europe, although usually not explicitly stated by projection agencies, could reflect expert judgment belief that population variables will tend to increase. This could be due to arguments such as future European fertility rates will increase because of the tempo effect – in other words, less further childbearing postponement (see, e.g., Bongaarts and Feeney 1998; Kohler and Philipov 2001). Other possible explanations for increasing fertility are the structural factors, following Easterlin's (1980) hypothesis that general optimism and higher fertility will follow from smaller cohorts experiencing less competition in education and labour markets.

Future fertility paths are extremely important for future fertility trends. Figure 1 highlights the importance of the timing of the possible recovery of fertility to replacement level in Europe. The fertility scenarios reflect the importance of the timing of fertility, where an immediate increase to replacement fertility compared to one taking place 20 years later implies very large differences in total population size.



Note: The three lines indicate different scenarios for the EU-15:
1 –Fertility immediately increases to replacement level and remains constant thereafter (black)
2 –Fertility rises to 1.8 immediately and rises to replacement level in 2020 (pink)
3 –Fertility remains at 1.5 until 2020, when it rises to replacement level (red)

Figure 1. Population EU-15. Effects of fertility variation. Source: Lutz et al. (2003).

Demographic components: Mortality

Mortality assumptions for projections are often simplified to changes in *e(0)*, i.e., life expectancy at age 0. This involves implicit assumptions on the ages at which mortality is reduced (*e(0)* could increase due to mortality reductions primarily early or primarily late in life). Current mortality projections typically assume a decennial increase of life expectancy at birth by a fixed number of years, e.g., 1.5 or more (e.g., Eurostat 2005; UN 2005; Lutz and Skirbekk 2005; Oeppen and Vaupel 2002) and a weakening of, or an end to this effect at a later point in time.

For countries with a higher level of life expectancy, assumptions about further developments in mortality at late ages are of crucial importance, mainly for economic reasons. These assumptions are the subject of heated debate in the literature, where some argue for a reduced future mortality decline and others for a continued reduction in mortality (Olshansky 2006; Vaupel and Jeune 1995).

One of the most commonly used mortality assumptions is the Lee and Carter (1992) method. This method allows for simultaneous changes in the level and age structure of mortality using a relational model consisting of two age-specific functions and one time-specific function, the latter reflecting advances in mortality dynamics.

Figures 2a-c present the long term changes in life expectancy for Austria and Sweden. Figure 2a shows the Austrian life expectancy for newborns, *e(0)*, relative to the highest life expectancy in the world (Oeppen and Vaupel 2002). Austrian life expectancy can be seen to rise faster than the world's best values. Decreasing infant mortality is a major cause of the increase in life expectancy. Figure 2b compares infant mortality in Sweden and Austria over the past two centuries. As can be seen, the high mortality differences narrow and eventually come close to convergence. Swedish-Austrian differences in life expectancy have persisted to a larger degree, as shown in Figure 2c.

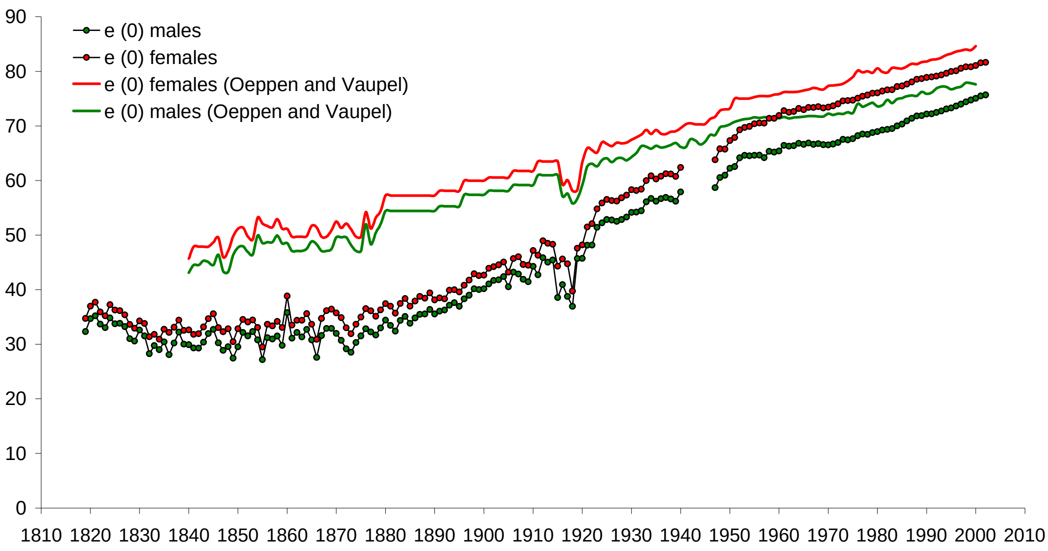


Figure 2a. Austrian life expectancy at age 0 *(e(0))* and the world's best values. Sources: Oeppen and Vaupel (2002); Dalkhat Ediev and Richard Gisser (personal communication).

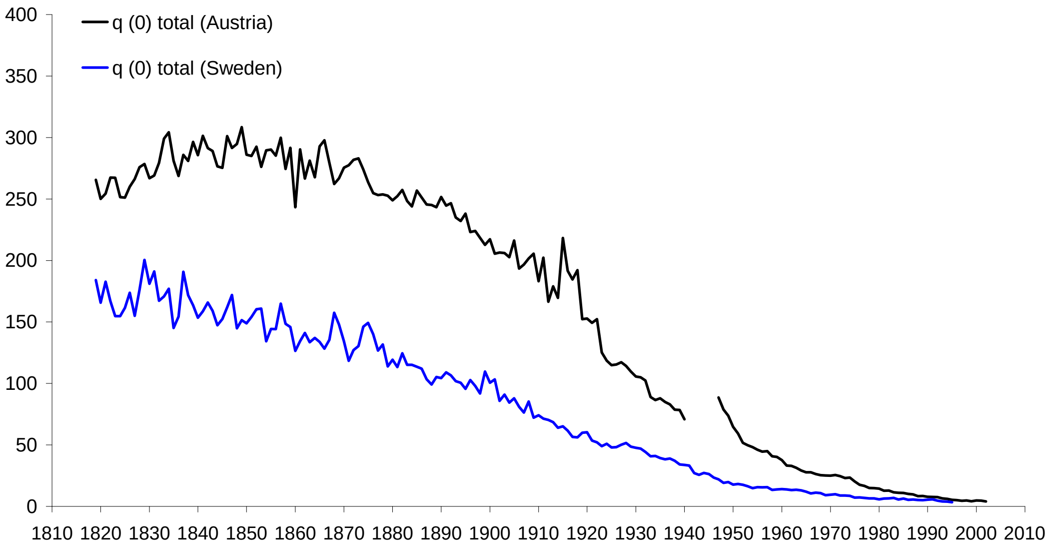


Figure 2b. Infant mortality *(q(0))* in Austria and Sweden. Sources: Dalkhat Ediev and Richard Gisser (personal communication).

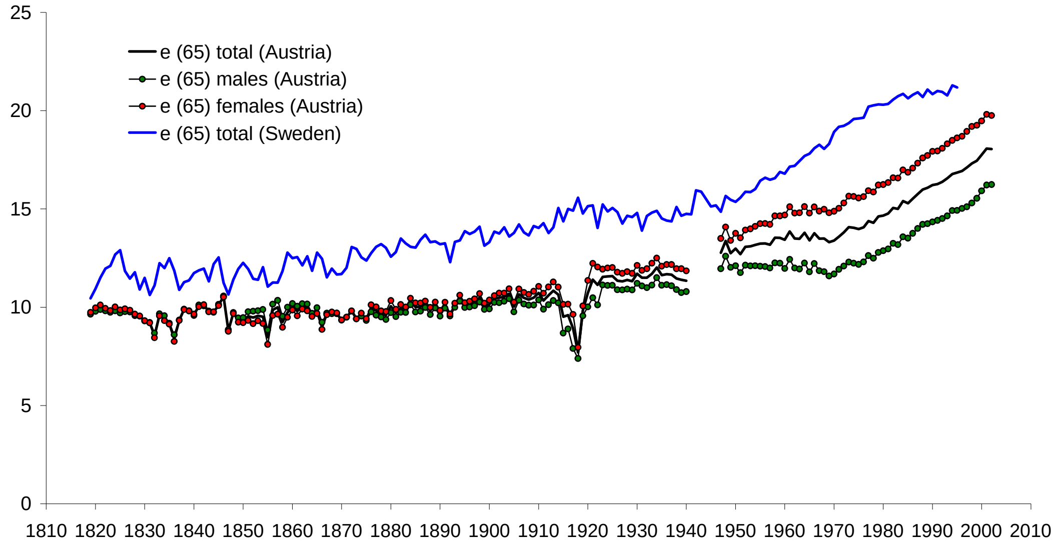


Figure 2c. Austrian life expectancy at age 65 *(e(65))* relative to Swedish life expectancy. Sources: Dalkhat Ediev and Richard Gisser (personal communication).

Demographic components: Migration

Migration flows fluctuate strongly and may depend on a large range of factors, including business cycles in both the sending and receiving countries, family connections in a destination country, cost of migration, destination's reputation, attitudes to immigration and immigration laws. Migration is strongly influenced by policies. This contrasts with mortality and fertility where the impact of policy is much less evident (e.g., OECD 2003a concludes that family policies are only weakly associated with fertility levels). Migration regulations and practices are difficult to foresee, which makes migration the possibly most difficult demographic component to predict. For example, family reunification is the most important cause of immigration in many west European countries and changes in laws that affect this type of migration are likely to have substantial effects on migration flows (OECD 2003b).

Migration has become increasingly important in recent years in determining change in population size; it may also affect national fertility rates if the number of migrants is sufficiently large (see, e.g., Goujon et al. 2006). With this increasing significance, more emphasis has been given to migration scenarios. In developing migration scenarios for Europe, Bijak et al. (2004) grouped countries according to migration regimes and used net migration target rates for both internal and international migration for 27 European countries.

George and Perreault (1992) found that among 30 industrialized countries, migration assumptions tended to be either zero net migration or a continuation of current trends. Zero net migration scenarios are often included in order to highlight the differences to other migration scenarios in affecting the overall population size and the age and sex structure. De Beer (1997) and Keilman and Pham (2000) are examples of studies that predict migration by using autoregressive models where the parameters are estimated using time series data. De Beer also incorporates expert judgment to determine migration-level targets for the projections.

Expert judgment

Surveying the conjectures of leading demographic researchers about what they see as likely future trends in migration, mortality and fertility is termed the *expert judgment* approach (Lutz et al. 2000). Most national statistical offices, IIASA and the UN use expert judgment as a basis for their assumptions on future trends that feed into their projections. This approach has been criticised for not taking uncertainty and experts' error sufficiently into account (Tuljapurkar 1997; Saariluoma 1995).

Lee (1999) identifies that the expert opinions about future fertility have been highly inaccurate. Substantial errors have also been found in predictions of mortality, which have often been higher than observed mortality. These predictions were often based on the incorrect assumption that life expectancy will not continue to increase in the same way as it actually increased (Alho and Spencer 1990).

Lutz et al. (2000) argue that structure and trend assumptions should be made explicit rather than be based on implicit judgment, in order to improve the accuracy and transparency of the projections. Experts' superiority is limited to their field of expertise, which means they can make serious errors in their prognosis for the complex interdisciplinary task of population projections. Estimates for the future cannot be taken as fact, even if presented by an acknowledged authority (institution or person), nor is it acceptable to resolve scientific issues on the ground of voting or concert. Lutz et al. conclude that there should be a separation of the expert and the argument, and that the latter should be used and be made explicit rather than relying on implicit judgment.

Population projection techniques

Extrapolation
Extrapolation builds on the assumption that future demographic developments can be derived from past population trends and hence, a continuation of observed demographic change is assumed. Extrapolation models are often conducted using univariate ARIMA (Auto Regressive Integrated Moving Average) models (Box and Jenkins 1976). This method is widely used in econometrics and refers to approaches where one uses past values of only the factor of interest and the error term (and disregards other variables) to calculate future trends.

The central weakness of basing predictions on past trends is the lack of accounting for other information. Some events may be made likely to happen (e.g., through knowledge of new technologies or policies that are likely to affect demographic variables). For example, new policies that affect maternity benefits could affect fertility rates – which may not be foreseen by past trends. Furthermore, advances in medical technologies could lead to a trend break in future mortality reductions.

Cohort-component method
The most common tool in population projections, at the national level, is the so-called *cohort-component* method. Eurostat, the UN and most national statistical bureaus use this method for their population projections. The cohort-component model is a deterministic population projection method, which means that it does not describe uncertainty, but refers to a set of scenarios chosen to represent plausible, possible or relevant (e.g., to investigate the impact of a policy change) future paths of migration, fertility and mortality.

In order to conduct a cohort-component population projection, one needs a description of the *base population* in the initial year of the projection. Information on the number of individuals by gender in every age group is required. Age-specific (using one- or five-year age groups) assumptions on future fertility, mortality and migration rates are used to project the population, normally in one- or five-year time intervals.

Cohort-component models are essentially *what-if* predictions of the future, where population trends are determined by a set of assumptions. These assumptions could reflect a continuation of past trends or an investigation into what would happen if there is a (constant) change in one or more of the demographic variables.

These assumptions are often stated as the total fertility rate, life expectancy at age 0, and net migration. Decisions on future assumed trajectories in the components, also called the scenario or variant selection, determines the projected trajectory of the population size and structure. In the end, the different variants, or scenarios, can be compared in a nice graphical manner keeping in mind the chosen initial assumptions on fertility, mortality and migration that led to them. The weight or likelihood of the output scenarios is essentially the same, and sometimes it is difficult to estimate which of the initial assumptions, or combination of assumptions, is most likely. This highlights well the *what-if* aspect of the method. The method is well suited for testing out different policy or other options to see a hypothetical range of future scenarios.

Structural models and other approaches
Structural models base population projections on the underlying socio-economic development and other determinants, including feedback mechanisms and the effects of changes to institutional settings (e.g., Lee 1990). However, most economic-demographic models are unable to take into account all relevant variables and when the relation between the different variables is not well known, structural models are not necessarily better than other models. In principle, these models are well suited for analyses of policy changes on demographic variables. In practice, however, the lack of data on one or more model parameters is often an Achilles heel.

As the accuracy of these models depends on correct forecasting of the determinants of population change, good projections depend on the association between the variables being strong, predictable and stable over time (Brass 1974). Whether these models produce more accurate projections than other methods remains disputed (Keyfitz 1982; Sanderson 1999). Sanderson, however, shows that the WORLD3 model, which takes into account land use change, resource limits, production and pollution when projecting population (Meadows et al. 1972) was, in fact, considerably more accurate than the United Nations Population Division's estimates when comparing with actual population development 25 years later.

Multistate population projections are a further possible way to improve population forecasts. Multistate methods project the population in different 'states', e.g., people with various levels of education. For example, several studies suggest that the relation between education and demographic outcome – mortality, childbearing and migration – could be partly causal (Hannum and Buchmann 2005; Skirbekk et al. 2004; Zhao 1997). The large increase in education combined with substantial differences in demographic outcomes of individuals with different education levels (Jejeebhoy 1995) would suggest that projecting population according to education subgroups could increase the accuracy of population projections. For example, if the share of the population that attains higher education increases, this could lower mortality and decrease fertility rates.

Figure 3 shows the composition of the population of the EU-25 and the USA disaggregated by four educational groups: no education, some or completed primary, some or completed secondary, and some or completed tertiary education. As can be seen, the current EU-25 countries started off from a situation in 1970 where they were less educated than the Americans, with larger proportions without education and with primary education. However, in 2000, most individuals in the EU-25 have at least some secondary education, while by 2030 (according to our projections), there is likely to be more tertiary educated individuals in Europe than in the US.

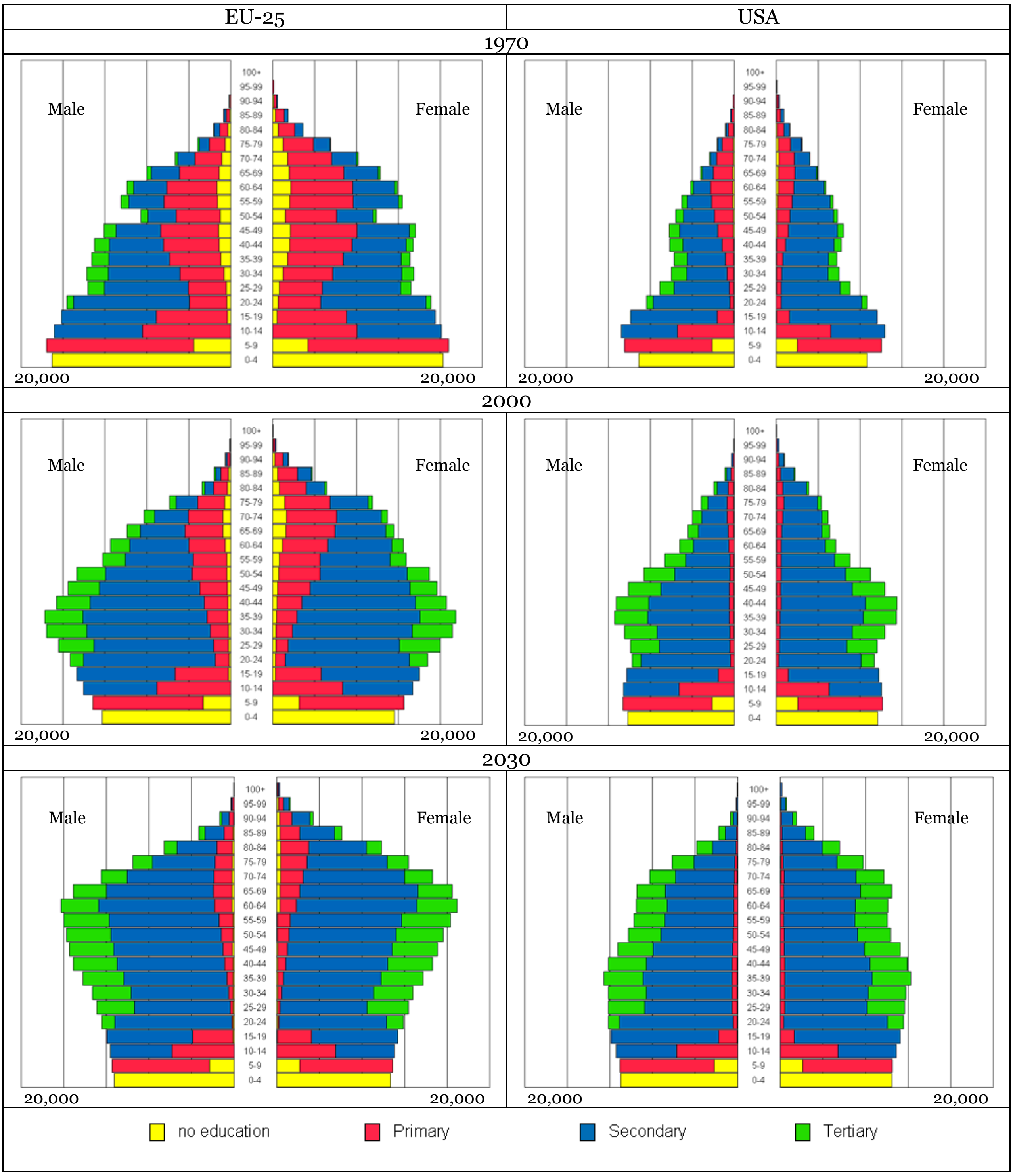


Figure 3. Population by education 1970-2030, EU-25 and USA (in thousands). Source: Goujon (2006).

Population projections are often based on a combination of different techniques. Cohort-component projections can be linked to structural models to investigate policy changes. For example, Lutz and Skirbekk (2005) incorporate a simple structural element in the cohort-component model for several European regions. They investigate the effect of making European primary and secondary school systems more effective and lowering the school leaving age, which is predicted to raise fertility levels and hence decrease the rate of population ageing in their cohort-component projections.

Towards probabilistic projections

The two main classes of demographic models are the deterministic and the probabilistic classes. The cohort-component approach falls into the former class. This above-mentioned method is well established and comprises the possibilities of using the scenario or variant approach to the choice of future trends in the demographic variables. Here the term scenario refers to a consistent system with embedded fertility, mortality and migration assumptions to give a comprehensive picture of what the future may look like in demographic terms (Lutz et al. 1999). Providing the three variants (or scenarios) has become the norm in projections provided by the United Nations World Population Division, Eurostat and in part IIASA (International Institute for Applied Systems Analysis). Stochastic projections, on the other hand, give a more detailed picture of the underlying uncertainty than will the deterministic ones, if only because of the sheer depth of the statistics they produce.

In order to take into account the uncertainty about the future development in the demographic forces, scenarios are used to consider alternative futures in deterministic projections. High values in fertility, high migration and low mortality often represent a so-called *high* scenario; medium fertility, medium migration and medium mortality a *medium* scenario, and low fertility, low migration and high mortality a *low* scenario. Thus the low scenario gives the smallest projected population size, the high scenario the largest projected population size, while the medium scenario projects a population size in between. Combining factors in this way is termed ‘bundling’ and is almost ubiquitous in official projections.

Those who utilise the results of the cohort-component population projections with high, medium, and low scenarios overwhelmingly treat the medium variant as being the ‘most likely’ outcome. The world medium gives a sense of neutrality and hence an apparent plausibility in future development. However, medium scenarios typically assume a continuation of current trends in fertility, mortality and migration with little or no attempt to take into account known future policy or other envisioned changes in demographic trends.

Forecasting uncertainty – Stochastic models

Combining the three scenarios for mortality, fertility and migration yields a total of 27 possible scenarios. One problem with the conventional three-scenario approach is that the three combinations often presented represent only 11% of all possible scenarios. Moreover, the ones presented may not necessarily be the most likely, for example decreasing fertility could coincide with large immigration flows and a continuation of current mortality trends. If further scenarios are needed to express uncertainty in some of the demographic indicators, the problems with a limited set of scenarios increase further.

In order to take into account the uncertainty of vital indices and migration, one can present the likely future in terms of confidence intervals. In this way, the perceived uncertainty can be incorporated in the demographic determinants. An example of this type of projection is Scherbov and Mamolo’s (2006) stochastic projections for the EU-25 (see Figures 4a and 4b). Confidence intervals are highest for those who are not yet born, or are already elderly at the time of the projection. This is due to high uncertainty on future childbearing, or for the older individuals, due to uncertainty regarding mortality.

Figures 4a and 4b show stochastic projections for the EU-25 for 2020 and 2030. As can be seen in Figure 4b in particular, uncertainty is greatest for those who are not yet born (hence widening confidence intervals). Moreover, uncertainty is also higher for older age groups relative to mid-age groups, as these have higher mortality risks. Moreover, migration is more important for the young adults, and hence these groups also have somewhat higher uncertainty.

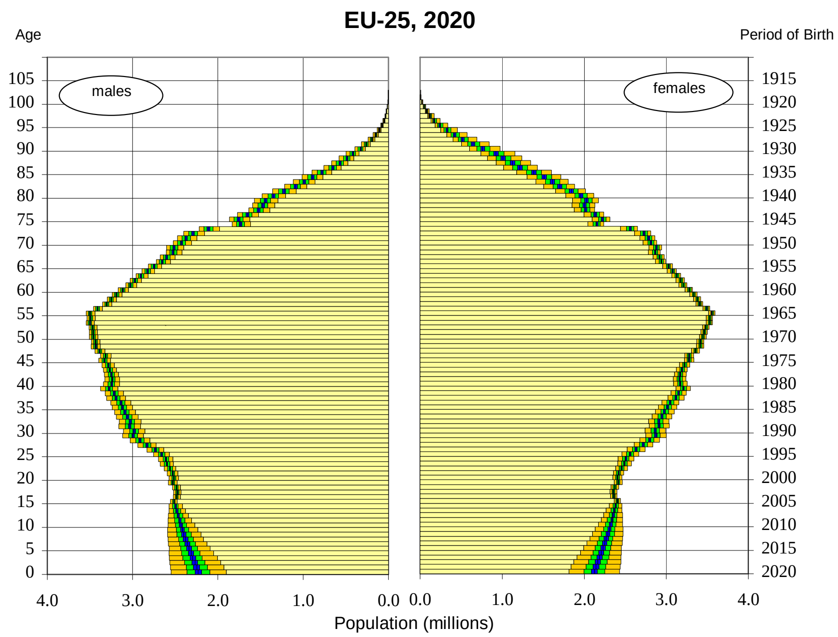


Figure 4a. Stochastic population projection for EU-25, 2020. Source: Scherbov and Mamolo (2006).

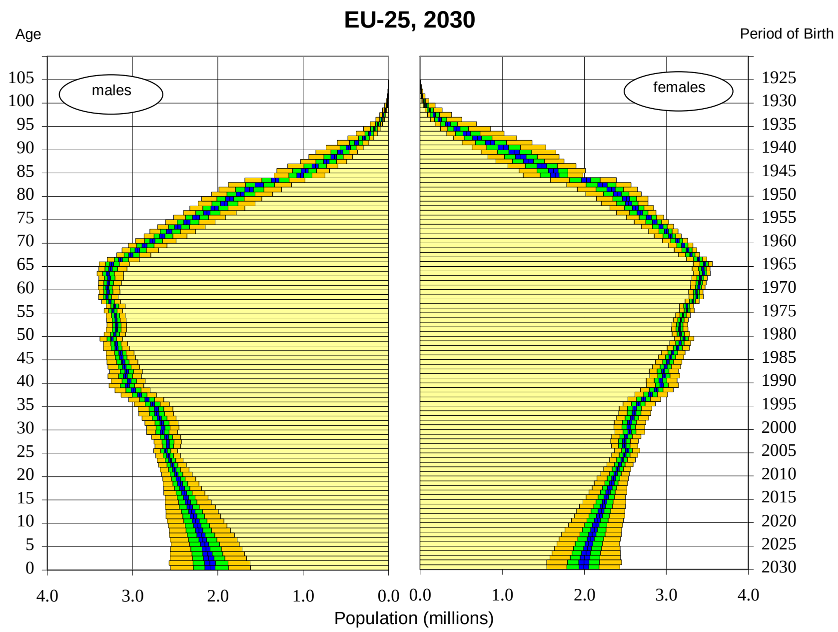


Figure 4b. Stochastic population projection for EU-25, 2030. Source: Scherbov and Mamolo (2006).

Stochastic projections of this form have been completed for several countries, including the United States, many European countries, Australia, Singapore, South Africa, and for the world as a whole and its large regions (Lutz et al. 1997; Alho and Spencer 1985; Keilman 1990; Lee and Tuljapurkar 1994; Scherbov and Mamolo 2006). As with all population forecasts, the initial input is the distribution of population by age and sex, forecasted total fertility rates, life expectancies at birth and net migration. The latter three are provided as distributions and not as points, which distinguishes the method from the deterministic one. All distributions are generated by expressing the variables as the sum of their mean and the deviation from their mean at time *t*. The deviation is a normally distributed random variable with mean zero and standard deviation σ. The evolution of the random variable is obtained by using the so-called autoregressive formation *(AR(1))* or the moving average formation of order *q (MA(q))* (Lutz et al. 2001).

Model
Source: Lutz et al. (2001)

Let υ be one of the demographic variable rates to be forecasted through periods 1 to T. Then υ_t is the forecasted value at time t and $\upsilon_t = \overline{\upsilon}_t + \varepsilon_t$, where $\overline{\upsilon}_t$ is the mean and $\sigma(\varepsilon_t)$ gives the standard deviation. Let $\{x_{2-n}, \dots, x_T\}$ be the values of $T+n-1$ independent draws from a standard normal distribution and n the number of moving point average periods, then the random variable becomes

$$\varepsilon_t = [\sigma(\varepsilon_t) / \sqrt{n}] \cdot \Sigma_{i=t-n+1}^{t} x_i.$$

Estimating standard errors of the input factors
It has been shown that errors in the baseline data are a serious source of uncertainty for all methods of population forecasting (Bongaarts and Bulatao 2000; Alho 1992; Keilman 1999). This is particularly true in forecasting the near future. In the longer run, however, the estimation of future trends becomes the dominating source of error (Lutz et al. 2001). This is also the reason for projecting world regions and not always country by country, much less region by region. Errors in estimating fertility and migration, for example, tend to cancel out when the observed area is sufficiently big.

Stochastic analysis based on past trends - Extrapolation
One can estimate the standard error from an observed time series of the indicators. However, changes in the chosen trend can quickly cause the indicator to go outside the observed 90% or even 95% confidence intervals, which are usually provided as the outer bounds of the output. The reason for this is that it is extremely difficult to predict changes in demographic variables. Examples of such shifts are the baby boom in the 1950s and 1960s, or the stalling of fertility decline in Egypt since 2000 (Engelhardt 2004).

The methods utilising extrapolation are problematic, as they do not take into account knowledge about factors that could lead to discontinuities in demographic indicators. This includes, for example, new medical advances that lead to a structural break in old age mortality decline, rising housing prices that lead to postponed and lowered childbearing levels, or changes in family reunification policies that affect migration levels. Such information could lead to structural breaks in the trends to which extrapolation techniques are unlikely to be able to respond.

Estimating uncertainty by expert opinions
Lutz et al. (1996) asked a group of demographic experts for their views on various aspects of population forecasting. In response, the experts produced estimates for high and low scenarios for fertility, mortality and migration. Lutz et al. interpreted the expert-derived high and low assumptions as corresponding to a roughly 90% confidence interval – where 5% of the time values would exceed the high scenario and 5% of the time values would fall below the low scenario. It is further assumed that these subjective probability distributions are of the standard normal distribution form, with the central projection values of the indicators being equal to the mean of the distributions.

For the method of stochastic population forecasting Lutz et al. (1996) used probability distributions in the input variables by randomly selecting the component indicators from normal distributions. The 90% confidence limits to the distributions were supplied by the experts, as described above. The projection runs produce one thousand values of each output population.

Another decision needed for the simulation scheme is whether the same random draw should be used to determine the projection indicator value for all components and for all separate population units. Lutz et al. (1996) carry out simulations where fertility and mortality are assumed either independent or correlated. Correlated projections involve using the same random number. In this case correlated projections result in a narrower range of projected populations than uncorrelated projections because of the way the high-high and low-low scenarios for fertility and mortality tend to cancel out. This compensation is also achieved by uncorrelated regional projections compared with correlated ones.

In 2001 Lutz and co-workers further studied the correlation phenomena by adding to the above studies the correlation of fertility and life expectancy, autocorrelation, and correlation across regions. They found that the main effect of fertility and life expectancy correlation is on the variance of the distribution of future population sizes. They discovered that for a century-long forecast, the maximum error in female population size for a country was 3 percentage points when the error in variance is the largest possible (Lutz et al. 2001). For shorter forecasts the error due to this correlation can be assumed to be insignificant with respect to greater errors caused by, e.g., baseline errors. Differences in the first order autocorrelation gave similar percentage errors as the fertility-life expectancy correlations.

Correlations across regions are expected to increase due to the globalisation of medical technologies and spreading of the burden of natural disasters (e.g., the whole world contributed to the costs of the December 2004 Tsunami in Asia). Further, for this study the correlations across regions have no great significance. Moreover, the errors in both the baseline population and the fertility assumptions can be expected to be minimal due to the level of high quality data available for the EU countries and the relatively short projection time.

Regional projections methods

The projection methodologies and practice of Eurostat and the NSOs (National Statistical Offices) for NUTS-2 or NUTS-3 projections are summarized in van der Gaag et al. (2003), van Wissen and Huisman (2002), and Eurostat (2006). Usually, the publications that contain the projection results contain only limited, if any, information on the projection method.

Eurostat’s (2006) regional projections for Europe (see Lanzieri 2007) assume a top-down approach, where fertility, mortality and international migration are consistent with the assumptions for the population projections at the national level. The change in the components does, however, reflect differences between the regional trends and the national average. Consistency between regional and national scenarios is achieved both at the input side (equivalent rates) and at the output side (equal numbers of events). The regional projections are computed by transforming the assumptions already formulated for the national projections into region-specific assumptions.

These regional variants are expressed using methods of indirect statistics: the national fertility and mortality age- and sex-specific rates are applied first to the regional population which yields a hypothetical number of events by which the observed number of events is divided to obtain a regional scaling factor. The scaling factor describes if either of the regional rates are above or below the national value. The regional scaling factors for fertility and mortality are set as the average value over recent years. The scaling factor for international migration has been estimated as a residual of the demographic balance and is the ratio of the regional crude migration rate to the national crude migration rate. The migration-scaling factor is set as the average value for recent years.

The baseline variant, high population variant and low population variant have been produced using “baseline”, “high population” and “low population” assumptions at the national level for fertility, mortality and net international migration, respectively. In the baseline variant, a partial convergence has been assumed by 2030: The difference between the national value and each regional scaling factor will decrease by one fourth (intermediate values are obtained by linear interpolation, e.g., an initial scaling factor of 0.80 will reach a value of 0.85 by the end of the period). In the low variant the scaling factor is kept constant through the projection period. The high variant assumes that the differences between the regional and national levels will reduce by 50% by 2030.

Interregional migration is modelled separately. The age- and sex-specific rates of interregional migration are estimated by using inter-NUTS-2 arrivals and departures by sex and age and region, and the total number of interregional NUTS-2 migration by region of origin and by region of destination (origin-destination migration matrix). The Eurostat model also takes into account national residential mobility and the degree of attractiveness of the regions. The assumptions are formulated as internal mobility as a whole plus the convergence/divergence of the regions in terms of attractiveness. In the baseline variant, both the interregional migration and regional differences remain constant throughout the projected time horizon. The high population variant assumes an increase of internal mobility by 20% compared to the base year level and a 50% decrease in differences in regional attractiveness by 2030. The low variant assumes that internal mobility drops by 80% compared to the base year level, and that regional differences in attractiveness increase by 50%.

Regional population projections by national statistical offices
The most recent study on subnational population projections by van der Gaag et al. (2003) is the update of the two previous inventories of the Eurostat/NIDI inventory (van Imhoff et al. 1994; van der Gaag et al. 1997), and of the Council of Europe/Leeds inventory (Rees and Kupiszewski 1999a, 1999b).

A recent paper reports survey findings from national statistical offices (Kupiszewski and Kupiszewski 2003). They find that the cohort-component projection method is used most often. Four countries declare using a cohort-component model, and use a multiregional cohort-component model, and other countries create more complex methodologies, sometimes incorporating other variables. Most regional projections are found to be consistent with the national projections (bottom-up and mixed methods are common). The geographies used for subnational projections vary substantially (such as from sub-municipal level in the Netherlands to NUTS-2 regions). The subnational projections get updated regularly, but only Austria produces NUTS-2 projections annually (interval between 2-5 years). The time horizon for the projections varies from 10 years for Flanders to 50 years for Austria, Belgium, and Italy.

Fertility and mortality
Each region may have its own set of age-specific fertility and mortality rates. When regional data are not available, one could either use the national values or assume that the regional values are equal to those of similar regions (when data are available only for some regions). When information is incomplete, parameterized functions are frequently used (e.g., when information on the age distribution of fertility is not known). As in the case of fertility, full variation of mortality by age, sex, and region may be restricted and aggregation and smoothing methods are used.

Migration
Migration movements are classified by a region of origin and by a region of destination. Internal migration data in Europe are generally derived from two different types of

migration data: migration registers and decennial censuses, with national differences in registration practices, laws and efficiency. The migration registers count all changes of address, sometimes conditional of crossing administrative borders, and allows registering events that otherwise could be left unrecorded, including multiple migrations and return migration. Such registers could produce complete origin-destination matrices by age and sex of the migrants. The decennial censuses collect transition-type data on migration by comparing places of residence in two points in time. These data do not capture certain events, including multiple migrations, or the migration of persons who both migrated and died within the given period. The main differences between the register and the census data are that the first one counts the migration *events*, and the second one counts the *migrants* (van der Gaag et al. 1997; Kupiszewski 2002; Kupiszewski and Kupiszewski 2003).

In contrast to many models that describe the pattern of past migration movements, the handling of migration in population projection models is conventionally carried out using models that exclude non-demographic factors (van Imhoff et al. 1994; Kupiszewski and Kupiszewski 2003; Wilson and Rees 2005). van Imhoff et al. (1994) distinguish three main types of models for internal migration: the multiregional models and the migrant pool models (both being gross migration models); and the net migration models. We also distinguish between (i) migration models based on explanatory models, and (ii) migration models based on demographic approaches (van der Gaag et al. 2003).

Demographic approaches: Net migration models
The net migration model, based on the sum of immigration-emigration to a region, can be useful for the population of small areas. It can be used when gross migration data are unavailable or unreliable, and it provides a low-cost alternative to the use of gross migration data (Smith and Swanson 1998, p. 249). On the other hand, this type of model cannot account for the differences in the characteristics of origin and destination populations. It cannot be used for rates in a probabilistic sense, and it can lead to misspecified causal models and unrealistic projections.

Smith et al. (2001) and Wilson and Bell (2004) distinguish among *top-down models* and *bottom-up models*. The top-down models first project the overall net migration based on recent levels, historical trends, structural models, or some other procedure. Then these overall projections are broken down into age-sex categories based on historical distributions. The bottom-up models develop separate net migration rates for each age cohort (these can be broken down by sex, ethnicity, and others). That means that the total volume of net migration projected for an area is the sum of the values for each age group. These models generally combine the effects of international and internal migration. Calculating net migration as a residual is the simplest approach.

Demographic approaches: Migrant pool models
The basis for this approach is applying out-migration rates and in-migration proportions for each region to be projected. The migrant pool methods can be used when the emigration and immigration rates for each region are known, but a full migration matrix cannot be applied (as one does not know both the origin and destination region of the migrants). That means that first the pool is filled with all projected out-migrants. The migrants in the pool are then allocated to the destination regions using a distribution algorithm. The distribution algorithm usually fixes immigration proportions to the different regions (van der Gaag et al. 1997; Smith et al. 2001; van der Gaag et al. 2003). One weakness is that the pool migrants are at risk of being immediately returned to their region of origin (van Imhoff et al. 1994). This approach was used by the U.S. Census Bureau during the 1960s and 1970s for state population projections (Smith et al. 2001).

Multiregional models
Multiregional models have become popular for regional population projections in particular in Europe. For example the most recent population projections of Eurostat employ a variant of the multiregional model (Eurostat 2006; van der Gaag et al. 2000;

Kupiszewski and Kupiszewski 2003; van der Gaag et al. 2003). Multiregional models have also been used by the U.S. Census Bureau in recent population projections of American states (Campbell 1996; Smith et al. 2001).

The interregional approach avoids conceptual problems and biases of conventional net migration approaches (Isserman 1993). Rogers (1966) introduced the multiregional model, linking the migration model to the life table based cohort-component model (Rogers 1975, 1985, 1995). Parameterized versions were later developed (Rogers 1986) and have been applied to many countries (Willekens and Drewe 1984; Willekens 1990; Wilson and Rees 2005). The multiregional models are based on model place-to-place migration flows, whereas the interregional flows are calculated as a function of population. Migration is viewed as part of an integrated modelling system of mortality, fertility, and origin-destination-specific migration flows by age and sex. There are several ways to include international migration. The origin-destination migration rates are period-cohort occurrence/exposure rates, and matrix algebra methods can be applied (Smith et al. 2001; Wilson and Bell 2004).

Explanatory approaches: Gravity and spatial interaction models
In the gravity models, migration is considered to be a direct function of the size of the origin and destination populations and an inverse function of distance between them (van der Gaag et al. 2003; Ravenstein 1885). In early models the push factors of origin and the pull factors of destination, the cost of migration and the term 'impedance' refer to the frictional effect of distance on migration. These factors were represented as gravity variables and were measured commonly by total populations of the origin and the destination, and the distance between them.

In the 1950s and 1960s Kutznets and Thomas (1957, quoted in Greenwood and Hunt 2003) modified the simple gravity models in the sense that the variables of the basic gravity model are given behavioural content, and additional variables that are expected to importantly influence the decision to migrate are included in the estimated relationship. The connection between modified gravity models and the migration decision process has not always been tight. Modified gravity models are frequently estimated in double logarithmic form (they show reasonably good fits, and the coefficients obtained can be directly interpreted as elasticities of migration's response to changes in the various independent variables of the estimated models).

Urban and peri-urban population projections
Small area demographic projections typically use the same methods as regional or national projections, especially the cohort-component model. Urban and peri-urban projections are carried out in many parts of Europe, such as Vienna, Oslo and Dublin (Marik-Lebeck and Lebhart 2006; Oslo Kommune 2006; Irish Central Statistics Office 2005). Small-scale projections typically cover a relatively short time span, often spanning 5-20 years in the future.

Central in the scenario selection is whether cities are expected to grow or shrink, and the way in which they grow. City growth can be dispersed or compact, depending on the inhabitants' preferences, the infrastructure of the peri-urban area and restrictions/opportunities for land use. Patterns of international migration (which tend to be highly concentrated in urban areas) and internal migration/urbanisation imply that demographic development in cities and peri-urban areas can diverge substantially from national patterns of change.

Moreover, smaller cities, or those located in areas with relatively low economic growth, may lose out to larger cities in terms of attracting population. The impact of *distance working* could mean that more individuals will choose to settle in peri-urban areas because they need to commute less frequently to the city centre.

Housing projects, urban planning strategies, planned industrial development and infrastructure or other foreseeable issues can have strong effects on future population trends, and inclusion of these factors can increase the accuracy of the models. Migration is often the strongest determinant of population change at the urban and peri-urban levels. Migration is often incorporated in projections using a standard migration model, such as a multiregional, migrant pool or gravity model.

Method to ensure consistency at multiple levels of aggregation

In PLUREL, we will provide probabilistic population projections for all EU-25 countries and other world regions and large countries; demographic projections (deterministic – variant method) for NUTS-2 regions in the EU-25; and demographic projections at the local level for specific case study regions within PLUREL. The methodology for projection for case study regions is more specialized and in this section we present only the method to ensure internal consistency between the demographic outcomes at the national and regional levels (NUTS-2).

Internal consistency between the population projections at multiple levels of aggregation will be investigated and analysed at the input and output level. At the input level, the internal consistency between the national probabilistic projection and the regional deterministic projection will be maintained by making similar assumptions regarding future demographic events.

We are exploring existing data on regional deterministic projections done mainly by Eurostat and the national statistical offices. We are reviewing the methods and assumptions in these regional projections. In the regional deterministic projection, we will provide data on age and sex distribution in the future for three variants or scenarios, namely low, baseline and high. These variants are based on different trajectories of future demographic events (fertility, mortality and migration) at the national and regional levels. The assumptions at the national level are set, which will be used during the assumptions development at the regional level along with more detailed region-specific assumptions. These assumptions are then used in projecting the population in the future. In cases where the regional values do not sum up to the national total, necessary adjustment is made to ensure consistency between the national and regional deterministic projections.

In the national probabilistic projection, the input in the model is not a single value of each component as for a deterministic projection but a probability interval from which a single point is chosen stochastically during each simulation. Hence, from each simulation we will have a different set of trajectories for each demographic component, which will be used to obtain the population projection using the same method as in the deterministic approach. The results of the numerous simulations are put together to obtain a probability range of desired demographic outcome such as an age- and sex-specific population distribution or total population (as shown in Figure 1).

At the input level, the internal consistency between the two methods will be maintained by using the baseline variant in the deterministic projection with an appropriate uncertainty interval as an input for the probabilistic projection.

At the output level, comparing the results at the appropriate level of aggregation ensures internal consistency. For example, the differences in the age and sex distribution of the population at multiple levels of aggregation will be investigated. Moreover, comparisons of specific demographic indicators at different levels of aggregation, such as the old age dependency ratio, will be carried out (see Figure 5 for an example of stochastic projections of the old age dependency ratio).

In cases where the methods of projection are different, as is described here, the results at the appropriate level of aggregation cannot be compared one-to-one as there is no simple correspondence between the deterministically obtained variants and the probabilistic range. We propose to develop an index representing the differences in the size and distribution of the population from the variant method to a given percentile in the population estimate.

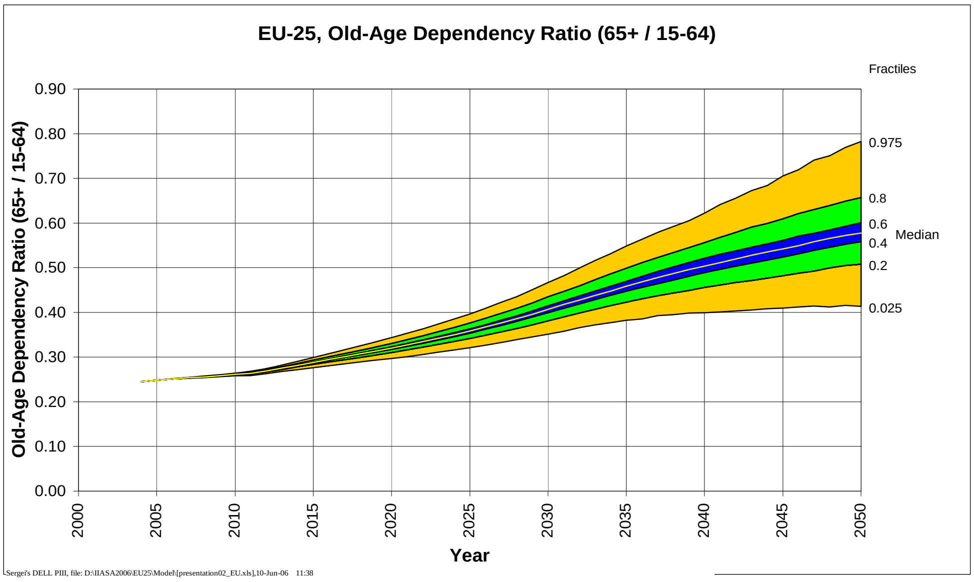


Figure 5. Stochastic projections of the old age dependency ratio, EU-25. Source: Scherbov and Mamolo (2006).

Conclusions

"The critical point to remember when choosing a projection method is that no single model or techniques is better than other for all purposes. Rather, each has its strengths and weakness and must be evaluated according to its face validity, timeliness, cost, data requirements, ease of application, and other characteristics." (Smith et al. 2001, p. 350).

In order to identify the optimal projection method, we have presented various approaches to demographic projections. A stochastic population projection could present a more realistic view as it presents uncertainty in a more realistic fashion: Users of stochastic projections would need to refer to projections by using likelihood estimates, as the projected demographic variables are likely to fall within a specified interval. Hence, the national projections in PLUREL will be based on stochastic projection techniques.

At the more detailed geographic level, stochastic population projections are less well suited, as uncertainty with respect to migration in particular could make the confidence intervals unnecessarily wide. Projecting stochastically for a larger number of small regions could be infeasible due to data limitations (particularly because interregional migration data are often missing or incomplete). A cohort-component model with a given set of migration, fertility and mortality scenarios could therefore be better suited for regional projections, for example at the NUTS-2 level.

At the NUTS-5 level, changes in city planning, migration and other difficult to predict factors suggest that the use of either extrapolation methods or cohort-component models are best suited. For example, migration occurring from a local employer relocating or a new housing project implies that it is difficult to predict for a long time horizon.

References

Alho, J. M. 1992. The magnitude of error due to different vital processes in population forecasts. *International Journal of Forecasting* 8: 301–314.

Alho, J. M. and B. D. Spencer. 1985. Uncertain population forecasting. *Journal of the American Statistical Association* 80: 306–314.

Alho, J. M. and B. D. Spencer. 1990. Error models for official mortality forecasts. *Journal of the American Statistical Association* 85: 609–616.

Bijak, J., M. Kupiszewski, and A. Kicinger. 2004. International migration scenarios for 27 European countries, 2002–2052. Working Paper 4/2004. Warsaw: Central European Forum for Migration Research.

Bongaarts, J. and R. A. Bulatao. 2000. *Beyond Six Billion. Forecasting the World's Population*. Washington, D.C.: National Academy Press.

Bongaarts, J. and G. Feeney. 1998. On the quantum and tempo of fertility. *Population and Development Review* 24(2): 271–291.

Booth, H. 2006. Demographic forecasting: 1980-2005 in review. *International Journal of Forecasting* 22: 547–581.

Box, G. E. P. and G. M. Jenkins. 1976. *Time Series Analysis: Forecasting and Control*. Englewood Cliffs, N.J.: Prentice Hall, revised edition.

Brass, W. 1974. Perspectives in population prediction: Illustrated by the statistics of England and Wales. *Journal of the Royal Statistical Society Series A* 137: 532–583.

Campbell, P. R. 1996. Population projections for states by age, sex, race, and Hispanic origin: 1995 to 2025. Washington, D.C.: U.S. Census Bureau, Population Division, PPL-47.

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.

Easterlin, R. A. 1980. *Birth and Fortune: The Impact of Numbers on Personal Welfare*. New York: Basic Books.

Engelhardt, H. 2004. Egypt's 'stalled fertility decline' and the possible role of 'tempo distortions'. *Popnet* 36: 2. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Eurostat. 2005. *New Cronos Database. Theme 3: Population and Social Conditions*. Luxembourg: Office for Official Publications of the European Community.

Eurostat. 2006. *Population Statistics*. Luxembourg, Office for Official Publications of the European Community.

George, M. V. and J. Perreault. 1992. Methods of external migration projections and forecasts. Pages 87–103 in N. Keilman and H. Cruijsen (eds.), *National Population Forecasting in Industrialized Countries*. Amsterdam: Swets and Zeitlinger.

Greenwood, M. J. and G. L. Hunt. 2003. The early history of migration research. *International Regional Science Review* 26(1): 3–37.

Goujon, A. 2006. Is progress in education sustainable? Pages 83–100 in I. Pool, L.R. Wong, and E. Vilquin (eds.), *Age-structural Transitions: Challenges for Development*.

Paris: CICRED. Available at www.cicred.org/Eng/Publications/pdf/AgeStructural-Book.pdf

Goujon, A., V. Skirbekk, K. Fliegenschnee, and P. Strzelecki. 2006. New times, old beliefs: Projecting the future size of religions in Austria. VID Working Paper 01/2006. Available at www.oeaw.ac.at/vid/download/WP2006_01.pdf

Hannum, E. and C. Buchmann. 2005. Global educational expansion and socio-economic development: An assessment of findings from the social sciences. *World Development* 33(3): 333–354.

Irish Central Statistics Office. 2005. *Central Statistics Office Data and Small Area Population Statistics (SAPS)*. Dublin: Stationery Office.

Isserman, A. M. 1993. The right people, the right rates. Making population estimates and forecasts with an interregional cohort-component model. *Journal of the American Planning Association* 59(1): 45–64.

Jejeebhoy, S. 1995. *Women's Education, Autonomy and Reproductive Behaviour: Experience from Developing Countries*. Oxford, UK: Clarendon Press.

Keilman, N. 1990.*Uncertainty in National Population Forecasting*. Amsterdam: CBGS Publications.

Keilman, N. 1999. How accurate are the United Nations world population projections? Pages 15–41 in W. Lutz, J.W. Vaupel, and D.A. Ahlburg (eds.), *Frontiers of Population Forecasting*, a supplement to *Population and Development Review,* Vol. 24 (1998).

Keilman, N. and D. Q. Pham. 2000. Predictive intervals for age-specific fertility. *European Journal of Population* 16: 41–65.

Keyfitz, N. 1982. Can knowledge improve forecasts? *Population and Development Review* 8: 729–751.

Kohler, H. -P. and D. Philipov. 2001. Variance effects in the Bongaarts–Feeney formula. *Demography* 38: 1–16.

Kupiszewski, M. 2002. How trustworthy are forecasts of international migration between Poland and the European Union? *Journal of Ethnic and Migration Studies* 26(4): 627-645.

Kupiszewski, M. and D. Kupiszewski. 2003. Internal migration component in subnational population projections in member states of the European Union. CEFMR Working Paper 2/2003. Warsaw: Central European Forum for Migration Research.

Lanzieri, G. 2007. Long-term population projections at regional level. *Statistics in Focus, Population and Social Conditions (European Communities)* Vol. 28. Luxembourg.

Lee, R. D. 1990. Long-run global population forecasts: A critical appraisal. *Population and Development Review* 16: 44–71.

Lee, R. D. 1999. Probabilistic approaches to population forecasting. Pages 156–190 in W. Lutz, J. W. Vaupel, and D. A. Ahlburg (eds.), *Frontiers of Population Forecasting*, a supplement to *Population and Development Review,* Vol. 24 (1998).

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

Lee, R. and S. Tuljapurkar. 1994. Stochastic population projections for the United States: Beyond high, medium and low. *Journal of the American Statistical Association* 89: 1175–1189.

Lutz, W., B. C. O'Neill, and S. Scherbov. 2003. Europe's population at a turning point. *Science* 299: 1991–1992.

Lutz, W., P. Saariluoma, W. Sanderson, and S. Scherbov. 2000. New developments in the methodology of expert- and argument-based probabilistic population forecasting. Interim Report IR–00–020. Laxenburg, Austria: International Institute for Applied Systems Analysis. Available at www.iiasa.ac.at/Admin/PUB/Documents/IR–00–020.pdf

Lutz, W., Sanderson, W., and S. Scherbov. 1996. Probabilistic population projections based on expert opinion. Pages 13–26 in W. Lutz (ed.), *The Future Population of the World: What can we assume today?* London: Earthscan, revised edition.

Lutz, W., W. Sanderson, and S. Scherbov. 1997. Doubling of world population unlikely. *Nature* 387: 803–805.

Lutz, W., W. C. Sanderson, and S. Scherbov. 1999. Expert-based probabilistic population projections. Pages 139–155 in W. Lutz, J.W. Vaupel, and D.A. Ahlburg (eds.), *Frontiers of Population Forecasting*, a supplement to *Population and Development Review,* Vol. 24 (1998).

Lutz, W., W. Sanderson, and S. Scherbov. 2001. The end of world population growth. *Nature* 412: 543–545.

Lutz, W. and V. Skirbekk. 2005. Policies addressing the tempo effect in low fertility countries. *Population and Development Review* 31(4): 699–720.

Lutz, W., V. Skirbekk, and M. -R. Testa. 2006. The low fertility trap hypothesis: Forces that may lead to further postponement and fewer births in Europe. Pages 167–192 in D. Philipov, A. C. Liefbroer, and F. C. Billari (guest eds.), *Vienna Yearbook of Population Research 2006, Special issue on "Postponement of Childbearing in Europe"*. Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

Marik-Lebeck, S. and G. Lebhart. 2006. Projections of small-area population dynamic in Austria. Presentation made at the European Population Conference held in Liverpool, U.K., June 21-24, 2006 (unpublished). Abstract available at http://epc2006.princeton.edu/download.aspx?submissionId=60092.

Meadows, D. H., D. L. Meadows, J. Randers, and W. Behrens. 1972. *The Limits to Growth*. New York: Potomac Associates.

OECD. 2003a. Low fertility rates in OECD countries: Facts and policy responses. Social, Employment and Migration Working Papers, 15. Paris: Organisation for Economic Co-operation and Development.

OECD. 2003b. *Trends in International Migration*. SOPEMI. Paris: Organisation for Economic Co-operation and Development.

Oeppen, J. and J. W. Vaupel. 2002. Broken limits to life expectancy. *Science* 296: 1029–1031.

Olshansky, S. J. 2006. Can a lot more people live to one hundred and what if they did? In Tom Perls (ed.), *Exceptional Longevity*. Baltimore, MD: Johns Hopkins University Press.

Oslo Kommune. 2006. Befolkningsframskrivning for Oslo 2006-2025 [Population Projections for Oslo 2006-2025]. Available at www.utviklings-og-kompetanseetaten.oslo.kommune.no/getfile.php/utviklings-%20og%20kompetanseetaten%20(UKE)/Internett%20(UKE)/Dokumenter/dokument/anskaffelser/BEFOLKNINGSFRAMSKRIVNING_FOR_OSLO_2006_Nett-publ0806.pdf. Web site accessed May 15, 2007.

Ravenstein, E. G. 1885. The laws of migration. *Journal of the Royal Statistical Society* 48(2): 167–235.

Rees, P. and M. Kupiszewski. 1999a. Internal migration and regional population dynamics in Europe: A synthesis. *Population Studies* 32. Strasbourg: Council of Europe Publishing.

Rees, P. and M. Kupiszewski. 1999b. Internal migration: What data are available in Europe? *Journal of Official Statistics* 15(4): 551–586.

Rogers, A. 1966. The multiregional matrix growth operator and the stable interregional age structure. *Demography* 3: 537–544.

Rogers, A. 1975. *Introduction to Multiregional Mathematical Demography*. New York: John Wiley.

Rogers, A. 1985. *Regional Population Projection Models*. Beverly Hills, CA: Sage.

Rogers, A. 1986. Parameterized multistate population dynamics and projections. *Journal of the American Statistical Association* 81(393): 48–61.

Rogers, A. 1995. *Multiregional Demography. Principles, Methods and Extensions*. Chichester: John Wiley & Sons.

Saariluoma, P. 1995. *Chess Players' Thinking*. London: Routledge.

Sanderson, W. C. 1999. Knowledge can improve forecasts: A review of selected socioeconomic population projection models. Pages 88–117 in W. Lutz, J.W. Vaupel, and D.A. Ahlburg (eds.), *Frontiers of Population Forecasting*, a supplement to *Population and Development Review,* Vol. 24 (1998).

Scherbov, S. and M. Mamolo. 2006. Probabilistic population projections for the EU-25. European Demographic Research Papers 2006/1. Vienna: Institute of Demography, Austrian Academy of Sciences. Available at www.oeaw.ac.at/vid/download/edrp_1_06.pdf

Skirbekk, V., H. -P. Kohler, and A. Prskawetz. 2004. Birth month, school graduation and the timing of births and marriages. *Demography* 41(3): 547–568.

Smith, S. K. and D. A. Swanson. 1998. In defense of the net migrant. *Journal of Economic and Social Measurement* 24: 249–264.

Smith, S. K., J. Tayman, and D. A. Swanson. 2001. *State and Local Population Projections. Methodology and Analysis*. New York: Kluwer Academic.

Tuljapurkar, S. 1997. Taking the measure of uncertainty. *Nature* 387: 760–761.

UN. 2005. *World Population Prospects. The 2004 Revision*. New York: United Nations, Department of Economic and Social Affairs, Population Division.

van der Gaag, N., E. van Imhoff, and L. van Wissen. 1997. Regional population projections in the countries of the European economic area. Update of the 1992 questionnaire. NIDI Working Paper No. 97/1. The Hague: Netherlands Interdisciplinary Demographic Institute.

van der Gaag, N., E. van Imhoff, and L. van Wissen. 2000. Internal migration scenarios and regional population projections for the European Union. *International Journal of Population Geography* 6(1): 1–19.

van der Gaag, N., L. van Wissen, P. Rees, J. Stillwell, and M. Kupiszewski. 2003. Study of past and future interregional migration trends and patterns within European Union countries in search of a generally applicable explanatory model. Report on behalf of Eurostat (invitation to Tender No. 2002/S 67-05015/EN;Lot 5). The Hague: Netherlands Interdisciplinary Demographic Institute and School of Geography, University of Leeds.

van Imhoff, E., L. van Wissen, and K. Spiess. 1994. Regional population projections in the countries of the European economic area. NIDI/CBGS Publications, Nr. 31. Amsterdam/Lisse: Swets & Zeitlinger.

van Wissen, L. and C. Huisman. 2002. Simulating the interplay between regional demographic and economic change in two scenarios. *Networks and Spatial Economics* 2: 127–150.

Vaupel, J. W. and B. Jeune. 1995. The emergence and proliferation of centenarians. In B. Jeune and J. W. Vaupel (eds.), *Exceptional Longevity: From Prehistory to the Present*. Odense Monographs on Population Aging 2. Odense, Denmark: Odense University Press.

Willekens, F. J. 1990. Demographic forecasting; state-of-the-art and research needs. Pages 9–76 in C. A. Hazeu and C. A. B. Frinking (eds.), *Emerging Issues in Demographic Research*. Amsterdam: Elsevier.

Willekens, F. J. and P. Drewe. 1984. A multiregional model for regional demographic projection. Pages 309–334 in H. ter Heide and F. J. Willekens (eds.), *Demographic Research and Spatial Policy: The Dutch Experience*. London: Academic Press.

Wilson, T. and M. Bell. 2004. Comparative empirical evaluation of internal migration models in subnational population projections. *Journal of Population Research* 21(2): 127–160.

Wilson, T., J. Hollis, and P. Rees. 2002. Providing a population projection framework. Pages 239–249 in T. Champion, S. Fotheringham, P. Rees, G. Bramley, et al. *Development of a Migration Model*. London: Office of the Deputy Prime Minister. Available at www.odpm.gov.uk/stellent/groups/odpm_housing/documents/page/odpm_

Wilson, T. and P. Rees. 2005. Recent developments in population projection methodology: A review. *Population, Space and Place* 11: 337–360.

Zhao, Yaohui. 1997. Rural labor migration and the role of education. *Economic Research* 2: 37–42.

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