Probabilistic Population Projections for the EU-25

Sergei Scherbov
Marija Mamolo

Sergei Scherbov is head of the Research Group on Population Dynamics and Forecasting at the Vienna Institute of Demography of the Austrian Academy of Sciences and research scholar in IIASA's World Population Program. Marija Mamolo is a research scientist at the Vienna Institute of Demography of the Austrian Academy of Sciences.

Abstract

This paper presents the first probabilistic population projections for the EU-25. The added value of this approach lies in the possibility of establishing measures of uncertainty for the future population dynamics of the EU as a whole. Such a comprehensive perspective on future trends complements other population projections for the EU. In particular, these new probabilistic projections are directly built on the most recent Eurostat population projections in terms of using identical baseline data and in terms of using their high and low scenarios for fertility to define the central 90 percent of the normal distribution assumed to cover the full range of uncertainty in possible future trends.

In terms of results these projections show that there is very little uncertainty about the fact that the EU is facing massive population ageing. There is an 80 percent chance that the old age dependency ratio will double from currently 0.25 to more than 0.5 in 2050. As to the proportion of the population that will be above the age of 80, a doubling over the coming decades is virtually certain (more than 95 percent chance) while there is even a 60 percent chance that it will increase by a factor of three or more. This implies that by the middle of the century it is likely that more than one out of eight EU citizens will be above age 80, while currently it is only one out of 25.

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1 INTRODUCTION

Europe is facing unprecedented population ageing caused by a low fertility level for a number of decades as well as a constant increase in life expectancy. Thus, because of the heavy consequences that such a process might bear for the society, the need for a comprehensive analysis of plausible future demographic developments should be of great concern not only to demographers, but also more generally to policy makers. Even though the burden of population ageing has been pointed out by scientists already some time ago, only rather recently has the issue entered more systematically the political debate, especially as regards the sustainability of the welfare and pension systems.

In 2050 the EU-25 population had 459.5 million inhabitants and, according to the baseline scenario of Eurostat population projections, it will stop rising around 2025. If we consider only the working age population, the negative trend starts even earlier. In 2025 the old-age dependency ratio will be about 35.7 percent. Relatively high life expectancy at birth and low fertility had characterised Europe for some time and pushed the EU population age profile towards a severely reversed age pyramid. The European Commission's "Green Paper" on demographic change, launched in March 2005, stresses the issue of demographic ageing in the EU context and highlighted various points that should be taken into account, both at EU and member country-level, in order to soften some of the consequences of the ageing process. Moreover, considering the overall socio-demographic changes occurring across the EU, common guidelines of the Lisbon Strategy and the new Social Agenda should be fully followed by member countries, in particular to raise employment and labour force participation of women and elderly workers, to increase employment opportunities for the young without compromising job security and stability, ease childbearing for young couples, facilitate reconciliation between work and family, provide families with appropriate community support in sustaining the elderly, etc.

In such a situation which involves all the EU countries, it is extremely important thus to shed light on what the future demographic development might be, and in particular how much confidence can be put on certain projections of the future course of the determinants of population dynamics, namely fertility, mortality and migration, at not only the country-level, but also the EU as a whole. Population forecasts should meet this task and inform the users about the uncertainties involved.

Among the most important questions related to population projections is the issue on how to deal with uncertainty in the evolution over time of the three basic components of demographic change. An increasingly large body of literature has addressed the topic over the last years[1]. Relying on the well established tradition of using the cohort-component method for population projections, different approaches have been followed in this direction. Among the most widely used are the "scenario" and "variant" approaches. Even though different in their basic meaning[2], both the approaches focus on the formulation of alternative assumptions in regard to the future trends of fertility, mortality and migration, remaining nonetheless within a deterministic framework of population projections. Usually medium, high and low variants are provided, i.e. in the UN *World Population Prospects*. As far as the European Union is concerned, Eurostat similarly provides different scenarios of future population trends for all the EU members and for the candidate countries, with the medium scenario

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1 The *International Journal of Forecasting* published a special issue in 1992 (Ahlburg and Land); *Population and Development Review* published a special supplement in 1999 (Lutz et al.1999a); the National Research Council has dealt extensively with uncertainty in its volume *Beyond Six Billion* (Bongaarts and Bulatao 2000); the *International Statistical Review* also published an issue on population forecasting in 2004 (Lutz and Goldstein).

2 The term "scenario" should be used in the sense of a consistent system in which fertility, mortality and migration assumptions are embedded to provide a comprehensive picture of how the future might look like (Lutz et al. 1999b).

being considered the "baseline". Many national statistical offices follow the same tradition. When considering macro-regions, and thus aggregating national-level projections, a weak point of this approach arises indeed. The high or low scenarios are supposed to be simultaneously prevalent in all the countries, which is far from a realistic picture where a combination of different scenarios is more likely to prevail across countries (Lutz and Scherbov 1998). Moreover, such an approach does not give any statistically founded information on the plausibility of the projection outcome. The high and the low projection variants are often considered as the upper and the lower bounds of the future population development and addressed as demarcating the plausible or probable range, even if such an interpretation gives often probabilistically inconsistent indications of uncertainty.

Alternatively, or better complementarily, probabilistic projections have been used in order to give a statistically more consistent measure of uncertainty in population projections. As pointed out by Keyfitz in 1981 (p. 579), the importance of population projections lies in the ability to provide a reasonable estimation of the error affecting these projections. Establishing more accurately the degree of plausibility should thus become one of the main ingredients of population projections and the added value indispensable for policy makers.

In the current research we adopt the so called expert-argument based probabilistic population projections approach (Lutz et al. 1997, 1998, 2001, 2004; Lutz and Scherbov 1998) and apply it to the EU-25 as a whole and therefore furnish a complementary picture to the already available population projections for the EU developed by Eurostat. In fact, such a probabilistic approach additionally allows to establish a range of uncertainty for the future developments of the EU population which might be useful to orient policy measures accordingly.

2 METHOD AND ASSUMPTIONS

Probabilistic projections have already been applied successfully to project population at national, macro-region and global levels (Lutz et al. 1997; Lutz and Scherbov 1998; Keilman et al. 2002; Alho et al. 2005; Lutz et al. 2003; Lutz and Scherbov 2004, etc.). There are mainly three approaches to probabilistic projections that are proposed in the scientific literature. The first approach is based on the time-series analysis of past vital rates, the second approach is based on the analysis of past projection errors and the third one is the probabilistic scenario approach based on expert opinion. A good overview of the current approaches is given by Bongaarts and Bulatao (2000). These three approaches are not mutually exclusive but often complementary. In particular, the expert judgement is implicitly or explicitly considered in all of them. The third approach, the one actually adopted here, explicitly uses expert opinion. The expert-based population projections were first proposed in the scientific literature by Lutz et al. (1996). Further use and development of the method can be found in Lutz et al. (1997), Lutz and Scherbov (1998), Lutz et al. (1999a, 2001, 2004).

There are several advantages of the method adopted here to carry out probabilistic projections (Lutz et al. 1997 and Lutz and Scherbov 1998). Practically, the approach does not deviate much from the current practice. It can utilise the established mechanisms of expert committees that define the alternative assumptions as in the variant approach. Moreover, it does not require difficult choices associated with the time-series analysis and the analysis of past projection errors, such as the length of the time series on which the assumed future variant should be based, or specific past projections that should be assumed to have the same error as the new projections. This approach only requires the additional assumption that the values already defined cover approximately a range of 90 to 95 percent of all the future cases. The expert judgement is thus used for both the mean and the range of uncertainty.

In our probabilistic projections for the EU-25 the data on population for the base year 2004, fertility, mortality and migration are derived from Eurostat[3]. Projections are made for single year age groups and are thus carried out on a yearly basis. The assumptions about the future trend of fertility are based on the high and low scenarios in the Eurostat projections. For fertility these high and low scenarios are assumed to cover 90 percent of all the future outcomes of the TFR. The base year age-specific fertility rates for the EU-25 are calculated as a weighted average of the last available age-specific fertility rates for each EU member. The shape of age-specific fertility curve is held constant throughout the whole projection period. The 2004 TFR for the EU-25 equals to 1.52 children per woman. The EU-25 average TFR for 2030 has been estimated relying on the baseline variant of Eurostat projection assumptions on TFR and it equals to 1.60. The range for the TFR for 2030 is set referring to the Eurostat low and high population variant and it is bounded by 1.30 and 1.90 children per woman. From 2030 onwards the range is held constant. The life expectancy at birth trend is assumed to increase by two years per decade (Lutz et al. 1997 and 2001; Sanderson and Scherbov 2004). This assumption gets additional support from Oeppen and Vaupel (2002). The range for life expectancy increases is set to 0-4 years per decade. The mortality pattern by age for the base year is calculated as a weighted average from age-specific mortality rates for each EU country. The reference year is 2002. In order to get some insight on net migration age profile, we consider the available information on in- and out-migration flows by age for the EU countries which gives us a rough but necessary picture of age-specific net migration trends. The net migration assumptions are based on Eurostat population projection variants. According to these variants the values for the net migration range are established. The baseline net migration represents the median, while the high and the low variant are the upper and the lower bound respectively up to 2010. From

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[3] Eurostat Database online at: http://epp.eurostat.cec.eu.int.

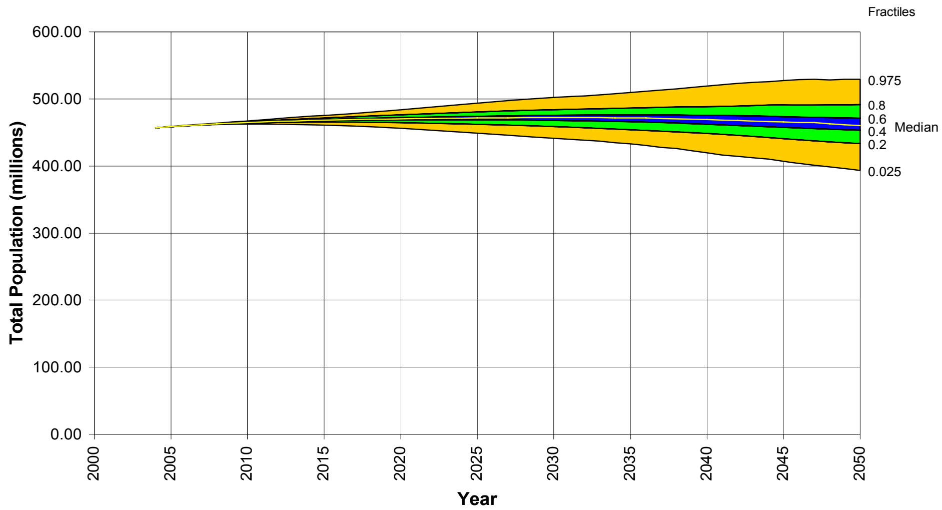
2010 onwards the range goes from zero to twice as much as the Eurostat baseline value.

In order to generate the required distributions of the future path of fertility, mortality and migration, we adopt the method used by Lutz et al. (2001). Each of these demographic components, ν, that has to be forecasted for periods *1* to *T*, is expressed at time *t* as the sum of two terms, its mean at time *t*, $\bar{\nu}$, and its deviation from the mean at time *t*, ε_t. The mean is chosen relying on the previously mentioned arguments. The deviation from the mean is assumed to be a normally distributed random variable with mean zero and standard deviation $\sigma(\varepsilon_t)$, also based on the aforementioned arguments. Because of the persistence of the factors represented by ε_t, we would generally expect them to be autocorrelated. In order to specify how the ε_t terms evolve over time, we use the moving average formation of order *q*, MA(*q*), where *q* is the number of lagged terms in the moving average. We choose 41 points. To define ranges of uncertainty at intermediate dates we use piecewise linear interpolation.

3 RESULTS

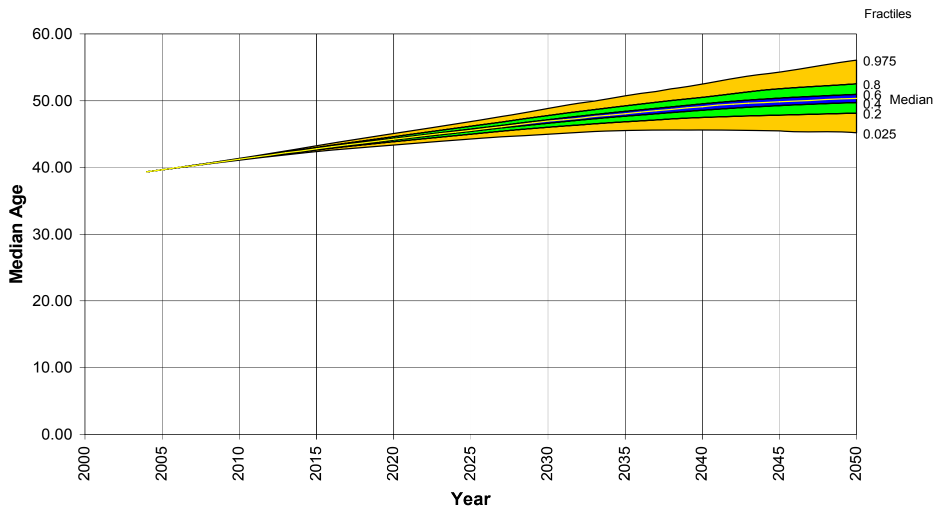
The population of the EU-25 is likely to decrease in the medium to long run, while in the short run some further growth is expected, mostly fuelled by migration. Figure 1 shows selected fractiles of the resulting distribution in total population size for all the EU-25 countries. Percentiles are marked with different colours. The whole range covers 95 percent of all possible projection outcomes, while the innermost area indicates the zone of projection outcomes considered most likely. According to the median projection there is a 50 percent chance that the EU-25 population will start decreasing around 2035, and somewhat less than a 50 percent chance that in 2050 the total population will be lower than today (Figure 1). The predicted number of EU-25 inhabitants is most likely to be 472.2 million in 2030 and 460.1 in 2050, even if, the future being uncertain, we cannot exclude the possibility that the future EU-25 population will differ from these values. The 60 percent prediction interval is in fact bounded by 458.9 and 483.8 million in 2030 and thus covers approximately 25 million potential Europeans, and by 433.5 and 491.6 in 2050, with a difference of 58 million people. Eurostat baseline projections predict that in 2030 the EU-25 population will amount to 469.4 million, while in 2050 the figure equals to 449.8. The Eurostat projection for 2030 lies within our most likely range, while if the value reported for 2050 is considered there is more than a 60 percent probability that the EU-25 total population size will be larger. The difference between our median level and Eurostat baseline variant for 2050 is mainly due to our more optimistic assumptions on the future gains of the life expectancy at birth.

Figure 1 EU-25, Total population.



The persistent shrinking of the base of the population age-pyramid due to the downward trend of the number of newborns observed for decades across Europe and the improvements in adult-age mortality have been contributing to the increase of the median age of the population. This gives a first rough idea of the impact of population ageing on the overall EU-25 population (Figure 2). From a value of 39.3 years in 2004 the median age is most likely to be as high as 50.4 years in 2050. In the same year the 95 percent prediction interval is bounded by 45.2 and 56.1 years. Thus, also in the most favourable but extremely unlikely case it would be anyway 6 years higher than today. In 2030 the most likely projections suggest that the EU-25 population will be characterised by a median age of 46.9, already 7.5 years higher than today. The 20 percent prediction interval ranges between 46.6 and 47.2 years. The major difference covered by the 95 percent uncertainty range is 4 years.

Figure 2 EU-25, Population median age.



According to different population projections that were performed for European countries (see Eurostat population projections[4] and Alho et al. 2005), there is hardly any doubt that the process of population ageing has been advancing rapidly all over Europe and has become an issue of major

[4] Available online at: http://epp.eurostat.cec.eu.int.

concern within the European political debate. The burden for the society of the process of population ageing is confirmed once again in our projections, as it is shown in Figure 3 where the future trend of the old-age dependency ratio for the EU-25 as a whole is depicted. The ratio stays currently at 24.9 percent, which means that there are 4 people of working age supporting one person above the age of 65. The future trend of this indicator emerges clearly from the projections, as it is already embedded in today's age structure of the EU population. Thus, there is no doubt about the direction of the future change. Even the lower bound of the 95 percent interval shows consistent increases in the old-age dependency indicator. The chance that the ratio will more than double by 2050 is about 80 percent, which implies less than two persons of working age for each elderly above the age of 65. According to the median projections, the increase will be up to 40.7 percent in 2030 and 57.7 percent in 2050. Shortly, in 2050 there are likely to be almost 6 elderly people for 10 persons of working age. Eurostat baseline projections suggest an old-age dependency ratio of 40.3 and 52.8 in 2030 and 2050 respectively. The former falls in the 20 percent prediction interval, while the latter is comprised in the 60 percent prediction interval.

It has to be pointed out, however, that the picture might be even less favourable in terms of the social burden of the ageing of the EU population. In fact, not all the working age people will participate in the labour market and some of them might be unemployed. Moreover, if we consider the contributors to the pension system, the dependency ratio takes into account people already starting at the age of 15. However, long permanence in the education system suggests that a certain proportion of this working age group is more likely to enter the labour market at higher ages. Furthermore, the increase across all the European countries of new forms of working arrangements which do not always ensure job stability and security, contrarily to what is promoted within the framework of the European Employment Strategy, will not ensure continuity in the contribution process. Also for this reason the short-term Lisbon Strategy targets which have to be reached by all the EU members by 2010, need to be taken seriously into account. We refer in particular to the increase of full employment and the employment of women, and to the prevention of long-term unemployment. These targets have to be considered even more seriously if we bear in mind that the future course of fertility, mortality and migration can only marginally alter this pervasive population ageing, a statement also confirmed if we take a look at Figure 4. Here the proportion of the working age population is plotted and it is shown that the uncertainty range is much smaller with the 95 percent prediction interval bounded by 50 and 60 percent by the year 2050.

Figure 3 EU-25, Old-age dependency ratio (65+/15-64).

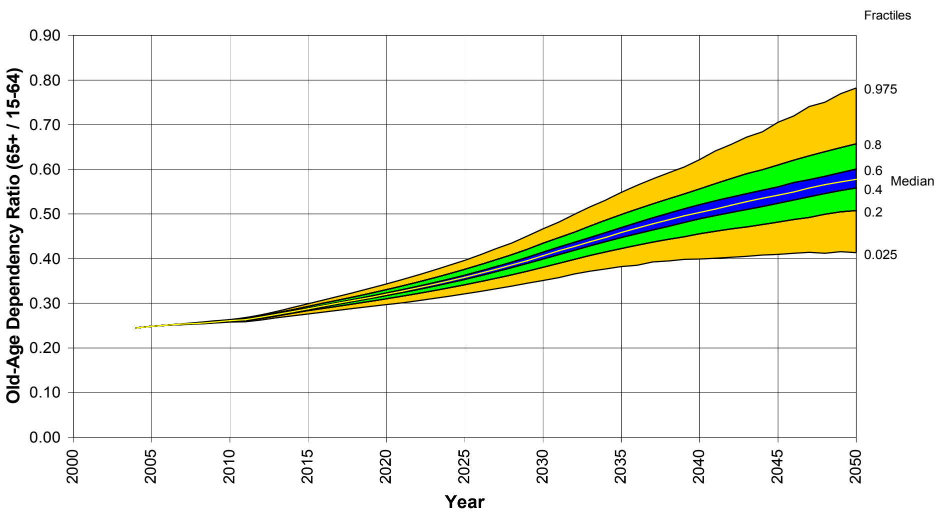
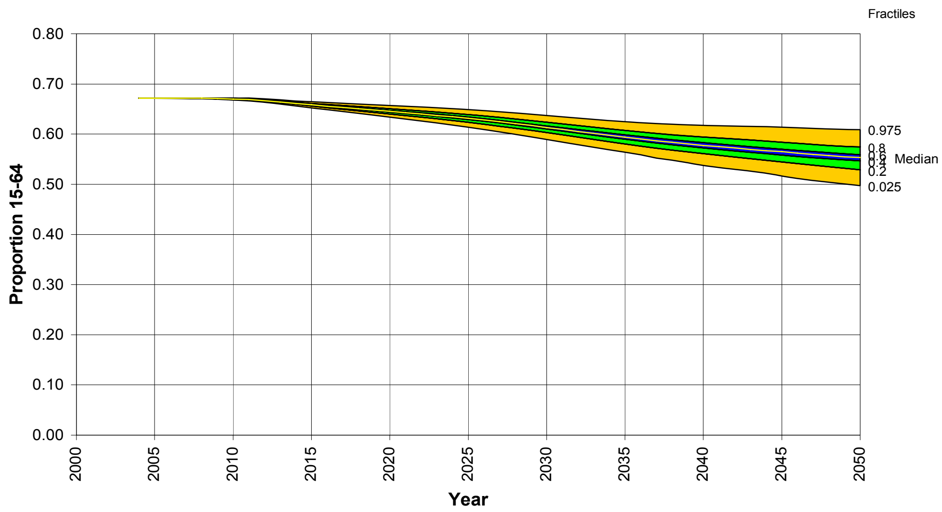


Figure 4 EU-25, Proportion of people aged 15-64.



Demographic uncertainty is increasing if we consider the possible future outcomes of the proportion of the population aged 80 and above (Figure 5). Currently only 4 percent of the EU population is above that age. The 60 percent prediction interval ranges between 6.5 and 8.3 percent in 2030 and between 10.6 and 15.8 at the end of the projection time horizon. The median projections show how the pace of the increase is likely to strengthen after 2025, as soon as the baby boom cohorts start entering this age group. At the same time the uncertainty range significantly increases due to the rather high uncertainty about the future path of old-age mortality. The 95 percent interval for 2050 ranges from 7.5 to 20.1 percent which means that a situation where 1 out of 5 persons is 80 years of age and over has a 2.5 percent chance. Eurostat predicts an increase in the proportion of elderly aged above 80 to 7.2 percent in 2030 and 11.4 in 2050, levels that are included in the 20 percent and 60 percent prediction interval respectively.

Figure 5 EU-25, Proportion of people aged 80 and above.

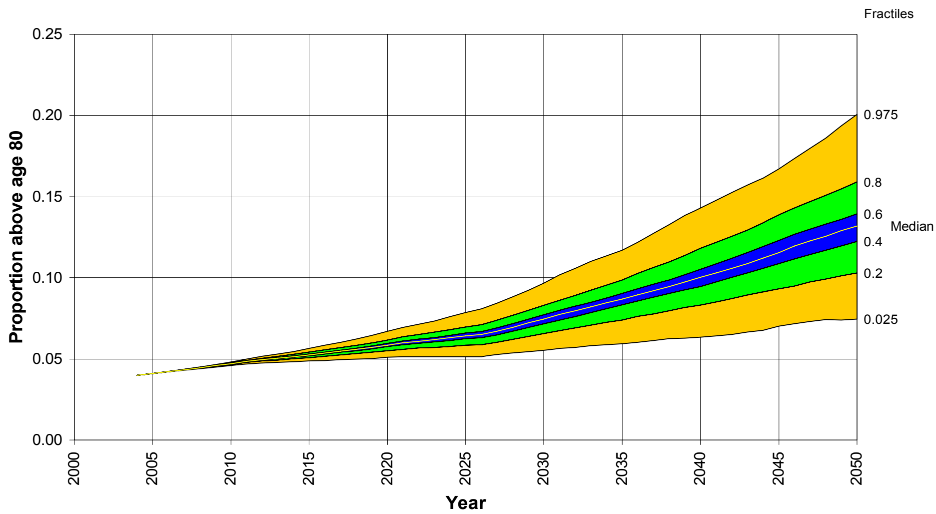
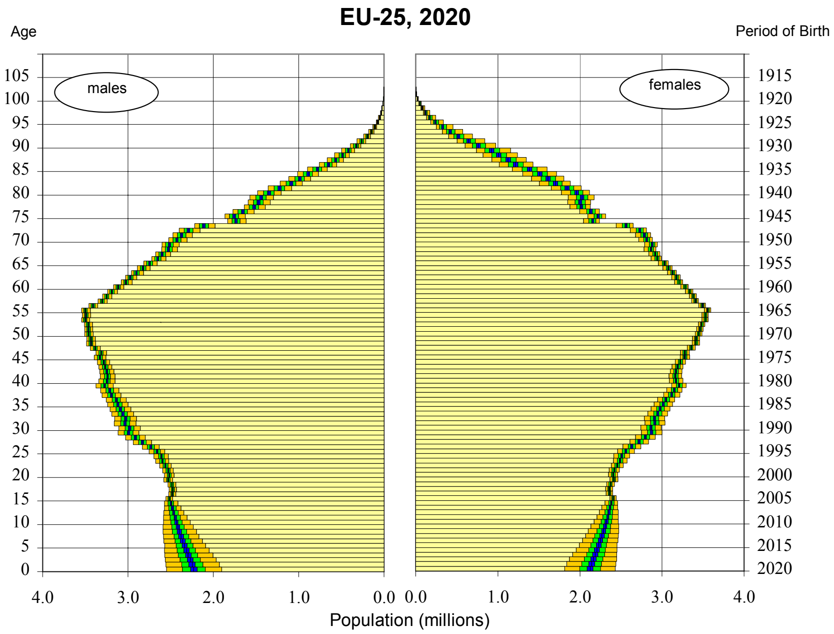
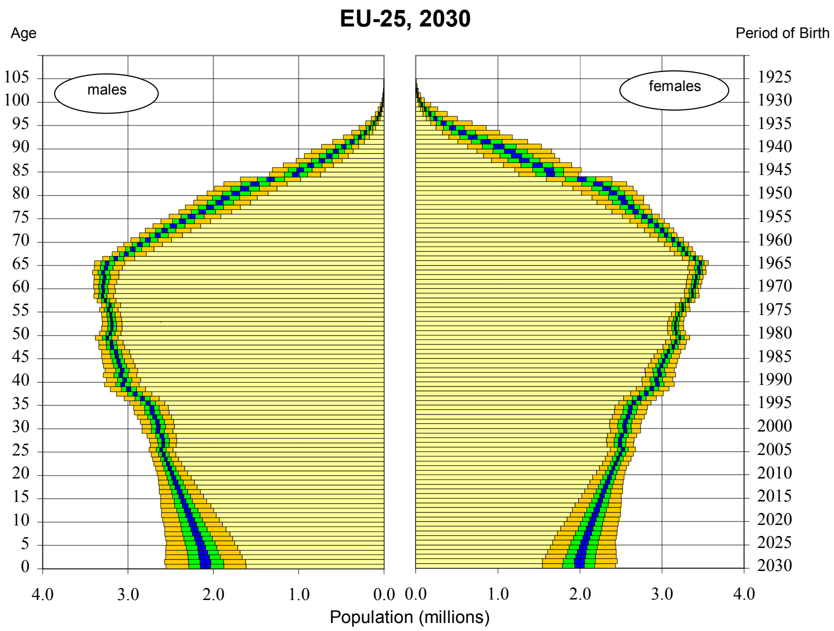


Figure 6 shows the EU-25 population age pyramid in 2004. The shrinkage of the base of the pyramid and a substantial expansion in correspondence of the baby-boom cohorts are evident. The future development of the EU-25 population age structure is depicted in Figure 7, which shows the fractiles of the uncertainty distributions for the full age pyramid in 2020, 2030 and 2050. In 2020 it is clear that the largest amount of uncertainty involves the ages below 10 and it is then linked mainly to the uncertainty in future fertility. Very low uncertainty is shown in regard to other age groups, which suggests that there is not much uncertainty in the mortality age schedule these cohorts will experience. Increased uncertainty arises in the 2030 age pyramid. Uncertainty still clearly differs by age, with the highest range affecting the future number of children (effect of uncertainty about the future fertility outcome) and people at higher ages due to the uncertain path of future old-age mortality. The lowest uncertainty is observed for the cohorts born around 1970 which are beyond their prime migration age but not yet affected by the uncertainty about future old-age mortality. In 2050 a larger amount of uncertainty is still observed for the base and the top of the age pyramid, even if the difference in the range of the prediction intervals across age groups seems to have diminished. The future is less uncertain for cohorts born around 1990, not affected substantially by the uncertainty related to the three basic components of demographic change.

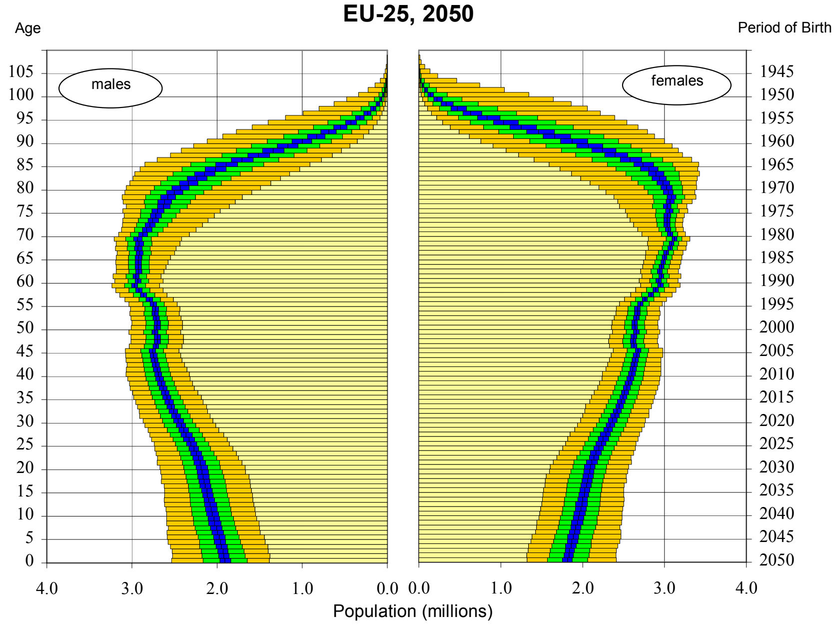
Figure 6 EU-25, Population age pyramid, year 2004.

Figure 7 EU-25, Fractiles of distributions of the European age pyramid, years 2020, 2030, 2050.





(Figure 7 - continued)



4 CONCLUSIONS

The use of probabilistic projections for the first time for the EU-25 member countries altogether has given additional insight on what the future European population might look like, both in regard to the total population size and the age-structure characteristics. The added value of the current research lies in the possibility to establish a measure of uncertainty of the future population dynamics in the EU as a whole. Such a comprehensive perspective complements other EU population projections in giving further valuable hints for orienting social, economic and population policies within an integrated EU framework. The most clear and impressive result concerns once again the process of population ageing which has involved all the current EU members. The issue has already become of great concern to the European Commission and it has been tackled in different contexts of the

European political debate. Purely demographic changes in terms of fertility and migration trends cannot solve the problem because of the population *inertia*. Nevertheless, clear guidelines at the EU level might help go in the right direction of rethinking the EU members welfare systems, especially in regard to the reform of the pension system, while trying to ensure the sustainability of future population dynamics. For this reason, having in mind how much confidence to put on the possible future outcomes regarding the EU-25 population characteristics is of crucial importance.

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APPENDIX Tables with the fractiles of the resulting distributions.

Table A.1 EU-25, Fractiles of the resulting distributions for the total population size.

Fractiles	2020	2030	2040	2050
0.025	456.3	441.4	419.5	393.2
0.2	464.8	458.9	448.7	433.5
0.4	468.8	468.0	462.3	453.2
0.6	472.2	475.7	475.5	471.2
0.8	476.5	483.8	488.8	491.6
0.975	483.7	502.4	519.4	529.5
Median	*470.4*	*472.2*	*469.5*	*460.1*

Table A.2 EU-25, Fractiles of the resulting distributions for the median age.

Fractiles	2020	2030	2040	2050
0.025	43.4	45.0	45.6	45.2
0.2	43.9	46.0	47.5	48.2
0.4	44.1	46.6	48.6	49.7
0.6	44.3	47.2	49.5	51.0
0.8	44.6	47.8	50.5	52.5
0.975	45.1	48.8	52.5	56.1
Median	*44.2*	*46.9*	*49.1*	*50.4*

Table A.3 EU-25, Fractiles of the resulting distributions for the proportion of population aged 15-64.

Fractiles	2020	2030	2040	2050
0.025	0.634	0.589	0.538	0.497
0.2	0.640	0.603	0.561	0.529
0.4	0.644	0.610	0.572	0.547
0.6	0.647	0.616	0.583	0.559
0.8	0.651	0.624	0.594	0.574
0.975	0.657	0.637	0.618	0.609
Median	*0.645*	*0.613*	*0.577*	*0.553*

Table A.4 EU-25, Fractiles of the resulting distributions for the old-age dependency ratio.

Fractiles	2020	2030	2040	2050
0.025	0.297	0.351	0.399	0.414
0.2	0.310	0.381	0.456	0.508
0.4	0.317	0.399	0.489	0.558
0.6	0.323	0.415	0.521	0.600
0.8	0.330	0.435	0.556	0.657
0.975	0.344	0.467	0.622	0.783
Median	*0.320*	*0.407*	*0.503*	*0.577*

Table A.5 EU-25, Fractiles of the resulting distributions for the proportion of the population of age 80 and above.

Fractiles	2020	2030	2040	2050
0.025	0.050	0.056	0.066	0.075
0.2	0.055	0.065	0.083	0.106
0.4	0.057	0.071	0.094	0.124
0.6	0.059	0.077	0.105	0.138
0.8	0.062	0.083	0.118	0.158
0.975	0.067	0.095	0.141	0.201
Median	*0.058*	*0.074*	*0.099*	*0.130*