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What Do We Know About Future Changes in the Proportions of Children and Elderly in Europe?

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Abstract

This report presents the first probabilistic population forecasts for the European Union following the approach of expert based probabilistic projections as developed at IIASA. The central, high and low assumptions used for future fertility, mortality and migration correspond essentially to those of Eurostat. These high-low ranges were assumed to cover 67 percent and 90 percent of all future paths, depending on the model. The results show convincingly that very significant population aging over the coming decades is not just a scenario of unknown probability, but is practically a certainty. By 2050 the proportion above age 60 is likely to increase by about 60 percent whereas the proportion of children and youngsters will fall by about 20 percent. This trend is much less uncertain for the elderly than for the young.

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What Do We Know About the Future Changes in the Proportions of Children and Elderly in Europe?

Wolfgang Lutz and Sergei Scherbov

When we speak of Europe, we usually do not think of it in a geophysical sense as a specific mass of land, but rather in a social, cultural and economic sense. It is the population of Europe that constitutes most of our interest in Europe. This European population, however, is not an amorphous and homogeneous mass. It is structured according to several important criteria. In Europe, usually the first factors that come to mind are linguistics, culture and national divides. We may also think in terms of place of residence, employment status and social class. In focusing on these structures we sometimes tend to forget about the two most fundamental structures of any population, namely age and gender. Gender has recently received increasing attention, and most governments as well as the European Commission have created special bodies to study gender issues and promote equal opportunities for men and women. The age dimension has not yet received similar attention. But since we are expecting very significant changes in the age distribution of Europe's population – a rapidly increasing number of elderly together with a shrinking number of children – the age dimension of the population structure and all associated issues of inter-generational relations are likely to receive increasing attention in the future.

Why should one be interested in age? At the individual level this sounds like a silly question. Whether you are one year old, 10 years old, 40 years old or 80 years old is probably the single most important determinant of how you feel and live, what you do, and what you still expect from life. It is directly related to the process of socialisation, development of skills, body strength, maturing, and last but not least, the remaining average life expectancy. On the level of society this question is less obvious. Does it make any difference whether half of the population is below age 15, as in some developing countries, or whether half is above age 40, as is already the case in several European countries? It is obvious that it makes a difference in demand for schools and for homes for the elderly. It is also evident that it significantly affects the balance of payments in a pay-as-you-go pension system in which those who are gainfully employed today pay for those who are entitled to retirement benefits. And it is expected to also have significant implications for the labour market. But one may even go beyond that and speculate about changing consumer demand and changing cultural preferences. It is also evident, that changing family structures are intimately related with both the reasons for population ageing (due to low fertility rates) and its consequences in terms of family networks. More generations are alive at the same time, while simultaneously there are fewer siblings. These changing quantitative relationships are likely to also affect the quality of the relationships.

Focusing here on these demographic relationships is not to say that they are necessarily the most important changes that we will see in Europe over the next decades, but they will without doubt present significant structural framework conditions that will affect many aspects of life and that can be forecast over several decades with relatively high certainty.

Population Dynamics

As compared to other social and economic factors, demographic trends are very stable and have a great momentum. For this reason population dynamics can be projected with greater accuracy over a longer time span. Of course, such projections are not absolutely certain because human behaviour is not purely mechanistic and there can be unforeseen disasters. But since most of the people that will live in 2015 are already alive today, we know with a high probability what the age structure of the labour force is likely to be in that year.

Future population size and age structures are determined by the present age structure and the future trends in the three basic demographic components fertility (birth rate), mortality (death rate) and migration. Any change in the population must operate through one of these three factors. But even rather rapid changes in one of the factors may take quite long to impact on the total population due to the great inertia of population dynamics. If, for instance, smaller and smaller cohorts of women are entering the childbearing ages, even a possible increase in the mean number of children per woman may not lead to an increase in the total number of births. Similarly, the “baby boom” of the 1960s (and not a discontinuity in life expectancy gains) is the main reason why we expect the proportion above age 60 to increase sharply after 2020.

The fact that there are only three factors to be considered in population projection does not necessarily make the task easier, because the projection of each of the factors is difficult and associated with significant uncertainties. Even the future of **mortality,** which traditionally has been considered the most stable demographic trend with steady improvements over the years, has recently become more uncertain. Over the last 50 years, life expectancy in Western Europe has increased by about 10 years, implying an average gain of two years per decade. Despite this significant gain that has surpassed all expectations expressed in earlier years, most statistical offices producing projections assume a slowing of improvements over the coming years, in some cases even constant life expectancy. Eurostat assumes, in the medium projection, a gain in life expectancy at birth of about three years over a period of 20 years (European Commission 1998). But there is increasing scientific uncertainty about limits to human longevity and consequently about the future gains still to be expected (Vaupel and Lundström 1996). In contrast to the traditionally dominating view that we are already very close to such a limit (actually, the assumed limits are being constantly moved upward by projectors as real gains surpass their expectations (Bucht 1996)) alternative views suggest that such limits (if they even exist at all) might be well above 100 years. This scientific uncertainty about the future trends in old-age mortality also needs to be reflected in the population projections.

Fertility is the most influential of the three demographic components under a longer time horizon. Changes in fertility not only impact on the number of children but also on that of the grandchildren, etc. For this reason relatively small changes in fertility may have very significant consequences on future population size and age structure. Despite its significance we know rather little about the future trends of fertility in Europe. The history since World War II does not help us anticipate the future trend. During the so-called baby boom of the early 1960s most Western European countries had period fertility rates of above 2.5 children per woman. This was followed by a rapid fertility decline during the 1970s, bringing the Western European average down to about 1.6. Since then we have seen diverging trends, typically at levels well below replacement fertility. The most significant fertility declines were found in the Mediterranean countries, with Italy and Spain having below 1.2 children per woman. There are also significant regional differentials within countries. A further uncertainty is due to the fact that it is not clear to what degree these trends are caused by "timing" changes, i.e., a postponement of births, and how far they are reflective of the lifetime fertility of younger generations of European women (Bongaarts and Feeney 1998). There is no clear scientific paradigm to adequately anticipate future reproductive behaviour. The notion of a "second demographic transition" has been suggested to capture these trends, but it does not say where and when the endpoint of this transition should be reached (Van de Kaa 1987; Cliquet 1991). For this reason, again, population projections need to reflect the uncertainty through a range of fertility assumptions.

Migration is the most volatile of the three demographic components. The number of people entering or leaving a country can change from one year to the next due to political events or the enforcement of new legislation. The past 10 years have witnessed great ups and downs in European migration levels. The problem with projecting migration trends is not only the intrinsic difficulty of foreseeing such political events, but also the fact that net migration is the result of two partly independent streams (in-migration and out-migration) and that they depend on the conditions in both the sending and receiving countries. In this respect projections can do little more than demonstrate the impacts of alternative net-migration scenarios (Lutz 1993).

Probabilistic Population Projections for the EU

Policies to manage the future and meet the demographic challenges require the best available information about future trends. The standard way to project the future population path, which is considered most likely by experts, is a well-established methodology, the so-called cohort component method. The more difficult issue is how to deal with uncertainty in future demographic trends. As indicated above there are significant uncertainties associated with all three components, fertility, mortality and migration. The usual way is to produce different scenarios or variants, which combine alternative fertility, mortality and migration assumptions. But here the users of projections are not informed about the likelihood of the different scenarios, whether they are very unlikely "horror scenarios" that may be dismissed immediately, or whether they are highly realistic trends that should be taken seriously. Only probabilistic projections can answer these questions.

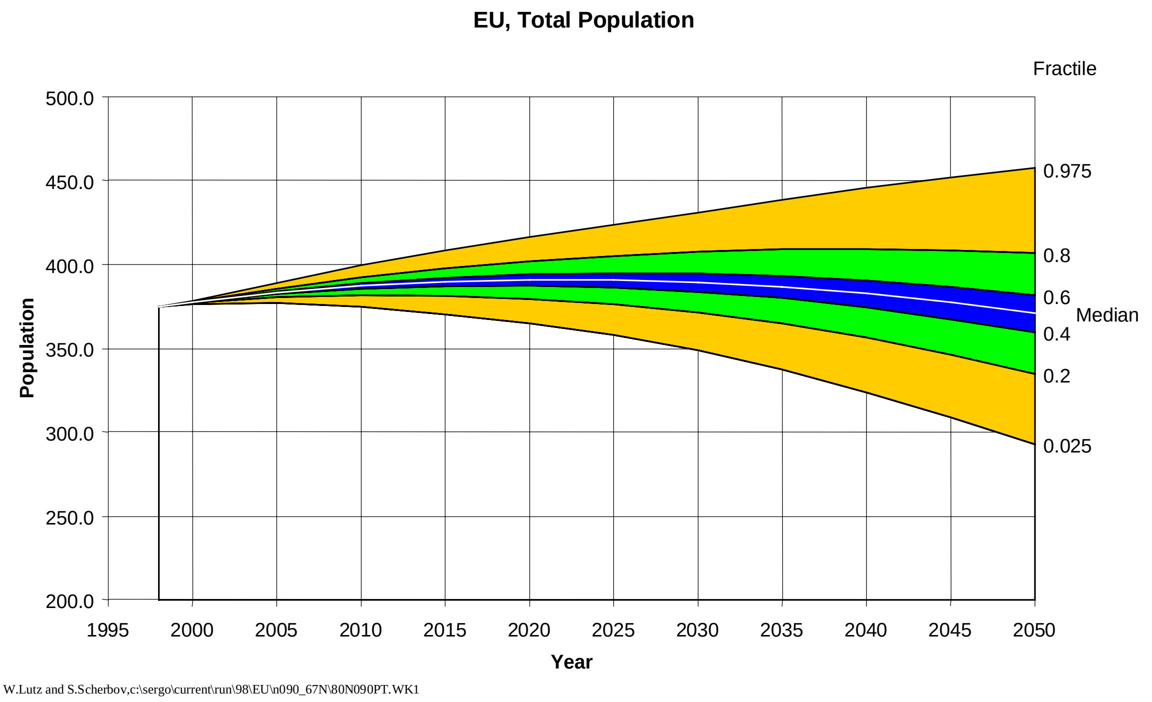
Expert-based probabilistic projections are a rather recent methodological development (at IIASA, the International Institute for Applied Systems Analysis in Austria) and here we present the first such projections for the European Union after earlier applications to Austria (Hanika, Lutz and Scherbov 1997), Germany (Lutz and Scherbov 1998), and 13 major world regions (Lutz, Sanderson and Scherbov 1997).

The basic idea of the chosen approach to probabilistic population projection lies in a process in which a group of experts defines assumptions about the likely proportion of all possible future paths in fertility, mortality and migration that fall within a given range of high and low values for each of the components. Since the methodology is extensively documented elsewhere (Lutz, Goldstein and Prinz 1996; Lutz and Scherbov 1997; Lutz, Sanderson and Scherbov 1996, 1999) we will not go into any details here. Assuming a normal distribution (the method also works for other distributions if there are reasons to choose them) typical assumptions are that 67 percent or 90 percent lie within the specified range of high and low values. Given the symmetric nature of the normal distribution the average of the high and low values (the central or baseline assumption) is also the assumption of highest probability. The tails of the distribution also include extreme assumptions with low probability. Based on these three distributions a large number of simulations (1,000 in the case of these projections) is performed by randomly drawing fertility, mortality and migration paths from the distributions and combining them in independent cohort-component projections. The resulting distributions of population size, sizes of specific age groups, etc., can then be presented numerically or graphically through selected fractiles as shown below.

The projections presented here for the whole European Union (treated as one region) are based on the assumptions as produced by Eurostat. There three scenarios have been defined to 2015 for each of the three components (European Commission 1998): Total Fertility Rate: 1.41 (low), 1.64 (baseline), 1.92 (high); Life Expectancy female: 81.5 (low), 83.1 (baseline), 84.4 (high); male: 75.0 (low), 77.2 (baseline), 79.2 (high). The assumed annual migration balances for 2010-14 are 398,000 (low), 592,000 (baseline), 788,000 (high). For each of the components specific paths have been defined between the base year 1995 and the target year 2015. For the extension to 2030 and 2050, which are presented in this study, constant rates have been assumed. Due to this correspondence of assumptions the median of the probabilistic projections is indeed identical to the baseline scenario of Eurostat. However, the quantitative uncertainty intervals around the median are new. For the set of projections presented here, they are based on the additional assumption that 90 percent of all future fertility and mortality paths fall between the stated high and low values. For migration only 67 percent has been assumed due to higher perceived uncertainty. Since annual migration flows are much more dependent on short-term political events than fertility and mortality, which are more difficult to predict, a significantly high degree of uncertainty has been assumed for migration. A sensitivity analysis of these assumptions will be described later.

Figure 1 shows the results of the probabilistic projections for the total population of the current 15 member states of the EU up to 2050. The median of these projections shows a slight increase from the current 375 million inhabitants of the EU to around 390 million in 2020, followed by a moderate decrease to 377 million (about the present level) by 2050. Hence population decline is not a likely medium term prospect for the European Union. The figure also shows the fractiles of the estimated uncertainty distribution. The inner 20 percent are represented by the black area, while the inner 60 percent are shown by the dark shaded area. Here the margin of uncertainty is still rather small, e.g., by 2015 (i.e., 17 years from now) 60 percent of all cases fall into a range of about 8 million up or down from the median. And even the interval containing 95 percent of the assumed future trends is less than 20 million (or 5 percent) up or down from the median. Of course, by the middle of the next century the trumpet will have opened further and the 95 percent interval in 2050 goes from 300 million to 413 million.

Figure 1. Total population, European Union.



Very different from this rather unexciting chart of total population size is Figure 2, which shows the proportion above age 60. Here the uncertainty is not whether it will go up or down, but by how much the proportion of elderly will increase. Presently 21 percent of Europe's population is above age 60. This proportion will certainly increase over the coming decades because the increase is already pre-programmed in today's age structure. By 2015 even the 95 percent intervals show a very narrow range of between 24 percent and 27 percent with the median at 25.6 percent. Still in 2030 the range of uncertainty is rather narrow, with 95 percent of all future paths between 29 percent and 36 percent. In other words, it can be considered virtually certain that the proportion of the European population above age 60 will increase from its present 21 percent by 8 to 15 percentage points or on average to about 1.5 times its current level. This is a very significant increase by any standard. And the best thing about these probabilistic projections is that they cannot be simply dismissed as "horror scenarios" of unknown probability. This increase is virtually certain up to 2030. Thereafter, the range of uncertainty opens up more quickly because the influence of the already given age structure of today gradually diminishes, and uncertainties related to future fertility, mortality and migration gain importance.

The expected proportion of the population below age 20 (Figure 3) is likely to further decline over the coming decades, but it is not directly a mirror image of the proportion elderly. For the younger population the range of uncertainty opens up much more quickly because of the stronger direct impact of the uncertain future fertility rates and a smaller influence of the already existing age structure. Yet it is evident that with a probability of 90 percent the proportion of children and teenagers in Europe will decline. In the median case it declines from presently 23 percent to less than 20 percent, but in the more extreme cases it could go below 15 percent.

Figure 2. Proportion above age 60, European Union.

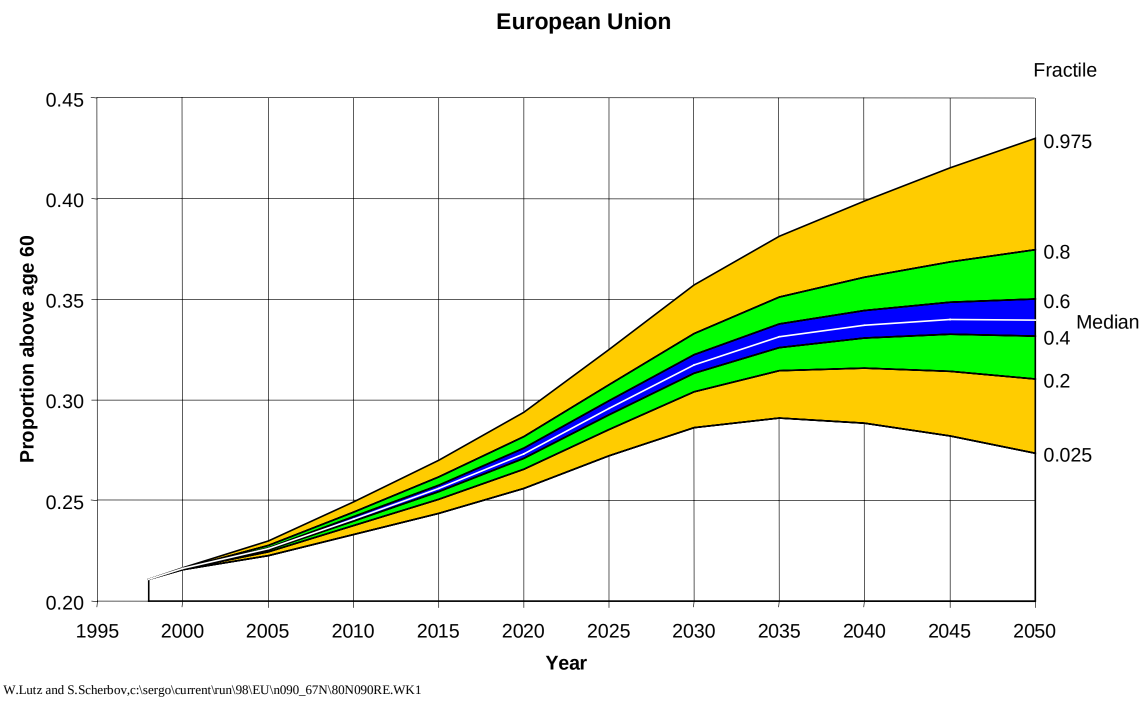
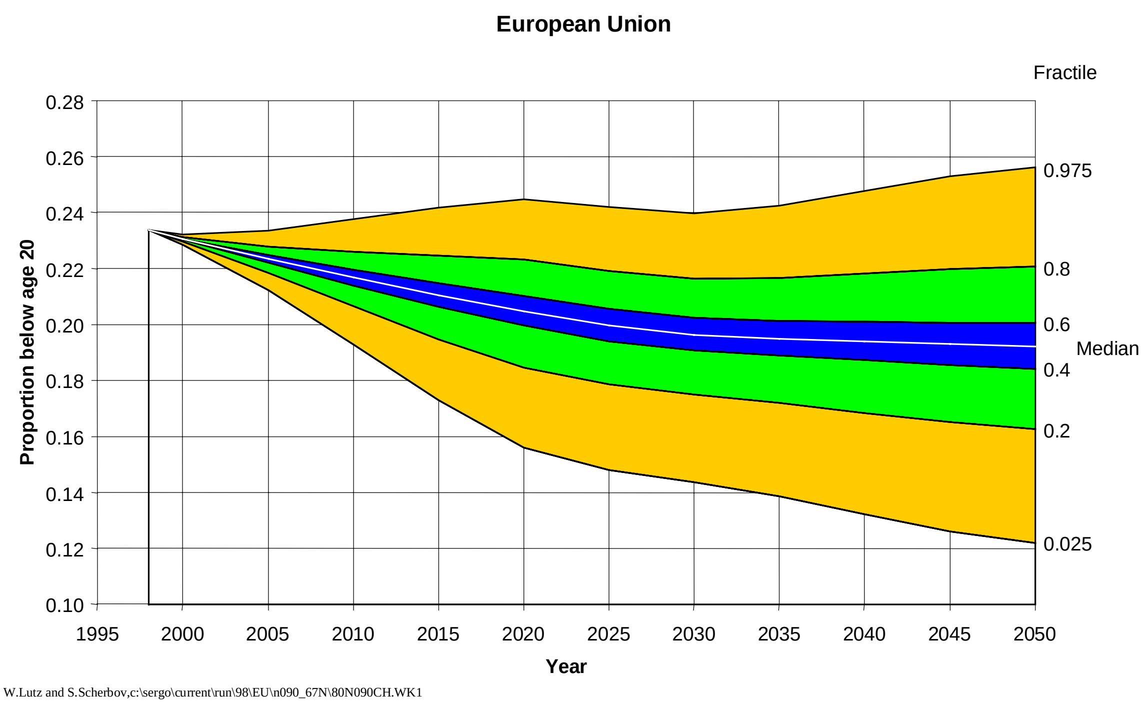
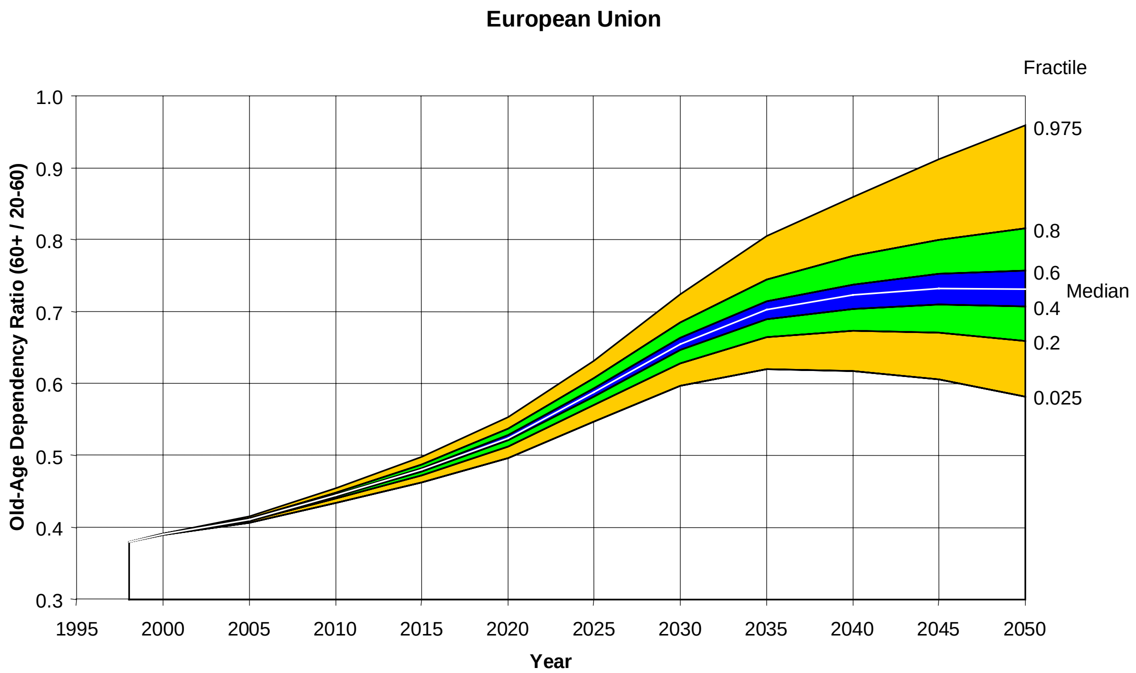


Figure 3. Proportion below age 20, European Union.



Both of these trends combined result in a significant and virtually certain increase in the mean age of the European population (see data in Appendix Table A5). It will increase from a present mean age of 39.3 years to between 42 and 48 years by 2030 and even 41 and 52 years by 2050. The median is expected to increase to around 46 years. It is important to note that these data not only reflect the increasing number of elderly and the shrinking number of children, but they also indicate significant changes of the age pattern of the working-age population. The average age of the population of working age (20-64 years) is also expected to increase from 40.5 years to 43 years by 2020. Expressed in yet a different way, the proportion of persons aged 50-60 will increase significantly, while the younger members of the work force aged 20-29 will decline strongly. This is certain to have significant implications for the labour market and it may also have consequences on economic productivity as some scholars and industrialists fear.

Figure 4. Old-age dependency ratio, European Union.



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Another significant challenge will be faced by pension systems based on the transfer across different age groups. Figure 4 plots the so-called old-age dependency ratio, which is commonly defined as the population above age 60 divided by the population aged 20-60. Although the ratio does not reflect the true ratio of beneficiaries to contributors in the social security system, it still gives an important indication of the underlying demographic dynamics. This ratio is presently around 38 percent which means that there are still almost three working-age persons for one person above age 60. By 2040 this ratio is likely to almost double to more than 70 percent. Already by 2018, i.e., 20 years from today, there will only be two working-age persons for one person above age 60. This will clearly require significant adjustments of the current pension systems that are, of course, based on many more parameters than the demographic ratios. Being aware of the fact that the issue of pensions is very complex and politically sensitive, here we only want to clarify two points from a strictly demographic perspective. 1) It is irresponsible to limit the time horizon of any policy reform to 2015 or even 2010 because we already know that an even more significant increase will come thereafter, which is associated with the retirement of the baby boom generation. 2) The probabilistic projections show that the range of uncertainty is amazingly small over the coming decades, which implies that there is good hard evidence even for longer term reforms. In this context, politicians cannot blame the scientists for giving them only ambiguous and uncertain information as they can rightly do on many other issues.

Sensitivity Analysis

The projections presented above are based on the assumptions that approximately 90 percent of all future paths in fertility and mortality and 67 percent of the paths in migration lie between the high and low values as assumed in the Eurostat projections. Since this assumption is based on more or less intuitive expert knowledge, it can rather easily be challenged by others. There is no space here to go deeply into the discussion of the problems associated with expert knowledge (for a very recent discussion of this issue, see Lee 1999; Lutz et al. 1999; Sanderson 1999). Other experts or users of the projections may challenge the assumptions made as being either too narrow or too broad, depending on the specific views about the future that people may have. Generally, one may say that an underestimation of uncertainty is more dangerous (one may be taken by surprise) than an overestimation (one cannot provide sufficiently specific information) for many of the potential users. For this reason, here we will compare the above results to a different set of projections which are based on the assumption of only 67 percent of all the future fertility and mortality paths falling into the range of the given high and low assumptions. This assumption of significantly greater uncertainty may, of course, seem to be an overly cautious assumption, but it is worth studying in some detail to determine how much it changes the results.

Table 1 compares the resulting uncertainty ranges for the 1,000 simulations that are based on a 90 percent range to those based on a 67 percent range. Detailed information on both sets of simulations is given in the appendix tables. Here the figures will only be compared for selected years and selected indicators. 2015 has been chosen as a frequently stated year and a target year for the Eurostat projections; 2030 is the year when the baby boom generation has reached pension age (past age 60) and is therefore a year that deserves special attention in the context of population ageing.

Table 1. Uncertainty intervals (inter-fractile ranges) based on the assumptions of 90% and 67% of all future fertility and mortality paths lying between the high and low Eurostat assumptions. The figures give those intervals divided by the median in percentage points.

	Inter-fractile ranges					
	20%		60%		95%	
	2015 (in %)	2030 (in %)	2015 (in %)	2030 (in %)	2015 (in %)	2030 (in %)
Total population						
90%	1.2	2.6	4.4	9.0	9.8	21.0
67%	2.3	4.6	6.9	15.2	15.4	34.7
Mean age						
90%	0.9	1.8	3.3	5.6	7.5	13.6
67%	1.6	2.4	5.1	9.8	12.2	24.1
Proportion under 20						
90%	4.3	6.1	14.3	20.9	32.8	49.2
67%	6.7	10.2	24.5	36.7	55.5	87.7
Old-age dependency ratio						
90%	0.6	2.6	2.0	8.7	4.7	19.0
67%	1.4	4.5	5.2	14.2	12.6	31.3

Table 1 shows the percentages indicating what proportion of the median value is covered by the stated inter-fractile range. For example, the 21 percent in the upper right corner of the table indicates total population size for 2030 under the assumption of 90 percent between the high and low values of fertility and mortality. This results in a range of 82 million persons (431-349, see appendix tables) between the upper and lower bounds indicating the 95 percent inter-fractile range of the results (divided by the median of the population in 2030 (82/390=21 percent). Under the assumption of 67 percent between the assumed high and low fertility and mortality assumptions, the corresponding value is 34.7 percent. As expected the resulting uncertainty intervals become broader when assuming wider uncertainty distributions for the fertility and mortality values.

The degree of widening of the uncertainty intervals is not identical for different population variables and different points in time. The uncertainty range opens up most quickly for the future proportion of children because this is almost entirely dependent on future fertility levels and much less on the given age structure which constitutes an element of low uncertainty. Correspondingly, the mean age of the population has the lowest uncertainty range. While under the 90 percent assumption the 95 percent uncertainty interval is only 7.5 percent (or 3.2 years) in 2015, under the 67 percent assumption it increases to 12.2 percent (or 5.2 years). The proportion of the population above age 60 divided by that aged 20-60 (the so-called “old-age dependency ratio”) shows a similar robustness because of the great influence that the already existing population structure still exerts over the coming decades.

In sum, it can be concluded from this sensitivity analysis that as expected, the uncertainty intervals widen somewhat when only 67 percent of all future paths are assumed to lie between the high and low values instead of 90 percent, but this does not change the principal results in any way. Hence, if one wants to be on the very safe side, one can choose the 67 percent assumptions, but the main trends on future population ageing in Europe remain the same: A significant increase in the proportion elderly is practically certain. With respect to the time horizon, uncertainty tends to be minimal over the coming two to three decades and then starts to increase significantly.

Conclusions

This study showed clearly that massive ageing of the European population structure over the coming decades is a certainty. Probabilistic population projections can demonstrate this fact even more convincingly than the traditional variants or scenarios of unspecified probability. This finding also turns out to be very robust irrespective of which specific model of probabilistic projection is chosen or what specific assumptions are being made with respect to the uncertainty intervals assumed for each of the three components fertility, mortality and migration. The main reason for this robustness lies in the fact that much of the future population ageing is already pre-programmed in today's population age structure.

This significant population ageing is likely to affect almost every area of society, the economy and even culture. It will change social institutions, political priorities, the relationship between generations and the relative political weight of different age groups. Because young citizens below a certain age do not have the right to vote in elections, in Europe we will soon have a majority in the electorate which is of retirement age or soon to be retired. The younger generations who will soon run our societies and will have to pay for the pensions under our pay-as-you-go pension schemes will become a minority. Unless appropriate mechanisms are found to give them a weighty voice in a structured manner, a significant potential for future societal conflict will be built up. This issue as well as many other structural changes associated with population ageing need more immediate attention by politicians and more resources for sound scientific analysis. The future will not simply be a continuation of the past, and mechanisms that proved useful in the past may not work in the future. Due to the special dynamics of age structural changes described above we still have a grace period of roughly two decades before the ageing process will hit Europe really hard in 2020-25 (when the baby boom generation retires). Shying away from reforming the pension system under opportunistic short-term political considerations and not giving increased attention to the issue of intergenerational equity on the micro and macro levels seem irresponsible under this perspective.

The family in its various forms and dimensions will be right at the heart of these processes. It will be greatly affected by these demographic changes and it holds the key for a potential moderation or even longer term reversal of this trend through individual reproductive decisions which in sum make up the population's fertility level. At the moment most of the apparent social, cultural and economic forces in Europe still seem to point towards lower fertility. But the process of individualisation, which seems to be a basic underlying determinant of this trend, cannot go on indefinitely because human beings by their constitution are social beings. It is an open question, however, how far it will go and what forces and conditions will stop or reverse the current trend. It is surprising how little we know about this very important phenomenon. The conditions under which fertility may start to increase again have been difficult to study scientifically not only because of its intrinsic complexity but also because of a combination of its assumed private nature and the heavy ideological load it often carries. But there is no doubt that due to the massive expected ageing this question will receive increasing attention in the years to come.

References

Bongaarts, John and Griffith Feeney. 1998. On the quantum and tempo of fertility. *Population and Development Review* 24(2):271-291.

Bucht, Birgitta. 1996. Mortality trends in developing countries: A survey. Pages 133-148 in Wolfgang Lutz, ed. *The Future Population of the World. What Can We Assume Today?* Revised Edition. London: Earthscan.

Cliquet, R.L. 1991. *The Second Demographic Transition. Fact or Fiction? Population Studies* 23. Strasbourg: Council of Europe.

European Commission. 1998. *Demographic Report 1997. Employment & Social Affairs.* Luxembourg: Office for Official Publications of the European Communities.

Hanika, Alexander, Wolfgang Lutz, and Sergei Scherbov. 1997. Ein probabilistischer Ansatz zur Bevölkerungsvorausschätzung für Österreich. *Statistische Nachrichten* 12:984-988 (in German).

Lee, Ronald D. 1999. Probabilistic approaches to population forecasting. Pages 156-190 in Wolfgang Lutz, James W. Vaupel, and Dennis A. Ahlburg, eds. *Frontiers of Population Forecasting*. Supplement to *Population and Development Review,* Vol. 24. New York: The Population Council.

Lutz, Wolfgang. 1993. The future of international migration. Pages 67-84 in Robert Cliquet, ed. *The Future of Europe's Population. Population Studies* 26. Strasbourg: Council of Europe Press.

Lutz, Wolfgang, Joshua R. Goldstein, and Christopher Prinz. 1996. Alternative approaches to population projection. Pages 14-44 in Wolfgang Lutz, ed. *The Future Population of the World. What Can We Assume Today?* London: Earthscan. Revised Edition.

Lutz, Wolfgang, Warren C. Sanderson, and Sergei Scherbov. 1999. Expert-based probabilistic population projections. Pages 139-155 in Wolfgang Lutz, James W. Vaupel, and Dennis A. Ahlburg, eds. *Frontiers of Population Forecasting*. Supplement to *Population and Development Review*, Vol. 24. New York: The Population Council.

Lutz, Wolfgang, Warren Sanderson, and Sergei Scherbov. 1997. Doubling of world population unlikely. *Nature* 387(6635):803-805.

Lutz, Wolfgang, Warren Sanderson, and Sergei Scherbov. 1996. Probabilistic population projections based on expert opinion. Pages 397-428 in Wolfgang Lutz, ed. *The Future Population of the World. What Can We Assume Today?* London: Earthscan. Revised Edition.

Lutz, Wolfgang and Sergei Scherbov. 1998. Probabilistische Bevölkerungsprognosen für Deutschland. *Zeitschrift für Bevölkerungswissenschaft* 23(2):83-109 (in German).

Lutz, Wolfgang and Sergei Scherbov. 1997. An expert-based framework for probabilistic national population projections: The example of Austria. *European Journal of Population* 14:1-17.

Sanderson, Warren C. 1999. Knowledge can improve forecasts: A review of selected socioeconomic population projection models. Pages 88-117 in Wolfgang Lutz, James W. Vaupel, and Dennis A. Ahlburg, eds. *Frontiers of Population Forecasting*. Supplement to *Population and Development Review,* Vol. 24. New York: The Population Council.

Van de Kaa, D.J. 1987. Europe's second demographic transition. *Population Bulletin* 42(1).

Vaupel, James W and Hans Lundström. 1996. The future of mortality at older ages in developed countries. Pages 278-295 in Wolfgang Lutz, ed. *The Future Population of the World. What Can We Assume Today?* Revised Edition. London: Earthscan.

Appendix Tables

Appendix Table A1. EU total population.

Interval	1998	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
0.025	374.8	376.4	377.3	374.9	370.3	364.9	358.0	348.8	337.5	323.9	308.8	292.8
0.2	374.8	377.0	380.7	381.9	381.4	379.6	376.4	371.6	365.2	356.5	346.2	334.7
0.4	374.8	377.3	382.4	385.6	387.2	387.4	386.4	383.8	380.1	374.5	367.5	359.6
0.6	374.8	377.6	384.0	389.0	392.3	394.2	394.9	394.6	393.4	390.7	386.8	381.8
0.8	374.8	377.9	385.7	392.6	397.8	402.0	405.1	407.6	409.2	409.2	408.5	407.0
0.975	374.8	378.5	389.0	399.6	408.4	416.5	423.7	431.0	438.5	445.9	451.9	457.5
Mean	374.8	377.5	383.2	387.2	389.6	390.7	390.6	389.4	387.0	383.2	378.0	371.7
Median	374.8	377.5	383.3	387.4	389.9	391.0	390.9	389.6	386.9	382.9	377.5	371.1
STDS	0.0	0.5	3.0	6.3	9.7	13.1	16.9	21.2	26.1	31.5	37.1	42.7

Appendix Table A2. EU proportion above age 60.

Interval	1998	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
0.025	0.211	0.216	0.223	0.233	0.244	0.256	0.272	0.286	0.291	0.289	0.282	0.273
0.2	0.211	0.216	0.225	0.238	0.251	0.266	0.285	0.304	0.314	0.316	0.314	0.311
0.4	0.211	0.216	0.226	0.240	0.254	0.271	0.293	0.313	0.326	0.331	0.333	0.332
0.6	0.211	0.216	0.227	0.242	0.258	0.276	0.300	0.323	0.338	0.345	0.348	0.350
0.8	0.211	0.216	0.228	0.244	0.262	0.282	0.308	0.333	0.351	0.361	0.369	0.375
0.975	0.211	0.217	0.230	0.250	0.270	0.294	0.325	0.357	0.381	0.399	0.415	0.430
Mean	0.211	0.216	0.226	0.241	0.256	0.274	0.297	0.319	0.333	0.339	0.343	0.344
Median	0.211	0.216	0.226	0.241	0.256	0.273	0.296	0.318	0.332	0.337	0.340	0.340
STDS	0.000	0.000	0.002	0.004	0.007	0.010	0.013	0.018	0.023	0.028	0.034	0.039

Appendix Table A3. EU proportion below age 20.

Interval	1998	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
0.025	0.234	0.229	0.212	0.193	0.173	0.156	0.148	0.144	0.139	0.132	0.126	0.122
0.2	0.234	0.230	0.219	0.207	0.195	0.185	0.179	0.175	0.172	0.168	0.165	0.163
0.4	0.234	0.230	0.222	0.214	0.206	0.200	0.194	0.191	0.189	0.187	0.185	0.184
0.6	0.234	0.231	0.225	0.220	0.215	0.210	0.206	0.203	0.201	0.201	0.201	0.201
0.8	0.234	0.231	0.228	0.226	0.225	0.223	0.219	0.216	0.217	0.218	0.220	0.221
0.975	0.234	0.232	0.233	0.238	0.242	0.245	0.242	0.240	0.242	0.248	0.253	0.256
Mean	0.234	0.230	0.223	0.217	0.210	0.204	0.199	0.196	0.194	0.193	0.193	0.192
Median	0.234	0.230	0.223	0.217	0.210	0.205	0.200	0.196	0.195	0.194	0.193	0.192
STDS	0.000	0.001	0.005	0.011	0.017	0.023	0.024	0.024	0.026	0.029	0.032	0.034

Appendix Table A4. EU old age dependency ratio.

Interval	1998	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
0.025	0.380	0.390	0.407	0.434	0.462	0.496	0.547	0.597	0.620	0.618	0.606	0.582
0.2	0.380	0.390	0.409	0.440	0.472	0.513	0.570	0.628	0.665	0.673	0.671	0.659
0.4	0.380	0.391	0.411	0.443	0.478	0.521	0.582	0.647	0.689	0.704	0.710	0.708
0.6	0.380	0.391	0.412	0.446	0.483	0.529	0.594	0.664	0.715	0.737	0.752	0.757
0.8	0.380	0.391	0.413	0.449	0.488	0.537	0.607	0.685	0.745	0.777	0.800	0.816
0.975	0.380	0.391	0.415	0.455	0.498	0.553	0.632	0.724	0.805	0.860	0.912	0.960
Mean	0.380	0.391	0.411	0.445	0.480	0.525	0.588	0.657	0.705	0.727	0.738	0.742
Median	0.380	0.391	0.411	0.445	0.480	0.525	0.588	0.655	0.703	0.723	0.732	0.732
STDS	0.000	0.000	0.002	0.005	0.009	0.014	0.022	0.033	0.048	0.063	0.079	0.098

Appendix Table A5. EU mean age.

Interval	1998	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
0.025	39.3	39.6	40.1	40.6	41.1	41.6	41.9	42.1	42.1	41.9	41.7	41.5
0.2	39.3	39.6	40.4	41.2	41.9	42.6	43.2	43.7	44.0	44.2	44.3	44.2
0.4	39.3	39.7	40.6	41.5	42.4	43.2	43.9	44.5	45.0	45.4	45.7	45.8
0.6	39.3	39.7	40.7	41.7	42.8	43.7	44.6	45.3	45.9	46.5	46.8	47.1
0.8	39.3	39.7	40.9	42.1	43.3	44.3	45.3	46.2	47.1	47.8	48.4	48.7
0.975	39.3	39.8	41.2	42.8	44.3	45.7	47.0	48.3	49.5	50.7	51.7	52.4
Mean	39.3	39.7	40.6	41.6	42.6	43.5	44.3	45.0	45.6	46.0	46.4	46.6
Median	39.3	39.7	40.6	41.6	42.6	43.5	44.3	44.9	45.5	45.9	46.2	46.4
STDS	0.0	0.0	0.3	0.5	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.8