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Population Division

# LONG-RANGE POPULATION PROJECTIONS

**Proceedings of the United Nations
Technical Working Group on
Long-Range Population Projections
United Nations Headquarters
New York
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**NOTE**

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The designations "more developed", "less developed" and "least developed" for countries, areas or regions are intended for statistical convenience and do not necessarily express a judgement about the stage reached by a particular country or area in the developing process.

Symbols of United Nations documents are composed of capital letters combined with figures.

This publication has been issued without formal editing.

# PREFACE

In addition to its biennial medium-range population projections, the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat has produced seven sets of long-range population projections since 1970. The first set of long-range projections was issued in 1974 and was consistent with the *1968 Revision* of the medium-range population projections. The most recent set was issued in 2000 and is consistent with the results of the *1998 Revision* of population projections to 2050.

The Population Division reviews regularly the assumptions used in projecting the fertility, mortality and international migration of national populations. Most recently, the Population Division has undertaken the systematic examination of the premises underlying the assumptions on future fertility trends. A series of three expert group meetings have been convened to discuss recent fertility trends and future prospects for different groups of countries. As a result of the deliberations of those meetings, the assumptions on future fertility trends have been modified significantly over the course of the three most recent sets of national population projections, namely, the *1998*, *2000* and *2002 Revisions* of *World Population Prospects*. In addition, the methodology for the projection of HIV/AIDS was revised considerably in the *2002 Revision* and the assumptions about international migration have also been changing as better information becomes available. Consequently, the long-range projections consistent with the *1998 Revision* are not consistent with the *2002 Revision* and there is a need for a new set of long-range projections.

The Population Division will adopt two major innovations in preparing a new set of long-range population projections consistent with the *2002 Revision.* For the first time, such long-range projections will be made at the national level, that is, for each of the 228 units constituting the world. In addition, the time horizon for the projections will be extended to 2300, so as to allow for the eventual stabilization of the population in at least one scenario.

In order to address the technical and substantive challenges posed by the preparation of long-range projections at the national level, the Population Division convened a meeting of the Technical Working Group on Long-Range Population Projections at United Nations Headquarters in New York on 30 June 2003. The purpose of the meeting was to discuss the assumptions and methodology that the Population Division was planning to use in the preparation of national population projections to 2300. The Technical Working Group consisted of fifteen invited experts participating in their personal capacity. Also attending were staff members of the Population Division, the Development Policy Analysis Division, the Division for Social Policy and Development, the Division for Sustainable Development, and the Statistics Division, all part of the Department of Economic and Social Affairs of the United Nations Secretariat.

This document presents the report of the meeting of the Technical Working Group together with the background paper prepared by the Population Division and the questions addressed by the meeting. As in the past, the Population Division drew valuable guidance from the deliberations at the meeting as well as from comments submitted in writing by experts. All these inputs are being taken into consideration in preparing the next set of long-range projections. The Population Division extends its appreciation to all the experts for their suggestions and contributions to the preparation of the long-range projections.

This publication may also be accessed on the Population Division world wide web site at www.unpopulation.org. For further information about the long-range projections, please contact the office of Mr. Joseph Chamie, Director, Population Division, United Nations, New York, NY 10017, USA, tel. 212-963-3179 and FAX: 212-963-2147.

## Contents

## Explanatory notes

Tables presented in this volume make use of the following symbols:

Two dots (..) indicate that data are not available or are not separately reported.
An em dash (—) indicates that the amount is nil or negligible.
A hyphen (-) indicates that the item is not applicable.
A minus sign (-) before a figure indicates a decrease.
A full stop (.) is used to indicate decimals.
Years given start on 1 July.
Use of a hyphen (-) between years, for example, 1995-2000, signifies the full period involved, from 1 July of the first year to 1 July of the second year.

Numbers and percentages in tables do not necessarily add to totals because of rounding.

Countries and areas are grouped geographically into six major areas: Africa; Asia; Europe; Latin America and the Caribbean; Northern America; and Oceania. These major areas are further divided into 21 geographical regions. In addition, for statistical convenience, the regions are classified as belonging to either of two categories: more developed or less developed. The less developed regions include all the regions of Africa, Asia (excluding Japan), and Latin America and the Caribbean, as well as Melanesia, Micronesia and Polynesia. The more developed regions comprise Australia/New Zealand, Europe, Northern America and Japan.

The results of the *2002 Revision* of World Population Prospects were finalized and announced on 26 February 2003. As of 12 April 2001, the group of least developed countries as defined by the United Nations General Assembly comprised 49 countries: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Cape Verde, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, Sudan, Togo, Tuvalu, Uganda, United Republic of Tanzania, Vanuatu, Yemen and Zambia.

# I. REPORT OF THE MEETING OF THE TECHNICAL WORKING GROUP ON LONG-RANGE POPULATION PROJECTIONS 30 JUNE 2003

## Opening

1. The United Nations Population Division convened a meeting of the Technical Working Group on Long-Range Population Projections at United Nations Headquarters in New York on 30 June 2003. The purpose of the meeting was to discuss the assumptions and methodology that the Population Division was planning to use in the preparation of population projections to 2300. The Technical Working Group consisted of fifteen invited experts participating in their personal capacity. Also attending were the staff of the Population Division as well as representatives of the Development Policy Analysis Division, the Division for Social Policy and Development, the Division for Sustainable Development and the Statistics Division, all part of the Department of Economic and Social Affairs of the United Nations Secretariat.

2. Mr. Joseph Chamie, Director of the Population Division, opened the meeting by noting that the Population Division had prepared long-range population projections several times in the past. Two sets of such projections had been issued during the 1990s. On both of those occasions, the projection horizon used had ended in 2150 and projections had been calculated only for a small number of major areas. This time, the plans for the preparation of long-range projections were more ambitious. For the first time, the Population Division proposed to extend the projection horizon to 2300 and to calculate the projections at the country level (that is, for more than 190 geographically disjoint units). The role of the Technical Working Group was therefore to provide a forum for the discussion of the various issues raised by such a project. Given the calibre of the members of the Technical Working Group, Mr. Chamie expected that their advice regarding both methodological issues and assumptions about long-term demographic trends would be very useful.

3. The meeting began with a general discussion on the reasons for preparing long-range population projections to 2300, their general utility and the challenges faced in making assumptions about demographic trends over very long periods. It was noted that population projections spanning more than one or one and a half centuries were needed by those studying environmental change and that projections at the country level were necessary to respond to requests about regional groupings different from those traditionally used by the Population Division in preparing long-range projections. In addition, only by considering a long time horizon could one address the issue of the eventual stabilization of world population size.

4. Members of the Working Group questioned the need of carrying out the long-range projections at the country level. It was argued that the current political configuration of countries was unlikely to remain unchanged during the next 300 years and, therefore, that it was not useful to consider the countries of today as the basic units for population projections to 2300. Instead, it was argued that large geographic regions provided a more appropriate basis for long-range projections. It was also noted that in projections to 2050 the heterogeneity of country experience tended to diminish and that it would do so even more according to the assumptions proposed by the Population Division for projections to 2300 so that, over the long run, maintaining the focus on individual countries that were becoming increasingly homogeneous might not add much value to the country-level exercise.

5. Participants also questioned whether the use of projection methodology based on the demographic components was appropriate for use over very long periods. It was argued that making independent assumptions about the future paths of fertility, mortality and international migration was not tenable since those phenomena were interrelated. Thus, trends in population size would have implications for international migration. Alternative methodologies to calculate population projections had been described in the U.S. National Academy of Sciences report entitled Beyond Six Billion or by Goldstein and Stecklov[1].

6. Some participants addressed the issue of uncertainties regarding the long-term future. A few argued that crises that would disrupt demographic trends significantly were bound to occur and that, because the assumptions proposed made no allowance for such occurrences, they were unrealistic. However, participants recognized that it was not possible to determine when or where those types of crises would strike. Others indicated that, given the uncertainty surrounding long-term trends, producing scenarios that differed only by 0.25 of a child in terms of total fertility would not convey well the levels of uncertainty involved. Using methodology that would yield measurable confidence intervals was suggested, although it was recognized that confidence intervals to 2300 would probably be too wide given the high levels of uncertainty involved. Nevertheless, it was argued that explicit allowance for variability was useful because the projections were aiming to illustrate not only the situation in 2300 but also for periods closer to the present. However, it was noted that use of probabilistic methods would severely strain data processing capabilities given the number of units considered (over 190) and the long projection periods involved. In addition, it was not clear that adequate measures of variability, even over the recent past, would be available for most countries.

## FERTILITY

7. Mr. François Pelletier presented the Population Division's proposed fertility assumptions. In the medium or central variant, it was suggested that countries whose total fertility had already been at below-replacement level for 95 years or more by 2045-2050 would return to replacement level by 2070-2075 and remain at that level until 2300. The fertility of other countries would be projected so that it would remain below replacement level for 95 years before returning to replacement level, a level that would then be maintained until 2300. For countries that were still projected to have a total fertility above 2.1 children per woman in 2045-2050, a period of fertility reduction until below-replacement level was reached would come first. In the high and low scenarios, total fertility would differ from that in the central scenario by 0.25 and –0.25 children, respectively.

8. Participants commented first on the cases of countries where mortality trends could conceivably be closely correlated to fertility trends under a Malthusian type of response to high population growth. For Niger or Yemen, for instance, countries whose populations were already projected to be very large by 2050 in the 2002 Revision, either the mortality check might dampen population growth or fertility decline brought about by hardship might be the motor for slower growth. If regional projections were carried out instead of those at the country level, those types of issues would not need to be addressed, as was noted by those who favoured regional projections. The cases of outliers such as Niger or Yemen helped illustrate the problems that would be inherited from the 2002 Revision and that were likely to be magnified in the long-range

[1] J.R. Goldstein and G. Stecklov, On long-range population projections made simple, *Population and Development Review*, vol. 28, No. 1, March 2002, pp. 121-141.

scenarios. The latter could thus be useful in making more patent the problematic cases in the projections to 2050.

9. Several participants commented on the proposal to maintain fertility at below replacement level for approximately the same length of time in all countries. Some participants thought that the crossovers in fertility levels that would result were not appealing since they would mean that today's high-fertility countries would in the future have lower fertility than that of today's low-fertility countries. It was noted that the return to replacement level over the long run seemed to be inconsistent with the conclusion of the meeting on completing the fertility transition that most populations would experience below-replacement fertility. However, some participants argued that, as concern about the consequences of sustained low fertility grew, such concern was likely to trigger measures to raise fertility levels. Those changes would probably happen in many countries at once, implying that the simultaneity of changes in fertility trends among groups of countries would be appropriate. It was noted that, although the medium variant of the projections to 2050 assumed that all countries whose fertility was at below-replacement level in 1995-2000 would remain at below-replacement level until 2050, that might not turn out to be so, and the 95 years that those countries would remain under replacement level depended on the assumptions made to 2050.

10. Other paths of fertility change were suggested. Instead of keeping fertility steady at replacement level, it was suggested that fertility swings consistent with Easterlin cycles be modelled and used in the projections. A different approach would not focus on fertility per se but rather on the dependency ratio (those aged 0-14 and 60 or over divided by the population aged 15-59), trying to keep it constant. Studies of European populations spanning nearly four centuries had shown that, whereas fertility had varied considerably, the dependency ratio had remained relatively stable. The projections could aim at ensuring such stability.

11. A discussion of economic changes that would affect fertility trends brought up the case of Japan, described as a traditional society where the traditional form of the family was no longer attractive to women who were increasingly participating in the labour force. However, Japanese women still tended to get low-paying jobs and would likely be the first to be laid off if economic circumstances deteriorated. Single working women in Japan were still benefiting from the relative affluence of their parents, the current generation of elderly. But as the process of population ageing continued, if women's status in the labour force did not improve markedly, young women in the future might find it more attractive to have children and raise a family than to work. Some participants noted that such a scenario assumed that individualistic values would not prevail among women and that the earning prospects for young men would be good, since they would have to provide for their wives and children. However, in ageing populations, employment prospects and salary levels for young workers, whether male or female, had tended to be worse than those for middle-aged workers and were not necessarily improving.

12. There was some discussion about age-specific fertility. It was noted that over the next 300 years it was likely that the childbearing span would be extended beyond age 50. If so, the age-specific fertility schedules used to project populations should be modified. It was judged, however, that such a change was still speculative and that there were other more important issues to deal with in making the long-range projections. By 2045-2050 in the 2002 Revision, most countries already had age-specific fertility schedules derived from the current experience of countries with very low fertility. Therefore, their further modification for projection purposes was probably not necessary.

13. Regarding the variation in fertility between the low and high variants, it was considered that scenarios with a difference of 0.5 and –0.5 children per woman should also be prepared. However, it was noted that a scenario that would keep fertility at about 1.6 children per woman would result, over the very long run, in a very peculiar age distribution.

14. It was pointed out that, if the aim was to attain a global population with unchanging size, it was necessary to ensure that the net reproduction rate would be slightly less than 1, taking into account both the sex ratio at birth and changing mortality levels. Otherwise, with a fixed total fertility at 2.1 children per woman and declining mortality, the population would continue to increase indefinitely.

15. Given the importance of the sex ratio at birth in determining the net reproduction rate and the increasing evidence of male preference in certain populations, it was suggested that projections with different trends in the sex ratio at birth be carried out for selected populations. However, it was argued that, as fertility declines and women become more like men in more spheres of life, including the economic, there is evidence that even cultures that have traditionally valued males over females are changing. Hence, it seems acceptable to expect that, over the long run, sex ratios that are closer to the biological levels will prevail even in those populations.

16. There were a number of comments on issues related to heterogeneity, both within and between populations. It was noted that fertility cycles at the country level could nevertheless yield an essentially unchanging world population. Similarly, some countries might maintain fertility above replacement level and others at below-replacement level in such a way that world fertility would ensure the replacement of the global population. Nevertheless, some types of heterogeneity could have very different outcomes in terms of genetics, for instance. Thus, if all couples had exactly 2 children, genetic variability would be maintained, whereas that would not be the case if half of all couples had 4 children and half had none. One could imagine a future where children might be so highly valued that some women might make a "career" of bearing and raising them, perhaps being economically rewarded for such services.

17. There could also be heterogeneity in the responsiveness of societies to development. Thus, some countries might not necessarily follow a path leading to below-replacement fertility. There might also remain considerable heterogeneity within countries. The fertility of cities, for instance, would probably be different from that of rural areas and that difference had to be taken into account in a context of increasing urbanization. In this regard, the assumption made in the projections that all countries would follow one scenario (e.g., low, medium or high) was weak since it was unlikely that all countries would follow similar fertility paths.

18. The possibility of using population density as a feedback mechanism that would indicate when rapid fertility reductions were necessary was discussed. Participants pointed out the difficulty of establishing appropriate thresholds with respect to density. The average population density of different regions had been and was expected to remain markedly different. In the more developed countries as a whole, average population density was 23 persons per square kilometre in 2000 and would remain virtually unchanged until 2050. In the less developed regions, population density was projected to rise to 93 persons per square kilometre by 2050 although only 10 per cent of the land in those regions was arable. Concentration of population in relatively small areas also complicated comparisons, given the expectation that the growth of cities and urbanization would continue. In view of the above, several participants concluded that population density per se should not be used as a guide to determine future fertility trends.

19. At the conclusion of the session participants provided their views on the effects that fertility trends would have on future population growth. That is, instead of focusing on fertility trends, they expressed views about the future size of the world population. There was a general consensus that world population would peak at some point during the next 300 years and then begin to decline. Some participants added nuances to this view, indicating that decline would be very slow; that the possibility of rapid and catastrophic decline could not be ruled out; and that swings of fertility would happen, probably being different in the zones of high and low fertility.

20. With regard to the wording used to describe the results of the projection exercise, it was suggested that the terms "forecast" and "projection" be avoided as much as possible and they be substituted by terms such as "simulation" or "hypothetical scenario". Similarly, it was suggested that the assumption that fertility would remain at replacement level in the long run be justified in terms of the fact that the population growth rate could not be above zero over long periods if sustainability was to be maintained.

## MORTALITY

21. Mr. Thomas Buettner presented the Population Division's proposed methodology for the projection of mortality. The proposal was to use to Lee-Carter method to extrapolate the estimated rate of change for 2000-2050 at the country level. Tests of the proposed methodology had only started but seemed to be producing adequate results. There was some concern about the possibility of obtaining implausible crossovers of the expectation of life at birth among countries.

22. The discussion centred on the known limitations of the Lee-Carter method, although it was generally recognized that the method was flexible and adequate for the task at hand. It was noted that in the examples shown for China and the United States the method seemed to be producing divergence of e(0) instead of convergence over the long run. It was reported that, with the collaboration of Ron Lee himself and members of his team, the Population Division would ensure that the projected levels of life expectancy would not diverge. Ron Lee had been working on a modification of the method that would project trends in life expectancy for a group of countries and would use country-specific factors to modify the group projections to represent the experience of each country. When applied over long periods, such a modified method would result, if not in convergence, at least in non-divergence.

23. Several participants commented on the proposal to cap future life expectancy at 100 years. They thought such a procedure should be avoided and that life expectancies above 100 for certain countries could be projected provided allowance was made for the necessarily modified shape of the mortality schedule. In this regard, use of the model schedules proposed by Preston-Himes for old ages was preferable to the Coale-Guo approach. It was noted that the Preston-Himes models had been used to extend the model life tables to very old ages and that they produced unacceptable crossovers at very advanced ages. To solve that problem, the Coale-Kisker method for the closure of the life table had been used.

24. There was some debate about the pattern of change of e(0) over time. It was noted that when e(0) was plotted over long periods it clearly did not change linearly with time. However, e(50) did seem to follow a linear decline. Analysis of long time series of mortality estimates for low-mortality countries had shown that, using the Lee-Carter decomposition, the parameter k(t) declined linearly and e(0) increased logistically. However, when e(0) became high enough that mortality at young ages was very low, a linear decline in k(t) resulted in an almost linear change

in e(0). It was suggested that a linear change in e(0) would also be more evident if changes in the model pattern, b(x) of the Lee-Carter method, were made.

25. Mention was made of tempo distortions in estimates of life expectancy. Essentially, over periods in which the mean age at death was rising, the period life expectancy would tend to be too high compared to that of cohorts. A tempo bias could lead to either over or underestimation of the rate of change of e(0) with respect to time.

26. Also noted were studies of long-term mortality trends in relation to GDP. One conclusion of those studies was that life expectancy among countries tended to converge as GDP rose rather than as a function of time. The underlying data for those studies included time series going back to the 1870s and covered the experience of developing countries, although there were no data for most of Africa.

27. The issue of whether, barring major crises, it was appropriate to project a universal reduction of mortality was raised. Concerns about the possible long-term effects of changes in life style that might increase the incidence of chronic and degenerative diseases in societies that had successfully controlled infectious disease were voiced. Societies where obesity was on the rise, smoking was increasing or the consumption of alcohol was high might not be able to reach the very low levels of mortality observed in the lowest mortality countries of today.

28. It was also noted that, historically, recovery from catastrophic mortality had been much slower than recovery from economic crises so that, perhaps, modelling catastrophic mortality should be incorporated in some way into the long-range projections.

## INTERNATIONAL MIGRATION

29. Ms. Cheryl Sawyer presented the Population Division's proposals for the projection of international migration. She noted that this was the variable that had shown the greatest volatility in the past and was therefore most difficult to project with some accuracy. Because the overall net international migration for the world had to sum to zero, the strategy proposed for projecting it involved deciding which countries would be net receivers of international migrants and which net senders over the projection period. By keeping the status of each country constant, it would be easier to set assumptions on future international migration levels that added to zero at the world level. It was also important that international migration assumptions take account of changes in the population size of the countries involved, otherwise the populations of some countries might disappear because of the cumulative effect of international migration.

30. Mr. Joel Cohen proposed a method for the automatic projection of international migration in such a way that the resulting net migration at the country level ensured a zero net migration at the world level. The method assumed that the matrix formed by the numbers of migrants flowing from country *i* to country *j* over a given year was available. In addition, it was assumed that the population of each country was available at the beginning of each year. Essentially, the method consisted in assuming that the number of international migrants from country *i* to country *j* was proportional to the product of the populations of both countries at the start of each period. A proposal for estimating the coefficients of proportionality (*c(i,j,0)*) at time 0 was made and one strategy for projection was to maintain those coefficients constant over time. Mr. Cohen noted that other variants of the same approach were also possible. For instance, the proportionality coefficients could be made to depend on distance between the countries concerned.

31. The discussion on international migration covered a few main issues. First, the question of whether to use a non-zero assumption for international migration was addressed. Several participants were of the view that, because any non-zero path adopted to project international migration over 300 years would have little credibility, it would be preferable to avoid making a non-zero assumption altogether. Projecting international migration as zero for all countries from 2050 to 2300 was the strategy they recommended. They considered that assumption to be "conservative".

32. Other participants countered that assuming zero international migration for all countries over the projection period would be neither realistic nor conservative. In fact, such an assumption was described as the most radical. However, it was considered that the bases for developing a sounder strategy were weak. It was pointed out in particular that time series data on international migration did not exist for many countries and that changes in policy or in economic circumstances, not to mention crises, war or conflict, could modify international migration trends at the country level very rapidly. There seemed to be no sound bases for modelling such volatility and even less for projecting it over the long run.

33. Assuming constancy of circumstances was not considered realistic. In terms of whether countries would remain as "senders" or "receivers" for centuries, multiple examples were cited of countries that had experienced one or several turnarounds in the direction of international migration flows over the course of the 19th and 20th centuries. Using an approach such as that suggested by Mr. Cohen also implied assuming that a certain relationship between population size and international migration remained unchanged. It was an empirical question whether that assumption had any validity. However, given the limitations of available data on past trends of international migration, testing that hypothesis might not be straightforward. It was noted in this respect that the basic matrix assumed to exist in Mr. Cohen's model could not be created from existing information. However, such a matrix could be estimated from assumed levels of net migration.

34. The attractiveness of Mr. Cohen's model and variants of it was that international migration levels and trends were made to depend exclusively on demographic factors (population size in the case of the most simple model discussed by Mr. Cohen). However, some participants noted that in actuality international migration levels depended more often than not on other factors, including economic conditions, a wide range of policies, the occurrence of crises and even a number of geo-political considerations, many of which were hard to forecast even over the short run.

35. Nevertheless, several participants advanced arguments linking demographic trends with international migration. One noted that some countries experiencing very low fertility had been resorting to international migration to maintain population growth. If fertility rose, international migration intakes might decline. Another mentioned that countries that were important sources of international migrants currently might experience a reduction or even cessation of those flows as their populations aged and population growth came to an end. The point was also made that increasing urbanization within developing countries might affect the supply of economic migrants, with people preferring to move to the large cities within their own countries instead of going abroad. Some of these considerations could be reflected in a modified model similar to that proposed by Mr. Cohen that took into account the populations with the greatest propensity to migrate (the young, for instance) instead of the total populations of the countries concerned. It was also suggested that the median ages of the populations concerned could be taken into account.

36. Regarding other possible methods for allocating international migrants, mention was made of the procedure used by the U. S. Bureau of the Census in making projections of the United States population by state. Projections are made in terms of out-migration rates for the states and the resulting numbers of internal migrants were distributed among the "receiving" states following the same pattern over time. The Population Division might consider adopting a similar approach.

37. Participants also discussed the possibility of making general assumptions about international migration trends at the regional level. Those who favoured making the long-term projections only at the regional level considered that this approach was satisfactory. Others warned that even with respect to regions some assumptions might not hold over the long run. It could be hoped that in 300 years the level of development of the least developed regions of today might have increased substantially. Similarly, there were examples of countries whose level of economic development had declined during the 20th century (e.g. Argentina). It was suggested, however, that countries belonging to regions whose members all had similar levels of development were unlikely to suffer such setbacks. For that reason, some participants thought that assuming that today's developed countries, as a group, would continue to be net receivers of international migrants over the next 300 years was an acceptable assumption.

## CLOSING

38. In the concluding session, the Population Division underscored that the preparation of population projections to 2300 at the country level was a new and special activity that was not meant to be repeated routinely at short intervals. The plan was to produce the projections to 2300 by the end of 2003.

39. Some participants suggested that instead of producing again long-range projections in future years, it would be very useful to produce population estimates extending back to 1900.

40. In their concluding comments, participants addressed a number of new issues or reiterated points made during the rest of the meeting. It was again suggested that the results of the projection exercise be called scenarios or simulations rather than projections. To make clear the illustrative nature of the scenarios produced, it was suggested that several be considered. The issue of whether the "central" scenario should be the one where fertility returned to replacement level was raised and the Population Division was urged to consider alternatives.

41. Participants who favoured the preparation of long-range projections only at the level of regions suggested that country-level projections be presented to 2150 but only regional results be presented thereafter. Another approach suggested would be to make country-level projections and regional projections independently and then compare results at least in one scenario to try and assess whether there was any advantage in making country-level projections.

42. Mention was again made of the use of simpler methodology to project over the long run (avoiding the cohort-component method). It was suggested that the cohort-component method be used for the first 100 years and a simpler method for the rest of the projection period.

43. The suggestion of modelling fertility cycles for the future was reiterated, together with the consideration of stochastic methods to reflect the possibility of crises. It was noted in this respect that the possibility of catastrophic mortality had not been considered sufficiently during

the meeting and that, whereas populations had recovered rapidly from some epidemics in the past, recovery would take longer if economic conditions were poor.

44. Lastly, it was suggested that the possibility of combining scenarios for different regions be considered since the normal presentation of results implied that all countries would follow the same variant or path in the future.

45. Although some members of the working group were sceptical about the value of population projections over very long periods, all agreed that the challenges posed by the exercise were interesting and that it would be illuminating to see the results obtained.

# II. BACKGROUND PAPER: UNITED NATIONS POPULATION PROJECTIONS TO 2300

*Population Division*

## Introduction

46. The Population Division has the task of producing the official population estimates and projections of the United Nations. The first set of population projections was issued in 1951 covering the period 1920-1980. Updated and expanded sets of projections were issued at varying intervals until 1973. Starting in 1978 the Population Division has been producing every two years updated population estimates and projections at the national level. The projection period used in the different *Revisions* has varied but it has been extended to 2050 since the *1994 Revision.*

47. The Population Division has also produced several sets of long-range population projections over a longer time frame. Until now, those long-range projections have been prepared only for a small number of mutually exclusive regional groups constituting the world. Long-range projections have been prepared on a less regular basis than the mid-range projections but during the 1990s they were produced at intervals of five years. The most recent set of long-range projections was issued in 2000 and was consistent with the results of the *1998 Revision*.[2]

48. Starting with the *1998 Revision*, the Population Division has undertaken the systematic examination of the premises underlying the assumptions on future fertility trends. A series of three expert groups meetings[3] were convened to discuss recent fertility trends and future prospects for the following groups of countries: (1) countries whose fertility had already reached below-replacement level, many of which had been experiencing such low fertility levels for a decade or more; (2) countries where fertility remained high and where fertility decline was either incipient or non-existent, and (3) countries that were already far advanced in the transition from high to low fertility but whose fertility levels remained well above replacement level. Largely on the basis of the findings of those meetings, the assumptions about future fertility trends in the different groups of countries have been modified on a step-by-step basis. In the *1998 Revision*, for instance, the fertility of countries that had already attained below-replacement levels was kept below replacement during the whole projection period. In the *2000 Revision*, the fertility of countries that still had high fertility levels was not necessarily projected to reach 2.1 children per woman during the projection period, that is, it could remain well above that level during the whole projection period. Lastly, in the *2002 Revision*, the fertility declines projected for countries with fertility above replacement level were no longer constrained to stop at 2.1 children per woman. Instead, 1.85 children per woman was used as the new lower limit beyond which fertility was not allowed to decline during the projection period for countries whose total fertility in 1995-2000 was still above 2.1 children per woman. In addition, as in the *2000 Revision*, countries whose fertility in 1995-2000 was still relatively high were not necessarily constrained to reach the lower limit of 1.85 children per woman by 2050.

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[2] *Long-range World Population Projections: Based on the 1998 Revision* (United Nations publication, Sales No. E.00.XIII.8).

[3] Below Replacement Fertility, *Population Bulletin of the United Nations*, Special Issue Nos. 40/41, 1999 (United Nations, 2000); United Nations Workshop on Prospects for Fertility Decline in High-Fertility Countries, New York, 9-11 July 2001 (United Nations, ESA/P/WP.167); Completing the Fertility Transition, New York, 11-14 March 2002 (United Nations, ESA/P/WP.172/Rev.1).

49. These changes have been necessary for several reasons, but two deserve mention. First, there is growing heterogeneity among countries regarding past trends in fertility and current fertility levels. In comparison with the 1950s or 1960s, when virtually all developing countries had high fertility and were only beginning to experience declining fertility levels and virtually all developed countries were far advanced in the transition to low fertility, by the 1990s there were countries in all stages of the transition to low fertility as well as numerous countries (59 according to the *2002 Revision*) where fertility had dropped below replacement level and had remained very low over protracted periods[4]. This empirical observation brings us to the second point, namely, that constraining the future decline of fertility for countries already far advanced in the fertility transition to remain ultimately at 2.1 children per woman (that is, close to replacement level) does not seem tenable given the experience of both developed countries and a growing number of developing countries which have not maintained replacement level fertility at the end of the transition to low fertility.

50. As a result of the process undertaken to modify the assumptions about future fertility levels in the preparation of the normal *Revisions* of population estimates and projections to 2050, the long-range projections consistent with the *1998 Revision* lack consistency with the *2002 Revision*. Therefore, users of long-range projections do not have results that reflect the important changes made to the medium-term projections and that have major implications for the long-term future of population.

51. In particular, the expectation that the last stages of the fertility transition will be characterized by long periods of below-replacement fertility levels suggest that the period of population growth may come to an end and that, over the long-term future, the world population may actually decline. Exploration of such a possibility or of the possible stabilization of world population size demand that long-term projections be made for horizons longer than 150 years.

52. For these reasons, the Population Division has decided to prepare a set of long-range projections consistent with the *2002 Revision* and with a time horizon ending in 2300. Furthermore, the plan is to produce, for the first time in the Population Division's history, long-term projections at the country level. The main reason to produce projections at the national level is the demographic heterogeneity that will still characterize countries by 2050 and that is likely to persist over another 50 or 100 years. Indeed, limiting long-range projections to a small number of country aggregates implicitly assumes that the populations of those aggregates are fairly homogeneous in terms of fertility and mortality levels as well as the momentum for population growth related to their age distributions, an assumption that is not tenable. Projections at the national level are also useful because they permit users to consider regional groupings different from those normally considered by the Population Division. In addition, calculation of regional projections as the sum of country-level projections whose errors are not correlated would, other things being equal, lead to smaller errors at the regional level. Nevertheless, it is clear that over a horizon of 300 years, the uncertainty about the future paths of fertility, mortality and international migration cannot but be very large. So, the projection variants proposed in this document can best be thought of as illustrative scenarios and not as possible forecasts of the long-term evolution of national populations.

53. Because the projections proposed will take off where those presented in the *2002 Revision* end, it is important to review the assumptions underlying the *2002 Revision*. The next section presents those assumptions. The following sections present our preliminary thinking about

[4] World Population Prospects: The 2002 Revision, Highlights, February 2003 (United Nations, ESA/P/WP.180), p. 7.

how to extend the projections of fertility, mortality and international migration. The concluding section outlines the main points for discussion at the meeting.

## A. ASSUMPTIONS UNDERLYING THE PROJECTIONS TO 2050 OF THE *2002 REVISION*

54. The full set of projections to 2050 from the *2002 Revision* includes eight projection variants. These variants have been named: low, medium, high, constant-fertility, instant-replacement-fertility, No-AIDS, constant-mortality and zero-migration. Among these eight variants, the first four plus the instant-replacement-fertility variants differ among themselves with regard to the assumptions made about the future path of fertility. The sixth and seventh variants differ from the medium in terms of the assumptions made about the course of mortality, and the eighth differs from the medium in terms of the future course of international migration.

55. To describe the different projection variants, the various assumptions made regarding fertility, mortality and international migration are presented first.

### *1. Fertility assumptions*

56. Fertility assumptions are described in terms of the following groups of countries:

57. *High-fertility countries*: Countries that until 2000 had had no fertility reduction or only an incipient decline;

58. *Medium-fertility countries*: Countries where fertility has been declining but whose level was still above 2.1 children per woman in 1995-2000;

59. *Low-fertility countries*: Countries with total fertility at or below 2.1 children per woman in 1995-2000.

***Medium-fertility assumptions:***

60. Total fertility in high-fertility and medium-fertility countries is assumed to decline following a path derived from models of fertility decline established by the United Nations Population Division on the basis of the past experience of all countries with declining fertility during 1950-2000. The models relate the level of total fertility during a period to the average expected decline in total fertility during the next period. Under the medium variant, whenever the total fertility projected by a model falls below 1.85 children per woman, the value actually used in projecting the population is set to 1.85. That is, 1.85 children per woman represents a floor value below which the total fertility of high and medium-fertility countries is not allowed to drop before 2050. However, it is not necessary for all countries to reach the floor value by 2050. If the model of fertility change used produces a total fertility above 1.85 children per woman for 2045-2050, that value is used in projecting the population.

61. Total fertility in low-fertility countries is generally assumed to remain below 2.1 children per woman during most of the projection period and reach 1.85 children per woman by 2045-2050. For low-fertility countries whose total fertility in 1995-2000 is estimated to be below 1.85 children per woman, projected total fertility often declines further before increasing slowly to reach 1.85 children per woman in 2045-2050.

***High-fertility assumptions***:

62. Under the high variant, total fertility is projected to remain 0.5 children above the total fertility in the medium variant over most of the projection period. By 2045-2050, total fertility in the high variant is therefore half a child higher than that of the medium variant. That is, countries reaching a total fertility of 1.85 children per woman in the medium variant have a total fertility of 2.35 children per woman in the high variant at the end of the projection period.

***Low-fertility assumptions***:

63. Under the low variant, total fertility is projected to remain 0.5 children below the total fertility in the medium variant over most of the projection period. By 2045-2050, total fertility in the low variant is therefore half a child lower than that of the medium variant. That is, countries reaching a total fertility of 1.85 children per woman in the medium variant have a total fertility of 1.35 children per woman in the low variant at the end of the projection period.

***Constant-fertility assumption***:

64. For each country, total fertility remains constant at the level estimated for 1995-2000.

***Instant-replacement assumption****:*

65. For each country, fertility levels over the 2000-2050 period are set so that, during each quinquennium, the net reproduction rate is equal to one.

*2. Mortality assumptions*

***Normal-mortality assumption***:

66. Mortality is projected on the basis of the models of change of life expectancy produced by the United Nations Population Division. A medium pace of mortality decline is generally used to project future mortality levels. However, for countries highly affected by the HIV/AIDS epidemic, the slow pace of mortality decline has generally been used to project the reduction of general mortality risks not related to HIV/AIDS.

67. In addition, for the countries highly affected by the HIV/AIDS epidemic, estimates of the impact of HIV/AIDS are made explicitly through assumptions about the future course of the epidemic—that is, by projecting the yearly incidence of HIV infection. The model developed by the UNAIDS Reference Group on Estimates, Modelling and Projections[5] has been used to fit past HIV prevalence estimates obtained from UNAIDS so as to derive the parameters determining the past dynamics of the epidemic. For most countries, the model is fitted assuming that the relevant parameters have remained constant in the past. For projection purposes, the parameters are kept constant until 2010. Thereafter, the parameter PHI, which reflects the rate of recruitment of new individuals into the high-risk or susceptible group, is projected to decline by a third over intervals of increasing length. In addition, the parameter R, which represents the force of infection, is projected to decline by 15 per cent over the same intervals. A reduction in R is based on the

[5] Improved methods and assumptions for estimation of the HIV/AIDS epidemic and its impact: Recommendations of the UNAIDS Reference Group on Estimates, Modelling and Projections. *AIDS*, vol. 16, pp. W1-W14 (UNAIDS Reference Group on Estimates, Modelling and Projections, 2002).

assumption that changes in behaviour among those subject to the risk of infection will reduce the chances of transmitting the virus.

***No-AIDS assumption****:*

68. For each country for which the impact of HIV/AIDS has been taken into account, mortality is projected by assuming that there is no AIDS. As mentioned above, in countries highly affected by the HIV/AIDS epidemic, the slow pace of mortality decline has generally been used to estimate and project the reduction of general mortality risks not related to HIV/AIDS, starting at the estimated time of onset of the HIV/AIDS epidemic. Consequently, the results of the No-AIDS variant differ from those of other variants, not only during the projection period (2000-2050) but also during the estimation period (mainly during 1980-2000).

***Constant-mortality assumption***:

69. For each country, mortality remains constant at the level estimated in 1995-2000.

### *3. International migration assumptions*

***Normal-migration assumption***:

70. The future path of international migration is set on the basis of past international migration estimates and an assessment of the policy stance of countries with regard to future international migration flows.

***Zero-migration assumption***:

71. For each country, international migration is set to zero for the period 2000-2050.

### *4. Synopsis*

72. Table 1 presents in a schematic way the different assumptions underlying the eight projection variants. As shown, the five fertility variants (low, medium, high, constant-fertility and instant-replacement-fertility) share the same assumptions regarding mortality and international migration. They differ among themselves only with respect to the assumptions regarding fertility. A comparison of their results allows therefore an assessment of the effects that different fertility paths have on other demographic parameters.

73. In addition to the five fertility variants, a No-AIDS variant, a constant-mortality variant and a zero-migration variant have also been prepared. They all have the same fertility assumption as the medium variant. Furthermore, the No-AIDS and constant-mortality variants have the same international migration assumption as the medium variant. Consequently, the results of these two mortality variants can be compared with those of the medium variant to assess the impact of HIV/AIDS and the effect of changing mortality, respectively, on other demographic parameters. The No-AIDS projections are hypothetical and serve only as a basis for comparison. Similarly, the zero-migration variant differs from the medium variant only with respect to the underlying assumption regarding migration. Therefore, the zero-migration variant allows an assessment of the effect that non-zero migration has on other demographic parameters.

TABLE 1. PROJECTION VARIANTS IN TERMS OF ASSUMPTIONS FOR FERTILITY, MORTALITY AND INTERNATIONAL MIGRATION

| | *Assumptions* | | |
|---|---|---|---|
| *Projection variant* | *Fertility* | *Mortality* | *International migration* |
| Low | Low | Normal | Normal |
| Medium | Medium | Normal | Normal |
| High | High | Normal | Normal |
| Constant-fertility | Constant | Normal | Normal |
| Instant-replacement-fertility | Instant-replacement | Normal | Normal |
| No-AIDS | Medium | No-AIDS | Normal |
| Constant-mortality | Medium | Constant | Normal |
| Zero-migration | Medium | Normal | Zero |

*Source:* Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2003). *World Population Prospects: The 2002 Revision. Highlights.* New York: United Nations.

## B. THE LONG-RANGE PROJECTION OF FERTILITY

74. The point of departure for a discussion of long-range assumptions about fertility trends is the medium variant of the *2002 Revision.* As table 2 indicates, by 2045-2050 the majority of the 192 countries whose population is projected using the components method had a total fertility level of 1.85 children per women. However, there were still 69 countries with a total fertility above that level and the range of variation of total fertility in 2045-2050 was from 1.85 to 3.85 children per women. That is, by 2050 a few countries were projected to still be far from completing the transition to low fertility. Consequently, in extending the medium variant of the *2002 Revision,* the first step is clearly to allow those countries that had not yet reached the floor level of 1.85 children per woman to reach it. In the case of Niger, the country with the highest fertility in 2045-2050, the models of fertility change over time used to project fertility in the *2002 Revision* can yield a level of 1.85 children per woman as early as 2080-2085 so that, by 2085, all countries could find themselves with that level of fertility were it to remain constant once it is reached.

75. Therefore, one possible way of extending the medium variant to 2300 would be to maintain the level of 1.85 children per woman constant once it is reached. Such an assumption would yield a declining world population over the long run because 1.85 children per woman is a level that does not ensure the replacement of the population.

76. In previous long-range projections, the medium scenario for future fertility levels was normally designed so that it would produce a stationary population if its fertility level remained constant over a sufficiently long time. In the case of the proposed new set of long-range projections, a medium scenario that can potentially produce a stationary population also seems appropriate so that it can serve as the "central" path with respect to which other scenarios can be compared. However, because this scenario must take off where the medium variant of the *2002 Revision* ends, it will "inherit" the below-replacement paths that many countries have been following for lengthy periods. Table 2 shows countries ordered in terms of the year when the period of below-replacement fertility started for each of them (for convenience, replacement level is assumed to be equal to 2.1 children per woman in all cases). Latvia, for instance, would have experienced 100 years of below-replacement fertility by 2050, whereas Jordan would have experienced just 20. That is, if all countries with a total fertility of 1.85 children per woman in

TABLE 2. TOTAL FERTILITY IN 2045-2050, PERIOD OF BELOW-REPLACEMENT FERTILITY AND POPULATION IN 1950, 2000 AND 2050, MEDIUM VARIANT, BY COUNTRY

| Count | Country or area | Total fertility in 2045-2050 | Beginning of period with TF < 2.1 | End of period of TF < 2.1 | Population (thousands) 1950 | 2000 | 2050 |
|---|---|---|---|---|---|---|---|
| 1 | Latvia | 1.85 | 1950 | 2070 | 1 949 | 2 373 | 1 331 |
| 1 | Japan | 1.85 | 1955 | 2070 | 83 625 | 127 034 | 109 722 |
| 1 | Croatia | 1.85 | 1965 | 2070 | 3 850 | 4 446 | 3 587 |
| 2 | Finland | 1.85 | 1965 | 2070 | 4 009 | 5 177 | 4 941 |
| 3 | Russian Federation | 1.85 | 1965 | 2070 | 102 702 | 145 612 | 101 456 |
| 4 | Ukraine | 1.85 | 1965 | 2070 | 37 298 | 49 688 | 31 749 |
| 1 | Austria | 1.85 | 1970 | 2070 | 6 935 | 8 102 | 7 376 |
| 2 | Belgium | 1.85 | 1970 | 2070 | 8 639 | 10 251 | 10 221 |
| 3 | Canada | 1.85 | 1970 | 2070 | 13 737 | 30 769 | 39 085 |
| 4 | Channel Islands | 1.85 | 1970 | 2070 | 102 | 144 | 126 |
| 5 | Denmark | 1.85 | 1970 | 2070 | 4 271 | 5 322 | 5 273 |
| 6 | Germany | 1.85 | 1970 | 2070 | 68 376 | 82 282 | 79 145 |
| 7 | Luxembourg | 1.85 | 1970 | 2070 | 296 | 435 | 716 |
| 8 | Malta | 1.85 | 1970 | 2070 | 312 | 389 | 402 |
| 9 | Netherlands | 1.85 | 1970 | 2070 | 10 114 | 15 898 | 16 954 |
| 10 | Sweden | 1.85 | 1970 | 2070 | 7 014 | 8 856 | 8 700 |
| 11 | Switzerland | 1.85 | 1970 | 2070 | 4 694 | 7 173 | 5 810 |
| 12 | United Kingdom | 1.85 | 1970 | 2070 | 49 816 | 58 689 | 66 166 |
| 1 | Australia | 1.85 | 1975 | 2070 | 8 219 | 19 153 | 25 560 |
| 2 | Belarus | 1.85 | 1975 | 2070 | 7 745 | 10 034 | 7 539 |
| 3 | Estonia | 1.85 | 1975 | 2070 | 1 101 | 1 367 | 657 |
| 4 | France | 1.85 | 1975 | 2070 | 41 829 | 59 296 | 64 230 |
| 5 | Italy | 1.85 | 1975 | 2070 | 47 104 | 57 536 | 44 875 |
| 6 | Norway | 1.85 | 1975 | 2070 | 3 265 | 4 473 | 4 895 |
| 7 | Singapore | 1.85 | 1975 | 2070 | 1 022 | 4 016 | 4 538 |
| 1 | Barbados | 1.85 | 1980 | 2070 | 211 | 267 | 258 |
| 2 | Bosnia and Herzegovina | 1.85 | 1980 | 2070 | 2 661 | 3 977 | 3 564 |
| 3 | Bulgaria | 1.85 | 1980 | 2070 | 7 251 | 8 099 | 5 255 |
| 4 | China, Hong Kong SAR | 1.85 | 1980 | 2070 | 1 974 | 6 807 | 9 431 |
| 5 | Cuba | 1.85 | 1980 | 2070 | 5 850 | 11 202 | 10 074 |
| 6 | Czech Republic | 1.85 | 1980 | 2070 | 8 925 | 10 269 | 8 553 |
| 7 | Greece | 1.85 | 1980 | 2070 | 7 566 | 10 903 | 9 814 |
| 8 | Hungary | 1.85 | 1980 | 2070 | 9 338 | 10 012 | 7 589 |
| 9 | Lithuania | 1.85 | 1980 | 2070 | 2 567 | 3 501 | 2 526 |
| 10 | New Zealand | 1.85 | 1980 | 2070 | 1 908 | 3 784 | 4 512 |
| 11 | Portugal | 1.85 | 1980 | 2070 | 8 405 | 10 016 | 9 027 |
| 12 | Slovenia | 1.85 | 1980 | 2070 | 1 473 | 1 990 | 1 569 |
| 13 | Spain | 1.85 | 1980 | 2070 | 28 009 | 40 752 | 37 336 |
| 1 | China, Macao SAR | 1.85 | 1985 | 2075 | 190 | 450 | 578 |
| 2 | Republic of Korea | 1.85 | 1985 | 2075 | 18 859 | 46 835 | 46 418 |
| 1 | China | 1.85 | 1990 | 2080 | 554 760 | 1 275 215 | 1 395 182 |
| 2 | Georgia | 1.85 | 1990 | 2080 | 3 527 | 5 262 | 3 472 |
| 3 | Ireland | 1.85 | 1990 | 2080 | 2 969 | 3 819 | 4 996 |
| 4 | Martinique | 1.85 | 1990 | 2080 | 222 | 386 | 413 |
| 5 | Poland | 1.85 | 1990 | 2080 | 24 824 | 38 671 | 33 004 |
| 6 | Romania | 1.85 | 1990 | 2080 | 16 311 | 22 480 | 18 063 |
| 7 | Serbia and Montenegro | 1.85 | 1990 | 2080 | 7 131 | 10 555 | 9 371 |
| 8 | Slovakia | 1.85 | 1990 | 2080 | 3 463 | 5 391 | 4 948 |

TABLE 2 (*continued*)

| Count | Country or area | Total fertility in 2045-2050 | Beginning of period with TF < 2.1 | End of period of TF < 2.1 | Population (thousands) 1950 | 2000 | 2050 |
|---|---|---|---|---|---|---|---|
| 9 | TFYR Macedonia | 1.85 | 1990 | 2080 | 1 230 | 2 024 | 2 156 |
| 1 | Armenia | 1.85 | 1995 | 2085 | 1 354 | 3 112 | 2 334 |
| 2 | Cyprus | 1.85 | 1995 | 2085 | 494 | 783 | 892 |
| 3 | Democratic People's Rep. of Korea | 1.85 | 1995 | 2085 | 10 815 | 22 268 | 24 966 |
| 4 | Iceland | 1.85 | 1995 | 2085 | 143 | 282 | 330 |
| 5 | Mauritius | 1.85 | 1995 | 2085 | 493 | 1 186 | 1 461 |
| 6 | Puerto Rico | 1.85 | 1995 | 2085 | 2 218 | 3 816 | 3 723 |
| 7 | Republic of Moldova | 1.85 | 1995 | 2085 | 2 341 | 4 283 | 3 580 |
| 8 | Thailand | 1.85 | 1995 | 2085 | 19 626 | 60 925 | 77 079 |
| 9 | Trinidad and Tobago | 1.85 | 1995 | 2085 | 636 | 1 289 | 1 221 |
| 1 | Kazakhstan | 1.85 | 2000 | 2095 | 6 703 | 15 640 | 13 941 |
| 2 | Netherlands Antilles | 1.85 | 2000 | 2095 | 112 | 215 | 249 |
| 3 | Sri Lanka | 1.85 | 2000 | 2095 | 7 483 | 18 595 | 21 172 |
| 4 | Tunisia | 1.85 | 2000 | 2095 | 3 530 | 9 519 | 12 887 |
| 1 | Azerbaijan | 1.85 | 2005 | 2100 | 2 896 | 8 157 | 10 942 |
| 2 | Brazil | 1.85 | 2005 | 2100 | 53 975 | 171 796 | 233 140 |
| 3 | Guadeloupe | 1.85 | 2005 | 2100 | 210 | 428 | 467 |
| 4 | Lebanon | 1.85 | 2005 | 2100 | 1 443 | 3 478 | 4 946 |
| 5 | St. Vincent and the Grenadines | 1.85 | 2005 | 2100 | 67 | 118 | 129 |
| 6 | United States Virgin Islands | 1.85 | 2005 | 2100 | 27 | 109 | 133 |
| 1 | Albania | 1.85 | 2010 | 2105 | 1 215 | 3 113 | 3 670 |
| 2 | Bahamas | 1.85 | 2010 | 2105 | 79 | 303 | 395 |
| 3 | Brunei Darussalam | 1.85 | 2010 | 2105 | 48 | 334 | 685 |
| 4 | Costa Rica | 1.85 | 2010 | 2105 | 966 | 3 929 | 6 512 |
| 5 | Indonesia | 1.85 | 2010 | 2105 | 79 538 | 211 559 | 293 797 |
| 6 | Iran (Islamic Republic of) | 1.85 | 2010 | 2105 | 16 913 | 66 443 | 105 485 |
| 7 | Réunion | 1.85 | 2010 | 2105 | 248 | 723 | 1 014 |
| 8 | Saint Lucia | 1.85 | 2010 | 2105 | 79 | 146 | 163 |
| 9 | Turkey | 1.85 | 2010 | 2105 | 21 484 | 68 281 | 97 759 |
| 10 | United States of America | 1.85 | 2010 | 2105 | 157 813 | 285 003 | 408 695 |
| 11 | Uzbekistan | 1.85 | 2010 | 2105 | 6 314 | 24 913 | 37 818 |
| 12 | Viet Nam | 1.85 | 2010 | 2105 | 27 367 | 78 137 | 117 693 |
| 1 | Algeria | 1.85 | 2015 | 2110 | 8 753 | 30 245 | 48 667 |
| 2 | Bahrain | 1.85 | 2015 | 2110 | 116 | 677 | 1 270 |
| 3 | French Polynesia | 1.85 | 2015 | 2110 | 61 | 233 | 355 |
| 4 | Guyana | 1.85 | 2015 | 2110 | 423 | 759 | 507 |
| 5 | Jamaica | 1.85 | 2015 | 2110 | 1 403 | 2 580 | 3 669 |
| 6 | Kyrgyzstan | 1.85 | 2015 | 2110 | 1 740 | 4 921 | 7 235 |
| 7 | Mexico | 1.85 | 2015 | 2110 | 27 737 | 98 933 | 140 228 |
| 8 | Mongolia | 1.85 | 2015 | 2110 | 761 | 2 500 | 3 773 |
| 9 | South Africa | 1.85 | 2015 | 2110 | 13 683 | 44 000 | 40 243 |
| 1 | Argentina | 1.85 | 2020 | 2115 | 17 150 | 37 074 | 52 805 |
| 2 | Belize | 1.85 | 2020 | 2115 | 69 | 240 | 421 |
| 3 | Chile | 1.85 | 2020 | 2115 | 6 082 | 15 224 | 21 805 |
| 4 | Libyan Arab Jamahiriya | 1.85 | 2020 | 2115 | 1 029 | 5 237 | 9 248 |
| 5 | Myanmar | 1.85 | 2020 | 2115 | 17 832 | 47 544 | 64 493 |
| 6 | New Caledonia | 1.85 | 2020 | 2115 | 65 | 215 | 382 |
| 7 | Suriname | 1.85 | 2020 | 2115 | 215 | 425 | 459 |

TABLE 2 (*continued*)

| Count | Country or area | Total fertility in 2045-2050 | Beginning of period with TF < 2.1 | End of period of TF < 2.1 | Population (thousands) 1950 | 2000 | 2050 |
|---|---|---|---|---|---|---|---|
| 8 | Tajikistan | 1.85 | 2020 | 2115 | 1 532 | 6 089 | 9 552 |
| 9 | Turkmenistan | 1.85 | 2020 | 2115 | 1 211 | 4 643 | 7 541 |
| 10 | United Arab Emirates | 1.85 | 2020 | 2115 | 70 | 2 820 | 4 112 |
| 11 | Uruguay | 1.85 | 2020 | 2115 | 2 239 | 3 342 | 4 128 |
| 12 | Venezuela | 1.85 | 2020 | 2115 | 5 094 | 24 277 | 41 733 |
| 1 | Ecuador | 1.85 | 2025 | 2120 | 3 387 | 12 420 | 18 724 |
| 2 | India | 1.85 | 2025 | 2120 | 357 561 | 1 016 938 | 1 531 438 |
| 3 | Israel | 1.85 | 2025 | 2120 | 1 258 | 6 042 | 9 989 |
| 4 | Kuwait | 1.85 | 2025 | 2120 | 152 | 2 247 | 4 926 |
| 5 | Malaysia | 1.85 | 2025 | 2120 | 6 110 | 23 001 | 39 551 |
| 6 | Morocco | 1.85 | 2025 | 2120 | 8 953 | 29 108 | 47 064 |
| 7 | Panama | 1.85 | 2025 | 2120 | 860 | 2 950 | 5 140 |
| 8 | Peru | 1.85 | 2025 | 2120 | 7 632 | 25 952 | 41 105 |
| 9 | Philippines | 1.85 | 2025 | 2120 | 19 996 | 75 711 | 126 965 |
| 10 | Qatar | 1.85 | 2025 | 2120 | 25 | 581 | 874 |
| 1 | Bangladesh | 1.85 | 2030 | 2125 | 41 783 | 137 952 | 254 599 |
| 2 | Cape Verde | 1.85 | 2030 | 2125 | 146 | 436 | 812 |
| 3 | Dominican Republic | 1.85 | 2030 | 2125 | 2 353 | 8 353 | 11 876 |
| 4 | Egypt | 1.85 | 2030 | 2125 | 21 834 | 67 784 | 127 407 |
| 5 | El Salvador | 1.85 | 2030 | 2125 | 1 951 | 6 209 | 9 793 |
| 6 | Fiji | 1.85 | 2030 | 2125 | 289 | 814 | 969 |
| 7 | French Guiana | 1.85 | 2030 | 2125 | 25 | 164 | 354 |
| 8 | Guam | 1.85 | 2030 | 2125 | 60 | 155 | 248 |
| 9 | Jordan | 1.85 | 2030 | 2125 | 472 | 5 035 | 10 154 |
| 10 | Syrian Arab Republic | 1.85 | 2030 | 2125 | 3 495 | 16 560 | 34 174 |
| 1 | Botswana | 1.85 | 2035 | 2130 | 419 | 1 725 | 1 380 |
| 2 | Colombia | 1.85 | 2035 | 2130 | 12 568 | 42 120 | 67 491 |
| 3 | Guatemala | 1.94 | 2035 | 2130 | 2 969 | 11 423 | 26 166 |
| 4 | Honduras | 1.95 | 2035 | 2130 | 1 380 | 6 457 | 12 630 |
| 1 | Paraguay | 1.90 | 2040 | 2135 | 1 488 | 5 470 | 12 111 |
| 2 | Solomon Islands | 1.91 | 2040 | 2135 | 90 | 437 | 1 071 |
| 3 | Saudi Arabia | 1.92 | 2040 | 2135 | 3 201 | 22 147 | 54 738 |
| 4 | Swaziland | 1.92 | 2040 | 2135 | 273 | 1 044 | 948 |
| 5 | Nicaragua | 1.97 | 2040 | 2135 | 1 134 | 5 073 | 10 868 |
| 6 | Lao People's Democratic Republic | 1.97 | 2040 | 2135 | 1 755 | 5 279 | 11 448 |
| 7 | Tonga | 1.97 | 2040 | 2135 | 47 | 101 | 122 |
| 8 | Micronesia (Federated States of) | 1.98 | 2040 | 2135 | 32 | 107 | 158 |
| 9 | Iraq | 1.99 | 2040 | 2135 | 5 158 | 23 224 | 57 932 |
| 10 | Bolivia | 1.99 | 2040 | 2135 | 2 714 | 8 317 | 15 748 |
| 11 | Zimbabwe | 1.99 | 2040 | 2135 | 2 744 | 12 650 | 12 658 |
| 12 | Democratic Rep. of Timor-Leste | 1.99 | 2040 | 2135 | 433 | 702 | 1 433 |
| 13 | Lesotho | 1.99 | 2040 | 2135 | 734 | 1 785 | 1 377 |
| 14 | Western Sahara | 2.00 | 2040 | 2135 | 14 | 285 | 641 |
| 15 | Kenya | 2.00 | 2040 | 2135 | 6 265 | 30 549 | 43 984 |
| 16 | Haiti | 2.03 | 2040 | 2135 | 3 261 | 8 005 | 12 429 |
| 1 | Gabon | 2.01 | 2045 | 2140 | 469 | 1 258 | 2 488 |
| 2 | Sao Tome and Principe | 2.01 | 2045 | 2140 | 60 | 149 | 349 |
| 3 | United Republic of Tanzania | 2.03 | 2045 | 2140 | 7 886 | 34 837 | 69 112 |

TABLE 2 (*continued*)

| Count | Country or area | Total fertility in 2045-2050 | Beginning of period with TF < 2.1 | End of period of TF < 2.1 | Population (thousands) 1950 | 2000 | 2050 |
|---|---|---|---|---|---|---|---|
| 4 | Ghana | 2.03 | 2045 | 2140 | 4 900 | 19 593 | 39 548 |
| 5 | Papua New Guinea | 2.03 | 2045 | 2140 | 1 798 | 5 334 | 11 110 |
| 6 | Vanuatu | 2.03 | 2045 | 2140 | 48 | 197 | 435 |
| 7 | Samoa | 2.05 | 2045 | 2140 | 82 | 173 | 254 |
| 8 | Nepal | 2.05 | 2045 | 2140 | 8 643 | 23 518 | 50 810 |
| 9 | Pakistan | 2.06 | 2045 | 2140 | 39 659 | 142 654 | 348 700 |
| 10 | Togo | 2.08 | 2045 | 2140 | 1 329 | 4 562 | 10 005 |
| 11 | Maldives | 2.08 | 2045 | 2140 | 82 | 291 | 819 |
| 12 | Namibia | 2.08 | 2045 | 2140 | 511 | 1 894 | 2 654 |
| 13 | Sudan | 2.08 | 2045 | 2140 | 9 190 | 31 437 | 60 133 |
| 14 | Cameroon | 2.10 | 2045 | 2140 | 4 466 | 15 117 | 24 948 |
| 1 | Côte d'Ivoire | 2.11 | >2050 | 2140-2175 | 2 775 | 15 827 | 27 572 |
| 2 | Gambia | 2.11 | >2050 | 2140-2175 | 294 | 1 312 | 2 905 |
| 3 | Cambodia | 2.13 | >2050 | 2140-2175 | 4 346 | 13 147 | 29 567 |
| 4 | Comoros | 2.14 | >2050 | 2140-2175 | 173 | 705 | 1 816 |
| 5 | Benin | 2.16 | >2050 | 2140-2175 | 2 046 | 6 222 | 15 602 |
| 6 | Senegal | 2.16 | >2050 | 2140-2175 | 2 500 | 9 393 | 21 589 |
| 7 | Equatorial Guinea | 2.17 | >2050 | 2140-2175 | 226 | 456 | 1 177 |
| 8 | Bhutan | 2.17 | >2050 | 2140-2175 | 734 | 2 063 | 5 288 |
| 9 | Rwanda | 2.17 | >2050 | 2140-2175 | 2 162 | 7 724 | 16 973 |
| 10 | Oman | 2.19 | >2050 | 2140-2175 | 456 | 2 609 | 6 812 |
| 11 | Eritrea | 2.23 | >2050 | 2140-2175 | 1 140 | 3 712 | 10 539 |
| 12 | Central African Republic | 2.24 | >2050 | 2140-2175 | 1 314 | 3 715 | 6 563 |
| 13 | Nigeria | 2.24 | >2050 | 2140-2175 | 29 790 | 114 746 | 258 478 |
| 14 | Mozambique | 2.29 | >2050 | 2140-2175 | 6 442 | 17 861 | 31 275 |
| 15 | Guinea | 2.33 | >2050 | 2140-2175 | 2 550 | 8 117 | 19 591 |
| 16 | Occupied Palestinian Territory | 2.34 | >2050 | 2140-2175 | 1 005 | 3 191 | 11 114 |
| 17 | Zambia | 2.36 | >2050 | 2140-2175 | 2 440 | 10 419 | 18 528 |
| 18 | Djibouti | 2.38 | >2050 | 2140-2175 | 62 | 666 | 1 395 |
| 19 | Madagascar | 2.38 | >2050 | 2140-2175 | 4 230 | 15 970 | 46 292 |
| 20 | Congo | 2.39 | >2050 | 2140-2175 | 808 | 3 447 | 10 643 |
| 21 | Mauritania | 2.44 | >2050 | 2140-2175 | 825 | 2 645 | 7 497 |
| 22 | Sierra Leone | 2.45 | >2050 | 2140-2175 | 1 944 | 4 415 | 10 339 |
| 23 | Malawi | 2.53 | >2050 | 2140-2175 | 2 881 | 11 370 | 25 949 |
| 24 | Ethiopia | 2.55 | >2050 | 2140-2175 | 18 434 | 65 590 | 170 987 |
| 25 | Chad | 2.56 | >2050 | 2140-2175 | 2 658 | 7 861 | 25 359 |
| 26 | Democratic Rep. of the Congo | 2.61 | >2050 | 2140-2175 | 12 184 | 48 571 | 151 644 |
| 27 | Burundi | 2.74 | >2050 | 2140-2175 | 2 456 | 6 267 | 19 459 |
| 28 | Afghanistan | 2.77 | >2050 | 2140-2175 | 8 151 | 21 391 | 69 517 |
| 29 | Liberia | 2.78 | >2050 | 2140-2175 | 824 | 2 943 | 9 821 |
| 30 | Guinea-Bissau | 2.86 | >2050 | 2140-2175 | 505 | 1 367 | 4 719 |
| 31 | Mali | 2.90 | >2050 | 2140-2175 | 3 520 | 11 904 | 45 998 |
| 32 | Uganda | 2.90 | >2050 | 2140-2175 | 5 210 | 23 487 | 103 248 |
| 33 | Burkina Faso | 2.93 | >2050 | 2140-2175 | 3 960 | 11 905 | 42 373 |
| 34 | Angola | 3.00 | >2050 | 2140-2175 | 4 131 | 12 386 | 43 131 |
| 35 | Somalia | 3.05 | >2050 | 2140-2175 | 2 264 | 8 720 | 39 669 |
| 36 | Yemen | 3.18 | >2050 | 2140-2175 | 4 316 | 18 017 | 84 385 |
| 37 | Niger | 3.85 | >2050 | 2140-2175 | 2 500 | 10 742 | 53 037 |

2045-2050 were projected to return to replacement level by a fixed date, they would in effect have spent periods of very different duration at below-replacement fertility levels.

77. If we assume instead that the fertility of all countries will remain during a relatively lengthy period at below-replacement levels and that the length of that period will be similar for all countries, then the transition back to replacement level should occur later for countries that reached below-replacement fertility later. Table 3 presents the distribution of countries according to the beginning of the period of uninterrupted below-replacement fertility. That is, a country whose below-replacement period begins in 1970, for instance, maintained a level of fertility below 2.1 children per woman from 1970-1975 to 2045-2050 in the medium variant of the *2002 Revision*. If, to extend that variant, countries are given a minimum of 20 years to move from a level of 1.85 children per woman to replacement level[6], then the period of below-replacement fertility would end in 2070 for the countries where it started at the earliest dates. If the dates to end the period of below-replacement fertility listed in table 3 are used, the countries that by 2000 had already experienced below-replacement fertility would, on average, be projected to spend 95 years at below-replacement levels before returning to replacement-level fertility. Using that length of time for countries projected to reach below replacement level after 2000, table 2 indicates that all but 37 countries would return to replacement level by 2040. Among the other 37, Niger would take the longest to both reach below-replacement level and return to replacement level, but it should reach the latter by about 2170. That is, following this scheme, most countries would spend at least 160 years at replacement level by 2300 and, provided mortality changes little, might be getting close to having a stationary population by then.

TABLE 3. DISTRIBUTION OF COUNTRIES BY YEAR IN WHICH THE PERIOD OF BELOW-REPLACEMENT FERTILITY STARTED AND PROPOSED YEAR WHEN THAT PERIOD WILL END

| *Year when TF drops below 2.1* | *Number of countries* | *Percentage of countries* | *End of period of TF<2.1* | *Difference in years* |
|---|---|---|---|---|
| 1950 ..... | 1 | 0.5 | 2070 | 120 |
| 1955 ..... | 1 | 0.5 | 2070 | 115 |
| 1960 ..... | 0 | 0.0 | 2070 | 110 |
| 1965 ..... | 4 | 2.1 | 2070 | 105 |
| 1970 ..... | 12 | 6.3 | 2070 | 100 |
| 1975 ..... | 7 | 3.6 | 2070 | 95 |
| 1980 ..... | 13 | 6.8 | 2070 | 90 |
| 1985 ..... | 2 | 1.0 | 2075 | 90 |
| 1990 ..... | 9 | 4.7 | 2080 | 90 |
| 1995 ..... | 9 | 4.7 | 2085 | 90 |
| 2000 ..... | 4 | 2.1 | 2095 | 95 |
| 2005 ..... | 6 | 3.1 | 2100 | 95 |
| 2010 ..... | 12 | 6.3 | 2105 | 95 |
| 2015 ..... | 9 | 4.7 | 2110 | 95 |
| 2020 ..... | 12 | 6.3 | 2115 | 95 |
| 2025 ..... | 10 | 5.2 | 2120 | 95 |
| 2030 ..... | 10 | 5.2 | 2125 | 95 |
| 2035 ..... | 4 | 2.1 | 2130 | 95 |
| 2040 ..... | 16 | 8.3 | 2135 | 95 |
| 2045 ..... | 14 | 7.3 | 2140 | 95 |
| >2050 ..... | 37 | 19.3 | >2140 | >95 |

[6] 2.1 children per woman will be used in this paper but, in the actual projections, true replacement level will be calculated

78. **Proposal for the medium scenario**: *The medium variant of the 2002 Revision will be extended by letting those countries that have not yet reached 1.85 children per woman move to that level. Once below-replacement fertility is reached, countries will maintain levels below replacement (that is, levels below 2.1 children per woman) for periods that will average 95 years. The exact period for each country is indicated in table 1. At the end of those 95 years, actual replacement level will be reached and maintained for the rest of the projection period.*

79. **Proposal for the low and high scenarios**: *In the 2002 Revision, the key variants were the low, the medium and the high. The fertility of the low and the high variants usually differed from that of the medium variant by 0.5 and –0.5 children, respectively, especially by 2045-2050. Previous long-range projections have shown that a difference of half a child above or below replacement level, if maintained over the long run, produces very dramatic increases or decreases of the population. Consequently, it is proposed that in this set of long-range projections the differences between the low, medium and high scenarios after 2050 be reduced to 0.25 of a child. That is, after a transition period of 20 years or so, total fertility in the low scenario will be 0.25 children less than that of the medium scenario and that of the high scenario will be 0.25 children higher than the medium.*

80. Figures 1 and 2 illustrate the paths of fertility for Niger (a high-fertility country) and Venezuela (an intermediate-fertility country) starting in 1950 and going to 2200. Beyond that point, fertility will remain constant. The narrowing of the difference between the low, medium and high scenarios is evident but the period of transition works well in both cases. It is not possible, however, to follow exactly the same strategy in the case of countries such as Latvia, where fertility has already fallen below 1.85 children per woman and whose fertility was projected to increase rather than decrease from 2010 to 2050 in the *2002 Revision*. In that case, the transition for the low scenario to become 0.25 children lower than the medium-scenario needs to be longer, whereas the high scenario, which starts at 2.35 children per woman, needs only remain constant to be 0.25 children higher than the medium when the latter reaches 2.1 children per women (see figure 3).

**Proposals for other scenarios**:

81. **Ultra-low and ultra-high scenarios:** *Total fertility is kept at –0.5 and +0.5 children below or above that of the medium scenario.*

82. **Scenario with 1.85 children per woman:** *Countries whose fertility has not reached 1.85 children per woman by 2045-2050 are allowed to reach it before 2100. Once reached, the level of 1.85 children per woman is maintained constant until 2300 for all countries.*

83. **Instant-replacement scenario:** *Continuation of the instant-replacement scenario of the 2002 Revision, that is, instant replacement starts in 2000.*

84. **Instant-replacement scenario 2050:** *Continuation of the medium variant of the 2002 Revision but ensuring instant-replacement as of 2050.*

85. **Constant-fertility scenario.** *Continuation of the constant-fertility variant of the 2002 Revision, that is, total fertility is kept constant at the level reached in 1995-2000.*

**Figure 1. Estimated and projected fertility, Niger, 1950-2200, low, medium and high**

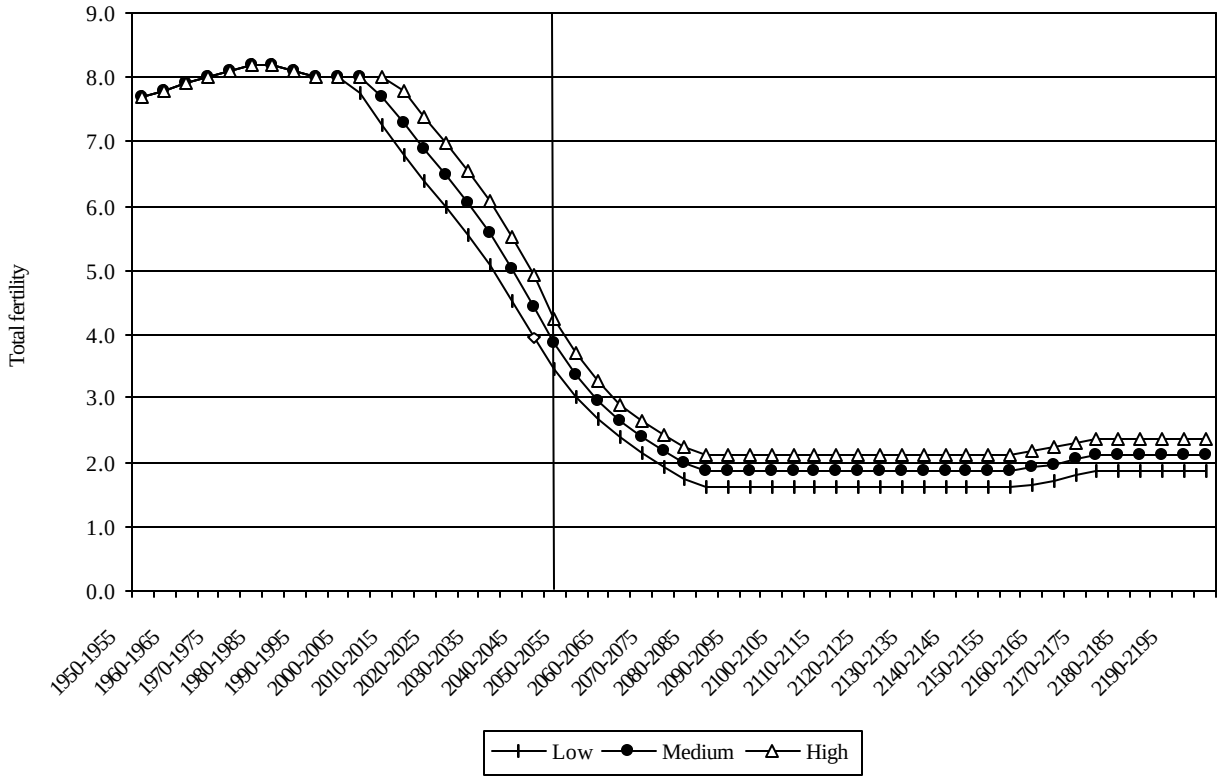



**Figure 2. Estimated and projected fertility, Venezuela, 1950-2200, low, medium and high**

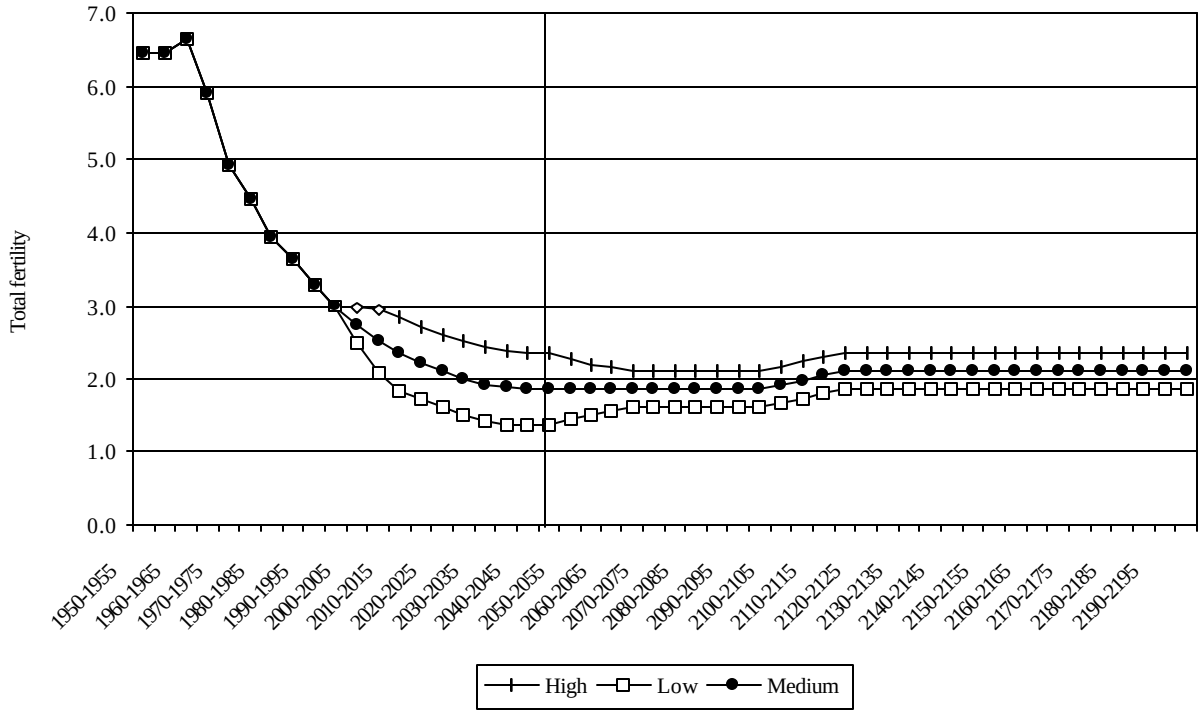
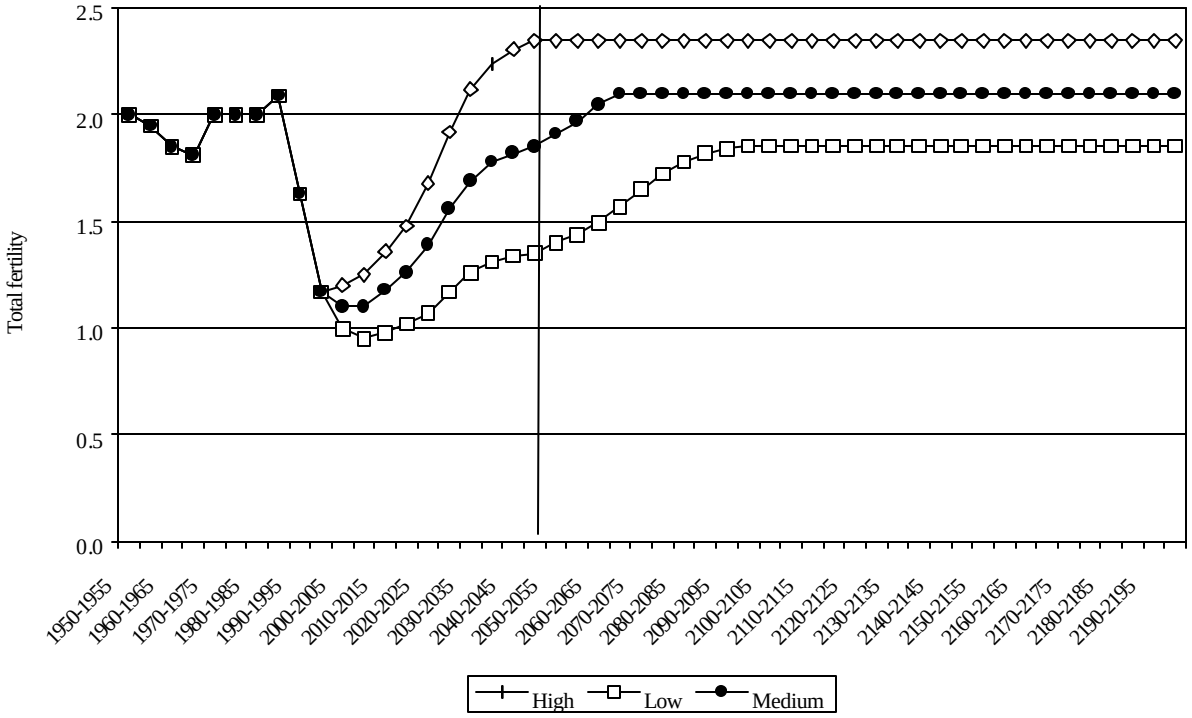


**Figure 3. Estimated and projected total fertility for Latvia, 1950-2200, low, medium and high variants**




86. **Constant-fertility scenario 2050**: *Total fertility is maintained constant at the level reached in 2045-2050 in the medium variant.*

### The projection of age-specific fertility

87. According to the medium variant of the *2002 Revision*, most countries would already be experiencing fertility at below-replacement level by 2045-2050. Hence, to facilitate the preparation of long-term projections, the shape of the fertility schedule for the following 250 years will be kept constant and equal to that reached by 2045-2050. In the case of countries whose total fertility in 2045-2050 was still substantially above replacement level, the shape of the fertility schedule will be projected in such a way that it conforms to the patterns typically observed among low-fertility countries by the time below-replacement fertility is reached (on or before 2080-2085). From there on, the shape of age-specific fertility will be kept constant until the end of the projection period.

## C. THE LONG-RANGE PROJECTION OF MORTALITY

88. The long-range projection of mortality probably poses more challenges than the long-range projection of fertility. As with fertility, we will focus here mostly on how to project mortality levels, although the issue cannot be totally separated from the consideration of changing mortality patterns by age. Traditionally, the Population Division has projected expectation of life at birth by using a model whereby the increments of e(0) over time diminish as higher levels of

life expectancy are reached. Once a future path of e(0) levels is established, life tables with those expectations of life are generated by using model life-table systems and an interpolation method based on the Lee-Carter method. Currently, the models used have a limiting life table with 92.5 years of life expectancy.

89. In addition, in the *2002 Revision* the projections of mortality for 53 countries take explicit account of the impact of the HIV/AIDS epidemic. As a result, both their levels and patterns of mortality by age are projected on the basis of a projection of the future incidence of the disease. The effects of HIV/AIDS in terms of excess mortality are superimposed on life tables projected using the traditional method. Although the incidence of HIV/AIDS is projected to decline over time, by 2045-2050 it is still far from negligible in several of the countries affected and the levels and patterns of mortality by age and sex in 2045-2050 still reflect the impact of the epidemic.

90. Given the great successes in improving health during the second half of the 20th century, mortality reductions were virtually universal until the 1980s and the projections of the Population Division reflected the general view that mortality would keep on declining everywhere. The emergence of HIV/AIDS put an end to that optimistic perspective. Furthermore, the stagnation or even increases of mortality levels recorded in some of the CIS countries and other countries with economies in transition also indicated that the universal reduction of mortality could not be taken for granted. However, except for the cases of countries already affected by the HIV/AIDS epidemic, the *2002 Revision* generally projects that mortality levels will decline steadily until 2050. In considering a 300 year horizon, one must admit that the possibility of setbacks increases. Epidemics caused by as yet unheard of infectious agents, high mortality due to conflict or political instability, increased mortality because of unsustainable modes of production in parts of the world are all possible and perhaps likely. However, it is not possible to pinpoint with some certainty where and when those setbacks might occur. Therefore, in making long-range projections at the country level, the scenarios proposed here will still reflect the view that progress in reducing mortality is expected everywhere.

91. To explore the changes in life expectancy recorded during the second half of the twentieth century and those projected by the *2002 Revision* over the first half of the twenty-first century, table 4 presents the expectation of life for both sexes combined in 1950-1955, 1995-2000 and 2045-2050, as well as the average annual increments in life expectancy for three periods. Table 5 presents the same information for the 53 countries that are highly affected by the HIV/AIDS epidemic. Figure 4 shows the scatterplot of life expectancy in 1950-1955 against the average annual increment in life expectancy between 1950-1955 and 1995-2000 for countries that are not yet significantly affected by HIV/AIDS. Although there are some exceptions among countries with relatively low life expectancies in the early 1950s, the general trend is for the average annual increments to decline as life expectancy rises. That is, over lengthy periods (45 years in this case), countries that started with a higher life expectancy made smaller gains in absolute terms than countries whose life expectancy was lower at the beginning of the period.

92. Figure 5 shows a similar plot as that in figure 4 but restricted to countries not affected by HIV/AIDS and whose life expectancies in 1950-1955 were already fairly high (at least 60 years). The declining trend of annual increments of life expectancy in relation to initial levels of expectancy is clearer. By fitting a curve to the data, it is possible to use that curve to project life expectancy over time. The resulting life expectancies for 2295-2300 are shown in table 6. They range from 88 to 99 years. They also reflect the same country rankings as those projected by the *2002 Revision* for 2045-2050. That is, crossovers are avoided.

TABLE 4. EXPECTATION OF LIFE AT BIRTH AND AVERAGE ANNUAL INCREASE IN LIFE EXPECTANCY BY COUNTRY, 1950-1955, 1995-2000 AND 2045-2050

| *Country or area* | *Expectation of life at birth (both sexes)* | | | *Average annual increase (years)* | | |
|---|---|---|---|---|---|---|
| | *1950-1955* | *1995-2000* | *2045-2050* | *1950-1955 to 1995-2000* | *1995-2000 to 2045-2050* | *1950-1955 to 2045-2050* |
| Japan | 63.9 | 80.5 | 88.1 | 0.37 | 0.14 | 0.24 |
| China, Hong Kong SAR | 61.0 | 79.1 | 84.8 | 0.40 | 0.10 | 0.24 |
| Sweden | 71.8 | 79.3 | 84.6 | 0.17 | 0.10 | 0.13 |
| China, Macao SAR | 54.0 | 78.1 | 84.2 | 0.54 | 0.11 | 0.30 |
| Spain | 63.9 | 78.4 | 84.1 | 0.32 | 0.10 | 0.20 |
| France | 66.5 | 78.1 | 84.0 | 0.26 | 0.11 | 0.17 |
| Belgium | 67.5 | 77.9 | 83.8 | 0.23 | 0.11 | 0.16 |
| Norway | 72.7 | 78.1 | 83.7 | 0.12 | 0.10 | 0.11 |
| Australia | 69.6 | 78.7 | 83.7 | 0.20 | 0.09 | 0.14 |
| Luxembourg | 65.9 | 77.4 | 83.7 | 0.26 | 0.11 | 0.18 |
| Malta | 65.9 | 77.3 | 83.7 | 0.25 | 0.12 | 0.18 |
| Austria | 65.7 | 77.7 | 83.6 | 0.27 | 0.11 | 0.18 |
| Israel | 65.4 | 78.3 | 83.5 | 0.29 | 0.09 | 0.18 |
| Germany | 67.5 | 77.4 | 83.5 | 0.22 | 0.11 | 0.16 |
| Iceland | 72.0 | 79.3 | 83.4 | 0.16 | 0.08 | 0.11 |
| Canada | 69.1 | 78.7 | 83.3 | 0.21 | 0.08 | 0.14 |
| Guadeloupe | 56.5 | 77.3 | 83.2 | 0.46 | 0.11 | 0.27 |
| Martinique | 56.6 | 78.8 | 83.1 | 0.49 | 0.08 | 0.26 |
| United Kingdom | 69.2 | 77.2 | 83.0 | 0.18 | 0.11 | 0.14 |
| Singapore | 60.4 | 77.2 | 83.0 | 0.37 | 0.11 | 0.23 |
| Finland | 66.3 | 77.2 | 83.0 | 0.24 | 0.11 | 0.17 |
| Switzerland | 69.2 | 78.6 | 82.9 | 0.21 | 0.08 | 0.14 |
| Italy | 66.0 | 78.2 | 82.5 | 0.27 | 0.08 | 0.17 |
| United States Virgin Islands | 64.9 | 77.3 | 82.5 | 0.28 | 0.09 | 0.18 |
| Greece | 65.9 | 77.8 | 82.3 | 0.26 | 0.08 | 0.16 |
| New Zealand | 69.6 | 77.6 | 82.3 | 0.18 | 0.08 | 0.13 |
| Channel Islands | 70.6 | 77.6 | 82.2 | 0.16 | 0.08 | 0.12 |
| Netherlands | 72.1 | 77.9 | 82.2 | 0.13 | 0.08 | 0.10 |
| Cyprus | 67.0 | 77.6 | 82.2 | 0.24 | 0.08 | 0.15 |
| Republic of Korea | 47.5 | 74.4 | 82.2 | 0.60 | 0.14 | 0.35 |
| Costa Rica | 57.2 | 77.3 | 82.0 | 0.45 | 0.09 | 0.25 |
| Slovenia | 65.6 | 75.2 | 81.9 | 0.21 | 0.12 | 0.16 |
| Ireland | 66.9 | 76.1 | 81.4 | 0.20 | 0.10 | 0.15 |
| Denmark | 71.0 | 75.9 | 81.4 | 0.11 | 0.10 | 0.10 |
| Barbados | 57.2 | 76.4 | 81.4 | 0.43 | 0.09 | 0.24 |
| Czech Republic | 67.4 | 74.3 | 81.4 | 0.15 | 0.13 | 0.14 |
| Uruguay | 66.1 | 74.2 | 81.3 | 0.18 | 0.13 | 0.15 |
| Brunei Darussalam | 60.4 | 75.5 | 81.2 | 0.34 | 0.10 | 0.21 |
| Portugal | 59.3 | 75.2 | 81.0 | 0.35 | 0.11 | 0.22 |
| Netherlands Antilles | 60.5 | 75.5 | 81.0 | 0.33 | 0.10 | 0.21 |
| Cuba | 59.3 | 76.0 | 80.9 | 0.37 | 0.09 | 0.22 |
| Kuwait | 55.6 | 75.7 | 80.9 | 0.45 | 0.09 | 0.25 |
| Jamaica | 58.5 | 74.8 | 80.8 | 0.36 | 0.11 | 0.22 |
| French Guiana | 53.3 | 74.2 | 80.8 | 0.47 | 0.12 | 0.27 |
| Chile | 54.7 | 75.3 | 80.7 | 0.46 | 0.10 | 0.26 |
| Argentina | 62.5 | 73.2 | 80.5 | 0.24 | 0.13 | 0.18 |

TABLE 4 (*continued*)

| *Country or area* | *Expectation of life at birth (both sexes)* | | | *Average annual increase (years)* | | |
|---|---|---|---|---|---|---|
| | *1950-1955* | *1995-2000* | *2045-2050* | *1950-1955 to 1995-2000* | *1995-2000 to 2045-2050* | *1950-1955 to 2045-2050* |
| New Caledonia | 51.4 | 74.0 | 80.4 | 0.50 | 0.12 | 0.29 |
| Panama | 55.2 | 73.7 | 80.4 | 0.41 | 0.12 | 0.25 |
| Guam | 57.0 | 73.5 | 80.3 | 0.37 | 0.12 | 0.23 |
| Puerto Rico | 64.3 | 74.9 | 80.3 | 0.24 | 0.10 | 0.16 |
| Réunion | 52.7 | 74.6 | 80.2 | 0.48 | 0.10 | 0.27 |
| Poland | 61.3 | 72.8 | 80.1 | 0.26 | 0.13 | 0.19 |
| United Arab Emirates | 48.0 | 73.8 | 80.1 | 0.57 | 0.12 | 0.32 |
| Venezuela | 55.1 | 72.8 | 80.0 | 0.39 | 0.13 | 0.25 |
| Albania | 55.2 | 72.8 | 79.9 | 0.39 | 0.13 | 0.25 |
| Bahrain | 50.9 | 73.0 | 79.8 | 0.49 | 0.12 | 0.29 |
| Lithuania | 64.8 | 71.4 | 79.7 | 0.15 | 0.15 | 0.15 |
| Tunisia | 44.6 | 71.7 | 79.7 | 0.60 | 0.15 | 0.35 |
| Mexico | 50.6 | 72.5 | 79.7 | 0.49 | 0.13 | 0.29 |
| Malaysia | 48.5 | 71.9 | 79.6 | 0.52 | 0.14 | 0.31 |
| French Polynesia | 48.9 | 71.7 | 79.6 | 0.51 | 0.14 | 0.31 |
| Slovakia | 64.3 | 72.2 | 79.6 | 0.18 | 0.13 | 0.15 |
| Croatia | 61.2 | 73.3 | 79.6 | 0.27 | 0.11 | 0.18 |
| Libyan Arab Jamahiriya | 42.7 | 71.6 | 79.6 | 0.64 | 0.15 | 0.37 |
| TFYR Macedonia | 55.0 | 72.7 | 79.5 | 0.39 | 0.12 | 0.25 |
| Sri Lanka | 55.5 | 71.6 | 79.5 | 0.36 | 0.14 | 0.24 |
| Saint Vincent and the Grenadines | 51.1 | 73.2 | 79.4 | 0.49 | 0.11 | 0.28 |
| Estonia | 65.3 | 70.1 | 79.4 | 0.11 | 0.17 | 0.14 |
| Saudi Arabia | 39.9 | 70.9 | 79.3 | 0.69 | 0.15 | 0.39 |
| Hungary | 63.6 | 70.6 | 79.3 | 0.15 | 0.16 | 0.16 |
| Lebanon | 55.9 | 72.6 | 79.2 | 0.37 | 0.12 | 0.23 |
| Colombia | 50.6 | 70.7 | 79.2 | 0.45 | 0.15 | 0.29 |
| Latvia | 66.0 | 69.3 | 79.1 | 0.07 | 0.18 | 0.13 |
| Iran (Islamic Republic of) | 44.9 | 68.6 | 79.1 | 0.53 | 0.19 | 0.34 |
| Syrian Arab Republic | 45.9 | 70.5 | 79.1 | 0.55 | 0.16 | 0.33 |
| Serbia and Montenegro | 58.0 | 72.2 | 79.1 | 0.32 | 0.12 | 0.21 |
| Qatar | 48.0 | 70.9 | 79.0 | 0.51 | 0.15 | 0.31 |
| Saint Lucia | 54.1 | 71.5 | 79.0 | 0.39 | 0.14 | 0.25 |
| Occupied Palestinian Territory | 43.2 | 71.4 | 79.0 | 0.63 | 0.14 | 0.36 |
| Bosnia and Herzegovina | 53.8 | 73.3 | 78.9 | 0.43 | 0.10 | 0.25 |
| Mauritius | 51.0 | 70.7 | 78.8 | 0.44 | 0.15 | 0.28 |
| Jordan | 43.2 | 69.7 | 78.8 | 0.59 | 0.17 | 0.36 |
| El Salvador | 45.3 | 69.5 | 78.8 | 0.54 | 0.17 | 0.34 |
| Bulgaria | 64.1 | 70.9 | 78.7 | 0.15 | 0.14 | 0.15 |
| Suriname | 56.0 | 70.1 | 78.6 | 0.31 | 0.15 | 0.23 |
| Nicaragua | 42.3 | 68.0 | 78.6 | 0.57 | 0.19 | 0.36 |
| Cape Verde | 48.5 | 68.6 | 78.6 | 0.45 | 0.18 | 0.30 |
| Oman | 37.6 | 71.6 | 78.5 | 0.76 | 0.13 | 0.41 |
| Turkey | 43.6 | 69.0 | 78.5 | 0.57 | 0.17 | 0.35 |
| Paraguay | 62.6 | 69.7 | 78.5 | 0.16 | 0.16 | 0.16 |
| Sao Tome and Principe | 46.4 | 68.4 | 78.5 | 0.49 | 0.18 | 0.32 |
| Philippines | 47.8 | 68.6 | 78.4 | 0.46 | 0.18 | 0.31 |
| Algeria | 43.1 | 67.9 | 78.4 | 0.55 | 0.19 | 0.35 |
| Belarus | 65.9 | 68.5 | 78.4 | 0.06 | 0.18 | 0.12 |

TABLE 4 (*continued*)

| *Country or area* | *Expectation of life at birth (both sexes)* | | | *Average annual increase (years)* | | |
|---|---|---|---|---|---|---|
| | *1950-1955* | *1995-2000* | *2045-2050* | *1950-1955 to 1995-2000* | *1995-2000 to 2045-2050* | *1950-1955 to 2045-2050* |
| Solomon Islands | 45.4 | 67.4 | 78.3 | 0.49 | 0.20 | 0.33 |
| Georgia | 61.5 | 72.7 | 78.3 | 0.25 | 0.10 | 0.17 |
| Ecuador | 48.4 | 69.8 | 78.3 | 0.48 | 0.15 | 0.30 |
| Egypt | 42.4 | 67.0 | 78.2 | 0.55 | 0.20 | 0.36 |
| Samoa | 45.9 | 68.4 | 78.2 | 0.50 | 0.18 | 0.32 |
| Ukraine | 66.0 | 68.1 | 78.2 | 0.05 | 0.18 | 0.12 |
| Viet Nam | 40.4 | 67.2 | 78.2 | 0.60 | 0.20 | 0.38 |
| Peru | 43.9 | 68.3 | 78.2 | 0.54 | 0.18 | 0.34 |
| Azerbaijan | 61.3 | 70.9 | 78.0 | 0.22 | 0.13 | 0.17 |
| Armenia | 64.8 | 71.4 | 77.9 | 0.15 | 0.12 | 0.13 |
| Morocco | 42.9 | 66.6 | 77.9 | 0.53 | 0.21 | 0.35 |
| Republic of Moldova | 58.4 | 67.3 | 77.8 | 0.20 | 0.19 | 0.19 |
| Fiji | 52.5 | 68.4 | 77.8 | 0.35 | 0.17 | 0.25 |
| Maldives | 38.9 | 65.4 | 77.5 | 0.59 | 0.22 | 0.39 |
| Guatemala | 42.0 | 64.2 | 77.5 | 0.49 | 0.24 | 0.35 |
| Micronesia (Federated States of) | 54.6 | 67.1 | 77.3 | 0.28 | 0.19 | 0.23 |
| Romania | 61.1 | 70.5 | 77.3 | 0.21 | 0.12 | 0.16 |
| Tonga | 54.6 | 67.0 | 77.2 | 0.28 | 0.19 | 0.23 |
| Indonesia | 37.5 | 64.9 | 76.9 | 0.61 | 0.22 | 0.39 |
| Uzbekistan | 56.4 | 68.3 | 76.8 | 0.27 | 0.15 | 0.20 |
| Kyrgyzstan | 55.4 | 66.9 | 76.6 | 0.26 | 0.17 | 0.21 |
| Tajikistan | 55.7 | 67.2 | 76.5 | 0.25 | 0.17 | 0.21 |
| Vanuatu | 42.0 | 67.2 | 76.5 | 0.56 | 0.17 | 0.35 |
| Bolivia | 40.4 | 62.1 | 76.5 | 0.48 | 0.26 | 0.36 |
| Iraq | 44.0 | 58.7 | 76.3 | 0.33 | 0.32 | 0.32 |
| Western Sahara | 35.5 | 61.2 | 76.3 | 0.57 | 0.28 | 0.41 |
| Comoros | 40.7 | 58.8 | 76.2 | 0.40 | 0.32 | 0.36 |
| Turkmenistan | 53.0 | 65.4 | 76.2 | 0.27 | 0.20 | 0.23 |
| Kazakhstan | 56.5 | 64.6 | 76.0 | 0.18 | 0.21 | 0.20 |
| Bhutan | 35.2 | 60.7 | 76.0 | 0.57 | 0.28 | 0.41 |
| Mongolia | 42.2 | 61.9 | 75.9 | 0.44 | 0.26 | 0.34 |
| Bangladesh | 37.5 | 58.4 | 75.0 | 0.47 | 0.30 | 0.38 |
| Nepal | 36.3 | 57.4 | 74.9 | 0.47 | 0.32 | 0.39 |
| Democratic People's Rep. of Korea | 49.0 | 63.1 | 74.7 | 0.31 | 0.21 | 0.26 |
| Pakistan | 41.0 | 59.0 | 74.7 | 0.40 | 0.28 | 0.34 |
| Yemen | 32.5 | 58.0 | 73.5 | 0.56 | 0.28 | 0.41 |
| Papua New Guinea | 34.7 | 55.5 | 73.3 | 0.46 | 0.32 | 0.39 |
| Lao People's Democratic Republic | 37.8 | 52.5 | 72.2 | 0.33 | 0.36 | 0.34 |
| Madagascar | 36.7 | 51.6 | 71.1 | 0.33 | 0.35 | 0.34 |
| Senegal | 36.5 | 50.9 | 70.9 | 0.32 | 0.36 | 0.34 |
| Democratic Rep. of Timor-Leste | 30.0 | 47.5 | 69.9 | 0.39 | 0.41 | 0.40 |
| Mauritania | 35.4 | 50.5 | 69.7 | 0.33 | 0.35 | 0.34 |
| Somalia | 33.0 | 44.8 | 68.4 | 0.26 | 0.43 | 0.35 |
| Niger | 32.2 | 44.2 | 65.4 | 0.27 | 0.39 | 0.33 |
| Afghanistan | 31.9 | 42.1 | 62.4 | 0.23 | 0.37 | 0.31 |

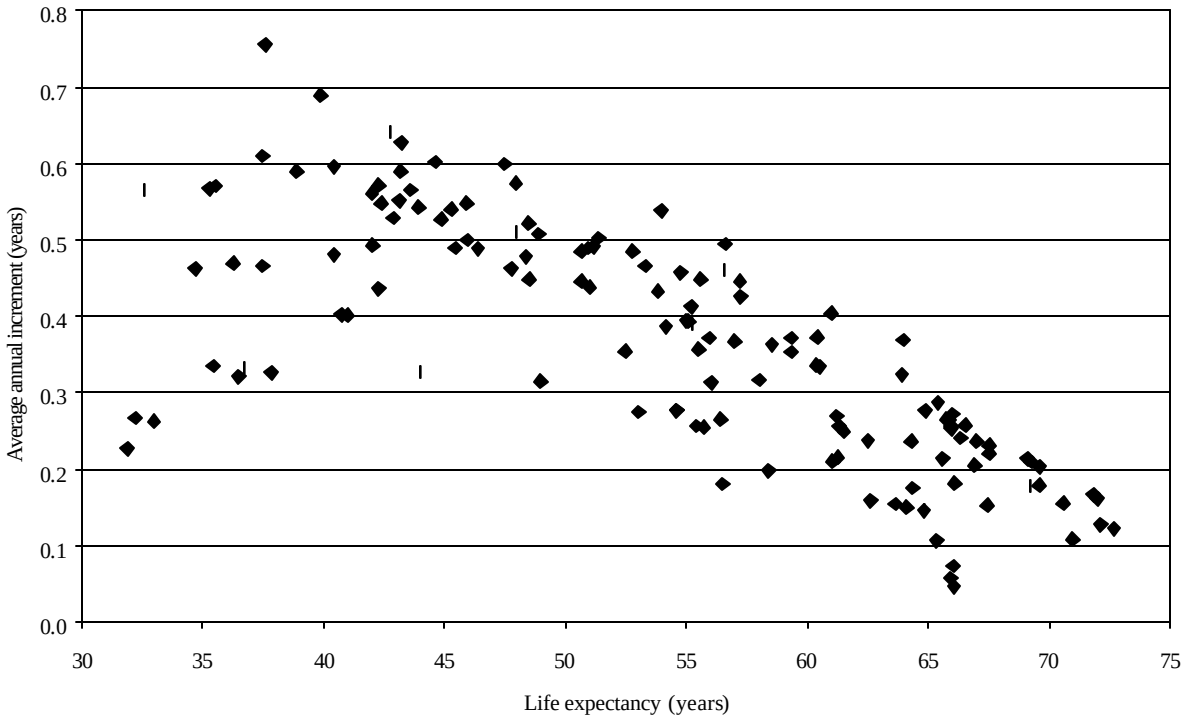
TABLE 5. EXPECTATION OF LIFE AT BIRTH AND AVERAGE ANNUAL INCREASE IN LIFE EXPECTANCY FOR COUNTRIES AFFECTED BY HIV/AIDS, 1950-1955, 1995-2000 AND 2045-2050

| | *Expectation of life at birth (both sexes)* | | | *Average annual increase (years)* | | |
|---|---|---|---|---|---|---|
| *Country or area* | *1950-1955* | *1995-2000* | *2045-2050* | *1950-1955 to 1995-2000* | *1995-2000 to 2045-2050* | *1950-1955 to 2045-2050* |
| United States of America | 68.9 | 76.2 | 81.6 | 0.16 | 0.10 | 0.13 |
| Thailand | 52.0 | 68.1 | 78.2 | 0.36 | 0.18 | 0.26 |
| Brazil | 50.9 | 67.1 | 77.9 | 0.36 | 0.20 | 0.27 |
| China | 40.8 | 69.7 | 76.7 | 0.64 | 0.13 | 0.36 |
| Trinidad and Tobago | 59.1 | 72.1 | 76.6 | 0.29 | 0.08 | 0.17 |
| Belize | 57.7 | 72.5 | 76.5 | 0.33 | 0.07 | 0.19 |
| Honduras | 41.8 | 68.6 | 75.6 | 0.60 | 0.13 | 0.34 |
| Russian Federation | 64.5 | 66.1 | 74.2 | 0.04 | 0.15 | 0.10 |
| India | 38.7 | 62.1 | 73.8 | 0.52 | 0.21 | 0.35 |
| Dominican Republic | 45.9 | 66.9 | 73.7 | 0.47 | 0.12 | 0.28 |
| Bahamas | 59.8 | 67.3 | 73.6 | 0.17 | 0.12 | 0.14 |
| Guyana | 52.3 | 63.6 | 71.7 | 0.25 | 0.15 | 0.19 |
| Ghana | 42.0 | 57.3 | 71.6 | 0.34 | 0.26 | 0.30 |
| Gabon | 37.0 | 56.6 | 71.6 | 0.44 | 0.27 | 0.35 |
| Gambia | 30.0 | 52.7 | 70.2 | 0.51 | 0.32 | 0.40 |
| Cambodia | 39.4 | 57.2 | 69.8 | 0.39 | 0.23 | 0.30 |
| Myanmar | 36.8 | 56.4 | 69.5 | 0.44 | 0.24 | 0.33 |
| Uganda | 40.0 | 41.1 | 69.3 | 0.03 | 0.51 | 0.29 |
| Sudan | 37.6 | 55.0 | 68.6 | 0.38 | 0.25 | 0.31 |
| Haiti | 37.6 | 48.2 | 68.4 | 0.24 | 0.37 | 0.31 |
| Eritrea | 35.9 | 52.0 | 68.3 | 0.36 | 0.30 | 0.32 |
| Guinea | 31.0 | 47.0 | 67.2 | 0.36 | 0.37 | 0.36 |
| Equatorial Guinea | 34.5 | 48.5 | 67.0 | 0.31 | 0.34 | 0.32 |
| Benin | 33.9 | 51.4 | 66.6 | 0.39 | 0.28 | 0.33 |
| Mali | 32.7 | 47.9 | 65.5 | 0.34 | 0.32 | 0.33 |
| Burkina Faso | 31.9 | 45.9 | 65.0 | 0.31 | 0.35 | 0.33 |
| Djibouti | 33.0 | 47.0 | 64.1 | 0.31 | 0.31 | 0.31 |
| Congo | 42.1 | 49.2 | 64.1 | 0.16 | 0.27 | 0.22 |
| Nigeria | 36.5 | 52.5 | 63.9 | 0.36 | 0.21 | 0.27 |
| Chad | 32.5 | 44.4 | 63.6 | 0.26 | 0.35 | 0.31 |
| Togo | 36.0 | 51.8 | 63.5 | 0.35 | 0.21 | 0.27 |
| Guinea-Bissau | 32.5 | 44.4 | 63.4 | 0.26 | 0.34 | 0.31 |
| United Republic of Tanzania | 37.0 | 45.5 | 63.3 | 0.19 | 0.32 | 0.26 |
| Ethiopia | 32.9 | 46.1 | 63.2 | 0.29 | 0.31 | 0.30 |
| Rwanda | 40.0 | 35.5 | 62.8 | -0.10 | 0.49 | 0.23 |
| Côte d'Ivoire | 36.0 | 43.2 | 62.7 | 0.16 | 0.35 | 0.27 |
| Burundi | 39.0 | 39.3 | 61.0 | 0.01 | 0.39 | 0.22 |
| Democratic Rep. of the Congo | 39.1 | 38.0 | 60.8 | -0.03 | 0.42 | 0.22 |
| Liberia | 38.5 | 41.8 | 59.2 | 0.07 | 0.32 | 0.21 |
| Cameroon | 36.0 | 52.0 | 59.0 | 0.36 | 0.13 | 0.23 |
| Angola | 30.0 | 40.2 | 58.2 | 0.23 | 0.33 | 0.28 |
| Central African Republic | 35.5 | 42.6 | 57.1 | 0.16 | 0.26 | 0.22 |
| Malawi | 36.3 | 40.7 | 56.5 | 0.10 | 0.29 | 0.20 |
| South Africa | 45.0 | 58.2 | 55.7 | 0.29 | -0.05 | 0.11 |
| Namibia | 39.2 | 54.5 | 54.3 | 0.34 | 0.00 | 0.15 |
| Mozambique | 31.3 | 41.5 | 54.2 | 0.23 | 0.23 | 0.23 |

TABLE 5 (*continued*)

| *Country or area* | *Expectation of life at birth (both sexes)* | | | *Average annual increase (years)* | | |
|---|---|---|---|---|---|---|
| | *1950-1955* | *1995-2000* | *2045-2050* | *1950-1955 to 1995-2000* | *1995-2000 to 2045-2050* | *1950-1955 to 2045-2050* |
| Kenya | 40.9 | 50.7 | 54.1 | 0.22 | 0.06 | 0.13 |
| Zambia | 37.8 | 35.7 | 52.3 | -0.05 | 0.30 | 0.15 |
| Sierra Leone | 30.0 | 34.9 | 52.3 | 0.11 | 0.32 | 0.22 |
| Zimbabwe | 47.4 | 40.8 | 45.7 | -0.15 | 0.09 | -0.02 |
| Lesotho | 41.7 | 46.9 | 44.1 | 0.11 | -0.05 | 0.02 |
| Botswana | 46.0 | 56.3 | 43.6 | 0.23 | -0.23 | -0.02 |
| Swaziland | 40.1 | 47.2 | 43.4 | 0.16 | -0.07 | 0.03 |

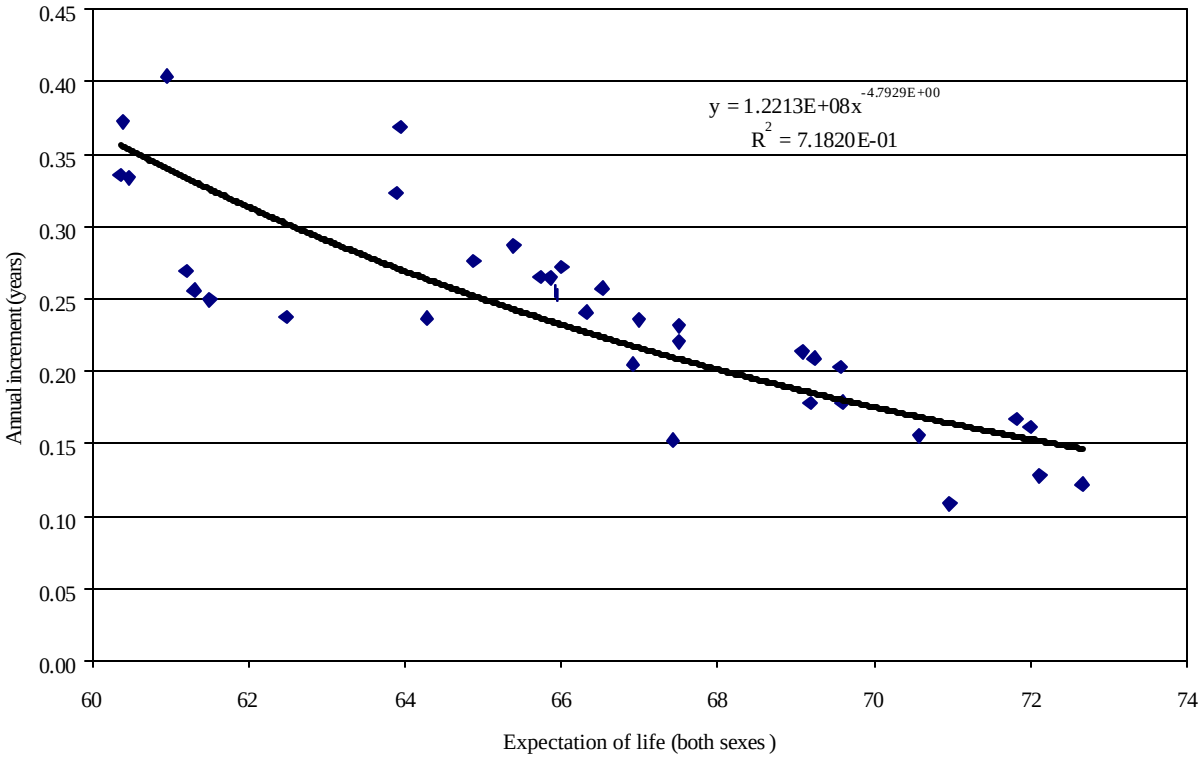
**Figure 4. Annual increments of life expectancy in 1950-2000 vs. life expectancy in 1950**




93. This exercise leads to two conclusions. The first is that, if current projection methodology is to be used in preparing the long-range projections, the highest level of life expectancy now in use by the projection program has to be increased. However, model life tables with an ultimate life expectancy of 100 years (both sexes combined) might suffice. The second is that, provided that the ultimate life expectancy is changed, projections that incorporate a steady increase in life expectancy for all countries are feasible and would seem compatible with past average experience.

94. However, the simple method used above to derive a path of e(0) for the future has several drawbacks. It does not reflect regional differences and it does not take into account the age structure of mortality. To derive a more flexible approach for the long-range projection of mortality, we propose to use the Lee-Carter model. Ronald Lee and Lawrence Carter (1992)

**Figure 5. 1950-1995 NoAIDS, high e(0) and rapid decline**




proposed a model for projecting future mortality. The model was based on a linear decomposition of the logarithm of age-specific mortality rates into a dominant component changing with respect to time and an age component that remained fixed as time elapsed. Carter and Lee used this model to produce mortality projections for the United States, based on data for 1900-1989. The singular value decomposition of the matrix of transformed mortality rates was used to identify the principal components and the first principal component provided the basis for projection. In particular, if m(x,t) is the central mortality rate at age x and time t, the Lee-Carter model fitted the following equation:

$$\ln(m(x,t)) = a(x) + k(t)b(x) + \text{å}(x,t) \qquad (1)$$

where a(x) represents the mean pattern of mortality by age, k(t) is an index indicating the level of mortality at time t, b(x) represents a set of age-specific values describing the relative speed of change of mortality at each age, and å(x,t) is the residual at age x and time t. To project mortality, an ARIMA time-series model was fitted to k(t), by assuming that k(t) would evolve as a random walk with a drift. That is, it was assumed that k(t) could be modeled by:

$$k(t) = k(t-1) + d + E(t) \qquad (2)$$

where d was the constant "drift" and E(t) are uncorrelated errors.

95. The Lee-Carter method has been successfully applied to project the mortality of several countries, both developed and developing. More recently, Li Nan has demonstrated that the principles of the Lee-Carter method can be applied to countries with at least two reliable

TABLE 6. LIFE EXPECTANCY IN 2045-2050 AND PROJECTED TO 2295-2300

| *Country or area* | *Affected by AIDS* | *2045-2050* | *2295-2300* |
|---|---|---|---|
| Japan | | 88.1 | 99.1 |
| China, Hong Kong SAR | | 84.8 | 97.4 |
| Sweden | | 84.6 | 97.2 |
| China, Macao SAR | | 84.2 | 97.0 |
| Spain | | 84.1 | 97.0 |
| France | | 84.0 | 96.9 |
| Belgium | | 83.8 | 96.9 |
| Norway | | 83.7 | 96.8 |
| Australia | | 83.7 | 96.8 |
| Luxembourg | | 83.7 | 96.8 |
| Malta | | 83.7 | 96.8 |
| Austria | | 83.6 | 96.8 |
| Israel | | 83.5 | 96.7 |
| Germany | | 83.5 | 96.7 |
| Iceland | | 83.4 | 96.7 |
| Canada | | 83.3 | 96.6 |
| Guadeloupe | | 83.2 | 96.5 |
| Martinique | | 83.1 | 96.5 |
| United Kingdom | | 83.0 | 96.5 |
| Singapore | | 83.0 | 96.4 |
| Finland | | 83.0 | 96.4 |
| Switzerland | | 82.9 | 96.4 |
| Italy | | 82.5 | 96.2 |
| United States Virgin Islands | | 82.5 | 96.2 |
| Greece | | 82.3 | 96.1 |
| New Zealand | | 82.3 | 96.1 |
| Channel Islands | | 82.2 | 96.1 |
| Netherlands | | 82.2 | 96.1 |
| Cyprus | | 82.2 | 96.1 |
| Republic of Korea | | 82.2 | 96.1 |
| Costa Rica | | 82.0 | 96.0 |
| Slovenia | | 81.9 | 95.9 |
| United States of America | 1 | 81.6 | 95.8 |
| Ireland | | 81.4 | 95.7 |
| Denmark | | 81.4 | 95.7 |
| Barbados | | 81.4 | 95.7 |
| Czech Republic | | 81.4 | 95.7 |
| Uruguay | | 81.3 | 95.7 |
| Brunei Darussalam | | 81.2 | 95.6 |
| Portugal | | 81.0 | 95.5 |
| Netherlands Antilles | | 81.0 | 95.5 |
| Cuba | | 80.9 | 95.5 |
| Kuwait | | 80.9 | 95.5 |
| Jamaica | | 80.8 | 95.5 |
| French Guiana | | 80.8 | 95.4 |
| Chile | | 80.7 | 95.4 |
| Argentina | | 80.5 | 95.3 |
| New Caledonia | | 80.4 | 95.3 |

TABLE 6 (*continued*)

| *Country or area* | *Affected by AIDS* | *2045-2050* | *2295-2300* |
|---|---|---|---|
| Panama | | 80.4 | 95.3 |
| Guam | | 80.3 | 95.2 |
| Puerto Rico | | 80.3 | 95.2 |
| Réunion | | 80.2 | 95.1 |
| Poland | | 80.1 | 95.1 |
| United Arab Emirates | | 80.1 | 95.1 |
| Venezuela | | 80.0 | 95.1 |
| Albania | | 79.9 | 95.0 |
| Bahrain | | 79.8 | 95.0 |
| Lithuania | | 79.7 | 94.9 |
| Tunisia | | 79.7 | 94.9 |
| Mexico | | 79.7 | 94.9 |
| Malaysia | | 79.6 | 94.9 |
| French Polynesia | | 79.6 | 94.9 |
| Slovakia | | 79.6 | 94.9 |
| Croatia | | 79.6 | 94.9 |
| Libyan Arab Jamahiriya | | 79.6 | 94.9 |
| TFYR Macedonia | | 79.5 | 94.8 |
| Sri Lanka | | 79.5 | 94.8 |
| Saint Vincent and the Grenadines | | 79.4 | 94.8 |
| Estonia | | 79.4 | 94.8 |
| Saudi Arabia | | 79.3 | 94.8 |
| Hungary | | 79.3 | 94.8 |
| Lebanon | | 79.2 | 94.8 |
| Colombia | | 79.2 | 94.8 |
| Latvia | | 79.1 | 94.7 |
| Iran (Islamic Republic of) | | 79.1 | 94.7 |
| Syrian Arab Republic | | 79.1 | 94.7 |
| Serbia and Montenegro | | 79.1 | 94.7 |
| Qatar | | 79.0 | 94.7 |
| Saint Lucia | | 79.0 | 94.7 |
| Occupied Palestinian Territory | | 79.0 | 94.6 |
| Bosnia and Herzegovina | | 78.9 | 94.6 |
| Mauritius | | 78.8 | 94.6 |
| Jordan | | 78.8 | 94.6 |
| El Salvador | | 78.8 | 94.6 |
| Bulgaria | | 78.7 | 94.5 |
| Suriname | | 78.6 | 94.5 |
| Nicaragua | | 78.6 | 94.5 |
| Cape Verde | | 78.6 | 94.5 |
| Oman | | 78.5 | 94.4 |
| Turkey | | 78.5 | 94.4 |
| Paraguay | | 78.5 | 94.4 |
| Sao Tome and Principe | | 78.5 | 94.4 |
| Philippines | | 78.4 | 94.4 |
| Algeria | | 78.4 | 94.4 |
| Belarus | | 78.4 | 94.4 |
| Solomon Islands | | 78.3 | 94.4 |
| Georgia | | 78.3 | 94.4 |

TABLE 6 (*continued*)

| *Country or area* | *Affected by AIDS* | *2045-2050* | *2295-2300* |
|---|---|---|---|
| Ecuador | | 78.3 | 94.4 |
| Egypt | | 78.2 | 94.3 |
| Samoa | | 78.2 | 94.3 |
| Ukraine | | 78.2 | 94.3 |
| Viet Nam | | 78.2 | 94.3 |
| Peru | | 78.2 | 94.3 |
| Thailand | 1 | 78.2 | 94.3 |
| Azerbaijan | | 78.0 | 94.2 |
| Armenia | | 77.9 | 94.2 |
| Morocco | | 77.9 | 94.2 |
| Brazil | 1 | 77.9 | 94.2 |
| Republic of Moldova | | 77.8 | 94.2 |
| Fiji | | 77.8 | 94.2 |
| Maldives | | 77.5 | 94.1 |
| Guatemala | | 77.5 | 94.0 |
| Micronesia (Federated States of) | | 77.3 | 94.0 |
| Romania | | 77.3 | 94.0 |
| Tonga | | 77.2 | 94.0 |
| Indonesia | | 76.9 | 93.8 |
| Uzbekistan | | 76.8 | 93.8 |
| China | 1 | 76.7 | 93.8 |
| Trinidad and Tobago | 1 | 76.6 | 93.7 |
| Kyrgyzstan | | 76.6 | 93.7 |
| Tajikistan | | 76.5 | 93.7 |
| Belize | 1 | 76.5 | 93.7 |
| Vanuatu | | 76.5 | 93.7 |
| Bolivia | | 76.5 | 93.7 |
| Iraq | | 76.3 | 93.6 |
| Western Sahara | | 76.3 | 93.6 |
| Comoros | | 76.2 | 93.6 |
| Turkmenistan | | 76.2 | 93.6 |
| Kazakhstan | | 76.0 | 93.5 |
| Bhutan | | 76.0 | 93.5 |
| Mongolia | | 75.9 | 93.5 |
| Honduras | 1 | 75.6 | 93.4 |
| Bangladesh | | 75.0 | 93.1 |
| Nepal | | 74.9 | 93.1 |
| Democratic People's Rep. of Korea | | 74.7 | 93.0 |
| Pakistan | | 74.7 | 93.0 |
| Russian Federation | 1 | 74.2 | 92.9 |
| India | 1 | 73.8 | 92.7 |
| Dominican Republic | 1 | 73.7 | 92.7 |
| Bahamas | 1 | 73.6 | 92.7 |
| Yemen | | 73.5 | 92.6 |
| Papua New Guinea | | 73.3 | 92.5 |
| Lao People's Democratic Republic | | 72.2 | 92.2 |
| Guyana | 1 | 71.7 | 92.0 |
| Ghana | 1 | 71.6 | 92.0 |
| Gabon | 1 | 71.6 | 92.0 |

TABLE 6 (*continued*)

| *Country or area* | *Affected by AIDS* | *2045-2050* | *2295-2300* |
|---|---|---|---|
| Madagascar | | 71.1 | 91.9 |
| Senegal | | 70.9 | 91.8 |
| Gambia | 1 | 70.2 | 91.6 |
| Democratic Rep. of Timor-Leste | | 69.9 | 91.5 |
| Cambodia | 1 | 69.8 | 91.5 |
| Mauritania | | 69.7 | 91.5 |
| Myanmar | 1 | 69.5 | 91.4 |
| Uganda | 1 | 69.3 | 91.4 |
| Sudan | 1 | 68.6 | 91.2 |
| Somalia | | 68.4 | 91.2 |
| Haiti | 1 | 68.4 | 91.2 |
| Eritrea | 1 | 68.3 | 91.2 |
| Guinea | 1 | 67.2 | 90.9 |
| Equatorial Guinea | 1 | 67.0 | 90.8 |
| Benin | 1 | 66.6 | 90.8 |
| Mali | 1 | 65.5 | 90.5 |
| Niger | | 65.4 | 90.5 |
| Burkina Faso | 1 | 65.0 | 90.4 |
| Djibouti | 1 | 64.1 | 90.2 |
| Congo | 1 | 64.1 | 90.2 |
| Nigeria | 1 | 63.9 | 90.2 |
| Chad | 1 | 63.6 | 90.2 |
| Togo | 1 | 63.5 | 90.1 |
| Guinea-Bissau | 1 | 63.4 | 90.1 |
| United Republic of Tanzania | 1 | 63.3 | 90.1 |
| Ethiopia | 1 | 63.2 | 90.1 |
| Rwanda | 1 | 62.8 | 90.0 |
| Côte d'Ivoire | 1 | 62.7 | 90.0 |
| Afghanistan | | 62.4 | 90.0 |
| Burundi | 1 | 61.0 | 89.7 |
| Democratic Republic of the Congo | 1 | 60.8 | 89.7 |
| Liberia | 1 | 59.2 | 89.5 |
| Cameroon | 1 | 59.0 | 89.5 |
| Angola | 1 | 58.2 | 89.4 |
| Central African Republic | 1 | 57.1 | 89.2 |
| Malawi | 1 | 56.5 | 89.2 |
| South Africa | 1 | 55.7 | 89.1 |
| Namibia | 1 | 54.3 | 89.0 |
| Mozambique | 1 | 54.2 | 89.0 |
| Kenya | 1 | 54.1 | 89.0 |
| Zambia | 1 | 52.3 | 88.8 |
| Sierra Leone | 1 | 52.3 | 88.8 |
| Zimbabwe | 1 | 45.7 | 88.6 |
| Lesotho | 1 | 44.1 | 88.5 |
| Botswana | 1 | 43.6 | 88.5 |
| Swaziland | 1 | 43.4 | 88.5 |

estimates of age-specific mortality by sex. Even for countries lacking data altogether, the Lee-Carter method can be applied to project mortality levels on the basis of a k(t) borrowed from other countries or from models. The proposal, therefore, is to project mortality levels on the basis of k(t) which, to the extent possible, will reflect the actual previous mortality change experienced by particular countries.

96. Projecting mortality in this way will likely result in continuous increases of life expectancy but there is no guarantee that the maximum level of life expectancy reached will be below 100 years (both sexes combined). The proposal is that, if projected life expectancy at the country level turns out to consistently surpass 100 years for both sexes combined, a limit of 100 years will be imposed artificially.

97. **Proposal for the projection of mortality**: *Mortality levels (and the age structure of mortality) will be projected using the Lee-Carter approach as modified by Li Nan. The parameter k(t) will be used to project mortality levels on the basis of information for each country or, if not available, on the basis of a borrowed model of change for k(t) that is appropriate. Expectation of life will be allowed to increase continuously until it reaches 100 years (both sexes combined). If that level is reached before 2300, it will be kept constant until 2300.*

**Proposals for other scenarios:**

98. **Unrestricted improvement scenario**: *If the method to project mortality reductions results in expectations of life above 100 (both sexes combined) for a significant number of countries, a scenario where the unrestricted improvement of longevity is combined with the medium-fertility path will be produced.*

99. **Constant-mortality scenario 2050**: *Mortality will be kept constant at the level it reached in 2045-2050 and fertility will follow the medium-fertility path.*

100. **Constant-mortality scenario**: *This scenario is a continuation of the constant- mortality scenario of the 2002 Revision where mortality is kept constant at the level it reached in 1995-2000 and fertility follows the medium-fertility path.*

## D. THE LONG-RANGE PROJECTION OF INTERNATIONAL MIGRATION

101. As both fertility and mortality decline further, international migration is likely to become a very important component of population change for a growing number of countries. However, as the most volatile component of demographic dynamics, the bases for projecting its levels and trends over the very long term are very weak. However, it seems important to include a non-zero migration assumption in the calculation of long-term population scenarios if only to assess how the results obtained would differ from the case in which international migration would not exist. Thus, one set of the key fertility scenarios will be produced under the assumption of zero international migration and a second set will incorporate non-zero international migration for most countries over the full projection period.

102. The non-zero migration scenario will be based on two principles: (1) countries will be classified as "receiving" or "sending" and their status will not change over the whole projection period; (2) the projected net numbers of international migrants have to add to zero at the world level. The second principle or constraint implies that either an algorithm has to be developed to

assign immigrants and emigrants to countries so as to ensure a zero sum at the world level or, as we do currently, the preliminary results of the projections will have to be checked manually and more emigrant or immigrants, as the case may be, will have to be allocated to ensure a world balance of zero.

103. In the normal projections to 2050, assumptions about future international migration levels are largely made in terms of net numbers of migrants and they tend to be kept constant over the projection period to facilitate the process of balancing world levels to zero. Such an approach may need to be followed also in preparing the long-range projections if time does not permit the development and testing of a programmable algorithm.

104. Given that long-term projections are likely to result in substantial changes in the population size of many countries, making assumptions on international migration in terms of net numbers of international migrants is not ideal. It would be better to use net migration rates as the means of establishing hypotheses about future trends. However, such a procedure will significantly increase the problem of getting a zero world balance. We propose to test a procedure whereby hypotheses on future trends in international migration are presented in terms of rates, a first projection is run and, on the basis of the results obtained, the rates of countries of emigration are changed to ensure that the total number of emigrants matches that of immigrants to the receiving countries (changes would be made in terms of the net number of emigrants). The net migration rates used to produce the first round of projections would largely be kept constant over the projection period, but the negative net emigration rates of some countries would change over time as a result of changes made to balance world migration to zero.

**Proposed international migration scenarios**:

105. **Zero-migration scenario 2050**: *Net migration will be kept to zero in all countries starting in 2050-2055. This scenario will be combined with the low, medium and high-fertility assumptions.*

106. **Zero-migration scenario 2000**: *Continuation of the zero-migration scenario of the 2002 Revision. It will be combined with the medium-fertility assumption.*

107. **Constant net migration rates**: *International migration rates will be kept constant at the level they reached in 2045-2050. This scenario will be combined with the low, medium and high-fertility assumptions. Implementation of this scenario depends on developing an algorithm for the computer-aided balancing of world migration to zero.*

108. **Constant net number of migrants scenario**: *The net number of international migrants will be kept constant at the level reached in 2045-2050. This scenario will be combined with the low, medium and high-fertility assumptions. This scenario will be used only if the one based on net migration rates cannot be implemented. Adjustments to the net number of migrants may be needed for sending countries whose population declines markedly over the projection period.*

## E. OBJECTIVES OF THE TECHNICAL MEETING

109. The Population Division plans to complete the calculation of the long-range population projections by October 2003. Since, as stated earlier, this is the first time that the Population Division undertakes population projections up to 2300 and that it plans to issue the results at the

country level, it is useful to obtain input from the research community regarding the adequacy of the assumptions made about the future paths of fertility, mortality, and international migration and the methodological challenges posed by their implementation at the country level. The meeting being convened on 30 June at United Nations Headquarters together with other input received by interested scholars will be useful in determining the final assumptions used and in refining the projection methods implemented.

More specifically, we seek to address the following issues:

110. With regard to fertility, should the attainment of a stationary population be the key underlying assumption behind the path fertility takes in the medium scenario? If not, what rationale could be used to justify a different path?

111. Also with respect to fertility, how much difference should there be between the fertility levels in the high and low variants with respect to those of the medium?

112. With regard to mortality, if the models used to project future mortality trends result in expectations of life in 2300 higher than 100 years for numerous countries, should that be the mortality used for the medium scenario? Is it appropriate to set constraints on the ultimate life expectancy reached during the projection period?

113. With regard to international migration, is it acceptable to maintain the status of a country fixed as either a net receiver or a net sender of international migrants? If not, what criteria could be used to modify that status over the projection period?

114. In terms of methodology, are there important considerations that should be taken into account? Are there specific methods that we ought to consider?

115. Regarding the illustrative scenarios proposed, which are the most useful? Should any be dropped or added?

116. Lastly, suggestions about the data outputs that would best be suited for further use and evaluation of the projection results are welcome.

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# III. QUESTIONNAIRE FOR EXPERTS

*Please find below as set of questions that the Technical Working Group will address during its 30 June 2003 meeting. We would appreciate it if you would prepare your response to the Population Division working document along the lines of these questions. Please be as explicit with your answers as possible Please expand on the answers to those questions that you think are most critical for the preparation of long-range projections.*

I. What is your outlook concerning the future of *fertility* over the next three centuries (300 years)?

- A. Do you think that, in the long-run, fertility in the countries of the world will average around two children per woman?
- B. Do you think that fertility will remain below-replacement level for lengthy periods in the majority of countries of the world?
- C. Do you think that some countries that still have moderate to high fertility levels may never experience below-replacement fertility?
- D. Do you think that fertility will converge to a similar level for all countries of the world?
- E. Where do you envision the level of fertility to be for the world and its regions in 2300?
- F. Please comment on the rationale for the answers you provide. Which social, economic, political, demographic or cultural trends or factors justify your opinions?

II. What is your outlook concerning the future of *mortality* over the next three centuries (300 years)?

- A. Do you generally foresee that mortality will decline over the long-run? If so, explain why.
- B. Do you think it likely that all countries might converge to similar levels of mortality?
- C. Are there reasons to believe that certain regions or groups of countries will lag behind in mortality reductions? If so, describe the regions or countries and state the reasons.
- D. Are there reasons to believe that certain regions or groups of countries will maintain a consistent lead in mortality reduction? If so, describe the regions or countries and state the reasons.
- E. Do you think there is an ultimate limit to the life expectancy of a population? If yes, provide an estimate.
- F. What do you think may be the highest life expectancy reached by a country in 2300? Provide an estimate.
- G. In projecting mortality, what should be the guidelines regarding cross-overs, that is, projections where countries with a lower initial life expectancy overtake those with higher initial life expectancies in the long run?
- H. Should the projections make allowance for possible reversals in the reduction of mortality? How?
- I. Is it acceptable to consider that the rates of mortality reduction by age observed in developed countries in the recent past will remain constant over the long-term future?
- J. Is it acceptable to apply the rates of mortality reduction by age observed in developed countries in the recent past to all developing countries without distinction? If not, what distinctions should be made?

III. What is your outlook concerning the future of *international migration* over the next three centuries (300 years)?

A. Is it acceptable to assume that the status of countries as net receivers or net senders of international migrants will not change over the next three centuries? Why?
B. Can you identify the countries or regions most likely to change status as net receivers or net senders of international migrants? State which and provide some explanation as to why.
C. Should population size have some effect on the number of emigrants or immigrants a country is expected to have?
D. In general, do you expect the overall volume of international migration to increase, decrease or remain stable over the coming centuries? How about net immigration to more developed countries?
E. Would it be acceptable to assume that net migration will converge to zero in all countries over the long run? Why?

IV. What is your general outlook concerning the future of world population growth over the next three centuries (300 years)?

A. Do you see world population size stabilizing at or around a certain level? Please provide a guess about the size it may stabilize at (or the size it may be at in 2300).
B. Do you see world population size oscillating over relatively short-term cycles (say 50 years or less) around a certain size? Again, if this is your choice, please provide a size.
C. Do you see world population peaking and then declining?
D. Do you think world population size will continue to rise over the next three centuries?

V. Please comment on any other issue that we ought to consider in preparing long-range population projections to 2300.

## Annexes

## AGENDA

**I. Opening of the Meeting**

Long-range population projections: major issues

**II. The Future of Fertility**

François Pelletier A proposal for the projection of fertility

**III. The Future of Mortality**

Thomas Buettner A proposal for the projection of mortality

**IV. The Future of International Migration**

Cheryl Sawyer A proposal for the projection of international migration

**V. Closing of the Meeting**

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