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Population and Scenarios: Worlds to Win?

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Abstract

Demographic developments have played an important role in the structure and functioning of the Earth's system. The exponential population growth of the last century has led to high pressures on the environmental system, with the issue of hunger as representative of harmful effects. Despite the fact that the population growth is currently negative in some of the world's regions, the world population is expected to increase, at least in the next couple of decades. Looking at the three basis components of the demographic changes, fertility, mortality and migration, one can better understand the dynamics and changes in size and structure of future populations. De simultaneous developments of these components are known as the demographic transition theory.

There are several institutions involved in developing and publishing population projections. The Population Division of the United Nations is possibly the best known institution, responsible for population projections up to 2050 for the majority of countries in the world. In addition to the UN projections, other projections are made on the national (e.g. the Netherlands) and regional scales (e.g. European). However, with different institutions developing projections at different aggregation levels, inconsistencies over the various geographical scales are almost inevitable. Furthermore, rock-solid sets of assumptions are often lacking, and uncertainties are only included by the definition of high, medium and low variants.

One of the ways to deal with uncertainties may be application of a scenario. Instead of covering up uncertainties with rather meaningless variants, a scenario methodology allows one or more consistent images of the future to be created. The IPCC has applied this methodology to gain better insights into future emission paths, resulting in an advanced and useful set of scenarios. In this approach, the two most relevant trends to cover most of the future uncertainties have been distinguished. These trends are globalization versus regionalization, and individualism/market orientation versus collectivity. Their combination will result in four scenarios.

The scenario approach has been applied to three aggregation levels, the Netherlands, Europe and the 17 major world regions. In these applications the assumptions on fertility, mortality and migration are, to the furthest extent, based on the underlying socio-economic and environmental determinants. By using the same methodology in all applications, a set of scenarios is created that is consistent for the various geographical scales. The associated simulation results show an assorted set of images of the future population.

Samenvatting

Bevolkingsontwikkelingen hebben een zeer belangrijke rol gespeeld bij het functioneren van het natuurlijk systeem. De hoge bevolkingsgroei in de afgelopen eeuw heeft geleid tot een hoge druk op het milieu, waarvan de voedselproblematiek een van de voorbeelden is waarin deze druk zichtbaar wordt. Alhoewel de bevolking in bepaalde regio's aan het afnemen is, zal de wereldbevolking nog verder stijgen, in ieder geval de komende decennia. Door te kijken naar de drie basiscomponenten van de demografische veranderingen d.w.z. fertiliteit, mortaliteit en migratie, kan de dynamiek van veranderingen in omvang maar ook in structuur van de toekomstige bevolking, beter begrepen worden. De samenhang en verandering van deze componenten wordt beschreven in de theorie van de demografische transitie.

Er zijn diverse instellingen die bevolkingsprojecties maken. De bekendste is wellicht de Verenigde Naties die voor de meeste landen projectie tot 2050 maken. Daarnaast worden er op nationale (bijvoorbeeld Nederland) en regionale schaal (bijvoorbeeld Europa) ook projecties gemaakt. Doordat deze projectie door verschillende instellingen gemaakt worden ontbreekt de consistentie over de schaalniveaus. Ook de onderbouwing van de veronderstellingen die ten grondslag liggen aan deze projecties ontbreken nogal eens, en de onzekerheden worden vaak slechts gepresenteerd in varianten: hoog, midden en laag.

Een mogelijkheid om beter om te gaan met onzekerheden is het gebruik van scenario's. In scenario's wordt getracht een of meerdere consistent beelden van de toekomst te geven. Door de IPPC is deze methodiek toegepast om een beter inzicht te krijgen in toekomstige emissies. Deze zeer bruikbare toepassing gaat uit van twee trends die tezamen een groot deel van de onzekerheden ten aanzien van toekomstige ontwikkelingen dien af te dekken. Deze trends zijn globalisering versus regionalisering, en individualisme / marktwerking versus collectivisme. De combinatie van deze twee dimensies resulteert in 4 scenario's.

Deze scenariomethodiek is toegepast op Nederland, Europa en de 17 belangrijkste wereldregio's waarbij de veronderstellingen voor fertiliteit, mortaliteit en migratie zoveel mogelijk gebaseerd zijn op achterliggende sociaal-economische en milieu-gerelateerde ontwikkelingen. Doordat een zelfde benadering gebruikt is voor de diverse schaalniveaus worden consistente bevolkingsprojecties verkregen. De resultaten voor de drie schaalniveaus laten zien dat, gegeven de twee scenariodimensies, een grote diversiteit van toekomstbeelden verkregen wordt.

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1. Introduction

Throughout history, human activities have been recognized as an important factor affecting the structure and functioning of the Earth’s system. Future population developments are therefore useful to assess the pressure on environmental and economic resources. Future population developments are not only represented by the total population size. Changes in structure and composition are equally or even more important than a continuing growth of the population, especially given the long-term perspective. Ageing, changing household dynamics and increase of multi-cultural diversity are just some examples of enormous changes in society. However, the demographic input used in many environmental-oriented approaches is often restricted to the total size of the population and other developments are ignored.

The three basic demographic components fertility, mortality and migration determine population developments in size and structure. On the basis of a particular set of assumptions of these three components, various institutions provide a wide spectrum of population projections for the 21st century. However, the reasoning for the underlying assumptions is often rather weak or unclear, and consistency is consequently lacking. A model-based scenario approach can be helpful in assessing future developments. Unfortunately, there have been only few attempts to have a systematic description of the suppositions.

In this report, a cautious step is taken towards a more systematic connection between population projections and scenarios. First, various components of the demographic transition are described with a historical consideration of the main driving forces behind demographic changes. Secondly, an overview is given of existing population projections and scenario applications. The Intergovernmental Panel on Climate Change (IPPC) scenario study will be elaborated on. Finally, a framework is presented to provide population projections consistent with a specific scenario approach.

2. Demographic developments

Demography is the science that studies developments in size, structure, composition and regional distribution of the population, and the societal causes and effects of these developments. In this report, the starting point of these demographic developments will be the population size and age structure since these facets have been more often the subject of studies exploring future developments. Nevertheless, the purpose of this report is to provide a broader scope and also include other relevant aspects like households and relationships, labour market, education, urbanization, ethnicity, and health and well-being.

2.1 Elements of demographic change

Population size and structure are determined by three fundamental demographic processes fertility, mortality and migration. For the first two, a generic pattern can be derived from historical patterns. A brief description of these demographic changes or transitions will be given below.

Fertility transition. This transition represents a shift from high total fertility rates[1] (TFR) of around 7-8 children per woman to levels below 2.1 children per woman, the so-called replacement level[2]. The situation of high fertility is associated with a more traditional society in which children are used as farm labourers and serve as old-age security. This pre-transitional stage is characterized by a low marrying age and hardly any use of birth-control methods. The process of modernization brings a higher marrying age and spreading of birth-control methods. Higher ages at marriage and commonly used modern methods of contraception mark the last stage of the fertility transition in which low levels of the total fertility rate are obtained. In Figure 1, the fertility decline in major regions is shown for 1950-2000. In more developed countries, the initial decline in fertility has set in long before 1950 and the TFR has been below the replacement level for a couple of decades. The least developed countries, on the other hand, seem to have entered the phase of fertility decrease, although the TFR is still high, at a level of more than five children per woman.

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[1] TFR is the number of births that a woman would have at the end of her reproductive lifespan if current age-specific fertility rates prevail.

[2] Replacement level indicates the fertility level that implies zero population growth in the long term under the condition of zero migration.

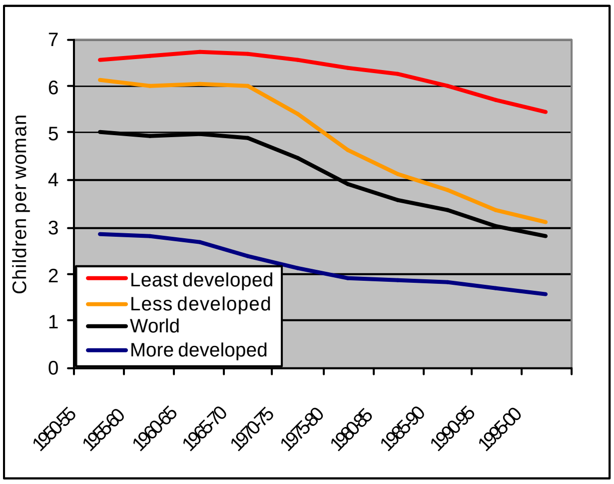

Figure 1. Total Fertility Rate for major regions, 1950-2000 (Source: UN, 2000).

Mortality or epidemiological transition. The epidemiological transition, also referred to as a component of the health transition (Frenk et al., 1993). This theory addresses changes in disease and mortality patterns, and the conditions associated with these changes (Bobadilla et al., 1993, Omran, 1983). It describes the shift from low levels of around 30 years of life expectancy at birth to levels that may rise to above 80 or even 90 years (see Figure 2).

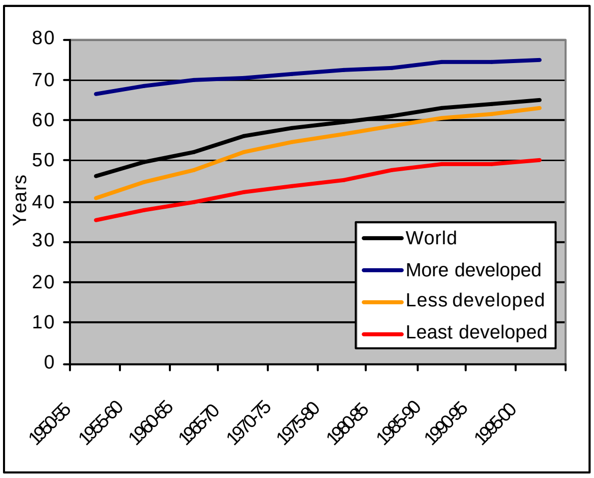

Figure 2. Life expectancy at birth for major regions, 1950-2000 (Source: UN, 2000).

The beginning of the epidemiological transition is characterized by poor conditions of sanitation, food provision and health services, as well as dominance of infectious diseases, causing high mortality rates, especially among children. The corresponding life expectancy at birth is very low, between 20 and 40 years. Later, improvements in overall conditions cause a shift towards a situation in which infectious diseases are prevented by immunization programs or controlled by community health services. The elimination of infectious diseases makes way for chronic diseases associated with the elderly. In combination with improved health care, these chronic diseases are less lethal than infectious diseases, but cause relatively high morbidity levels. Most of the chronic diseases have declined in the Netherlands in the last 50 years, probably due to improved food preservation or changes in hygiene, nutrition and antibiotics. On the other hand, other causes of death (heart diseases, several types of cancer, traffic accidents and homicide) have shown an increase. These causes of death might be associated with behavioural factors like high cholesterol intake, smoking, and inactivity. Improved conditions like education, health services and female autonomy have paved the way in these countries to low mortality levels (Caldwell, 1993) with a corresponding life expectancy of around 75-80 years. Nevertheless, new emerging diseases can still cause a setback in the progress made by countries. Figure 3 illustrates the differences in mortality patterns well.

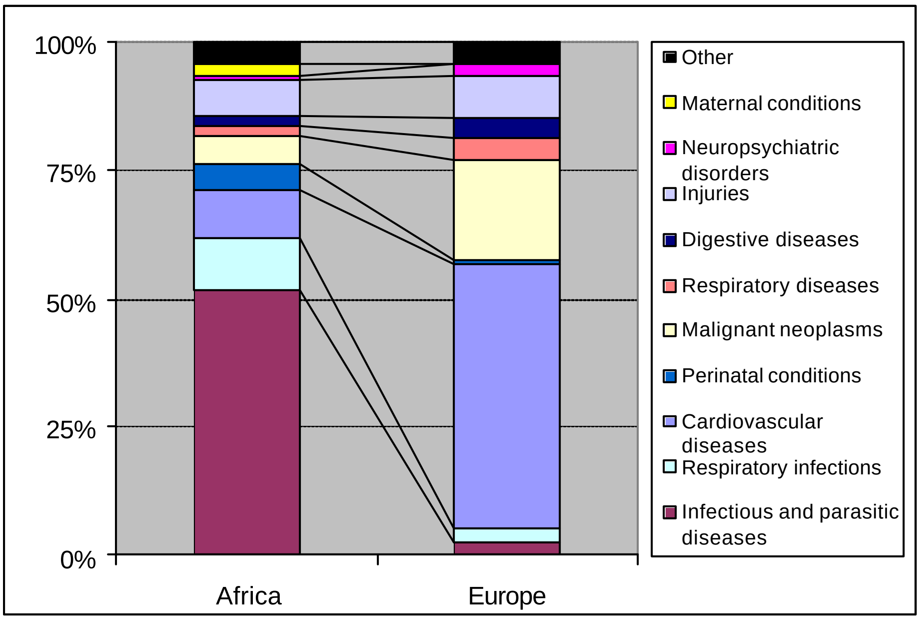

Figure 3. Distribution of causes of death in Africa and Europe, 2000 (Source: WHO, 2002).

Migration process. The process of migration cannot be captured in such clear patterns as fertility and mortality. The underlying dynamics are affected by a complex of push-and pull-factors, but also by policy development and enforcement in many receiving countries. In addition, the state of migration statistics, not only on emigration and immigration, but also on net migration, hamper empirical foundation of any theory. However, some patterns can be distilled. International migrations have consistently moved towards regions of economic opportunity. Until World War I, the main flow consisted of Europeans seeking their fortunes in the USA, Canada, Australia, and South America (Bongaarts, 2000). After World War II this pattern had changed and migrants came increasingly from developing countries. The number of sending and receiving countries increased enormously, bringing about a high diversity of migrants. In 1990, the foreign-born population numbered 120 million, corresponding with just over 2% of the world population. This percentage remained at that level since 1965. Nowadays, the yearly net number of persons migrating to more developed countries is around 10 million (Figure 4).

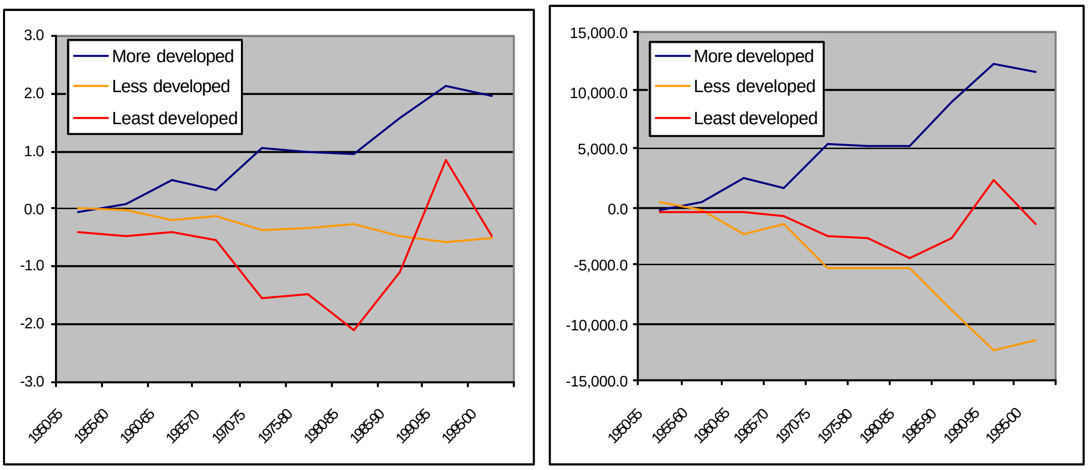

Figure 4. Migration rates (per 1000 persons) and the total number of net migrants (x 1000) in major regions (note that the 'least developed' is part of the 'less developed'), 1950-2000 (Source: UN, 2000).

2.2 Demographic transition

The profound transformation of changing fertility and mortality patterns is generally referred to as *demographic transition* (Notestein, 1945, Davis, 1945). The demographic transition can be characterized by three stages (see Figure 5). Each stage of the demographic transition is typified by a specific combination of fertility and epidemiological transition, as described above. Alas, the process of migration cannot be directly related to these stages, although aspects of push-and-pull factors of migration show some similarities. An advantage here is that the effect of migration on population growth has been small for the majority of countries, although this might change in the future.

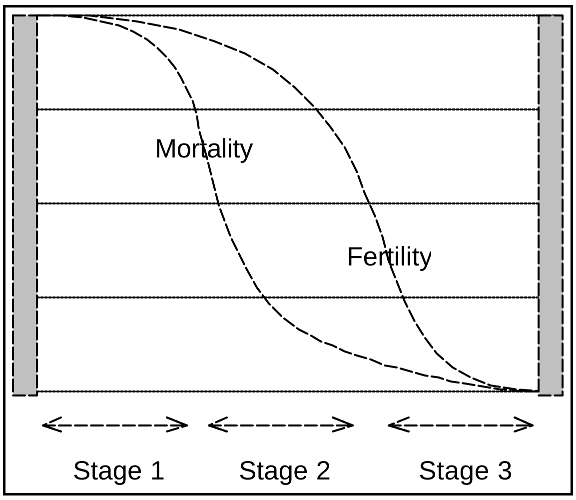

Figure 5. The three stages of the demographic transition (Source: Niessen and Hilderink, 1997).

In the *first* or *pre-transitional* stage, both mortality and fertility are high, approximately cancelling each other out and resulting in a slow population growth. The occurrence of infectious and parasitic diseases is usually responsible for mortality patterns, resulting in high infant and child mortality. Total fertility can vary appreciably as a result of changes in the propensity to marry and age at marriage. Birth control is restricted to traditional methods and hardly influences fertility levels. The characteristic population pyramid, representing age structure of a population, is broad at the bottom and steep in the direction of the higher ages. In Europe, fertility and mortality remained high until the mid-19th century. Almost all countries have now already passed this stage.

In the *second* or *transitional* stage, mortality starts falling, while fertility remains high; it or may even rise as a result of the erosion of old systems of control (Wrigley and Schofield, 1981). This period is characterized by a rapid population growth until fertility also starts to decline. Modern methods of contraception are introduced and widely spread. Most countries show a time lag before the fertility level drops, although some countries like Germany experienced a fertility drop coinciding with a decline in mortality rates (Coale, 1973). Most developing countries are in the second stage, some of them at the beginning (Sub-Sahara region) and others almost at the end (Frank and Bongaarts, 1991). The corresponding age pyramid shows some levelling off for the younger cohorts.

In the *third* or *post-transitional* stage, the populations that have completed the transition exhibit low levels of mortality and fertility, and little or no population growth. The shift of the causes of death from infectious diseases to chronic diseases has been completed. The developed countries are either in this stage of the transition, or have actually gone through this stage. The corresponding population pyramid shows the onset of the process of ageing. In many countries, the TFR is far below replacement level (e.g. Spain at 1.2 children per woman) and causes the population to decline if these fertility levels persist. This is accompanied by a continuing ageing of the population. Postponement of child-wish has resulted in relatively high ages of the mother at first birth, and to some extent even abandonment of child-wish.

This *fourth*, additional stage has been referred to as the second demographic transition by Lesthaeghe and Van de Kaa (1986) to describe major changes in demographic patterns in Western Europe from the 1960s onwards. Nowadays, all European populations are characterized by a life expectancy close to 80 years, mortality being confined to the older age groups and dominated by degenerative diseases, and a fertility level that, in general, is too low to guarantee replacement of generations. Yet there is some growth, attributable to the effect of the demographic momentum of higher fertility in the years 1945-1965, and a correspondingly large number of women in the reproductive age groups, combined with a rising tide of immigration from less-developed countries.

In the figure below, regions and countries are shown which represent different stages of the demographic transition. The 2030 situation is given for Spain (UN Medium projection), which illustrates the dramatic effect of a TFR that remains below replacement level, with only a slight increase from 1.1 children in 2000 to 1.6 in 2050.

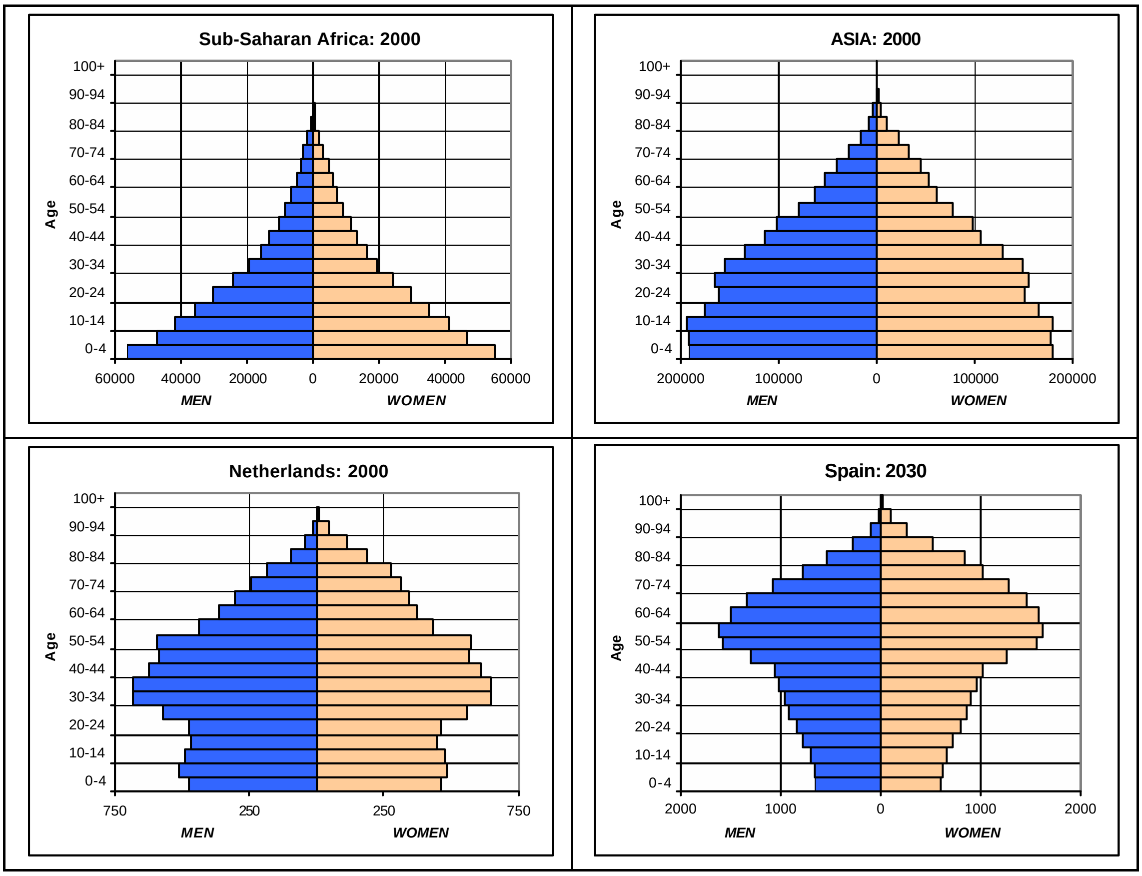

Figure 6. Age pyramids for countries at different stages of the demographic transition (Source: UN, 2000, Spain 2030 medium variant).

The demographic transition is not an isolated process; it is part of a much broader transformation seen in a growing number of countries since the 18th century and commonly referred to as *modernization* (Easterlin, 1983). In the economic domain, this involves a rise in real output and wide-ranging innovations and improvements in the production, transportation and distribution of goods. On the demographic and social side, modernization involves significant alterations in fertility, mortality and migration, as well as in family size and structure, education and the provision of public health. At the level of the individual, modernization is characterized by an increased openness to new experience, increased independence from authority, belief in the efficacy of science, and ambitions for oneself and one's children (Easterlin, 1983).

3. Future population

Forecasting the size of a population has a long history. Frejka (1996) has provided us with an overview of existing long-range population projections dating from the time of Gregory King (1648-1719) at the end of the 17th century; he had even made estimates up to the year 20,000. The selected long-range population projections are defined as projections that span a century or more. The early long-range projections were based on mathematical extrapolation of total numbers or growth rates. In 1945, Notestein (1945) provided a general component framework for the calculation of global population trends based on assumptions for fertility, mortality and migration. The population projections since 1945 have applied and refined this methodology. Although the United Nations has become an authority in the field of population projections, other institutions like the U.S. Census Bureau, the World Bank and IIASA are also used as sources. On the basis of a particular set of assumptions on fertility, mortality and migration, these institutions provide a wide spectrum of population projections for the 21st century.

Box 1. Projection terminology

Projection refers to model-derived estimates of the future population, given a set of assumptions.
Probabilistic Projection refers to model-derived estimates of the future population, given a distribution of the value of the assumptions, often based on a forecast.
Variant can be seen as a projection without any judgement of the likeliness of the assumptions.
Forecast/Prediction is the most likely projection and is based on the most likely set of assumptions. A forecast usually covers a short- or medium-term period, since statements concerning the long-term (50-100 years) can hardly be labelled as 'most likely'.
Scenario is a coherent, internally consistent and plausible description of a possible state of the world (e.g. future population). A projection can be a part of a scenario, but also a more qualitative description (story) can characterize a scenario. A set of different scenarios can give a range in projections.
Baseline/Reference refers to one particular projection or scenario that is often used to indicate differences between scenarios, taking this baseline as a gauge.

In the last 25 years, the methodology has been further refined by linking fertility, mortality and migration components to economic, social and environmental aspects instead of applying exogenously set assumptions. Applications of this third modelling approach are few: World3 (Meadows et al., 1974), Threshold21 (Millennium, 1996), TARGETS (Rotmans and De Vries, 1997) and PHOENIX (Hilderink, 2000). Even though the projection of population size is one of the outcomes, the aim of these models is to provide insights into the underlying mechanisms causing population growth and into the possible consequences of this growth. Although Cohen (1995) distinguishes a fourth method for population projection, namely, the stochastic population projection resulting in confidence intervals, this can be seen as a method to deal with uncertainty (e.g. see Lutz et al., 1997, Keilman, 2001). In this fourth method, assumptions for input variables concerning fertility, mortality and migration are taken stochastically where, for example, the UN provides non-probabilistic clusters of the assumptions. The probabilistic approach results in confidence intervals while the UN results are clustered in variants, which are usually simply labelled as low, medium and high. The use of scenarios, i.e. the use of consistent sets of assumptions, representing a particular view on how future developments can be clustered, is still in an infant stage. The terminology of future images is not always used unequivocally or even considered to be interchangeable. Box 1 overviews the main terms and characteristics. However, the terminology in this report keeps to the original terminology used by institutions themselves, which is not always consistent with terms in the list below.

3.1 Existing population projections

Only a selection of population projections will be discussed here. This selection is based on the geographical coverage of the projections (preferably including the Netherlands, Europe and world regions) and the applications (providing a set of variants or scenarios). Table 1 shows an overview of this selection, with geographical coverage and brief remarks about the underlying assumptions. The next section will discuss the population projections in more detail. The accompanying figures showing the projection can be found in Appendix 1.

Table 1. Selection of population projections developed by various institutions.

Institution/Model	Level of detail	Scenarios/Variants/Forecast
UN World Population Projections (2000)	Global country-based 5-year age groups 1950-2050	Fertility: medium, high, low, constant, instant replacement (net reproduction rate[3] equals 1) Mortality: general, constant. Additional (NO) AIDS variants Migration: general and zero migration
UN Long-Range (1998)	Global 8 regions 5-year age groups 1950-2150	See UN WPP
RIVM/TARGETS (1997)	Global, 1 world 5 age groups 1900-2100	Nine variants consisting of three model variants or perspectives and three perspectives of management styles
IIASA (2000)	Global 13 regions 5-year age groups 1995-2100	Expert-based assumptions on fertility, mortality and migration
RIVM-Population Research Centre /PHOENIX (2000)	17 regions 1-year age groups 1950-2100	One scenario, fertility and migration based on socio-economic and environmental conditions, migration exogenous
Eurostat scenarios (1995-1999)	EU15+4 Age group: 5-year-olds 1950-2050	High-/Medium-/Low-based on high/medium/low assumptions for fertility, mortality and migration
CBS/Netherlands Interdisciplinary Demographic Institute (NiDi, 1999)	Europe 38 countries 1-year age groups year age 1996-2050	Two scenarios: diversity and uniformity based on a consistent set of fertility, mortality and migration assumptions
Statistics Netherlands (CBS, 2001)	The Netherlands 1-year age groups 1950-2050	Forecast with 67% and 97.5% confidence intervals

[3] The average number of daughters that would be born to a woman if she passed through her lifetime conforming to the age-specific fertility and mortality rates of a given year.

3.1.1 UN World Population Prospects (2000)

The UN has a long history of population projections. The latest UN World Population Prospects (UN, 2000) consist of population projections up to 2050 for 228 countries (detailed statistics for 183 major countries). The UN also makes long-range projections up to 2150 based on a 1998 revision (United Nations-LR, 2000). The three variants (Medium, High and Low[4]) are actually only fertility variants, since the TFR is the only varying factor. Countries are clustered in three fertility categories. Assumptions corresponding with the three categories are made for each variant on the pace (change in the TFR per decade) or the convergence level (e.g. replacement level). Mortality is projected on the basis of the models for change of life expectancy. Clustering is not applied to mortality. In countries highly affected by the HIV/AIDS epidemic, estimates of the impact of the disease are made explicitly through assumptions on the future course of the epidemic, i.e. by projecting the yearly incidence of HIV infection.

The future path of international migration is set out on the basis of past international migration estimates and an assessment of the policy stance of countries with regard to future international migration flows. Migration differs only slightly for the three variants. It is based on numbers of migrants which are also assumed to be constant over time. No explanation is given on the source of these assumptions.

3.1.2 UN Long-range projections (based on the WPP 1998)

The *Long-range World Population Projection*s, prepared by the United Nations Population Division (United Nations-LR, 2000), extend the World Population Prospects 1998 from 1950-2050 to 1950-2150. The results are presented for the world as a whole, and for six major areas and two large countries: Africa, Asia excluding China and India, Europe, Northern America, Latin America and the Caribbean, Oceania and China, and India. There are three scenarios more-or-less comparable with scenarios presented above: *medium-fertility,* in which fertility in all major areas stabilizes at replacement level by 2050 or thereafter; *low-fertility,* in which fertility is lower than in the medium-fertility scenario by about 0.5 child per woman after 2050; *high-fertility,* in which fertility is higher than in the medium-fertility scenario by about 0.5 children per woman after 2050). In addition, there are two intervening scenarios (*low-medium fertility* and *high-medium fertility).* In each of the scenarios, mortality is assumed to decline steadily during the projection period.

3.1.3 RIVM/TARGETS

The TARGETS model (Tool to Assess Regional and Global Environmental Health Targets for Sustainability) consists of five highly aggregated submodels (Population and Health, Energy, Land, Water and the Global Bio-chemical cycles) and an economic module

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[4] The UN also publishes several other variants (Constant fertility, Instant-replacement fertility, Constant mortality, Zero migration, No AIDS). These variants can be regarded as theoretical and provide hardly any additional information

resulting in scenarios for the gross world product. The model, which uses a systems dynamic approach, describes the Earth’s system including both the environmental and the human system. The various projections result from taking how the world functions into uncertainty (‘world view’) and how the world should be managed (‘management style’). These aspects of uncertainty are ‘filled in’ with the perspectives of the hierarchist, the egalitarian and the individualist on the basis of the cultural theory of Thompson (see Rotmans and De Vries, 1997). A worldview and management style have been combined to form one of nine possible futures. The population projections are based on different socio-economic and environmental conditions, influencing various aspects for fertility and morbidity/mortality. Since TARGETS is a one-world model, migration is not applicable.

3.1.4 IIASA

Another institute providing population projections is IIASA (Lutz, 1996). A multi-regional cohort-component model with five-year age groups and five-year projection intervals is used for these projections. Population projections for 13 world regions are obtained on the basis of high, low and central values for future fertility, mortality and migration levels. This modelling approach is rather extensive and advanced, although the withholding of information on vital assumptions and insights makes it hard to evaluate the approach and analyze model outcomes. The basis and justification of the assumptions is not explicitly given, but only referred to as being based on ‘the judgement of an interacting group of experts’ (Lutz, 1996, p. 42). Population projections are constructed on the basis of a combination of fertility, mortality and migration. In addition, interrelationships between fertility and mortality, but also between regions, are used to calculate confidence intervals (Lutz et al., 2001).

3.1.5 RIVM-Population Research Centre/PHOENIX

PHOENIX is a simulation model developed to assess the impact of developmental and policy factors on population dynamics (Hilderink, 2000). The model is part of an integrated framework of global change models developed by RIVM. In addition, a visualization package was developed to display the various components of population dynamics graphically. The model was used to assess the effect of such socio-economic factors as income and literacy on fertility behaviour using Bongaarts’ approach (Bongaarts and Potter, 1983) of proximate determinants for fertility (e.g. contraceptive use, age at marriage, divorce). The mortality approach is partly based on the population and health module used in TARGETS 1.0 (Niessen and Hilderink, 1997). In the Mortality subsystem, the population is subdivided by distinguishing people according to mortality risks strongly allied to socio-economic factors (e.g. poverty and education) and environmental factors (e.g. food availability and access to drinking water).

3.1.6 EUROSTAT

Eurostat collects and publishes demographic statistics for all EU15 countries at national, but also at a regional, level (NUTS3). National population projections are made on a regular basis up to the year 2050. The latest projections were made in 1995 with a revision of the assumptions and outcomes in 1999 (Eurostat, 2003). Although four additional EFTA countries (Norway, Switzerland, Iceland and Liechtenstein) are officially included, they have been left out here. Only straightforward assumptions are made for the 15 countries on life expectancy, total fertility rate and the net number of migrants. No further qualitative scenario embedding seems to be used. The results for the EU15 countries are presented in Appendix 1.

3.1.7 CBS/NiDi

For the European Population Conference (EPC) in The Hague in 1999, NiDi/CBS had developed two different population scenarios for all 33 countries in Europe. These two scenarios are *Uniformity*, where, in the long term, economic and cultural trends will converge and, consequently, differences across countries will decline, and *Diversity*, where differences will persist or even increase, resulting in different levels of fertility mortality and migration for various regions in Europe. In these scenarios, possible future images are depicted on the basis of cause and effect relationships. One major source of uncertainty is whether the differences in cultural and economic developments between countries will be reduced, remain at the same level or even increase. In view of these uncertainties, two different scenarios have been compiled for 33 European countries.

The first scenario, *Uniformity,* assumes that economic and cultural trends will, in the long term, converge and, consequently, differences between countries will disappear. In this scenario, increasing political integration and easy diffusion of cultural values are assumed, with successful transition from a communist to a capitalist economy for the former communist nations. Large economic growth, stimulated by internal free trade, will be achieved through a high rate of technological progress. The second scenario, *Diversity*, assumes that existing economic and cultural differences between countries will persist or increase. Political integration will be limited and will thus hamper the free market and, consequently, economic and technological growth.

3.1.8 Statistics Netherlands (CBS)

Statistics Netherlands published a population forecast in the Netherlands in 2000. This forecast is supposed to describe the most likely future demographic developments up to 2050. This forecast is based on assumptions on fertility, mortality and migration, specified by both emigration and immigration. The fairly advanced methodology used consists of mortality patterns related to six factors of influence, e.g. smoking, antibiotics, sex-differences, fertility related to women's ideas about their expected number of children, educational level and migrants in the population. For the different categories of migrant groups immigration number and re-migration chances are specified to determine the total migration flows.

Although the forecast is supposed to reflect the most likely future changes, forecasting over a period of 50 years involves many uncertainties. Confidence intervals reflecting the probability of deviations from the forecast have been calculated to take these uncertainties into account. For example, the population forecast for 2050 is 18 million, but with a probability of 67%, the range is 15.8 to 20.1 million, and for a 95% confidence interval, 14.4 to 22.8 million.

3.2 Discussion of projections

All the projections listed above cover a broad range of methodologies, geographical aggregation levels and projection periods. The UN WPP data show an extraordinary level of completeness, with widespread use and virtually no critical review of the results or questioning of assumptions. Especially assumptions concerning future fertility levels - the dominant factor for future population size – have only recently been adjusted to a more state-of-the-art knowledge. For a long time, the medium - and most commonly used - variant was based on the assumption of convergence to replacement levels, while the theoretical foundation was, and still is, lacking such an assertion. In addition, one of the most obvious shortcomings is the lack of feedback. The effect of possible food shortages on the mortality levels is not taken into account; this is especially relevant for Sub-Saharan Africa, where the population is expected to triple in the coming 50 years. Including variants for different mortality levels, and even migration, can partly solve this shortcoming. The IIASA modelling approach, on the other hand, is well described and is a good alternative to the UN projections. A point of criticism relates to the reasoning behind the assumptions; this could be better founded since a proper description is lacking. The use of probabilistic projection adds valuable insights to uncertainties concerning population projections. Another point of criticism is the homogenous approach of all countries and regions. In both the approaches, high scenario values are applied to all regions, while a combination of two trends in different regions is completely left aside.

The TARGETS model tries to deal with these feedbacks by applying a systems dynamic approach to the whole global system. One of the disadvantages is the high aggregation and abstraction level, which lacks any geographical diversity of population characteristics. The use of cultural perspectives to reveal unavoidable uncertainties in projection results in a valuable application. The PHOENIX model has a geographical dimension (17 world regions) and a strong integrated systems dynamic approach. However, since only the human system is described, no direct feedbacks of population growth on environmental conditions are taken into account.

For projections in European countries the CBS/NiDi approach is more advanced and transparent than the EUROSTAT projections. This approach represents one of the few attempts to apply the scenario methodology to population projections, although the basis (and with that the results) might already be superseded. The national projection made by Statistics Netherlands for the Netherlands might be one of the most advanced projections, especially regarding the specification of emigration and immigration. Specifying fertility and migration rates for all kinds of migrant groups is sophisticated, but so data-intensive that it can probably only be applied on a small scale. In the publication of a forecast - the most recent one with confidence intervals and previous ones with high and low variants – we can state how future developments might unfold. However, adjusting the peak level of a population of 0.7 million people (in the 1998 forecast, 17.4 million and in the 2000 forecast, 18.1 million) represents a 50% adjustment of what was supposed to be the most likely population increase two years ago.

4. Scenarios in brief

Scenarios are widely used in all kind of approaches. There are different definitions in circulation. Originating in the theatre world, a scenario refers to a sequence of screenplays. Later, scenarios were used in mathematical war game strategies and are now widely applied to all kinds of scientific spheres. Since the time dimension plays an important role in scenarios, environmental sciences have welcomed the concept with open arms. There are now many examples of (environmentally oriented) scenario studies. In social sciences, on other hand, relationships tend to be multi-causal (Blossfeld and Rohwer, 1995) and often only the associative nature of social processes hampers the systematic exploration of future developments. Demography is one of the few exceptions in social sciences lending itself to scenario applications. However, it is especially these types of uncertain processes that could benefit from a scenario approach.

4.1 What is a scenario?

From the broad spectrum of scenario definitions in existence the most cited one is that: ‘scenarios are hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points’ (Kahn and Wiener, 1967). There are also other definitions commonly used, such as ‘Scenarios as archetypal descriptions of alternative images of the future created from mental maps or models that reflect different perspectives on past, present and future developments’ (Greeuw et al., 2000), or ‘Images of the future, or alternative futures that are neither predictions nor forecast, but an alternative image of how the future might unfold ’ (Alcamo, 2001).

The images of the future are not static snapshots, but a dynamic movie that consists of a logical sequence of possible images of the future, which, in turn, consist of states, events, action and consequences that are causally linked (Greeuw et al., 2000). As a result of causal interlinkage, internally consistent, plausible and recognizable stories are formed, which can then be used to construct (quantitative) scenarios.

4.2 Scenario types

There are different types of scenarios or ways to build scenarios. Various dimensions can characterize a scenario. Although the list of dimensions can be elaborated extensively, only a selection of these – the most relevant for population projections – will be described here.

Geographical scale. As shown above, population projections may have a high level of geographical aggregation, e.g. TARGETS with only one (world) population or rather extensive, such as the UN WPP giving projections for 238 countries. Often, a clustering is applied of countries expecting to have the same future patterns or changes. This clustering is mostly based on geographical setting (CBS/NiDi) or on socio-economical characteristics (PHOENIX). The interaction between different geographical levels is recognized by several authors, but seldom included in the assumptions for projections. The effect of population growth, combined with economic inequities, on migration patterns is not explicitly taken into account in all approaches. Even within regions, like the EU, mutual influences between regions or countries are not included in scenarios.

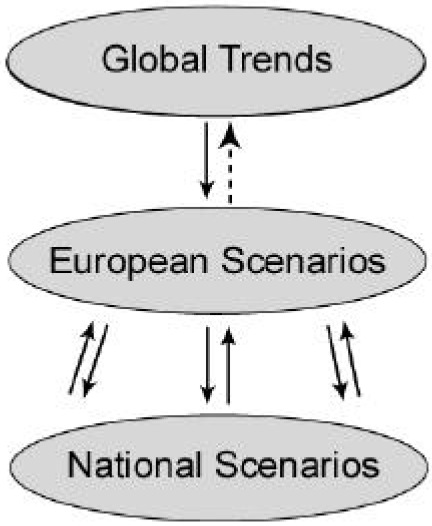

Figure 7. Linkage of different geographical scales (Source: Greeuw et al., 2000) .

Time horizon. For population scenarios, a long-term scale would seem more applicable. Population changes are rather slow; historical birth patterns are accountable for the current and near future age structure, although migration should be noted as well. Current changes, for example, in the number of children per woman, do not only have a direct effect on the number of young people now, but also an indirect effect after 25-30 years, this generation's children. In demography this inertia is well-known as the so-called population momentum (Keyfitz 1985), a factor indicating to what extent a population would grow to a stable level if its fertility rates were immediately reduced to replacement levels and maintained at these levels. Fifty to hundred years seems an appropriate time span for following new generations completely.

Level of integration. This dimension deals with framing issues. The scenario approach can be narrow and single-theme (only taking demographic components, e.g. UN WPP, into account) or broad and integrated (considering interplay between economic, social and environmental processes, e.g. TARGETS and to less extent PHOENIX). The single-theme approach involves mainly single-discipline experts. By applying a causal chain approach, in which the single-theme scenarios are coupled or linked, the false impression of having reached an integrated approach can be created. An iterative methodology, in which the results of one theme are used as a feedback for other subsystems can result in soft integration. The IPCC-SRES scenarios represent an example of coupled scenarios with no feedback (see next section).

Theme-specific approaches, which regard problems separately, have been complemented by *integrated assessment* (IA) approaches. The integrated approach results in a more consistent description, but also requires knowledge about the mutual interplay of various processes. IA modelling has facilitated a multi- or interdisciplinary approach. Two dimensions can be followed for integrating processes (Rotmans et al., 1997a):

- *Vertical integration* or the closing of cause–effect relationships. This implies, for example, that the impacts of environmental changes on health outcomes are taken into account in overall demographic developments (and might result in adjustment of the environmental changes).

- *Horizontal integration* takes into account the cross-linkages and interactions between the subsystems. This dimension safeguards a level of consistency to some extent. For example, income distribution and poverty issues are important for demographic dynamics, but also for implementation and acceptance of all kinds of (environmental) policy measures.

These two dimensions of integration are eminently applicable to the Pressure-State-Impact-Response organizing framework, which proved to be a helpful mechanism in structuring complex system (UNEP, 1997, Rotmans et al., 1997b, Hilderink, 2000). The vertical integration is implicitly incorporated in the PSIR mechanism by linking pressure variables to state variables, state variables to impact variables, impact variables to response variables and closing the cycle by linking response variables to state and pressure variables.

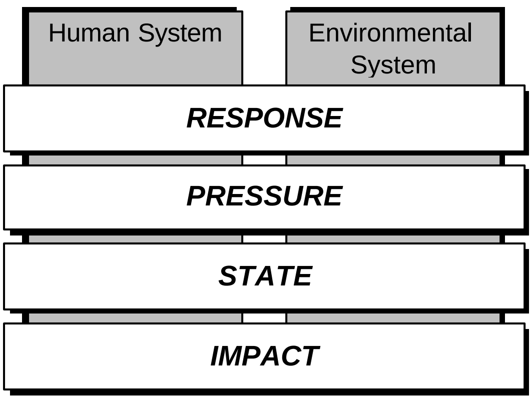

Figure 8. PSIR representation of the human and environmental systems (Source: Rotmans and De Vries, 1997).

Qualitative versus quantitative. 'Qualitative scenarios describe possible futures in the form of words or visual symbols rather than numerical estimates' (Alcamo, 2001). On the basis of some key words, a narrative text or story line is developed which may form the context of a more quantitative scenario. The quantitative scenario is formed mainly by the outcomes of a (computer simulation) model. The quantification of causal or associative relationships results in a numerical description of a selection of relevant variables over future periods. This description is only restricted to variables included in the model (i.e. those which can be quantified, and are relevant for the processes described by the model). Another disadvantage may be that a model is taken as a 'truth machine'. Most uncertainties and (subjective) decisions about the structure of the model are covered up and the focus is only on a strict selection of a huge number of simulation results. On the other hand, consistency is guaranteed more than in a qualitative description since all relationships are formalized. In the TARGETS model these uncertainties are made transparent by the inclusion of cultural perspectives, one way to have a good mix of qualitative and quantitative aspects. Most of the population projections strongly emphasize a quantitative approach.

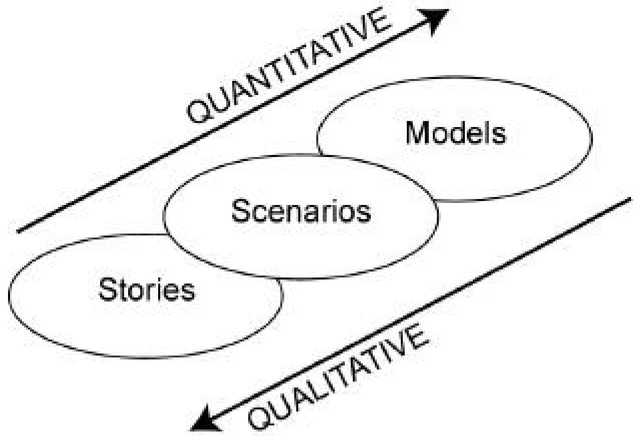

Figure 9. Quantitative versus qualitative scenarios (Source: Nakicenovic and Swart, 2000).

Exploratory versus anticipatory. This is also referred to as forecasting versus backcasting, where the exploration or forecasting describes the future, taking the current situation as a starting point for exploring the future through persisting trends. The anticipatory scenarios take as a starting point a desirable future (or the definition of undesirable developments) and point out the possible pathways to this desired situation. These pathways can be achieved by all kinds of policy measures that will influence developments in a particular direction. This implies a normative description of desirability of developments. This scenario dimension can therefore also be regarded as descriptive versus normative. All projections described above are explorative scenarios. There's no explicit inclusion of normative measures, although some models as TARGETS and PHOENIX include endogenous response behaviour, which can be seen as a normative reaction to changes in the system.

Baseline versus policy scenarios. This dimension is often applied in climate models. Since climate policies, which aim at reducing emissions, have a long-term effect on stabilizing concentrations, the timing or setting-in of policies results in a corresponding intensity of the measurements. However, policy measures for population policies are less dominant than for environmental processes. Regulations for abortion or marriage, or the stimulation of contraceptive use can influence reproductive behaviour only slightly and the autonomous behaviour of individuals and couples could be leading factors. Health determinants (e.g. food availability and water quality) and the demand for health services are subjected to policies, but most projections don't connect their mortality assumption with aspects like these. Migration could be the most easily influenced demographic component for policies, as more restrictive migration policies seem to be coming into fashion, especially within the EU. However, this is sometimes based on the erroneous idea of migration being a solution for ageing.

4.3 Scenario development

A step-wise scenario procedure should be applied to develop a scenario, as specified by the dimensions listed above. The scenario process distinguishes the following steps, derived from Alcamo (2001):

1) Selection and framing of the process or issue which will form the object of study: in this case, population size and structure, or demographic changes.
2) Driving forces: distinction of the main factors or determinants of influence on the process.
3) Base year, time horizon and time step.
4) Selection of a scenario type. This is based on the dimensions described above. This may be a storyline in which a narrative description is given of future images, but also a set of numerical assumptions. It may also be a combination of types: for example, first developing a set of qualitative storylines and then translating these storylines quantitatively into relevant model assumptions.

These procedural steps will be used as a guiding principle for the construction of demographic scenarios.

5. Population & Scenarios

The next step is to link the dimensions of scenarios to the elements of demographic processes. There are or have been several initiatives to introduce consistent scenarios for both the human/social system and the environmental system. One of the most impressive ones is the Special Report on Emission Scenarios (SRES) by the intergovernmental panel for climate change (IPCC, Nakicenovic and Swart, 2000). The title of the report does not completely reflect the contents, since the scenarios covered a broad spectrum of developments. This study will be taken as a starting point in creating a framework for population scenarios.

In 1996, the IPCC decided to develop new emission scenarios, resulting in the SRES in 2000. The writing team of 28 lead authors and an additional 26 contributors constructed four scenario families, each with its own storyline and model-based quantification. They differ in assumptions on driving forces like population, economic activity and technology, but also in assumptions about specific measures and policies with regard to the North-South income gap, poverty and trade issues, and environmental problems.

The four scenarios are formed by the combination of two dimensions representing trends assumed to be dominant or most distinctive for future developments. One dimension specifies whether leading trends are towards more or less globalization, with corresponding less or more regionalization. The second dimension specifies whether leading trends are towards a more market-oriented situation, in which economic efficiency is a main priority, or more towards a situation in which environmental and equity issues lead the priority list. This dimension can also be characterized by individualism versus collectivity. The four quadrants, A1-B1-A2-B2, then represent the different scenarios of each family, with its own specification of the main driving forces.

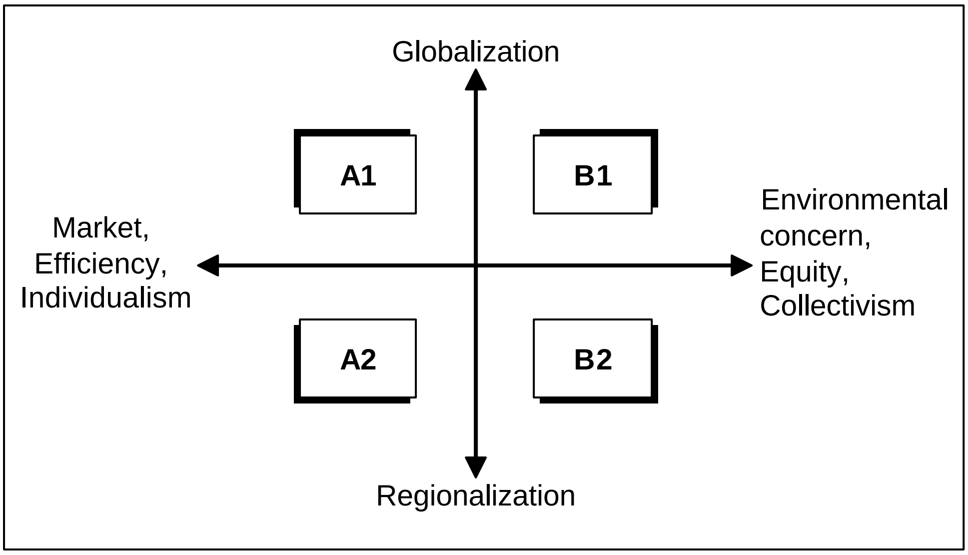

Figure 10. Four scenarios in SRES.

5.1 The four worlds [5]

The four worlds cover a wide range of key 'future' characteristics such as demographic change, economic development and technological change. For this reason, their plausibility or feasibility should not be considered solely on the basis of an extrapolation of *current* economic, technological and social trends. The four worlds can be characterized as follows (IMAGE, 2001) into the worlds, A1, A2, B1 and B2.

A1 World

The A1 world experiences vary rapid economic growth, spurred on by globalization and rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions and increasing regional interactions.

Key elements: globalization, liberalization and privatization trends intensify; material prosperity is the key driver for people and governments; the role of governments is confined to upholding the 'rules of the game' and such accepted domains as defence and justice, and communication and trade nourish the development of 'global culture'.

A2 World

The A2 world is very heterogeneous. The underlying theme is self-reliance and preservation of local cultural identities. In economic terms, A2 is oriented to material-intensive lifestyles, but trade barriers slow down technological development and economic convergence.

Key elements: cultural identity and traditional values are dominant value-oriented; a strong role for governments, including market interference; inward, protectionist orientation and suspicion of globalization; pluralism in styles of governance, economic regimes, employment skills and organization, and resource management and the like.

B1 World

The B1 world emphasizes global solutions for economic, social and environmental sustainability, however, without climate initiatives. In economic terms, B1 will focus on a transition towards a services-oriented economy, with sharp reduction in material intensity and use of clean, resource-efficient technologies.

Key elements: material prosperity supplemented with concern on global and regional income equality; environmental integrity; governance effective on each scale level using the subsidiary principle; an emerging stronger role for the United Nations in

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[5] An extensive description and application of these four worlds can be found on the IMAGE CD-ROM (IMAGE, R.-. (2001) *The IMAGE 2.2 implementation of the SRES scenarios,* Rijksinstituut voor Volksgezondheid en Milieu (RIVM), Bilthoven.

communication and trade nourishing the development of a 'global culture' but using global rules.

B2 World

The B2 world focuses on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2. Intermediate levels of economic development, and less rapid and more diverse technological change are shown than in the B1 and A1 storylines. While the scenario is also oriented to environmental protection and social equity, it focuses on local and regional levels.

Key elements: material prosperity supplemented with concern about regional income equality and environmental integrity; technology is a means, not an end, and should be directed by societal concerns; governance is effective at the national and regional level, not at the global level, while communication and trade emphasize local and regional culture and advantages.

5.2 Demography in SRES

Demographic developments are only mentioned briefly in the description above, but analyzing the underlying data might reveal more. There were existing population projections taken to represent the four worlds. Actually, demographically speaking there are only three worlds, since A1 and B1 are equal. The population scenarios are presented and described below.

Population

The following population projections were selected by IPCC as representative of the four worlds (Sources: Lutz, 1996; UN, 1998):

A1/B1 adapted the LLC-IIASA scenario (Low fertility, Low mortality, Central migration). This means fertility levels of around 1.5 children per woman for the centrally planned Asian countries and China, and 2.0 for the rest of Asia and Africa, in 2030-2035. For the other regions fertility remains at levels below replacement (1.7-1.85). Gains in life expectancy will be around 2-4 years per decade until 2030-2035. Central migration implies that a net number of 1.7 million migrants can be expected, most flows originate in Latin America and Asia, go on to North America and Africa, then proceed to Western Europe. Western Europe also receives a substantial number of migrants from Eastern Europe and the former Soviet Union.

A2 HHC-IIASA scenario (High fertility, High mortality, Central migration). This scenario assumes a fertility increase for presently developed countries reaching levels between 2.1 and 2.3. In developing countries, fertility rates will reach 4.0 in North Africa &

Middle East, Sub-Saharan Africa and 3.0 in South Asia and Latin America. An increase in fertility can be expected in China and Pacific Asia (3.0 children per woman), and in Central Asia (4.0). The high mortality scenario assumes declines in life expectancy of two years per decade in Sub-Saharan Africa, mainly due to HIV/AIDS. In other regions, life expectancy will stay at present levels or just slightly increase.

B2 UN long-range 1998 medium projection. This scenario is selected because the UN has greater recognition internationally, and garners considerable attention. In this scenario, all regions are assumed to converge to replacement-level fertility in 2100. Life expectancy will increase from around 79 years in Africa to 86 years in North America in 2100. No migration assumptions are specified.

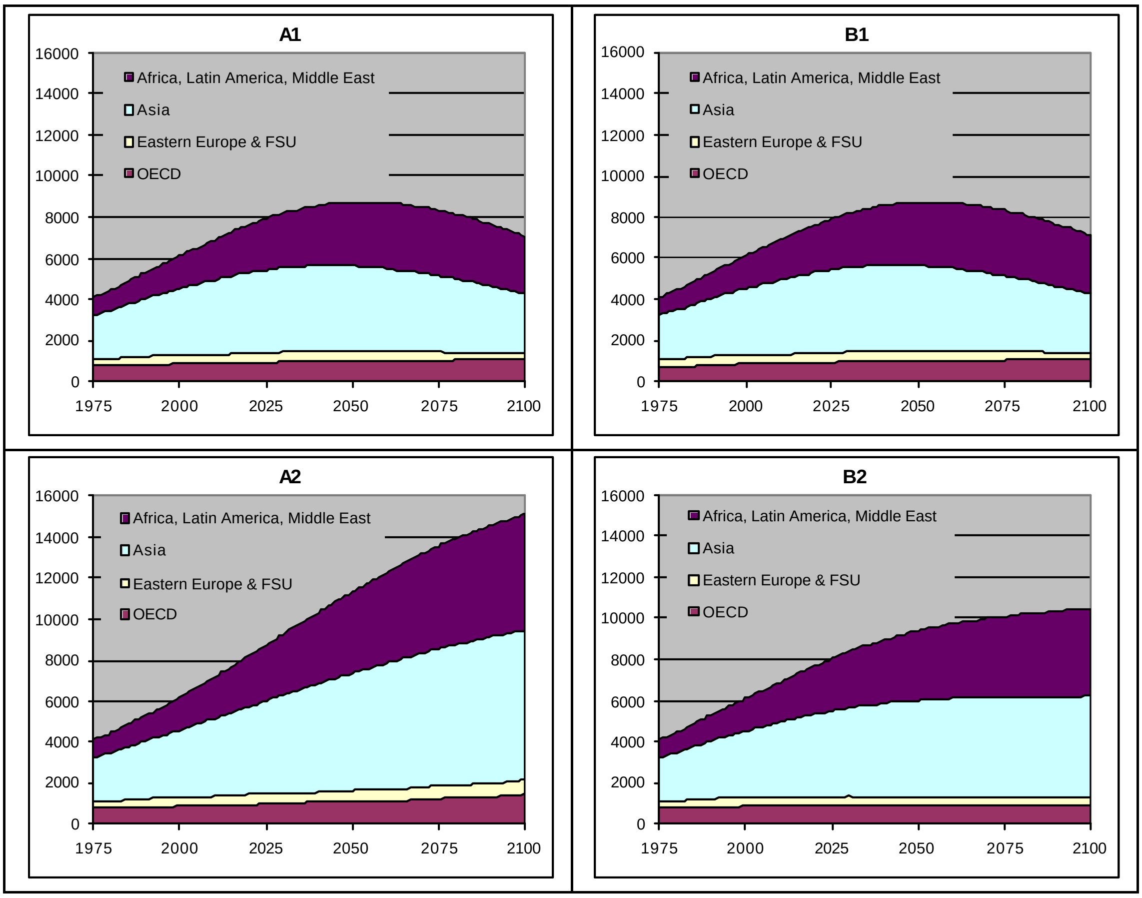

Figure 11. Four population projections of the scenarios (Source: IPCC, 1999).

Ageing

Ageing is recognized as an important aspect in SRES, especially in relation to household developments. With the ageing of a population, the household size might further decrease and result in a higher growth of households than the population growth might suggest. The level of energy use is related to the number of households, which is further enforced by the higher energy use per person in smaller households. However, household developments are not included in the scenarios, since household formation rates are not well enough understood.

Urbanization

Urbanization is also mentioned as one of the important demographic factors. Especially in developing countries, urbanization has expanded enormously resulting in mega cities which have their own specific problems. Because of the differences in demographic dynamics - urban populations tend to have lower fertility rates but also lower mortality rates- changes in urban population differ from rural population changes. In combination with a foreseen rural-to-urban migration, the impacts on infrastructure, transportation use and energy consumption (urban populations use more energy) can be huge. However, these relationships are not well-founded. Under influence of the SRES scenarios, urbanization rates are not interlinked with population growth, but taken independently and consequently not used as deviating factor in the economic and energy subsystems.

5.3 Discussion of SRES

Regrettably, an adequate justification for selecting population projections in SRES is missing. It seems to be that the population scenarios are selected on the basis of the total population size, instead of taking the components of demographic developments as a starting point for the scenarios. Consistency of the associated assumptions with the storylines can therefore not be verified and appearances belie this - at least in some cases. For example, B2 stands for a scenario in which all regions keep their regional identity; however, total fertility is expected to converge to replacement level in all regions. On the other hand, although A1/B1 represents globalization, there is still a socio-demographic gap between sub-Saharan Africa and the rest of the regions. Even the horizontal axis, which includes the equity facet, does not influence this gap since the A1 and B1 scenarios are assumed to be completely equal.

The reasoning for assuming A1 equal to B1 can thus be questioned. This assumption implies that in a globalizing world, the demographic behaviour of people does not differ if emphasis is more on sustainability and equity than on material wealth. Although resulting population projections could be equal, in mortality patterns caused by different medical technology or income assumptions, for example, and given different sets of assumptions, are more likely to result in diverging demographic futures. In addition, even in the case of mutual compensating effects (lifestyle and/or education could have a similar positive effect on *average* life expectancy in B1 and income growth in A1) underlying age-specific mortality will show differences given the more equal distribution in B1. Obviously, this has its effect on the age structure and population size.

The scenarios are not distinctive on migration. The effect of migration on the total size of the global population might be limited in scenarios in which all regions develop the same mortality and fertility patterns. But even in these scenarios, the distribution of the global population growth over the regions is partly determined by migration patterns. Moreover, the globalization-regionalization dimension is an outstanding characteristic that should be represented by different migration scenarios. In addition, unequal distribution of wealth (i.e. the horizontal axis) might form an irrepressible pressure on people's migration intentions.

In the scenarios, only the total population size is taken into account. The other population characteristics mentioned (households, consequences of ageing, and urbanization) are not considered to be distinctive in the SRES scenario dimensions. One of the arguments used is that these processes are not understood well enough. Giving the importance of these issues - ageing considered as one of most challenging demographic issues - they may warrant special attention in the scenarios. A similar lack of attention has resulted in inconsistent assumptions about urbanization; it is not that plausible that urbanization rates in the A2 world with 15 billion people are equal to the 7 billion of the A1 and B1 worlds.

6. Towards consistent population scenarios

Following the stepwise procedure, as described in Section 4.3, the next step taken should result in a more consistent set of population scenarios. The application of this procedure to the population is therefore described in this section, followed by a reconsideration of points of departure for the SRES scenarios.

6.1 Stepwise procedure towards population scenarios

The first step is framing the process and the issues for description. The broad definition of demography, in which population is not only considered in absolute numbers, but also characterized by its structure and composition, is taken as a stepping stone. The three basic demographic processes of fertility, mortality and migration are explicitly described and interconnected. The level of detail that will be used to describe each of the components is fairly subjective. For example, the description of migration can vary from relatively simple net migration numbers, with no distinction as to origin and destination, or to migration motives and ethnic backgrounds. The choice for these levels will be based on the relevance and feasibility of the component, starting from the demographic transition theory as a framework for coherence.

The second step is the distinction of the main determinants of these processes. The geographical scale is important in the selection of determinants. Socio-economic and environmental conditions are important for both developing and developed countries although a gradation - for example, in basic and higher levels - should be distinguished (such as literacy and higher levels of education, malnutrition and diets). Aspects of access to or distribution of natural, economic and social resources play an important role in demographic dynamics. The main determinants are listed for each of the components and will be used to describe the various scenarios. Table 2 presents these determinants. They require further explanation since the effect of the determinant is not always unambiguous. For example, at the beginning of the fertility transition the fertility levels drop with increased educational levels, but at the end of the fertility transition in a situation with a low average TFR, high education levels might show a relatively higher TFR. The complex relationship between socio-economic conditions and fertility outcomes is recognized and well described in many studies (e.g. Easterlin, 1983, Becker, 1991, Becker, 1993, McDonald, 2002). Most of the changes in the underlying determinants will be given in the detailed description of the scenarios. A brief overview is given in Table 2. The order of the determinants does not reflect a direct ranking of importance. First of all, some determinants (e.g. education) have both a direct and indirect effect and, secondly, the magnitude of the effect depends on the stage of the demographic transition (e.g. lifestyle).

Table 2 Hypotheses of determinants of the various demographic components.

Fertility (TFR)	Mortality (LE)	Migration	Household size
Education levels	Lifestyle e.g. Smoking Diet, Blood Pressure	Income inequalities / gap	Fertility levels
(Expected) income and distribution	Access to and level of health services	Labour market / Unemployment	Housing market
Labour participation	Access to drinking water	Presence of ethnic groups	System of student grants
Availability of contraceptives	Malnutrition	Conflicts/unstable situations	Old-age mortality
Age at marriage	Medical Technology	Environmental migrants/refugees	Social cohesion
(In)fertility technology	Air Pollution	Social security system	
Childcare facilities	Crowding		

The choice regarding *time* leaves more space for choices. The base year could be the present, although a thorough description, analysis or even simulation of historical trends and patterns is quite indispensable or at least preferable. The time step and horizon depend on the questions to be addressed. As previously argued, the inertia of population dynamics often requires a time period that covers at least the reproductive career of one generation (i.e. 50 years), but to see the indirect effects 100 years would be even more appropriate, although it also involves more speculations.

The next step is probably the most comprehensive and difficult one: the selection of the type of scenario and dealing with the dimensions listed earlier (see Section 4.2). Only the most relevant ones will be discussed here. The interlinkage of various geographical levels (local, regional, and global) is essential. There are no or hardly any isolated effects in a particular region or country. The national-regional-global connections will serve as the context for specific developments. Integration is still one of the most important aims for a consistent and broad description of this context, but also of a modelling approach. All the scenarios described have strong emphasis on the quantitative side of the scenarios and could benefit from a qualitative consideration as well. Nevertheless, population scenarios are mostly used as input for other models, endorsing that particular quantitative approach. Although population projections have a long history, the construction of population scenarios is more recent. All existing population scenarios (e.g. the CBS/NiDi, see Section 3.1) have a strong exploratory or descriptive nature. This has also to do with the varying and complex idea about desirable population developments, not to mention how to operationalize policy measures to obtain desirable directions. There are some examples of countries with a strict population policy, which undeniably has had an effect on population growth (e.g. one-child policy in China, Romania prohibiting abortion in the 1960s). These effects are hard to assess and fairly incidental. Exploratory scenarios or the use of sensitivity analyses might be more applicable to indicate the impact of these kinds of events.

6.2 Population in SRES revisited

Two of the procedural steps have to be addressed: specification of the driving forces and dimensions of the scenarios. For driving forces, the main determinants of the SRES scenarios should be distinguished. Socio-economic developments are represented by income (i.e. GDP per capita[6]). Appendix 2 shows these developments (Figure 27 and Figure 28). The enormous growth in A1 is coupled with a more equal distribution between regions in 2100. This converging pattern can also be observed in B1 (increase of GDP per capita with a factor 22-34 for regions other than OECD), and to less extent in B2 (increase with factor 10-23). The absolute levels in A2 are the lowest, but this scenario also shows the widest distribution. The figure below presents the rich-to-poor income ratio. The total income of the 20% richest persons is divided by the total income of the 20% poorest. For example, in 2000 the income of the richest 20% was 60 times higher than the income of the poorest 20%. Remarkable is the assumed closure of the income gap in all scenarios, despite the historical pattern in which convergence is only shown in the last 20 years, at a speed much slower than all four scenarios assume. Other issues, such as education levels or distribution of wealth within a region, have to be derived from this factor since they are not specified in SRES other than the narratives. Given the importance of these factors for demographic behaviour, additional assumptions for these scenarios will be made for the scenarios at issue. Assumed is that income (in)equalities within a region remain the same, in A1 and A2, as currently observed in terms of the GINI-coefficient, while in B1/B2, inequalities will be reduced.

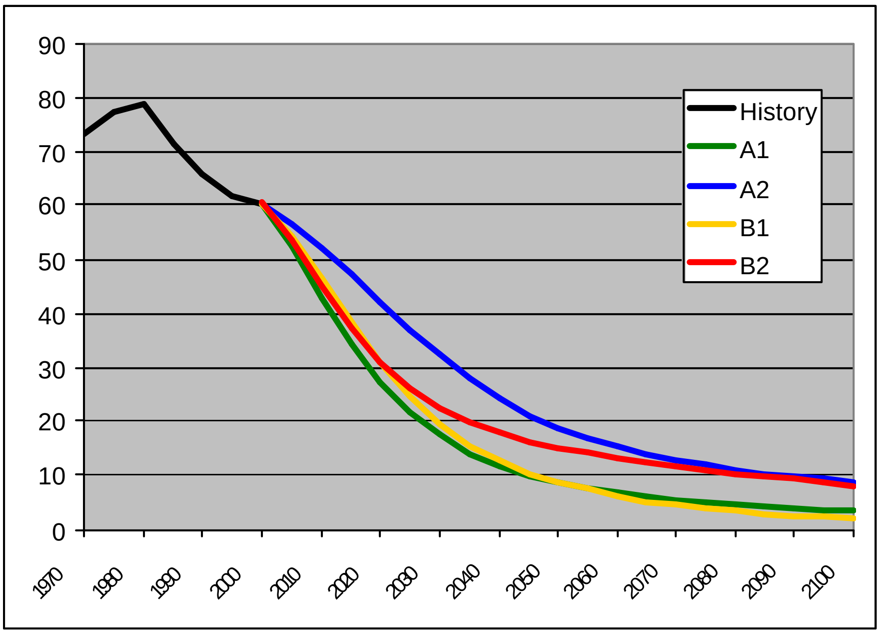

Figure 12. Rich-to-poor income ratio (20% poorest versus 20% richest) for the four SRES scenarios (derived from IPCC, 1999).

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[6] In the SRES scenarios income levels are expressed in 1995 US$. Correcting these levels making use of Purchasing Power Parity (PPP) might result in smaller differences between regions.

The other key question is how to link the dimensions and assumptions listed above with the SRES axis? Two axes in the SRES scenarios are useful and distinctive. However, for fertility behaviour and mortality outcomes the use of individualism versus collectivity as second dimension might be more applicable than economic versus environmental, or efficiency versus equity. For migration, this dimension is better characterized by material wealth (market) versus sustainability.

Assuming these interpretations the following demographic characterizing is obtained as described in the next sections. The other demographic variables, household and urbanization, are also briefly included in these views. This is only done in a narrative way since, for example, the total number of households is an outcome of ageing and population growth, two aspects that are actually the result of the assumptions described below.

6.2.1 A1 Globalization, individualization and material wealth

Fertility: Regions will converge to levels just below replacement. There will be a slight increase in developed countries at the beginning due to higher fertility levels of migrants, but these differences will disappear after a couple of decades since developing countries themselves are completing the demographic transition. Age at marriage, and with this, age at first birth, will increase further, since female education, labour participation rates and income levels will increase. Fertility techniques will become more available to deal with higher sub- or infertility due to the higher age at marriage. High level of individualism and income inequalities cause diversity of fertility patterns within a region. There is a relatively high proportion of singles and couples who stay childless, while other couples have 3-4 children. In most of the developed regions the TFR will increase slightly because of a higher migrant population, high economic growth, making children affordable, and the use of fertility techniques which may eliminate infertility. Finally, all regions will converge to a level slightly higher than currently observed in most of the developed regions.

Mortality: Rapid spreading of health services technology, but mostly only affordable for the rich (‘health is for sale’). Unequal and inefficient but, on average, high spending on health services. Basic health services will become available for everybody (including developing countries) because of average higher incomes combined with a rapid spreading of medical technology. More special health services are only affordable for people who are willing to pay a high price. This causes a modest increase in life expectancy, but finally converges to the same potential levels for all regions, depending on socio-economic differences caused by an equal income distribution. Besides this, lifestyle related health risks (e.g. smoking, work-related stress), poverty, malnutrition and water quality will still be present.

Migration: Higher intercontinental migration, especially from developing countries towards developed countries. Migrants are seen as (cheap) labour sources. There is hardly any regulation or restrictive policy (‘Market rules’). This labour migration flow initiates a delayed migration flow of family migrants. The migration process can be enforced or weakened by higher or lower inequities in wealth or faster or slower transformation of economies in developing countries. Intra-continental migration (e.g. from Eastern to Western Europe) will remain at the same levels.

Households: Individualism, lower fertility levels and material wealth will decrease the average household size further, resulting in a higher growth of households than the growth of the population might suggest.

Urbanization: An unequal distribution of wealth within the regions causes side-effects like strong concentration of poor/less rich people in urban areas where others can afford to have several houses per person or family. This results in higher urbanization rates, but also expansion of urban area and/or transformation of rural areas into urban ones.

6.2.2 A2 Regionalization, individualization and material wealth

Fertility: Regions will not converge. Developed countries will remain below replacement levels that are forced downward because of –necessary– high labour participation and a lower increase in income, making it more difficult on the housing market. Developing countries are no longer following the classic pattern of the demographic transition as developed countries have shown, but will develop their ‘own’ fertility patterns. These fertility levels are based on socio-economic conditions, but cultural factors will also play an important role (e.g. son preference in India) and will end up at levels between 1.5 and 2.5. There will be a high diversity in fertility due to SES inequalities. In developed countries, average fertility levels will be lower than in A1 for a worse economic situation.

Mortality: No spreading of health services technology. Developed countries have on average a higher income, but also higher income inequalities. Regions are more vulnerable to extreme events, since they depend heavily on their own production. As a result, life expectancy shows a high variation between regions, but also over time. On average, there are slightly higher life expectancies in developed countries, but also inequalities within these regions (‘health for few’).

Migration: Restricted intercontinental migration, only selected (economic) groups. Migrants are seen as a (cheap) labour source, but permanent stays are not allowed (‘the Swiss model’). Intra-continental migration flows will increase slightly.

Households: Differences between regions. In developed regions, the decrease in household size will be even stronger than in A1, being caused by a lower overall level of fertility and advancing ageing. In developing countries where fertility is higher, the household size will be correspondingly higher.

Urbanization: Regional identity puts stronger emphasis on rural activities, regions have to be more self-supporting. On the other hand, the market demands labour-intensive industries, which stimulates urbanization.

6.2.3 B1 Globalization, collectivity and equity

Fertility: Regions will converge to a level just below replacement at the end of the century. At first, developed countries can face slightly higher fertility levels because of higher fertility of migrants. For women work and caring for children can be combined because equity and higher education levels are aimed at, stimulated by policies. Children will be affordable because of the high economic growth and a more equal distribution of income. The ageing process will be faced as something natural, but in the long-term a zero or slightly negative population growth will be aimed at in all regions.

Mortality: Rapid spreading of health services technology made available for everybody (‘Health for all’), no excessive health services expenditures, but efficient and equal use of available techniques. Infectious diseases will be eliminated and major technological breakthroughs can be expected, mainly decreasing the level of 50+ mortality rates. Lifestyle risks (such as smoking inactivity and stress) will be reduced by active policies. There will be converging life expectancies to average high levels in all regions with hardly any inequities (i.e. low premature mortality in combination with natural mortality in old age).

Migration: In the first half of the century, intercontinental and intra-continental migration from developing to developed regions might remain at current levels, but will be discouraged so as to reduce population growth in a medium-long term. To achieve this, further development of developing countries will be aimed at to reduce the pull factors. Initiating regional refuge centres in regions of instability will reduce asylum migration. In the second half of the century, push and pull factors have become less relevant and migration will decrease.

Households: Household size will converge to a level currently observed in developed countries (around 2.3 persons per household). Sustainable use of natural resources such as space results in more community-oriented living arrangements.

Urbanization: Rural to urban migration drops to zero (see description of migration) and demographic dynamics are the same for rural and urban areas.

6.2.4 B2 Regionalization, collectivity and equity

Fertility: Regions will not converge to the same fertility levels. Developed countries will increase slightly, but remain below replacement levels. Developing countries will develop their ‘own’ fertility patterns and will end up somewhere around replacement levels, given the previously mentioned cultural factors. Contraceptives will be made available widely for family planning. Average age at birth will decrease somewhat since work and childcare can be combined, by both men and women.

Mortality: Only spreading of basic health services technology takes place. Some variations in life expectancy exist between regions. Relatively high life expectancies in developed countries can be reached without much inequity within these regions (‘Health is more than dying old’). Lifestyle-related risks (smoking, inactivity) are eliminated. Physical and mental well-being will be stimulated by more activity, improved dietary patterns and no stress. Labour participation rates will be lower, resulting in a lower economic growth, but in an increase in free time to spend on family and friends.

Migration: Low intercontinental migration flows, restricted to asylum seekers who cannot be admitted to regional refuge centres. Borders will be closed. Economic pull factors become less important. There will be some intra-continental migration.

Households: Household size will show diversity over the regions, but not decline below levels currently observed in developed countries. Similar to B1, households will be more community-oriented due to affordability and changing attitudes towards family values. Living with your parents (or children) will be seen as quality time.

Urbanization: Rural to urban migration drop to zero and demographic dynamics are the same for rural and urban areas.

7. Applications

In this section, the methodology and scenario procedure are applied to different geographical scales. First, the Netherlands is dealt with on national scale. Secondly, the implications of the scenarios are considered in the context of 40 European countries, followed by the application for the major 17 world regions. This geographical order could also be reversed, since consistency should be taken care of in this methodology. Since the scenarios for the Netherlands are the result of an intensive collaboration between various authoritative institutions in the Netherlands, the assumptions will only be described briefly.

Assumptions are not basically new but, as far as possible, derived from or related to existing data and assumptions. The description of general changes as given in Section 6.2 needs further elaboration in some cases and specification for the applications. Furthermore, the applications are only finger exercises; they should be followed by an iterative or integration steps in which the effects of these outcomes are used as inputs for other models (e.g. economic). Furthermore, we should see if these results are consistent in the broad spectrum of scenario assumptions and geographical aggregation levels.

7.1 The Netherlands

The assumptions of the scenario procedure have been translated to the specific case of the Netherlands. These assumptions, related to historical data, have been extensively discussed in several workshops in the context of the National Sustainability Outlook. Only a brief overview of the assumptions is given here. The extensive justification of the assumptions can be found in the report on long-term population scenarios (De Jong and Hilderink, 2004).

7.1.1 Assumptions

Assumptions, in line with the previous description of the scenarios, are derived in a straightforward manner. To get a better idea of the range of the assumptions, we will put them in historical perspective, covering the period from 1950 to 2000. The time horizon chosen for this application is 2050.

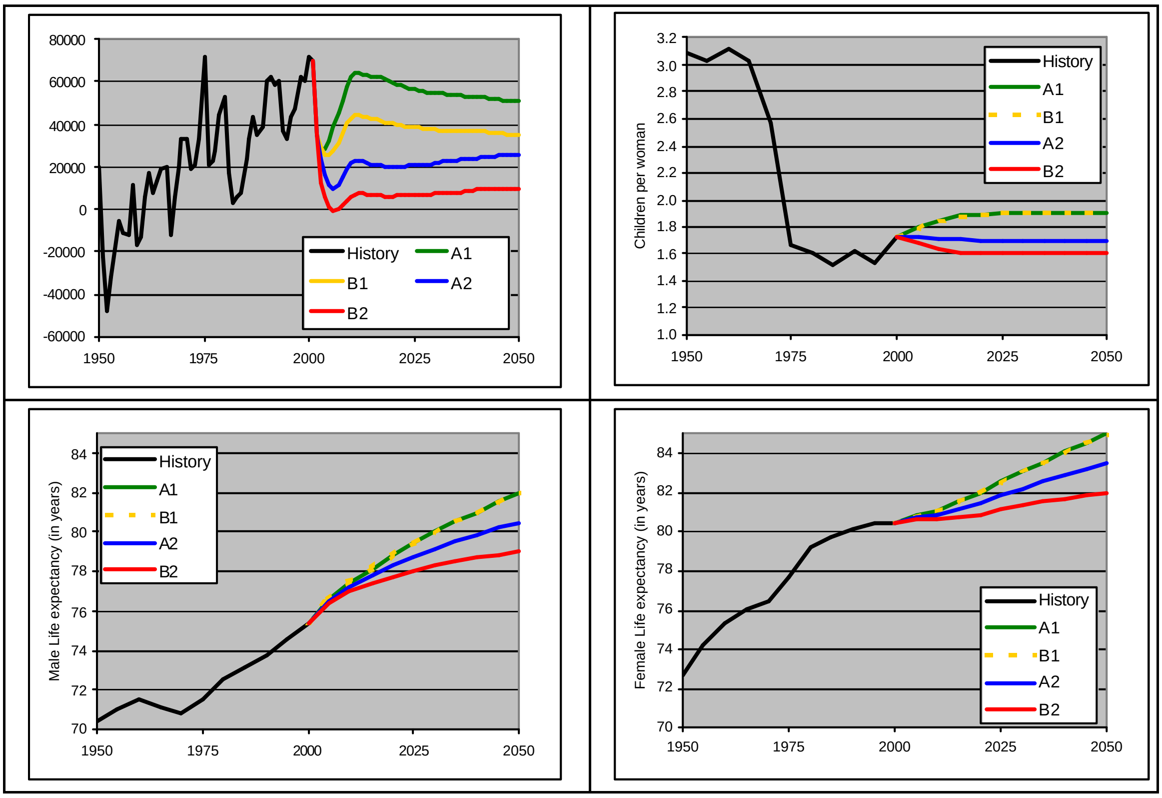

Figure 13. Historical pattern and assumptions for the Netherlands (upper left: net number of migrants; upper right: TFR; lower left: male life expectancy; lower right: female life expectancy), 1950-2000 (Source: CBS, 2002).

In addition to these assumptions, the average household will be expected to reach a level of 2.1, 2.0, 2.3 and 2.5 persons per household in 2050 for A1, A2, B1 and B2, respectively.

7.1.2 Results

The corresponding simulation results are shown in the figure below. The A1-world results in the highest population due to relatively high levels of migration and TFR. The number of households is also the highest in A1 even though the average household size is with two persons per household not the highest. The pattern of household developments in A2 is the result of a decrease in household size on the one hand, and an increase of population on the other. The B1 world shows a high population growth to 19 million in 2050, but due to increasing household size, the number of households shows only a modest increase. In B2 the number of households is the lowest (a peak of 7.5 million in 2030), with a modest growth in the population to a level of 17 million in 2030. The process of ageing will continue in all four worlds, at least for the coming three decades. B2 shows the highest proportion of elderly, while the inflow of young migrants and higher fertility have their effect in A1. In B2 the double-ageing (percentage over 85) is even going to triple.

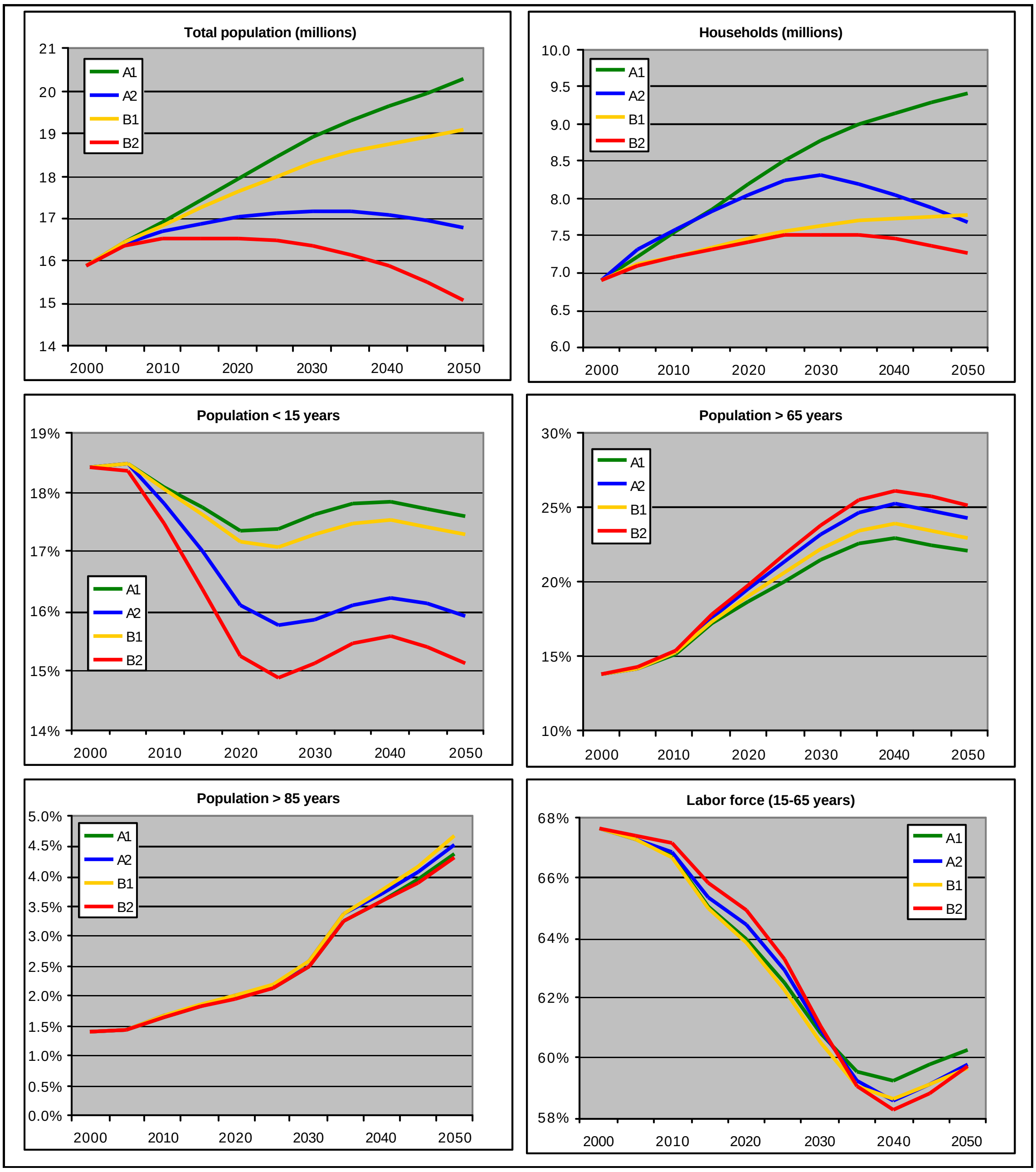

Figure 14. Results for the Netherlands, 2000-2050.

7.2 Europe

For this application, all European countries included in the previously mentioned NiDi/CBS study were selected. The application to these 38 European countries involves a choice for all the specific countries. To develop a country-specific set of the assumptions for all countries requires analyses beyond the scope of this report. Instead, a clustering of countries is used to describe changes similar to the NiDi/CBS approach (Section 3.1.7). All 38 European countries are classified, making use of six clusters (see Section 0). For each cluster, assumptions are made taking the assumptions for the Netherlands on life expectancy and TFR as reference points or representative of European developments. For migration, crude migration rates (i.e. net number of migrants per 1000 of the population) will be used instead of absolute numbers. This enables comparison of developments among the countries (and reflects a more quota-oriented EU policy, which might be implemented in the future). Nevertheless, a more extensive description, in which consequences of different future developments concerning expansion of the European Union are taken into account, is obviously preferable. The scenarios here are meant to provide a steppingstone for further analyses and implementation of these facets.

7.2.1 Assumptions

The vertical axis of the scenarios (globalization versus regionalization) is also used for the interpretation of the future of the European Union (See CPB, 2003). In the A1/B1 worlds, Europe is successfully enlarged within the coming 15 years with 10-15 countries. All European countries will reach the levels similar to those in the Netherlands (as described in the application of the Netherlands) in the corresponding scenarios, although some faster than others. The convergence levels in scenario A1 of 3 migrants per 1000 inhabitants and 2.1 in scenario B1 differ only slightly from the original NiDi/CBS assumptions (3.5 in south Europe and 2.5 in all other countries). The expansion also implies free traffic of persons, and leads to higher (intra-continental) migration flows between 'new', mostly Eastern European countries and the other EU countries. This is reflected in higher migration rates[7].

In the A2/B2 worlds only the clusters Western, north and south Europe (the current EU-15) will reach the representative levels of the Netherlands while others will stay behind. In this 'two-speed' or even 'three-speed Europe', Eastern European countries will have lower life expectancies combined with low fertility rates, as currently observed in these countries. In A2/B2, expansion will not be as successful and results in lower migration flows from – if any – new countries to the old ones due to higher barriers, since only restricted labour migration will be permitted. The values for migration, fertility and mortality for the other countries (i.e. those not specified by the previously described values for the Netherlands) are based on the NiDi/CBS diversity scenario. An overview of all scenario values is given in Appendix 2.

Table 3. Overview of assumptions for European population projections.

Input	A1	A2	B1	B2
Fertility	Converging High	Diversity Low	Converging High	Diversity Medium
Life expectancy	Converging Medium High	Diversity Low	Converging High	Diversity Medium
Migration	Converging High	Diversity Low	Converging Medium High	Diversity Low

[7] An origin-destination matrix would be a more adequate way to describe migration flows. Far more analysis is required to be able to pinpoint the flows correctly and goes beyond the scope of this exploration of European futures.

7.2.2 Results

A selection of simulation results is shown in Figure 15. Simulation results are shown in Figure 15 for the five clusters. The results for the total population are more distinctive for the 1 versus 2 World than the A versus B World (see Figure 15). In 2050, the collective population of all the countries ranges from 625 million in B2 to 925 million in A1. These outcomes are explained in the combination of low and high values especially for migration and fertility, respectively. The population in Former Soviet Union, however, will decrease, at least for the coming decades. Differences in age structures due to different historical patterns underlie these deviating outcomes.

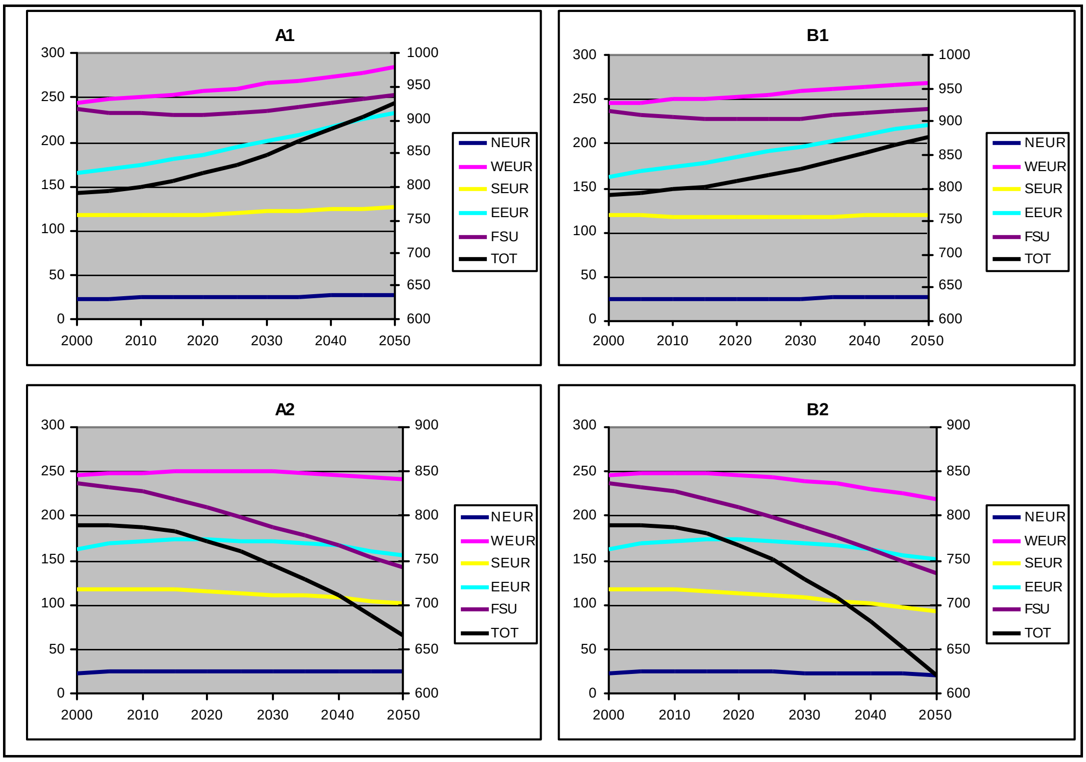

Figure 15. Population (in millions) simulation results for the clusters in Europe (black line shows the total population displayed on the right axis), 2000-2050.

Focusing on the EU-15, a similar range can be seen. Figure 16 shows the results for the EU15 countries. In the A1 World the high migration rates result in the highest population of 425 million, which is comparable to the highest projection of Eurostat. The low fertility, mortality and migration assumptions of the B2 Scenario result in a population of just above 320 million, a decrease of 50 million compared to the current size. This result is higher than the low Eurostat projection, mainly due to a somewhat higher level of the number of children per woman. The annual net migration into the EU15 ranges from just over 1 million migrants per year in A1, 760 million in B1, 550 million in A2 and 288 in B2. Consequences for ageing are also presented in the figure below. Results are given for the green (population younger than 15 years as a ratio of the potential economically active population aged 45-65 years) and grey pressure (65 and over as a ratio of 15-64 years). The green pressure shows clearly the differences in fertility levels. The higher fertility levels cause a higher inflow in the younger cohorts. On the other hand, the grey pressure illustrates the ageing process. The population of 65 and over is expected to increase substantially. This reconfirms the upcoming wave of ageing, which can neither be averted by higher fertility levels, nor by high migration inflows. Ageing seems to be inescapable and has to be dealt with in all scenarios.

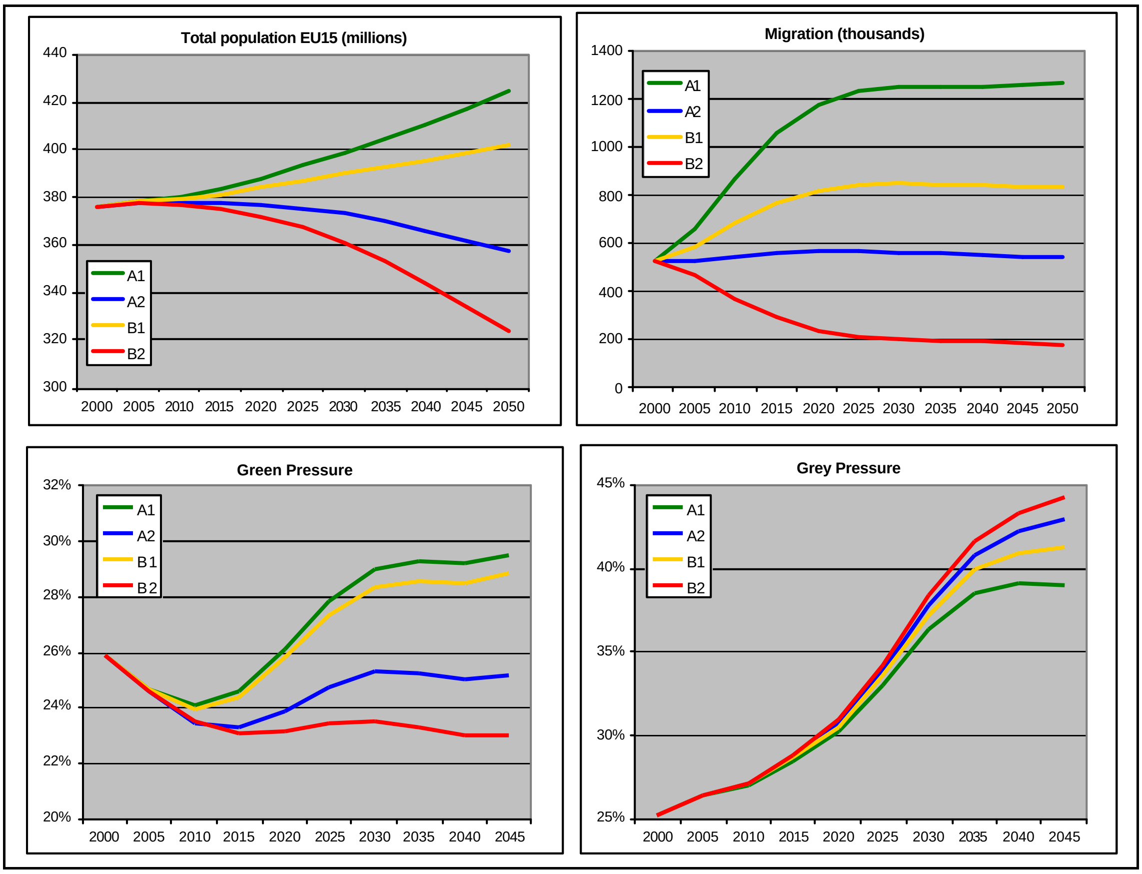

Figure 16. Population (in millions) simulation results for the EU-15, 2000-2050.

7.3 The World

The next and final step is the implementation of the scenarios for the World. The scenarios are applied to the 17 world regions, as defined and implemented by the RIVM (Kreileman et al., 1998, Hilderink, 2000, Hilderink, 2002). Contrary to the previous two applications, the year 2100 is taken as time horizon. This extended simulation period implies more speculative assumptions, which will be elaborated on.

7.3.1 Assumptions

Most of underlying factors for the assumptions are implicitly or explicitly described in previous chapters and will only be summarized briefly. Ideally, the assumptions for

Western and Eastern Europe would be -as far as possible- based on the application for Europe, and the aforementioned assumptions for other countries given by IIASA. The lack of a thorough description and of variation in mortality and migration make the UN variants less useful, despite them being widely used.

The IIASA assumptions for the European regions, however, deviate from the previous applications. The TFR range is a bit broader in 2050, with 1.3-2.2 children per woman for Western and Eastern Europe, but does not show extreme disparities with the range applied as described in Section 7.2 (i.e. 1.5-1.9 children per woman in 2050). The TFR will therefore be based on the Europe application. The values for life expectancy, on the other hand, show developments which are beyond the range of the other projections.

In A1, the life expectancy in Western Europe is expected to increase in the coming 50 years to respective levels of 86 and 94 years for men and women. In the Pacific-OECD region (Japan, Australia and New Zealand) women will surpass the age of 97 in 2050 and even 103.4 years in 2100, a value which not achieved by any other region. Remarkable here is that all maximum values are already reached in 2080 and no further increase in life expectancy will be achieved afterwards. These improvements, which are 'more significant than those assumed by most other national and international population projections' (Lutz, 1996, p. 367), are based on historical achievements in mortality reduction per decade and extrapolated for future time periods (see also Oeppen and Vaupel, 2002). The overview given by Bongaarts (2000) states that it is now more collectively suggested that a limit to life is probably much higher than 85 years. On the other hand, others found that life expectancies of 100 years will require changes in health practices and mortality schedules that appear to be inconsistent with what is practically achievable (Olshansky and Carnes, 1996, Olshansky et al., 2001).

These differences cause difficulties in the world application, where consistency among the regions is considered to be of more importance than the comparison with the previous Europe application, given the perspective that 'the interpretative and instructive value of an integrated assessment model is far more important than its predictive capability' (Rotmans et al., 1997b, p. 38). Moreover, the additional value of this scenario exploration does not come up with a new set of data on the assumptions, but with a more well-founded and transparent method of scenario application in the field of demography. Migration, as the third component, has an important contribution to these outcomes since it will be one of the major issues distinguishing the scenarios. The migration rates are also based on the IIASA assumptions.

In the A1/B1 worlds convergence is the keyword. All regions will end up at level just below replacement: 1.9 children per woman as in the previous applications. In A1 this is induced by high economic growth, and slightly faster than in B1 due to the enormous economic growth in all regions. In B1, economic growth is accompanied by full access to modern methods of contraception, which make it possible for couples to apply family planning. In A1, mortality level will increase to relatively high levels (in 2100 the life expectancy will be 83 years for men and 90 for women). In B1, developed countries will reach medium-high levels, the average of the highest and the central set of assumptions of IIASA, while developing countries will, after starting at the central level, ultimately reach their highest level. This is induced by the fast economic recover period by developing countries. Open borders and free traffic of persons will result in high migration flows, mainly from developing to developed countries. These flows will be higher in A1 due to differences between regions e.g. in population growth and the demand for labour in developed countries.

The A2 and B2 worlds are characterized by internal orientation. Regions maintain their own fertility and mortality patterns, which are more social-culturally determined than pure economically. The demographic transition will not be fully completed in all developing countries by 2100. In some regions, fertility levels will decrease, but remain above replacement levels, both for A2 as B2. In B2, however, contraception will be made available, which results in lower fertility levels than A2. Mortality patterns show a wide diversity between developed and developing regions. The latter regions will stay behind, and will depend more and more on their own resources, technology and infrastructure. Migration flows will be low due to more restrictive immigration policies. In A2 migration will be somewhat higher as a result of selective labour migration.

The assumptions for the 17 world regions are derived from existing sets of assumptions. Part of the work done for SRES can be directly applied here. A summary of the assumptions is given in Table 4, while the underlying data for the scenario assumptions can be found in Appendix 3.

Table 4. Overview of assumptions for world population projections.

Input	A1	A2	B1	B2
Fertility	Converging High	Diverging Medium (developed)-Medium-High (developing)	Converging High	Diverging Medium-Low (developed)-Medium-High (developing)
Life expectancy	High	Low (developing) - Medium (developed)	Medium-High	Low
Migration	High (from developing to developed)	Medium-Low	Medium-High (from developing to developed)	Low

7.3.2 Results

The simulation results of the set of assumptions presented above show a deviating picture (Figure 17). Four scenarios are obtained with a world population ranging from 8 in B2 to 12 billion persons in A2, a range which is quite a bit narrower than the SRES one. The order of outcomes also differs. In the SRES, the A1/B1, with 7 billion, is the lowest, and in this exercises the B2 scenario turns out to be lowest. The combination of high fertility with high mortality (A2 and B2), and lower fertility with lower mortality (A1 and B1), results in a more balancing effect. A1 and B1 are contrastive concerning migration and the speed of the fertility transition, which result in a slight difference. The A2 scenario is the highest, but with 12 billion is far lower than the 15 billion in SRES.

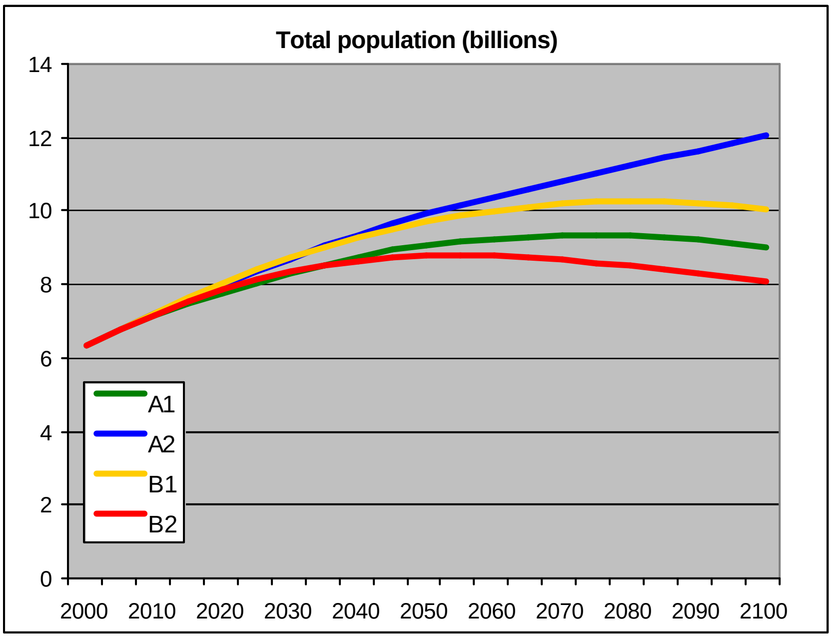

Figure 17. Results for the World Population, 2000-2100.

Figure 18 shows the results for a clustering of the 17 regions. In all scenarios, South Asia (now with around 1.5 billion people) is fairly dominant with respect to the overall outcome and range from 2.5 billion in A1 and B2 to over 4 billion in A2. An increase of the same magnitude can be observed in Africa. Africa grows from 850 million persons in 2000 to 1.7 billion in A1 and B2, and 2.2 billion in B2.

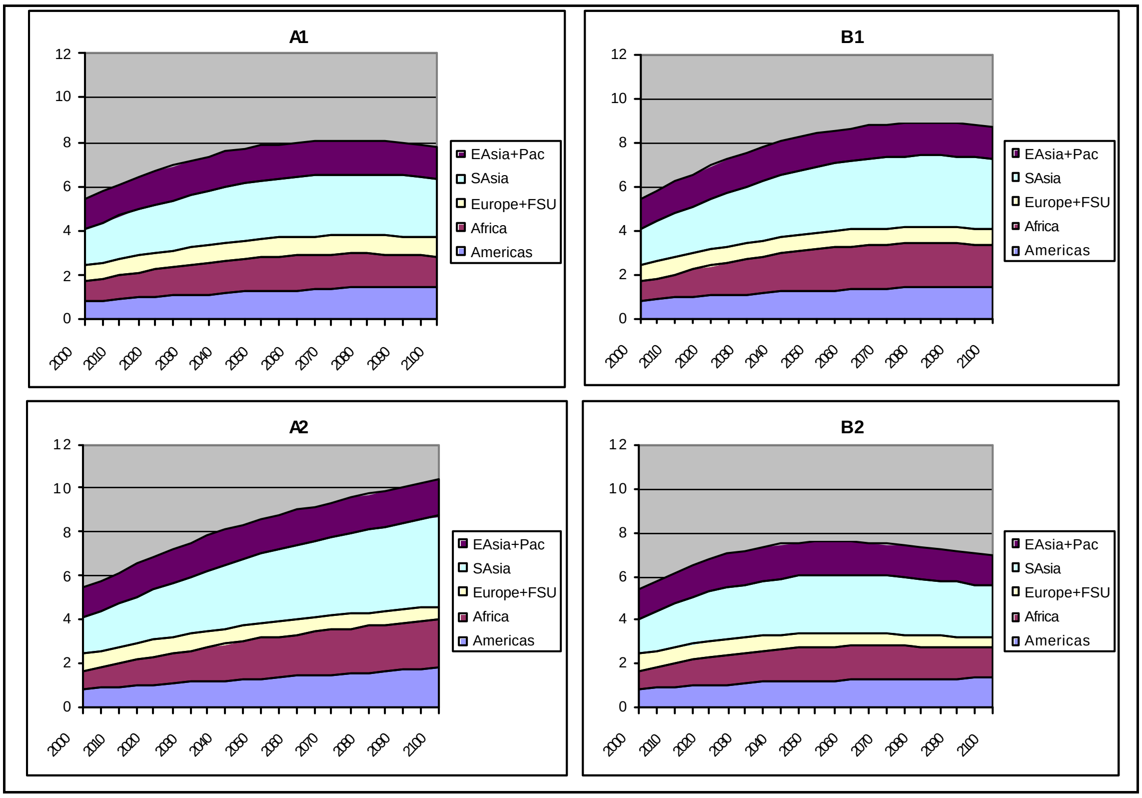

Figure 18. Results for the World Population (in billions) by region, 2000-2100.

As indicator for the ageing process, the old age dependency ratio (i.e. population over 65 as ratio of the working age population between 15 and 65 years) is shown in Figure 19. The differences between A1 and B1 can be obtained from this figure as well. The relatively high levels of life expectancy in A1 (in line with the SRES assumptions) result in relatively high levels of dependency ratios. In A2 and B2, the mortality levels are not expected to decrease that much more in developing countries; this results in lower dependency ratios, which is also reinforced by the higher fertility rates. Another remarkable observation for all regions in all scenarios is that the process of ageing is inevitable. All regions will, some more and sooner than others, be faced with a higher proportion of elderly.

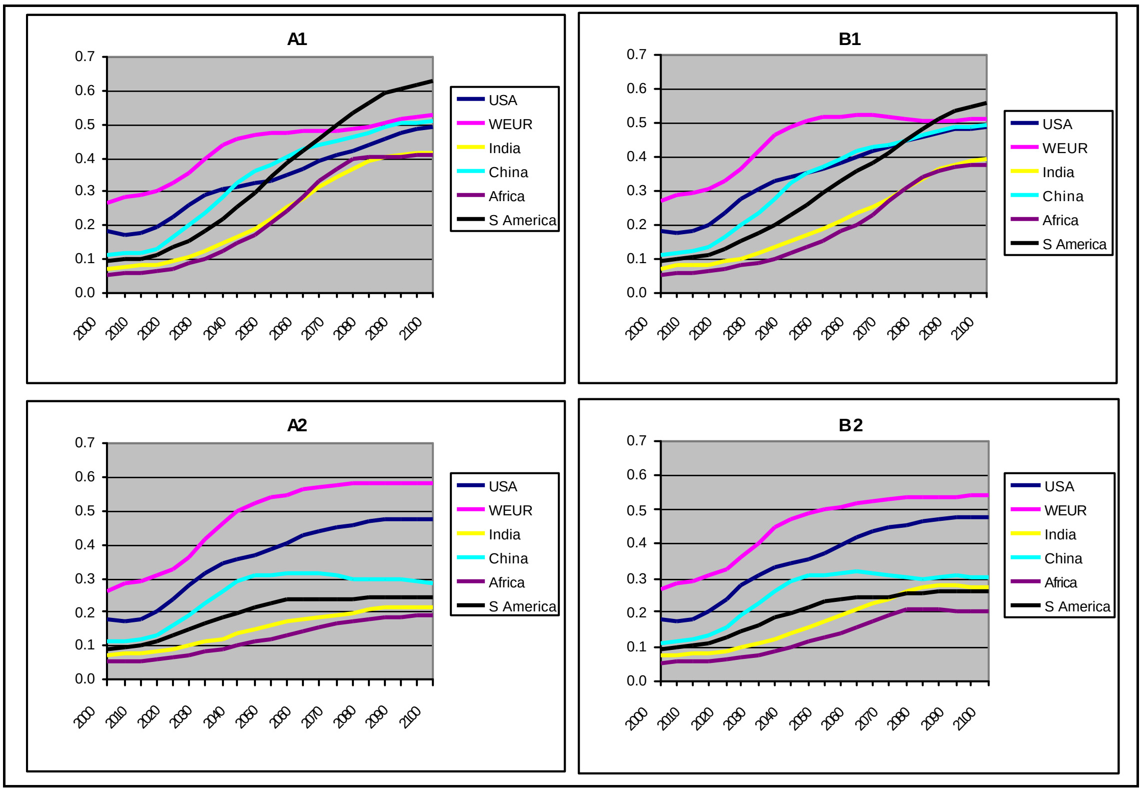

Figure 19. Results for the selection of regions/countries, old age dependency ratio, 2000-2100.

8. Conclusions and recommendations

The purpose of this study was to obtain a better understanding of the construction of various population projections and how these can be improved. Based on a systematic review of a selection of existing population projections the following conclusions can be drawn.

- Current population projections are mostly based on assumptions for fertility, mortality and migration developments. The grounds for these assumptions was often found lacking (UN, EUROSTAT), although in some applications these components were taken into account endogenously (TARGETS, PHOENIX) or based on a scenario-approach (NiDi/CBS). A more scenario-oriented approach can be very helpful in creating a contextual description of these assumptions, but also to arrive at more consistent, and more plausible, population projections.

- The SRES scenario approach is quite advanced, but only shows an extensive description of environmental and economical modelling. The selection of the population scenarios is unclear and might even be inconsistent with the underlying storylines.

- Two dimensions of the SRES scenarios are useful and distinctive. However, for fertility behaviour and mortality outcomes, the use of individualism versus collectivity as second dimension might be more applicable than economic versus environmental. For migration, this dimension is better characterized by material wealth (market) versus sustainability. The restriction of the scenarios to fertility and mortality, and not taking migration as an equally important component, is a missed opportunity in the SRES scenarios.

- The dimensions of scenarios can be easily interlinked with components of demographic development. The theory on the demographic transition, consisting of different stages, can serve as a framework for a more systematic approach to demographic developments.

- Scenario dimensions, such as interlinkage of geographical aggregation levels and level of integration, are often not taken into account. Especially the interlinkage between the different geographical aggregation levels can play an important role in population developments. Migration can hardly be considered independent of EU-related developments, for example, matters on asylum, or population growth, and economic equalities in other regions.

- Other demographic factors such as household developments, urbanization and ageing should be included if broad developments (e.g. in the context of sustainability) are considered. Although the underlying mechanisms are not that well-understood, especially concerning migration, leaving them out of the scenarios might lead to crucial developments being missed.

- The applications of the SRES methodology to future developments in the Netherlands, Europe and the World represent a valuable first step towards projections that have more power of expression than medium-high-low variants or confidence intervals. First, a more elaborate description and sound founding of the underlying assumptions shows that results can be rather controversial. It is not claimed that these results are not acclaimed as representing better population projections, but do give more entry points for a systematic discussion of the storylines and associated assumptions. Secondly, the internal consistency through linking different geographical aggregation levels can be seen as one of the strong points of this approach. Nevertheless, further integration of socio-economic aspects, medical technology and health services, along with corresponding life expectancies, and overall societal and technological achievements will be necessary.

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Appendix 1 Population Projections

UN WPP

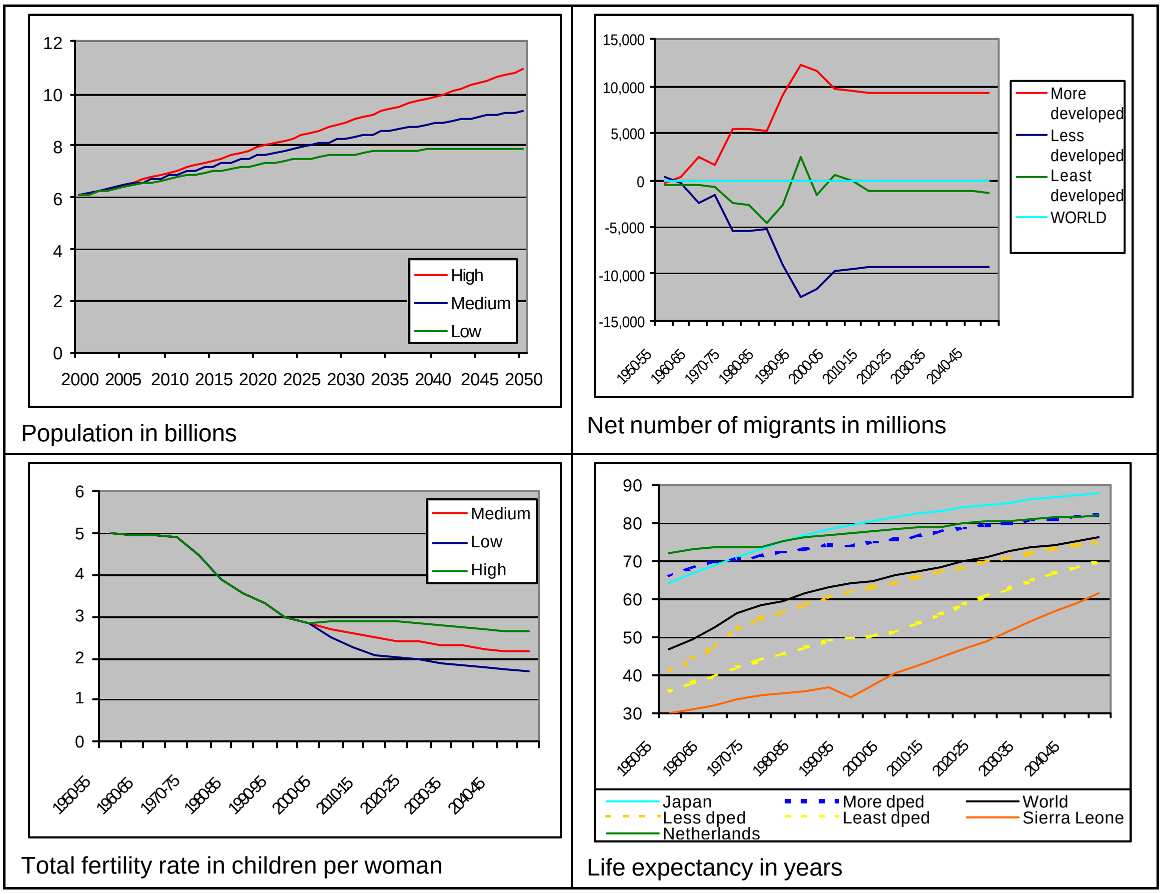

Figure 20. UN World Population Prospects (2000), Total population, net migration, life expectancy and total fertility rate for three variants (high, medium, low), 1950-2050.

UN Long-range

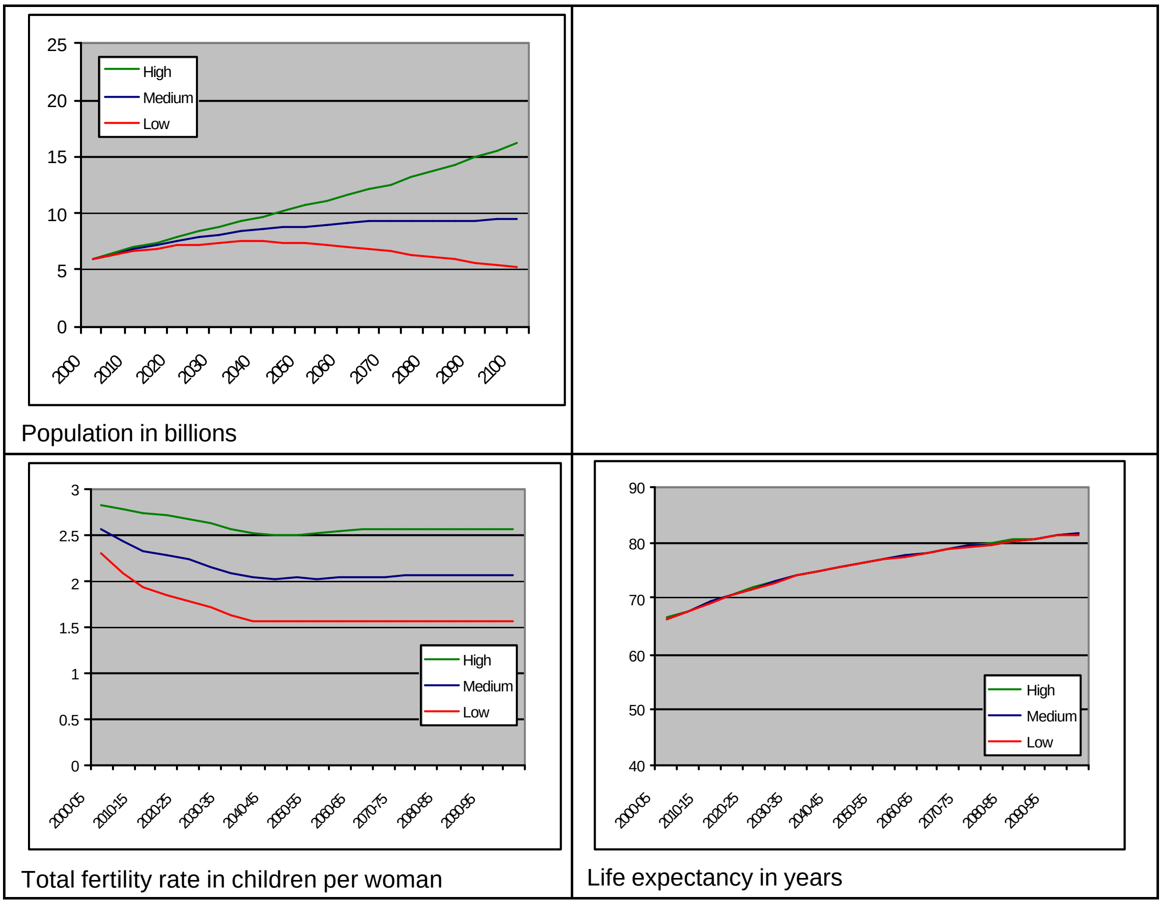

Figure 21. UN Long Range Global Population Projection based on the 1998 revision (2000), Total population, life expectancy and total fertility rate for three variants (high, medium, low), 2000-2100.

TARGETS

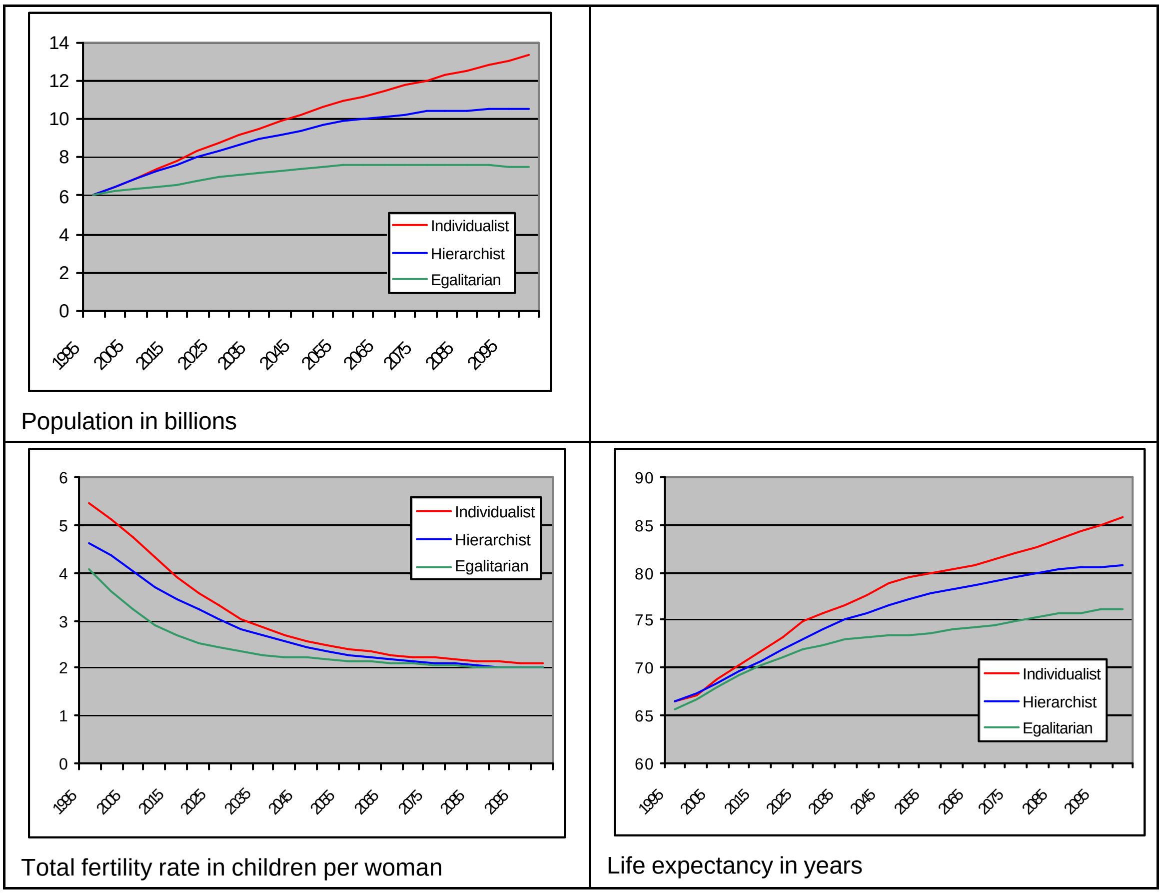

Figure 22. TARGETS projections, Total population, life expectancy and total fertility rate for three perspectives (Individualist, hierarchist and egalitarian), 1995-2100.

IIASA

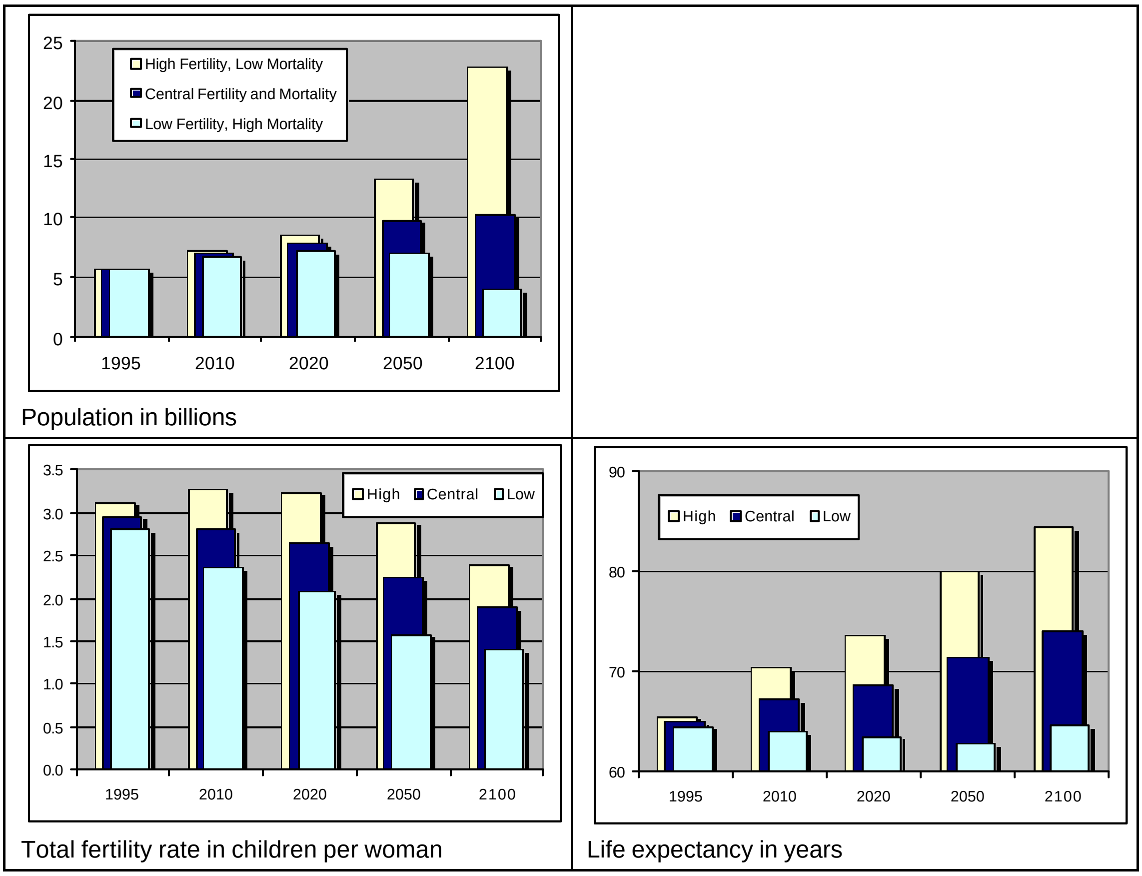

Figure 23. IIASA Global Population projections, Total population, life expectancy and total fertility rate for three scenarios (Central, HIGH (high fertility-low mortality), LOW (Low fertility-high mortality)), 1995-2100.

EUROSTAT

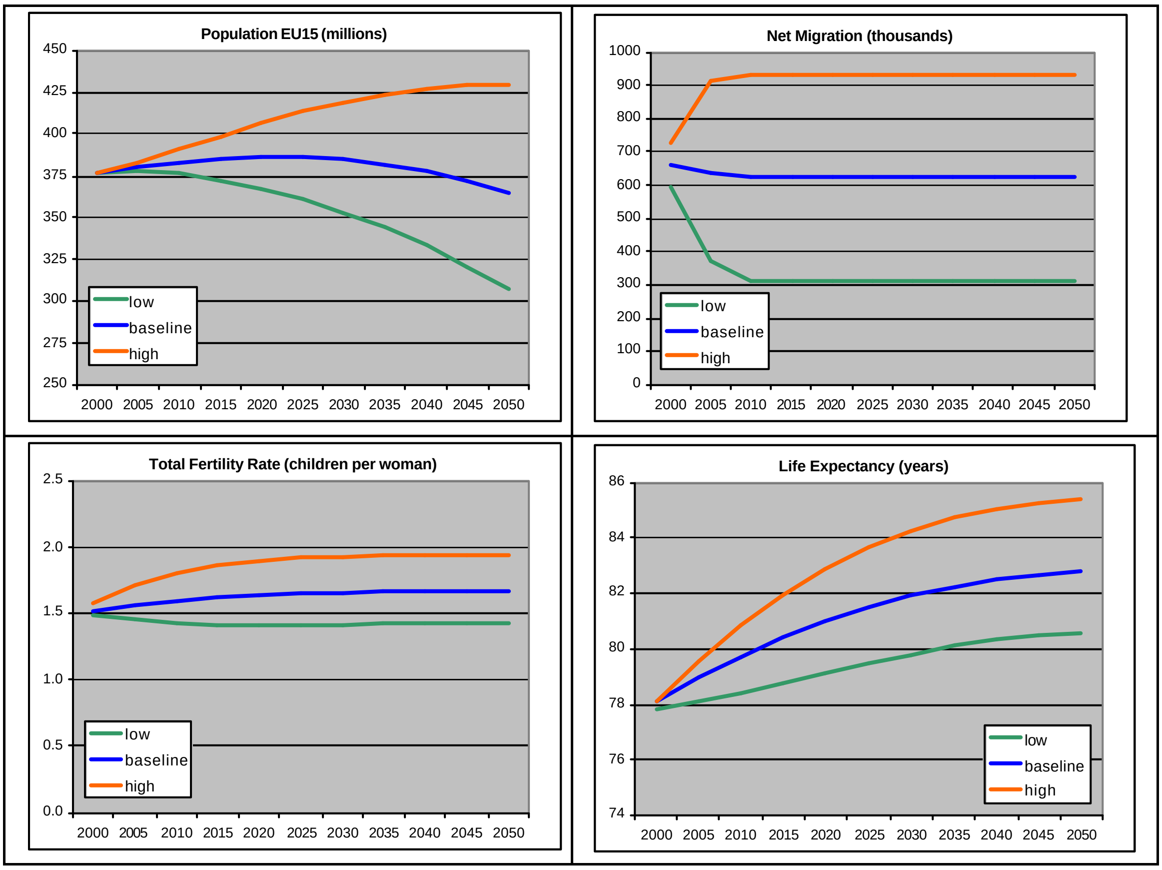

Figure 24. EUROSTAT EU15 Population projections, Total population, life expectancy and total fertility rate for three scenarios (base, high, low), 1995-2050.

CBS/NiDi

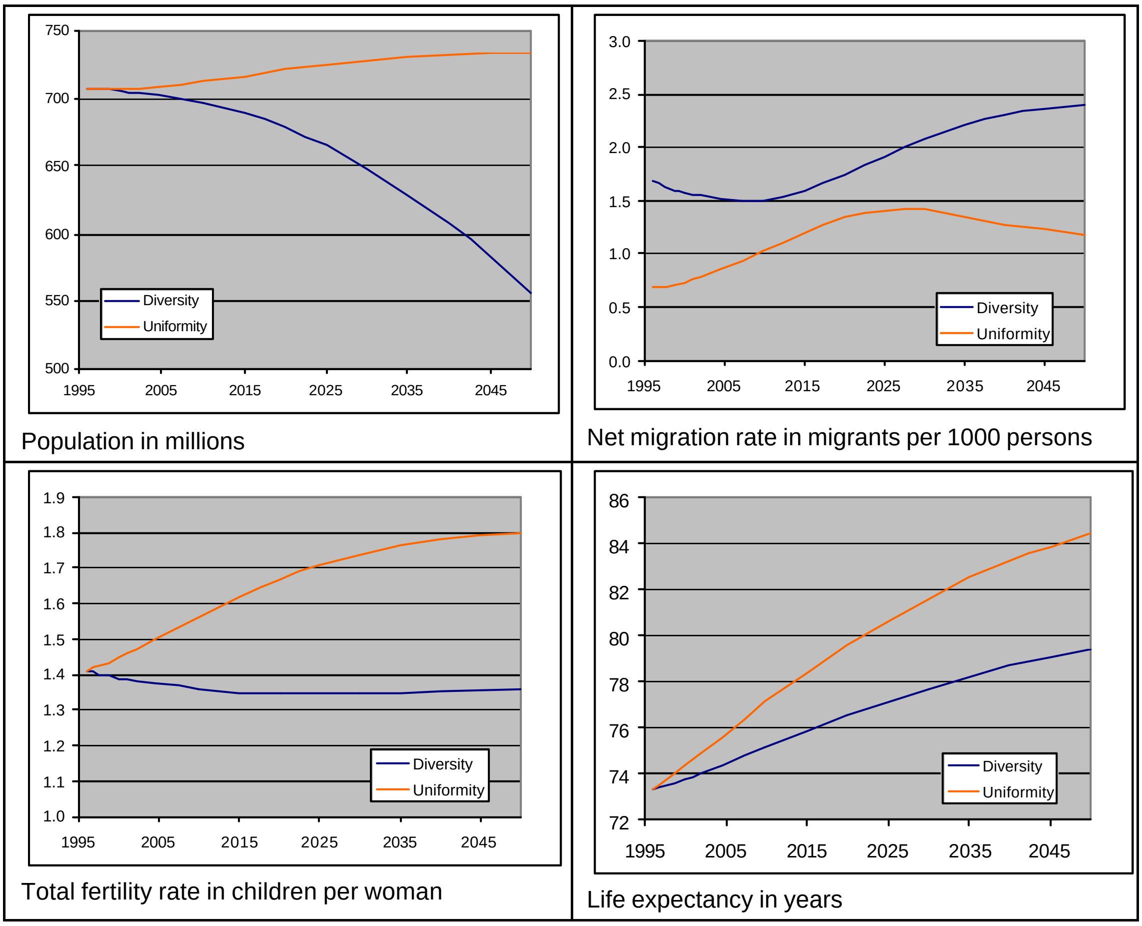

Figure 25. CBS/NiDi Europe Population projections, Total population, life expectancy and total fertility rate for two scenarios (diversity, uniformity), 1995-2050.

CBS

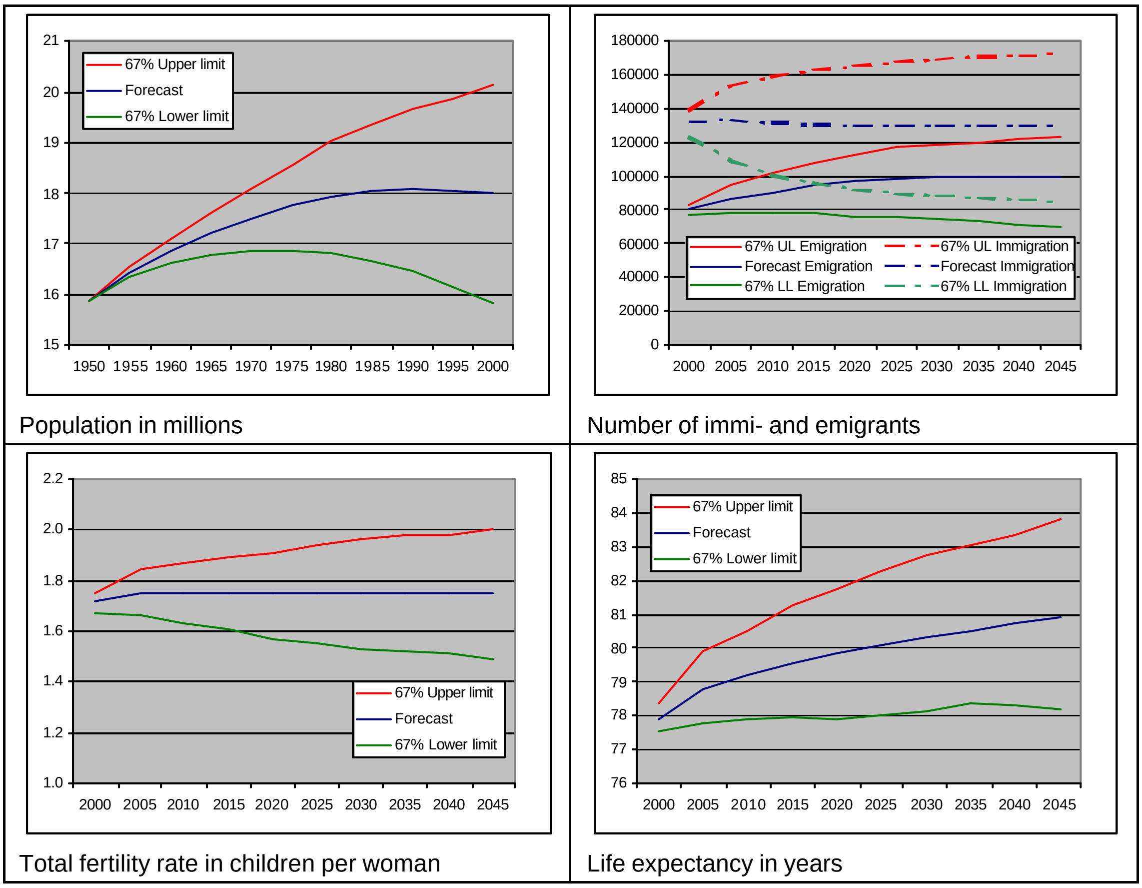

Figure 26. CBS/NiDi Netherlands Population projections, Total population, life expectancy and total fertility rate for two scenarios (diversity, uniformity), 1995-2050.

Appendix 2 SRES Economic Scenarios

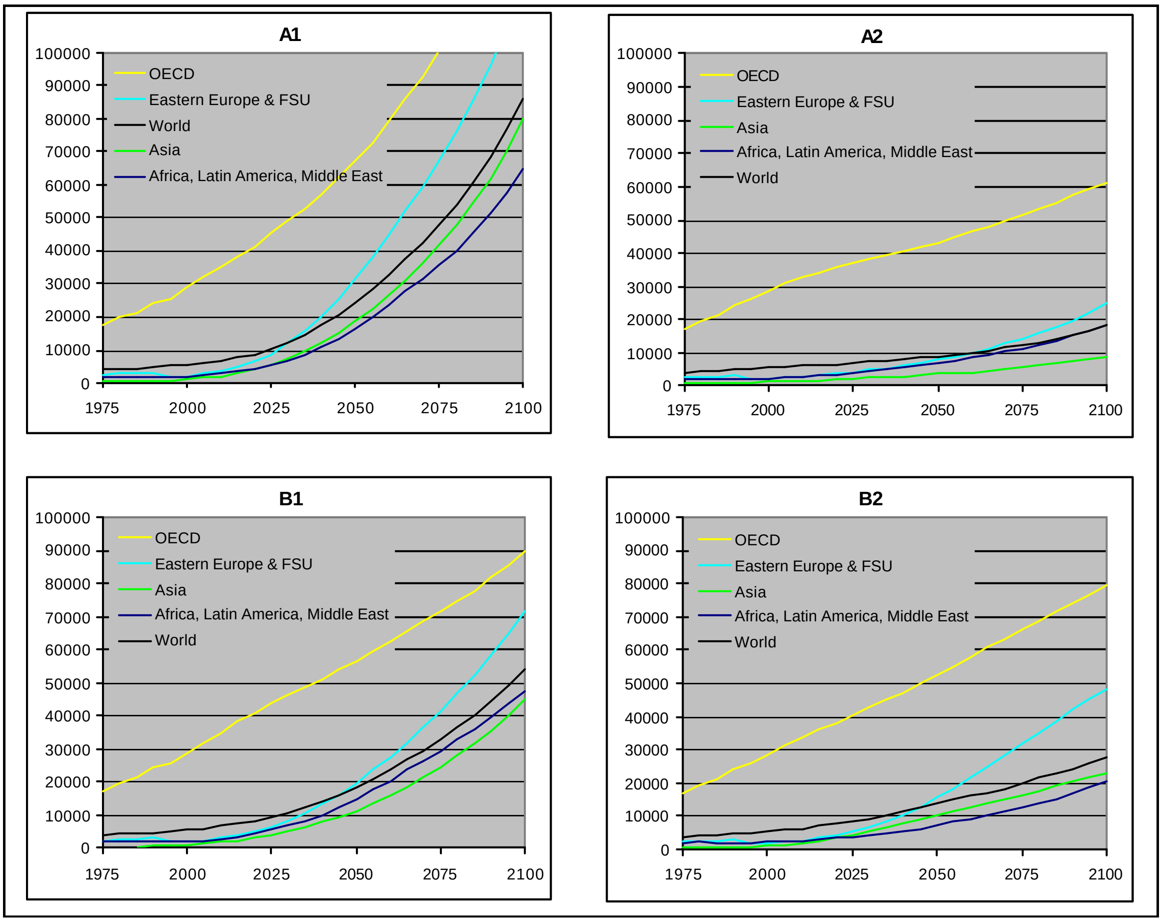

Figure 27. SRES Economic Scenarios Gross Domestic Product (GDP) per capita, in 1000 US$1995 per year.

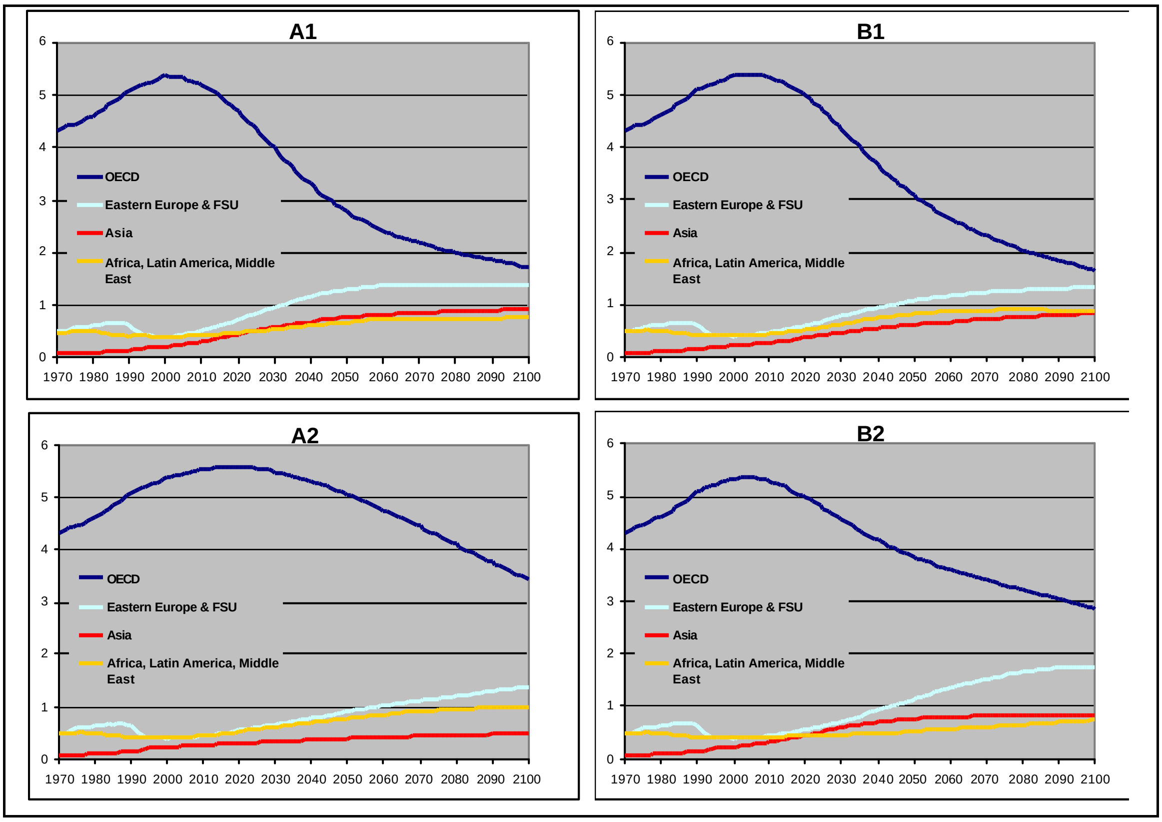

Figure 28. SRES Economic Scenarios, GDP per capita as ratio of world average.

Appendix 3 Assumptions for presented projections

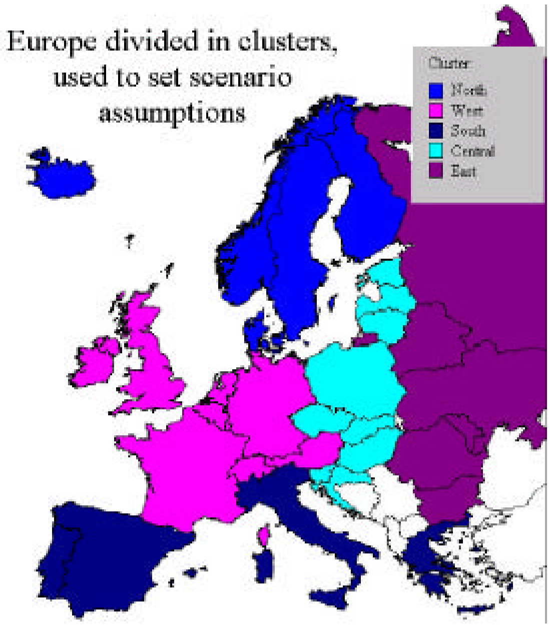

Figure 29. Clustering of European countries (Source: Huisman and Imhoff, 1999).

Table 5. Assumptions for Europe.

A1

TFR	Clusters						Clusters				
	1	2	3	4	5	Migration	1	2	3	4	5
2005	1.87	1.87	1.87	1.87	1.87		3.3	3.3	3.3	3.3	3.3
2010	1.85	1.85	1.85	1.85	1.85		3.2	3.2	3.2	3.2	3.2
2015	1.88	1.88	1.88	1.88	1.88		3.2	3.2	3.2	3.2	3.2
2020	1.89	1.89	1.89	1.89	1.89		3.2	3.2	3.2	3.2	3.2
2025	1.90	1.90	1.90	1.90	1.90		3.2	3.2	3.2	3.2	3.2
2030	1.90	1.90	1.90	1.90	1.90		3.1	3.1	3.1	3.1	3.1
2035	1.90	1.90	1.90	1.90	1.90		3.1	3.1	3.1	3.1	3.1
2040	1.90	1.90	1.90	1.90	1.90		3.0	3.0	3.0	3.0	3.0
2045	1.90	1.90	1.90	1.90	1.90		3.0	3.0	3.0	3.0	3.0
2050	1.90	1.90	1.90	1.90	1.90		3.0	3.0	3.0	3.0	3.0
LE	1M	2M	3M	4M	5M		1F	2F	3F	4F	5F
2005	76.2	76.2	76.2	76.2	76.2		81.0	81.0	81.0	81.0	81.0
2010	77.4	77.4	77.4	77.4	77.4		81.1	81.1	81.1	81.1	81.1
2015	78.2	78.2	78.2	78.2	78.2		81.5	81.5	81.5	81.5	81.5
2020	78.9	78.9	78.9	78.9	78.9		82.0	82.0	82.0	82.0	82.0
2025	79.5	79.5	79.5	79.5	79.5		82.5	82.5	82.5	82.5	82.5
2030	80.0	80.0	80.0	80.0	80.0		83.1	83.1	83.1	83.1	83.1
2035	80.5	80.5	80.5	80.5	80.5		83.6	83.6	83.6	83.6	83.6
2040	81.0	81.0	81.0	81.0	81.0		84.1	84.1	84.1	84.1	84.1
2045	81.5	81.5	81.5	81.5	81.5		84.5	84.5	84.5	84.5	84.5
2050	82.0	82.0	82.0	82.0	82.0		85.0	85.0	85.0	85.0	85.0

A2

TFR	1	2	3	4	5	Migration	1	2	3	4	5
2005	1.74	1.63	1.52	1.41	1.20		1.5	1.5	1.5	-0.5	-1.0
2010	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2015	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2020	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2025	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2030	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2035	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2040	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2045	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
2050	1.82	1.71	1.59	1.48	1.25		1.5	1.5	1.5	-0.5	-1.0
LE	1M	2M	3M	4M	5M		1F	2F	3F	4F	5F
2005	75.6	75.6	75.6	70.9	66.2		80.6	80.6	80.6	76.8	74.9
2010	77.2	77.2	77.2	72.4	67.6		80.9	80.9	80.9	77.0	75.1
2015	77.8	77.8	77.8	72.9	68.1		81.1	81.1	81.1	77.3	75.4
2020	78.3	78.3	78.3	73.4	68.5		81.5	81.5	81.5	77.6	75.7
2025	78.8	78.8	78.8	73.9	68.9		81.9	81.9	81.9	78.0	76.0
2030	79.2	79.2	79.2	74.2	69.3		82.2	82.2	82.2	78.3	76.4
2035	79.6	79.6	79.6	74.6	69.6		82.6	82.6	82.6	78.6	76.7
2040	79.9	79.9	79.9	74.9	69.9		82.9	82.9	82.9	79.0	77.0
2045	80.2	80.2	80.2	75.2	70.2		83.2	83.2	83.2	79.2	77.3
2050	80.5	80.5	80.5	75.5	70.4		83.5	83.5	83.5	79.5	77.5

B1

TFR	1	2	3	4	5	Migration	1	2	3	4	5
2005	1.86	1.86	1.86	1.86	1.86		2.3	2.3	2.3	2.3	2.3
2010	1.85	1.85	1.85	1.85	1.85		2.2	2.2	2.2	2.2	2.2
2015	1.88	1.88	1.88	1.88	1.88		2.2	2.2	2.2	2.2	2.2
2020	1.89	1.89	1.89	1.89	1.89		2.2	2.2	2.2	2.2	2.2
2025	1.90	1.90	1.90	1.90	1.90		2.2	2.2	2.2	2.2	2.2
2030	1.90	1.90	1.90	1.90	1.90		2.2	2.2	2.2	2.2	2.2
2035	1.90	1.90	1.90	1.90	1.90		2.1	2.1	2.1	2.1	2.1
2040	1.90	1.90	1.90	1.90	1.90		2.1	2.1	2.1	2.1	2.1
2045	1.90	1.90	1.90	1.90	1.90		2.1	2.1	2.1	2.1	2.1
2050	1.90	1.90	1.90	1.90	1.90		2.1	2.1	2.1	2.1	2.1
LE	1M	2M	3M	4M	5M		1F	2F	3F	4F	5F
2005	76.3	76.3	76.3	76.3	76.3		81.1	81.1	81.1	81.1	81.1
2010	77.4	77.4	77.4	77.4	77.4		81.1	81.1	81.1	81.1	81.1
2015	78.2	78.2	78.2	78.2	78.2		81.5	81.5	81.5	81.5	81.5
2020	78.9	78.9	78.9	78.9	78.9		82.0	82.0	82.0	82.0	82.0
2025	79.5	79.5	79.5	79.5	79.5		82.5	82.5	82.5	82.5	82.5
2030	80.0	80.0	80.0	80.0	80.0		83.1	83.1	83.1	83.1	83.1
2035	80.5	80.5	80.5	80.5	80.5		83.6	83.6	83.6	83.6	83.6
2040	81.0	81.0	81.0	81.0	81.0		84.1	84.1	84.1	84.1	84.1
2045	81.5	81.5	81.5	81.5	81.5		84.5	84.5	84.5	84.5	84.5
2050	82.0	82.0	82.0	82.0	82.0		85.0	85.0	85.0	85.0	85.0

B2

TFR	1	2	3	4	5	Migration	1	2	3	4	5
2005	1.88	1.76	1.64	1.53	1.29		0.6	0.6	0.6	-0.5	-1.0
2010	1.75	1.64	1.53	1.42	1.20		0.6	0.6	0.6	-0.5	-1.0
2015	1.72	1.61	1.51	1.40	1.18		0.6	0.6	0.6	-0.5	-1.0
2020	1.71	1.60	1.50	1.39	1.18		0.6	0.6	0.6	-0.5	-1.0
2025	1.71	1.60	1.49	1.39	1.17		0.6	0.6	0.6	-0.5	-1.0
2030	1.71	1.60	1.49	1.39	1.17		0.6	0.6	0.6	-0.5	-1.0
2035	1.71	1.60	1.49	1.39	1.17		0.6	0.6	0.6	-0.5	-1.0
2040	1.71	1.60	1.49	1.39	1.17		0.6	0.6	0.6	-0.5	-1.0
2045	1.71	1.60	1.49	1.39	1.17		0.6	0.6	0.6	-0.5	-1.0
2050	1.71	1.60	1.49	1.39	1.17		0.6	0.6	0.6	-0.5	-1.0
LE	1M	2M	3M	4M	5M		1F	2F	3F	4F	5F
2005	76.0	76.0	76.0	71.2	66.5		80.9	80.9	80.9	77.0	75.1
2010	76.9	76.9	76.9	72.1	67.3		80.6	80.6	80.6	76.8	74.9
2015	77.4	77.4	77.4	72.6	67.7		80.7	80.7	80.7	76.9	75.0
2020	77.8	77.8	77.8	72.9	68.0		80.9	80.9	80.9	77.1	75.1
2025	78.0	78.0	78.0	73.2	68.3		81.1	81.1	81.1	77.3	75.3
2030	78.3	78.3	78.3	73.4	68.5		81.3	81.3	81.3	77.5	75.5
2035	78.5	78.5	78.5	73.6	68.7		81.5	81.5	81.5	77.6	75.7
2040	78.7	78.7	78.7	73.8	68.9		81.7	81.7	81.7	77.8	75.9
2045	78.9	78.9	78.9	73.9	69.0		81.9	81.9	81.9	78.0	76.0
2050	79.0	79.0	79.0	74.1	69.1		82.0	82.0	82.0	78.1	76.1

Assumptions for 17 world regions

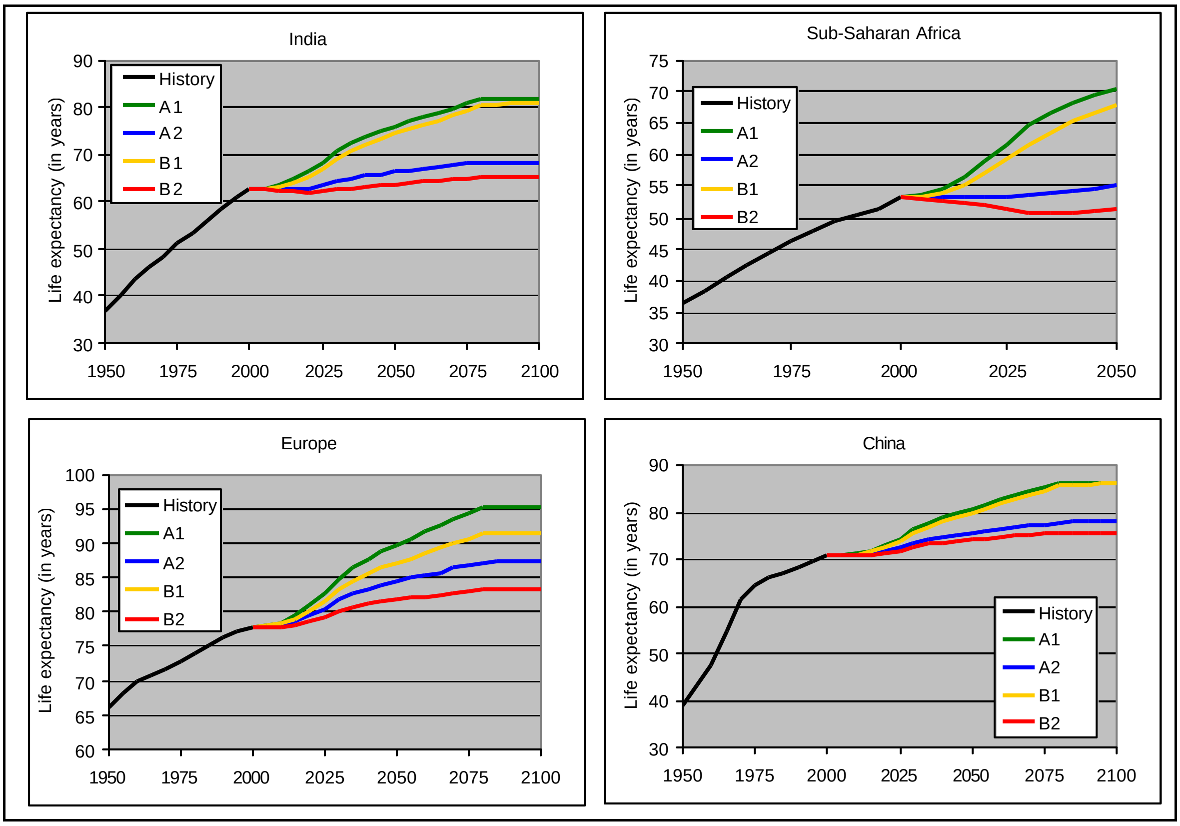

Figure 30. Average life expectancy for men and women for selected regions.

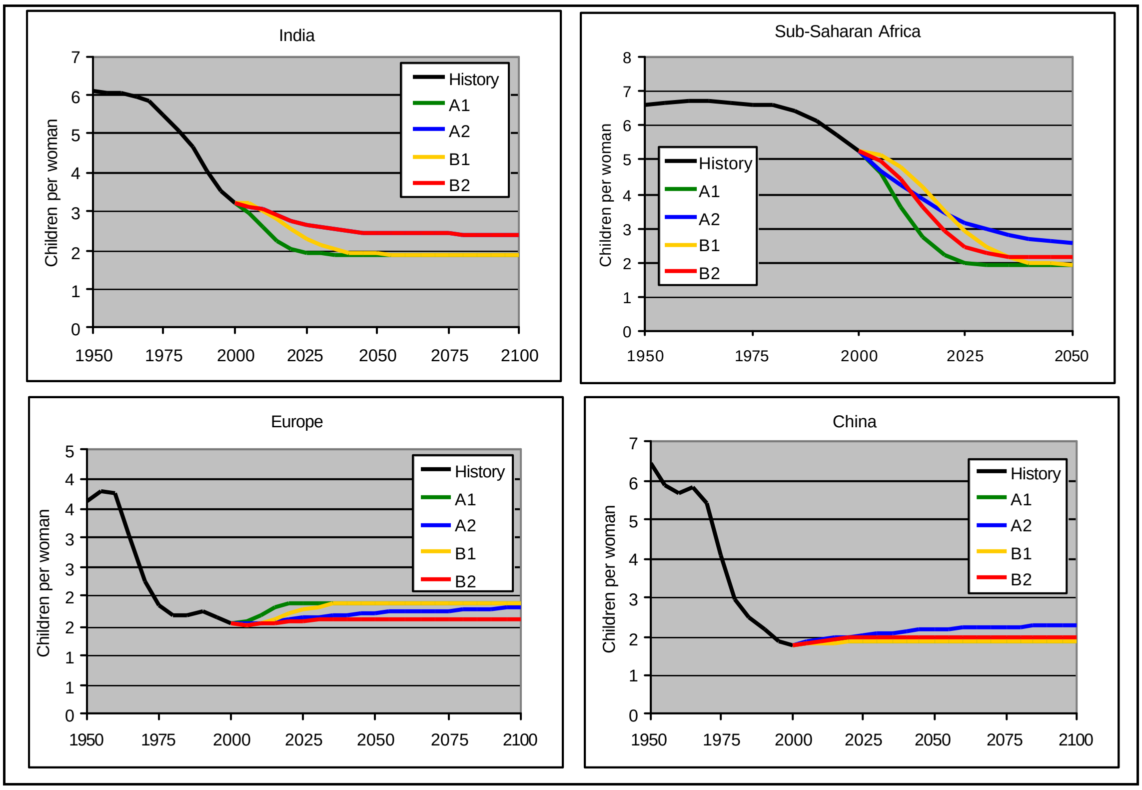

Figure 31. Total Fertility Rate for selected regions.

Table 6. Net Migration per year, 2100 level.

	A1	B1	A2/B2
CAN	171000	85500	4275
USA	1829000	914500	45725
CAC	-225000	-112500	-5625
SAM	-595000	-297500	-14875
NAFR	-375000	-187500	-9375
WAFR	-107000	-53500	-2675
EAFR	-97000	-48500	-2425
SAFR	-106000	-53000	-2650
WEUR	1000000	500000	25000
EEUR	-150000	-75000	-3750
FSU	-265000	-132500	-6625
WAS	-5000	-2500	-125
SAS	-495000	-247500	-12375
EAS	-370000	-185000	-9250
SEAS	-560000	-280000	-14000
OCE	150000	75000	3750
JAP	200000	100000	5000