International Data Base: Population Estimates and Projections Methodology

International Programs, Population Division, U.S. Census Bureau

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Document History

#	Date	Author	Summary of Revisions
1.0	September 2013	International Programs, Population Division, U.S. Census Bureau	Baseline document
2.0	December 2020	International Programs, Population Division, U.S. Census Bureau	Revised document structure and formatting; revised explanation of AIDS mortality; incorporated methodological results of extension of projection time horizon forward to 2100.

Contents

Figures

1. Introduction

The U.S. Census Bureau has prepared population estimates and projections for other countries since the 1960s. In the 1980s, the Census Bureau released its first comprehensive set of estimates and projections for over 200 countries and areas of the world. Since then, the Census Bureau has routinely updated estimates and projections for countries as new data have become available. Estimates and projections for countries, as well as for regions and the world, are available through the International Data Base (IDB) on the Census Bureau's website <https://www.census.gov/programs-surveys/international-programs/about/idb.html>.

The IDB estimates and projections have several distinguishing features. The IDB provides population size and components of change for each calendar year beyond the initial or base year through 2100 for countries and areas recognized by the U.S. Department of State that have populations of 5,000 or more.[1] Within this time series, the Census Bureau has developed sex ratios, population, mortality, and net migration measures for single ages through age 100-plus. Because of single-year age and calendar-year accounting, IDB data capture the timing and demographic impact of important events such as wars, famine, and natural disasters with a high detail of precision.

2. Methodological Overview

2.1. General Methodology

The estimation and projection process involves data collection, data evaluation, parameter[2] estimation, developing assumptions about future change, and final projection of the population for each country. The Census Bureau begins the process by collecting demographic data from censuses, surveys, vital registries, and administrative records from a variety of sources. Available data are then evaluated with particular attention to internal and temporal consistency.

The Census Bureau strives to base the population estimates and projections for each country on a modified de facto population universe when possible. A strict interpretation of the de facto population includes all persons who are physically present in the country at the reference date, whether or not they are usual and/or legal residents. In contrast, the de jure population consists of all usual residents, whether or not they are present at the reference time. Our estimates and projections exclude foreign military populations, tourists, and others visiting for short periods from the country's de facto population. After appropriate adjustments are made, the data are then used to estimate population by single years of age, as well as to estimate the fertility, mortality and migration parameters needed for population projection.

Estimation and projection procedures make use of a variety of demographic techniques and incorporate assumptions formed by consulting the social science and health science literature, as well in consultation with experts in the social and health sciences and in discussion with colleagues in international agencies and national statistical organizations around the world. In addition to using

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[1] Accordingly, based on U.S. Department of State guidelines, the Census Bureau provides estimates and projections for geographic divisions that may not be provided by the United Nations or other organizations. For instance, the IDB includes estimates and projections for Kosovo, Taiwan, as well as the West Bank and Gaza Strip areas.

[2] A parameter is a numerical description of a population characteristic or event, such as age, sex, fertility, mortality, and migration.

demographic data, Census Bureau demographers consider information on public health efforts, socio-political circumstances, and catastrophic events such as natural disasters and armed conflict in preparing the assumptions for population projections. The best available estimates and carefully derived assumptions are then placed as inputs into the Census Bureau's Demographic Analysis and Population Projection System (DAPPS) or Rural/Urban Projection (RUP) program. Finally, the DAPPS or RUP program processes the inputs and generates cohort-component projections up through 2100 for each country. Regional and world populations are obtained by projecting each country's population separately and then combining the results to derive aggregated totals.

2.2. U.S. Population Estimates and Projections

The estimates and projections for the United States provided in the IDB are based on the resident population and prepared using data and procedures that differ slightly from those used for all other countries.

U.S. population estimates, which span 1950 to the year prior to the current year, are developed using decennial census counts and information about vital statistics and international migration. For years in between the most recent census and the present, the IDB uses the official U.S. population estimates from the Census Bureau's Population Estimates Program.[3] For the current calendar year to 2060, data in the IDB are drawn from official U.S. population projections. These projections are based on the 2010 Census, projected forward using historical trends in vital statistics and international migration, and use the cohort-component method for future fertility, mortality, and international migration assumptions.[4] There is a break in the time series between the previous and current year because the population estimates and the population projections are not entirely consistent.

IDB population projections to 2100 for the U.S. territories of American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, Puerto Rico, and the U.S. Virgin Islands are produced using the same methodology as other countries.

2.3. Data Quality

The Census Bureau prepares national estimates and projections for all countries using census and survey data, vital statistics, administrative statistics from those countries, and information from multinational organizations that collect and publish data for these countries. The Census Bureau's evaluation process focuses on internal and temporal consistency of data. Information on statistical measures of uncertainty (e.g., standard errors) are considered in the evaluation when such data are available.

Although the Census Bureau applies methodologically sound demographic techniques to evaluate and estimate population and its components of change, the accuracy of the estimates and projections in the IDB is limited. First, the accuracy of parameter estimates and assumptions can be compromised due to deficiencies in their source data. Second, regardless of the accuracy achieved in estimating the current demographic situation in countries, assumptions about the future can turn out to be highly inaccurate,

[3] For a complete description of the U.S. population estimates methodology, and to access additional data, see https://www.census.gov/programs-surveys/popest.html

[4] For a complete description of the U.S. population projections methodology, and to access additional data, see https://www.census.gov/programs-surveys/popproj.html

since some population dynamics are influenced by events that are unpredictable. Natural disasters and the scale of their impact on a population, for example, cannot be foreseen.

2.4. Tools and Update Procedures

To produce these estimates and projections that comprise the content of the International Data Base (IDB), we employ a standard set of U.S. Census Bureau software: the Demographic Analysis and Population Projection System (DAPPS) and Rural/Urban Projection (RUP) program.[5] DAPPS is a user-friendly program for entering demographic data and performing population projections. RUP, which predates DAPPS, remains the underlying projection engine. DAPPS also incorporates tools for demographic analysis based on the data inputs, the outputted values of which can be readily incorporated back into the projections. These demographic analysis tools mimic the Census Bureau's spreadsheet-based Population Analysis System (PAS).[6] All of these software tools are publically available for download. Other relevant software, such as the MortPak from the United Nations, are used to evaluate existing data, make adjustments, and create new data inputs.[7]

The IDB is updated regularly. Countries are chosen for updates based on the availability of new data as well as available funding. The U.S. Census Bureau does its best to identify and fund additional countries whose updates would best serve the public.

2.5. Standards and Definitions

Country names used in the IDB are consistent with federal government standards established by the U.S. Board on Geographic Names (BGN).[8] Regional definitions in the IDB are consistent as much as possible with the United Nations M49 standard.[9]

Country codes shown in the IDB are from multiple sources.[10] For convenience and data interoperability, the IDB includes both the Federal Information Processing Standard (FIPS) 10-4 country codes as well as the Geopolitical Entities, Names, and Codes (GENC) standard. The FIPS 10-4 standard was withdrawn in 2008, and has subsequently been replaced by GENC, which is maintained by the National Geospatial-Intelligence Agency and endorsed by the Federal Geographic Data Committee. GENC is a U.S. government profile of the international ISO 3166 country codes standard. Country names shown in the GENC standard are consistent with BGN country names.

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[5] For more information on the U.S. Census Bureau's Rural/Urban Projection (RUP) program, see https://www.census.gov/data/software/rup.Overview.html. For more information on the Census Bureau's Demographic Analysis and Population Projection System (DAPPS), see https://www.census.gov/data/software/dapps.html.

[6] For more information on the U.S. Census Bureau's Population Analysis System (PAS), see Arriaga and Associates (1994) as well as https://www.census.gov/data/software/pas.html

[7] For more information on the United Nations' MortPak software, see https://www.un.org/en/development/desa/population/publications/mortality/mortpak.asp

[8] For more information about the U.S. Board on Geographic Names, see https://geonames.nga.mil/gns/html/bgn.html

[9] For more information on the United Nations M49 standard, see https://unstats.un.org/unsd/methodology/m49/

[10] For more information about U.S. government country code standards, see https://www.fgdc.gov/standards/news/GENC and https://geonames.nga.mil/gns/html/countrycodes.html

Definitions of demographic terms used in this document are available online from the IDB glossary.[11] The Census Bureau strives to apply terms consistent with their usage in the broader demographic research community, though there may be deviations from common usage for applications specific to the Census Bureau or the IDB.

3. Data Sources and Base Estimates

Producing a cohort-component population projection is a multi-step process. Its complexity lies not in the calculations required—computer programs handle this efficiently—but in the derivation of parameter estimates and assumptions about future change used as projection inputs.

An essential step in deriving these inputs is the development of estimates that accurately represent the current de facto population, as well as past and present trends in fertility, mortality, and migration. The development of estimates involves gathering available demographic data, assessing their quality, adjusting them as necessary using demographic techniques, and reviewing their comparability among countries. These estimates, in the context of the projection process, are referred to as "base estimates" or "base data." Once base estimates are developed, they can be used to make reasonable and consistent assumptions about the future course of fertility, mortality, and international migration. Both the base estimates and the assumptions about the future which are formulated by the base estimates comprise the projection inputs which, when integrated and subjected to mathematical calculations embedded in DAPPS or RUP, generate population projections from the base year through 2100.

The following sections describe in more detail the processes of developing base estimates and, thereafter, generating population projections. Also provided is information on data sources. It is important to note that DAPPS and RUP allow the entry of population sex and age structure estimates only for the initial or base year. Thereafter, subsequent measures for the population are used in evaluating the populations projected by DAPPS or RUP but are not entered into the program.

3.1. Base Population: Evaluation of Its Size as Well as Age and Sex Structure

The base population by age and sex is most often derived from census data if available and of acceptable quality. Another source of the base population is official population estimates produced by the national statistical office. Typically, countries which produce good population estimates also have vital registration systems with complete coverage of births and deaths and administrative data that capture international migration. For a limited number of countries where neither an acceptable census nor official estimates are available, a stable population is generated to represent the base age-sex distribution.

Census enumerations are not perfect, and reported data on the population may be affected by several factors. The total population may be undercounted due to the inability of census enumerators to cover the country adequately. Furthermore, the age and sex structure may be affected by age misreporting, by underenumeration of people of certain ages, and in some cases by duplications of people of certain ages. Before using the census counts as the base for projection, they must be evaluated for errors and adjusted when necessary.

[11] To access the IDB glossary, see https://www.census.gov/programs-surveys/international-programs/about/glossary.html

In evaluating census age-sex structures for base population estimates, special attention is given to possible underenumeration of the youngest age groups, 0-4 years and 5-9 years. Underenumeration of the youngest age groups is common in census data of most countries, although the degree of the problem varies. Errors in these ages may have significant impacts on the cohort-component projection. Suppose, for example, that children ages 0-4 were underestimated in the base population. In the projection, not only would the surviving cohorts of these children be smaller than they should be, but when the projected female cohorts reach reproductive ages, their number of births would also be underestimated.

Various methods are applied to detect errors in the census population before it is accepted for use in developing a base population. In evaluating the census population, the errors that the Census Bureau aims to detect are those affecting the total population and its age and sex distribution. While the true values of a country's population and its population by age can rarely be known, these values can often be approximated. Demographic methods can be used to measure net census error, or the difference between what is considered to be the correct value and the value measured by the census.

The main approach for evaluating a census is referred to as demographic analysis (Siegel and Swanson, 2004). This approach essentially entails calculating demographic indices using data from the census under study, and if available, results from other censuses and additional demographic data sources. Using data from the census under study, crude and approximate measures can be made to check for errors in the count of persons. For example, the Census Bureau determines if the census covered all of the country's geography. For some countries, especially those engaged in border disputes or wars, geographic sub-entities are left out of the census altogether. The Census Bureau identifies alternative data sources to measure the population of these omitted areas.

Applying more rigorous demographic techniques, the Census Bureau further utilizes the census results to detect errors in population distributions by sex and age. These techniques entail the analysis of distributions or ratios, including analysis of digit preference, age ratios, and sex ratios.[12] In some cases, analyses are conducted by comparing the census age distribution with an age distribution that would

[12] Indices frequently used by the Census Bureau for detecting digit preference in base population data for the IDB include those developed by Myers (1940), Whipple (1971), and Bachi (1951, 1953). These indices provide an overall idea of the extent of age misreporting as well as the preference for ages ending in certain digits. Age ratio analysis (United Nations, 1952) using population data for 5-year age groups is used to detect age misreporting in populations where fertility has not fluctuated greatly during the past and where international migration has not been significant. Calculations entail dividing the population in a specific 5-year age group by the average population of the two adjacent 5-year age groups, times 100. The larger the fluctuations of these ratios and the larger their departure from 100, the greater the probability of errors in the data. Sex ratios are simply calculated by dividing the male population by the female population in a given age or age group, times 100. For most middle age groups, and depending on the level of sex-specific migration in a population, the larger the departure from 100, the larger the possibility for errors in the data. For the youngest ages, 0 or 0-4, the sex ratio tends to range between 103 and 105 due to biological factors which result in an excess of male births. For some countries, sex ratios for births occurring in the latter half of the 20th century have dramatically increased, to levels above 112 for example, as a result of sex-selective abortions where some parents have a preference for male children over female children. For the oldest age groups, the number of females tends to exceed males; however there are exceptions to this trend as well, largely in societies that favor males. Joint age- and sex-indices -- the sex-ratio score, the age-ratio score, and the age-sex accuracy index -- developed by the United Nations (1952, 1955) are used as summary measures of the age and sex ratios.

have resulted from constant fertility and mortality over a fairly long period of time in a population which has not experienced international migration (a stable population). Through this comparison, age and sex distribution irregularities are detected.

Evaluating a census through demographic analysis is also undertaken using data from previous censuses of the same population. Using data from a previous census, an expected census count of population can be calculated and compared with the census under consideration for base population estimation. More specifically, the previous census total and an assumed rate of intercensal growth can be used to project an alternative population for the base population year. This alternative population—considered the expected population—can be compared with the census under study as a measure of census accuracy. The assumed rate of intercensal growth is calculated using a total population from an additional previous census, or through a more elaborate estimation strategy that entails calculating intercensal growth separately for each of the components of population change—fertility, mortality, and international migration.[13] The level of sophistication applied in estimating intercensal growth varies depending on data availability.

Given that errors in the census population under age 10 are frequently found, demographic analysis oftentimes focuses on examining this age group. The completeness of enumeration for this young population is often evaluated by checking for consistency between its enumerated size and estimated levels of fertility and mortality during the 10-year period prior to the census date, as children under age 10 at the census date represent the survivors of births during the 10-year period prior to the census date. Consistency is checked by first estimating the number of females of reproductive age during the two 5-year periods prior to the census date using the census data and mortality information from another demographic data source. Based on this estimated female population and fertility and mortality levels measured by other demographic data, the male and female births during the two 5-year periods prior to the census date are then estimated. The two estimated 5-year birth cohorts are then projected to the census date, when they will have aged to 0-4 and 5-9 years old. Finally, the projected populations ages 0-4 and 5-9 are compared to the enumerated census population ages 0-4 and 5-9, in order to gauge the census enumeration accuracy.

The Census Bureau also uses a later census to evaluate the base population's under-10 and over-10 estimates. This comparison is performed following the estimation of inputs for the cohort-component projection (which will be more fully elaborated in the sections on mortality, fertility, and net international migration) and the subsequent projection of the base population using the components of change.

For some countries, censuses can be evaluated using results from "Post Enumeration Surveys" (PES). The volume of information available from a PES varies. Ideally two different types of information will be available for a given census: (1) information from a sample survey, taken shortly after the census, wherein residents who responded to census questionnaires are re-interviewed and, less commonly, (2) information from a post-censal matching study that consists of the re-enumeration of an independently-

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[13] This approach also involves evaluating the quality of data related to successive censuses as well as all three components of demographic change and then formulating assumptions about how these pieces of the demographic balancing equation fit together. Data sources used to formulate these assumptions include surveys, vital registration data, administrative records, and, in some cases, estimates of rates from country statistical offices or international statistical organizations.

selected probability sample of the target census population. The Census Bureau will consult the results of both types of PES operations, if available, as part of the process of evaluating the census results that will be used to derive the base population.

In addition to demographic analysis and review of PES results, evaluations of the census population or subpopulations can be made in a rough manner, via comparing them to administrative statistics or survey measures. These aggregate level analyses are often executed using Demographic and Health Survey (DHS) data, available for many countries.[14]

Once errors are detected, techniques are applied to make needed adjustments. Younger age groups found to be underenumerated are often adjusted upward using the results of one of the various aforementioned demographic analysis techniques. If warranted, the age distribution for the older age groups might be adjusted per information from alternative population data sources, as well as smoothing techniques.[15]

For some countries, age data from high quality national-level surveys can also be used to adjust problematic census age data. Country DHS surveys collect age data that the Census Bureau sometimes uses in adjusting a census age structure. Sometimes a combination of such survey data and census data is used. For example, the census totals by sex might be disaggregated by 5-year age groups using survey data.

Once any needed adjustments are performed for the base population, an extra step of moving the base population to midyear[16] is performed using information about fertility, mortality, and migration during the short period between the census reference date and midyear.

After the base population is moved to midyear, the oldest open-ended age group usually needs to be extended to represent age groups up through 100 years and over.[17] Because many country censuses do not tabulate and publish age data for these older age groups and because age misreporting may be especially problematic in older populations, the Census Bureau uses models that take into account assumptions about mortality and population size for various enumerated age groups 55 and older. Currently, the adjustments applied draw from stationary and stable population models.

Decades of evidence and observation confirms that age and sex structure generally reflects an area's level of socio-economic development. Age-sex structures are often referred to as "population pyramids" because in developing societies the base of the pyramid (at younger ages) tends to be far wider than the higher levels (at progressively older ages), reflecting both higher birth rates (which widens the base) and higher death rates (which narrows the higher levels). An example for Afghanistan

[14] The Demographic and Health Surveys Program started in 1984. It was designed to gather demographic data in countries which did not have vital registration systems that adequately captured births and deaths. Under DHS auspices, surveys have been carried out in countries in Africa, Asia, Latin America, the Caribbean, and parts of Europe. For more information about the DHS Program, see https://dhsprogram.com.

[15] Arriaga and Associates (1994: 39-42) provide a comprehensive description of demographic techniques for smoothing in *Population Analysis with Microcomputers*.

[16] The shift to the midyear is undertaken because demographic events for each calendar year – births, deaths, and net migration – when converted to rates, should be reckoned against the average population for each calendar year (for instance, the crude birth rate is births divided by the midyear population). The Census Bureau traditionally has used July 1 as the midyear date for its population estimates and projections.

[17] Extension of the base population to 100 years and over can be performed before or after it is moved to midyear.

as of 1979 is shown in Figure 1. However, as countries develop, both deaths rates and birth rates tend to fall, a process known as the demographic transition, which also leads to an age-sex structure that will be progressively more like a rectangle (or thicker in the middle) than a pyramid (see for instance, the age-sex structure of Finland's population according to its 1990 census; Figure 2).

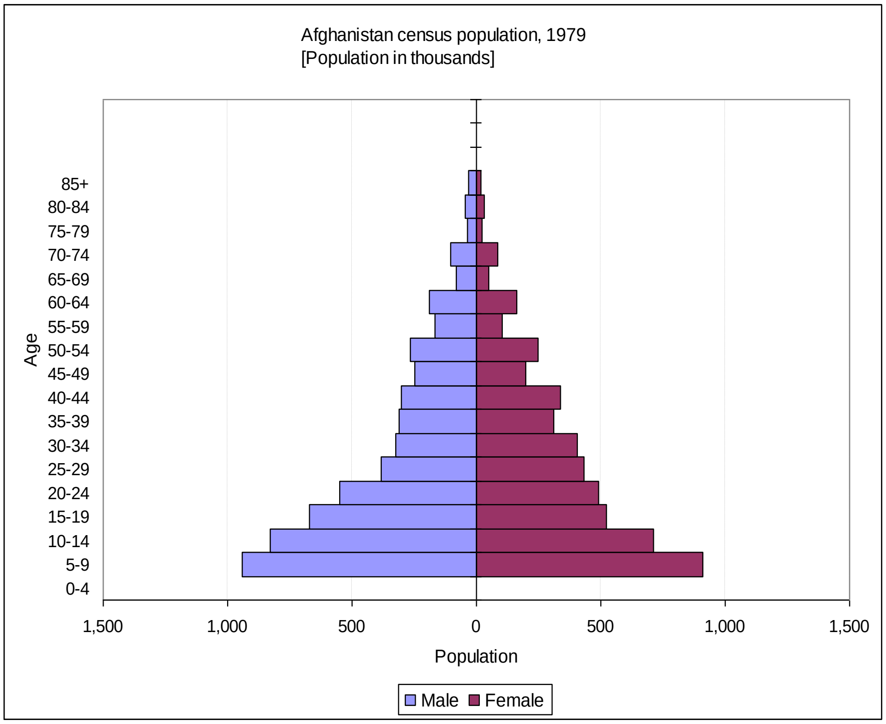

Figure 1: Afghanistan census population, 1979. Source: Census 1979 of Afghanistan as published in the Demographic Yearbook, Historical Supplement 1948-1997 (United Nations, 2000).

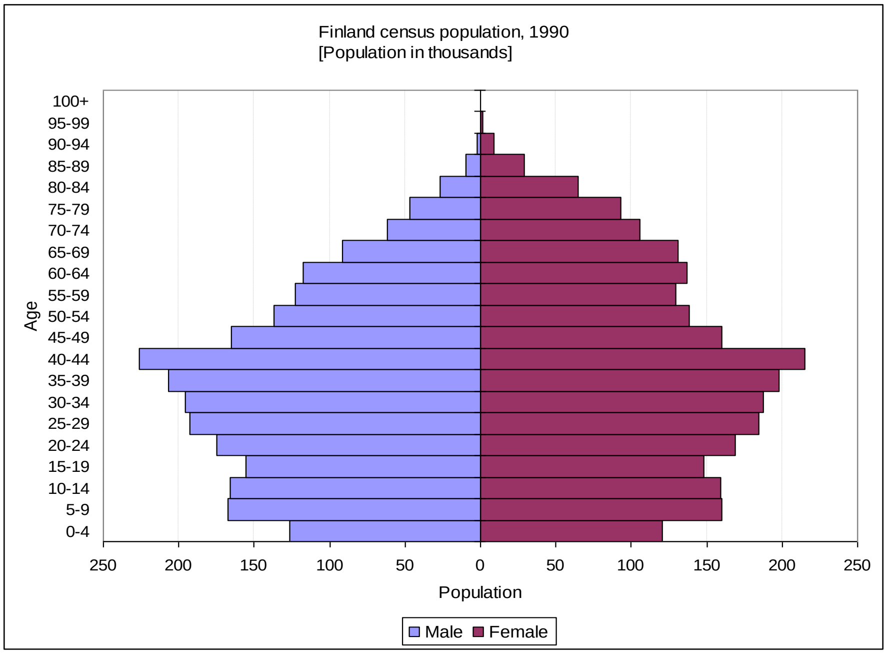

Figure 2: Finland census population, 1990 (in thousands). Source: Census 1990 of Finland as published in the Demographic Yearbook, Historical Supplement 1948-1997 (United Nations, 2000).

Assessments of census coverage errors can go beyond looking for the common problem of under-10 under-enumeration and age misreporting at older ages. Sometimes coverage errors occur in other age groups as well, depending on the political, economic, and social events in a particular country. An apparent dearth in the number of men of military age, for example, can occur when a particular population subgroup is at odds with the national government. Similarly, under-enumeration of the working age population can occur when part of this age group consists of unauthorized immigrants, who may deliberately evade census enumeration for fear of apprehension. On the other hand, excesses in some population groups can be found, depending on their relationships with the national government. Adjusting for these coverage errors usually entails evaluation based on comparison with prior censuses and population change in the interim period, taking into account evidence from special reports or articles about the group in question.

The Census Bureau also has to look beyond census numbers in order to decipher problems in data collection from actual deficits —or in some cases, excesses—in a population for certain age groups and for one gender or the other. This involves knowing the history of a country and examining the extent to which past events have affected the population structure. Some countries with a history of civil strife enumerate relatively small numbers in the male cohorts who had been of military-age at the time of civil unrest. These population losses, furthermore, remain in the population structure as time progresses, and the Census Bureau must calculate the timing of the historical event and ensure that the smaller population size of a particular cohort matches the date of a significant event. The effects of war in 1963 on males ages 20-24, might be apparent in a 2013 population among males ages 70-74, for example.

For other countries, special adjustments must be performed in order to ensure excesses of certain age groups are accurately represented. In many Persian Gulf states, for example, a large proportion of the labor force consists of international migrants who are predominantly male. Because of this particular feature in Persian Gulf countries, the base population age-sex structures for these countries necessarily include a large male-dominant working-age population.

Figure 3 presents the pyramid representing the 2005 preliminary census population for the United Arab Emirates (U.A.E.), as well as the two subgroups of this population: (1) U.A.E. nationals and (2) U.A.E. non-nationals who largely consist of international migrants who moved to the U.A.E. as labor migrants. The two subpopulations, combined, represent U.A.E.'s 2005 de facto population in its entirety.

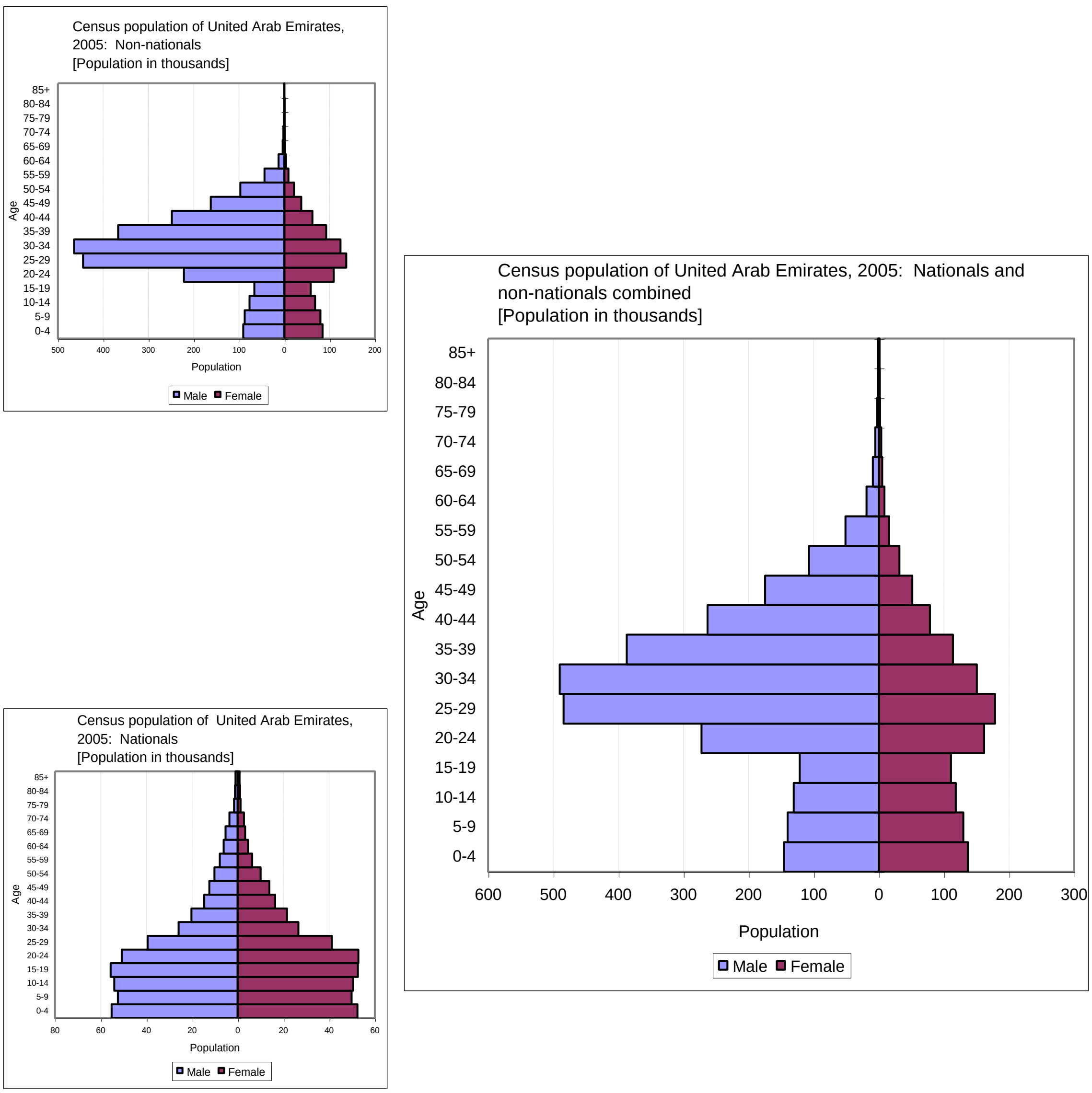

Figure 3: United Arab Emirates population, 2005. Sources: Preliminary Census 2005 of the United Arab Emirates, as published in the United Arab Emirates Statistics Yearbook 2007 (United Arab Emirates).

3.2. Mortality

3.2.1. General mortality estimation procedures

Base estimates of mortality levels and age- and sex-specific patterns needed for cohort-component projections are derived in a variety of ways, depending on data available for each country. For many statistically more developed and higher income countries, base data on mortality are taken from vital registration systems. Official estimates of life expectancy at birth and mortality rates derived by national statistical offices are also sometimes used. For most statistically less developed countries and lower income countries, however, the U.S. Census Bureau develops base mortality estimates using a combination of data sources: nationally-representative household surveys; to a lesser degree, censuses; and increasingly, vital registration data. Additionally, in order to capture unusual increases in mortality, or demographic shocks, special tallies and research reports from various national and international organizations are used.

When a country has high quality death data, we often use the data directly in the cohort-component projection. In cases where country death data do not have a high enough quality to allow for direct use in this way, the data are used as input in life table construction, and the age-specific central death rates generated from the life tables are then used as input in the cohort-component projection. Depending on the quality of the death data, the life table construction process varies in complexity. This process can include 1) an evaluation and adjustment of registered deaths or deaths reported in response to a census or survey question about deaths of household members during the past year; 2) indirect estimation from census or survey questions about child survival, orphanhood, and widowhood; or 3) intercensal population change.[18] Assessments of completeness and of errors affecting registered deaths from the UN Statistics Division's Population and Vital Statistics Reports (United Nations, 2020), the annual UN Demographic Yearbook (United Nations Department of Economic and Social Affairs, 2019), and the World Health Organization's Statistical Information System (WHOSIS) (WHO, 2020) are consulted as a first step in deciding whether registered deaths from a specific country are likely to be usable without adjustment.

When a country does not have high quality death data, mortality for all age groups can be estimated using information on infant and child survivorship collected in censuses and surveys as a guide to both level of mortality and age pattern. In the absence of either registered deaths or a census- or survey-based age distribution of deaths at adult ages, the distribution of deaths across age groups under age 5 provides evidence in the selection of a pattern of mortality at older ages. Both the Coale-Demeny regional model life tables (Coale and Demeny, 1966) and the United Nations model life tables (United Nations, 1982) are used to construct complete life tables consistent with estimated level and pattern of child mortality. With information about the likely pattern of death across all ages, survey-based direct estimates can be integrated with model life tables, in order to generate age-specific death rates.

[18] Methods used to evaluate and adjust both registered deaths and deaths during a 12-month period prior to a census or survey include: 1) Brass' growth balance method and the Preston and Coale technique (United Nations 1983: ch. V) and (2) the general growth balance method (Hill 1987, Bhat 2002). Methods for estimating childhood mortality, including the Brass technique and Palloni-Heligman reformulation, are described in United Nations (1983: ch.III) and United Nations (1990). The Johnson technique is presented in Arriaga and Associates (1994: 167-168). Methods based on survivorship of parents and siblings are described in United Nations (1983: ch. IV). Intercensal survival techniques are covered in United Nations (1983: ch. IX).

However, survey-based estimates of child mortality are not accepted without review. In a distribution of child mortality deaths by month, an examination of the magnitude of infant deaths in the 12th month category, compared with the number of deaths in the 0-11 month categories, and 13-plus month categories, may indicate heaping on the 12th month mark due to normal recall bias. Since a measure of infant mortality requires deaths from 0 through 11 months (the 12th month is not included in the measure) heaping of infant deaths on the 12th month results in an underestimate of infant mortality (and an over-estimate of mortality for children ages 1-4).

An example of age heaping found in child deaths data from Niger DHS surveys for 1992, 1996, and 2006 is shown in Figure 4.

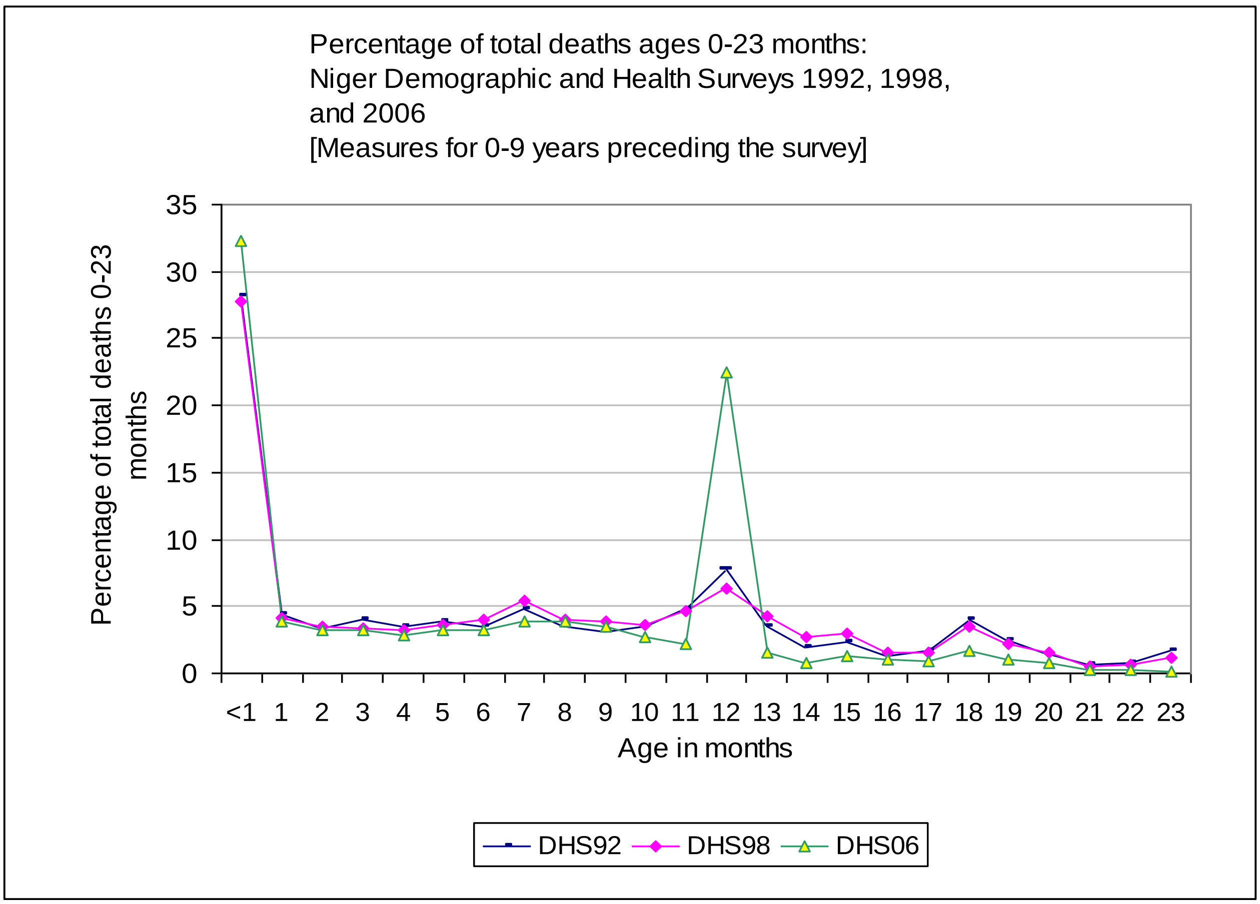

Figure 4: Niger infant mortality from DHS surveys 1992, 1998, and 2006. Sources: Niger Demographic and Health Survey 1992 (Kourgueni et al., 1993), Niger Demographic and Health Survey 1998 (Attama et al., 1998), and Niger Demographic and Health Survey 2006 (Institut National de la Statistique (INS) et Macro International Inc., 2007).

Where birth-history based estimates of infant and child mortality are available from multiple surveys for a country, those estimates are compared across measurement periods. For example, infant mortality rates (IMRs) measured for 0-4 years before a 1995 survey can be compared with IMRs measured 5-9 years before a 2000 survey as a check on consistency. For some countries, estimated under-5 mortality may be distorted by birth transference – misdating that selectively biases estimated child mortality levels (Sullivan 2008). In addition to internal data checks, part of any mortality data evaluation process may involve checking for consistency between adjusted or estimated mortality levels and other demographic indicators for a country. For example, adjusted mortality levels can be evaluated by integrating them into the projections process and by checking the population projected using the mortality inputs against a reliable census or adjusted census population count.

Mortality estimation techniques reviewed thus far are used by the Census Bureau in deriving measures suitable for cohort-component projection input. In some cases, the Census Bureau can rely on mortality estimates produced by other agencies and organizations and will opt to insert these estimates directly into the estimates and projections process, with little or no adjustment to them. Organizations such as the United Nations Inter-Agency Group for Child Mortality Estimation (IGME, 2020) derive and publish such estimates, based on the evaluation of data and development of direct and indirect estimates described above. Acceptance of mortality estimates developed by outside agencies and organizations follows a thorough evaluation of them by the Census Bureau. Evaluation entails a comparison of the organization's estimates with alternative estimates from other sources. The Census Bureau might also develop its own alternative set of mortality estimates as a point of comparison.

Because country populations and the world population as a whole are aging, the Census Bureau now produces estimates and projections of mortality by single age for ages 0-99 and 100 and over for all countries. For some countries, this process is straightforward. For other countries, and often those countries lacking mortality data for older age groups, models are used to estimate the age pattern of mortality at older ages. Even in countries where death data are available for older ages, the use of models for extending mortality up through the older ages is sometimes favored over relying solely on empirical data because empirical deaths from the smaller populations of older age groups are subject to greater age reporting error than those at younger ages. Empirical deaths from the smaller populations of older age groups are also more subject to year-to-year fluctuation and are therefore less stable than are deaths from younger, larger age groups.

The models used to extend mortality to 100-plus begin with the assumption that underlying death rates of older age groups follow a smooth progression, and therefore any fluctuations in empirical deaths rates are due to small numbers of events or errors in the data that are masking the underlying smooth trends. The approach taken draws on research by Coale and Guo (1989) in extending the Coale-Demeny model life tables to age 100-plus using a logistic function.

Due to special circumstances, estimated age-sex patterns and time trends in mortality for some countries rely neither on standard demographic mortality models nor on the patterns found in similar countries. Natural disasters and conflicts distort mortality levels and patterns, requiring additional modeling. Estimated numbers and the age-sex composition of deaths may be taken from reports by various national and international organizations, including the World Health Organization (WHO), the U.S. State Department, the U.S. Agency for International Development (USAID), and the U.S. Centers for Disease Control and Prevention (CDC). Additionally, some national statistical offices conduct their own death accounting and make the results available to the public. More often than not, these special mortality statistics are rough estimates and they do not include complete information on the distribution of deaths by age and sex. Furthermore, such accounts tend not to capture important patterns of immediate death increases and longer-term mortality impacts indirectly related to the unusual event.

Where information supporting the modeling of mortality associated with disasters and conflict is available, these data are incorporated into base mortality estimation. The impact of the 2004 Indian

Ocean tsunami on the mortality rates in Indonesia, for example, was captured for Indonesia's base mortality estimates using special tallies of tsunami deaths combined with survey and other on-the-ground evidence indicating that the relative risk of tsunami deaths was higher for females than males. In other instances, where less information is available, simplifying assumptions are made in deciding how to distribute excess deaths by age and sex. Excess mortality resulting from the 2003 earthquake of Iran, for example, was calculated using a total death tally from the Iran State Statistical Centre and the age-sex distribution of Kerman ostan, the subnational area in which the earthquake occurred. The resulting shock to mortality levels and resulting changes in life expectancy at birth are shown in Figure 5.[19]

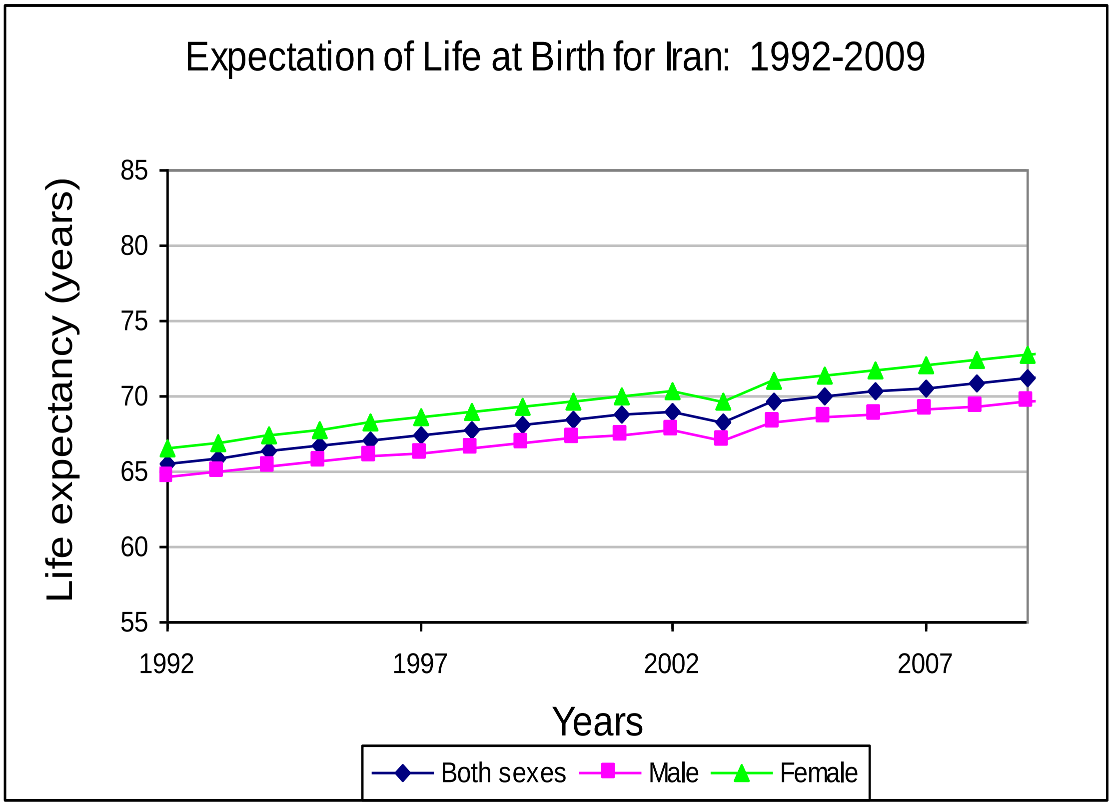

Figure 5: Iran life expectancy at birth, 1992-2009. Source: Based on the U.S. Census Bureau's estimates and projections update for Iran (August 2006).

3.2.2. Population Estimates and Projections Incorporating AIDS

The estimation and projection procedure for countries seriously affected by HIV/AIDS is somewhat complex. For these countries, the Census Bureau models mortality levels and trends under the hypothetical scenario of no epidemic, then adds estimated AIDS-related mortality based on measured HIV prevalence, ensuring that the "with-AIDS" mortality levels are consistent with empirical, population-based estimates. The starting point for the procedure is the Census Bureau's HIV/AIDS Surveillance Database. This tool can be found at https://www.census.gov/programs-surveys/international-programs/about/hiv.html.

[19] Life expectancy at birth for Iran measured in Iran's estimates and projections update, August, 2006.

Information on HIV prevalence found in the Census Bureau's HIV/AIDS Surveillance Database is used to model the AIDS component of mortality for seriously affected countries.[20] Mortality attributable to AIDS is separately modeled because the shape of age-sex-specific mortality in affected countries departs from patterns found in countries having good quality vital statistics and in countries reasonably described by any of the age-sex patterns available from the Coale-Demeny or United Nations regional model life tables. AIDS mortality is added to estimated non-AIDS mortality prior to projection. Since first incorporating AIDS mortality into estimates and projections in the early 1990s, AIDS mortality was modeled over the years for approximately 52 countries located in Asia, Latin America and the Caribbean, Sub-Saharan Africa, and Eastern Europe. Over time, some countries fell below the generalized epidemic threshold. Therefore, we dropped those from the listing of countries where AIDS-only mortality was explicitly modeled. In a few instances, a country or two were added back onto the list of countries with generalized epidemics when new data existed to justify re-inclusion on the list.

We extract the AIDS mortality by sex and age from the Spectrum country files submitted to the Joint United Nations Programme on HIV/AIDS (UNAIDS).[21] In generalized epidemics, the epidemic is modeled in Spectrum as urban/rural using data from pregnant women tested either in the antenatal clinic sentinel surveillance system, or more recently in prevention of mother-to-child transmission (PMTCT) programs. Much of this surveillance data in the Spectrum files can be found in the HIV/AIDS Surveillance Database. Each Spectrum file contains the most recent estimates of national-level HIV prevalence since 1970, the usual base year used in the Spectrum file, along with other indicators of the HIV epidemic such as adults and children on anti-retroviral treatment (ART), new HIV infections, AIDS deaths, PMTCT coverage, and—of importance to us—the AIDS mortality rates.[22] These are only a few of the numerous indicators available from Spectrum. The benefit of using the Spectrum-generated AIDS mortality rates in our own estimates and projections is that we are using the official estimates and short-term (five-years into the future) projections that the country's epidemiologists consider appropriate for the epidemic in that country.

Spectrum incorporates estimates of HIV prevalence from the Estimation and Projection Package (EPP), an epidemiologically realistic model developed by the World Health Organization (WHO) and UNAIDS. EPP functionality is built into the Spectrum software. EPP produces a national "best fit" curve of adult HIV prevalence using sentinel and PMTCT surveillance data pertaining to pregnant women visiting

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[20] The U.S. Census Bureau compiles HIV prevalence information for all countries and areas of the world with at least 5,000 population, with the exception of Northern America (including the United States) and U.S. territories in its HIV/AIDS Surveillance Database. This database contains over 200,000 records from various publications, surveillance reports, and conference proceedings. HIV prevalence points taken from this database are the basis for projecting HIV prevalence and estimating AIDS mortality in countries that have generalized HIV/AIDS epidemics only. A generalized epidemic is an epidemic that is widespread in the general population. HIV transmission is mainly through heterosexual sex. The criterion for determining whether a country has a generalized epidemic is when HIV prevalence is consistently above one percent in pregnant women.

[21] The Spectrum software is available for download free of charge at www.avenirhealth.org.

[22] UNAIDS uses 1970 as the starting year for any Spectrum projection since it is generally agreed that little, if any, AIDS mortality impact occurred in that year or prior. Spectrum must use a base year where AIDS has not affected the population age and sex structure.

antenatal clinics, as well as data from population-based surveys that are used to calibrate the urban and rural EPP modeled fits. In order to model AIDS-related mortality, the most recent country-specific adult HIV prevalence estimates from EPP were generated for years from the beginning of the epidemic to 2025. UNAIDS recommends that Spectrum users constrain the end year of the projections to five years into the future. The Spectrum software has built into it epidemiological assumptions from the UNAIDS Reference Group on Estimates, Modelling and Projections about, among many, the age and sex distribution of HIV incidence, sex ratios of new infections, the mother-to-child transmission rate, and disease progression in both adults and children. This reference group provides the relevant technical basis for the UNAIDS global estimates and projections of HIV prevalence. They represent the consensus reached at meetings held with representatives from the United Nations Population Division, U.S. Census Bureau, United Nations Children's Fund (UNICEF), WHO, and UNAIDS among others. Further, the model allows for competing risk of death and projects HIV incidence implied by the EPP estimates of HIV prevalence through 2025, or whatever the final year in the Spectrum file is.

As scientists began to understand the changing nature of the HIV epidemic, the software was updated for that increased complexity, with the software calculations getting progressively more complicated over time. However, Spectrum remains a user-friendly package especially for the user who understands infectious disease epidemiology and modeling. The fitting of prevalence point estimates is conceptually quite simple. Each country has at least several sentinel surveillance sites that measure the number of HIV-infected pregnant women. The number of women infected with HIV from each site is then used to develop one prevalence point estimate for the country by year. These point estimates represent a "best fit" of all available empirical data for the years where data are available. A realistic pattern from which to project future prevalence is also established.

The EPP model conceptualizes the AIDS epidemic curve as taking place via the following process: a population is initially separated into two parts, people not at risk of HIV infection and people at risk. The population increases with new "entrants" – those who reach the age of 15. The population decreases by the "exit" of people who die – those who become infected with AIDS and progress to AIDS death and those who die from causes other than AIDS. Child infections occur either in utero, during delivery of the child, or during the post-partum period through breastfeeding. At the same time, a certain percentage of the newly infected population go onto treatment and are successful with that treatment, some fail on first line treatment and subsequently take up second (and third line) treatments, and some individuals never get put on treatment at all.

The Census Bureau uses cohort-component methods to prepare population estimates and projections using the Census Bureau's Demographic Analysis and Population Projection System (DAPPS). Both a "Without AIDS Scenario" and a "With AIDS Scenario" are produced. The hypothetical "Without-AIDS Scenario" shows what the Census Bureau's modeling work indicates would have happened if a country had not been affected by the HIV/AIDS epidemic. The "With-AIDS Scenario" is then generated showing what has happened and what is projected to happen in a country as a result of AIDS mortality and its demographic consequences. The "Without-AIDS Scenario" modeling takes into account not only lower death rates but also associated changes to a country's age and sex profile and, indirectly, the combined effects of lower mortality and changing population composition on demographic indicators. The "Without-AIDS Scenario" currently assumes the same fertility rates (based on observed data) as the "With-AIDS Scenario" and thus likely underestimates what fertility might have been in the absence of AIDS. In the "With-AIDS Scenario", the number of births decreases because of mortality-induced reductions in the number of women of reproductive age. There is also ample evidence that the fertility of HIV-infected women is suppressed through biological alterations in reproductive physiology and systemic illness, stress, weight loss, and a reduction in sexual activity due to illness. However, with the widespread use of ART, fertility among HIV-infected women is likely to return to a more normal level.

3.3. Fertility

As in the case of mortality, procedures for estimating fertility depend on the availability of data and on the level of details in the available data. For countries where vital registration is complete, fertility can be measured directly using classical demographic procedures. Some countries have vital registration systems that produce data that are reliable, accurate, and which capture the timing of births with relative precision. Such data tend to be released on a regular, usually annual basis, and they include births by age of mother for single years of age. In cases where births are not available, official government estimates of fertility, such as age-specific fertility rates (ASFRs) published in country statistical yearbooks or other regional statistical databases are accepted. Country censuses also provide fertility data, although in practice census data alone are not used to measure fertility for most countries.

Fertility for statistically less developed countries is estimated using data from surveys, censuses and, to a lesser degree, vital registration systems. Additionally, in order to capture unusual changes in fertility levels and patterns, information from special surveys and epidemiological studies is routinely consulted.

Registered births, like registered deaths, are evaluated in order to identify potential problems. The extent and sophistication of the evaluation varies by country. Many countries have historically lacked vital registration systems that produce statistics of a quality suitable for direct estimation, although during the latter half of the 20th century the systems of many countries had shown marked improvements. Before accepting registered births for projection, the Census Bureau checks available completeness ratings of the data—the United Nation's Population and Vital Statistics Reports (United Nations, 2020) provide country-specific assessments indicating if completeness is 90 percent or higher—and will evaluate births by comparing fertility levels implied by registered births with fertility estimates from other sources.

Since many countries have historically lacked reliable vital registration systems, techniques have been developed to measure fertility indirectly based on census or survey data for these countries. Some of these techniques rely on the age structure of a population from a census or the ages of children and their mothers, and an independent estimate of the level of mortality in a population. Other techniques use census and survey data from questions asked about births occurring during a fixed period of time preceding the inquiry and about the number of births a woman has ever had.

Census data that can be used in fertility analyses are available to some degree for most countries. Some fertility estimation techniques do not require the collection of census data related specifically to fertility. The age structure measured by the census can be used to estimate fertility levels through several techniques. Using the age structure of a census population, the crude birth rate is sometimes estimated by the rejuvenation technique, in which the population at the youngest ages is "reverse survived" to determine the number of births from which there are survivors. This technique is attractive because it does not require the collection of data related specifically to fertility. However, the reliability of the estimate depends on the quality of both the census data on age and the survival ratios used for the rejuvenation. Under certain circumstances, census data by age can be used to obtain not only a crude birth rate but age-specific fertility rates as well. This can be done by using the own-children technique based on information on children and women by single years of age (Arriaga, 1994; Siegel and Swanson, 2004; United Nations and National Research Council, 1983).

Other techniques, such as the Rele technique, use census data by 5-year age groups to calculate the net reproduction rate or total fertility rate (TFR) based on the relationship of children of specified ages to the number of women in childbearing ages (Rele, 1993). The Rele technique is used in slightly different ways, depending on the quality of census data being utilized. For less statistically less developed and lower income countries with extreme underenumeration in the under-10 age groups, the Rele technique is used to establish a lower-bound fertility level. For countries whose census data appear to have relatively minimal undercount in the under-10 age group, the results of the Rele technique are given more weight and sometimes accepted as the TFR measure for a particular time point.

Many countries' censuses and surveys include questions related specifically to fertility, such as number of births in the past year and the number of children to which women have given birth. Responses to such questions can be used to evaluate fertility as well as to estimate fertility indirectly. The responses to these questions produce two measures of fertility that, when compared, can speak to the reliability of the data. Numbers of births within the past year per cohort of women are used to estimate ASFRs. Similarly, the number of children ever born across a woman's reproductive life time can be used to approximate ASFRs. Two techniques utilize these comparative measures of fertility: (1) the P/F ratio technique and (2) the Arriaga technique.[23] The P/F ratio technique, developed by Brass (United Nations and National Research Council, 1983; Chapter II), is based on the average number of children ever born to women in 5-year age groups and women's age pattern of fertility derived from births in the year preceding the census or survey. The Arriaga technique is similar to the P/F ratio technique but links data for more than one date (Arriaga, 1983 and Arriaga and Associates, 1994: 233-235).

National-level surveys that provide data for fertility estimation include those undertaken as part of the USAID DHS Program's surveys (USAID, 2020a); the World Fertility Surveys (WFS)(USAID, 2020b); the U.S. CDC Reproductive Health Surveys (CDC, 2020); Pan Arab Project for Child Development (PAPCHILD) surveys (UNESCWA, 2020a), as well as its derivatives, the Pan Arab Project for Family Health (PAPFAM) (UNESCWA, 2020b) and Gulf Family Health Survey (GFHS); and United Nations Children Fund's Multiple Indicator Cluster Surveys (MICS) (UNICEF, 2020). These surveys capture birth history data, or data on the number of births per woman and timing of births by year and age of mother. In some cases these data are of a high enough quality to use directly.

Before accepting these direct estimates for projection, they are evaluated by the Census Bureau. In evaluating survey data, special attention is given to the coverage in surveys. Coverage in some countries can be challenging given unstable political and economic situations.

Estimated age-sex patterns and time trends in fertility for some countries rely neither on standard demographic fertility models nor on the patterns found in similar countries due to special circumstances. Natural disasters and famines distort fertility levels and patterns, requiring additional calculations. Estimated numbers and sex composition of births may be taken from reports by various

[23] Reported age-specific fertility based on vital registration data can also be used in these techniques; however, in practice, survey data and secondarily, census data, are most often used.

national and international organizations. Often these special fertility measures are rough estimates and they might not include complete information on the distribution of births.

Where information supporting the modeling of fertility associated with disasters is available, these data are incorporated into base fertility estimation. Where information is not available for a particular country, information from a similar country might be used in place of data for the country under study. In some instances, simplifying assumptions are made in deciding how to adjust fertility levels and patterns. For example, a one-year dip in childbearing may be assumed for a population affected by famine, as the Census Bureau did for Sudan, which was affected by a severe famine in 1988 (Figure 6).[24]

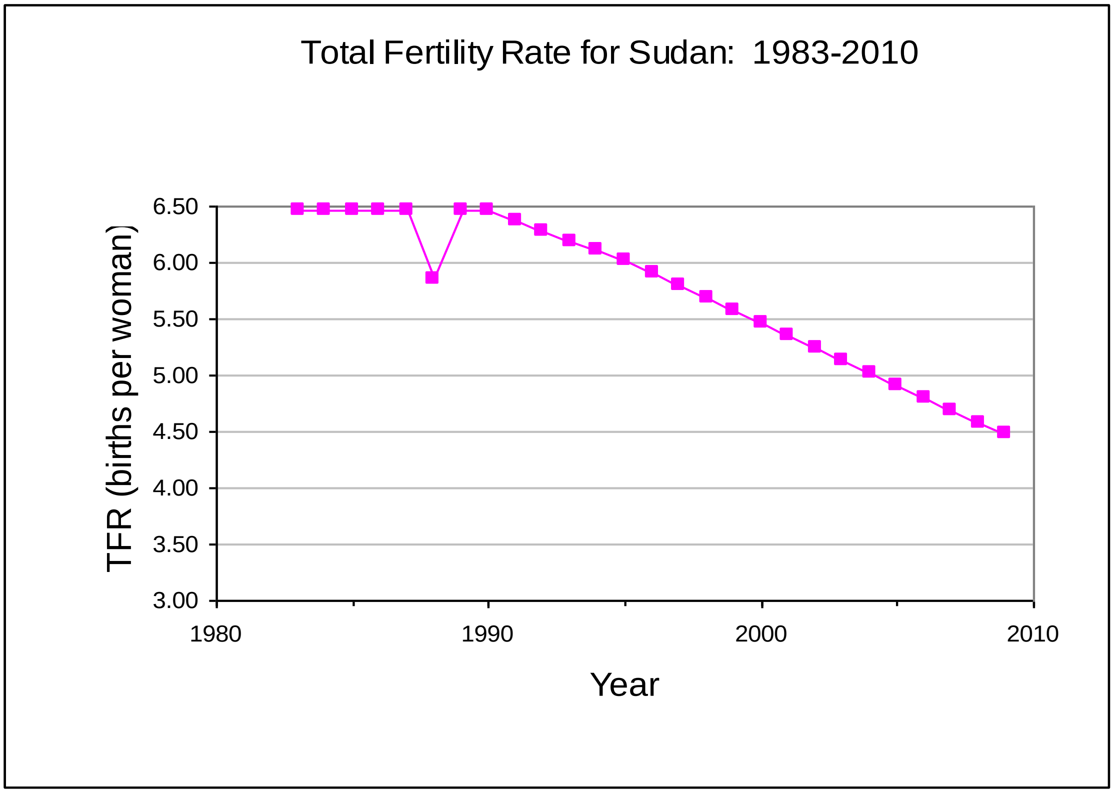

Figure 6: Total fertility rate for Sudan: 1983-2010. Source: Based on the U.S. Census Bureau's estimates and projections update for Sudan (July 2006).

3.4. Net international migration

Unlike births and deaths, few countries are able to assess net international migration with great confidence. A key challenge is that net international migration results from two separate streams of inflows and outflows. Yet even for countries with strong statistical systems, the ability to track each of these flows is limited, especially in countries where informal or undocumented migration is prevalent. In addition to using direct estimates available from various sources, the U.S. Census Bureau often attempts to estimate net international migrations based on 'residual' and other indirect techniques of demographic analysis.

[24] Sudan fertility from update for July, 2007.

Since the early 2000s, the amount of data sources for migration has increased, thereby providing new opportunities for the Census Bureau to improve its international migration estimates. Specific data sources for migration vary widely across countries. However, some general sources consistently used by the Census Bureau for net international migration estimates include country census data on the foreign born population, European Commission data compilations on immigrants and emigrants, country arrivals and departures data, country records of visas and residence permits issued, specialized surveys, and administrative records from the United Nations High Commissioner for Refugees (UNHCR, 2020). In addition, the following organizations publish reports on a regular basis from which the Census Bureau extracts international migration statistics: the Economic Commission for Latin America and the Caribbean (UNECLAC,2020), Eurostat (European Commission, 2020a), the International Labour Organization (ILO, 2020), International Organization for Migration (IOM, 2020), the Organisation for Economic Co-operation and Development (OECD, 2020), the Norwegian Refugee Council (NRC, 2020), the United Nations High Commissioner for Refugees (UNHCR, 2020), the U.S. Committee for Refugees(USCRI, 2020), and several U.S. government departments (e.g., Department of State, Department of Homeland Security, and Department of Defense).

Some country censuses contain data on place of birth of the foreign-born population that are especially useful for estimating net migration. Net migration of the total foreign-born population over time can be measured with these data by comparing cohorts of the foreign-born across an intercensal period. With place of birth data, migration for a particular country can be gauged through the same technique. This is especially useful in trying to capture emigration levels from that country since statistics on emigration tend to be scant. Census data on the foreign-born are generally more helpful in estimating legal migration. Legal migration can also be estimated with country arrivals and departures data, if the data were processed in a way that renders them useful for statistical purposes. Similarly, if good country records are available on visas, work permits and residence permits of the foreign laborers, the Census Bureau tries to use them at least as a supplement to estimates of legal net migrants.

International refugee movements are a subset of legal cross-border migration and these kinds of movements are particularly important to demographic change in some countries. These special migration flows are incorporated by considering reported numbers of refugees documented in administrative statistics by international organizations, country sources, and media reports. In order to estimate refugee movements directly, we generally use UNHCR refugee data and subtract the refugee stock populations across two consecutive years in order to capture a net flow from one year to the next. Net flow can be more precisely tracked by examining and adjusting for data limitations. Because refugee data are collected typically in unstable situations, they often cannot capture the change in the refugee population due to births and deaths. Another issue that is commonly addressed is change in, or cessation of, refugee status. When this occurs groups of migrants might cease to show up in official accounting. Special UNHCR reports, and reports by groups such as Human Rights Watch and Amnesty International, are then relied upon to aid in quantifying the migrants. Where possible, the Census Bureau adjusts the refugee data for these population dynamics and status changes.

Refugees are largely considered as temporary migrants, since the goal of the United Nations is often to repatriate them to their home country; therefore where data aren’t available, the Census Bureau usually assumes that most refugees will repatriate to their home country.

Some refugee populations, however, are relatively long term. For countries hosting these long-term refugees separate base populations are calculated and recombined to produce a total population of de facto residents. For example, Pakistan has hosted a large settled group of refugees and refugees' families from Afghanistan since 1979 when a large influx of Afghan refugees sought asylum there. In order to capture the population dynamics of the Afghan refugees, the U.S. Census Bureau developed a separate 1981 base population for them,[25] and estimated their population dynamics using a special set of indicators.

The adjustments reviewed thus far are used by the Census Bureau in estimating net migration. In some cases the Census Bureau can rely on net migration estimates produced by other agencies and organizations and will opt to insert these estimates directly into the estimates and projections process, with little or no adjustment to them. Organizations such as the European Commission and the United Nations Economic Commission for Latin America and the Caribbean, as well as country statistical agencies, sometimes publish such net migration estimates. Acceptance of net migration estimates developed by outside agencies and organizations follows a thorough evaluation of them by the Census Bureau. Evaluation entails a comparison of the organization's estimates with alternative estimates from other sources. The Census Bureau might develop its own alternative set of net migration estimates as a point of comparison, as well.

Where no direct estimates are available for net migration estimation and where no data are available to produce direct estimates, indirect techniques are used. Indirect methods to estimate migration vary widely by country, and this document does not cover all the methods' nuances (Siegel and Swanson, 2004). However, indirect techniques are usually applied through an iterative process to try to generate plausible results.

There are some fundamental techniques used to varying degrees to estimate migration indirectly, including census cohort analysis and residual techniques. Census cohort analysis entails examining population by year of birth for each sex based on data from at least two censuses. Usually, the comparison is conducted by graphing 5-year and 10-year cohorts by year of birth. By graphing the population by year of birth, the comparison illustrates irregularities of the population's age structure that may have resulted from net migration. Such a comparison cannot disentangle actual demographic history from statistical errors; however, it can be useful as an initial step in examining possible migration movements.

The indirect method often used to estimate net intercensal migration for countries lacking good statistics involves deriving migration as a residual. This residual method—based on the demographic balancing equation—compares age-sex distributions from a census (or an adjusted census) with an age-sex distribution resulting from a population projection that accounts for natural increase only, excluding the impacts of migration. The difference between the two populations is then attributed as net migration. The graph in Figure 7 illustrates the technique used to measure net migration of males in

[25] The 1981 base population for estimating and projecting Afghani refugees was developed by projecting the total 1979 refugee population to 1981, accounting for fertility and mortality. Thus, a small percentage of the 1981 "refugee" population included Afghani children, 0-2 year olds, who are not migrants. In our estimates and projections accounting process, the children of Afghani refugees are placed in the category of "refugees" since their demographic experience is more similar to their Afghani refugee parents, even though Pakistani citizenship rules allow for the acquisition of Pakistani citizenship by birth.

Niger between 1977 and 1988. In the graph, the "Reported" line represents the reported age-sex distribution of Niger, taken from the Niger 1988 census and adjusted for coverage errors, and smoothed. The "RUP Interpolated" line represents a 1988 population projected forward from a 1977 census-based population. The gap between the two lines implies net emigration from Niger, largely between ages 5 and 59.

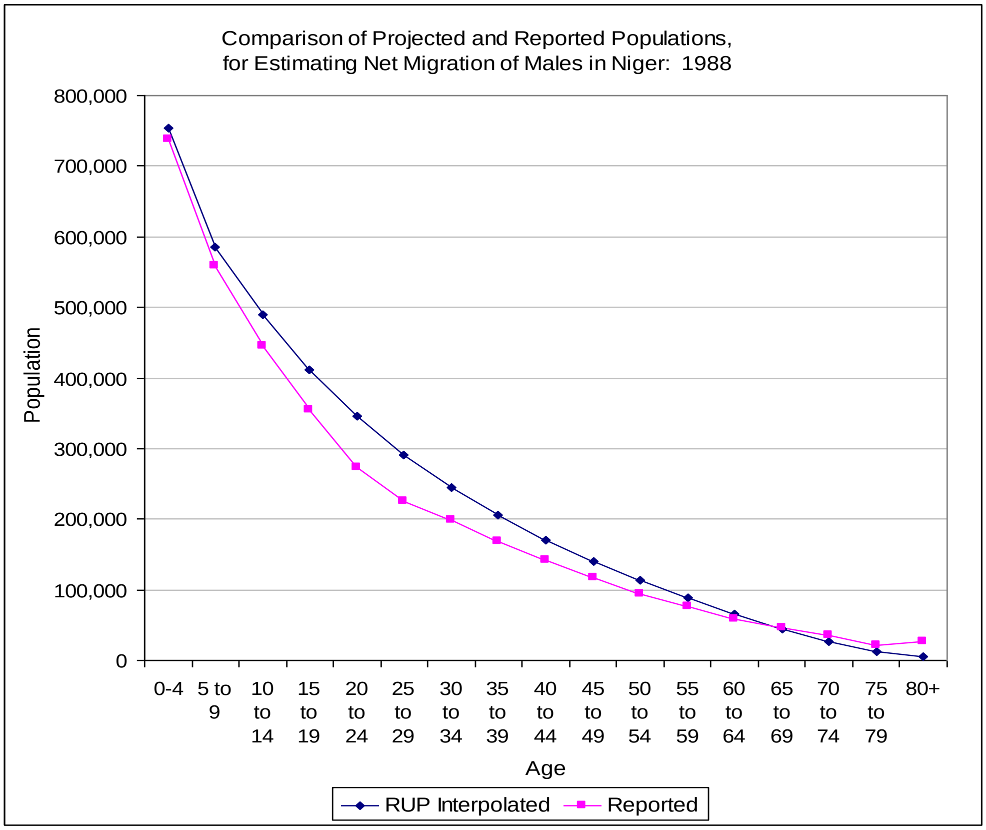

Figure 7: Comparing Projected and Reported Populations, for Estimating Net Migrations of Males in Niger: 1988. Source: Based on the U.S. Census Bureau's estimates and projections update for Niger (December 2008).

For some estimates, the age-sex distribution implied by the comparison is used in combination with official statistics from country governments. This technique of combining data was used for estimating Canada's net migration. Specifically, official statistics on migration totals were accepted and then disaggregated by age and sex using the distribution implied by the residual procedure.[26] Figure 8 shows an example of the age-sex distribution for females implied by a comparison of a 1996 projection with an adjusted 1996 census population for Canada.

[26] This technique was used for the estimates and projections update of Canada in March, 2008.

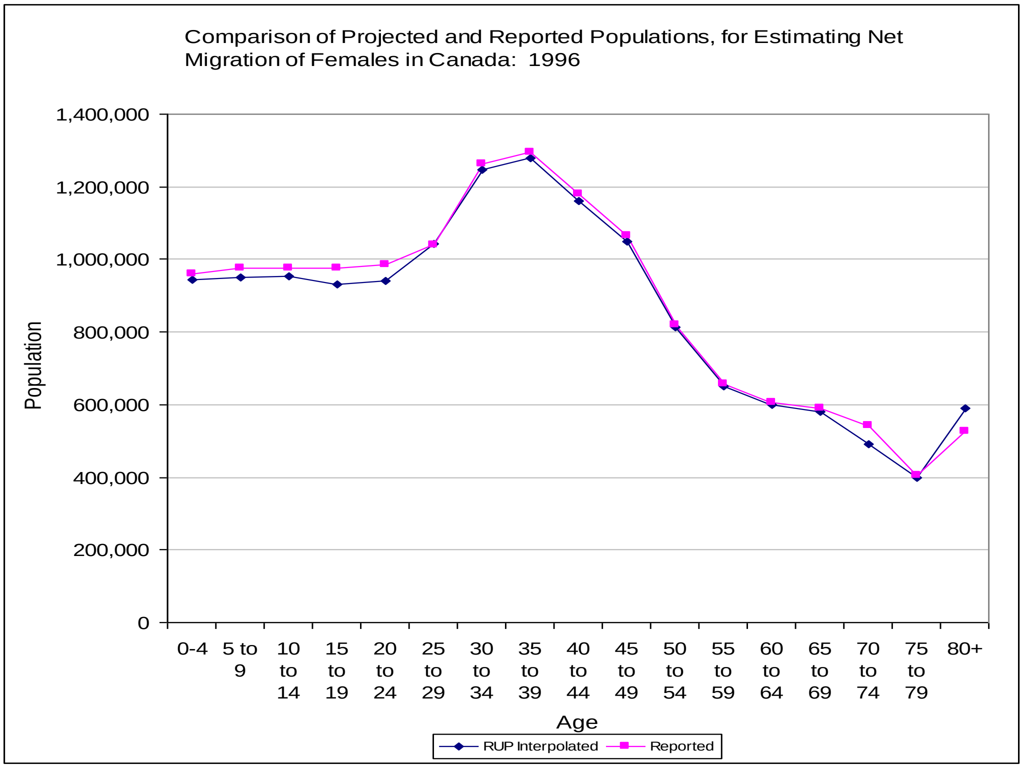

Figure 8: Comparison of Projected and Reported Populations, for Estimating Net Migration of Females in Canada: 1996. Source: Based on the U.S. Census Bureau's estimates and projections update for Canada (March 2008).

The residual technique is used, as needed, in migration estimation for most countries, sometimes in combination with data on international migration available from population registers, censuses, surveys, and administrative records where such data of suitable quality are available.

Indirect techniques are often used in cases where a substantial proportion of migrants are unauthorized, since unauthorized migrants are often not represented adequately in statistical systems. Additionally, sometimes the Census Bureau takes information from news media or special migration reports and studies. Destination country records on immigrants, too, can provide at least a partial representation of emigration for some countries. For many countries, a combination of estimates derived from indirect techniques and those calculated directly from source data are used. Because of the uncertainty involved in estimating unauthorized migration, broad and sometimes extensive assumptions are necessarily made. In analyzing data on unauthorized migration and formulating assumptions, special attention is often given to the principal countries of origin and destination.

4. Projecting Population and Components of Change

Once estimates of mortality, fertility, and net international migration have been developed, each component must be projected into the future. Although the procedure for doing this is often mechanical, care must be taken in determining projected levels, trends, and patterns by age. Not only must the assumptions be appropriate for the particular country in question, but an accurate measure of consistency must be established across countries.

4.1. The Cohort-Component Method

Census Bureau population projections rely on the cohort-component method. A cohort-component population projection follows each group of people of the same age and sex throughout its lifetime, exposing it to assumed age- and sex-specific mortality, fertility, and migration (Arriaga and Associates, 1994; Siegel and Swanson, 2004).

An initial or base year population, disaggregated by age and sex, is exposed to estimated age-sex-specific chances of dying as determined by estimated and projected mortality levels and age patterns. Once deaths are estimated, they are subtracted from each age, yielding the next older age in the subsequent period. Although 5-year age groups can be used in implementing the cohort-component method, the Census Bureau uses single years of age in developing the estimates and projections provided in the IDB. Fertility rates are projected and applied to the female population of childbearing age to estimate the number of births every year. Each cohort of children born is also followed through time and survivors are calculated after exposure to mortality. Finally, the cohort-component method takes into account immigrants who are incorporated into the population and emigrants who leave the population. Net migrants are added to, or subtracted from, the population at each specific age. The whole procedure is repeated for each year of the projection period, resulting in the projected population by age and sex, through 2100.

4.2. Mortality

Some assumptions about mortality trajectories are consistent across countries and regions. In general, mortality is expected to continue to decline in most countries, as economic development occurs and healthcare improves. A particular exception relates to the impact that AIDS will have on the mortality of some countries. While there is no single correct method to make assumptions about the future, the Census Bureau relies heavily on extrapolation of past trends in indicators, coupled with validation checks against published estimates of mortality determinants and correlates in preparing assumptions about future trends.[27] S-shaped logistic functions (bounded by a ceiling and a floor) are typically used to model the transition from low to high life expectancy at birth.

In order to project future mortality levels, the Census Bureau fits a logistic curve to recent estimates of life expectancy at birth by sex. The results of the logistic projection are carefully scrutinized to ensure

[27] Correlates of mortality include childhood immunization coverage, for example.

that they yield an acceptable projected level for the given individual country's circumstances.[28] Currently, the Census Bureau uses a variant of the basic logistic to project e(0) that assumes the same slope for each country. This variant was developed at the Census Bureau in the late 1990s by fitting the logit transformation of e(0) for a number of countries and denoted as the fixed-slope logistic.

After assumptions about future levels of components are developed, age patterns of mortality for each of the projected values are then produced since these patterns tend to vary as overall levels change. For each level of projected life expectancy at birth, a set of central death rates is estimated using an iterative interpolation process. The interpolation is logarithmic and uses a set of central death rates for the last input year—an ultimate set of rates with very low mortality. Life tables constructed with the interpolated rates correspond to the life expectancies at birth projected previously.

Finally, distinctive mortality assumptions are made for selected countries because of the death risk due to AIDS. Using methodology that takes into account the effect of AIDS, country projections are prepared that assess its impact on future populations in countries where the HIV prevalence is significant. See section 3.2 for more information on AIDS mortality.

4.3. Fertility

As with the case for mortality, some assumptions about the fertility trajectories are consistent across countries and regions. An expected increase in contraceptive prevalence is implicit in the assumptions about future fertility declines for many countries. For some countries, future fertility levels are projected to experience only minor change, either slight decreases or slight increases. The Census Bureau also relies heavily on extrapolation of past trends in fertility indicators, coupled with validation checks against published estimates of determinants and correlates in preparing assumptions about future fertility trends. Logistic functions are typically used to model the transition from relatively high fertility to relatively low fertility.

In order to project future fertility levels, the Census Bureau generally fits a logistic curve (again, shaped like an “S”) to one or more estimates of total fertility rate (TFR). If estimates of TFR are available for more than one date in the past and the TFR is not already below 1.7, a logistic function is fitted to these

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[28] In using the logistic function to project life expectancy at birth (e(0)), the Census Bureau utilizes sex-specific upper and lower limits, called asymptotes, to control the values projected by sex. The formulation of the standard logistic function expresses predicted e(0) as a function of defined lower and upper asymptotes and the estimated slope and intercept of an ordinary least squares regression line fitted to the logits of estimated e(0)s. Logit transformations are calculated as:

$$\mathrm{logit}(e(0)t) = \ln\left[\frac{(e(0) - LB)/(UB - LB)}{1 - (e(0) - LB)/(UB - LB)}\right]$$

where UB is the upper asymptote for the logistic function, LB is the lower asymptote for the logistic function, and t is time in years. Predicted values based on the fitted, linear relationship, $\mathrm{logit}(e(0)t) = \hat{a} + \hat{b}t$, are then converted to predicted e(0)s:

$$\hat{e}(0) = \left(\frac{e^{a+bt}}{1 + e^{a+bt}}\right) * \left(UB - LB\right) + LB$$

where a is the intercept of a line fitted to the logit transformations and b is the slope of a line fitted to the logit transformations.

data. The results of the logistic projection are carefully scrutinized to ensure that they yield an acceptable projected level for the given individual country's circumstances. In some instances, no data on past trends in fertility are available for fitting a logistic curve. In that case, the past experience of neighboring or similar countries may serve as a guide for fitting the likely pace of future change.

In our recent extension of projections to 2100, a linear extension from 2050 to 2100 was often presumed for consistency with prior projections, one which look like a logistic function. A logistic function is typically used to project TFRs to 2050 or 2100, with lower and upper limits depending on the current level of fertility in a country. There are some commonalities within regions, however. Regions that tend to be transitioning from higher to lower fertility have high TFR limits of up to an average of 9 births per woman and a lower limit for 2050 of 2.[29] An example of TFR projected along a logistic curve with an upper asymptote of 7 and a lower asymptote of 2 is shown in Figure 9.

[29] The functional form of the standard logistic curve used to project TFR is:

$$\hat{TFR}_t = \left(\frac{e^{a+bt}}{1+e^{a+bt}} \right) * \left(UB - LB \right) + LB$$

where

UB is the upper asymptote for the logistic function

LB is the lower asymptote for the logistic function

b is the slope of a line fitted to the logit transformations of observed TFRs

a is the intercept of a line fitted to the logit transformations of observed TFRs

t is time in years

and the logit of each observed TFR is

$$\ln\left[\frac{(TFR - LB)/(UB - LB)}{1-(TFR - LB)/(UB - LB)} \right]$$

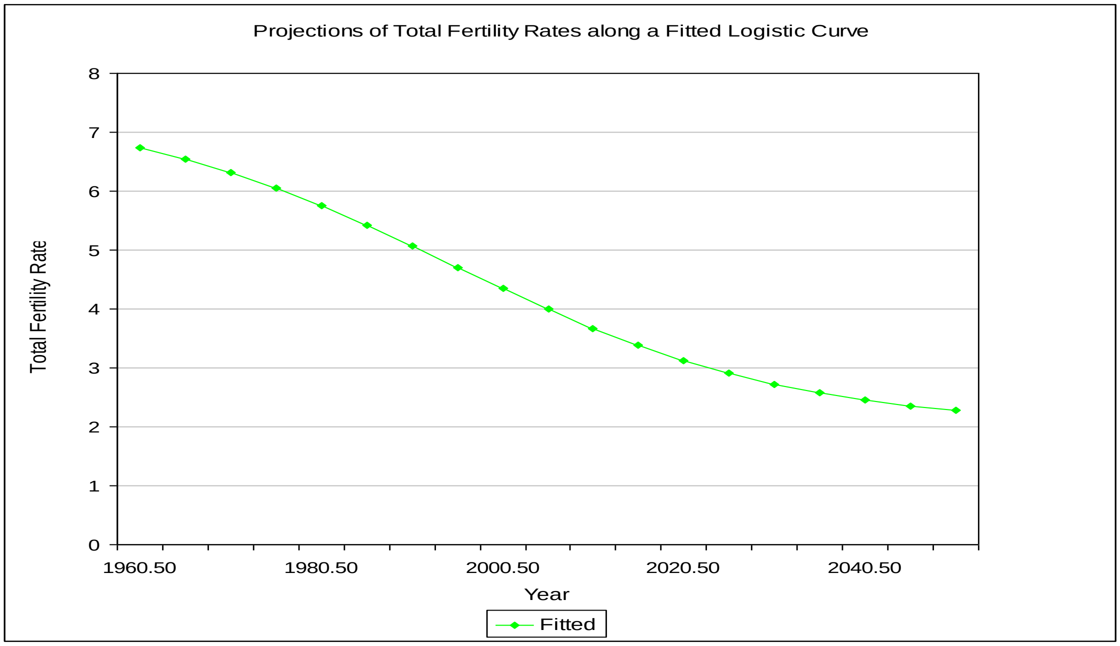

Figure 9: Projections of Total Fertility Rates along a Fitted Logistic Curve. Source: U.S. Census Bureau.

The results of logistic projections are evaluated in light of recent socioeconomic trends, social policies, public health and program coverage, and the proximate determinants of fertility. Trends in women's educational attainment and labor force participation, for example, are examined. Family planning program efforts are also reviewed, as are age at marriage and the proportion of women using contraception. Recent data on the current use of family planning methods are gathered primarily by surveys such as the DHS, the family health and contraceptive prevalence surveys of the CDC, and the various survey programs in Europe and the Middle East. Once fertility has been tentatively projected for each country according to its particular circumstances, the projections are compared with projected values for other countries in the same region.

After assumptions about future levels of TFR are formulated, age patterns of fertility for each of the projected values are developed, since these patterns tend to vary as overall levels change. For each level of projected TFR, a set of ASFRs is estimated using an iterative interpolation process. The interpolation is logarithmic and uses a set of ASFRs for the last input year and an ultimate set of rates with very low fertility. For our recent projection extensions to 2100, a revised set of age-specific fertility rates were developed based on patterns in countries with low fertility. Those patterns suggest a likely plateau of birth rates between ages 25 to 34.

4.4. Net international migration

Assumptions about future net international migration are generally much more speculative than assumptions about fertility and mortality. International migration may occur as a result of changing economic conditions, political unrest, persecutions, famines, and other extreme conditions in the countries of origin as well as destination.

Due to the unpredictability of conditions such as economic downturns, emerging violence, and war, migration forecasts are subject to large errors. Assumptions about future net international migration are formulated based on the type of stream the majority of migrants comprise. If the migration estimated consists mainly of people moving for economic reasons, future migration is assumed to reach a level equal to the average of net economic migrants for the past 20 years or longer. If the migration estimated consists mainly of people moving in response to humanitarian crises, future migration is usually assumed to reach a level of zero. For some of these migrants, who have been granted protections from the international community, assumptions are developed about when and to what degree return migration to a home country will occur. The age and sex composition of international migrants depends on the situation in each country. If information is not available, model patterns of migrant age and sex composition are sometimes used.

Population estimates and projections for countries are revised on a flow basis. Therefore, migration streams across all countries may not balance to zero, and net migration for the world may be positive or negative.

For some countries, the population of net international migrants and their movements from year to year are substantial enough, predictable enough, and are represented by enough data of acceptable quality in order to allow for separate cohort-component projections of them. Such is the case in many Persian Gulf countries where large portions of individual country populations consist of labor migrants who enter the countries to work on a regular basis. For these countries, separate cohort-component projections for the national population and the non-national population of migrants are made and then re-combined to produce a composite set of cohort-component projections to represent the de facto population of the country.

The next series of figures show an example of the U.A.E. cohort-component projections of nationals and non-national migrants and the resulting composite cohort-component projection representing the de facto population of U.A.E. In the first set of population charts representing the 1986 base population (Figure 10), the base year age-sex composition for the combined national and non-national populations of the U.A.E. are shown at the top, the national population is on the lower right, and the non-national population on the lower left. The atypical structure for the non-national population, dominated by males of labor force age, influences the age-sex composition profile of the total U.A.E. population of nationals and non-nationals combined.

1986 Base population

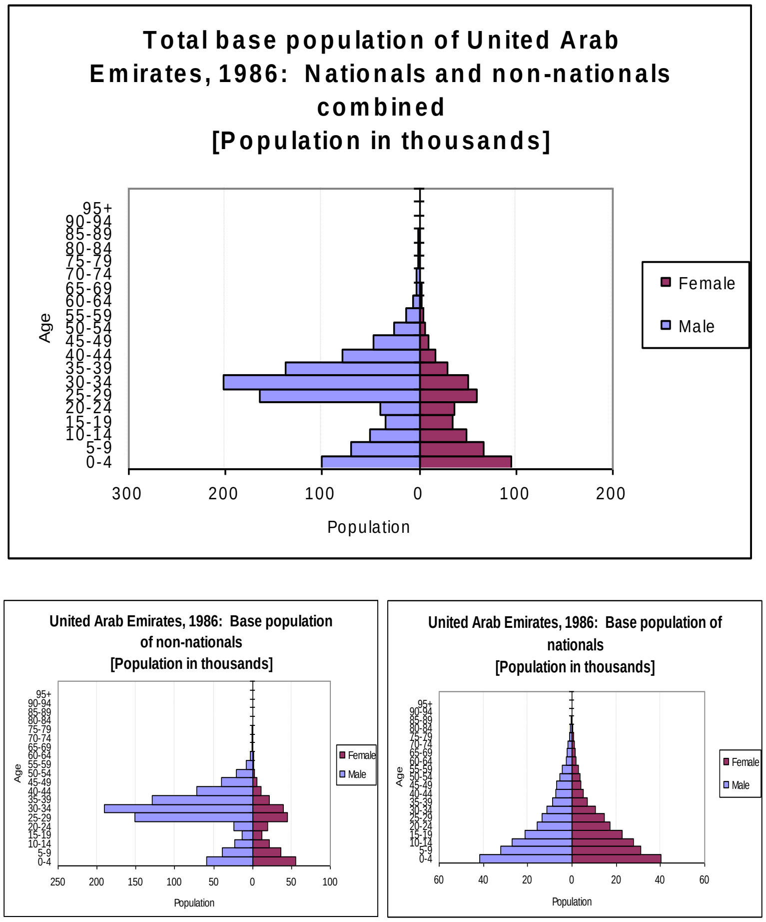

Figure 10: United Arab Emirates 1986 Base population. Source: Based on the U.S. Census Bureau's estimates and projections update for U.A.E., July, 2007.

Next, we see in Figure 11 the separate 2009 cohort-component projections of nationals and non-nationals at the top. The composition profile on the lower left again reflects the male-dominated non-national age-sex structure.

2009 Population projection

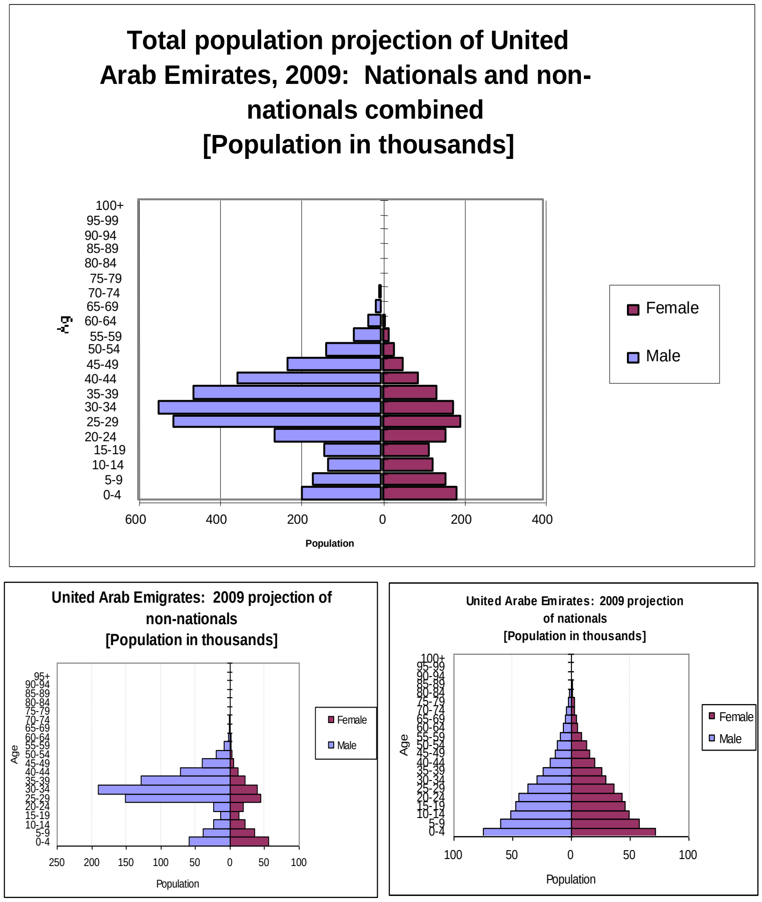

Figure 11: United Arab Emirates 2009 Population projection. Source: Based on the U.S. Census Bureau's estimates and projections update for U.A.E., July, 2007.

Finally, in Figure 12, the separate cohort-component projections of nationals and non-nationals to 2050 continue to imply distinct patterns of nationals and non-nationals. The age-sex pattern of migration for non-nationals was calculated based on the assumption of a particular total stock of non-nationals in 2050 and that the population age-sex structure of non-nationals would resemble that of recent years. The composition profile at the top sustains in large measure the influence of the male-dominated non-national age-sex structure.

2050 Population projection

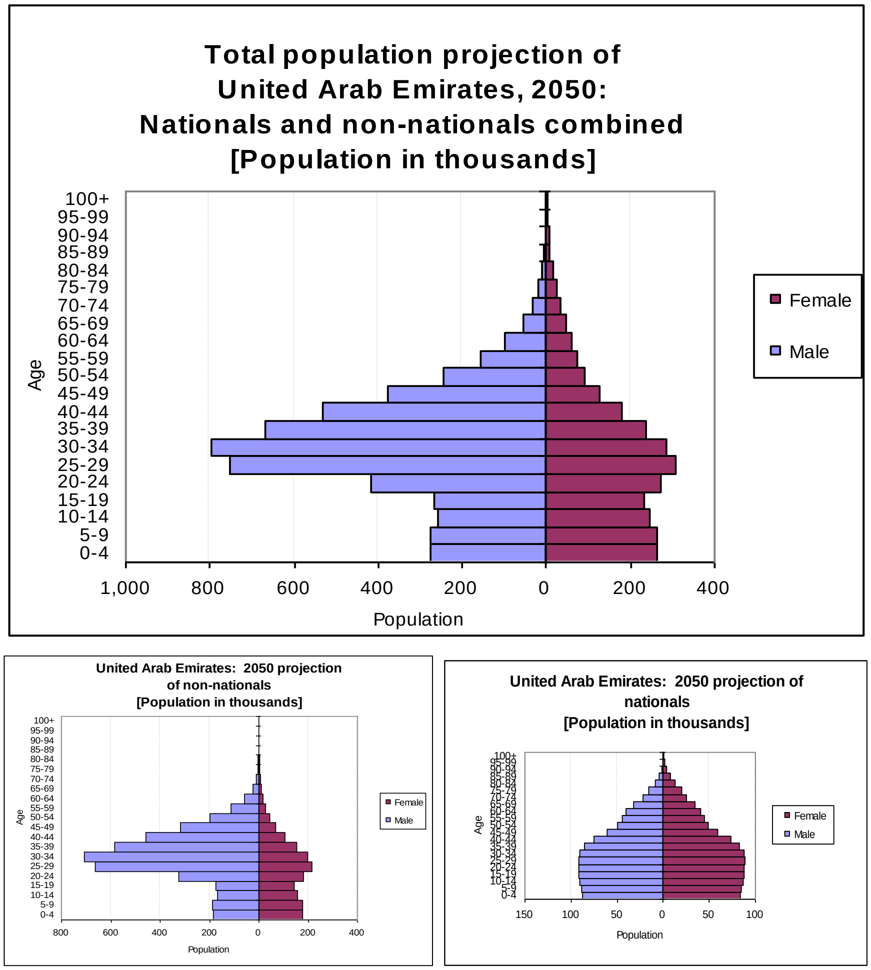

Figure 12: United Arab Emirates 2050 Population projection. Source: Based on the U.S. Census Bureau's estimates and projections update for U.A.E., July, 2007.

4.5. Estimating demographic shocks

The Census Bureau estimates and projects the impact of demographic shocks on population and components of change. Examples of demographic shocks include war, famine, other natural disasters, and severe and sudden economic downturns. Data sources for the timing of and deaths resulting from such events, include The International Disaster - Emergency Events Database (EM-DAT)(European Commission, 2020b), The Armed Conflict Location and Event Data Project (ACLED, 2020), news articles, deaths tallies produced by the WHO, special surveys, and epidemiological studies conducted by various government agencies and research groups (including the CDC's National Center for Health Statistics). Fertility impacts are more difficult to quantify, but some evidence is available from post-event census and survey data and from news articles. International migration flows attributed to demographic shocks are documented by the UNHCR and other organizations listed earlier, as well as news articles.

The Census Bureau translates the short-term aggregate properties of demographic shocks into estimates and projections by specifying the time period (half-year, year, or range of years) during which the event occurred as part of a country's projection assumptions. RUP enables the Census Bureau to limit the immediate impact of an event on the components of change to as little as a half-year period. The after-effects and gradual return of population size and patterns to pre-shock level are also integrated into assumptions. For example, in 1994 the population of Rwanda suffered a genocide during April, May, and June. The Census Bureau was able to estimate the death toll and immediate change in population size by isolating the event to the first half of 1994. Subsequent changes in other population components, the gradual reduction in the mortality rate, and the replenishment of the population over time was then modeled in the projections through subsequent years to 2050, and more recently onward to 2100. The charts in Figure 13 illustrate the Census Bureau's measurement of the impact of genocide in Rwanda in 1994 on projected population and other demographic indicators.[30]

[30] From estimates and projections update of Rwanda in August 2006.

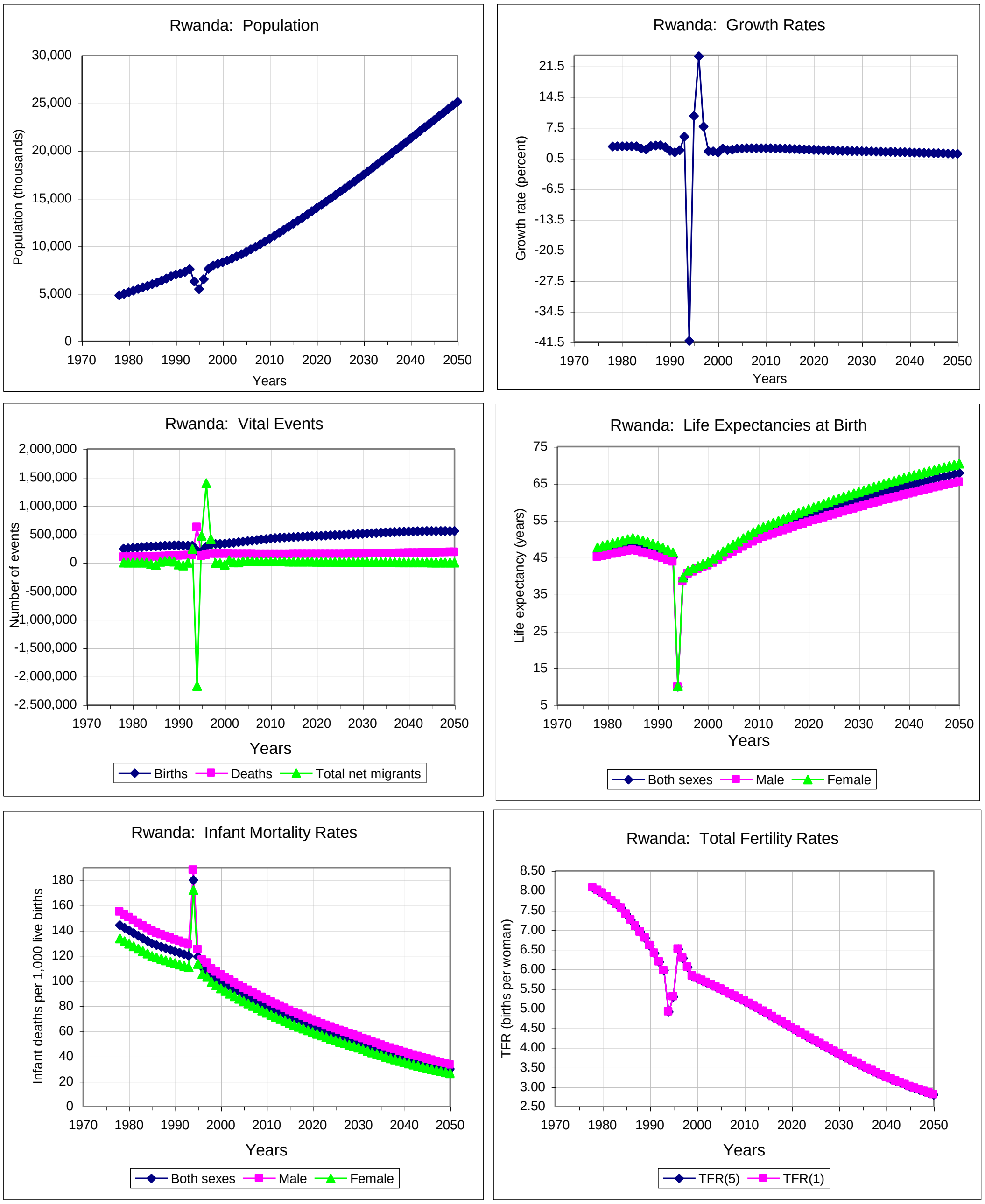

Figure 13: Rwanda population and summary measures of components of change, 1978-2050. Source: Based on the U.S. Census Bureau's estimates and projections update for Rwanda (August 2006).

4.6. Pre-base year data in the IDB

Due to the differing nature of the base data for each country, there is no standard starting date for each country's cohort-component projection. The projection period may start only a few years ago, when the base information was current to that date. On the other hand, the projection period may start several decades ago although information from a later date was available. In this case, information from the later date may have been taken into account when deriving parameter estimates for the early years of a projection. For some countries whose projection base year is in the more distant past—in the 1970s, for example—newer information may pertain to the 1980s or 1990s. If the more recent information is deemed as higher quality and better enables the projection to generate accurate measures, it will supersede the 1970s data. Thus, the population estimate in the revised projection may change for any year in the past. Components also can change in this way. Population age structure and components of change are available in the IDB for each country from the base year onward.

Total midyear population estimates and projections in the IDB are available for 1950 onward for all current countries whether or not they existed in 1950. The data and methods through which the 1950 populations were developed vary depending on the availability of data for each country. For many statistically less developed and lower income countries, modern censuses were not conducted until the 1960s or 1970s, and reliable population data therefore are not available. Midyear population for the 1950s in the IDB has been estimated using census data for later years and assumptions about population growth rates for countries. Total midyear populations for each year between 1950 and the base year of the cohort-component population estimates and projections are revised periodically, specifically when the base year population is changed.

Total midyear populations pertaining to the base year from which the cohort-component projections are developed are changed periodically, specifically when new data or a reinterpretation of older data suggests they should be changed. Base population totals often change when the age and sex composition of the population is revised. The age and sex composition of the base population is revised oftentimes in order to render it consistent with new assumptions about fertility, mortality, and the age-sex distribution and size of a more recent census.

4.7. Extension of projections to the year 2100

In 2020, the Census Bureau extended the projected time horizon for all countries and areas on the IDB —except for the United States[31]— forward from the year 2050 to the year 2100. Such extensions included a raised ceiling of life expectancy at birth to 95 for males and 100 for females. These assumptions are based on our review of historical trends, recent patterns, and academic studies. Implied improvements are expected to begin after current 2020 assumptions in most countries, and after 2050 in some others where life expectancies are very low.[32]

For fertility and net migration, we maintained previous assumptions of demographic change through 2050 when possible. The total fertility rate by 2100 was assumed to be 1.7 in most countries, except for those where the TFR is currently below 1.4, for which the TFR was expected to rise no higher than 0.3 above recent levels. For higher fertility countries, given the extended timeline to 2100, the TFR was assumed to decline to between 1.7 and 2.1. In certain cases, assumptions were adjusted to avoid sharp jumps in fertility (or migration) through 2100 and/or to avoid unreasonably skewed age-sex patterns in the population or implausible changes in the overall population.

[31] As of the release date of this document, the latest available vintage (v2017) of population projections for the United States only included projections to the year 2060.

[32] As before, we assume a fixed logistic pattern of life expectancy improvements over time (an S-shaped pattern bounded by a ceiling and a floor), which implies a kind of escalator advancing upwards based on wherever one steps onto it. Although the raising of the life expectancy ceiling implied immediate improvements going forward for most countries, such improvements slowed in countries with higher mortality (which form the lower, now more horizontal, part of the S compared to prior mortality projections. To avoid that slowdown in those countries, we began the escalator of improvements after 2050.

For all countries undergoing extensions to 2100, we revised the long-run age patterns of mortality (by sex) and fertility. That age pattern of mortality (by sex) was chosen based on aforementioned presumptions of life expectancy at birth matched to the Coale-Demeny West model life table. The age pattern of fertility assumed peak rates spanning ages 25 to 34, a pattern based on current tendencies in higher income societies.

Due to the revised assumptions of demographic change used in these extensions, the new projections in the IDB differ from previous projections through the year 2050, albeit typically by small amounts.

5. References

The Armed Conflict Location and Event Data Project (ACLED). 2020. <https://acleddata.com/#/dashboard>

Arriaga, Eduardo E. 1983. Estimating Fertility from Data on Children Ever Born, by Age of Mother. U.S. Bureau of the Census, International Research Document No. 11. ISP-RD-11. Washington, D.C.: U.S. Government Printing Office.

Arriaga, Eduardo E. and Associates. 1994. Population Analysis with Microcomputers. U.S. Census Bureau, International Programs Center: Washington, D.C.

Attama, Sabine, Michka Seroussi, Alichina Idrissa Kourguéni, Harouna Koché et Bernard Barrèm. 1998. Enquête Démographique et de Santé, Niger 1998. Calverton, Maryland, U.S.A.: Care International and Niger et Macro International Inc.

Bachi, Roberto. 1951. "The Tendency of Round Off Age Returns: Measurement and Corrections," in Bulletin of the International Statistical Institute, Vol. 33, No. 4, pp. 195-222.

___. 1953. "Measurement of the Tendency of Round Off Age Returns," in Bulletin of the International Statistical Institute, Vol. 34, No. 3, pp. 129-137.

Bhat, Mari PN. 2001. “Completeness of India’s sample registration system: an assessment using the general growth balance method.” Population Studies (Camb). Delhi, India: Institute of Economic Growth.

Bogue, Donald J., Eduardo E. Arriaga, and Douglas L. Anderton. 1993. Readings In Population Research Methodology. Chicago, I.L.: Social Development Center.

Bongaarts, John. 1984. “A simple method for estimating contraceptive prevalence required to reach a fertility target.” Studies in Family Planning, Vol. 15, No. 4 (Jul-Aug., 1984), pp. 184-190.

Brass, William, et al. 1968. Chapter III in The Demography of Tropical Africa. Princeton, N.J.: Princeton University Press.

Brass, William. 1975. Methods for Estimating Fertility and Mortality from Limited and Defective Data, International Program of Laboratories for Population Statistics, The Carolina Population Center, University of North Carolina at Chapel Hill.

___. 1981. "The use of Gompertz relational model to estimate fertility," in Proceedings of the International Population Conference, Manila, International Union for the Scientific Study of Population, Vol. 3, pp. 345-362. Liège.

Centers for Disease Control and Prevention (CDC). 2020. Reproductive Health Surveys. <https://www.cdc.gov/reproductivehealth/global/tools/surveys.htm>

Cho, Lee-Jay. 1973. "The own-children approach to fertility estimation: an elaboration," in Proceedings of the International Population Conference, Liège 1973, International Union for the Scientific Study of Population. Liège.

Coale. Ansley J. and Paul Demeny. 1966. Regional Model Life Tables and Stable Populations. Princeton, N.J.: Princeton University Press.

Coale, Ansley J. and Guang Guo. 1989. "Revised Regional Model Life Tables at Very Low Levels of Mortality." Population Index, Vol. 55, No. 4, pp. 613-643.

___. 1990. "Revised Regional Model Life Tables at Very Low Levels of Mortality." [Full set of appendix tables and an additional reference]. Population Index, Vol. 56, No.1, pp. 26-41.

Davis, Kingsley and Judith Blake. 1956. "Social structure and fertility: An analytic framework." Economic and Cultural Change Vol. 4. No. 2, pp. 211-235.

European Commission. 2020a. Eurostat. <https://ec.europa.eu/eurostat>

_____. 2020b. The International Disaster - Emergency Events Database (EM-DAT). <https://ec.europa.eu/knowledge4policy/dataset/ds00107_en>

Ghys P., N. Walker, W. McFarland, et al. 2008. "Improved data, methods and tools for the 2007 HIV and AIDS estimates and projections." Sexually Transmitted Infections, Vol. 84 (Supplement I), pp. i1-i4.

Hill, K. 1987. "Estimating census and death registration completeness." Asian Pacific Population Forum. May; Vol. 1, No. 3, pp. 8-13 and pp. 23-4.

Hobbs, Frank. 2004. "Age and Sex Composition." Chapter 7 in The Methods and Materials of Demography, Second Edition. Edited by Jacob S. Siegel and David A. Swanson. New York, N.Y.: El Sevier Academic Press.

Institut National de la Statistique (INS) et Macro International Inc. 2007. Enquête Démographique et de Santé et à Indicateurs Multiples du Niger 2006. Calverton, Maryland, USA: INS et Macro International Inc.

International Labour Organization (ILO). 2020. <https://www.ilo.org/global/lang--en/index.htm>

International Organization for Migration (IOM). 2020. <https://www.iom.int/>

Johnson, Peter. 2006. Extension of the Population to Age 100+ Using the Pop100 Workbook. Unpublished paper. Washington, D.C.: U.S. Census Bureau, International Programs Center.

___. 2006. Revised Methods for Extending Mortality to 100+ Using the LTEXTNew and LTSPLTNew Workbooks. Unpublished paper. Washington, D.C.: U.S. Census Bureau, International Programs Center.

Joint United Nations Programme on HIV/AIDS. 2007. "Financial Resources Required to Achieve Universal Access to HIV Prevention, Treatment, Care and Support." <http://data.unaids.org/pub/Report/2007/20070925_advocacy_grne2_en.pdf>. Geneva, Switzerland.

Joint United Nations Programme on HIV/AIDS/World Health Organization. 2007. The UNAIDS/WHO Estimation and Projection Package (EPP 2007). Version 3.0.

___. 2009. Estimating National Adult Prevalence of HIV−1 In Generalized Epidemics. Draft Manual. <http://data.unaids.org/pub/Manual/2009/20090407_epp_genepi_2009_draft_en.pdf>. Geneva, Switzerland.

Kourgueni, Idrissa A., Garba, Bassirou, and Barrere, Bernard. 1993. Niger: Enquete Demographique et de Sante 1992. Columbia, M.D.: Macro International.

Myers, Robert. 1940. "Errors and Bias in the Reporting of Ages in the Census Data," in Transactions of the Actuarial Society of America, Vol. 41, Part 2, pp. 411-415.

Norwegian Refugee Council (NRC). 2020. <https://www.nrc.no/>

Organisation for Economic Co-operation and Development (OECD). 2020. <http://www.oecd.org/>

Popoff, Carol and D.H. Judson. 2004. “Some Methods of Estimation for Statistically Underdeveloped Areas.” Chapter 22 in The Methods and Materials of Demography, Second Edition. Edited by Jacob S. Siegel and David A. Swanson. New York, N.Y.: El Sevier Academic Press.

Rele, J.R. 1967. Fertility Analysis Through Extension of Stable Population Concepts, Population Monograph Series, No. 2, Institute of International Studies, University of California, Berkeley.

___. 1993. “The Rele Procedure for Indirect Estimation of Fertility.” Chapter 9 in Readings In Population Research Methodology. Edited by Donald J. Bogue, Eduardo E. Arriaga, and Douglas L. Anderton. Chicago, I.L.: Social Development Center.

Siegel, Jacob and David. A. Swanson. 2004. The Methods and Materials of Demography, Second Edition. New York, N.Y.: El Sevier Academic Press.

Stover, John. 1998. “Revising the Proximate Determinants of Fertility Framework: What have we learned in the Past 20 Years?” Studies in Family Planning. Vol. 29, No. 3.

___, P. Johnson, B. Zaba, et al. 2008. The Spectrum projection package: improvements in estimating mortality, ART needs, PMTCT impact and uncertainty bounds. Sexually Transmitted Infections, Vol. 84 (Supplement I), pp. i24-i30.

Thatcher, A.R., V. Kannisto, and J.W. Vaupel. 1998. The Force of Mortality at Ages 80 to 120. Monographs on Population Aging, 5. Odense, Denmark: Odense University Press.

United Arab Emirates, Ministry of the Economy. (?). Statistic Abstract 2007. <http://www.economy.ae/English/EconomicAndStatisticReports/StatisticReports/StatisticAbstract/Pages/sa2007.aspx>

United Kingdom Border Agency. Vol. I. The British Nationality Act caseworking instructions. Chapter 14, Annex J: Pakistani Citizenship Law. [Accessed 3/20/09]

<http://www.ukba.homeoffice.gov.uk/sitecontent/documents/policyandlaw/nationalityinstructions/nichapter14/>

United Nations. 1952. "Accuracy tests for census age distributions tabulated in five-year and ten-year groups," in Population Bulletin, no. 2, ST/SOA/Ser.N/2, pp. 59-79. New York, N.Y.

___. 1955. Methods of Appraisal of Quality of Basic Data for Population Estimates. Manual II, Series A, Population Studies No. 23, pp. 42-43. New York.

___. 2000. United Nations Demographic Yearbook: Historical Supplement 1948-1997. Geneva, Switzerland.

___. 2003. World Population Prospects: The 2002 Revision. "File 5: Life Expectancy at Exact Age, e(x), for Both Sexes Combined, by Major Area, Region and Country, 1990-2050." Data file POP/DB/WPP/Rev.2002/5/F5. New York: UN Population Division.

___. 2020. Population and Vital Statistics Report. United Nations Statistical Paper Series A Vol. LXXII. Economic and Social Statistics. January. <https://unstats.un.org/unsd/demographic-social/products/vitstats/sets/Series_A_2020.pdf>

United Nations and National Research Council. 1983. Manual X. Indirect Techniques for Demographic Estimation. New York, N.Y.: United Nations.

United Nations Children's Fund (UNICEF). 2020. Multiple Indicator Cluster Surveys (MICS). <https://mics.unicef.org/surveys>

United Nations Department of Economic and Social Affairs. 2019. 2018 United Nations Demographic Yearbook, Nations Unies Annuaire Demographique. Sixty-ninth issue/Soixante-neuvième edition. New York: United Nations. <https://unstats.un.org/unsd/demographic-social/products/dyb/dyb_2018/>

United Nations Economic and Social Commission for Western Asia (UNESCWA). 2020a. Pan Arab Project for Child Development (PAPCHILD). <https://www.unescwa.org/pan-arab-project-child-development>

_____. 2020b. Pan Arab Project for Family Health (PAPFAM). <https://www.unescwa.org/pan-arab-project-family-health>

United Nations Economic Commission for Latin America and the Caribbean (UNECLAC). 2020. <https://www.cepal.org/en>

United Nations High Commissioner for Refugees (UNHCR). 2020. <https://www.unhcr.org/en-us/>

United Nations Inter-Agency Group for Child Mortality Estimation (IGME). 2019. "Explanatory Notes: Child mortality trend series to 2018." <https://childmortality.org/wp-content/uploads/2019/09/UNIGME-Explanatory-Notes_ENGLISH.pdf>

_____. 2020. "Explanatory Notes: Child mortality trend series to 2019." <https://childmortality.org/wp-content/uploads/2019/09/UNIGME_explanatory_notes_EN_2020.pdf>

U.S. Agency for International Development (USAID). 2020a. The DHS Program Demographic and Health Surveys.

<https://dhsprogram.com/search/index.cfm?itemsperpage=100&bydoctype=publication&bypubtype=5%2C21%2C26%2C30%2C39%2C100&byyear=2019&byyear=2018&byyear=2017&_srchd=1>

_____. 2020b. The DHS Program Demographic and Health Surveys World Fertility Survey. <https://wfs.dhsprogram.com/index.cfm>

U.S. Bureau of the Census. 1971. The Methods and Materials of Demography, by Henry Shryock, Jacob Siegel and Associates, Vol. 1, pp. 205-211. Washington, D.C.: U.S. Government Printing Office.

___. 1983. "Estimating fertility from data on children ever born, by age of mother," by Eduardo E. Arriaga, International Research Document No. 11. Washington D.C.

___. 2004. Unpublished life table values from RUP projections for countries modeled up to age 100+ in the International Data Base, September 30, 2004 update. Washington, DC: Population Division, International Programs Center.

___. 2005. Unpublished work tables for estimating Iran's mortality. Washington, D.C.: Population Division, International Programs Center.

___. 2009. Unpublished work tables for estimating and projecting populations for the International Data Base, various years. Washington, D.C.: Population Division, International Programs Center.

___. 2009. Unpublished work tables for estimating and projecting HIV/AIDS prevalence and mortality levels with AIDS, various years. Washington, D.C.: Population Division, International Programs Center, Health Studies Branch.

___. 2009. Unpublished work tables for estimating and projecting HIV/AIDS prevalence, various years. Washington, D.C.: Population Division, International Programs Center, Population Studies Branch.

_____. 2019. Population Estimates and Projections Guidelines. Washington, D.C.: Population Division, International Programs. Unpublished.

U.S. Committee for Refugees and Immigrants (USCRI). 2020. <https://refugees.org/>

World Health Organization (WHO). 2008. "Towards Universal Access: Scaling up Priority HIV/AIDS Interventions in the Health Sector, Progress Report 2008." Geneva, Switzerland. <http://www.who.int/hiv/mediacentre/2008progressreport/en/index.html>.

_____. 2020. WHO Statistical Information System (WHOSIS). <https://www.who.int/whosis/en/>