Population Estimates and Projections: Methods, Providers, and Major Drivers

Select Topics in International Population and Health[1]

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BACKGROUND

Population estimates and projections are essential for tracking trends in health and socioeconomic development and directing resources to where they are most needed. Yet population metrics from multiple providers may vary, and the reasons for such differences are often not comprehended by those who use them. We begin with a review of data sources and methodologies, all of which typically rely on the demographic balancing equation, a means of accounting for population change through births, deaths, and migration. We then identify various providers of population estimates and projections, commonalities and differences in their assessments of population change, as well as other relevant information available. We then consider which among the three components of population change can have the most impact on population growth and under what circumstances.

ASSEMBLING EVIDENCE ON POPULATION AND DEMOGRAPHIC CHANGE

The Demographic Balancing Equation

Three basic components determine population change between two points in time for a given area: births, deaths, and migration. The relationship among them is known as the demographic balancing equation:

population (time 2) = population (time 1) + births – deaths + net migration (inflows minus outflows)

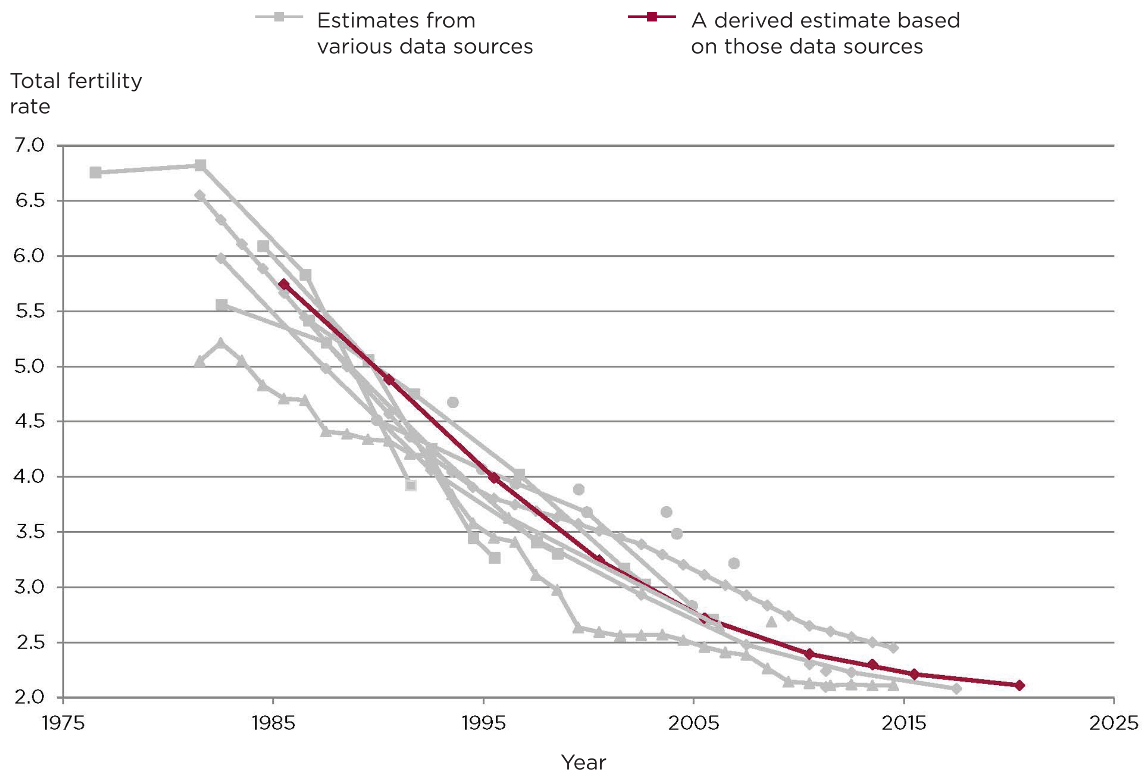
This equation can be expressed either in numbers (as above) or in rates, the latter typically being population change (between time 1 and time 2) per 1,000 population. As an accounting system, it provides the foundation for both estimating and projecting the population of any country or area (for the world as a whole, net migration equals zero in the absence of space travel). The reliability of the projections, based on the elements on the right-hand side of the equation, depend on accurate measurements of both the starting population as well as trends in fertility, mortality, and migration.

The sources of demographic data related to the balancing equation include censuses, surveys, vital registration, local demographic surveillance systems, and administrative data such as population registers. Two types of estimates are possible. Direct estimates come from a source that was collected specifically to measure a particular parameter. Indirect estimates, such as births derived from population age structure, come from similar sources and are used when direct estimates are not available or unreliable. In both cases, it is important that estimates and projections include and reflect the latest data available at the time.

Estimates of the same demographic parameters often differ from source to source. Illustrations of such differences are apparent when plotted on a line chart. In Figure 1, estimates of total fertility rates (or, expected births per woman based on annual estimated birth rates by age) are shown for Bangladesh. The lines reflect either direct or

[1] This technical note is part of a series on *Select Topics in International Population and Health* that explores matters of interest to the international statistical community. The U.S. Census Bureau helps countries improve their national statistical systems by engaging in capacity building to enhance statistical competencies in sustainable ways.

Figure 1.
Fertility Estimates From Censuses, Surveys, Vital Registration, and Trends Analysis in Bangladesh: 1975–2021



Source: U.S. Census Bureau.

indirect estimates. Given the notable differences in fertility estimates for any particular year, producers of population estimates and projections need to assess the quality of each source and then determine a preferred estimate. In this case, the preferred estimate is the red line marked by diamonds. Convergence is not only informed by multiple sources of estimates, but also by how well the derived estimates fit into the balancing equation, as discussed in the next section regarding demographic analysis of the completeness of population counts.

Assessments of Completeness of Population Counts

There are two basic methods for evaluating the completeness of a national population count such as a census. The first is through a survey taken immediately after a census—a post enumeration survey (PES)—which is designed to identify people who were either missed (uncounted) or counted more than once. A PES can also identify which groups were least accurately counted based on their age, sex, and other characteristics. The key challenges for conducting an effective PES are complex design, implementation, and cost.

The second approach for evaluating the completeness of population counts is called demographic analysis, an umbrella term that includes a broad range of tools related to the balancing equation. Such tools provide a comparative standard by age and sex against which a new population count can be evaluated. For most countries, that standard is a cohort component projection forward from a prior census to the date of the new census based on annual estimates of the components of demographic change. The component information must include details on birth rates by age of mothers, mortality rates by age and sex, and net migration (if it exists) by age and sex.

Figure 2 depicts how cohort component projections are implemented by showing a hypothetical census taken in 2015 with population counts at single years of age. This figure shows females aged 0 to 7, since each sex is usually projected separately. Based on these counts, the female population was projected to decrease the following year (2016) based on the death rates estimated at each specific age group in that year (migration was assumed to be zero). The projected cohort proceeds along the diagonals, so that the cohorts counted in the 2015 census are exactly 1 year older when projected to 2016. The process is repeated annually based on the estimated mortality and migration for each year.

Figure 2.
Stylized Depiction of Output of Females From a Cohort Component Projection Starting in 2015 and 2022

Census year	Age 0	1	2	3	4	5	6	7
2015	**694**	661	632	597	555	516	478	455
2016	**711**	681	654	628	594	554	514	476
2017	**721**	699	675	650	625	593	552	513
2018	**724**	709	692	671	648	624	591	551
2019	**723**	713	703	689	669	646	622	590
2020	**715**	712	707	699	686	667	645	621
2021	**701**	704	706	704	697	685	666	643
2022	**683**	692	699	703	702	696	684	665

Note: The cells are colored to identify and track same-age cohorts as they progress through time.
Source: U.S. Census Bureau.

The number of people entering the population each year at age 0 is determined by the number of females counted at childbearing ages in the prior year, whereby females within specific age groups are multiplied by assumed birth rates in that age group for that year. The implied number of births are summed across all age groups and form the basis of the population at age 0. This process is repeated annually. Once a cohort is generated at age 0, they live along the diagonals, advancing along each axis annually by 1 calendar year and by 1 year of age.

The value of cohort component projections to demographic analysis of censuses is illustrated in Figure 3. In this example, the projected populations at 0–4 years and 10–29 years are higher than the census count at those ages, which implies relative undercounts in the new census (also known as net census error), assuming the standard is accurate. Conversely, demographic analysis may suggest that the census count is more reliable than the comparative standard, which implies that the estimated parameters of demographic change used to construct the standard should be revised.

Cohort component methods are routinely used to project populations into the future. They are considered the gold standard because they reflect the components that cause populations to grow and change. Yet the methods and assumptions used to project the components of change may differ from organization to organization.

PRODUCERS OF POPULATION ESTIMATES AND PROJECTIONS

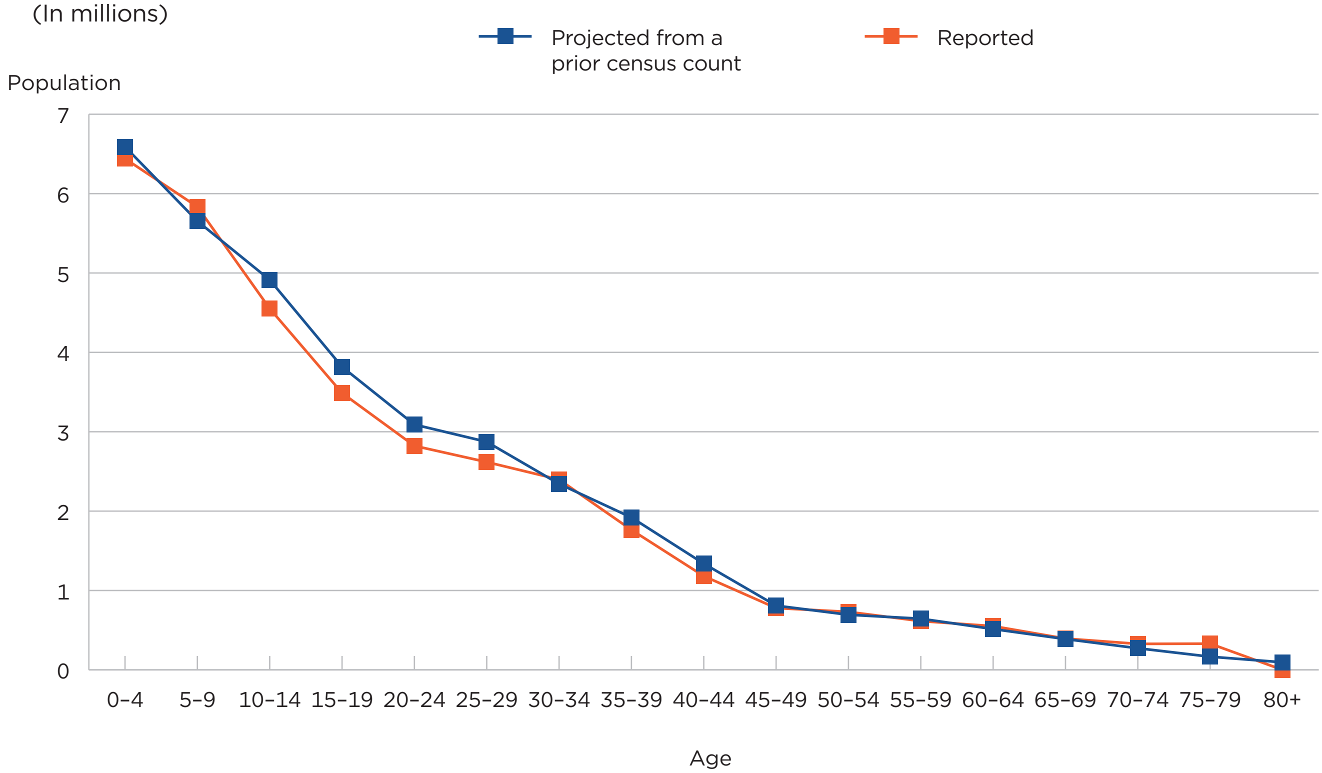
National

As noted earlier, population estimates and projections are intertwined. Population projections build upon demographic estimates and trends in the past, and those estimates themselves are often derived by fitting together pieces of the balancing equation. Whether confined to the past or extending into the future, population projections also typically require floor or ceiling assumptions (asymptotes) of demographic change in the future (minimum/maximum life expectancy).

Most countries have a national statistical office (NSO) that provides population estimates and projections along with other statistical data. Such agencies may undertake official population projections using the methods described above and often after a national census. In some countries, separate government agencies may be tasked with conducting censuses and related surveys or assembling vital statistics such as national health ministries.

In some countries, multiple population estimates of the same demographic parameter may be available. For example, some parameters may be collected directly from a census versus an indirect, comparative standard derived from demographic analysis or a PES. Although comparative standards provide a quality check that may be used to adjust the counts, these comparisons are often used

Figure 3.
Comparison of a Hypothetical New Census Count to a Population Projected to That Date From an Earlier Census
(In millions)



Source: U.S. Census Bureau.

only for diagnostic purposes, such as to reveal potential flaws in the census that may aid in planning for the next census or to inform interpretation of census results. Decisions about the relative quality of census counts vs. comparative standards need to be approached on a case-by-case basis.

Global

In addition to NSOs, a variety of institutional providers undertake population estimates and projections on a worldwide basis. The two organizations with the longest history of producing global estimates and projections using cohort component methods combined with demographic analysis are the United Nations (UN; 2019) and the U.S. Census Bureau (2021). More recently, other organizations have undertaken cohort component projections such as the International Institute for Applied Systems Analysis (IIASA; Wittgenstein Centre, 2018) and the Institute for Health Metrics and Evaluation (IHME; refer to Vollset et al., 2020). Other organizations provide population estimates or projections on a more limited scale through noncohort component methods such as the World Bank and the Population Reference Bureau. Academic researchers, typically focused on a particular country or region, may also produce population estimates and projections, and typically disseminate results through journals and other reports.

The estimates and projections produced by each organization vary. Figure 4 shows world population estimates and projections (as of May 2022) from 2020 to 2060. The graphic shows the central estimates for each organization, and all organizations except the Census Bureau provide high/low estimates based on hypothetical scenarios. In general, projections to 2060 by the UN and Census Bureau are quite close (about 10.2 billion) in contrast to somewhat lower projection by the IIASA and IHME (9.6 to 9.7 billion). Although most central estimates are well inside the bounds of high/low estimates, an exception is that the UN's low projection nearly coincides with the central projection by the IIASA.

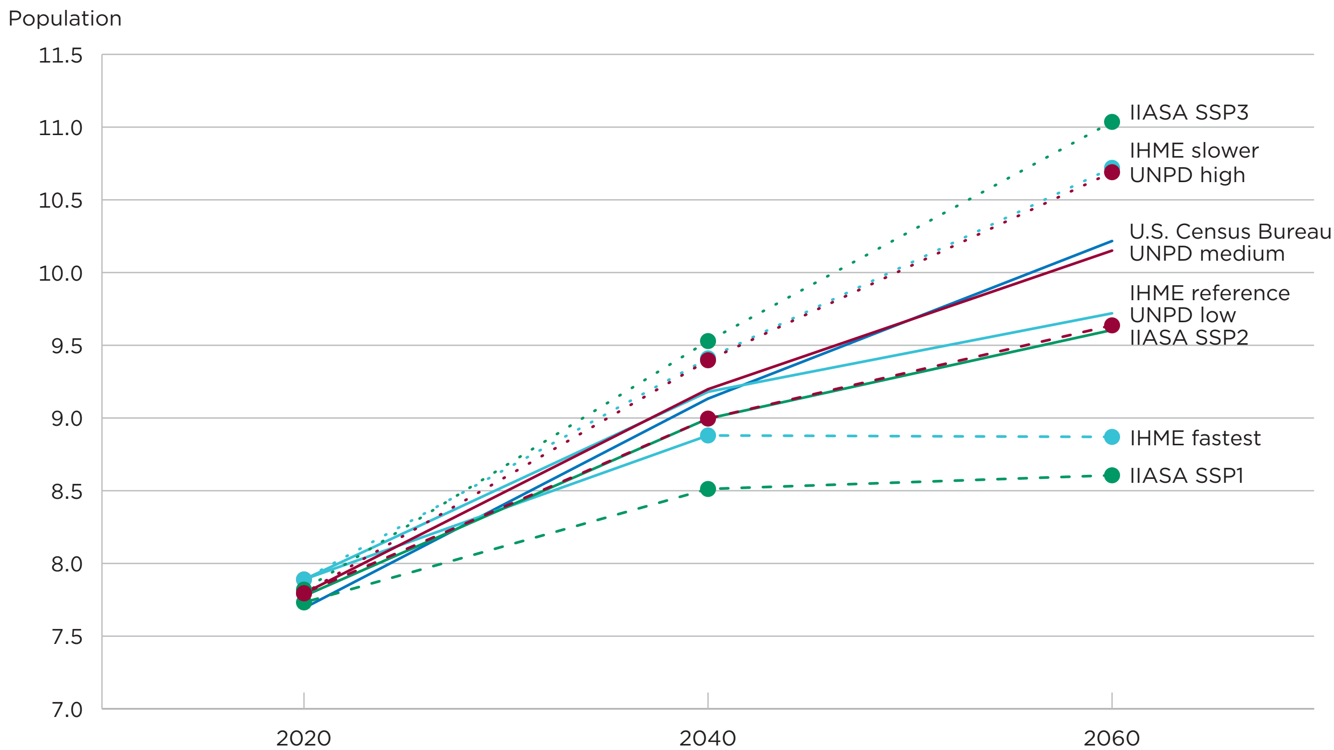
Such minor differences may become more relevant when significant demographic thresholds are surpassed such as when the world population is projected to reach 8 billion people. The exact date of crossing this milestone varies by almost one-half a year across the four organizations.

Differences in estimates and projections reflect not only varying assumptions and methodologies (such as future assumed trends in fertility) but also structural features of the organization. Table 1 indicates some of these general features such as their historical scope, geographic coverage, and demographic details. Users should keep these attributes in mind when considering which source to consult and evaluating differences among them.

Figure 4.

World Population Estimates and Projections for 2020–2060 as Compiled by Organizations Using Cohort Component Methods

(In billions)



Source: U.S. Census Bureau, 2021; United Nations, 2019; Vollset et al., 2020; Wittgenstein Centre, 2018.

Table 1.

Comparisons of Institutional History and Scope of Data Products From Organizations That Provide Cohort Component Population Estimates and Projections on a Worldwide Basis Through 2100

Characteristic	United Nations Population Division WPP19	U.S. Census Bureau	International Institute for Applied Systems Analysis	Institute for Health Metrics and Evaluation
Online debut year	1996	1996	2014	2020
Number of countries/areas and basis for inclusion	235 (193 United Nations member states plus 42 territories)	228 countries and areas	201 countries	195 countries and territories
Basic details of estimates and projections	Annual, by single-year age groups	Annual, by single-year age groups	5-year time periods and 5-year age groups by education	Annual, by 5-year age groups

Source: U.S. Census Bureau, 2021; United Nations, 2019; Vollset et al., 2020; Wittgenstein Centre, 2018.

VARIABLE IMPACTS OF EACH COMPONENT OF CHANGE

Although assessments of demographic change may differ, it is fair to ask how much of an impact such differences will have on population estimates and projections. We should also consider which, among the three components of change, tends to drive population growth the most.

The short answer is that fertility is the primary driver of population growth. Although inmigration also contributes to growth and change in some countries or areas, it subtracts equally from the growth of others. Thus, population growth in most countries is governed largely by the differences between birth and death rates, also known as the natural growth rate.

In this document, we show examples of the relative contribution of these two components, as well as migration between countries and areas, to population growth. We also specify the contextual circumstances under which each component predominates, as well as its effect on age and sex structure.

Birth Rates, Death Rates, and the Gap Between Them

Population growth often accelerates over the course of development because death rates tend to fall faster than birth rates. This process, which almost all countries have experienced, is known as the demographic transition. High and lingering birth rates provide the primary fuel for population growth during the early to middle stages of the transition.

A study during the early stages of worldwide demographic transition examined which component would contribute more to long-term population growth: the elimination of death altogether—i.e., immortality—or a 10-percent increase in birth rates (Coale, 2003). Cohort component projections based on these two hypothetical scenarios revealed a surprising and counterintuitive conclusion that the world's population would be larger under the assumption of a very modest increase in fertility compared to one in which nobody died.

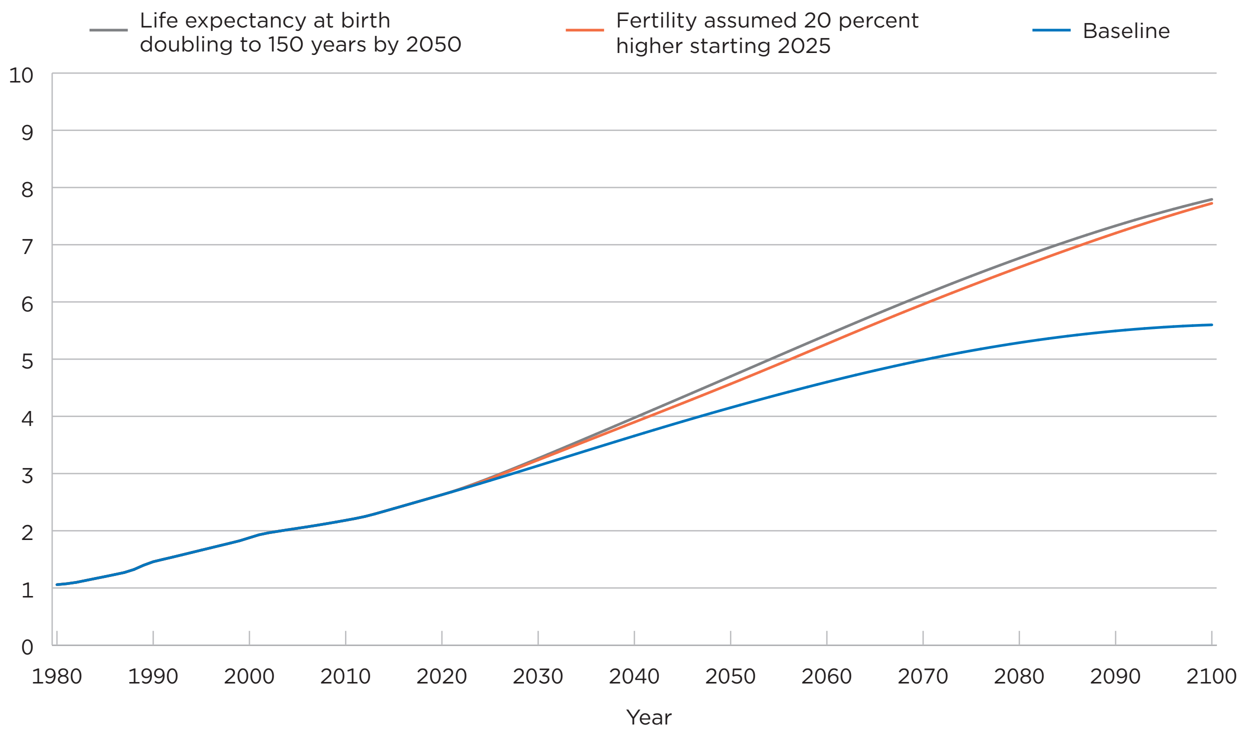
More recent studies suggest that mortality improvements have played an increasingly influential role in population growth as worldwide fertility has declined (Hughes et al., 2015). Nevertheless, through the first decade of the 21st century, fertility differences remain key to understanding the pace of population growth.

We illustrate the relative impact of these two factors on population growth in a hypothetical developing country. We compare a baseline scenario of expected demographic change (from 2020 forward) to two alternate scenarios: one in which life expectancy doubles to 150 years by 2050 for both males and females, and the other where fertility rates in 2025 and beyond are raised 20 percent above projected levels as of 2022. Figure 5 shows the resulting total populations projected through 2100. The two alternative scenarios both imply larger populations in the future, with the mortality improvement scenario slightly larger than the fertility increase scenario through 2095.

The relatively similar projection of total population in these two alternative scenarios masks decidedly different demographic processes at work. Figures 6a–c show age-sex structure by 2060 in both the baseline and two alternative scenarios. In the higher fertility scenario, the population increase is confined to those under the age of 40. Conversely, in the doubling of life expectancy scenario, most of the population increase occurs at the oldest ages in which death rates are highest. In fact, the projected population of centenarians undergoes astounding growth, from just 7 individuals in 2020, to nearly 97,000 in 2060 (shown in the Figure 6c), to nearly 1,000,000 by 2100 (not shown). Nevertheless, despite that growth the cumulative power of 20-percent increases in fertility implies that the overall population gap between the two alternate scenarios remains fairly steady after 2060 (Figure 5).

The alternate scenarios proposed here are not suggestions of what might reasonably occur. Nevertheless, these "what if" scenarios illustrate the dynamics by which mortality and fertility affect population change. For further details on such modelling and their implications, refer to Hughes et al. (2015).

Figure 5.
Population Projections for a Hypothetical Developing Country: 1980–2100
(In millions)



Source: U.S. Census Bureau.

When Migration Matters Most

Among the three components of demographic change, migration can change faster than the others and alternate between positive or negative over short periods of time. For this reason, making projections of future migration trends and even assessing the level of uncertainty of this component are inherently challenging. There are, however, several conditions under which migration tends to contribute more to population change relative to fertility and mortality:

- In less populous countries and areas, where migration can have a larger impact on population size and age/sex structure than in more populated countries and areas.
- In countries and areas with well-established migration patterns, either with a large proportion of residents living abroad (e.g., South Asian workers in the Middle East) or a large proportion of foreign-born residents (e.g., migrant destinations in Europe and North America).
- In countries and areas experiencing substantial social, economic, or political instability that may exhibit a rapid increase in outmigration.
- When migration is most concentrated at younger ages, where population movements most affect where future births occur.

Figure 6a.
Baseline Population Projection of Hypothetical Developing Country to 2060
(In millions)

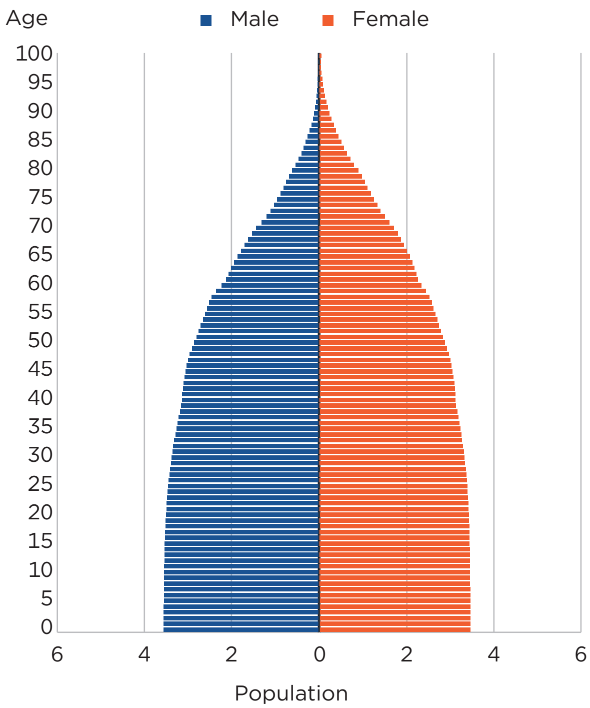


Figure 6b.
Alternate Projection of Hypothetical Country Assumes Fertility Is 20 Percent Higher Starting in 2025
(In millions)

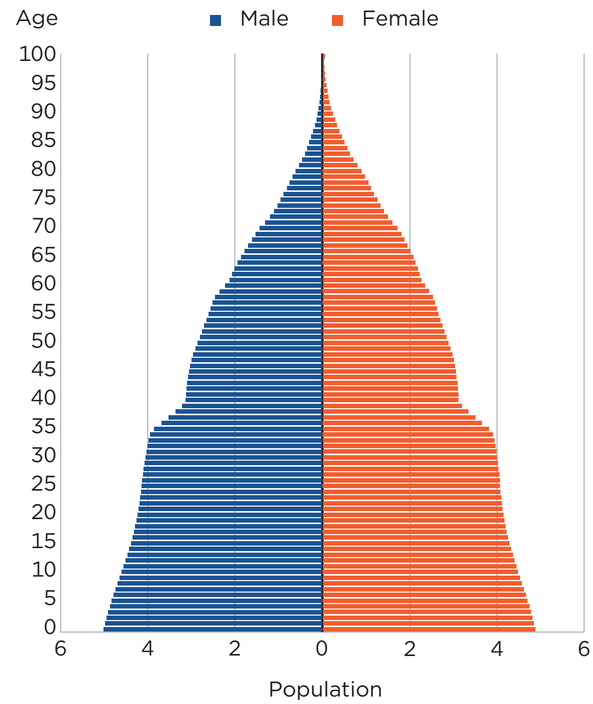
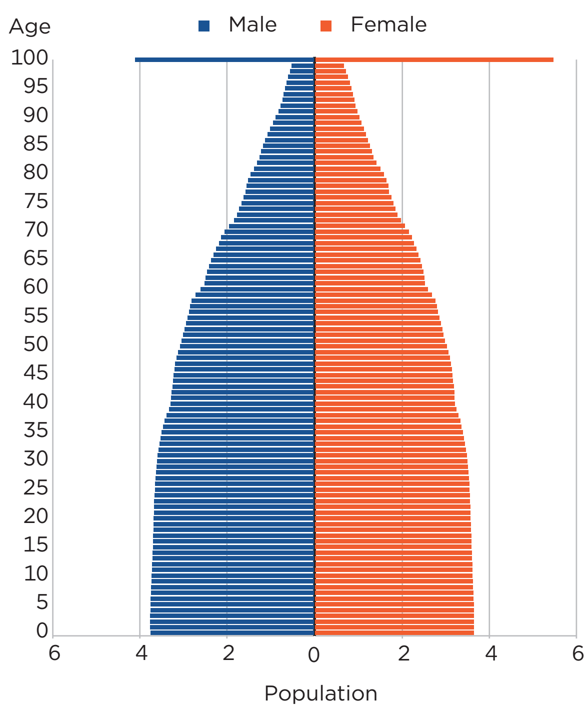


Figure 6c.
Alternate Projection of Hypothetical Country Assumes Life Expectancy Doubles by 2050
(In millions)



Source: U.S. Census Bureau.

SUMMARY

This report attempts to demystify the process of estimating and projecting human populations, which entails assessments of data on population as well as the three components of demographic change—births, deaths, and migration. Estimates and projections may differ among providers based on their assessments of the quality and completeness of various data sources. Yet all providers face a common constraint, the balancing equation, which requires that these demographic elements fit together in a systematic way across time. The relative influence of the three components of change on population growth vary from society to society based on development, population size, and other contextual factors.

REFERENCES

Coale, Ansley, "Increases in Expectation of Life and Population Growth," *Population and Development Review*, 29(1), 2003 (reprint from 1959), pp. 113–120, <www.jstor.org/stable/3092737>.

Hughes, Barry B., Randall Kuhn, Eli S. Margolese-Malin, Dale S. Rothman, and José R. Solórzano, "Opportunities and Challenges of a World With Negligible Senescence," *Technological Forecasting and Social Change*, 99, 2015, pp. 77–91, <www.sciencedirect.com/science/article/pii/S0040162515001985>.

United Nations (Department of Economic and Social Affairs), "World Population Prospects 2019," accessed on May 12, 2022, <https://population.un.org/wpp/>.

U.S. Census Bureau, International Data Base, 2021, accessed on May 12, 2022, <www.census.gov/data-tools/demo/idb/#/country?COUNTRY_YEAR=2022&COUNTRY_YR_ANIM=2022>.

Vollset, S. E. et al., "Fertility, Mortality, Migration, and Population Scenarios for 195 Countries and Territories From 2017 to 2100: a Forecasting Analysis for the Global Burden of Disease Study," *The Lancet*, 396(10258), October 17, 2020, pp. 1285–1306, <www.sciencedirect.com/science/article/pii/S0140673620306772?via%3Dihub>.

Wittgenstein Centre, Wittgenstein Centre Human Capital Data Explorer, 2018, accessed May 12, 2022, <http://dataexplorer.wittgensteincentre.org/wcde-v2/>.

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