United Nations Department of Economic and Social Affairs

Population Division
Technical Paper No. 2020/02
October 2020

Census counts, undercounts and population estimates: The importance of data quality evaluation*

François Pelletier**

Abstract

Within the framework of the biennial publication, *World Population Prospects*, the Population Division of the United Nations Department of Economic and Social Affairs (UN DESA) has been producing estimates and projections of populations by age and sex and other demographic indicators for several decades and for all countries or areas of the world. The information included in these datasets is used widely by the United Nations system, academia and civil society, including for the monitoring of indicators used to track progress towards the Sustainable Development Goals (SDGs). In recent years, Member States have requested international organizations to base their estimation processes on data reported by the national statistical authorities.

In reviewing different sets of official population estimates provided by Member States from various regions of the world and comparing them to estimates from *World Population Prospects*, this paper provides an overview of the challenges involved in producing consistent time series of population estimates by age and sex. At the same time, it promotes an understanding of some of the causes of discrepancy across different sets of population estimates, and showcases examples where observed population counts or reported estimates require some adjustments. The purpose is to foster a better understanding of data quality and to urge caution, among both data producers and users, not to accept or use all observed data or reported estimates at face value.

Keywords: Population estimates, census, undercounts, data quality
Sustainable Development Goals: 1, 3, 4, 5, 6

* The current version benefits from the inputs and feedback from Patrick Gerland, Sara Hertog, Bela Hovy, Karoline Schmid, Frank Swiaczny and John Wilmoth. Guangyu Zhang assisted in the manuscript's review and publication.

** Population Division, United Nations Department of Economic and Social Affairs

CONTENTS

The Population Division of the Department of Economic and Social Affairs provides the international community with timely and accessible population data and analysis of population trends and development outcomes. The Division undertakes studies of population size and characteristics and of the three components of population change (fertility, mortality and migration).

The purpose of the **Technical Paper series** is to publish substantive and methodological research on population issues carried out by experts both within and outside the United Nations system. The series promotes scientific understanding of population issues among Governments, national and international organizations, research institutions and individuals engaged in social and economic planning, research and training.

Suggested citation: Pelletier, François (2020). *Census counts, undercounts and population estimates: The importance of data quality evaluation.* United Nations, Department of Economics and Social Affairs, Population Division, Technical Paper No. 2.

This technical paper is available in electronic format on the Division's website at www.un.org/development/desa/pd/. For further information, please contact the Population Division, Department of Economic and Social Affairs, Two United Nations Plaza, DC2-1950, New York, 10017, USA; phone: +1 212-963-3209; e-mail: population@un.org.

I. INTRODUCTION [1]

In September 2015, the 2030 Agenda for Sustainable Development was adopted by the United Nations General Assembly and laid the foundation for international cooperation in the economic, social and environmental fields for the next decade and a half.[2] The new Agenda ushered in the era of the Sustainable Development Goals (SDGs), which rely on the annual monitoring of a wide array of quantitative indicators. Accurate monitoring of progress towards the SDGs requires high-quality, timely data, including data from censuses, civil registration systems and household surveys, which are used to derive estimates that should be comparable across countries and over time. Such data or estimates are the result of different processes carried out by national authorities and/or international or supranational organizations. Given the heterogeneity of sources, approaches and methods used across the world to generate time series of population estimates by age and sex, an evaluation and discussion surrounding their quality or accuracy are warranted.

Initiatives and discussions to address issues of data quality, both at the national and international levels, have been on the agenda of various statistical groups. As part of the development of the Statistics Quality Assurance Framework, the Statistics Division of the United Nations Department of Economic and Social Affairs (UN DESA), hereafter referred to as Statistics Division, produced a generic *National Quality Assurance Framework* (NQAF), comprising a *Template and Guidelines,* with principles and frameworks that targeted national statistical organizations (UNCTAD and task team, 2016). Furthermore, for international organizations that produce statistics, the Committee for the Coordination of Statistical Activities (CCSA) in 2005 adopted the *Principles Governing International Statistical Activities,* whose principles are similar to the *Fundamental Principles of Official Statistics* (ibid).[3]

In 2017, as part of a dialogue on quality assurance within the Committee of Chief Statisticians of the United Nations system, it was suggested that official statistics received by international organizations from a national statistical office (NSO) or other national authority should be adjusted in either of two circumstances:

• to adhere to standard classifications, definitions or methods and be harmonised with data from other countries; and/or

• to correct evident errors or implausible results, based on internal inconsistencies or comparisons with data from similar countries (UNCTAD and task team, 2016).

More recently, in 2018 at a meeting in Vienna, the CCSA discussed the use of population data for monitoring progress towards the SDGs. Some participants expressed concern about differences between the population estimates provided by countries and those published biennially in *World Population Prospects* (WPP) by the Population Division of the United Nations Department of Economic and Social Affairs, hereafter referred to as Population Division, as they considered that such differences were an important cause of discrepancies between national estimates of key development indicators and those produced by international agencies (UN DESA/Population Division, 2019a).

Overall, the SDG reporting process is led by national authorities. This approach should ensure coherence, at least within each national data framework, when the calculation of indicators requires multiple

---

[1] This paper has been prepared as background documentation for the Committee for the Coordination of Statistical Activities (CCSA) task team on population estimates.
[2] General Assembly resolution A/70/1 (www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E).
[3] Available at: https://unstats.un.org/unsd/dnss/gp/fp-english.pdf

inputs (e.g., numerators and denominators) that can be obtained from the same source. Even within a country, however, the inputs required for the calculation of some indicators often come from different sources (e.g., censuses, registration systems, surveys). Furthermore, when Member States do not have the information readily available or the means to provide specific indicators, the only available estimates may be those provided by international organizations. Such estimates may be some transformation of observed data or of reported estimates, using demographic analysis or statistical modelling. Several United Nations system entities produce country-specific estimates of internationally agreed or recognized indicators for the main purpose of generating regional and global estimates.

In recent years, Member States have requested international organizations to base their estimation processes on data reported by the national statistical authorities.[4] Such requests can pertain to specific indicators (e.g., under-five mortality rate, maternal mortality ratio, net enrolment rate)[5] or to underlying components used for the calculation of such indicators. To generate these indicators, international organizations may utilize components (e.g., numbers of births or deaths, population estimates by age and sex) derived from the work of other organizations. Data published within the WPP are used widely, including for the global monitoring of around one third of the SDG indicators currently classified in tiers 1 and 2. For example, the two mortality indicators mentioned above require numbers of births as inputs. For several years and across many countries, numbers of births estimated by the Population Division in the biennial editions of *World Population Prospects* have been used by the United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) and the United Nations Maternal Mortality Estimation Inter-Agency Group (MMEIG) for the computation of under-five and maternal mortality. Similarly, net enrolment rates by education levels produced by the UNESCO Institute of Statistics (UIS) require estimates of the number of children or young adults in specific age groups, which serve as denominators of the rates. For that purpose, UIS has been using the interpolated annual population estimates by single year of age, as made available by the Population Division. Although a discussion on the quality of population data could be expanded to include measures of the demographic components of population change (e.g., birth and death rates), for the purposes of this technical paper, the main focus will be on population estimates by age and sex. An example involving mortality indicators serves to illustrate that, in the absence of reliable data, one should inquire whether the derived indicators are in line with other variables of a given country and if the implied country ranking as compared to others is plausible or not.

In reviewing different sets of official population estimates provided by Member States (referred to here as “country data”) ranging from the regions of Northern America to Western Asia and Southern Africa, and comparing them to estimates from *World Population Prospects*, this paper seeks to provide an overview of the challenges involved in producing consistent time series of population estimates by age and sex. At the same time, it promotes an understanding of some of the causes of discrepancy across different sets of population estimates and showcases examples where observed population counts or reported estimates require some adjustments. The purpose is to foster a better understanding of data quality and to urge caution, among both data producers as well as users, not to accept or use all observed data or reported estimates at face value.

Aside from the example on mortality indicators mentioned above, the discussion will be centred on the use of population data as reported by Member States compared to the estimates produced by the Population Division and published in the WPP. The Statistics Division has the mandate within the United Nations system to collect from Member States and to disseminate relevant statistics, including annual population

---

[4] Although international organizations use data reported by Member States as inputs for the estimation of many indicators, various adjustment and imputation methods are used to correct errors or to fill in missing data.

[5] Furthermore, estimates of life expectancy at birth from the Population Division are also being used by UNDP, namely for the *Human Development Report*, and by the World Health Organization.

estimates and related metadata.[6] This paper also briefly addresses possible shortcomings in reporting processes that may hinder a timely flow of the information required to minimize differences between national and international authorities.

[6] In the above mentioned 2009 *Report of the Task Team on Population estimates* (SA/2009/7), some suggestions had been made regarding the collection of metadata (see Annex 1 in report).

II. THE USE OF POPULATION ESTIMATES IN THE MONITORING OF SDGS

At the 12th Inter-Agency and Expert Group meeting on Millennium Development Goals (MDGs) indicators, it was agreed that all United Nations agencies should use population estimates from *World Population Prospects* as inputs to the production of MDG indicators (UN DESA/Statistics Division, 2007). There was also a discussion about which population datasets were better suited for use in the monitoring of specific indicators (UN DESA/Population Division, 2008 and 2009). However, in contrast to the SDGs, "the MDGs were not, strictly speaking, a formal intergovernmental mechanism, but rather an initiative driven by the UN Secretariat" (MacFeely, 2018, p. 2). Consequently, the United Nations and several of its funds and specialized agencies were at the core of the MDG reporting process. The monitoring of relevant trends in the context of the SDGs, on the other hand, is a State-led process, with some countries insisting that only official data from national sources be used for SDG monitoring (ibid). Thus, from the MDGs to the SDGs, the approach adopted for the monitoring process made an important shift towards giving priority to national data and a State-led review processes.

In the era of the MDGs, an earlier CCSA task team on population estimates recognized "that there were cases where the United Nations population estimates should not be used as, for instance, when the data available on a certain indicator referred to a different population from that reflected in the United Nations population estimates or when the use of the latter would result in unacceptable biases". Especially for developed countries, whose national data were seen as reliable and timely, the task team observed that "indicators at the national level might best be derived using official population estimates generated by NSOs" (UN DESA/Population Division, 2008, p. 16). In the same report, it was also mentioned: a) that inconsistencies between statistical concepts such as *de facto* or *de jure* populations could also be a source of discrepancy, and b) that interpolating the United Nations population estimates from five-year age groups to single years of age produced bias indicators (ibid). Lastly, although the 2008 task team had raised concerns about the lack of internationally agreed standards for producing population estimates, it took no systematic action or offered precise recommendations on how to make progress towards that goal.

The 2008 task team included in its final report a list of possible limitations in using population estimates from the United Nations in specific cases. First, it noted that for some countries, discrepancies in population estimates are related to differences in territorial coverage. Current examples include the region of Crimea, claimed by both Ukraine and Russia, the Greek and Turkish parts of Cyprus, the Transnistria region in the Republic of Moldova, and the territory of Western Sahara, claimed by Morocco. Discrepancies in population estimates due to variation in territorial coverage can usually be identified or confirmed in the available metadata. In this situation, users can decide about the appropriate source of information for their specific needs and make any necessary adjustments.[7]

Second, the 2008 task team noted that differences in population estimates related to the distinction between *de facto* and *de jure* population concepts are complex, as countries may not report data according to both definitions, and their choice of a population concept used for national statistics may change over time. For most countries, however, the difference between *de facto* and *de jure* population counts tends to be rather small at the national level (for the total population), except in countries where temporary migration flows are significant.[8] In recent years, the growing use of a "usual residence" population concept has added an additional challenge to the comparability of population estimates across countries and over time. The *de facto* concept has been favoured in the preparation of the *World Population Prospect* to insure a complete

[7] This matter will not be further explored in this paper and no example will be provided.

[8] Overall, differences between *de facto* and *de jure* population counts are more significant at the sub-national level, mainly because of internal migration and multiple places of residence.

and universal count and to minimize the risk of counting the same people in different countries. However, many countries only report *de jure* populations and may not provide adjustment factors for converting to a *de facto* concept. To illustrate the challenges related to population concepts when trying to develop a time series of population estimates, we will use as an example the reported population figures of Lesotho.

Another source of discrepancy addressed by the report from the 2008 task team on population estimates was the interpolation procedures used in the WPP to convert the quinquennial population estimates by five-year age groups into annual estimates with single-year age categories. Indeed, this procedure can distort the estimated population size at some ages as compared to reported population estimates, especially for countries with significant numbers of migrants. Distortions can also result from rapid annual variation in fertility levels, which can cause discontinuities in the size of adjacent age cohorts. Likewise, interpolation of quinquennial data to produce annual estimates may produce distortions if a mortality crisis affects just one or two years within a five-year period. Such sporadic events cannot be replicated by interpolation procedures, which tend to smooth out short-term variations. Yet, further investigation is required to determine how much the interpolation procedures distort the estimates of all other countries that fall outside these specific settings mentioned above, and how this potential source of error compares to other underlying causes of discrepancies (e.g., data quality of reported estimates or lack of correction for census undercounts). Though not explicitly mentioned as major issues in the report of the 2008 task team on population estimates, concerns about data quality and census undercount were addressed in a progress report of a more recent CCSA task team on the same topic (UN DESA/Population Division, 2019a). These various observations highlight the need to address the lack of uniform practices in the production of population estimates by age and sex and other demographic indicators.

Lastly, in the context of SDG monitoring, one important principle is the comparability of indicators across countries. As noted in the 2017 SDG report: "Where possible, global monitoring should be based on comparable and standardized national data obtained through well-established reporting mechanisms from countries to the international statistical system... To fill data gaps and improve international comparability, countries will need to adopt internationally agreed upon standards…" (United Nations, 2017, p. 58). In that regard, producing estimates for all countries of the world with a standard approach is preferable to compiling country estimates based on different definitions or methods. As pointed out by MacFeeley (2008, p.7): "Even for those indicators that fall within the scope of traditional official statistics, general quality and adherence to international standards will still vary significantly across countries. Thus, it may be sensible to apply a healthy scepticism to any of the resultant country rankings when published". He also stated that "using alternative sources to official national data might also be reasonable where problems with data exist. Problems with data could mean anything from errors or inaccuracies, non-adherence to international standards, incompleteness or data gaps, inconsistencies over time or imbalances" (ibid).

III. Census counts and undercounts

The report of the Principles and Recommendations for Population and Housing Censuses states that "it is universally accepted that a population census is not perfect, …but these errors should be measured. Errors in the census results are classified into two general categories—coverage errors and content errors" (UN DESA/Statistics Division, 2017, p.118). "Net coverage error takes into account the underestimates due to omissions and the overestimates due to duplications and erroneous inclusions. When omissions exceed the sum of duplications and erroneous inclusions, as is usually the case in most countries, a net undercount is said to exist; otherwise, a net overcount results" (ibid, p. 119-120). Furthermore, age misreporting and age-selective underenumeration are common problems in censuses, and if not corrected, can distort the population age structure and generate errors in the calculation of certain indicators. The report also recommends that the "final publication of census results should include an estimate of coverage error, together with a full indication of the methods used for evaluating the completeness of the data" (ibid, p.119).

For the vast majority of countries of the world, censuses continue to be the main source and the basis for producing population estimates by age and sex.[9] Censuses are conducted, for the most part, every 10 years (sometimes every 5 years), even though several countries have not conducted a census in over 10 years, including for several decades for countries like Afghanistan and Lebanon. Thus, not all countries have actual data to inform the production of annual population estimates. Furthermore, census enumerations typically do not cover 100 per cent of the population of a territory at a given time and therefore require some form of adjustment, often based on an estimated net undercoverage rate (overcounts also occur in certain age groups). Several countries have conducted post-enumeration surveys or applied other methods to estimate the actual coverage of a census enumeration. However, the practices of correcting the census population and, if so, documenting the method used as part of the census metadata varies by country. Indeed, several countries only provide the enumerated census count by age and sex and do not report adjusted populations to international organizations.[10] As stated by O'Hare: "Many countries do not conduct systematic assessment of the Census and/or they do not make them publically [sic], or at least easily available" (2017, p. 297). According to Anderson, "undercount is a problem in all countries, especially among children and young men", and "issues of undercount, estimation of undercount, and whether to adjust population figures are fraught with practical and political consideration throughout the world" (2004, abstract). Census undercounts should not be seen as an exception but rather as a norm. The magnitude of undercount varies across countries and over time for a given country due to various reasons ranging from challenges in enumerating hard-to-reach populations to the institutional capacity and experience in conducting a complex and labour-intensive exercise in data collection and compilation. In conclusion, a census is not, in reality, a full and accurate count of the number of people in a country; rather, it is itself an estimate of the size of the population at a moment in time (Moultrie and Dorrington, 2012).

Over time and across countries, different methods have been developed and used to estimate the census undercount. In the United States, for example, both the demographic analysis (DA) method and the dual systems estimates (DSE, also called post-enumeration survey) method provide quantitative results for assessing census accuracy (O'Hare, 2017). The two methods tend to yield different results. For the 2010 census, "the net undercount estimate for children age 0 to 4 produced by the DA methodology is 4.6 percent compared to 0.7 percent produced by the DSE method" (O'Hare, 2017, p. 290). The U.S. Census Bureau Task Force on the Undercount of Young Children concluded that demographic analysis is the best method for assessing the net undercount of young children (ibid). The United Nations has observed that

---

[9] Population registers are also being used in a number of countries. The accuracy of registers has also been questioned in some countries.

[10] In some cases, reported census population counts may have been adjusted though not necessarily indicated in the respective metadata, which could potentially lead to the estimated population being adjusted twice.

demographic analysis offers a powerful methodology for evaluating the quality of a census and has encouraged countries to use it as part of their overall census evaluation approach (UN DESA/Statistics Division, 2017).

The Population Division produces population estimates for all countries of the world. In order to do so, it applies the demographic reconstruction approach, which is similar to the DA method described above.[11] For some countries, the underlying data on the demographic components of change (fertility, mortality and migration) may be sparse and relatively unreliable. One advantage of using the demographic reconstruction approach is that it helps the analyst to identify if the estimates associated to these three components of population change are consistent with the population counts of successive censuses or official population estimates. This approach, combined with some analysis of the underlying information, provides some indication about which item(s) of the demographic equation (any of the components or the populations at different points in time) may require adjustment to resolve discrepancies. For instance, a survey conducted in a country may yield a total fertility rate of 5 live births per woman; when applied to the female population in the reproductive age range, it will yield a specific number of births that should be echoed in subsequent cohorts, and these can be compared to the populations observed in existing censuses or future ones, once the new data is made available. If such an analysis reveals inconsistencies across these inputs, it may be necessary to adjust the population estimate, the fertility estimate or the estimated number of women of reproductive ages. Evaluating a stand-alone census count or population estimate for a single point in time offers no assurance that all age cohorts are consistent with prior observations or events.

As mentioned above, not all countries have actual data or recent census counts to provide the basis for producing annual estimates of population size by age and sex, nor do all of them report such information. Moreover, how such estimates are derived varies considerably across countries and not all countries publish metadata providing the details of the estimation process. There are multiple reasons why different estimates may not agree, including that they may have been produced by different parties using different information and that various adjustment procedures may have been applied. These observations highlight the need to develop standards for generating annual estimates of population size by sex and single-year ages.

[11] For further details, see section V.

IV. POPULATION ESTIMATES FROM MEMBER STATES

The practice of reporting annual population estimates between censuses varies by country, as well as the approach used to generate these estimates. Regrettably, there are still no internationally agreed standards for producing annual population statistics (UN DESA/Population Division, 2008). Having said so, guidelines have been provided for the recalculation of intercensal estimates[12] and more generally for data quality assessments.[13] [14] In practice, procedures vary considerably from one country to another and are not always well documented, starting with adjustments made to the actual census counts, if any, followed by the procedures used to generate intercensal estimates, and whether previous estimates were recalculated once the results of a new census are made available. A common practice among Member States is to compute population projections following a census; in several cases, the results of these projections are reported as official estimates over the following years, until the next census results become available. Once the results of the next census are made available, some countries recalculate past intercensal estimates to generate a consistent time series of population figures, though not all countries do this important step. Consequently, breaks or discontinuities in time series of population estimates continue to exist for many countries.

Based on some of the issues raised above, the agreement made during the MDG era (referred in section 2), or simply out of convenience because of the readily available time series, many UN agencies or entities responsible for the monitoring of specific SDG indicators continue to use population estimates as published in *World Population Prospects.* In that regard, the following section briefly provides some information on the process and framework of producing population estimates in *World Population Prospects*.

[12] Available at: https://ec.europa.eu/eurostat/documents/3888793/5828513/KS-CC-03-022-EN.PDF/d87b010c-52a1-4d9c-8a49-67377ac960d1
[13] Available at: www.un.org/en/development/desa/population/publications/pdf/manuals/estimate/manual1/pre_toc.pdf
[14] Available at: www.un.org/en/development/desa/population/publications/manual/estimate/appraise-data.asp

V. WORLD POPULATION PROSPECTS

The population estimates and projections contained in the latest revision of *World Population Prospects* cover a 150-year time horizon, from 1950 to 2100.[15] The estimates were produced by starting with a base population by age and sex for 1 July 1950 and advancing the population through successive 5-year time intervals using the cohort-component method, based on age-specific estimates of the components of population change (fertility, mortality, and international migration). Population counts by age and sex from periodic censuses or official estimates were used as benchmarks. The relevant estimates of demographic components were taken directly from national statistical sources, including surveys, or were estimated by staff of the Population Division when only partial or poor-quality data were available. Necessary adjustments were made for deficiencies in age reporting, underenumeration in censuses, or underreporting of vital events (UN DESA/Population Division, 2019b).

A key aim within each revision of *World Population Prospects* is to ensure the consistency and comparability of estimates within countries over time and across countries. Accordingly, for the estimation period from 1950 up to present, newly available demographic information was subjected to quality analyses and was also evaluated by analysing the impact of its incorporation on recent trends in fertility, mortality, or migration, and by comparing the simulated outcome with existing population estimates by age and sex at successive time intervals (UN DESA/Population Division, 2019b). This process also aims at maintaining some consistency between the different components of demographic change and the overall population by age and sex. Therefore, within the WPP, the estimated or reported populations by age and sex from a given country are not simply copied from national sources or inserted as is within an existing time series of population figures. The populations by age and sex are reconstructed using the cohort component method. Within this demographic reconstruction exercise, it is important to point out that when using official demographic indicators, such as the total fertility rate from a survey or vital registration system, it may yield population levels by age that differs from population counts. For countries with high-quality data where the demographic components are synchronized with the estimated population, this approach has proven to produce fairly consistent cohorts of population estimates that are in line with observed ones. However, in countries where demographic indicators may not be so reliable, adjustments are often required.

The accounting framework of the WPP process, for both estimates and projections, is based on 5-year age groups moving through successive 5-year time intervals.[16] Interpolation routines are then used to produce estimates and projections for single calendar years and for single years of age (for further details, see UN DESA/Population Division, 2019b). Interpolation procedures cannot recover the true series of events or the true composition of an aggregated age group.

Indeed, depending on the population trend and as discussed above, interpolation procedures are not always optimal and can be a source of discrepancy with official estimates, especially in countries that have witnessed important migration flows, mortality crises or have experienced significant annual variations in fertility levels. However, in many countries, differences between official estimates and those produced by the Population Division are related to other sources, such as adjustments that are made in the population counts and/or in the levels of different demographic indicators that contribute to this population estimation process. Lastly, within WPP, there is an attempt to replicate populations under the *de facto* concept in order to capture all people within a given country though there are exceptions to this rule as not all countries provide their population estimates based on that concept. The use of different population concepts is also a cause of discrepancies.

---

[15] Results from *World Population Prospects 2019* are available at: https://population.un.org/wpp/

[16] These years, for example 2000, 2005 and 2015, which are sometimes referred to as "anchor" years and are the basis for the annually interpolated figures.

VI. CENSUS COUNTS, ESTIMATES AND ADJUSTMENTS: SOME EXAMPLES

In order to illustrate different matters raised above (census counts, estimates, adjustments, interpolation issues, etc.) the following sections will review different examples comparing data or estimates reported by countries from different regions of the world and estimates from *World Population Prospects*.

Population figures for the total population count of a country and/or by age and sex are made available by Member States or national statistical authorities for different years over time and are usually based on population censuses, population registers and/or official estimates. The Statistics Division compiles such information[17], including metadata, which are made available via its *Demographic Yearbook* (DYB) and associated databases. Within this data compilation, metadata, when provided, allows the user to know, for instance if a census has been adjusted or not. Some validation procedures are used by the Statistics Division to identify possible errors or atypical estimates, though, overall, no extensive data quality control is conducted; for the most part, the data is published as reported.[18] The Population Division also proactively searches on websites of national statistical offices for other relevant or timely information, including data and metadata. In some cases, the data included in the DYB may differ from data found on national websites. For instance, based on the 2016 census of Australia, the overall net undercount was estimated at 1.0 per cent, though reaching 5.1 per cent for the 0-4 years old and 5.0 and 4.9 per cent respectively for the 20-24- and 25-29-year age groups; overall, male undercount was higher (Australian Bureau of Statistics, 2018). When using the 2016 census and official adjusted population estimates that have been reported to the DYB, the estimated undercount is higher.[19] Such differences might be explained by the timeliness of the reporting and/or updates to data series.

Furthermore, in the DYB, e.g., only the enumerated population of the 2010 census of the United States of America is made available. However, after the census was conducted, a net undercount of about 4.6 per cent for young children, defined as children aged 0-4 years, was estimated with the "Demographic Analysis" method referred above. This translated into a net undercount of almost 1 million young children (Hogan and others, 2013). The population in young ages in subsequent estimates from 2012 onward in the DYB do not seem to have been adjusted upwardly to take into account this correction. For both Australia and the United States, this brings about the issue that for a given year, different sets of estimates have been generated. Under such circumstances, a better dialogue may be required with countries when data and metadata are being reported to the Statistics Division. "The Task Team called upon the UN statistical system to reinforce its efforts to improve the availability of metadata for censuses, surveys and basics statistical indicators" (UN DESA/Population Division, 2008, p. 16). The following section will further explore different comparisons of estimated populations for selected countries, while looking more closely at the age dimension.

A. Canada

Statistics Canada provides timely population data by age and sex to the United Nations system that is considered of high-quality. Canada conducts censuses every 5-years, calculates net undercoverage rates following a census that are applied to their official population estimation process, and, as needed, revises past estimates.

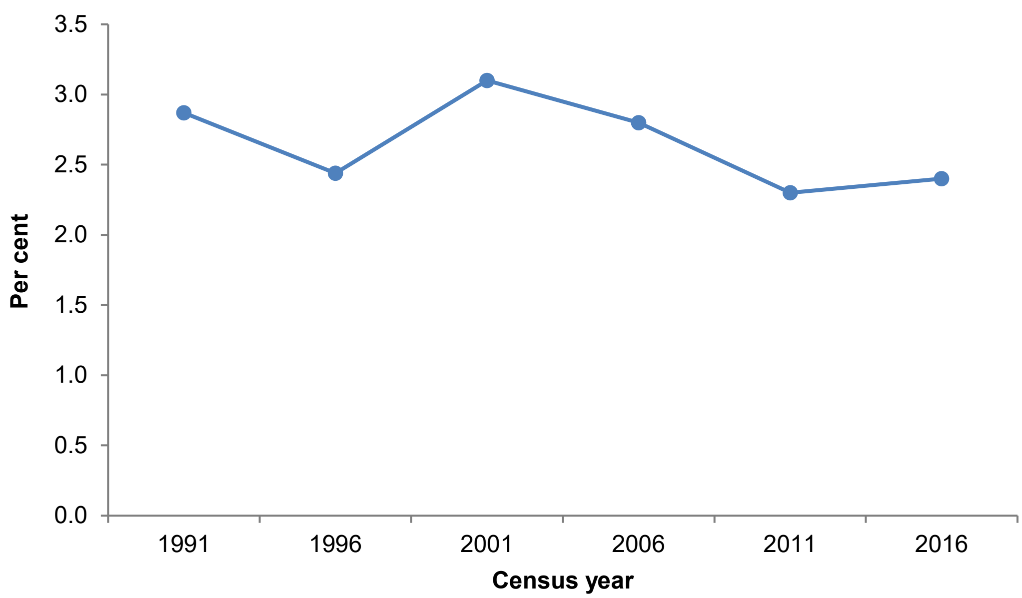
[17] Available at: https://unstats.un.org/unsd/demographic-social/products/dyb/#questionnaires

[18] In some cases, the Statistics Division may consult with the country to receive a justification for specific numbers, may ask to revise the estimates, search for other information within official sources and may decide not to publish the submitted estimates.

[19] These differences might be related to the application of the net undercount rate for persons on census form vs. the total net undercount rate (see Harding and others, 2017).

Figure 1 shows the **net** undercoverage rates from six different censuses conducted from 1991 to 2016 in Canada. Overall, there has been a net undercoverage that ranges more or less from 2.5 to 3 per cent (also see Annex figure 1 for undercoverage rates which are higher). The net undercoverage rates in Canada have been revised over time and Statistics Canada does indicate that "comparisons with previous censuses should be made with caution, as the methodology for both the census and its coverage studies changes with the objective of producing the best information possible at each occasion" (Statistics Canada, 2018 [20]). Furthermore, the actual census data are not adjusted by the results of the coverage studies, though these are used to rebase the population estimates (ibid).

Figure 1. Net undercoverage rates, 1991-2016 censuses of Canada

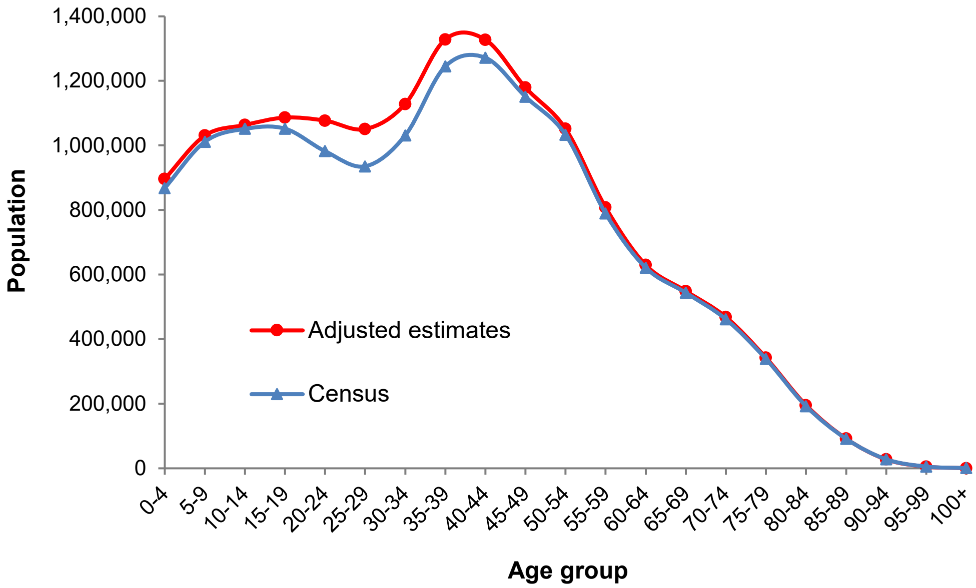


Sources: For 1991 and 1996: Statistics Canada, 2011 census, 2011 reverse record check and 2011 census overcoverage study. For remaining years: census coverage studies, 2001 to 2016 (see note below and annex).

Figure 2 compares the population by age and sex for the male population of Canada as enumerated in the 2001 census and the adjusted official population estimates. The estimated net undercoverage rate for the 2001 census was estimated at 3.1 per cent though it reached close to 9 per cent in young men aged 20-24 years. When such information is made available to the United Nations system and is considered reliable, the ideal practice, while updating the population estimates from *World Population Prospects,* is to replicate or approximate the adjusted population, not the enumerated census population. This practice applies for many countries that produce and report reliable estimates. However, not all countries generate such information or make it easily available.

[20] See: www150.statcan.gc.ca/n1/en/daily-quotidien/180927/dq180927k-eng.pdf?st=CTly4z52

Figure 2. Population by age, males, Canada, 2001: census vs. adjusted estimates



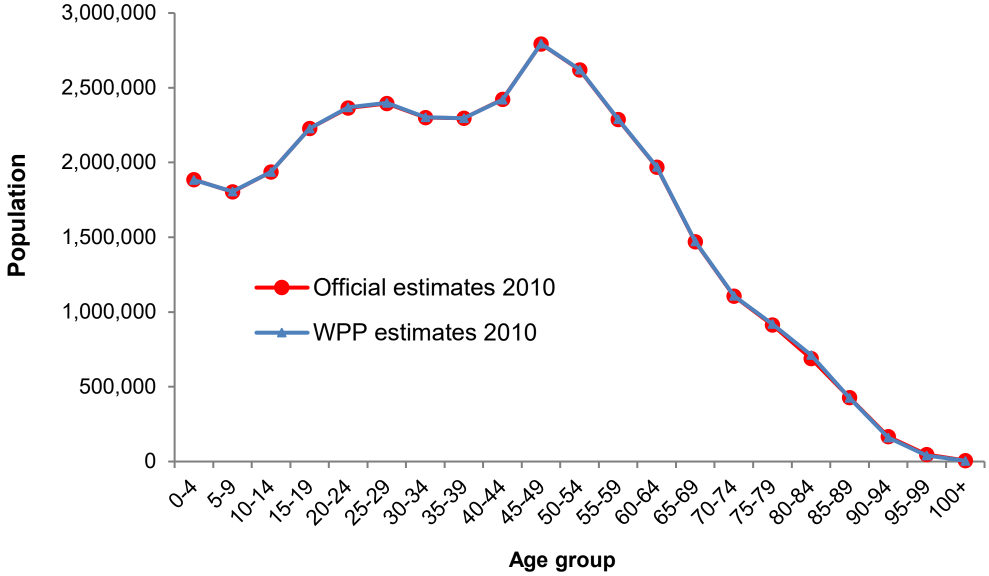
Source: Statistics Canada: 2001 census count (May 2001); estimates are adjusted for census net undercoverage (official estimates were reported for July 1 2001 and adjusted to May 2001, while matching the official net undercoverage.

Interpolation issues

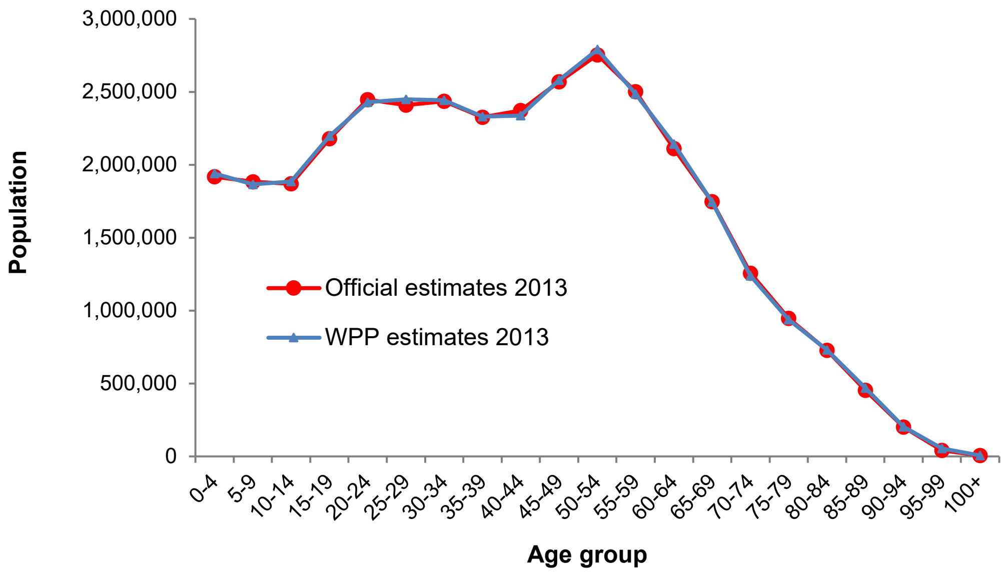
As discussed above, the current accounting framework of the WPP process is based on 5-year age groups moving through successive 5-year time intervals. Therefore, estimates by single year of age and estimates for any years between the "anchor" years such as 2005, 2010 or 2015, are derived from interpolations procedures. To illustrate the effect of these interpolations, figure 3-A shows the population of Canada by quinquennial age groups as reported by Statistics Canada for the year 2010 for both sexes combined (this refers to the "adjusted" population) and WPP estimates for the same year. Considering that 2010 is an "anchor" year within the WPP accounting framework and that the reported estimates had already been adjusted and are considered reliable, there is a very good match between both estimated series. Figure 3-B shows the same information for the year 2013, which is not an "anchor" year and therefore is the outcome of interpolation procedures, as briefly explained above. Overall, the two series are also quite consistent though there is some slight variation in young adults where migration and/or the magnitude of the official adjustments may play a larger role. In the end, when reliable data is available and properly used, the interpolation procedures do not seem to distort significantly the estimates of population by age and sex. However, if WPP estimates would be compared to non-adjusted census figures, one would recognize larger differences, as the demographic reconstruction in WPP would entail some adjustments.

Figure 3. Population by five-year age groups (both sexes combined), official estimates and WPP estimates, Canada, 2010 (A) and 2013 (B)

(A)



(B)



Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database[21] (as reported by Statistics Canada) and *World Population Prospects*, *the 2017 Revision*.

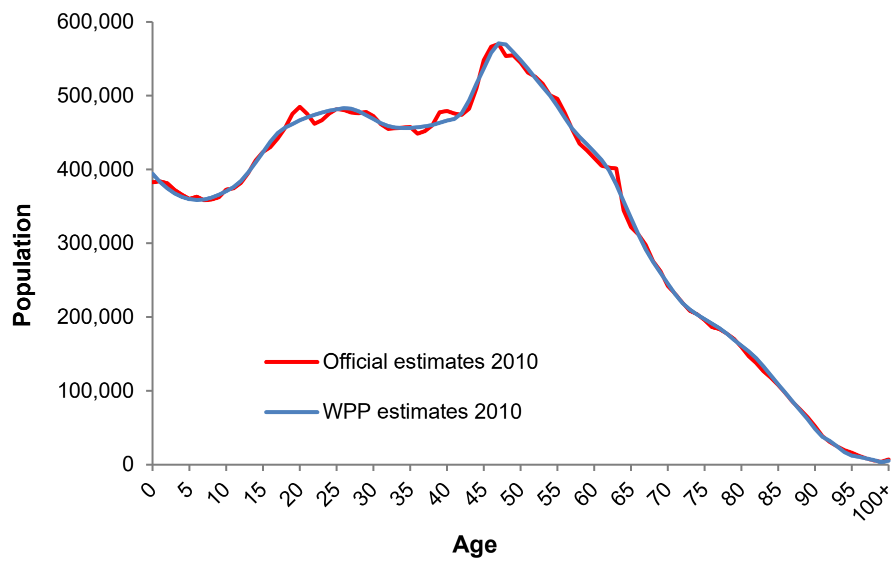
To continue the review and illustrate the effect of the interpolation procedures with respect to the annual/single year of age estimates (also known as 1 x 1), which are widely used by UNESCO UIS for constructing specific population age groups (e.g. 6-11, 12-17, 18-23), figures 4-A and 4-B show the single-year official estimates of Canada and WPP interpolated figures, respectively for the years 2010 and 2013.

[21] Publicly available at: http://data.un.org/Data.aspx?d=POP&f=tableCode%3a22. In the case of Canada, estimates submitted to the United Nations Statistics Division may have been updated. Estimates may differ slightly from those used in this paper and in the WPP revisions.

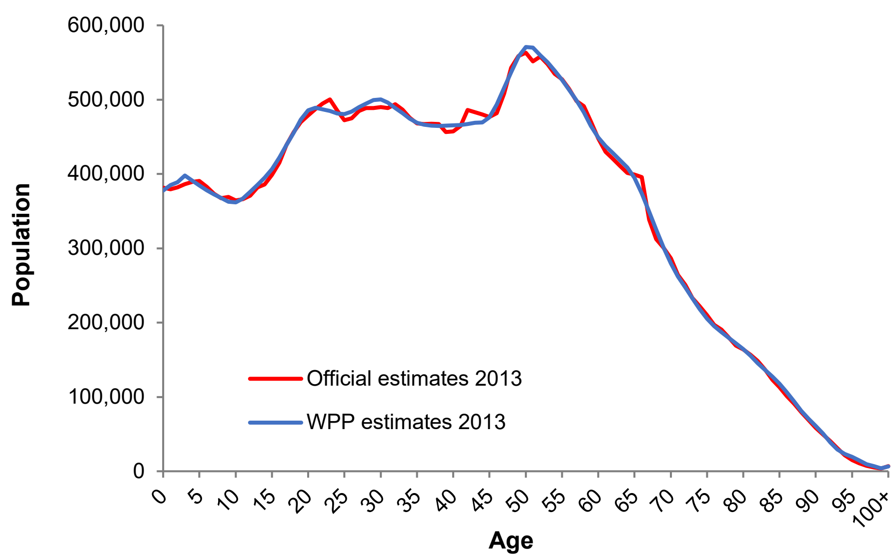
In both years, greater differences are encountered than with the quinquennial estimates shown in figure 3 above, though, overall variations are quite small with a few exceptions in selected ages (young and middle age adults). It can be argued that using a 1 x 1 accounting framework would contribute in improving the matching of reported data in selected ages. However, these population differences in young adults are considerably smaller than what was assumed in the census undercount correction factors. In that regard, if Canada had not provided the adjusted census populations, the differences with WPP estimates would probably have been greater. Having said so, the observed fluctuations in the population of young adults (around ages 20-24) could also be related to fluctuations in fertility estimates in the late 1980s early 1990s, which are not well captured by indicators computed on 5-year averages.

Figure 4. Population by single year of age (both sexes combined), official estimates and WPP estimates, Canada, 2010 (A) and 2013 (B)

(A)



(B)

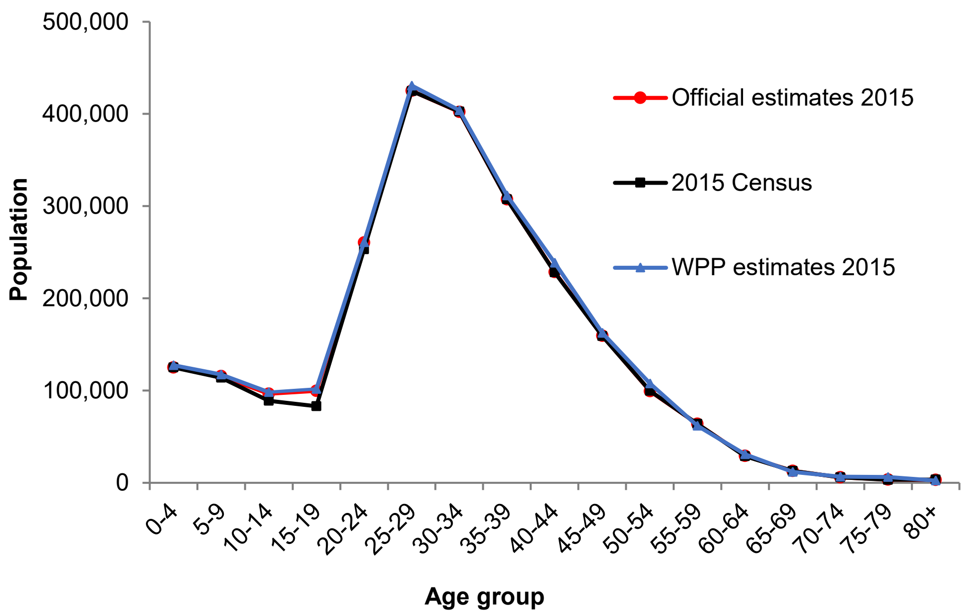


Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by Statistics Canada) and *World Population Prospects*, *the 2017 Revision*.

B. Qatar

Qatar is a country with population dynamics that are significantly influenced by the inflow of migrants, including many "temporary" migrant workers. Figure 5 compares the population by five-year age groups (both sexes combined) based on the official estimates, the 2015 census[22] and WPP estimates from the 2017 revision. The 2015 official estimates were adjusted as compared to the 2015 census population, most noticeably in ages 15-19 and 10-14, for which differences reach 17 and 8 per cent, respectively.[23] In updating the estimates from WPP, it was decided to better approximate the official estimates from 2015, and overall, the differences are relatively small (except at higher ages, in relative terms).

Figure 5. Population by five-year age groups (both sexes combined), official estimates, census and WPP estimates, Qatar, 2015



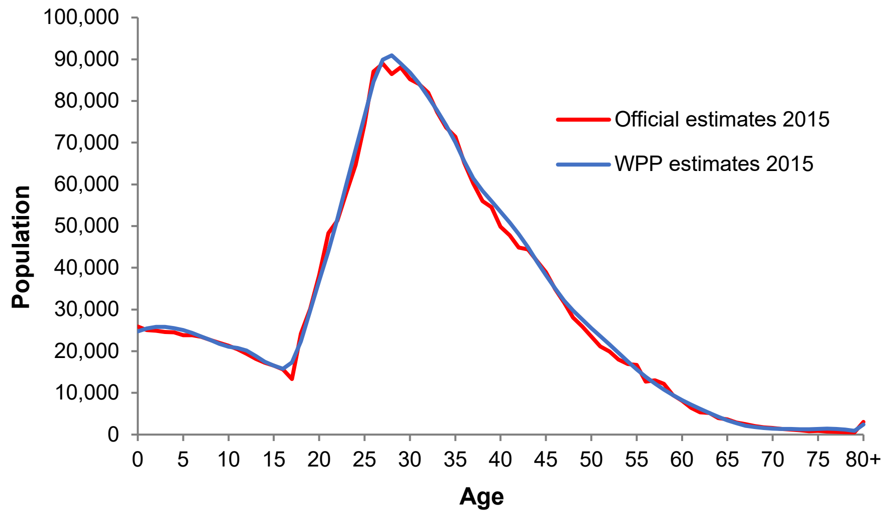
Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by the Ministry of Development, Planning and Statistics of Qatar) and *World Population Prospects*, *the 2017 Revision*. Estimates refer to July 1 2015 while census figures refer to 20 April 2015.

However, when looking at the annually interpolated population from WPP as compared to the official estimates (figure 6), variations are more important. For instance, there is a difference of 30 per cent for the 17-year-old population, which translates in an absolute difference of just over 4,000 persons. This could be partly explained because the inflow of migrants in the age group 15-19 is not equally distributed across single years of age, as implied by the interpolation procedure used in WPP. Indeed, labour migrants coming to Qatar are required to be 18-years-old or more and Qatari nationals in that age group, for instance, may also emigrate to study abroad, making it quite difficult to measure adequately the population. Yet, when looking at all ages, there is, overall, some degree of coherence or simply a good match between the different sets of population data.

[22] In the DYB, the census population is reported for 5-year age groups only; single year of age estimates are not provided.

[23] Estimated differences are based on reported figures, not taking into account the different dates of the census and the official estimate, that is April 20 2015 and July 1 2015. The estimated population in these age groups affect the education statistics. Overall, adjustments in other age groups were relatively small.

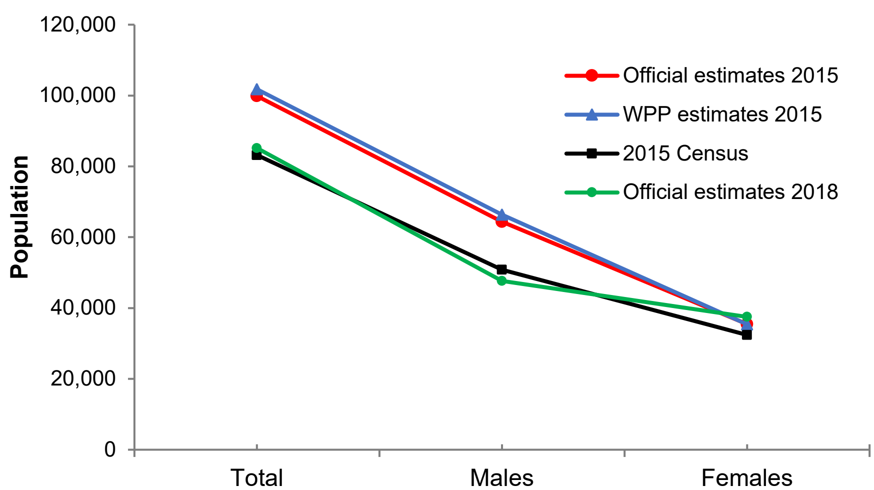
Figure 6. Population by single year of age (both sexes combined), official estimates and WPP estimates, Qatar, 2015



Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by the Ministry of Development, Planning and Statistics of Qatar) and *World Population Prospects, the 2017 Revision*.

In trying to better understand the different estimates for the population in ages 15-19, figure 7 shows a comparison between different sources and years for both men and women. As shown, WPP estimates are very close to the official estimates for the year 2015. Surprisingly, however, the 2018 official estimates[24] for both males and the total are closer to the enumerated census figures from 3 years before. For females, all four data points are relatively close, pointing to the effect that migration has for the estimation of the male population.

Figure 7. Population in age group 15-19 by sex and for the total, official estimates for 2015 and 2018, 2015 census and WPP estimates for 2015, Qatar



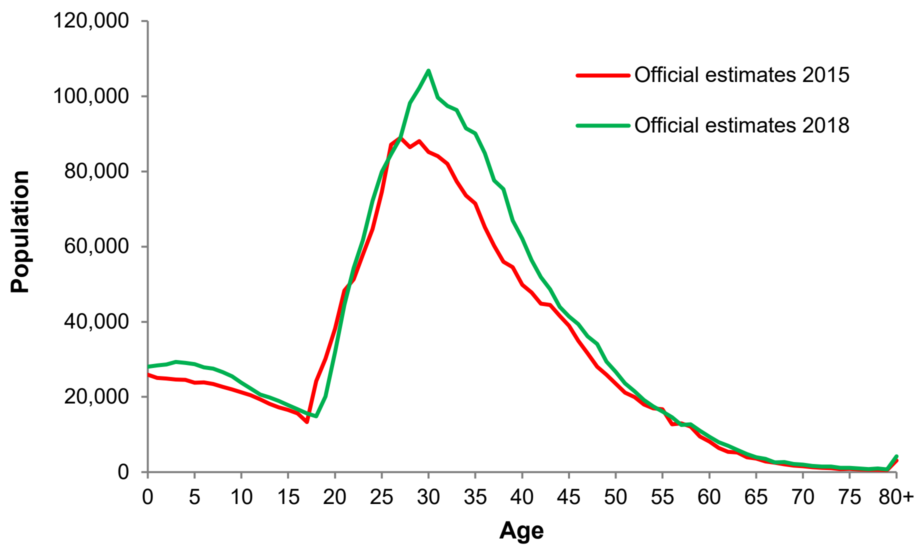
Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by the Ministry of Development, Planning and Statistics of Qatar) and *World Population Prospects, the 2017 Revision.*

[24] Qatar adopted a population register as of 2016.

Based on the official estimates, the total population of Qatar grew by 13 per cent between 2015 and 2018 while the population aged 15-19 years was reduced by close to 15 per cent. Generally speaking, such opposite trends are not what would be expected when trying to produce population estimates or short-term projections. In that regard, during the preparation of the 2017 revision of WPP, the latest official estimates that were available at the time were from the year 2015. Considering the production cycle of WPP (every 2 years) and possible delays in receiving the latest official estimates, WPP estimates, once published, might become quickly outdated for countries with fast-changing demographic trends.

Qatar is a good example of a country that has a rapidly changing population. Figure 8 compares the officially reported populations by single year of age of Qatar for the years 2015 and 2018. Given the magnitude of the population change over a 3-year period, that is predominantly driven by international migration, it would be very difficult, if not close to impossible, to match the 2018 population correctly while starting a projection in 2015, even if the WPP estimates and projections would be computed in an annual/single year of age framework. Having access to the latest information at the time of production of WPP is essential to minimize the risk of disparities with national data and using single-year estimates will help to reduce the gaps up to the latest year for which observed data is made available (including for the number of people at age 17, as discussed above). However, some differences are likely to remain for countries with fast-changing populations, such as Qatar.

Figure 8. Population by single year of age (both sexes combined), official estimates, Qatar, 2015 and 2018



Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by the Ministry of Development, Planning and Statistics of Qatar).

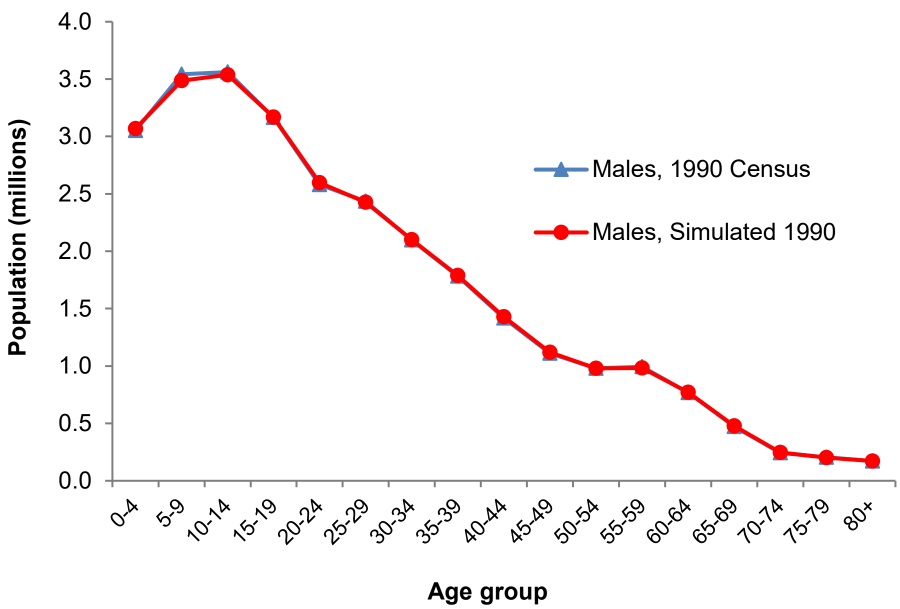
C. Undercount in age group 0-4: the example of Turkey

Though population estimates based on censuses are often not accurate for young adults, especially for men, and age misreporting is more common in advanced ages, the undercount in the number of young children in the age group 0-4 is quite prevalent in many countries and requires special attention; in some countries age misreporting between ages 0-4 and 5-9 also contributes to the problem. Overall, adjustments in the age structure of an enumerated census population are often required.

As discussed above, the net undercount for children aged 0 to 4 years was estimated at 4.6 per cent in the 2010 census of the United States of America (about 1 million children were omitted from the count) and 5.1 per cent in the 2016 census of Australia (Hogan and others 2013; Australian Bureau of Statistics, 2018). Based on analysis conducted for WPP, these values are substantially higher in a number of countries for different censuses. Therefore, to produce consistent population estimates over time, it is crucial to apply proper adjustments to the population aged 0-4 years, and to prevent errors from being carried over into subsequent years as cohorts age over time.

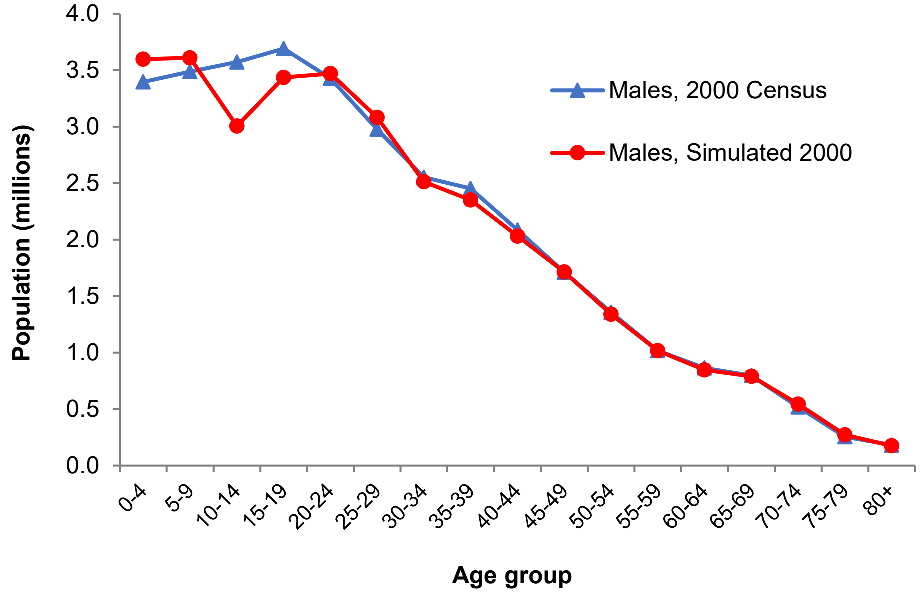
To illustrate this matter, figure 9-A shows the enumerated population by age and sex from the 1990 census of Turkey (non-adjusted male population) and an almost identical simulated population that is projected 10 years later using standard assumptions, and then compared to the 2000 census population, as shown in figure 9-B. In this sensitivity exercise, the population aged 0-4 years from the 1990 census was intentionally not corrected to demonstrate the consequence of not making any adjustments. It can be observed, as we follow the cohort ten years later, and while omitting to apply a correction factor to the 1990 population count, that the projected simulated population in the age group 10-14 in the year 2000 is substantially lower as compared to that of the 2000 census (by about 16 per cent). In this case, an adjustment to the population aged 0-4 years in 1990 would be a necessary step to yield a better match with the 2000 census population.

Figure 9-A. Population by five-year age groups, 1990 census and simulated population, Males, Turkey, 1990



Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by TURKSTATS) and own simulation.

Figure 9-B. Population by five-year age groups, 2000 census and simulated population, Males, Turkey, 2000



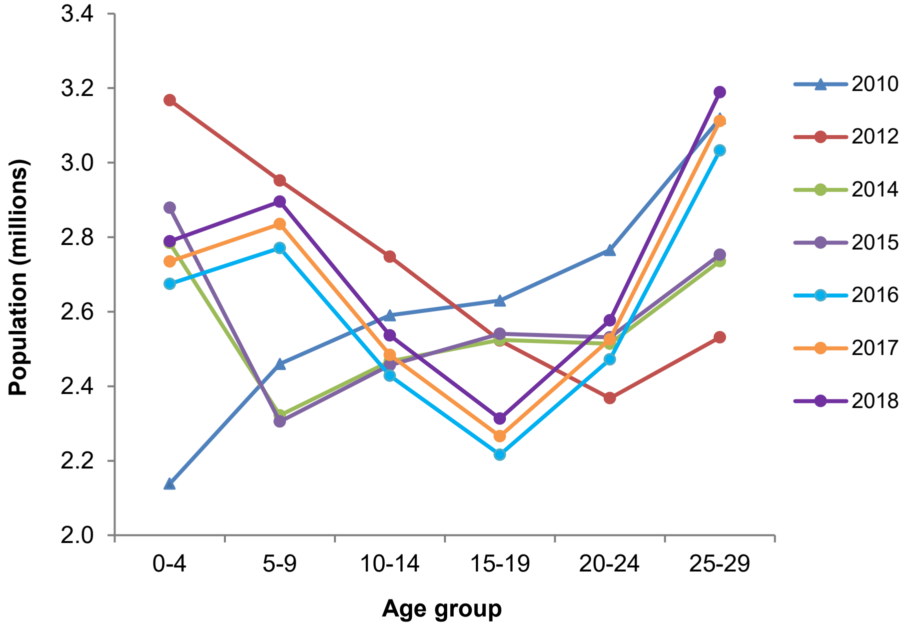
Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by TURKSTATS) and own simulation.

D. Saudi Arabia

Figure 10 presents the 2010 census population estimates for age groups 0-4 to 25-29 as provided by the Statistical Office of Saudi Arabia, as well as official estimates for most years from 2012 to 2018. The variability between the different sets of population estimates indicate a degree of inconsistency that should not be reconciled by adjusting, for example, the net migration levels from one year to another while doing a demographic reconstruction exercise. The gap between the populations of 2010 and 2012 is quite important, and then, the 2014 and 2015 estimates seem to follow a very different pattern. Lastly, the 2016-2018 estimates are quite consistent among each other (though not with the prior estimates) and are possibly the outcome of a projection. Based on that information and a dialogue with representatives of the General Authority of Statistics of Saudi Arabia, the estimates from WPP have been modified over the years and across revisions. When trying to reconcile estimates that vary significantly from one year to another, it is necessary to evaluate which set should be considered more suitable as a basis for WPP estimates. Lastly, it should be highlighted that based on the population estimates reported by the Statistics Office of Saudi Arabia, the estimated net enrolment rates levels, as calculated by UNESCO UIS, vary from year to year.[25]

[25] Based on communication with UNESCO UIS.

Figure 10. Population by age group 0-4 to 25-29 (both sexes combined), Saudi Arabia, 2010 census and 2012, 2014, 2015, 2016, 2017 and 2018 official estimates

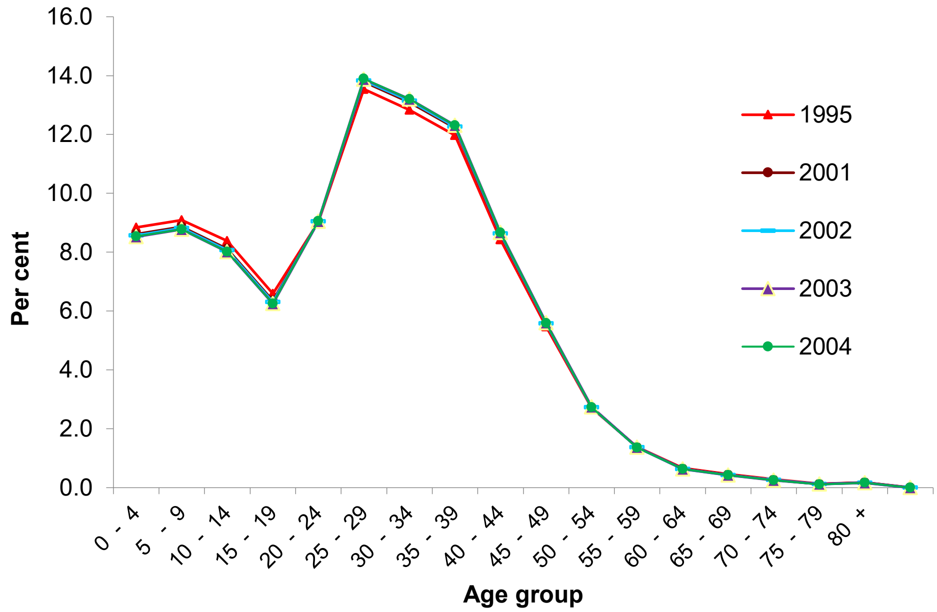


Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by the General Authority for Statistics, Kingdom of Saudi Arabia).

E. United Arab Emirates

As an example of practices used by Member States or national statistical authorities to produce population estimates between censuses, figure 11 shows the population age distributions of the 1995 census of the United Arab Emirates as well as for official estimates from 2001 to 2004 (another census was undertaken in 2005). As one can observe, the population age distributions for all reported years are very similar and almost identical to that of the 1995 census population, even though the total population increased from 2.4 million to 4.3 million inhabitants between 1995 and 2004. Even under circumstances of fast demographic growth, mainly as a result of international migration, the age structure of the official estimates was maintained almost constant. This can be taken as one example of how post-censal estimates are generated by some countries. The age structure was then modified based on the results from the 2005 census and the past intercensal estimates were not revised after these latest census results were made available. Since then, no official age structure has been published in the *Demographic Yearbook* though the reported total population for the year 2017 has increased to an estimated 9.3 million.

Figure 11. Population age distributions (both sexes combined) of the 1995 census and official estimates from 2001-2004, United Arab Emirates



Source: United Arab Emirates Federal competitiveness and statistics authority (formerly the Ministry of Planning).

F. Examples from the Southern Africa region

The region of Southern Africa is comprised of five countries, as listed in table 1, for which population censuses have been conducted in the itemized years and population estimates by age and sex have been reported to the United Nations system. To our knowledge, post-enumeration surveys have been conducted following the census enumeration in some of these countries (e.g. Lesotho and South Africa) though as indicated above the practice of reporting this information or applying a correction factor to the reported population varies by country. Table 1 presents the "implicit" undercount or overcount in recent censuses from the Southern Africa region as derived by comparing reported populations with the results from *World Population Prospects 2019*. These are not the official estimates of undercount as reported by the countries, if any.

TABLE 1. "IMPLICIT" UNDERCOUNT OR OVERCOUNT IN RECENT CENSUSES FROM THE SOUTHERN AFRICA REGION AS DERIVED BY COMPARING REPORTED POPULATIONS WITH THE RESULTS FROM *WORLD POPULATION PROSPECTS 2019*

Country	*Census year*	*"Implicit" undercount or overcount (per cent)*
Botswana	2011	-0.35
South Africa	2011	0.88
Eswatini/Swaziland	2007	2.23
Namibia	2011	2.31
Lesotho	2016	3.10

Note: A negative value implies an overcount and a positive value an undercount. For South Africa, the 2011 adjusted census population was used in the above calculation.

The differences between the reported census data and WPP estimates depicted in table 1 are relatively low, with the highest figure reaching just over 3 per cent in Lesotho, indicating a close match between WPP estimates and the reported information in those countries.

Focussing on South Africa, where post-enumeration surveys (PES) were conducted for the last three censuses, relatively high undercounts were estimated at 10.7, 17.0 and 14.6 per cent, respectively in 1996, 2001, and 2011 (Statistics South Africa, 1996, 2003 and 2012a). In the *Demographic Yearbook* database (DYB), it is noted that some of these estimates have been adjusted for underenumeration but details are not always provided. However, for the total 2011 census population of 51.77 million reported in the DYB, there is no indication that the population has been adjusted.[26] The estimate from WPP is only slightly higher, as noted in table 1, as it was understood that the reported census population had already been adjusted. The official PES reports an omission rate of 14.6 per cent, with 95 per cent confidence intervals limits ranging from 14.34 and 14.86 (Statistics South Africa, 2012b). Nonetheless, two top officials from Statistics South Africa had estimated the undercount at 18.3 per cent (Ndenze, 2013). Some researchers have also questioned the accuracy of the adjustment factors, while indicating that a census is not necessarily a full count of the number of people in the country; it is an estimate of the size of the population (Moultrie and Dorrington, 2012). Furthermore, it was also indicated that the PES estimate for the 2011 census was derived from a small sample and that the true number of people, with a 95 per cent probability, could be between 49.8 and 53.7 million people (ibid and Statistics South Africa, 2012b), a range of almost 4 million persons. Considering all the above, there seems to be a debate among government officials and academics about the exact measurement of the undercount in the 2011 census of South Africa and/or its actual population size.

It should be further noted that for both Eswatini (Swaziland) and Lesotho, the respective *de jure* and *de facto* concept definitions may have been modified over time and the derived underlying population trends are not very consistent.[27] This points to the need for a better reporting of metadata to prevent ambiguity around definitions such as *de jure* and *de facto* concepts used for different estimates. For both countries, the comparisons in table 1 are made with the *de jure* concept population.[28] In the case of Lesotho, the census populations by age and sex for 2006 and 2016 have only been reported based on a *de jure* concept in the *Demographic Yearbook*.

As indicated earlier, to illustrate some of the challenges in developing consistent time series of population estimates, the reported populations figures of Lesotho are shown below. Figure 12 illustrates the different total census and official population estimates that have been reported over time under different population concepts, as well as the latest WPP estimates. As observed, there is significant variation across the different estimates, especially in the time series related to the official *de facto* estimates for which a peak value of 2.1 million for the year 2000 was reported (overall, this represents a good example of both a break and discontinuity in a reported time series)

In the case of the 2006 census of Lesotho, it was estimated that the census had a coverage of 93 per cent with an omission rate of 7 per cent (Bureau of Statistics, 2006).[29] Furthermore, the report indicates that there was a 12 per cent undercount of children under age five in the census. However, the 2006 census population that was reported to the *Demographic Yearbook* was not adjusted, though the mid-year *de facto*

[26] For the population by age and sex, there is a note stipulating that the mid-year estimates have been adjusted for underenumeration though without any indication of the correction factor.

[27] In the case of Eswatini (Swaziland), the official *de facto* total population estimates after the 2007 census are in line with the census count defined as *de jure*. The reported *de facto* total population from the 2007 census is not in agreement with prior official estimates or subsequent ones (data not shown).

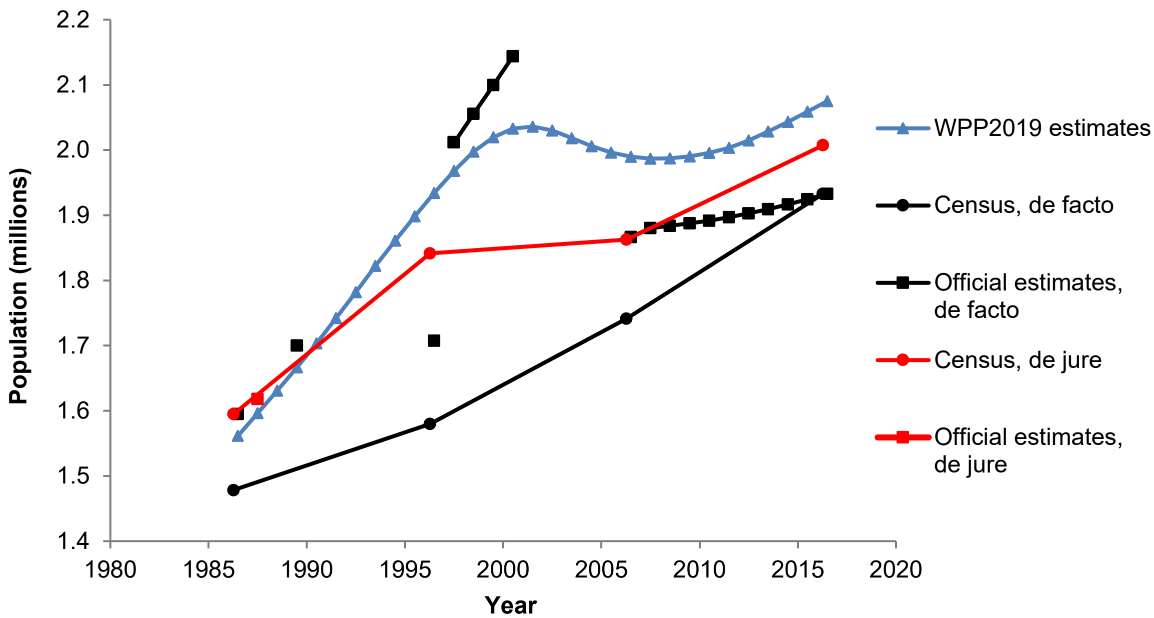
[28] For Lesotho, the comparison of WPP estimates with the 2016 *de facto* total census population yields an implicit undercount of 6.7 per cent, though the "DYB database" only reports the population by age and sex based on the *de jure* concept. For Eswatini (Swaziland), the implicit undercount as compared to the 2007 *de facto* census population is also higher.

[29] The 2006 PES was Lesotho's first; such information was not made available or encountered for the 2016 census.

official estimate, which is based on a projection, is higher; the figure is actually very close to the *de jure* census population which is in line with subsequent *de facto* estimates (Figure 12). As indicated in table 1, the implicit undercount with the *de jure* 2016 census population was estimated at 3.1 per cent, considerably lower than in the previous census.

One could also try to envisage the underlying population estimates by age and sex for each of these total population estimates to understand the challenge of reconstructing demographic estimates while considering the reported data. Indeed, the challenges in producing a consistent times series for estimates of the total population also apply to the estimation of the population by age and sex. Both, total population and population by age and sex are used as denominators in the calculation of different SDG indicators. Furthermore, the estimation of time series of numerators for monitoring SDGs, e.g. the number of children enrolled in school, can also be challenging. Lastly, there is also the challenge of "reconciling or matching" numerators and denominators under the same population "universe", for example, when estimating net enrolment rates in specific levels of education, as they are often derived from different sources and may refer to populations from different statistical concepts.

Figure 12. Total population (both sexes combined), official and census estimates (*de facto* and *de jure*) and WPP estimates, Lesotho



Source: United Nations Department of Economic and Social Affairs, Statistics Division, Demographic Statistics internal database (as reported by the Bureau of Statistics Office of Lesotho).

When the results from the 2007 census of Eswatini (Swaziland) were released, there were some concerns about the relatively small enumerated population as compared to past estimates and census counts, indicating that the new census count may have been significantly underestimated. In an attempt to explain or understand the underlying population levels and trends, it had also been suggested that AIDS mortality or emigration might have been higher than anticipated. However, "not everyone is persuaded of the Swazi figures: "Experience has taught me to be skeptical of census data in general," said Rob Dorrington, a professor of actuarial science at the University of Cape Town, who said he finds it hard to believe that AIDS-related mortality could be so high, and suspects other causes for the drop" (Global Ministries, 2008). Nonetheless, the population estimates for the year 2007 that have been reported to the DYB are from the census and have not been adjusted. And the estimate from WPP 2019 indicates only a small implicit undercount of 2.2 per cent as compared to the reported census data. In order to attain that population figure, the fertility levels in WPP were estimated, for several years, to be lower than the reported figures from different surveys.[30]

Compared to the 2011 census of South Africa, which had already been adjusted by about 15 per cent, the encountered differences between WPP 2019 estimates and other non-adjusted censuses of the regions are relatively low. This could be a consequence of the Population Division trying to avoid large differences with official estimates because of the "on-going pressure" to match them and/or differences in the assessment in the quality of census counts.[31] However, in the current assessment, this would also imply that all these censuses, except for the three of South Africa, have had similar or even better coverage than recent Canadian censuses when it comes to enumerating the population on their respective territories, and that South Africa is basically the outlier in the region.

Further exploration is required to better understand the quality of population estimates and counts in the Southern Africa region and how this may influence the calculation of selected SDG indicators. For example, the estimates for the year 2017 of the total net enrolment rate (primary education, both sexes combined) stands at 99 per cent for Namibia, 98 per cent for Lesotho, 93 per cent for South Africa and 83 per cent for Eswatini (UNESCO Institute of Statistics, 2019). The use of correction factors to adjust upwardly the estimated population, as a denominator of the net enrolment rate, would result in lower enrolment rates, for instance, in both Lesotho and Namibia.

[30] It could be argued that, in the context of high HIV prevalence countries where the mortality is atypically high for women in reproductive ages, the reported fertility from surveys (based on the response of surviving women) could be slightly overestimated.
[31] In some of these countries, the estimated differences were actually higher when using the results from the 2017 revision of *World Population Prospects*.

VII. THE PROS AND CONS OF TAKING DATA AT FACE VALUE AND THE ADVANTAGE OF WORKING ON MULTIPLE COUNTRIES

Overall, the quality of data and metadata submitted by Member States to the United Nations varies significantly. Accordingly, there is a need to conduct a data quality evaluation in order to use them in the production of time series. When Member States provide high-quality data, they should be, for the most part, taken at face value and used for producing WPP estimates and calculating SDG indicators. This implies that either the collected data is already of high-quality or that necessary adjustments have been made, as illustrated above in the case of Canada. It should be stressed that many countries report good quality estimates to the United Nations system. However, globally, empirical data are often not accurate and adjustments are not always applied or reported. It has been shown in this paper that population estimates reported by countries are not always consistent over time, and that correction factors are often required even though these are debatable in some cases.

Another challenge in producing time series of population and demographic indicators over a long period (e.g. 1950-2020) arises when the required data is not available for specific years or periods of time. This can occur with population data and other demographic indicators. One advantage of working with a wide array of countries, as oppose to working on estimates for a single country, is the ability to put in context specific results from a given country.[32] For example, in the absence of mortality data or where the quality of the information might be not so reliable, comparing mortality levels across countries (e.g. by listing country rankings) may provide some information to decide if an adjustment is required. This implies that information, for example, about the socio-economic or socio-sanitary and health conditions of the different countries, is available.

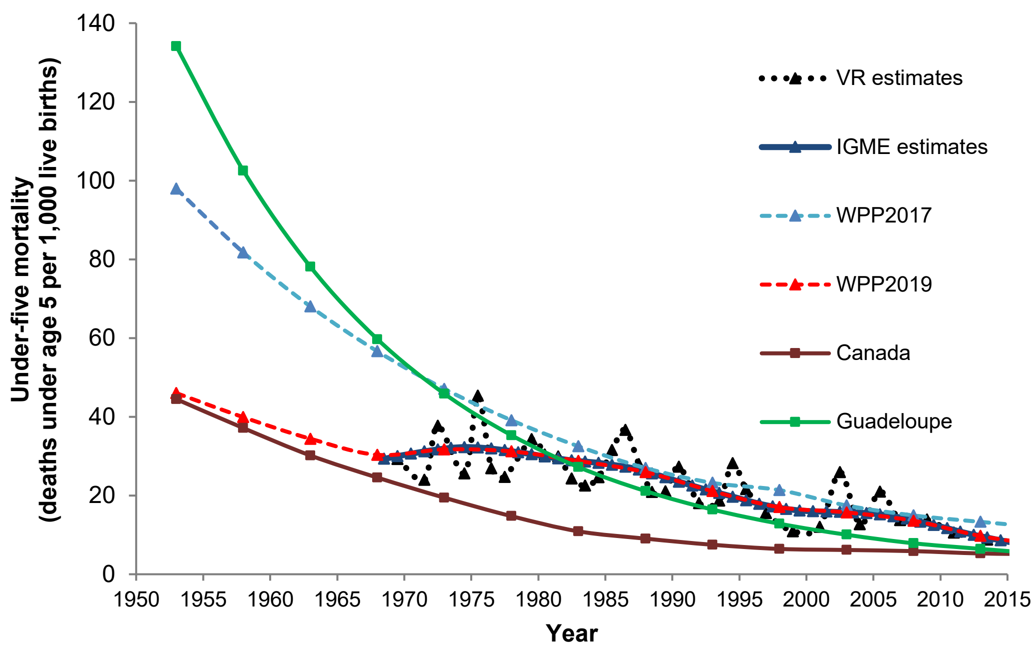
As an example of the challenge of producing time series when data is seemingly unreliable or missing, and to promote the idea of using "contextual" information, figure 13 compares the under-five mortality estimates for the Bahamas according to different sources with estimates for Canada and Guadeloupe from WPP 2019. This example differs from others in this paper, as it refers to mortality estimates produced by an inter-agency group, the United Nations Inter-agency Group for Child Mortality Estimation (UN IGME), of which the Population Division is a member.[33] The estimates based on vital registration (VR) data from the Bahamas are the starting point of this estimation process and, as observed, tend to fluctuate considerably over time (see VR estimates series). The estimates from the UN IGME are based on a "curve-fitting" process using the underlying VR data. The IGME did not apply any adjustments to the VR estimates from the Bahamas, implying that the coverage of the vital registration system is fairly complete and that all underlying components used in the calculation of the estimates are fairly reliable. Overall, WPP has used IGME estimates for several years, but there have been some exceptions. As observed below, the estimates for the Bahamas from the 2017 revision of *World Population Prospects* (WPP2017) differed from the IGME estimates, reaching a peak difference between the time series in the late 1960s, when the IGME series started; no information was available before 1969. In the 2019 revision, WWP followed the IGME estimates and extrapolated back to 1950 substantially lower levels of mortality as compared to those from the 2017 revision (44 vs. 98 for the period 1950-1955 respectively in the 2019 and 2017 revisions). As noted, there is no underlying data for that period. However, based on the results from the 2019 revision, this would imply that the under-five mortality estimates for the Bahamas in the early 1950s would be similar to that of Canada (and lower than several European countries including Belgium, France, Germany, Luxembourg, etc.), about one third the level of Guadeloupe and also considerably lower than estimates for

[32] This argument may be more relevant with indicators, for instance, related to mortality levels than with population figures alone.
[33] The UN IGME is led by UNICEF and includes WHO, the World Bank Group and the United Nations Population Division.

all other countries or areas from the Caribbean. With that estimate, the Bahamas now ranks the fifteenth country with the lowest under-five mortality level in the world in 1950-1955. This estimate for the early part of the time series is doubtful and is an example of the consequences of using existing data at face value (e.g. from the late 1960s) and extrapolating trends without evaluating the results within a broader context. Statistical approaches or "curve-fitting" methods have the advantage of being transparent and reproducible, while taking empirical data into consideration, though they demand fairly high-quality data. In the case of the Bahamas, the example shows that adjusting or correcting the underlying observed data would have been necessary for deriving a plausible time series of estimates.

In this example, the effect of the adjustments made in the 2017 revision of WPP was largest in the early phase of the time series. However, similar situations could occur in current estimates of different indicators where reliable data, if any, may not be available. Consequently, if taken at face value, the estimated value of an indicator and the implied country ranking may be questionable. Comparing country rankings of indicators is a useful method to detect possible outliers.

Figure 13. Under-five mortality estimates for the Bahamas according to different sources, and comparison to estimates for Canada and Guadeloupe (WPP2019)



Source: United Nations Inter-agency Group for Child Mortality Estimation (2019) and *World Population Prospects*, *the 2017 and 2019 revisions*.

VIII. Discussion

In reviewing different sets of official population estimates provided by Member States, ranging from the regions of Northern America to Western Asia and Southern Africa, and comparing them to estimates from the 2017 and 2019 editions of *World Population Prospects*, this paper attempted to provide an overview of the challenges involved in producing consistent time series of population estimates by age and sex. At the same time, it has provided information that may help to understand some of the causes of discrepancy across different sets of population estimates and has showcased examples where adjustments in population counts or with reported estimates were necessary. Indeed, the paper demonstrates that the quality of the population figures reported to the United Nations varies considerably over both time and space, and that estimates produced by the Population Division may also require adjustments and fine tuning across revisions. The main purpose was to foster a better understanding of data quality and to urge caution, among both data producers as well as users, not to accept or use all observed data or reported estimates at face value.

As illustrated by the case of Canada, when countries report consistent time series of population by age and sex that have already been adjusted to correct for data quality issues, along with metadata substantiating the estimation process, a relatively high degree of consistency can be observed with the estimates from WPP. However, in the absence of such information being provided or adjustments being made by countries, the Population Division may generate population estimates that differ from country data because of adjustments made to account, for example, for undercounts or other enumeration problems. Furthermore, discrepancies can occur when inconsistent or non-revised time series are reported. In such cases, differences in population estimates may also become a source of discrepancy when calculating SDG indicators that use such data as inputs. For example, if the reported population of a country is underestimated, any per capita quantity that is calculated using the “faulty” denominator will “overestimate” the indicator, potentially affecting both the evaluation of a country’s progress towards a particular Goal or its ranking among Member States. Assessing the quality of population data and making the necessary adjustments are therefore important steps for ensuring the reliability of a broad range of SDG indicators.

Users of population estimates should also be cautious about the lack of uniform practices in the production of post-censal estimates and in the revisions of intercensal estimates. A failure to revise population estimates following the arrival of new census information can produce spurious discontinuities in national data series. By contrast, the methods used to produce WPP estimates ensure internally consistent time series without such discontinuities. Nevertheless, the advantages of internal consistency and comparability across countries provided by the WPP must be weighed against the principle of country-led reporting on progress towards the SDGs, which implies a preferred consideration of national data (UN DESA/Population Division, 2019a).

Some discrepancies between WPP and national sources of population estimates are due to the interpolation procedures used in WPP to derive annual estimates by single year of age. This can be a problem, especially in countries where important annual fluctuations have occurred affecting trends in fertility, mortality or migration: for instance, large flows of migrants involving specific age groups, a mortality crisis of limited duration or significant historical variations in annual numbers of births. However, in many countries for which the demographic trends are relatively regular or smooth, the interpolation procedures used in WPP to generate annual population estimates do not seem to be the main cause of the observed differences, when compared to estimates produced by Member States. As shown for Canada, although the interpolation procedure may not replicate the exact reported population at all ages, the differences are smaller than those observed between the enumerated and adjusted populations as reported by Statistics Canada. On the other hand, annual estimates produced without interpolation procedures are preferable for countries that provide reliable annual figures and have witnessed historical fluctuations in the size of successive cohorts, for example, because of rapid changes in numbers of births occurring at the start or end of World War I or II. In Japan, for instance, data pertaining to cohorts born in the late 1940s cannot be well reproduced using interpolation procedures. However, not all countries adjust their census population counts by age and sex or report the adjusted data to the United Nations, nor all provide consistent time series of estimates. For such countries, further adjustments may still be required for sake of cross-national comparability in producing a global data set. In the case of Canada, for example, the priority was to match WPP estimates to the reported adjusted estimates not the census figures. However, this practice cannot be applied to all countries since consistent time series of adjusted estimates are not always made available.

When population estimates are derived from a demographic reconstruction exercise, as in the case of WPP, another source of differences in population estimates is related to the measurement of the components of population change (fertility, mortality and migration). For instance, if the fertility level based on a survey is overestimated or if the mortality level is underestimated, these inaccuracies will have an effect on the derived estimates of population size. Choices about whether or not to adjust these components have implications on the population size. In practice, official demographic estimates are often derived from different sources─e.g., censuses for population size and surveys for the fertility level─and there may be no immediate verification of the consistency between the various inputs. In trying to reconcile the population counts from consecutive censuses with the components of intercensal population change based, for example, on survey data, it is often not possible to match all components as reported, which is indicative of data quality issues and some adjustments are therefore required. As a final control and as illustrated by the example of the mortality levels in the Bahamas, in the absence of reliable data, one should investigate if the derived indicators are in line with other variables of a given country. Applying standard approaches to the estimation process for groups of countries and considering the plausibility of a country's position in international rankings are some of the advantages of deriving estimates for several countries simultaneously, as opposed to producing estimates for a single country. As implied by MacFeeley (2018), if reported SDGs indicators are produced by individual countries while using data with different levels of quality and reliability (i.e., some with adjustments and others without) the resulting country rankings may not be valid.

Based on examples provided in this paper, an important source of difference between population estimates from WPP and from national sources is related to the adjustment of census data for enumeration errors such as an undercount. For countries that report only the enumerated population without making adjustments to improve data quality, differences between WPP estimates and national census counts are inevitable. However, as discussed in the section on the Southern Africa region, it would be helpful to have a better reporting mechanism that documents systematically appropriate adjustments that have been made. Countries should be encouraged to make any necessary adjustments to their data and to report both adjusted and non-adjusted population figures and related metadata to the United Nations, as several of them do already. Furthermore, standardization of adjustment procedures would be beneficial to all and for improving comparability and transparency. Countries that make no adjustments to their data could, implicitly, give the impression that there are no enumeration errors in the census, that vital registration data are complete and reliable, and that survey estimates of fertility and mortality are accurate. Yet, a degree of error in population and demographic data is the norm not the exception.

The Population Division is working to upgrade the WPP production system to generate annual population estimates by single year of age without using interpolation procedures, as previously done. However, since interpolation is only one cause of the differences observed between WPP estimates and those reported by Member States, the upgrade will not resolve all issues of discrepancy between population estimates from different sources, including those due to different "assumptions" about census undercount (UN DESA/Population Division, 2019a). Quality assessment of the underlying empirical data will remain a critical aspect of producing the WPP data set, and therefore it will not be possible to match data reported by Member States that have not been adjusted for known inadequacies. Improved documentation of methods and adjustments, including comparison of WPP estimates to the information reported by Member States, is another important element of the upgrade.

References

Anderson B.A. (2004). Undercount in China's 2000 Census in Comparative Perspective. PSC Research Report, No 04-565, Population Studies Center, University of Michigan, Ann Arbor, MI, 2004.

Australian Bureau of Statistics (2018). *Census of Population and Housing: Details of Overcount and Undercount, Australia, 2016*. Available at: www.abs.gov.au/ausstats/abs@.nsf/PrimaryMainFeatures/2940.0?OpenDocument

Bureau of Statistics (2006). *Post-enumeration survey: 2006 Lesotho Population and Housing Census*. Ministry of Finance and development, Planning, Maseru, Lesotho.

Global Ministries (2008). *Where have all the Swazis gone*? (by Stephanie Nolen, 2007) Available at: www.globalministries.org/where_have_all_the_swazis_gone_10_10_2014_1122

Harding, S., and others (2017). *Report on the quality of the 2016 Census data*. Available at: www.abs.gov.au/websitedbs/d3310114.nsf/Home/Independent+Assurance+Panel.

Hogan, H., and others (2013). Quality and the 2010 Census. *Population Research and Policy Review*, vol. 32, No. 5, pp. 637-662, doi: 10.1007/s11113-013-9278-5.

MacFeely, Steve (2018). The 2030 Agenda, An Unprecedented Statistical Challenge. International Policy Analysis. Friedrich Ebert Stiftung.

Moultrie, Tom and Rob Dorrington (2012). The Census: Some more questions. Opinion/Policticsweb Available at: www.politicsweb.co.za/opinion/the-census-some-more-questions

Ndenze, Babalo (2013). Census: why two were fired, *IOL News*. Available at: www.iol.co.za/news/southafrica/census-why-two-were-fired-1.1556165#

O'Hare, William P. (2017). An International perspective on the undercount of young children in the U.S. Census, *Statistical Journal of the IAOS* vol. 33, pp. 289-304, doi: 10.3233/SJI-161008.

Statistics South Africa (1996). *Calculating the Undercount in Census '96"*, Report No. 03-01-18. Available at: http://microdata.worldbank.org/index.php/catalog/915

Statistics South Africa (2003). *Census 2001: How the count was done*. Pretoria: Statistics South Africa, 2003 Previous title: The people of South Africa: Population census, 1996: The count and how it was done 55p. [Report No. 03-02-02 (2001)].

Statistics South Africa (2012a). *Census 2011 Statistical release* – P0301.4. Available at: www.statssa.gov.za/publications/P03014/P030142011.pdf

Statistics South Africa (2012b). *Post-enumeration Survey (PES)*. Pretoria: Statistics South Africa, 2012 Report no. 03-01-46

UNCTAD and task team (2016). UN Statistics Quality Assurance Framework: Including a Generic Statistical Quality Assurance Framework for a UN Agency (UNSYSTEM/2017/3), presented at the Committee of the Chief Statisticians of the United Nations System.

UNESCO Institute of Statistics (2019). Online database, available at: http://data.uis.unesco.org/index.aspx?queryid=145 Accessed on 02 Oct 2019.

United Nations (2017). *The Sustainable Development Goals Report 2017*. Available at: https://unstats.un.org/sdgs/report/2017/note-to-reader/

United Nations, Department of Economic and Social Affairs, Population Division (UN DESA/Population Division) (2008). *Report on Issues and Practices in the Use of Population Estimates by International Organizations* (UN/POP/TTPE/2008/1). United Nations Task Team on Population Estimates.

____________ (2009). *Report of the Task Team on Population Estimates, Committee for the Coordination of Statistical Activities* (SA/2009/7). United Nations Task Team on Population Estimates.

____________ (2019a). *Progress report of the task team on the use of population data for the global monitoring of progress towards the SDGs, Committee for the Coordination of Statistical Activities meeting*. Copenhagen, 12-13 September 2019 (SA/2019/10). United Nations Task Team on Population Estimates.

____________ (2019b). *World Population Prospects 2019: Methodology of the United Nations Population Estimates and Projections* (ST/ESA/SER.A/425).

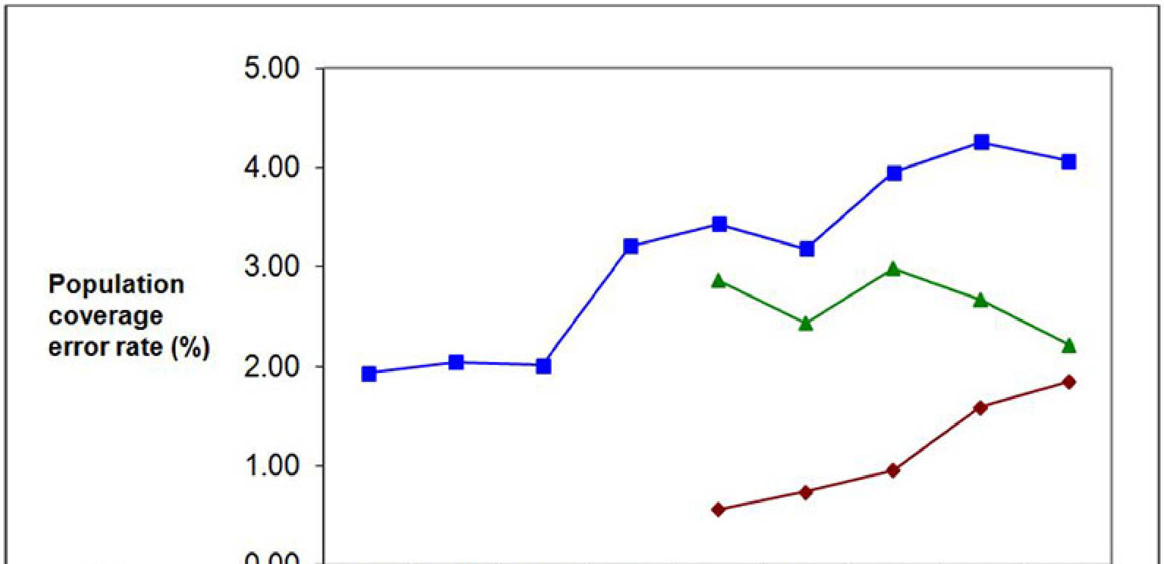
United Nations, Department of Economic and Social Affairs, Statistics Division (UN DESA/Statistics Division) (2007). *Report of the Meeting, 12th Inter-Agency and Expert Group Meeting on MDG Indicators* (ESA/STAT/AC.138/19). Paris, 14-16 November 2007.

____________ (2017). *Principles and Recommendations for Population and Housing Censuses, Revision 3*, United Nations Publication ST/ESA/STAT/SER.M/67/Rev.3

United Nations Inter-agency Group for Child Mortality Estimation (UN IGME) (2019). Online database, available at: https://childmortality.org/

Annex

Figure A.1. Population coverage error rate, 1971-2011, Canada



Census year	1971	1976	1981	1986	1991	1996	2001	2006	2011
undercoverage rate	1.93	2.04	2.01	3.21	3.43	3.18	3.95	4.26	4.07
overcoverage rate	...	...	...	...	0.56	0.74	0.96	1.59	1.85
net undercoverage	...	...	...	...	2.87	2.44	2.99	2.67	2.22

Sources: Statistics Canada, 2011 Census, 2011 Reverse Record Check and 2011 Census Overcoverage Study.