I. CONSIDERATIONS OF QUALITY IN POPULATION ESTIMATES

1. Determination of the accuracy of estimates

Population estimates are like tools, some of which can properly be used for rough work only while others are refined instruments. Accurate estimates can serve a great variety of purposes; approximate estimates have more limited uses and cannot safely be employed where precision is important. The user of population estimates needs to know how much he can rely on their accuracy. It is the responsibility of the producer of the estimates to state as definitely as possible the magnitude of the possible errors, and thus to guard against misuse of the figures.

In some instances the margins of error of a population estimate can be determined with considerable precision on the basis of adequate investigation and experimentation. Where such precise indications are not possible, at least an approximate indication of the possible amount of error can usually be furnished. As a rule, the determination of the margins of error requires an appraisal of the accuracy of the data on which the estimates are based; for example, an investigation of the completeness of census enumeration and of birth and death registration. The methods of appraising various types of data used for population estimates are to be discussed in a later publication. Knowledge of the accuracy of these data being given, it remains to determine the consequent margins of error in the population estimates, and this problem is treated in the present Manual, with reference to each of the major types of estimates.

Most current estimates of population have two components: (*a*) a "base figure", that is, a count or estimate of the population at a previous date, and (*b*) a "time adjustment", that is, an allowance for population increase or decrease since the previous date. The accuracy of the estimate, of course, depends on the accuracy of both components.

In the case of conjectural estimates and of certain estimates based on non-censal counts or defective census enumerations, even the base figure is an estimate. In making estimates of these types, the base figure is often established by counting or estimating a certain element or category of the population, or some other quantity which bears a numerical relation to population, and multiplying the result by a factor in order to reach the total population figure. In that case, the accuracy of the base figure has to be considered in view of the possible error, not only in the statistics used but also in the multiplier.

In most cases, however, the time adjustment is considerably less accurate than the base figure. The relative importance of the error in the time adjustment depends on the length of the period between the date of the base figure and the current date. If the base figure is of recent date, the reliability of the current estimate is almost entirely controlled by the accuracy of the base figure. Population usually does not change abruptly within a short period of time, and although some error is introduced by the time adjustment, this error is likely to be smaller than that in the base figure. On the other hand, if the base figure refers to a date in the distant past, the error in the time adjustment may be the more important.

Example: A count resulted in a population figure of, say, 5 million. In the following year, it is estimated that the population has increased by 50,000. If the total of the count was subject to an error of 2 per cent, and the estimated increase was subject to an error of 20 per cent, the population may have increased from 4,900,000 to 4,940,000, on a minimum assumption, whereas on a maximum assumption it may have increased from 5,100,000 to 5,160,000. An intermediate estimate of the population in the following year is 5,050,000 subject to an error of 110,000, or only slightly over 2 per cent.

After the lapse of twenty years, however, the situation is changed. If an annual increase by 50,000, subject to a relative error of 20 per cent, is assumed for the entire period, the population may have increased by as little as 800,000, or by as much as 1,200,000. Under extreme assumptions, it may have grown to a total of 5,700,000 as the minimum, or 6,300,000 as the maximum. The estimate may then be put at an intermediate value of 6 million, subject to an error of 5 per cent.

In the foregoing example it is assumed that the probable direction of the errors both in the base figure and in the estimated increase, is unknown; the figures may equally well be too large or too small. In some cases, an assessment of the quality of the data used will give evidence of an error in one direction, and in those cases the data should be corrected before the estimate is made. If the amount of the correction required remains in doubt, an effort should be made to determine reasonable upper and lower limits for the correction, and these limits should be considered in stating the margins of error of the resulting population estimate.

Example: In a census, 5 million persons were enumerated. Tests of the completeness of enumeration were carried out in two sets of sample areas, indicating, in one set of areas, an under-enumeration of 4 per cent, and in the other, an under-enumeration of 2 per cent. There is no *a priori* reason to suppose that either test was more valid than the other. The correction for the census count may be estimated at 3 per cent, and its upper and lower limits may be placed, after due consideration of all the relevant facts, at, say, 5 per cent and 1 per cent, respectively. The corrected census figure is then 5,150,000. A population estimate for the next year, using vital statistics which

show an increase of 50,000 subject to an error of 20 per cent in either direction, would be 5,200,000. The possible error of the estimate may be put at about 110,000, or slightly more than 2 per cent, in either direction.

In considering the possible errors in statistical time series which may be used as a basis for time adjustments in population estimates (notably, statistics of births, deaths and migration) it is useful to distinguish what may be called biased, random and self-correcting errors. Biased errors are those which tend systematically either to minimize or to exaggerate the population increase over a period of years; an example is under-registration of either births or deaths. Random errors, in the sense intended here, may tend toward either an underestimate or an overestimate of the increase during any year; an example is the error in an estimated correction for under-registration of births or deaths. Self-correcting errors are those, the occurrence of which in one year creates a tendency toward a compensating error in subsequent years; an example is the error due to late registration of births or deaths. It is the biased errors which present the most serious problem. Self-correcting errors do not accumulate in the long run, and random errors accumulate only slowly, but biased errors accumulate in direct relation to the number of years over which the time adjustment is continued.

Where time adjustments are made by mathematical extrapolation of population increases observed in the past (for example, by extrapolation of the increases between successive census dates) it is difficult to find the basis for an objective evaluation of the possible errors. Certain biases are inherent in each method of extrapolation, and the selection of a particular method depends on an individual's judgment, which may also be biased. Nevertheless, there are means, which will be discussed in a later chapter of this Manual, of arriving at an indication of the possible errors in such time adjustments.

Where information on the population is scant and the levels of birth rates, death rates and rates of increase are unknown, it is necessary to make time adjustments rather arbitrarily, by assuming some plausible rate of population increase, or by merely holding a figure, derived at some time in the past, at a constant value. Possible errors arising from such assumptions with respect to population increase can be evaluated, though only very roughly. There are upper and lower limits for the rates of population change (increase or decrease) which, in a given situation, can be regarded as within reason. With the passing of time, the error resulting from either holding a previous figure constant, or from adjusting it at an arbitrary rate, is likely to increase cumulatively.

The accuracy of the time adjustment has an especially important bearing on the usefulness of population estimates as indicators of population growth, or of changes from one time to another in per capita measures such as income and production or consumption of various items per person. For such comparisons over time, population estimates are adequate if the time adjustment is nearly accurate, even though the base figure is unreliable and the magnitude of the population in any year is therefore uncertain. Conversely, comparisons over time are vitiated if the time adjustments are inaccurate, even though the base figures may be of the highest quality. Since one of the most frequent uses of current population estimates is comparison over time, it is important that the method of adjustment be known.

Adjustments using statistics of births, deaths and migration of at least tolerable accuracy may be regarded as adequate for this purpose since they reflect, more or less faithfully, the true variations in population size from year to year. Adjustments depending on an assumed rate of increase, on the other hand, can tell us nothing new about recent population changes, since they merely reflect those assumptions which were made beforehand; a time comparison of estimates of this type leads, so far as population size is concerned, to foregone conclusions. The same is also true of current estimates adjusted by mathematical extrapolation which reflect an assumption that recent rates of population change are a continuation of changes observed in the past.

One way of determining margins of error of an estimate, particularly of one based on certain assumptions (conjectures, estimates involving the use of a multiplier, and extrapolations) is to make several independent estimates using different assumptions, all of which are within reason, and then to compare the results. The extreme values obtained may indicate approximately the limits of the range which should be stated, and the figure derived by what is believed to be the most reliable method may be taken as the best estimate. A critical comparison of the several values which are derived by different methods may, however, lead to the conclusion that the best estimate is some other figure than that derived by the method that was at first believed to be most reliable, or perhaps some intermediate value between the figures resulting from estimates of similar reliability. In the case of conjectural estimates, in particular, it may even be desirable to compare several estimates made by a number of fairly competent persons independently of one another, to consider the range within which their estimates are contained, to determine some intermediate figures as the "best estimate" subject to an error represented by the extreme estimates.

In some cases, when the result of a census was of dubious quality, or when vital statistics of dubious quality have been used in an adjustment over a long series of years, some of the above processes may also be helpful in determining a reasonable margin of error for the estimate or in suggesting some upward or downward revision.

2. Methods of stating the degree of reliability

Where the information available permits a quantitative statement of the margins of error in a population

estimate, it is desirable to publish this statement, perhaps in the form of a percentage of possible error in each direction, together with the estimated figure. The foregoing discussion, however, makes it clear that in many cases the evidence regarding possible errors is not sufficient to permit such a definite statement. In many cases the best that can be done is to make an informal guess at the possible extent of errors, based on knowledge of the statistical procedures in the country and of the extreme values which can be assumed for data and assumptions relating to population size and population change, combined with critical judgment. The margins may be indicated in such cases by a statement such as "figure believed correct within about 5 per cent", or "approximate estimate; believed correct within about 10 per cent", or "figure believed correct to the nearest 100,000". The margins stated should be such that it is unlikely, though not necessarily impossible, that the error exceeds the stated amount.

If it is felt that the margin of error of a figure cannot be safely expressed as a percentage of that figure, it should be indicated by qualifications such as "estimate believed to be fairly accurate", or "approximate estimate", or "very approximate estimate, possibly subject to a large error".

It is unfortunate that the practice of indicating margins of error in population estimates, as well as many other types of statistics, is not more generally followed in the national statistical offices. The failure to indicate the approximate nature of certain statistics may sometimes be motivated by an expectation that figures not so annotated will give an impression of being exact, or at least nearly so. However, it is a well-known fact that in many countries, in view of very obvious difficulties, it is next to impossible to obtain highly accurate statistics. On the other hand, it is the practice of many countries with well developed and highly accurate statistics to indicate errors, however small, which are present in the figures. Indications of inaccuracies are an almost unfailing sign that efforts are made to appraise the quality of the statistical information, and hence to improve it. Far from detracting from the value of the figures, indications of the degree of their reliability actually increase their usefulness.

An indication of the methods used in making the estimates is also very valuable, as has been shown above, to the user of the statistics. Such information, together with an assessment of the probable accuracy of the results, not only helps to prevent unjustified uses of the estimates, but also to encourage those uses for which the estimates are adequate.

In certain countries, the population has been estimated arbitrarily by an authority guided only by the intention of producing a desired figure, for purposes of propaganda or to increase the prestige of the country or its government; such estimates are, of course, useless. Cautious users of population estimates may be led unjustly to suspect that figures for some other countries have been arrived at equally arbitrarily. Statements of the methods used can dispel such suspicions where they are not warranted.

3. The rounding of figures

It is common practice to round large figures for one of two reasons. In the first place, figures running into many digits are cumbersome to handle in computations, while little is gained in their usefulness by presenting all the digits; for this reason it is often found more expedient to abbreviate them, showing only the first few significant digits, perhaps the nearest 100 or the nearest 1,000, as the case may be. On the other hand, it is often felt that a figure is not sufficiently reliable to justify showing it to any large number of significant digits, and it is therefore preferred to show only the first two or three digits, as the case may be, in order to indicate that they are approximate.

However, the mere rounding of a figure is not a sufficient indication that it is inexact. Thus, if the population of a country is stated to be 7 million without any qualifying remark, there is no way of telling whether this figure can be subject to an error of 20 per cent or one-twentieth of 1 per cent. On 21 July 1946, the population of Austria was reported to be 7,000,003, an estimate which was probably fairly accurate, though not to the last digit. The population of Afghanistan, on the other hand, was estimated very roughly for the years 1927 to 1939 by the League of Nations at 7 million, a figure which may have been in error by several million.

The greatest shortcoming of rounded figures is that they vitiate comparisons of estimates over time. The population of a country may have been estimated very roughly at 7 million at some time in the past and may be assumed to have increased by 5 per cent in each of two subsequent periods of time. Accepting 7 million as the initial figure, we should have to estimate the population at 7,350,000 at the end of the first, and at 7,717,500 at the end of the second period. Rounded to the nearest million, the figure would remain at 7 million at the end of the first, but would rise to 8 million at the end of the second. A comparison of these rounded figures would suggest no increase in the first, by an increase by 14.3 per cent in the second period. The rounding of figures in such a case may obscure valuable information regarding possible population changes.

The rounding of figures is, therefore, only a poor substitute for other indications regarding their reliability, and should not be used for that purpose. Some rounding may be desirable for purposes of abbreviation with the intent of saving space and labour in computing where a higher degree of precision is unnecessary. Also, in an estimate of a low order of reliability it is clearly absurd to show all digits. As a rule, estimates should be shown to at least as many figures as are significant in view of the method of estimating (e.g., from the assumption of certain rates of increase, etc.), while indications of the approximate

nature of these figures are given in annotations or separate statements.

4. The problem of internal consistency

An estimate of population can hardly be reliable unless its components are at least approximately consistent in regard to the definition of population and the area covered. Where estimates are made from census statistics adjusted to current dates by means of vital statistics and migration statistics, the area and population covered by all these types of statistics should be the same. It is particularly important where results of several censuses are used in making estimates by mathematical extrapolation that the coverage and the completeness of enumeration in the series of censuses should be constant.[1] Likewise, the coverage of series of vital statistics and migration statistics used in making population estimates should be the same from year to year. Where estimates of the total population of an area are built up with data for component parts of the area, the figures used for the parts should be consistent as regards not only the definition of population but also the dates to which they refer, and to the procedures of counting employed. If the conditions of consistency are not satisfied, it is desirable to make corrections in the various figures, in order to bring them into line.

Consistency is important not only in the components of each single estimate, but also in a series of estimates. If the coverage of the estimates for one period of years differs considerably from that for another period, the usefulness of the series is obviously much impaired. The problems of establishing consistency in a historical series of population estimates are to be taken up in a later publication.

A fairly common source of major inconsistencies is changing national boundaries, which obviously require corrections in series of demographic statistics which may be used in making population estimates. Another source of inconsistencies which often assume major dimensions is the failure to cover some parts of the national territory or of its population. Vital statistics are sometimes confined to "registration areas" which comprise more or less large fractions of the areas covered by the censuses. Records of migration are sometimes taken only at certain points of entry or exit, for example at the ports but not at land frontiers. In such cases the partial statistics of births, deaths and migration may have to be amplified before they can be used for reliable adjustments of census figures to current dates.

The exclusion of certain population categories, such as native population in various African territories or tribal aborigines in some Latin-American countries, may create problems of consistency. Such categories may be covered by one census, but not by another; if covered by the census they may be excluded from the vital statistics and from records of migration. In such cases, difficult problems of estimation may be involved in establishing a consistent series of figures relating to the whole population.

Such groups as prisoners of war, displaced persons and armed forces at home or abroad may be excluded from some of the statistical series and included in others, and their coverage may change from time to time within the same series. In many cases vital statistics relate only to the births and deaths of residents, and migration statistics to persons entering to take residence in the country or leaving to take residence elsewhere, whereas census statistics refer to all persons present in the country at the time of enumeration. It may be safe to ignore these inconsistencies in many instances because the changes in population indicated by the vital and migration statistics may be nearly the same as those which would be shown by data defined in a manner consistent with the census definition. In other instances a "correction", either in the census total or in the vital and migration statistics, may be necessary in order to avoid substantial distortion of the estimates.

Inconsistencies may be created by changes in the degree of completeness of enumeration from one census date to another, or by changes in the completeness of registration of births and deaths, or the completeness of recording of migration, over a period of time. The elimination of such inconsistencies is, of course, part of the problem of evaluating the accuracy of the statistics and correcting them for use in population estimates.

If important adjustments or corrections in the data are made, this fact should be indicated in the publications which contain the estimates of population. For example, a census enumeration limited to the settled population may have given a figure of 800,000, to which an estimate of the number of nomads, say 50,000 at the time of enumeration, is added to arrive at the total population. Population estimates for subsequent dates, based on this total for the census date, should be accompanied by a statement such as, "Includes nomads estimated at 50,000 at the time of the census". If there is no further information regarding the nomads, adjustment for population changes in time may be carried out on the assumption that the nomadic population increases at the same rate as the original population. If, on the other hand, there is reason to believe that the nomadic population is either stationary or increases at a rate different from that of the rest of the population, adjustments for change in time should be made separately for the enumerated population and for the estimated number of nomads. This should then be recorded in a note saying "estimate adjusted to include nomads estimated at a fixed number of 50,000", or "estimate adjusted to include nomads, estimated at 50,000 at the time of the enumeration, and believed to be increasing at a rate of . . ."

If known inconsistencies in the components of an estimate cannot be eliminated by correcting and adjusting the figures, the nature of these inconsistencies should be stated in the publications presenting the estimates.

[1] See chapter V, section C.

5. The problem of international comparability

Consistency is desirable, not only among the components of each population estimate and within each time-series of estimates, but also between these estimates and other statistical series, in conjunction with which they are often used. An important aspect of consistency in this broader sense is consistency between the estimates for one country and those for another — that is, international comparability.

It is highly desirable that estimates be internationally comparable, so that the density or growth of population, and various per capita measures for a nation can be compared with those of other nations. It is often desirable to obtain data for a group of countries, and this cannot be done satisfactorily by adding together several estimates which are not strictly comparable. It is also advisable that internationally comparable data be available for identical dates so that they may be added up to give simultaneous data for entire regions.

It is difficult, if not impossible, to apply identical census definitions, or identical definitions in vital statistics and migration statistics, in all countries. The conditions under which enumerations are made in different countries vary greatly, and public expenditure is always directed toward obtaining those results which are of the most immediate interest to the administrative requirements of the particular country and which are relatively less difficult to obtain. Differences in definitions in the statistics collected in various countries are, therefore, likely to persist.

It has been recommended by the United Nations that census statistics be obtained in accordance with certain standard definitions wherever possible, without prejudice to obtaining those statistics which are of immediate interest to the country concerned. These recommendations favour a "modified *de facto*" definition of the total population including all persons present in the country, with the exception of foreign armed forces stationed in the area, but including national armed forces located abroad.[2] It is, of course, understood that for many purposes, both national and international, this population may not be relevant; but from the point of view of ensuring complete world coverage, free of double counting, it is the most desirable type of figure to obtain. Recommendations for standards in vital statistics and migration statistics are also being prepared by the United Nations.

While it is not possible in many countries to collect all statistical data in conformity with such definitions, it should always be possible to form at least those estimates of total population size which would conform to the standard, or to "correct" a figure conforming to a different definition by the amount by which it is estimated to differ from the standard definition. If, for different purposes, a different definition of the population is also required, it is desirable to provide separate figures for those population categories (e.g., foreigners temporarily present, nationals temporarily abroad, etc.) which are involved in the change of definition. If appreciable differences obtain, it is also desirable to estimate separately numbers of births, deaths and migrants, according to different definitions of the population.

In some instances, it may be felt that "corrections" made for purposes of conformity with standards may result in much loss of accuracy while national statistics, although diverging from international standards, are fairly accurate. If this is the case, it may be preferable to give a non-comparable national estimate rather than one conforming to standards. In all such cases, however, indications should be given to show in what manner a national population estimate deviates from international standards in order to provide the means, whereby users of statistics can make some alternative estimate conforming to international standards.

With regard to time reference, it has become a practice of most countries with a well-established statistical office to provide mid-year figures for every year. An annual mid-year figure, dated 30 June or 1 July, may therefore be regarded as the international standard. Theoretically, for the computation of birth and death rates or other per capita rates, the best possible figure for a year would be the figure for the "mean population", i.e., the average population for the entire year. In a few countries, such a "mean population" is computed by averaging the twelve monthly estimates.[3] This, however, is a great refinement which can make only a very small difference, particularly if the accuracy of population statistics is not very great. The difference between the mid-year and the "mean population" of a year can be disregarded in most cases.

If, however, population figures refer to some other time of the year, this circumstance is a considerable handicap to international comparability. Such figures are also less useful than mid-year estimates for many national purposes, since they differ to a greater extent from the "mean population" and introduce some errors into the computation of vital rates and other per capita ratios calculated on a calendar-year basis.

In some countries, population estimates are made for the first or the last day of every year. An arithmetic average, or some other interpolation, between two subsequent end-of-the-year (or beginning-of-the-year) figures may then be suitably used instead of a mid-year figure. In fact, while such interpolation usually results in a mid-year figure which differs slightly from the true mid-year figure, it may differ no more from the annual "mean population" than does the true mid-year figure.

In some countries, a mid-year estimate is not given for a year during which a census was taken, even though the date of the census was not 1 July. The reason may be that the census figure is considered more reliable

[2] United Nations. *Population Census Methods* (Population Studies No. 4). Lake Success, November 1949.

[3] In some countries, averages of national estimates for the beginning and the end of each year are published as "mean population" estimates.

than an estimate for some other date. However, unless the census was taken exactly at mid-year, the figure does not meet standards of comparability and is not appropriate for certain uses.

6. Conclusions

The discussions in the present chapter lead to the following principal conclusions:

1. It is desirable to appraise the possible errors in population estimates, at least in broad terms, and to publish a statement of the approximate degree of reliability in order to minimize the dangers of misuse and to encourage legitimate uses.

2. Estimates should ordinarily be presented with at least as many digits as are useful, in view of the degree of reliability for purposes of indicating both population size and population change.

3. Where there are important inconsistencies in the data used for population estimates, the data should be rendered consistent by adjustments or "corrections". These adjustments or corrections should be indicated in the publications containing the estimates, and any remaining inconsistencies should be pointed out.

4. In general, estimates are internationally comparable if they conform to the "modified *de facto*" definition. Deviations from this definition should be indicated.

5. Estimates should be made for the middle of each year, both for the sake of international comparability and for their greater general usefulness in computing annual rates.