The Limits of Population Forecasting

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Future population depends on many factors—social, economic, technological—that cannot be taken into account in population projection. However interdisciplinary we become, there are some clear limits to knowledge of the interrelations of the variables whose combined operation will bring about the future population. Demographers can no more be held responsible for inaccuracy in forecasting population 20 years ahead than geologists, meteorologists, or economists when they fail to announce earthquakes, cold winters, or depressions 20 years ahead.

What we can be held responsible for is warning one another and our public what the error of our estimates is likely to be. Statistics started to approach scientific maturity with the calculation of probable errors (for instance in astronomical observations), and then it went on to confidence intervals and tests of significance. Statisticians are distinguished from other people who use numbers by their effective techniques for dealing with error. The agronomist-statistician not only tells farmers that they will have a higher yield from a new variety of potato, but within what limits that yield will probably fall, with odds 19 to 1, say. The experimental trials are set up to correspond to a probability model, and on the model exact confidence intervals are calculated and promulgated.

The user of a population forecast has no less need to know its error than the user of a yield estimate or of an estimate of unemployment. Unfortunately, population forecasts cannot be framed in a probability model through random allocation of treatments or random choice of units. But demographers have a resource not yet systematically exploited: past forecasts, and the comparison of these with the subsequent population performance. The use of such comparisons for telling the accuracy of a present forecast depends only on finding a set from the past that somehow corresponds to the present forecast. In 1980 we estimate the population of the year 2000. To judge its accuracy we look back at an estimate of the year 1970 made in 1950 by the same method and see how close it came to the 1970 realization. If (a) the method used for forecasting was the same, and (b) the fluctuations of population in the future are similar to those in the past, then the 1950–70 check provides a unit of information for 1980–2000.

One might have thought that population forecasters would be obsessed with eagerness to see how well they have done in the past, and that users would insistently demand reports on the error of current forecasts. No such obsession or demand is to be seen. The only analysis of this kind in print of which I know is that of Louis Henry (1977) on the French Departments. He finds the error to be large, and rests with the modest assertion that forecasts are better than simply assuming the past population will remain constant.

The total population is the most commonly used single number referring to the future, but in particular applications some subgroup is usually of more interest. Males and females at the several ages, the labor force, children at school, people retired, have all been forecast many times. To undertake for each of these an evaluation of past forecasts similar to that made in the following pages would seem to be a useful project for the future.

This article on forecasts of total population has implications beyond the single figure, if one bears in mind that the error of the single figure is the average of the errors of all ages, and that older ages are more precisely given than younger. We exhibit a method that is useable well beyond the subject with which it deals, indeed well beyond population. The technique could be applied to income, prices, and other matters. It not only makes countries and time intervals comparable but permits statements on whether the population is more precisely forecast than income or the cost of living index. These extensions are material for a later article.

Aggregating past experience

To bring the error of past forecasts to bear on present ones, we need to aggregate many previous comparisons. Nothing beyond an anecdote, perhaps a horror story, can come out of one single past error, but a few dozen can provide reliable information. The problem is then to put the past experience into such a form that it can be aggregated.

As in other statistical analysis, the first task here is systematic recordkeeping. Only after forecasts made in the past have been collected, and compared with the population that was subsequently counted, do questions of inference arise. This paper will summarize past projections and forward estimates used as forecasts, in terms of certain averages. It will provide the user of population forecasts with a rule of thumb on the degree to which he can trust current forecasts of what is still the future.

I have taken each projection period as a unit, and have gathered over

1,100 such unit forecasts and the corresponding realizations. For example, India's Third Five-Year Plan, published in 1962, gave a 1961 population of 438 million and a 1966 population of 492 million, implying an average annual increase of 2.352 percent. The actual population as subsequently known from later censuses was 447 million in 1961 and 502 million in 1966, that is, a rate of 2.348 percent, lower than the forecast by 0.004 percentage points. In the same document a forecast of 555 million was made for 1971, and this implied an average increase of 2.396 percent, against the performance of 2.352 percent, an error of 0.044 percentage points. These were regarded as separate observations.

What permits taking the projection to each future time as a separate case and then averaging is that the interval over which the projection is made seems to have no effect on its accuracy on this measure, as will appear in what follows. The argument against is that the estimates of error for 1961–66 and for 1961–71 are not independent. Anyone who in 1961 declares too low an estimate in 1966 is likely to declare too low for 1971.

Independence is out of reach in such work as this. The same tendency to be low was shown for a majority of countries and agencies working in the 1940s; the perspectives shared by demographers concerned with the developing world had in common an underestimate of how fast mortality was about to fall. For the developed countries forecasts made in the 1940s were low, in the 1950s high, in the first instance because the baby boom was a surprise, in the second because no one knew that the end of the baby boom was imminent. Even if forecasters were wholly isolated from the common climate of opinion and from one another, the errors of estimate of neighboring countries cannot be independent; when the birth rate of one Western European country unexpectedly falls, that in others is likely to fall.

Lack of independence does not on the whole bias such results as these—no one can say that they would be higher or lower if we confined ourselves to independent observations. But it does a secondary kind of harm in preventing any statement of the error in our estimate of error. To ascertain that would be a further advance, unfortunately requiring data not now available and hard even to imagine.

Differences among forecasters

One might be tempted to use the data here gathered to assess the quality of work of the several agencies and individual scholars who have gone into print with estimates of future population. That is no part of the present objective, and as I see it comparison of individual forecasters is essentially futile. Think of a number of marksmen, all equally competent, facing a target that moves about erratically. Some will do better than others, not because of differences in competence, but because they were fortunate enough that the target stood still when they fired, while others had the bad luck to shoot just before the target moved. It would be pointless to give the several marksmen grades on their accuracy in such circumstances. [The analogy comes from Ronald Lee (1980).] Michael Stoto (1980) has shown that the date when the forecast was made is the major factor determining error.

We will treat the forecasters, then, as competent marksmen aiming at an erratic target, and their errors as measures, not of individual marksmanship but of the intrinsic difficulty of hitting the target at the time. What is important is whether they find it easier to hit a target that is only five years away than one that is 20 years away; whether they come closer in slowly growing or in rapidly growing countries. We are not studying forecasters, but the degree of forecastability of population.

It is well to keep separate questions of accuracy of census counts. This is a big subject and no attempt is made to deal with it here. All official figures constituting the population realization are accepted without comment even though we know that they are themselves subject to error. Any differential error of counting (for example, greater completeness in 1980 than in 1970 in the United States) is incorporated in the error of forecasting as the present calculations are made; it is not believed that the error would be much reduced if this could be subtracted out. In every case the rate of increase was calculated from the same publication, so that at least we have guarded against including data revision with forecast error.

Overall error

We can summarize in a single number the 1,100 or so comparisons of forecast with realization: expressed in rounded form for ease in remembering and exposition, the experience of the past 30 years points to a root-mean-square error of 0.4 percentage points for estimates made now. Many other averages of the errors could be used; I have preferred to average the squares and take the square root because this gives more weight to larger errors than does a simple arithmetic mean.

If one knows nothing more than this, and it is forecast that India will grow at 2.0 percent during the next five or 25 years, then the probability is two-thirds that the range of 1.6–2.4 percent will straddle the increase that actually occurs—taking it that our ignorance is normally distributed. If India is now at 690 million, the odds are 2 to 1 that its population five years hence will be between 747 and 777 million, and for the year 2001 between 948 and 1,109 million. If it is asserted that India will grow at 0.7 percent per year over the next century, and attain 1,386 million, then one could bet 2 to 1 odds only that it will be between 931 and 2,060 million. In the nature of the exponential, a projection fan calculated in this way widens rapidly. Such use of the exponential is justified by the finding that the departure of the forecast rate of increase from the realized rate is virtually independent of the span of time over which the projection is made.

The practical conclusion, then, is that relatively short-term forecasts, say up to ten or 20 years, do tell us something, but that beyond a quarter-century or so we simply do not know what the population will be. That is a consequence of the shape of the projection horn constituted by exponential curves; we repeat that the validity of using exponentials in this way is suggested by the constant error in percentage points in the range from five to 20 years.

Table 1 summarizes various collections of estimates in relation to what subsequently occurred. The three collections prior to 1950 were much less close than those since; there is apparently an improvement with time that appears within the United Nations group as well. One must give somewhat more weight to recent cases, and that is why I have not used the grand average of 0.530 percentage points in the above illustration, but rather 0.4.

TABLE 1 Root-mean-square departure of forecast from subsequent realization, estimates published 1939–1968, expressed in percentage points

	Date of forecast	Forecasts for years	Number of forecasts	Root-mean-square error
Canada[a]	1939–54	1950–70	14	1.123
United States[b]	–1950	1955–75	15	0.907
	1950+	1955–80	92	0.340
Europe and the Soviet Union[c]	1944	1950–70	96	0.949
9 countries of Eastern Europe[d]	1965	1965–80	96	0.219
All countries[e] >1,000,000	1958–68	1960–75	810	0.476
All forecasts	1939–68	1950–80	1,123	0.530

[a] Statistics Canada (1954) [b] US Bureau of the Census (1975) [c] Notestein et al. (1944) [d] US Bureau of the Census (1965) [e] United Nations (1958, 1966, 1973, 1979)

In order to investigate forecasting in more detail it seems preferable to take a single large and relatively homogeneous set. The medium variant of the United Nations includes 810 forecasts made on three different occasions for countries of one million or more, omitting a very few cases where boundaries changed so that the unit could not be readily identified. This is the set on which I have carried out the most detailed analyses. Not only is it the largest and most varied collection, but it has been developed by a succession of competent technicians, who have been in touch with demographers throughout the world, and much concerned to improve their methods. It is referred to far more often than any other single set of projections.

The first set of supporting figures is the overall average of the 810 UN projections made from the late 1950s onward, for countries varying in size and growth rate, some developed and some not, some with good basic statistical data and some not. The measure used in each case was the average annual rate of increase implied by the forecast, r, less the subsequent performance R. Four averages of departure of forecast from the subsequent realization expressed in percentage points are as follows:

Mean departure, recognizing sign	−0.070
Root-mean-square departure	0.476
Standard error of departure	0.471
Mean absolute value of departure	0.340

The minus sign on the first figure signifies that on the whole forecasts over the 1950s and 1960s were slightly too low, that is, there was a downward bias. The root-mean-square departure includes a component of overall bias in each of the periods when projections were made, plus a component of variance. The standard error is the square root of the variance only, and would apply as minimum error even if there were no bias for all countries together. The mean absolute departure is, here as elsewhere, about two-thirds of the root-mean-square.

While none of these is entirely without interest, the basic result is the root-mean-square departure. Strict rounding to the nearest 0.1 percent from 0.476 makes it 0.5 percentage points, but to round down to 0.4 seems justified for current use because the more recent projections show somewhat smaller error. A secondary reason is that projections of lower rates of increase show smaller error, and rates of increase are likely to fall from present levels. The rounding down is a concession to these two considerations.

Forecasts apparently improving

Table 2 shows our four measures of departure of forecast from realization as they appeared in work published in three different periods. The root-mean-square, the standard error, and the mean absolute error all show steady decline. Forecasts of the late 1960s showed only about two-thirds the error of those of the late 1950s.

One would like to be able to say that methods have been improving, and this is a clear likelihood. An alternative possibility is that sudden changes occurred during the 1960s, including the ending of the baby boom in Europe and the fall of mortality elsewhere, and that the 1970s showed less unanticipatable change. Aside from these, knowledge of the actual levels and rates of increase of population has improved in recent years. To discriminate between the three sources of improvement and know how much is due to each is impossible with existing data.

Given such uncertainties, then, there are at least three ways of treating the results of the table in application to what is now the future, that is, for forecasts being made in 1981:

1 One could argue that the future will be as changeable as the past, and present demographic methods on the whole are neither better nor worse than

TABLE 2 Four measures of error shown for UN forecasts made in three periods

Period	Mean departure (1)	Root-mean-square (2)	Standard error of forecast (3)	Mean absolute error (4)
	Errors of forecast to 4 subsequent periods			
1958	−0.266	0.555	0.487	0.417
	Errors of forecast to 3 subsequent periods			
1963	0.123	0.429	0.411	0.293
	Errors of forecast to 2 subsequent periods			
1968	0.159	0.357	0.319	0.257
	Average of all forecasts			
	−0.070	0.476	0.471	0.340

those of the past, and average over the entire record, with a root-mean-square of about 0.5 percentage points.

2 One could say that the early work has been improved on, and the current forecasts would at most be subject to the amount of error shown in the late 1960s. Corresponding to this view, one would take the root-mean-square as 0.00357, or roughly 0.4 percentage points.

3 One could go on to say that errors of the later 1960s are two-thirds of those of the late 1950s, and hence those of the late 1970s will be two-thirds of those of the 1960s, a root-mean-square of about 0.24 percentage points. To count on the narrow range derived from this consideration would seem imprudent.

It will require another decade or two to decide among these interpretations, but in the meantime it seems reasonable to place more weight on the more recent evidence.

Constancy over different projection spans

Table 3 summarizes the 810 UN forecasts as they compared with the subsequent performance, showing forecasting spans of five to 20 years. The departures of forecast from performance are relatively uniform over spans. Note, for instance, the right-hand column. In the first set the lowest root-mean-square is 0.536, the highest 0.589; in the second set the range is 0.408 to 0.465. Some variation appears for the jumping-off point, as we would expect from Table 1, as well as for the rate of increase.

The important conclusion from Table 3 is that the error in estimating the prospective rate of increase is nearly invariant with respect to the time period over which the estimate is made. Extrapolating in the top part of Table 2 would show slightly less error in a 100-year span of projection, but such extrapolation from the second part of the table would show greater error for a longer period. The slight tendencies to decline or rise can be disregarded.

There are some differences in precision on this measure for rich as against poor countries, for large as against small countries, and for the different continents. But all of these seem of secondary importance, and derive ultimately from differences associated with rate of increase. The trials indicate clearly that on the measure used (root-mean-square error of the percentage points of departure of forecast from realization), slowly growing countries are more precisely given than rapidly growing ones.

A rough summary of the basic difference is obtained for the 810 estimates, dividing them into three groups. The 30 slowest growing countries, increasing up to 1.8 percent per annum, showed a root-mean-square of 0.29 percentage points. The middle 30 countries, increasing from 1.8 percent to 2.6 percent per annum, showed a root-mean-square of 0.48 percentage points. The 30 fastest growing countries, increasing more than 2.6 percent per annum, showed a root-mean-square of 0.60 percentage points. These differences are clearly important. Let us see what they mean in application.

TABLE 3 Root-mean-square error of UN forecasts for three jumping-off years, percentage points

Jumping-off year	Forecast period	Rate of increase: Slow	Medium	Fast	All rates of increase
1958	1955–60	0.320	0.555	0.793	0.589
	1955–65	0.338	0.545	0.713	0.553
	1955–70	0.323	0.534	0.698	0.541
	1955–75	0.310	0.538	0.691	0.536
	Total	0.323	0.543	0.725	0.555
1963	1960–65	0.236	0.421	0.527	0.413
	1960–70	0.248	0.447	0.487	0.408
	1960–75	0.250	0.481	0.596	0.465
	Total	0.245	0.450	0.539	0.429
1968	1965–70	0.298	0.359	0.398	0.354
	1965–75	0.245	0.418	0.390	0.359
	Total	0.273	0.390	0.394	0.357
All		0.288	0.478	0.604	0.476

The United States is officially forecast (1980 *Statistical Abstract*) to rise from a 1980 population of 222 million to a 2000 population of 260 million, implying an average annual rate of increase of 0.79 percent. The two-thirds confidence bounds on this will be 0.79± .029, or 0.50 to 1.08. That means we could bet 2 to 1 odds—but no higher—that the population in the year 2000 would be between 222 $(1.0050)^{20}$ and 222 $(1.0108)^{20}$, or between 245 and 275 million. Variants are given in the same official table, a low of 246 million and a high of 280 million. We have thus shown that the officially published low and high variants are slightly wider than the two-thirds confidence intervals—the probability that the official variants will straddle the actuality is slightly more than two-thirds.

We should state our result more carefully. If the forecasts now being made are as good as those of the past and no better, and if the unpredictable twists and turns of the components of population are as great as those of the past but no greater, then we can take it that the error now being made is drawn from the same distribution as past error, so the chance that the 2000 population will fall between 245 and 275 million is two-thirds, and the chance that the official range will straddle is slightly more than two-thirds. There is nearly one chance in three that the 2000 population will be less than the low published variant of 246 million or above the high variant of 280 million.

This result will be disappointing to those who thought of population as perfectly predictable, but it will hardly surprise those with good memories of past errors, being in fact nothing more nor less than a way of averaging those past errors. It tells us that we have some knowledge of the population 20 years ahead, but the bounds on that knowledge are wide.

A similar calculation shows that we know virtually nothing about the population 50 years from now. We could not risk better than 2 to 1 odds on any range narrower than 285 to 380 million for the year 2030.

For faster growing countries we should use not the 0.29 appropriate for the United States, but 0.48, or for most of the developing countries, 0.59.

Distribution of error

It would hardly be expected that all forecasts are subject to an error of 0.4 percentage points or any other number; the error is to be thought of as a random variable. Some forecasts can be seen after the event to anticipate perfectly the future population, while others are very far out.

The distribution for 20-year forecasts made in 1958 turned out as follows for 90 countries:

Departure of forecast from realization	Number of cases
More than 1.5 percentage points below	1
Between 1.5 and 1.0 percentage points below	6
Between 1.0 and 0.5 percentage points below	15
Betweeen 0.5 and 0 percentage points below	35
Between 0 and 0.5 percentage points above	31
More than 0.5 percentage points above	2

The distribution has a satisfactory single peak; the whole is skewed downwards by the fact that forecasts for developing countries were low through underestimates of the fall of mortality.

Forecasts for areas larger and smaller than countries

Subnational data—for states, provinces, countries, departments, cities—is even more plentiful than the national data discussed up to this point, and calculations such as those presented could easily be carried out once the data were assembled.

The states of the United States provide an example. The precensus estimates of population for 1980 of those states can be set against the 1980 counts. When this is done the root-mean-square with 50 degrees of freedom is 1.164 percentage points, which is to say more than double the error with which national populations are forecast, and this despite the fact that the forecast in this case made use of indicators from the states up to 1979. Evidently unanticipated internal migration is greater than the unknowns of fertility and international migration, but by how much greater remains to be investigated in more detail and for other countries.

For higher level aggregates—continents or the world—there is an intrinsic lack of data. Tomas Frejka (1981) has recently provided a useful history of world population forecasts, but his collection shows that the material available is not sufficient for probability statements. One surmises that the bounds become narrower as aggregation increases, so for the world as a whole the bounds would be narrower than the root-mean-square of 0.4 percentage points that we suggested for all countries together, but how much narrower is hard to say.

Naive projections

To judge a sophisticated method we need to know more than its error. The effectiveness of a professional forecast ought to stand out in comparison with a naive method like supposing last year's increase to continue into the future. If the error were greater than the error of a naive method, we would have to conclude that the demographic techniques had no value for forecasting. In general we would expect the sophisticated method to show less error than a naive method, and we will want to know by how much it is less. Ronald Lee (1978) has pointed out how close Census Bureau forecasts of fertility are to the actual fertility of the years prior to the forecast, and this suggests the experiment shown in Table 4.

For assessing projections made in the late 1950s, we can take the observed 1950 and 1955 populations, and suppose that the rate of increase that they show will persist into the future. Column (1) of Table 4 tells how good is the resulting forecast; its average root-mean-square error is 0.90 percentage points, while the corresponding figure in Column (3) is 0.48. Thus professional work making explicit judgments on mortality and fertility gives a narrower range of uncertainty. Taking the ratio of squares, one can say that the professional forecast contains three times as much information as the projected geometric increase.

TABLE 4 Root-mean-square error in percentage points of 1955–75 forecast on two simple methods and that for the forecast actually made: 18 populations in each of five groups of rate of increase

	With geometric increase from actual 1950–55 (1)	With geometric increase from projected 1955–60 (2)	With method actually used in published UN forecast (3)
Slowest growing	0.58	0.32	0.26
↑	1.03	0.41	0.36
	0.93	0.73	0.63
↓	0.76	0.68	0.58
Fastest growing	1.18	0.87	0.71
Average	0.90	0.60	0.48

Table 4 also shows countries classified into five groups according to their rate of increase. The geometric increase derived from the past is grossly inferior throughout. Column (2) reports on a somewhat less naive method, making a demographic estimate for five years ahead and assuming that rate of increase will continue. It is very much better than column (1), and indeed approaches the accuracy of published forecasts. It shows that what counts is the direction of the initial takeoff; a forecaster does not make much further improvement by explicitly forecasting changes from this initial direction five, ten, and more years in the future. This accords with the fact that in only a very few cases did the forecast curve cross the realized curve; most commonly the two simply diverged from the start. In short, the forecaster was doing something very similar to what was done in column (2).

The limits of forecasting

The motivation of this paper is the need to tell the user of forecasts how far published estimates of future population can be relied on. It disproves the charge that demographers know nothing about the future, as well as the hope that they can tell exactly what will happen. The most compact way of describing accuracy is by showing the average error of past forecasts. Applied first in astronomy, then in industrial processing, agronomy, pharmacology, human population sampling, and many other fields, the statistical tradition takes forms appropriate to the particular subject matter, but it is always preoccupied with inference and with error. The present article applies this tradition to population forecasting.

Forecasting is difficult enough to discourage the most hardy, and for a long time demographers did it under the heading of projection, contending that they merely worked out the consequences of variant sets of assumptions. Yet if demographers cannot judge which variant level of mortality or fertility is likely to be realized, no one can, and in practice users have depended on demographers for such judgment. The interpretation of middle-variant projections as forecasts has been nearly universal among users.

To describe the quality of a forecast, one can provide a range within which the reality can be counted on to fall with a given level of confidence. We have summarized the present investigation in one number, saying that the odds are 2 to 1 that the forecast rate of increase ±0.4 percentage points will straddle the realized rate of increase over future periods. In practice, that means useable forecasts for the next five to 20 years, virtually no information at all on population 100 years hence.

Tables 1 and 2 show that the error is apparently diminishing over time, either because population is changing in more regular fashion, or because forecasters are becoming more skilled. The root-mean-square for UN forecasts made in the late 1950s was 0.555, for those of the early 1960s, 0.429; for those of the late 1960s, 0.357. The difference is not due to the fact that we have had a shorter time to check up on the more recent work, since it appears also when we confine the comparison of jumping-off points to forecasts with a ten-year span. In concession to the possibility that there is a trend here, I have suggested rounding down the one-figure summary from the inclusive average .530 to 0.4.

Aside from assessing projection methods in absolute terms, I have examined how they compare with naive methods. One way of doing so is simply to find the rate of increase of the preceding five years and carry the population forward into the future with that rate of increase. The departure of that rate from the rate that materialized shows a root-mean-square error of 0.90 (Table 4) as against the 0.48 of actual forecasts. Judgment and the techniques of demography do indeed diminish forecast errors.

The user who objects that the probability set that provided the data for the estimate of error is not the same as the one to which it is to be applied is making an absolutely true assertion. But equally the farmer who trustfully plants potatoes using a variety that came out well in a trial cannot be assured of drawing a random sample from the urn of the trial; he is operating at a later time, in which external circumstances differ in many respects. The kind of logical jump that we make from the past degree of success of forecasts to the prospective success of the one now being made is required wherever statistical data are applied. The agronomist can design an experiment to reduce the error of application but cannot eliminate it.

Note that this is different in fundamental respects from the present practice of showing a number of estimates, calling one high, another low, another medium. Without some probability statement, high and low estimates are useless to indicate in what degree one can rely on the medium figure, or when one ought to use the low or the high. Nor do we derive any help from the notion that each of the projections corresponds to a different set of assumptions and that it is up to the user to consider the three sets of assumptions, decide which is the most realistic, and choose that one. If he actually goes to the trouble and has the skill to reflect on the alternative sets of assumptions and decide which is most realistic, then he might as well make the calculations in addition—that is a relatively easy matter once the assumptions are specified. If on the other hand, as more commonly happens, the user looks at the results and takes whichever of the three projections seems to him most likely, then the demographer has done nothing for him at all—the user who is required to choose on the basis of which of the results looks best might as well choose among a set of random numbers.

Should we calculate error?

Given the certainty that the future will be different from the past, it may seem wrong to suppose that future fluctuations will be drawn from the same probability set as past fluctuations. Yet the forecasts themselves face this difficulty; however sophisticated they may be, they cannot avoid assuming that the future resembles the past in important respects. Anyone who objects to this assumption ought not to make forecasts. One can respect the view that nothing at all should be said about future population, that our science is too little developed to provide a basis for forecasting. But if it is thought good enough for forecasting, then it is good enough to estimate the errors of forecasts.

It may be argued that projection is professional work analogous to that of a physician. The patient is less interested in confidence intervals on the outcome of an operation than in the physician doing the best possible job. Just as physicians ordinarily do not discuss error with their patients, so the client who is paying for the projection does not want horror stories of how bad projections have been in the past; all he needs is confidence in the demographer.

This is not the view taken in the present paper. The client I have in mind is not a nervous patient whose calmness and confidence are to be preserved, but an intelligent policymaker who should know the presumed accuracy of information before he proceeds to base a decision on it. There are major difficulties in estimating the error of projections, but so there are also in the projections themselves. If we can usefully extrapolate population from the past, then we ought to use the past to put bounds on the extrapolated population. Demographers realize that there is a limit to the accuracy with which the future can be known, in respect of population as in other matters. The experience of the past tells us something about that limit.

Appendix: method of calculation

In order to put the several units on a common basis, each forecast is assessed on the difference between the annual rate of increase it implies and that of the subsequent population performance. The UN publications listed in the references provide material to illustrate the necessary calculations. For Ethiopia the departure of r, the forecast rate of increase, from R, the realized rate, is $-.01283$ percentage points for the span 1955–75. For the other three countries of Eastern Africa the figures are $-.00588$, $-.00908$, and $-.01255$.

The average error of the four forecasts is

$$\frac{-.01283 - .00588 - .00908 - .01255}{4} = -.01008 \quad .$$

The root-mean-square error is

$$\sqrt{\frac{(-.01283)^2 + (-.00588)^2 + (-.00908)^2 + (-.01255)^2}{4}} \quad .$$

The standard deviation of the error is

$$\sqrt{\frac{(-.01283 + .01008)^2 + (-.00588 + .01008)^2 + (\ldots)^2 + (\ldots)^2}{4}} \quad ,$$

and the mean absolute error is

$$\frac{.01283 + .00588 + .00908 + .01255}{4} = .01008 \quad .$$

Note

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References

Frejka, Tomas. 1981. "World population projections: A concise history." Center for Policy Studies Working Paper No. 66. New York: The Population Council.

Henry, Louis, and Hector Gutierrez. 1977. "Qualité des prévisions démographiques à court terme: Etude de l'extrapolation de la population totale des départements et villes de France, 1821–1975." *Population* 32, no. 3: 625–647.

Lee, Ronald D. 1978. "Appraisal of the fertility assumptions employed in the social security projections." Unpublished ms.

———. 1980. "Aiming at a moving target: Period fertility and changing reproductive goals." *Population Studies*: 206–226.

Notestein, Frank W., et al. 1944. *The Future Population of Europe and the Soviet Union: Population Projections 1940–1970*. Geneva: League of Nations.

Statistics Canada. 1954. "Memorandum on the projection of population statistics, 1954." Ottawa: Dominion Bureau of Statistics.

Stoto, Michael A. 1979. "The accuracy of population projections." Working Paper-79-75. Laxenburg, Austria: International Institute for Applied Systems Analysis.

United Nations. 1958. "The future growth of world population." Population Studies No. 28. New York: United Nations.

———. 1966. "World population prospects as assessed in 1963." Population Studies No. 41. New York: United Nations.

———. 1973. "World population prospects as assessed in 1968." Population Studies No. 53. New York: United Nations.

———. 1979. *World Population Trends and Policies, 1977 Monitoring Report,* Vol. I, *Population Trends*. Population Studies, no. 62. New York: United Nations.

US Bureau of the Census. 1965. "Projections of the population of the Communist countries of Eastern Europe, by age and sex, 1965–1985," by James L. Scott. *International Population Reports*, Series P-91, No. 14. Washington, D.C.

———. 1975. "Population estimates and projections: Projections of the population of the United States: 1975 to 2050." *Current Population Reports,* Series P-25, No. 601.