# INTERPRETATION OF VITAL STATISTICS

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The field of vital statistics is as open to investigation, analysis and experimentation as it was three hundred years ago when John Graunt (1620-1674) introduced the observations on the London Bills of Mortality. The research possibilities are sometimes overlooked by statisticians and demographers because the registration systems now established in developed countries seem routinized and sterile. Also, in developing countries where vital statistics registration systems are yet a century or more away the focus has been on survey techniques and surveillance systems with their own special problems and methods of analysis.

This paper considers some conceptual schemes which may help in the understanding of population structure and change, theoretical constructions which serve to explain population dynamics, and methods for assessing vital statistics and census data. The purpose of the paper is to show that, through the reconstruction of the past using relatively simple models, vital statistics can be continuously reinterpreted for the improvement of data and for more refined analysis.

### Population Projection

The interpretation of vital statistics can be aided by a hypothetical projection into the future, a familiar technique for making sense of birth and death data. Such projection is distinguished from forecasting the future which is too difficult a task at the present state of knowledge. Demography does well to confine itself to accounting for past demographic phenomena, a difficult enough enterprise. Another technique, with which we are concerned here, is to break down the phenomenon under investigation into simple elements and then see how well the phenomenon can be reconstructed by putting these elements together into a suitable model.

If statistical data speak for themselves, they speak in a very low voice. Most of what they say is inaudible without some theoretical and practical amplification. As an example of how vital statistics are made to talk think of the birth data for the United States and for Mexico. In recent years Mexican births have been running about 2,500,000 per year, while those of the United States have been about 3,500,000 per year. The direct comparison of these numbers seems to tell us that the United States is higher than Mexico by about 1,000,000 births or 40 per cent. Nearly anything that one could say on the basis of this fact alone would be wrong.

Interaction starts when we note that the population of the United States at the present time is 210,000,000 and that of Mexico about 55,000,000; that in terms of these the birth rates are 17 per thousand and 45 per thousand respectively; that overall death rates are similar, Mexico's higher age-specific rates being offset by its much younger population. By a succession of such derived facts we gradually approximate to the true meaning of the birth totals of the two countries. We go on to age specific rates of birth and death; make the death rates into a life table; use the life table along with the birth rates to calculate intrinsic rates; find that the intrinsic rate of natural increase, the growth of the population that would result in due course if the age-specific rates of birth and death were to persist. is 7 per thousand for the United States and 35 per thousand for Mexico. Then we can assert that continuance of the Mexican rates would ultimately result in a doubling of the population each 20 years, of the United States rates only once each 100 years. At the end of a century of such rates the United States would contain 400,000,000 people, while Mexico would have multiplied by 32. and so contain 1,600,000,000 persons.

Now the figures begin to talk. For the above very rough calculation tells us that the Mexican rates of increase cannot continue for 100 years, while the United States rates can continue. They tell us that anyone who opposes birth control as a matter of principle for Mexico may claim to be taking a high moral position, but that he is in fact proposing a course that can only lead to an increase in the death rate.

The technique used in this argument amplifies a difference by projecting into the future. When we use raw births to ascertain age-specific birth rates in the two countries, and then go on to calculate intrinsic rates of about 0.007 for the United States and about 0.035 for Mexico, we find Mexico to be higher but the difference looks trifling; in any one year it could hardly have any effect. An amplification is provided by the hypothetical projection into the future: the future that enters the calculation is not in real time, but is rather in the special kind of time on which a conditional prediction is based.

The censuses help explain vital statistics. Births of the United States would be much greater, without any change in the chance of childbearing for individual women, if the population was as young as that of Mexico. With such a young population our birth rate would be 20 per thousand instead of 17 per thousand--merely because of the different mix of ages. On the other hand if Mexico was of the age distribution of the United States it would show only about 42 births per thousand rather than the actual 46. A principle of inertia applies in demographic affairs -having a high birth rate in the past is in itself an influence making for a high birth rate in the future. A high past birth rate combined with a low death rate similarly reduces deaths, and so makes for an especially rapid population increase, simply by virtue of the way that high births and

low deaths generate a young age distribution.

We have seen that a hypothetical future is one of the demographer's instruments for understanding the present. But he also needs the past for instance in explaining how the age distribution as shown in the 1970 census came to be what it is. Here the past vital statistics serve as the means of explanation of the present crosssectional distribution. We proceed to look into this aspect.

### Explaining Population Characteristics

To understand a phenomenon, we must break it down into its simplest elements, then put these elements together again in such a way as to reconstruct the phenomenon. This at least was the method of Descartes, and it seems the way to make intelligible the population characteristics presented as census and other data. Such characteristics as age, sex, marital status, birthplace, occupation, and industry, are suited to Cartesian treatment, but we will stay with characteristics that can be explained by vital statistics.

Past rates of birth and death are especially convenient for explaining age distributions. By partitioning and reassembling the observations from their constituent elements, the stable model can be utilized. By use of this or some other suitable model we can say that the ages of any country would be if previous age-specific birth and death rates had been of certain amounts.

As an example we explain some differences between Venezuela in 1965 and Sweden in 1803-7 so comparing a present developing country with an underdeveloped country of the early 19th century. We observe that in early 19th century Sweden about 30 per cent of the population was under 15 years of age, while in Venezuela now about 45 per cent is under 15 years of age. The difference is great and of serious consequence for the economy and society of the two countries. How much of it is due to difference in birth rates and how much to difference in death rates?

An answer is given by putting together an artificial population based on the stable model. (What model to use is a question that has to be considered afresh according to the circumstances of each occasion.) On this model Venezuela shows 47.7 per cent under 15 and Sweden 31.3 per cent under 15. If we make up an artificial population with the birth rates of contemporary Venezuela and the death rates of early 19th century Sweden we find a proportion under 15 of 43.6. Thus holding birth rates fixed we find that the effect of the difference of death rates--especially early 19th century Sweden's higher infant mortality-is to lower the under 15 by 4 percentage points out of the 16 percentage points of total difference. Presumably the remaining 12 percentage points are accounted for by the difference in birth rates. We can check this by doing the calculation in the other direction (with Venezuelan death rates and Swedish birth rates) and find

the same result. Apparently the two sequences in our experiment leads to an unambiguous result: interaction between birth and death rates is small. Of the total difference between the 47.7 per cent under 15 for Venezuela and the 31.3 per cent for Sweden, three quarters are due to the difference in births and one quarter to the difference in deaths.

It is more surprising to learn that about the same is also true for the differences between the two populations in proportion of old people, in dependency ratios, and in rates of natural increase. The calculation can be improved by allowing for changing rates of birth and death. But where such complications give essentially the same result we can gladly dispense with them.

Demographers concede that our ability to predict the future is limited to those cases where no sharp turning appears. Non-demographers agree heartily: the difference between them comes in whether population science ought to be able to foretell the future. Forecasting of complex concrete situations is too difficult a task to be the test of a science. A less severe test, though one difficult enough, is to account for the past. Where the stable population or other mathematical model is too simple to be useful we ought to be able to set up a random birth process on the computer that would produce a set of vital statistics and censuses indistinguishable by the methods of statistical inference from the vital statistics we observe. This more modest ideal of accounting for the past by a mathematical or simulation mechanism can serve as a target for demographic theory until we are bold and strong enough to hope for precise forecasts.

Along these lines we have the development of several population simulation models using Monte Carlo techniques. One of these, POPSIM, is a dynamic demographic model designed for computer simulation of the principal demographic processes occurring in human populations.  $\underline{1}$  It is classed as a microsimulation model because it generates a vital event history, including the dates of birth, marriage, divorce, widowhood, remarriage, and death of each individual in the computer population. While it is a two-sex model, it may be used for simulating cohort as well as period data. It is a stochastic model in the sense that random sampling from probability distributions is used to determine which events occur to an individual and when they occur; and it is a dynamic continuous time model permitting the probabilities to change with time. The original version of the computer program was not designed to distinguish between social segments of the population; the program has now been modified to permit distinctions by hypothetical segments in terms of race, residence, and family income.

One point to be made have is that while the technique may be developed, it should be more widely tested with published results so that more statisticians and demographers may become concerned with the technique and its applicability. The problems inherent in the appraisal of the technique only foreshadow the many technical-analytical problems which computer based simulation is only now beginning to compel us to resolve.

Some simplistic estimates of population changes have been used, for example, to determine the effect of the so-called Zero Population Growth; they may be scientifically inappropriate because they take into account only a few variables. On the other hand, using hundreds of variables, one study has already provided implications of considerable social and economic consequence; such findings are too often given as final interpretations whereas the method is essentially theoretical and should be considered only as basically useful for continued testing and experimentation. Probability studies infer experimentation.

Simulation models can be used not only for projection from today on but also, in the light of the observations of this paper, for testing past experience with both census and vital statistics data. One can incorporate the details of the demographic history of the past into the actual development of various population futures to see how these were derived and what the alternate consequences might have been.

# Verification

But prior even to drawing conclusions about the future, and tracing population characteristics into the past, is checking whether the vital statistics are correct. There is no substitute for the checking that goes on in vital statistics offices, but that checking needs some supplementation, in particular from the attempt to interpret and use the vital statistics that are published.

As for error, for example, there are a number of questions regarding the possible errors in the death certificate. More persons seem to have a hand in the production of a death certificate than in the production of most statistical reporting forms. From the point of view of what constitutes good reporting or survey technique too many uncontrolled persons are involved in the process. In some hospitals the form goes through several hands in different departments; the physician fill out the medical certification, and/or signs it; the funeral director fills in what is called the demographic information from various sources. Apart from the question of error on medical certification in terms of selectivity and subjective judgement as made by the physician is the fact that from a purely scientific point of view the process is unreliable. Yet the process itself and questions concerning the derivation of selected items have not been subject to the intensive investigation they deserve.

A set of death statistics may look satisfactory, but when one makes a life table from them it may turn out that the expectation of life at birth is 110 years. At the very least then one would want to re-examine the data, both those referring to the deaths and to the exposed population, and see whether anything could have gone wrong. Such a test is very gross, and would reveal only the most inexcusable errors.

A finer test is available if one is looking at mortality for a number of countries. Grouping the countries according to the factors that have a known influence on mortality--income per head, for example--one could see how the rates and expectations for any one group of countries, say a group that is homogeneous in respect of income, are distributed. If one of the groups is far outside of the distribution then its vital statistics need looking into. This test can be especially effective for particular causes of death; in a recent unpublished work Samuel Preston has shown that a given cause shows similar age profiles at very different levels of fertility.2/

In other instances we can check a birth rate by asking whether the persistence of that rate in the past would have accounted for the present age distribution as shown by a census. If the age distribution is very steep, then the births must have been correspondingly high. When we see that Colombia (1964) reported about 46 per cent of its population under age 15, and registered births were only 38 per thousand population, we suspect omission in the vital statistics. Fitting a stable model to the ages 5 to 29 gives over 47 births per thousand population. But the births could have been falling in the preceding years, so we fit (to ages 5 to 70) a modified stable distribution that allows for falling births. This gives over 44 births per thousand. The ratio of children 5-9 to women 20 to 50, less dependent on the stable assumption, shows about 45 births per thousand. The virtual agreement of all these ways of looking at the age distribution reinforces our suspicion that many births, possibly as many as one quarter, were unregistered.

Demographers do not come to their data without preconceptions. They carry around in their heads a set of anticipations of what birth rate ought to appear for developed and for developing countries. They know what age distributions ought to look like for different kinds of populations. A question worth raising is whether these anticipations can be more formally used as a priori probabilities in a Bayesian scheme. On a Bayesian way of doing demography one would sketch out his conclusions in advance, and indeed draw up a complete picture of his subject, necessarily vague in that each of the parameters would be expressed as a fairly wide range with a probability attached. Then the new data would be brought in, and would serve to narrow the ranges within which the diagram was sketched out. It would not always merely narrow an a priori range; it could move the range to some other position altogether, and even increase it.

## The Truth Attained by Assembly and Selection

The assembly of material from diverse sources can help us to discern the defects of any one source. Births and deaths are nearly always underregistered in newly established vital statistics systems, and often in old ones as well. All censuses undercount certain categories, for example men about age 20. Yet defective vital statistics can be used along with defective censuses to produce a complete account.

The method is based on the fact that as individuals are born and pass through their lives they are noted at various statistical checkpoints. A child may be missed by the birth registration network, and again by the decennial census taken when he is age 3, but then caught in the next census at age 13, missed in the census of age 23, and so on. The statistical system has enough redundancy that being caught some of the time suffices, and Coale and Zelnick have ingeniously taken advantage of this for the United States.3/ We may have to match the sources name by name in order to catch everyone, and this is often done in historical demography.

But if there are certain ages in which most individuals are caught in the census, then we can use purely demographic or aggregate methods, without matching. The census level at ages 5 to 14, for example, may be perfectly complete, and adding an estimate of preceding deaths to it enables us to infer the births. From the improved birth total so obtained we can go on to the distribution of births, say by age of mother or parity, for which the vital statistics may be adequate. This is an example where the vital statistics are assessed and improved by the census.

In other instances a pair of censuses can check one another and provide at least a hint of what is happening to births and deaths. Suppose a sharp fall in a 1967 census population enumerated as 10-14 from the enumerated as 5-9, a notch in the age distribution occurs, such as actually shown for Indonesia. It could be due to a real rise in successive cohorts, if for instance to a drastic fall in infant mortality occurred about 1950, or else it could be due to a simple understatement by enumerators of the age of children, exaggerating the 5-9 total and reducing the 10-14. In the second case the notch would be wholly imaginery, and if the same census method was used in 1971 the notch would reappear at the same ages. If, on the other hand, the notch was real it would have moved along to ages 15-19 and 20-24 by 1971. Real people get 10 years older in the course of 10 years; imagining people do not age. We now have the 1970 Census of Indonesia, and its preliminary count shows that some of both (a large youth cohort and age misstatement) are present.

### **Fertility**

In the same way the vital statistics can serve to check the census as in the comparison of cumulative fertility rates and vital statistics period rates. Census data on children ever born can be compared with vital statistics accumulations and the differences analyzed. There are special problems here, deriving from underenumeration rather than under-registration and from survivorship. Yet, while not be an easy matter to interpret, significant differences in magnitude and in estimated rates should stimulate new questions as to causality and validity. Also, data by age of mother, marital status and race can be compared. Hypothetical projections of what the cumulative data will be, as based on vital statistics estimations, or even what actual experience shows, can be developed and used as baselines for interpretation.

### <u>Rearrangement</u> of Data

The interpretation of vital statistics information often requires its drastic rearrangement. The best known example is the translation of period into cohort material. We may wish to follow groups of individuals rather than take cross-sections of events across time, and consider the births to women aged 18 in 1930, aged 19 in 1931, 20 in 1932, ..., assembling these together and speaking of them as the cohort born in 1912. Their reproductive activity can be compared with the corresponding activity of those born in 1913, 1914, .... The total children born to cohorts may vary less than do the total children born from one calendar year to the next. An unusually high death rate when a cohort is young may eliminate less hardy members, so that its subsequent mortality is lower than that of another cohort not subject to as rigorous selection.

The difference between cohorts and periods is unimportant as long as age-specific birth and death rates are constant through time. But once fluctuations occur in births then cohorts and periods are no longer equivalent. Suppose a dip in the United States economy followed by immediate recovery. If parents typically control their births with a view of having a certain number of children, there may be a dip in births but it will be followed by a subsequent offsetting rise. The delay in the formation of some families has had only a trifling effect on the growth of the population. But if the economic dip is prolonged, so that some parents pass the prime childbearing ages, then they are likely not to make up all the lost births, and the economic recession will have caused a net loss of population. The full meaning of the vital statistics is not revealed until we know how long an economic dip causes what loss in population. Full knowledge would show how the birth rate mimics the ups and downs of the economic cycle.

#### Combinations of Elements

We have been discussing studies in which new approaches develop as inherent in the data. There are other needed investigations in which insight emerges from new combinations of data. One of these is the manipulation of medical certification of death to provide combinations of diseases or multiple causes of death, and all other related factors reported on the death certificates, in simple tabular form. In countries of populations in the millions where the total number of deaths are in the hundreds of thousands or millions, and thousands of variables (causes) are involved, the problem heretofore has remained unsolveable. By the use of the computer both as a combining and as a selective tool, the problem is now solved. After some years of work the Automated Classification of Medical Entities (ACME) is a reality; the great potential of this system now awaits the work of scientific analysts.4 While the system automatically selects the underlying cause of death for national totals and international comparisons, any combination of causes can be determined by prescribed programming. This may throw new light on what mortality itself is from the statistical standpoint. To carry the method one step further; it should be possible to use ACME to develop a model for more refined study of the past effects of selected morbidity and combinations of causes of death on population growth. Whenever something like this comes along we must ask ourselves what other combinations of elements can be investigated.

#### Extension of Life Table Techniques

The model population distribution which we know as the life table has a number of uses other than that of indicating life expectancy on the basis of established fertility and mortality rates. It has been used to assess the effect on the population of the elimination of selected diseases, for example, and has indicated the number of persons, especially older ones, who would have survived had these diseases not taken their toll. It is possible to consider the model as a form for testing various estimations of fertility and mortality by age, race, and sex. In other vital statistics areas the technique has been successfully used as a theoretical device as, for example, where marriages are considered as births and divorces as deaths. These have apparently been more successful than the epidemiological model of using pregnancy as a disease and contraceptives as a cure but both approaches indicate that techniques have no limits as regards conceptual development.

## Sampling from Vital Records

Because of the cost factor and demands on limited staff, it may become necessary to consider how to simplify the record processing task by reducing the one hundred percent sample of births or deaths to a direct 50 percent sample, or to a selective item sampling of 5, 10, or 25 percent. Sometimes decisions to affect these procedural changes are not evaluated until the data year is completed and the results are in. At other times decisions to do selective sampling are made on the basis of statistical inference, without testing. With the vital statistics data available for past years it should be possible to experiment extensively to determine the effect of differential sampling on final frequencies and rates.

For an example, the decision in the United States to go to the 50 percent sample of births made impossible the production of detailed tabulations on multiple births. Other means had to be developed to produce estimates for twins, triplets, and so on, but these data have not been considered adequate by some programs. What else was eliminated, not so visible as twinning, has not been fully explored. On the other hand, to see if legitimacy rates could be produced for those registration areas which did not have the item on the birth certificates, a retrospective test, the Inferential Method, was used. 5/ In this method, data derived from complete reporting for a past year was compared to that from incomplete information from the same certificates which inferred illegitimacy. The rates were found to be comparable. Unfortunately, the method was also found to be too costly for processing on a regular basis.

The use of vital records of any past period for laboratory purposes generally is probably limited because of matters respecting confidentiality and accessibility but local and national offices may wish to consider the scientific potential inherent in these investigations. The use of vital records for any past year as a sampling frame for retrospective studies in fertility, mortality and nuptiality, has already proven fruitful.

#### Conclusion

Before anyone can hope to forecast the future he must learn to interpret the past. The interpretation can consist in breaking down the phenomenon under investigation into simple elements, and then seeing how well past instances of the phenomenon can be reconstructed by putting these elements together. One example is the explanation of an age distribution in terms of the birth and death rates of the preceeding 90 years. Another is referring the present increasingly higher death rates of males to the different incidence of causes for the two sexes. A third is showing how cohorts defer and advance their childbearing in accordance with economic conditions, thus allowing a relatively constant number of children per family to give rise to widely fluctuating period rates. Such reconstruction facilitates causal analysis, and tells what would occur if one of the underlying elements were different. It can be used to say what increase in the proportion of old people would result from eliminating cancer or heart disease; what the ultimate population would be if couples immediately dropped their childbearing to bare replacement; what effect emigration has on the subsequent birth curve. The reconstruction of the past through the use of models, some relatively simple and others complex, can be carried further and will help in the interpretation of vital statistics.

There are other areas for experimentation as in the case of comparing vital statistics and census data, the rearrangement of data such as in cohort fertility, in new combinations of data elements, and an extension of established techniques, such as life table applications, and so on.

There is more to come from vital statistics analysis. In the past 25 years the new techniques, measures, and methodologies developed by Whelpton, Greville, Campbell, Lee, Linder, and a number of others, have shown that this area of investigation is by no means dead. This paper is a reminder that the field of thought opened by John Graunt three centuries ago is still wide open for stimulating statistical investigation and analysis.

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- 2. Samuel Preston, unpublished paper.
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