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The Population Growth Estimation (PGE/ERAD) Method of Obtaining Death Rates: An Overview

The inadequacy of demographic data for the majority of the human race due to the paucity and recency of population censuses, and even more so due to the non-existence or incompleteness of the registration of vital events, has led to much ingenious search for substitute data. Another stimulus to such a search was given by the need for data required by makers of population policies, and by designers and evaluators of family planning programmes.¹ Both groups were brought into existence through the emergence of the so-called "population problem", arising precisely in the countries with inadequate demographic data. Demographers in the United Nations and those grouped around the Princeton Office of Population Research made important contributions to the development of analytical techniques (e.g., U.N. No. 39 and U.N. No. 42) leading to the assessment resulted often in the estimation of demographic parameters, possibly and probably, closer to reality than the reported data. There is, however, no substitute for real data. Hence, the ingeniousness in the development of new analytical techniques aimed at increasing the usefulness of such unreliable data as made available traditionally, was paralleled by ingeniousness in the collection of new types of data and new methods of collecting data.

1. The main focus of formulators of population policies and that of family planning programme designers and evaluators is on the measurement of births. Nevertheless, the measurement of deaths could not help benefiting from this interest through the link with the rate of natural growth.

Among the many new survey and non-survey sources of data, three distinct groups have become important in recent years : the service statistics for family planning programmes, KAP surveys (knowledge, attitude, practices), and PGE/ERAD surveys (Population Growth Estimation of Estimation du Rhythme d'Accroissement Demographique). It so happens that the Population Council of New York sponsored or is sponsoring the production of handbooks in each of the three fields (Ross *et al.*, 1968 ; Caldwell *et al.*, 1970 ; Marks *et al.*, 1974). The purpose of this paper is to present the state of the art reached by the PGE/ERAD techniques, particularly as it applies to the measurement of mortality. The PGE/ERAD literature includes by now a large number of titles and only scant justice can be paid to this interesting topic in a brief paper. Reference must be made to the sources cited (as well as to other sources given in the citations, but not- in this paper) for further elaborations, particularly with regard to the field experiences, as this paper is limited to the sketching out of the underlying principles.

Briefly, the PGE/ERAD technique consists of the collection of data by two independent methods for the same population with regard to the same time period. The results are then compared case by case. From the case-by-case comparison three categories of events are obtained : caught by both methods, caught by one method only but not by the other, caught by the other method but not by the first one. Finally, an estimate of events missing by both methods can be obtained through a well known and long established proposition in probability. It will be readily recognized that the success of the technique depends on the effectiveness of the case-by-case comparison and on the independence between the two methods. With regard to the comparison, the novelty lies in the case-by-case feature, because comparisons in the aggregates obtained by more than one method were made often in the past. Such global comparisons, if giving similar results, were deceptive as to level, and productive of unjustified confidence, when the composition of the cases under each method was different.²

2. There are uses of a case-by-case comparison, other than for purposes of PGE/ERAD estimation, such as, for example, the case-by-case checking of two lists of two heaps of documents or one list and one heap of documents for administrative purposes or control purposes. The theory of matching and record linkage is applicable to all of them, but this paper is limited to the PGE/ERAD facets and uses of such comparisons.

The independence between the two systems, about which more will be said later, justifies the application of the probability proposition. Basically, if two events occur independently of each other, then the probability of joint occurrence is equal to the probability of one event occurring times the other event occurring. In algebraic notation³: the probability

$$(A \text{ and } B) = \text{probability } (A) \cdot \text{probability } (B), \quad (1)$$

where

$$\text{probability } (A) = \frac{A}{A + \text{not } A} \cdot$$

$$\text{probability } (B) = \frac{B}{B + \text{not } B} ;$$

It will be remembered that the condition for equation (1) to be true, is that the occurrence of *A* has no effect on the occurrence of *B* and *vice versa*.

Equation (1) can be rewritten as follows

$$\text{Pr } (A) = \frac{\text{Pr } (A \text{ and } B)}{\text{Pr } (B)}. \quad (2)$$

The three terms occurring in equation (2) can be redefined as follows :

$$\text{Pr } (A) = \frac{N_1}{N} = P_1 \quad (3)$$

$$\text{Pr } (B) = \frac{N_2}{N} = P_2 \quad (4)$$

$$\text{Pr } (A \text{ and } B) = \frac{M}{N} = P_{1, 2} \quad (5)$$

where,

N = true total number of events irrespective of whether reported or missed ;

*N*₁ = number of events caught by method 1 ;

*N*₂ = number of events caught by method 2 ;

M = number of events caught by both methods.

3. Different notations are used by different writers. In this paper we follow Marks *et al.*, 1974, pp. 13-17.

We substitute the old notation in equation (2) by the new notation in equations (3), (4) and (5), and after transformation obtain :

$$\frac{N_1}{N} = \frac{M}{N_2} \quad (6)$$

Performing a similar exercise for the other method we obtain :

$$\frac{N_2}{N} = \frac{M}{N_1} \quad (7)$$

Equations (6) and (7) mean that the match rate of either method in a PGE/ERAD collection is equal to the completeness rate of the other method ; more directly : the match rate of one gives the completeness rate of the other.⁴

As already indicated in the introductory paragraphs, we also obtain an estimate of the total number of events, including events omitted by both methods, apart from the estimates of completeness of either method shown in equations (6) and (7). The estimate of the total events (N) is obtained by transforming the terms of equations (6) or (7) into the following result :

$$N = \frac{N_1 N_2}{M} \quad (8)$$

It must be clear by now that the estimate derived through equation (8), is not in any way a new, unique, or special statistical adjustment. It has been in use for a long time and for many purposes. To suit the needs arising in connection with vital statistics estimation, the last equation can be further transformed. Let

$$N_1 = M + U_1, \quad (9)$$

$$N_2 = M + U_2, \quad (10)$$

4. It has been reported (Seltzer, 1969, p. 401) in respect of 19 PGE/ERAD studies that the median completeness for deaths was 69 per cent (range 23 to 91), lower by 8 per cent points, but with a similar range than births. This variability reflects true differences in completeness, as well as biases. As indicated later in the text, loss or lack of independence, usually overestimates completeness, matching errors can have a bias effect in either direction, out-of-scope event, if not included by the other method, under-estimate completeness, spuriously, of the other method.

where N_1 , N_2 and M continue carrying their previous meanings, and

U_1 = events caught by method 1 only,

U_2 = events caught by method 2 only.

Equation (8) can then be rewritten

$$N = \frac{(M + U_1)(M + U_2)}{M} \quad (11)$$

Through simple transformations

$$N = M + U_1 + U_2 + \frac{U_1 U_2}{M} \quad (12)$$

Equation (12) is clearly message-conveying. The four terms on the right side correspond to the basic four PGE/ERAD categories described earlier: events caught by both methods, events caught by one method but not by the other, events caught by the second method but not the first, events missed by both methods. The last term is the "fourth category" celebrated in PGE/ERAD literature.

Historically, the origin of the ideas behind this method is hidden in the mist of the past. The earliest application of it to vital events known to the present writer and his colleagues, is the Canadian evaluation of the completeness of birth registration in 1931 (Tracy, 1941). Another is the estimate of birth under registration in the United States in 1939 (Grove, 1943). This latter exercise, and some of the related work, have been reported extensively in some detail in technical literature (e.g., Shapiro, 1950). An important step has been taken by Ghandrasekaran and Deming in their 1949 article when they moved from what we described earlier as equation (8) to equation (12).⁶ In the forties a number of exercises were undertaken on this general theme, usually limited to the provision of estimate of completeness (our equations (6) and (7)), that is to say, without endeavouring to estimate the "fourth category", given in equation (12). For twelve years the Chandrasekaran-Deming article has only faint echoes, until attention to it has been drawn at the New York conference of the International Union for the Scientific Study of Population (Coale, 1961).

5. They also made other significant contributions to the development of the PGE/ERAD techniques.

At the next conference of the Union in Ottawa, at a session organized by a French demographer (Louis Henry) the first report on a practical application of the PGE/ERAD techniques has been presented (Krotki, 1963). Since then, a large number of exercises have been undertaken and a somewhat smaller number reported upon in technical reports and professional journals.

To date some forty surveys employing PGE/ERAD techniques have been carried out or are being carried out.⁶ The countries involved include : Algeria, Brazil, Chile, Egypt, India, Kenya, Korea, Liberia, Malawi, Morocco, Pakistan, Sierra Leone, Tanzania, Thailand, Tunisia, and Turkey. PGE/ERAD techniques feature in an important manner in the International Program of Laboratories for Population Statistics sponsored by the University of North Carolina and the first task of the first laboratory, situated at Columbia, under this programme is the elaboration of various alternatives of data collection for PGE/ERAD purposes.

For the two methods required by the PGE/ERAD technique two of the following are frequently used : civil registration, special registration (that is special to PGE/ERAD), one time survey, multiple visit survey. Typically, the estimates of completeness for deaths are proportionately lower than for births, but not absolutely; for example, a true birth rate of 50 reported as 40 will be accompanied by a true death rate of 20 reported as less than 16, but not less than 10; thus, the true natural increase of 30 will be reported as lying somewhere between 24 and 30 or less, but not, typically, more than 30. The consequence of this phenomenon is, incidentally, that in the absence of PGE/ERAD techniques there is a tendency to underestimate the net population growth. This writer's current preference is for the combination of a special PGE/ERAD registration and multiple visit surveys at regular intervals every six months with recall periods of a year. However, no definite preference in principle can be suggested. Too much depends on details of local circumstances and the time horizon of the PGE/ERAD survey. An extensive discussion of some of the relevant considerations is offered in the PGE/ERAD Handbook referred to earlier.

At this stage of the discussion, we must refer to a number of important topics. The first, and most important, topic is the question of indepen-

The actual count depends on definitions used (Seltzer, 1969, p.395; Beaujot, 1974).

dence between the two methods. All of the theoretical basis of the PGE/ERAD technique rests on it and yet it is subject to two dangers. The first is the likelihood that similar types of events will tend to be omitted by both methods because of characteristics inherent in the event, for example mortality of transients and of cases subject to neo-natal mortality. Chandrasekaran and Deming suggested that much of this disadvantage can be remedied by breaking up the events available for analysis of characteristics, which separate the population in this manner. The PGE/ERAD estimation is then carried out separately for each of the population groups so isolated. Chandrasekaran and Deming were able to improve their estimates in this way, but attempts to do so in two other countries (Pakistan, Thailand) did not produce significant improvements in the PGE/ERAD estimates. Possibly, the population was not broken up on the most relevant characteristics.

The other danger to independence is the risk of cooperation between the two methods. To take an extreme case: perfect collision will result in perfect matching: (and low estimates of vital rates);⁷ all events will fall into the first category, and each of the other three categories will be equal to zero. An attempt is made in Liberia to reward field workers of one system for verified events caught by them but not by the workers of the other method. One can imagine the kind of "cooperation" which might arise between the two groups of field workers. In fairness to each other, they would scrupulously divide their cases between them: the first category would be zero, the second and third category would contain exactly half of the events reported, and the fourth category would be zero again. Strangely enough, the final result would produce a perfect estimate, if the two parties would really exert themselves to ferret out the last event, but one shudders to think what will happen to the Liberian budget. The bias of the present writer is that no special steps whatsoever should be taken, but that the independence between the two methods should have two separate organizations, quite independent of each other, so that the first common supervisor is the Director General at the national headquarters; during the lifetime of the experiment, lessons learned about the inadequacies of one method, including the slovenliness of field workers should *not* be fed into the system by the other method as errors of the first method. The Director General, if schizophrenic

7. This is an extreme case of the effect of lack of independence indicated in footnote 4.

enough, might in his more secretive moods contemplate means of improving either method from *his* experience gained in the other method, but the responsibility for quality must rest on supervision internal to each system. Certainly reconciliation procedures required because of discrepancies between the events as reported by each method, must be investigated in the field by a third unit under the Director-General, with no means of feedback into the other two systems. The duties of the field workers of the two systems must be highly structured. The PGE/ERAD Handbook makes a large number of elaborate suggestions. The responsibilities must not be left to general admonitions such as "You must try to locate all births and deaths in your area", "midwives, tea-shops, barbers are good sources of local gossip", "work hard" and the like. And, of course, in line with this reasoning, inspectors from headquarters travelling around the country with evidence from one system, attempting to find out why the other system did not report events found by the first system, can only lead to disaster.

It will be noted that the extreme attitude with regard to independence represented in the paragraph above has not been accepted in the Gujarat exercise where the work of a member of one system was checked by a member of the other system (Mehta, 1969). No wonder that it has been found that these other workers "consulted the registration list" produced by the first worker (*ibid.*, p. 406). Furthermore, during the field reconciliation they were unwilling "to list any event that the registrar has found but that they themselves had not found" (*ibid.*, p. 408). The findings (*ibid.*, p. 410) that the two systems should be carried out by independent organizations, matching should be done in headquarters, field enquiries should be carried out by a third party, confirm recommendations long available in PGE/ERAD literature.

We also said that the accuracy of the PGE/ERAD estimate depends on the accuracy of M and N_i or N_z (or their complements U_i and J_2), that is the events matched and non-matched, which quite plausibly are not the same categories as caught and not-caught by either of the two methods. The values of M and N_i and N_z rely on the adequacy of the matching system and on the incidence of out-of-scope events. As far as matching is concerned, a PGE/ERAD estimate depends 'on the net error, i.e., it is necessary to strike such matching rules that the net difference

between erroneous matches and erroneous non-matches is at a minimum.⁸ The net error can be either positive or negative. The rules depend in turn on the discriminating power of the characteristics used for matching and, obviously, this power varies for the same characteristic between anthropological cultures.

The incidence of out-of-scope events depends on a number of considerations, but specifically, on the time concept of the respondents and their recollection for temporal out-of-scope and on the number of sample areas, and consequent length of boundaries at which spatial out-of-scope cases arise. Doubtful matches and doubtful non-matches, particularly when bringing the suspicion of out-of-scope occurrence, must be investigated, reconciled, and confirmed in the field by investigators working directly from, or at least for, headquarters, without any responsibility to either of the two systems. To begin with, this is likely to be an expensive part of the experiment, because a high proportion, probably all, doubtful cases need to be reconciled. All gross errors have to be looked at. When with experience, matching rules have been established at the level of lowest net errors, the importance and expense of the field reconciliation will dwindle altogether or even disappear. As a minimum precaution to preserve independence, the instructions given to the third force should be on identical documents irrespective of the system through which the doubtful event has arisen. In the course of talking to respondents the member of the third force might discover the system through which the event has been reported (and consequently the system that omitted the event), but as long as this information is of no further consequence to him or to anybody within his reach, the discovery is not likely to create much excitement. Much of the art of PGE/ERAD designing rests on ways of avoiding or measuring the sources of bias discussed above as well as the likelihood of bias in the estimate of the base population. An increasing number of theoretical discussions and empirical reports provides relevant suggestions of how to deal with erroneous matching (e.g., Srinivasan and Muthiah, 1968), erroneous inclusion of events, and lack of statistical independence between the two systems of data collection (e.g., Jabine and Bershad, 1968).

8. In this consideration "mis-matches" are irrelevant and non-damaging. Mis-matches are documents that should be properly matched, but have been coupled with the wrong document, a matter grievous administratively, but not affecting estimates of vital events.

A survey of the complexity and expense of a PGE/ERAD survey depends for its success on a large number of various services and considerations.⁹ It is almost axiomatic that it depends more on the mode of application of a method than on the selection of the method itself. It is another truism that the results depend on the total error, and not only, on the sampling error. This writer suffered greatly from out-of-scope problems and is very impressed with boundary problems. He is, therefore, in favour of large clusters, and is ready to pay the price of large sampling errors. Judging from such data on variances as are available from various experiments, a PGE/ERAD survey covering 100,000 people in some 30 clusters will produce estimates of death rates with coefficients of variation varying around 6 per cent (4 per cent in the case of births).¹⁰ It needs only some slight violence to the purity of estimation techniques to lower these sampling errors, when the data are cumulated after the experiment has been in existence for more than a year. In any case, these sampling errors are likely to be small in comparison with non-sampling errors, in an average survey. Much depends on local circumstances, and it can be suggested that *counting all costs* a complete PGE/ERAD survey, covering 100,000 people or 25,000 households, without compromises on the principle of independence, will cost up to two hundred thousand US dollars annually. Again, it must be repeated, much depends on circumstances, including the accounting system of the organizations concerned. At eight or less dollars per household, we can buy a system that is relatively reliable, self-checking and producing measureable errors.¹¹ This is not an exorbitant bill. For somewhat larger samples in the States of India, expenditure of one-fifth of the above suggestion has been reported (Agrawal, 1969, pp. 382 and 383), but it remains to be ascertained that *all* expenses were included and

9. For example, we have not covered in this brief paper all the problems related to the establishment of the base population appropriate to the vital events estimated through PGE/ERAD.

10. The larger CV for deaths than for births is typically due to fewer events with the same population size in the sample rather than to greater variability in the occurrence of deaths.

11. It goes without saying that no analyst would take PGE/ERAD estimates as the final word. They must be viewed as complementary with estimates derived through demographic analysis of such other data as might be available (including age distributions obtained as a by-product of one or the other of the two systems employed in a PGE/ERAD experiment),

what the total cost would be if all the PGE/ERAD principles were followed.¹²

References

1. Agrawal, B. L. 1969, Sample Registration in India, *Population Studies (London)*, 23(3), 379-394.
2. Beaujot, Roderic, 1974, The PGE/ERAD system of data collection in Africa and a comparison of its results with those of analytic techniques, Paper presented to the annual meeting of the *Canadian Association for African Studies*, Halifax, Nova Scotia, February-March 1970.
3. Caldwell, *et al.*, John, C., Harvey, M, Choldin, Louisa, F. Noe, David, L. Sills and Frederick, F. Stephan, 1970, *A Manual for Surveys of Fertility and Family Planning: Knowledge, Attitudes and Practice*, New York, The Population Council.
4. Chandrasekaran, C. and Deming, W. Edwards, 1949, On a Method of Estimating Birth and Death rates and the extent of Registration, *Journal of the American Statistical Society*, **44** (245), 101-115.
5. Coale, Ansley J., 1963, The Design of an Experimental Procedure for Obtaining Accurate Vital Statistics, *International Population Conference, New York, 1961*, London, Union internationale pour l'etude scientifique de la population, 372-375.
6. Grove, Robert D., 1943, Studies in the Completeness of Birth Registration: Part I. Completeness of birth registration in the United States ; December 1, 1939 to March 31, 1940, *U. S. Bureau of the Census. Vital Statistics—Special Reports, XVII* (18).
7. Jabine, Thomas B. and Bershad, Max A., 1968, Some Comments on the Chandrasekaran-Deming technique for the Measurement of Population Change, *CENTO Symposium on Demographic Statistics held in Karachi, West Pakistan : 5-12, November, 1968*. Ankara, Turkey : Central Treaty Organization, pp. 189-206.
8. Krotki, Karol J., 1963, First Report on the Population Growth Estimation Experiment, *International Population Conference, Ottawa 1963*. Liege : Union interantionale pour l'etude scientifique de la population, 159-174.
9. Marks *et al.*, Eli S., Karol, J. Krotki and William, Seltzer, 1974, *Population Growth Estimation. A Handbook for Vital Statistics Measurement*, New York : The Population Council (in print).
10. Mehta, D.C., 1969, Sample Registration in Gujarat, India, *Demography*, (PAA)6(4), 403-411.
11. U.N. No 39, Department des affaires economiques et sociales. Etudes demographiques, No. 39. *Le concept de population stable. Application a l'etude des populations des pays te disosant pas de bonnes statistiques demographiques*. New York : Nations Unies, 1966.

12. For most of India crude death rates for the same period (January—June 1968) have been reported of 5 (from statutory registration), 9.5 (from sample registration), and 10.1 (from "intensive" surveys), all three probably too low. It is not reported whether all the PGE/ERAD principles have been rigorously applied to the field work and whether the PGE/ERAD estimation have been used to reach the level of 9.5 (The Registrar General's Newsletter, 5(2): 11, April 1969).

12. Ross *et al.*, John, A., Frederic, F. Stephan and Walter B. Watson, 1968, *A Handbook for Service Statistics in Family Planning Programs*, New York, The Population Council.
13. Seltzer, William, 1969, Some Results from Asian population growth studies, *Population Studies* (London), 23 (3), 695-406.
14. Shapiro, Sam, 1950, Development of Birth Registration and Birth Statistics in the United States, *Population Studies* (London), 4 (1), 86-111.
15. Srinivasan, K., and Muthiah, A., 1968, Problems of Matching of Births Identified from two Independent Sources, *The Journal of Family Welfare*, **14** (4), 13-22.
16. Tracy. 1941, Fertility of the Population of Canada, *Seventh Census of Canada*, 1931, vol.2: ...—...xi reprinted as Census Monograph No. 3. Ottawa : Edmond Cloutier.
17. U. N. No. 42, Department of Economic and Social Affairs. Population Studies No. 42. *Methods of Estimating Basic Demographic Measures from Incomplete Data*. New York : United Nations, 1967.