C. R. Malaker

Estimation of Adult Mortality in India : 1971-81

Introduction

IN most of the developing countries not much is known about the dimensions of mortality. Information on levels, trends and differentials in mortality is virtually non existent in many of these regions even today. Reliable registration data are available at fairly regular intervals in the developed countries and as such specification of mortality in terms of its various components such as age, sex, occupation, education, marital status, residential status etc., helps an analyst to get a deeper insight into the mortality history of the population. But in developing countries like India registration figures are not satisfactory. The Census Actuaries had, so long, been entrusted with the task of construction of national life tables by using data of successive censuses. Only recently has the use been made of the Sample Registration System (SRS) for estimation *of* mortality and construction of Life Tables. But the coverage in most cases is incomplete and it is debatable whether mortality rates, used in the construction of these life tables as estimaied from SRS can be taken as reliable as many scholars have pointed out deficiencies of these statistics particularly with mortality. As the state of arts in the field of population analysis has vastly improved since the 1960s and as we are well equipped with a battery of indirect estimation techniques due mainly to the brilliant work of Brass, Coale and others, it should be appropriate to undertake a study of mortality using the preliminary census results for 1981. An attempt has, therefore, been made here to estimate the adult mortality level for India by using two methods of estimation—one based on information on widowhood (Hill, 1977) in the *1981* census, and the other based on census age distributions (Preston and Bennett, 1983) in 1971 and 1981. We believe, more is known almost universally, about levels, trends

and differentials in respect of infant and child mortality than in respect of adult mortality. This is partly due to the development and application of powerful techniques for estimation of child mortality and it will be rewarding to examine the application of these indirect estimation techniques to the Indian situation with adult mortality as illustration. The life table functions under both the methods have also been presented here.

Mathematics of Adult Mortality Estimation

In the following paragraphs we will briefly describe the two methods of estimation of adult mortality based on (*i*) information on widowhood and (*ii*) census age distributions. For details the reader may refer to the literature cited in this paper.

(*a*) *Adult Mortality from Information on Widowhood*

The following symbols will be used :

${}_5P_N$ = proportion not widowed in the age group $(N, N + 5)$

W_N = weighting factor

N = central point of two adjacent age groups $(N - 5, N)$ and $(N, N + 5)$

The basic equations for estimating male adult mortality from widowhood of female respondents are

$$\frac{l_{N+5}}{l_{22.5}} = W_N \, {}_5P_{N-5} + (1 - W_N) \, {}_5P_N \qquad (1)$$

and

$$\frac{l_{N+5}}{l_{27.5}} = W_N \, {}_5P_{N-5} + (1 - W_N) \, {}_5P_N \qquad (2)$$

The first equation is used where the mean age at marriage for females is below 20 and the second where it is higher.

The corresponding estimating equations for female adult mortality from widowhood of male respondents are

$$\frac{l_{N-5}}{l_{17.5}} = W_N \, {}_5P_{N-5} + (1 - W_N) \, {}_5P_N \qquad (3)$$

and

$$\frac{l_{N-5}}{l_{22.5}} = W_N \, {}_5P_{N-5} + (1 - W_N) \, {}_5P_N \qquad (4)$$

for male mean ages at marriage of under 25 and over 25 respectively.

Ideally one should collect information on widowhood from first spouse to remove the effect of remarriage. In the absence of such information, as a first step, widow remarriage has been assumed to be negligible though as an input some preassigned values as to the proportions of widow remarriage can always be introduced into the model. Again marriage being universal in India, occurr-

ing early for both sexes, the estimates will be robust to variations in the levels and patterns of mortality and will be applicable to the total adult population of the country.

(b) Adult Mortality Based on Two Successive Censuses

Preston and Bennett have shown that in any closed population at any moment of time

$$N(x) = N(0) \exp\left[- \int_0^x r(u)\, du \right] p(x) \tag{5}$$

where $N(x)$ = the number of people aged x at that moment,

$p(x)$ = probability of survival from birth to age x referred to the period life table,

and $r(u)$ = age specific growth rate at age u.

After some simplication the discrete approximation is obtained as

$${}_5L_y = {}_5\bar{N}_y \exp\left[5 \sum_0^{y-5} {}_5r_x + 2.5\ {}_5r_y \right] \tag{6}$$

where ${}_5\bar{N}_y$ = average inter censal population in the age group $(y, y + 5)$,

${}_5r_x$ = inter censal growth rate for the age group $(x, x + 5)$,

and ${}_5L_y$, T_j, l_j, e_j are the conventional life table functions.

$$T_j = \sum_{y=j}^{\infty} {}_5L_y,$$

$$l_j = \frac{{}_5L_j + {}_5L_{j-5}}{10}$$

and $$e_j = T_j/l_j.$$

Preston and Bennett recommend the use of the formula

$${}_5\bar{N}_x = \frac{{}_5N_x(t + 10) - {}_5N_x(t)}{(10)\ {}_5r_x} \tag{7}$$

with inter censal interval as 10 years, where ${}_5N_x(t)$ = population in the age group $(x, x + 5)$ at time t. In effect they use the equation ${}_5N_x(t + 10)/{}_5N_x(t) = \exp[10\ ({}_5r_x)]$. It is to be noted that the period life table so obtained refers to the period t to $t + 10$.

As has been shown by the authors the method does not make any assumption about the stability of the age distribution. The national population can be

regarded as closed and when we come to state level estimation, correction due to migration is called for. The method does not give an estimate of l_0 and e_0, and independent estimates are needed for age 0. Again there are certain problems for higher ages and for open ended age intervals but they are of minor nature and, in any case, some model values at higher ages can be taken as input without much difficulty.

Application to Indian Data

(a) *Adult Mortality from Widowhood*

Table 1 shows the age specific proportions not widowed for males and females—India, 1981 and the corresponding weighting factors. For indicators, we have taken the singulate mean age at marriage (SMAM; Hajnal, 1953) rather than the age distribution weighted mean as these two measures are expected to agree reasonably well. The SMAMs are calculated from the 1981 census proportions single and are observed to be 23.3 and 18.1 years for males and females respectively. Thus the weights correspond to $l_{N+5}/l_{22.5}$ and $l_{N-5}/l_{17.5}$ for male and female adult mortality.

TABLE 1—PROPORTIONS NET WIDOWED IN THE CENSUS OF INDIA, 1981 AND THE WEIGHTING FACTORS

Age group	*Proportions*		*N*	W_N	
	Male	*Female*		*Female from male information*	*Male from female information*
20-25	.9913	.9923	25	.4837	.3971
25-30	.9901	.9845	30	.2694	.4515
30-35	.9856	.9684	35	.2849	.5089
35-40	.9799	.9455	40	.3324	.5640
40-45	.9660	.8908	45	,3837	.6049
45-50	.9544	.8397	50	.4348	.6192
50-55	.9249	.7016	55	.4740	.6271
55-60	.9084	.6808	60	.4879	.5811
60-65	.8551	.4371	65	.4969	.5267
65-70	.8243	.4122			

SOURCE : Census of India, 1981. Series 1, India, Paper 2 of 1983, Key Population Statistics Based on 5 Percent Sample Data.

Now as a starting point $l_{22.5}$ (male) and $l_{17.5}$ (female) are taken by reconciling three different estimates—one from all India Life Tables—1971 published by the Bureau of the Census (1978), the second from the Indian Life Tables for 1961-70 prepared by the Registrar General of India (1977), and the third by using Brass one parameter logit model ($\beta = 1$; 1971; 1975) with l_2 taken from the all India Life Tables 1961-70. With the final reconciled values ($l_{22.5} = .7390$ for males and $l_{17.5} = .7320$ for females) the number of life table survivors at different ages obtained.

It has been noted that the l_x values thus obtained are not perfectly smooth. This is quite expected in view of the approximations involved and the nature of the data available. As one of the essences of the life table functions is the smoothness and also the fidelity in the light of real experience, we proceed to graduate the l_x values by fitting a two parameter Brass logit model

$$Y(x) = \alpha + \beta\, Y_s(x) \tag{8}$$

where $Y(x) =$ logit l_x

$Y_s(x) =$ logit l_x^s

$l_x^s =$ standard life table function taken from Brass General standard

and $$Y(x) = .5 \log_e \frac{1 - l_x}{l_x}$$

whe parameters α and β are estimated as :

$$\beta = \frac{\sum_{30}^{45} Y(x) - \sum_{55}^{70} Y(x)}{\sum_{30}^{45} Y_s(x) - \sum_{55}^{70} Y_s(x)}$$

and $$\alpha = 1/9 \sum_{30}^{70} [Y(x) - \beta\, Y_s(x)] \text{ for males;}$$

$$\beta = \frac{\sum_{20}^{35} Y(x) - \sum_{45}^{60} Y(x)}{\sum_{20}^{35} Y_s(x) - \sum_{45}^{60} Y_s(x)}$$

and $$\alpha = 1/9 \sum_{20}^{60} [Y(x) - \beta\, Y_s(x)] \text{ for females.}$$

The graduated values of l_x along with those obtained by the widowhood method are presented in Table 2 below. To test for adherence to data we have also presented the values of the survivorship function for all India Life Tables 1971, published by the Bureau of the Census.

Males

Age *x*	*Life table survivor at age x (unit radix)*		
	Widowhood method	*Brass two parameter*	*Bureau of the census*
30	.7298	.7516	.7271
35	.7210	.7272	.7133
40	.7074	.7003	.6952
45	-6811	.6692	.6690
50	.6434	.6312	.6269
55	.5817	.5574	.5723
60	.5127	.5222	.4979
65	.4277	.4438	.4029
70	.3144	.3470	.2923

Percentage error (Reference : Bureau of the census table, see text)
Widowhood method : 2.3%
Brass two parameter : 3-5%

Females

Age *x*	*Life table survivor at age x (unit radix)*		
	Widowhood method	*Brass two parameter*	*Bureau of the census*
20	.7252	.7360	.7207
25	.7223	.7251	.7039
30	.7184	.7146	.6852
35	.7105	.7042	.6658
40	.7018	.6933	.6459
45	.6864	.6810	.6235
50	.6706	.6664	.5964
55	.6450	.6486	.5599
60	.6146	.6289	.5047

Percentage error (Reference **: Bureau of** the census table, **see** text)
Widowhood method : 8.7%
Brasi two parameter : 8.6%.

(6) *Adult Mortality from Two Successive Censuses*

Tables 3 and 4 present the calculations showing the application of census based method to Indian males and females, 1971-81.

TABLE 3—ADULT MORTALITY ESTIMATION FOR **INDIAN** MALES, 1971-81

Start of age interval (x)	*Average annual growth rate of interval* ${}_5r_x$	*Mean number of person years lived in interval*[1] ${}_5\bar{N}_x$	*Sum of* ${}_5r_x$ *from age 5 to mid point of interval*[2] S_x	${}_5L_x = ({}_5N_x) \cdot exp\ (S_x)$	T_x	l_x	e_x
0	.009103	473965	—.02276	463299	5492465	—	—
5	.017371	435398	.04343	454724	5029166	91802	54.8
10	.024764	383581	.14876	445105	4574442	89983	50.8
15	.026792	318401	.27765	420297	4129337	86540	47.7
20	.024595	266745	.40612	400380	3709040	82068	45.2
25	.022682	231827	.52432	391628	3308660	79201	41.8
30	.020736	204210	.63286	384525	2917032	77615	37.6
35	.022776	182124	.73664	380440	2532507	76496	33.1
40	.023814	160846	.84812	375616	2152067	75606	28.5
45	.027473	138525	.97633	367742	1776451	74336	23.4
50	.029149	112659	1.11789	344556	1408709	71230	19.8
55	.030067	89028	1.26593	315728	1064153	66208	16.1
60	.032665	68220	1.42276	283014	748425	59874	12.5[3]

4. Estimated mortality level (West Model) = 15.1; e^0_0 = 52.1 (See text).

SOURCE. India, Registrar General, Census of India, 1971, Series I, Paper 3 of 1977, Age Tables.
India, Registrar General, Census of India, 1981, Series I, Paper 1 of 1984, Population Projections for India 1981-2001.

1. in OO's.
2. growth rates at ages 0-4 are cumulated backwards.
3. taken by reconciling different official estimates.

Evaluation of Results

Having applied the two methods of estimation of adult mortality to Indian data it will be in order to examine the results. It has been claimed that both

TABLE 4—ADULT MORTALITY ESTIMATION FOR **INDIAN** FEMALES, **1971-81**

Start of age interval (x)	*Average annual growth rate in interval* ${}_5r_x$	*Mean number of person years lived in interval*[1] ${}_5\bar{N}_x$	*Sum of* $({}_5r_x)$ *from age 5 to midpoint of interval*[1] S_x	${}_5L_x = ({}_5\bar{N}_x) \exp(S_x)$	T_x	l_x,	e_x
0	.009117	453965	— .02279	443736	5149507	—	—
5	.017869	409486	.04467	428192	4705771	87193	54.0
10	.023369	351936	.14777	407980	4277579	83617	51.0
15	.024135	294655	.26653	384650	3869599	79263	48.8
20	.023171	254236	.38479	373550	3484949	75820	46.0
25	.022570	224448	.49914	369734	3111399	74328	41.9
30	.021414	195648	.60910	359753	2741665	72949	37.6
35	.023371	168991	.72107	347552	2381912	70730	33-7
40	.027971	143524	.84942	335601	2034360	68315	29.8
45	.031422	119798	.99790	324962	1698759	66056	25.7
50	.032406	96701	1.15748	307693	1373797	63265	21.7
55	.032824	78433	1.32055	293769	1066104	60146	17.7
60	.037028	62404	1.49518	278330	772335	57210	13.5[3]

4. Estimated mortality level (West Model) = 13.7; $\hat{e_0^0}$ = 51-8 (See text).

SOURCE: Same as in Table 3.

1. in 00's.

2. growth rates **at ages 0-4 are** cumulated backwards.

3. taken by reconciling different official estimates.

these methods show distinct promise and from that perspective a critical evaluation is all the more necessary.

Taking widowhood method, it should be tested on different types of data pertaining to wide range of cultures before we can give any judgement regarding the efficacy of the method. Looking at the results obtained (Tables 1 and 2), several interesting points emerge. To have some reliability on the widowhood technique, the values of the survivorship function obtained by this method as well as the graduated values obtained by fitting Brass two parameter logit model have been compared against those published by the Bureau of the Census. For such an analysis the percentage error, $\underset{x}{E}|(l_X - l_{xB})| / \underset{x}{E} l_{xB} \times 100$, has been calculated

where l_x = life table survivors at age x according to widowhood method (or those obtained by Brass two parameter logit model),

and l_{xB} = corresponding values according to life tables published by the Bureau of the Census.

In the above calculation we have assumed that the widowhood method gives us estimates of mortality for the decade 1971-81 (Centering at 1976) and adult mortality has not changed substantially during the 5 year period 1971-76.

The results of the above analysis reveal that as far as the estimation of male adult mortality is concerned the method seems to be reasonably accurate. But the same cannot be claimed in case of estimation of female adult mortality as the percentage errors arc quite large, being of the order of 10 percent. Though one must be very cautious in making this type of conclusion as different types of errors interact (both in data collection as well as in methodology) and possibly in different directions—such as age misreporting, misreporting of marital status, assumption of no mortality differential by marital status etc., the fact remains that female adult mortality as obtained by this technique is very much under estimated. Possibly two reasons can be ascribed to this. First, widows experience substantially higher mortality risks than the currently married and as such adult mortality obtained by this method is underestimated. Second, and we think this is more important in Indian situation, remarriage may not be totally negligible particularly in case of males. The present method is a proxy to the theoretically correct procedure where information about widowhood from first spouse need to be collected, and is valid under the assumption that there is no remarriage in the population. It may be of interest to consider some model values for remarriage and to examine their effect on the estimates. The present author has made some experimentation with this type of exercise taking the 1974 Bangladesh Survey data on evermarried, everwidowed and widowed of the first spouse and it has been observed that the type of remarriage affects the estimates to a considerable extent. To save space and time, and also because one is completely uncertain about the pattern of remarriage among the Indian population, the results of this analysis are not incorporated here. In passing we must mention another limitation of the widowhood method which has not been fully discussed in the literature, namely time reference for the estimates. Of course an approximate dating in the line of Brass technique as applied to estimation of infant and child mortality is possible and it will perhaps be reasonable to take the adult mortality estimates as those pertaining to the decade 1971-1981.

Coming to the second method, we are aware of the different types of errors with census age data such as age misreporting, underreporting, coverage error etc. Though it has been recommended that the method may be used with reported age distribution in conjunction with model life tables, we have preferred to use the adjusted rather than the reported distributions. Of course, the adjusted

age data are not always completely free from various types of criticisms. But as they have been made smooth and more amenable to different tests of age errors it is believed these distributions will yield better estimates of adult mortality for the country. Now a look at Tables 3 and 4 shows that the age sequence of estimates of life expectancy are reasonably smooth. The method, however, fails to provide an estimite of life expectancy at birth. Several procedures are available for such an estimation. As age bias affects both l_x *and* e_x, first three point moving averages of the e_x values as obtained in Tables 3 and 4 taken as the final estimates *ex* (e_5 e_{10} and e_{15} are averaged to give a robust estimate of e_{10} for example). Now resorting to West Model Life Table (Coale and Demeny, 1966) corresponding to each e_x we obtain a mortality level. The median of the first five levels is taken as the final estimate of mortality level for the country. The summary results have been shown below Tables 3 and 4. According to the census based method the life expectancies at birth in India for the decade 1971-81 are 52.1 and 51.8 years for males and females respectively. The results seem to be quite in tune with those for the decade J96J-71 (Dyson, 1979) and also with the estimates for 1971-81 using Preston Bennett technique with unsmoothed age data (India, Registrar General, 1984). Further, whereas the use of unsmoothed results yields a higher life expectancy at birth for females (e_0= 52.9) compared to males (e_0 = 52.5), the results obtained by us seem be more coniistent and representative of the sex differentials of mortality in India.

Conclusion

In recent years indirect methods of estimation have shown distinct promise in population analysis. In developing countries there is a lacuna in the field of collection of accurate demographic information. The analyst is often confronted with data problems and has to make several types of adjustments to extract the demographic parameters as accurately as he can. It is more often than not that several procedures are to be applied to get the best possible results.

The present paper describes the application of two methods of estimation of adult mortality to 1981 census data for India. It has been shown that the results are highly plausible and consistent particularly with the census based method. The widowhood method also gives reasonable estimates of male adult mortality. The female adult mortality as obtained by this technique is severely underestimated. Theoretically, one should collect information on widowhood from the first spouse. In the absence of such information, the method is susceptible to the incidence of remarriage. From our analysis it appears that remarriage among Indian males is not negligible, at least as far as the estimation of adult mortality is concerned. The second contributory factor is the higher mortality risks for the widowed relative to the currently married. Of

these two, however, the latter seems to have secondary effect on adult mortality estimation. With some reliable data on remarriage as input, at least on a sample basis, better estimates of adult mortality level for the country may be obtained.

References

1. **Brass, W.** and Coale, A. J., 1968, *The Demography of Tropical Africa,* princeton, Princeton University Press.
2. Brass, W., 1971, **On** the scale of mortality, I*n :* W. Brass (ed.), *Biological Aspects of Demography,* Taylor and Francis, London.
3. Brass, W., 1975, *Methods for Estimating Fertility and Mortality from Defective Data.* International Programme of Laboratories for Population Statistics, University of North Carolina, Chapel Hill.
4. Bureau of the Census, Department of Commerce, 1978, *Country Demographic Profiles-India.* Washington, D. C.
5. Coale, A. J- and Demeny, P., 1966, *Regional Model Life Tables and Stable Populations.* Priticeton, Princeton University Press.
6. Dyson, Tim, 1979, Working Paper on Fertility aod Mortality Estimates for the States of India. Paper Presented at the Workshop of India Panel, Committee on Population aad Demography, National Academy of Sciences, New Delhi.
7. Hajnal, J., 1953, Age at marriage and proportions marrying, *Population Studies, 7(2}.*
8. Hill, K., 1977, Estimating adult mortality level from information on widowhood. *Population Studies, 31(1).*
9. Preston, S. H. and Bennett, N. G., 1983, A Census based method for estimating adult mortality. *Population Studies,* 37(1).
10. Registrar General, 1977, *Life Tables* (Series 1- India, Paper 1 of 1977), New Delhi, Office **of** the Registrar General, India.