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A Comparative Study of the Application of the Gross-Check and Indirect Methods for Estimating Vital Rates Using Data of the Mysore Population Survey, India

1. Introduction

IN developing countries where routine vital registration data are non-existent or grossly deficient, retrospective demographic sample surveys have been widely used to obtain estimates of birth and death rates, age-specific fertility and mortality rates, trends in the number of children ever born and children surviving and various other demographic variables. In spite of their potential utility, demographic estimates obtained from retrospective surveys are known to be liable to error because of such factors as memory lapse, selectivity of the population interviewed due to deaths or migration and several other features which stand in the way of obtaining a true picture of the past. Two important procedures have been suggested to improve the estimates of vital events provided by retrospective surveys viz. the cross-check method proposed by Chandra Sekar (now Chandrasekaran) and Deming(1949) and the indirect method of estimation developed by Brass, Coale and others (United Nations, 1967; United Nations, 1983). Neither of these procedure! is foolproof and their deficiencies have been discussed from time to time. However, comparative studies of the precision of the estimates given by the two procedures have been rare. One such study was made using the data of a dual re-

cord project by Madigan and Herrin (1977) A unique opportunity for such a comparison is provided by the data available in the Mysore Population Study (United Nations, 1961).

The purpose of this paper is to examine the quality of the estimates provided by the two procedures using the data obtained by this study. Such an attempt was considered worthwhile as the Mysore Population Survey (MPS) which provided much of the data for the Mysore Population Study had incorporated in its design several features to improve the accuracy of the data it obtained In addition, a continuous series of population census reports are available for the erstwhile Mysore state which now forms part of Karnataka state in which the MPS was undertaken and the data provided by these census reports can also be useful in judging the efficacy of the two procedures of estimation referred to above. Before discussing the results obtained by the application of these procedures it will be in order to describe MPS briefly and its evaluative procedures.

2. Some Features of the Mysore Population Survey

(a) *Organisation*

The Study was essentially an experiment in the use of samping survey techniques to obtain information on the inter-relationship of population characteristics and social and economic treads. The feasibility of obtaining data on vital statistics, particularly of birth and death rates in areas with different economic and social characteristics, was a primary aim of the Study.

The five areas selected for survey were the following :

(i) Zone I—Rural hills with large-scale anti-malarial operations;

(ii) Zone II—Rural hills without large-scale anti-malarial operations;

(iii) Zone III—Rural plains, tank irrigated areas;

(iv) Towns with population of 10,000 to 25,000 in 1951;

(v) Bangalore City divided into five strata on the basis of religious composition and literacy status.

The following features of the MPS are of special interest. The household schedule which was the major source for obtaining vital data carried a number of ancillary questions to remind the interviewee of past occurrences of births and deaths and the schedule had a series of cross-checks printed on it to make sure that the interviewer had made systematic use of the various items of information provided by the interviewee. By interviewing an important member of the household, it collected data on births and deaths which had occurred in the household since *Ganesh* festival in 1950 which fell on 15 September 1950 and the date of survey. Apart from obtaining dates of birth

or dates of death and other particulars relating to the vital events, the household schedule enquired whether the event took place within 12 months of Ganesh festival 1950 The household survey in some of the survey areas began in December 1951 and the timing in the different areas had to be adjusted to suit weather conditions Work in zones I and II began in February 1952 and was completed in June 1952. In zone III and 'towns' the survey was carried out intermittently from December 1951 to April-May 1952. The survey in Bangalore City started in February 1952 and was completed in August! 952. As such the earliest recording of vital events for the 12-month period following 15 September 1950 was 3 months after the end of this period and the latest about 11 months after the end of the period.

(6) Evaluation *Procedures Used*

Evaluation of accuracy of the data was one of the aims of MPS. Such evaluation was partly built into the design of the survey; in addition, several demographic techniques which were known at that time were also used to gauge the accuracy of the data obtained. The accuracy with which births and deaths had been recorded by the Survey relied mainly upon the cross-checking of the births and deaths recorded in it with those found in the registration records. Such cross-checking was possible in rural areas However, because of lack of maintenance of records only those of 146 out of the 191 villages surveyed in rural areas could be used for the cross-check. The cross-checking was done locally in consultation with the village seniors by supervisors shortly after the interviewers had completed the survey work Birth and death records were obtained from the Office of the Registrar General of Births and Deaths of Mysore state, who statutorily received from each village or other registration area a monthly statement of the registered vital events. These lists were up-dated by the supervisors who visited the local administrative office where the village registrars were expected to send their records, before undertaking the cross-check.

Such cross-check method could not be used in 'towns' and Bangalore City mainly because the identification of the household where the birth or death occurred and a scrutiny of whether it was included in the MPS would have involved too much labour Another method proposed in statistical literature to judge the accuracy of the data obtained could be used instead in Bangalore. This is the design of 'inter-penetrating samples' in which the survey work in Bangalore City was organised (Mahalanobis, 1946).

Additionally, the Fertility-Attitude Survey (FAS) which was undertaken in Zone III and four of the five strata of Bangalore City selected provided a complete fertility history of a number of currently married women aged 18-33

years[1]. Cross-checking of the birth data obtained in the household survey with those obtained in the later survey was also undertaken.

The number of children born to each woman recorded in the household schedule was also cross-checked with that on the FAS schedule. The data in the former was obtained by a male worker interviewing a responsible member of the household and asking the three separate questions on (1) the number of children living in the household, (2) the number of children living elsewhere and (3) the number of children that had died. The fertility history in the FAS was obtained independently by female interviewers. In Zone III and the strata of Bangalore City where the cross-check was undertaken, the household survey had recorded the number of children born with almost complete accuracy. A small percentage of the children who had died were missed in the household schedule; but it was not of any consequence in studying family size from the data.

3. Salient Findings of the MPS

The cross-check with the registration lists showed that for the 12-month period following 15 September 1950, the survey had succeeded in detecting 91 per cent of the births which occurred in Zone I, 93 per cent in Zone II and 94 per cent in Zone III. For deaths the corresponding percentages were 89, 83 and 94 respectively. These percentages related to event« which had occurred within the village and therefore had no relevance to events which took place outside the village surveyed.[1] Further as indicated earlier not all villages surveyed could be included for the cross-check as the registration lists were not available for some of the villages surveyed. The findings of the cross-check of the birth records of the household survey with those on the FAS although partial, corroborated the results obtained from the cross-check with the birth registration records in zone III. It further showed that the percentage of births recorded in the household survey in Bangalore City, viz 91 per cent, was slightly worse than in zone III 'towns'. The 'interpenetrating' sample design used in Bangalore City showed that no significant difference existed between the interviewers in their recording of births or deaths in the City; but the design by itself could not provide any evidence of the extent to which the births and deaths were recorded by the Survey, However, the death rate for Bangalore City shown by the Survey was lower than the rates record-

1. For some other restrictions us;d in selecting the women for the Fertility-Attitude Survey see the report of the Mysore Population Study (United Nations 1961, pp. 39-40).

2. The MPS showed that in Zone III about 23 per cent of births to residents occurred outside the surveyed dwelling unit. (United Nations, 1961, Table 16.9, p. 230). The cross-checking done in the PGE System (Marks, Seltzer and Krotki, 1974) covers all births to residents irrespective of the place of occurrence.

ed by Ceylon in a contemporary period, the deficiency being more marked among females aged 45 year and over.

The crude birth and death rates for the 12-month period following 15th September 1950 and their standard errors, and the rates of natural increase for 1950-51 as given in the MPS are reproduced in Table 1.

TABLE I—CRUDE BIRTH AND DEATH RATES AND THEIR STANDARD ERRORS AND RATE OF INCREASE, FOR DIFFERENT AREAS

Areas	*Estimated Population*	*Birth Rate per 1,000 population*	*Standard error as per cent of estimated birth rate*	*Death rate per 1,000 population*	*Standard error at percent of estimated death rate*	*Rate of natural increase*
All Areas	5,696,603	40.0	...	18.0		22.0
Zone I (Rural hills@)	443,948	44.4	6.73	15.1	14.00	29.3
Zone II (Rural hills@@)	598,419	44.7	6.13	189	11.71	25.8
Zone HI (Rural plains)	3,740,997	39.9	6.41	18.6	7.35	21.3
Towns	223,282	38.9-39.8	7-82	13.8—23.9	...	15.9-25.1
Bangalore City	689,957	33.0	4.25	13.7		19.3

@With anti-malarial operations.

@@Without anti-malarial operations.

SOURCE. *Mysore Population Study*. United Nations (1961), p. 78.

Note. The birth and death rates given were obtained by inflating the observed figures using correction factors mainly obtained by the cross-check method. See the text for details. The rates given refer to the resident population.

In computing the birth, death and natural increase rates, the following procedures were followed. The corrected rates for the rural zones, zone I, II and III, were obtained by inflating the births obtained in the survey by the degree of omission as estimated by the cross-checking of the survey entries with those on the registration lists. The degree of omission found in the three zones have been cited earlier. The inflation factor for births in Bangalore City was obtained by inflating the births recorded by the household survey by the degree of omission as assessed by the cross-check with the FAS.

The death rate in Bangalore City is given by the registration records for the City in 1951, with some adjustment made for the non-resident deaths. This death rate of 13.7 was much higher than the rate of 8.1 per 1000 recorded by the household survey. For 'towns', a range was provided both for birth and death rates, one based on the assumptions that omission in the recording of births and deaths were to the same extent as in the rural zones, and that the omissions were of the same magnitude as in Bangalore City. The range was quite narrow for births but quite large for deaths. In the calculation of birth and death rates the resident population, as given by the household survey, was used as the denominator. It may be pointed out that the weighted rate of natural increase as estimated in the MPS by using the correction factors well exceeded the estimated rate of natural increase for Mysore State as a whole during the 1941-50 decade (Jain, 1955).

Another vital statistic which is important in the application of indirect method of estimating births by the use of the Brass technique is the age-specific fertility rate. The rates for the different age-groups as estimated by the MPS, are presented in Table 2. These rates are as by the survey and

TABLE 2—AGE-SPECIFIC FERTILITY RATES IN DIFFERENT AREAS DURING THE 12-MONTH PERIOD !5 SEPTEMBER 1950 to 14 SEPTEMBER 1951 ACCORDING TO MPS (AS OBSERVED)

Age Group	*Zone I*	*Zone II*	*Zone III*	*Towns*	*Bangalore City*
15-19	186	182	204	109	122
20-24	335	259	259	270	186
25-29	249	265	260	229	160
30-34	177	174	134	199	128
35-39	126	92	117	147	63
40-44	15	40	39	47	24
All age groups	1088	1012	1013	1001	683
Total Fertility Rate	5.4	5.1	5.1	5.0	3.4

Note. As the specific fertility rates were derived by reckoning the births which occurred to residents during 1950 1951 against the women enumerated during the Survey the rates in Zones'1 & II, Zone III, 'towns' and Bangalore City given in the table are likely to be in deficit by 1.4, 1.7, 4.7 and 7.9 per cent respectively, if the populations in these areas had increased at the annual rate of growth observed between the 1941 and 1951 censuses.

not inflated to allow for omissions. The age-groups used for the calculation of the age-specific fertility rates related to the ages of the women as in the household survey; the births refer to those which occurred during the 12-month period, 15 September 1950 to 14 September 1951.

4. Estimation Using Brass Techniques

(a) Assessment *of the Accuracy of Births Recorded in the MPS*

The MPS had obtained data on number of children ever born and number of children surviving, in addition to births and deaths which had occurred between 15 September 1950 and the date of the household Survey. Because of the relatively small number of women interviewed, data on the average number of children born and average number of children surviving for ever-married women had been tabulated in the MPS report in ten-year age-groups 15-24, 25-34 etc. upto 55-64. An attempt was made to use the P/F technique to assess the accuracy with which births had been recorded by the MPS. As the births analysed in the MPS referred to the 12-month period following 15 September 1950 and the survey began in December 1951 and concluded in August 1952, appropriate 'multipliers' for the use of the P/F technique were worked out by using the fertility curve suggested by Brass and the procedure used by him for obtaining the oft quoted multipliers for the *quinquennial* groups 15-19, 20-24 etc. with displacement of one-half of a year between the occurrence of the birth and the survey. The multipliers obtained by us for the three rural zones, 'towns' and Bangalore City for the three age groups 15-25, 25-35 and 35-45 are given in Table 3.[3] The displacement in years, f/f_2 where F_1 and f_2 are the specific _ fertility rates for the age-groups 15-19 and 20-24 years during 1950-51 and m the mean age at fertility for the different areas are also given in Table 3. The mutipliers for the ags groups 15-25 are based on the

TABLE 3—MULTIPLIERS FOR ADJUSTING $f_i's$ TO CORRESPOND TO P_i's USING BRASS'S FERTILITY POLYNOMIAL

Age Group	*Zone I*	*Zone 11*	*Zone III*	*Towns*	*Bangalore City*
15-25	5.1882	5.5556	5.6622	4.7312	5.5349
25-35	6.5628	6.5337	6.4704	6.3924	6.6162
35-45	7.9621	7.8796	7.8560	7.5497	7.9556
(f_1/f_2)	0.555	0.703	0.788	0.404	0.656
m	26.44	26.78	26.61	28.24	26.73
Displacement (in years)	1.083	1.083	1.000	1.063	1.167

3. The procedure used in obtaining the multipliers is explained in the Appendix. It will be noted that in the absence of information on P_1 and P_2 , f_1 and f_2 have been used instead.

values f_1/f_2 while those for the other two age groups are based on the value of m. The displacement was taken to be the interval from the mid-point of 15 September 1950 to 14 September 1951 and the mid-point of the survey period as applicable to each rural zone, 'towns' and Bangalore City.

The value of *PI* the average number of children ever born to woman in the age group *i*, f_1 the specific fertility rate in the age group *i* for 1950-51 and the corresponding P/F ratios are given in Table 4 for the three age-groups 15-25, 25-35 and 35-45 for each rural zone, 'towns' and Bangalore City. The total fertility rate (TFR) obtained by using the spacific fertility rates are also shown in the table.

At the outset it may be noted that the TFR for Zones I, II and III exceed the values of $P_{35\text{-}45,}$ while for 'towns', it is lower. For Bangalore City the TFR value is markedly lower than the $P_{35\text{-}45}$ value for 'towns.' The current fertility level seems markedly lower in Bangalore City as compared with past fertility, and slightly so in 'towns'.

The P/F values for the age-group 15-25 are less than unity in all areas except 'towns' where it is 1.102. The values show, in general, an increasing trend with age, this is most marked in Bangalore City, less so in Zone I, II and III and least in 'towns'. Among the rural zones, the values of P/F for the age groups 25-35 and 35-45 are higher in zone III and not far off from unity, as compared with zones I and II. Between these three zones, zone III values are closest to unity while zone II values are nearer unity as compared with zone I Besides, while in Bangalore City the values of P/F for the age group 35-45 and 25-35 are markedly above unity, in the three rural zones they are less than unity. In 'towns' the P/F values for the age groups 25- 35 and 15-25 are about the same but is a little higher in the age group 35-45,

These observations suggest the following tentative conclusions. The P/F method does not allow any adjustment in current fertility as compared with life-time fertility except possibly in 'towns'. The following possibilities may have to be considered to understand the significance of the data presented in Table 4 :

(i) The use of a longer reference period than 12 months for births, especially in the rural areas ;
(ii) an increase in fertility m rural areas, and a decline of fertility in urban areas ; and
(iii) the effects of mortality and migration trends on fertility.

Before considering these aspects, an assessment of the recorded mortality data and a reassessment of the recorded fertility data will be taken up.

TABLE 4- P/F RATIOS FOR RURAL ZOMBS, TOWNS AMD BANGALORE CITY AS OBTAINED FROM MPS

	Zone I				*Zone II*				*Zone III*			
Age Group	*Pi*	*fi*	*P/F*	*P/F adjusted*	*Pi*	*fi*	*P\F*	*PIF adjusted*	*Pi*	f_1	*PIF*	*P/F adjusted*
15-25	1.064	.250	.821	0.810	1.000	.218	..827	0.816	1.165	.231	.890	0.875
21-35	3.366	.215	.860	0.849	3.486	.223	.959	0.946	3.596	.208	.983	0.966
35-45	4.863	.069	.934	0.922	4.573	.068	.925	0.913	5.100	.082	1.014	0.997
TFR	—	5.34	—	—		5.09	—		—	5.21	—	

Age Group	*Towns*				*Bangalore City*			
	Pi	f_2	*P/F*	*P/F adjusted*	*Pi*	*fi*	*P/F*	*P/F adjusted*
15-25	.968	.186	1.102	1.053	.839	.153	.991	0.918
25-35	3.553	.217	1.095	1.046	3.051	.148	1.215	1.125
35-45	5.561	.107	1.150	1.098	4.786	.046	1.419	1.315
TFR	—	5.10	—		—	3.47	—	

Note. The f_i's given in ten year age groups were obtained by using the specific fertility rates given in Table 2. As such the remark given in the note under Table 2 will apply to the values of f_2 and [P/F] ratios given in the above table. The [P/F] ratios adjusted for the possible deficit in the age specific fertility rates used in their calculation (see note under Table 2) are also given in the above table. Since the adjustment is conditional and does not alter the [P/F] picture, the original [P/F] values are used throughout the discussion in this paper.

(b) Assessment of Mortality

(i) *Childhood Mortality*. The childhood mortality was estimated by the Brass technique using the data on the average number of children ever born and average number of children surviving for women in the ten-year age groups 15-25, 25-35 . . . 55-65. The 'multiplying factors' used for converting the proportions of children dead into survival rates were obtained by using f_1/f_2 and *m* values with allowance for displacement, to interpolate the figures given in UN Manual IV (United Nations, p 125). The estimated *q* and l life-table functions are presented in Table 5. The time reference *T* (number of years prior to MPS) to which the different sets of the life-table functions are applicable was estimated by the method proposed by Brass (unpublished). These time references, the levels of mortality to which the life table functions correspond as indicated by the a values of Brass as well as the Coale-Demeny "West" Model Life Tables and e^0_0 corresponding to the "West" Model are also given in Table 5. The « values, in particular, indicate a marked decline in childhood mortality during the period of two to seven years prior to the MPS in zones I and II. A moderate decline is shown in zone III which already had a higher survival rate for children than zones I and II. While a general improvement in survival rates of children is indicated for rural areas, in 'towns' and Bangalore City there appeared to have been a marked deterioration in the few years prior to the survey. As a result the childhood mortality rates in these two areas at the time of the MPS were practically the same as in the rural areas.

(ii) *Adult Mortality*. Adult Mortality was estimated by the 'widowhood method' proposed by Brass but using its Hill-Trussel variant (1977). The MPS had obtained information on the age at first marriage for males and females and the mean age at marriage could be worked out for birth cohorts. The mean age at marriage for males born during 1918-22 was 25.03 for the three rural zones taken together; for 'towns' the mean was 23.95 and for Bangalore City 25.19. For females born during 1928-32 the corresponding mean ages at marriage were 15.60, 16.00 and 16.60. The difference between the mean age at marriage of the spouse was 9 4 years in rural areas and a little less in 'towns' and Bangalore City and such large differences have persisted in Mysore state from the known past. The mean age at marriage noted above was used in place of the singulate mean age at marriage in the regression equation. Also, as widowhood data were available only in 10-year intervals, Newton's formula for halving the interval was used for obtaining data for 5-year intervals. The estimates of adult mortality so obtained are presented in Table 6 upto 45 years of age for which the analysis could be

TABLE 5-CHILD MORTALITY IN RURAL ZONES, TOWNS AND BANGALORE CITY-MPS

Area	*Age Group*	$\alpha^{(1)}$	$q_x^{(2)}$	$lx^{(2)}$	$\alpha^{(3)}$	T(4) *(Years ago)*	*Level*$^{(5)}$	e^0_0*(5)*
	15-25	2	.237	.763	.1306	3.08	9.23	39. 18
	25-35	5	.294	.706	.1635	7.31	8.78	38.08
Zone I	35-45	15	.343	.657	.1881	12.58	8.58	37.44
	45-55	25	.387	.613	.1529	19.71	8.80	38.13
	55-65	35	.438	.562	.1250	27.71	9.22	39.16
	15-25	2	.247	.753	.1579	2.96	8.78	38.08
	25-35	5	.344	.656	.2787	7.15	6.98	33.66
Zone II	35-45	15	.302	.698	.0942	12.37	9.95	40.95
	45-55	25	.432	.568	.2461	19.44	7.40	34.69
	55-65	35	.526	.474	.3017	27.44	6.68	32.93
	15 -25	2	.228	.772	.1054	2.96	9.64	40.19
	25-35	5	.279	.721	.1268	7.19	9.36	39.50
Zone III	35-45	15	.311	.689	.1154	12.42	963	40.16
	45-55	25	.335	.665	.0401	19.51	10.49	42.27
	55-65	35	.385	.615	.0154	27.51	10.80	43.03
	15-25	2	.241	.759	.1416	2.45	9.04	38.72
	25-35	5	.256	.744	.0681	6.47	10.27	41.73
Towns	35-45	15	.309	.691	.1107	1149	9.70	40.34
	45-55	25	.351	.649	.0756	18.26	9.96	40.97
	55-65	35	.437	.563	.1229	26.26	9.25	39.23
	15-25	2	.231	.769	.1139	3.01	9.50	39.85
	25-35	5	.251	.749	.0549	7,22	10.48	42.25
Bangalore	35-45	15	.263	.737	—.0021	12.45	11.40	44.52
City	45-55	25	.311	.689	—.0148	19.55	11.30	44.27
	55-65	35	.372	.628	—. 0122	27.55	11.20	44.20

(1) x denotes the exact age to which a child would survive after birth.

(2) q_x and l_x are the usual life table functions and refer to both sexes combined.

(3) α is the level of mortality according to General Standard Life Tables (Brass *et al.* (1968)) assuming β—1 IN his logit relationship
$Y(x) - \alpha + \beta Ys$ (x).

(4) The method given in "A simple Approximation for the Time-location of Estimates of Child Mortality from Proportions Dead by Age of Mother" (unpublished) by Brass has bean ased.

(5) Derived from Coale and Demeny "West Model" Life-Tables (United Nations, 1X7 Manual IV) and refer to both sexes combined

Undertaken[4]

Although the level of mortality and the time o reference given in this table refer to males, in further work and discussion here it is assumed that the same levels and time reference will also apply to females, This assumption had to be made as separate data for widowhood for males were not available . As a result the study may be over-estimating the combined mortality.

Adult mortalty appears to have improved very much from 1941 onwards in Rural Areas and to have reached the same level as that of Benglore city by 1946. Levels in both areas continues to remain the same at least for the next couple of years as indicated by the Data in table 6, In towns mortality was higher than in Rural Areas in recent years.

Area	*Age (n)*	*Conditional Probability of surviving to age n of males* alive at age 20	*Level of mortality and time reference*	
			*level (*a)	*Time reference in Calendar years*
Rural Area	25	.96428	11.65	1948.8
	30	.92208	11.06	1946.5
	35	.85770	9.40	1944.1
	40	.75629	6.95	1941.7
	45	.69465	7.55	1939.7
Towns	25	.95528	9.28	1949.0
	30	.90862	9.36	1946.6
	35	.86083	9.65	1944.3
	40	.81101	10.00	1942.1
	45	.75074	10.08	1940.1
Bangalore City	25	.96322	11.35	1948.4
	30	.92525	11.49	1946.0
	35	.88422	11.62	1943.7
	40	.83491	11.49	1941.6
	45	.78625	11.85	1939.7

(a) The levels refer to Coale-Demeny's West Model Life-Tables (United Nations, 1967).

4. As the widowhood data were not available separately for each rural zone, adult mortality was estimated for the three rural zonss combined together. Besides as MPS had not given the requisite data for identifying women who had become widowed for the first time before reaching the age of 45 years among those who had remarried, they could not be included in the proportion widowed for the first time. This omission is negligible and is not expected to affect the estimates of mortality given in Table 6 significantly. However, it should also be pointed out that the ratio of widows to ever-married women used in the analysis included some 'separated' women as the MPS had provided data only for women 'widowed or separated' taken together. This inclusion will have a compensating effect and would reduce the bias in our estimates.

(iii) *Linking Childhood and Adult Mortality.* An attempt is now made to derive life tables by linking together the childhood and adult mortality and applying them to the age distribution of MPS in order to obtain estimates of of death rates. Of the several methods recommended for linking (United Nations, 1983) we have made use of the Coale-Demeny method as it is easier to apply and gives estimates similar to the logit system. The n^{m_x} values were obtained from the q_x's given by the linked life table using the formula $n^{m_x} = \left\{ -\frac{1}{n} \log_e (1 - nq_x) \right\}$ The crude death rates for the rural areas, 'towns' and Bangalore City were found to be 21.7, 19 8 and 18.5 respectively. The corresponding expectations of life at birth were 39 8, 40.5 and 42 5 years. Mortality conditions reflected by these figures refer to those prevailing some six years prior to the survey.

(c) *Estimation of Fertility and Mortality from l_x and C (5)*

The l_x values obtained by applying Brass's method using the number of children ever-born and the number of them surviving for women in the different age-groups can be clubbed with the values of $C(x)$—the cumulated proportion of persons under age x to get reasonably good estimates of fertility rather than of mortality. This method which is relatively more independent of the age pattern of mortality is considered superior to the one which uses r the population growth rate and $C(x)$ to estimate birth rates using the stable/ quasi-stable population model. The $[l_2, (C5)]$ method of estimating fertility which is equivalent to the 'reverse-survival' method for estimating the number of births during the five years preceding the survey will be applied here.[5] In addition to estimating fertility, mortality estimates using this method will also be obtained.

l_2 and $C(5)$ relate to conditions which prevailed some 4 to 5 years before observation From the MPS data it was estimated that in all the rural zones, 'towns' and Bangalore City, l_2 and the equivalent ${}_2q_0$ values were centred some 2 to 3 years before the Survey. The actual values are given in Table 5. The estimated e_0^0 values and the birth and death rates obtained by using the l_2 and $C(5)$ values and the "West" Model Life Tables (United Nations, 1967) are given in Table 7. The estimated birth rates are lower than those given by MPS corrected for omission in the recording of births (Table 1) in the three rural zones and 'towns' and higher in Bangalore City. The difference is relatively small in zone III and Bangalore City, a little more in 'towns', and somewhat higher in zones I and II. A possible increase in fertility in the rural zones

5. The $[l_2, C(5)]$ was preferred to $[l_5, C(15)]$ as MPS had recorded the ages of children in the 0-4 age group with great care.

TABLE 7—DEMOGRAPHIC PARAMETERS BASED ON l_3 AND C(5) VALUES

Area	l_2	C(5)	*Level(1)*	e^0_0	*Birth rate per 1,000*	*Death rate per 1,000*	*Death rate obtained by deducting r from the estimated birth rate (2)*
Zone I	.763	.153	9.23	39.18	39.90	22.84	27.4
Zone II	.753	.152	8.78	38 08	39.95	23.82	27.5
Zone III	.772	.148	9.64	40.19	38.03	22.06	20.7
Towns	.759	.139	9.04	38.72	36.07	23.36	—8.03
Bangalore City	.769	.139	9.50	39.85	35.85	22.47	—31.95

(1) According to Coale and Demeny West Model Life-Tablet given ia Annex I United Mations (1967), Manual **IV.**

(2) r is the inter-cenjal growth rate during 1941-51.

and a slight decline in fertility in Bangalore City in the two or three yeafs prior to MPS could be responsible. An explanation in the case of 'towns' is not so apparent.

As stated above an attempt was also made to obtain the death rates given by the *[1₂,* C(5)] procedure. The death rates given by this model are all much higher than those given by the MPS. The difference is most marked in zone I among the rural areas, less so in zone II and the least in zone III. In Bangalore City, MPS value in spite of the marked enhancement which was made in the estimate obtained from the Survey data is only 57 per cent of the estimate obtained by the *[l_2, C(5)]* procedure. In 'towns' also this procedure gave a value which was nearer to the maximum limit recorded in the MPS.[8] Even the adjustments for declining mortality did not change the estimates u'gnificantly.

This use of the [/₂, C(5)] method is not above criticism. As such, it has been recommended that the death rate should rather be estimated by subtracting from the birth rate the appropriate value of *r* which gives the annual rate of growth of population (United Nations, 1967; United Nations 1983). As often happens, r has to be estimated from the growth of the population between two censuses. The MPS has provided data of the annual rate of increase for zones I and II taken together, zone III, 'towns' and Bangalore City. Since these rates are affected by the net-migration whose magnitude is not known but recognised as being high in 'towns' and Bangalore City, the death rates obtained by taking into account the annual rate of increase of population is likely to be meaningful only in the case of rural areas. The death rates obtained for the five areas by making use of *r* are also presented in Table 7. Even in the rural areas it is only in the case of zone III that the estimate obtained by making use of *r* gives a death rate which is rather close to the one obtained by the [l_2 ,C(5)] procedure. In zones I and II, the death rates obtained by making use of *r* are even higher than those given by the [l_2,C(5)] method. The death rate estimates for 'towns' and Bangalore City are unrealistic but can be improved only by estimating the net migration rates and this in itself is not an easy problem

The main outcome of the above discussion is that the method of estimating mortality by linking childhood and adult mortality applied earlier is more promising than the use of *[l_x, C(x)]* procedure for estimating death rates. The estimates of birth and death rates given by the MPS and those obtained by using Brass techniques are summarised in Table 8.

6. The death rates obtained by using the mortality rates given by the estimated levels in the "West" Model Life Tables and the age-distribution of the population recorded in the MPS gave death rates which were **very** similar to those given in Table 7.

TABLE 8-BIRTH AND DEATH RATES ESTIMATED BY THE CROSS-CHECK METHOD AND BY BRASS TECNIQUES

Area	*Birth rate per 1000 population*			*Death rate per 1000 populaticn*			
	MPS		*[I_2 C(5)]*	*MPS*		*Childhood and adult mortality*	[I_2, C(5)]
	Observed	*Corrected by Cross-check method*		*Observed*	*Corrected by Cross-check method*		
	1950-51		*1946-51*	1950-57		*Centred at 1944*	*1946-1951*
Zone I	40.4	44.4	39.90	13.3	15.1		22.84
Zone II	41.6	44.7	39.95	15.7	18.9	21.7	23.82
Zone III	37.5	39.9	38.03	17.6	18.6		22.06
Towns	36.2	38.9-39.8	36.07	124	13.8-23.9	19.8	23.36
Bangalore City	30.0	33.0	35.85	8.1	13.7	18.5	22.47

Note. The estimates given by applying the Brass techniqe made use of the uncorreefed data of MPS. The estimates given by the linked life table refers to the average mortality conditions over a 12-year period centred at 1944.

5. Discussion

(i) *Pertinent Demographic Features of the Zone taken up for MPS*

To begin with, it will be useful to provide a background of the demographic setting in which the MPS was undertaken. The MPS covered about 61 per cent of the population of the then Mysore State whose geographical area remained substantially unchanged from the time of the fall of Tippu Sultan in 1799 till two years succeeding the Mysore Population Survey. Judged by the decennial census figures the population growth rate in the State has been accelerating since 1921. The population of the State increased by 9.7 per cent in 1921-31, by 11.8 per cent in 1931-41 and by 23.7 per cent between 1941-51. The Census Actuary estimated the net migration into the Mysore state during 1941-51 as 3.16 per cent of the mean population; he also estimated the average natural increase as 18 per 1000, birth rate of 37 death rate of 19 (Jain, 1955). These estimates give an average rate of population increase of 2.15 per cent per annum during 1941-51 for Mysore state compared with an annual population growth rate of 1.13 per cent for India as a whole.

The difference in the rate of population growth between Mysore and India is partly attributable to the difference in death rates. Mysore state had a better record of public health activities which began in the late 20's. Yet, there were areas in the state where the health conditions were relatively poor and these were reflected in the rates of population growth. The hill areas of Malnad comprising zones I and II of the MPS recorded a diminution in the size of its population from 1901 to 1931, a very slight increase of 0,8 per cent during 1931-41 and an increase of 13 percent during 1941-51. Since 1946 anti-malarial programmes using D.D.T. were started in Malnad and by the time of the MPS a very sharp fall in the incidence of malaria had taken place in that area. Zone I comprised villages taken up for intensive anti-malarial programme. In zone II anti-malarial programme was less intensive. In both zones I and II, as well as zone III, a large number of health units were started after 1947. The population of the towns included in the MPS increased by 54 per cent and of Bangalore City by 92 per cent during 1941-51. Such large increases were no doubt due to heavy net-migration to urban areas.

Two other demographic features may be mentioned. First, while the official family planning programme was pursued in Mysore as early as in 1930, the use of family planning methods other than abstinence was low at the time of MPS even in Bangalore City (United Nations, 1961). Second, age at marriage of females had shown a steady but only a small increase in the four decades prior to the MPS.

(ii) *The Application of P/F Method*

The use of P/F method did not allow for any adjustment in the current

fertility recorded by the MPS in the rural areas and Bangalore City as the P/F values for the age-group 15-25 were less than unity; in 'towns' this value was higher than unity. So, possibility of the use of a reference period longer than the one year prescribed by the MPS and changes in the levels of fertility in the different areas may be considered.

(a) The Reference Period. The MPS bad several probes to ensure that the births used for the calculation of the rates had occurred during the 12-month period following 15 September 1950. As Ganesh festival which was used as a bench-mark for the occurrence of births (and of deaths) fell on 15 September in 1950 and 5 September in 1951, the observance of the 12-month period specified in the MPS instructions for the study of birth (and of death) rates should have been relatively easy. In addition, the cross-check method used for judging the efficiency of the recording of births (and of deaths) in the rural areas was carried out in the villages in the presence of elders and there was considerable probing on the actual dates of birth reported in the MPS. It is very unlikely that the reference period used could differ from 12-monthsto the extent shown by the P/F values. This impression is further corroborated by the values of P/F in 'towns' where people could not be expected to respond very differently from those in rural areas; besides the survey work in 'towns' was undertaken after a lapse of about the same interval of time from the end of the 12-month period as in rural areas. The [l_2,C(5)] method also gave estimates of birth rates which were close to the uncorrected estimates provided by the MPS except in Bangalore City. This finding is reassuring that the reference period used for the recording of the vital events in the MPS proved quite satisfactory.

(b) Trends in Fertility. The difference in the set of P/F values in the different areas and their trend in the different age-groups within each area lend credence to the impression that the observed P/F values, which were mostly below unity, were due to change in fertility levels.

Before the advent of the family planning programme much, if not all, of the trends in fertility in Mysore state were related strangely enough to changes in mortality, such changes operating indirectly through the prevalence of the cultural taboo on the remarriage of widows. In the analysis of the difference between the average number of children born to ever-married women in the course of the entire reproductive life between those living in rural areas and Bangalore City, the MPS study found that completed fertility was higher in urban areas than in rural areas (Chandrasekaran, 1954). Women aged 45 years and over in Bangalore City had given birth to 5.3 children as compared to 4.8 children for women in rural areas The difference could be explained by earlier and more frequent widowhood in rural areas. The P/F values in

zones I, II and lit show that as a set the values were lowest in zone I, intermediate in zone II and highest in zone III, The likelihood of faster declines in mortality in zones I and II as compared to zone HI after 1945 brought out above fits in with the proposition that current fertility increased in zones I and II faster than in zone III. The absence of a marked lowering in death rates after 1946 in 'towns' noted above is also likely to explain the absence of any indication of an increase in current fertility brought about by a reduction in tho death rate. The P/F values show a lowering in current fertility rates in the higher age groups in Bangalore City which is in keeping with the beginning of family limitation by older couples in Bangalore City.

(c) Evaluative Roles of P/F and Cross-check Methods. The P/F values do not show the typical form of a decrease with increase in age; the value for the youngest age-group being greater than unity would have lent a firm basis for estimating underreporting of births. The possibility of an increase in fertility in zone I, II and III and a decrease in fertility in 'towns' and Bangalore City makes the interpretation of the picture revealed by the P/F values ambiguous. While the P/F method is unable to help in drawing any conclusion on the accuracy of the recording of births in all the three rural zones, some indication could be obtained in the case of 'towns' and Bangalore City subject to certain assumptions. If, for instance, it can be assumed that there had been no recent decline in fertility both in 'towns' and Bangalore City, the P/F method shows about a ten per cent omission in the recording of births in both these areas.

The cross-check method on the other hand, irrespective of the trend in fertility, clearly indicates nine to ten percent omission in rural zones, omission often per cent in 'towns' and of about nine per cent in Bangalore City. The point to be noted is that the cross-check method does not lead to any ambiguities as those faced in the application of P/F method.

(iii) *Estimates of Birth Rates*

The P/F method did not help in assessment of the accuracy of the MPS data on the occurrence of births, except possibly in 'towns'. For 'towns' both the P/F and 'cross-check' methods yielded the same degree of omission of about ten per cent.

The birth rate given by the [l_2, C(5)] method differ from those of the corrected MPS rates; yet they bear close comparison with the MPS rates, as the [l_2, C(5)] gives the mean birth rate over a five year period prior to the MPS. Comparing the [l_2, C(5)] estimates and the MPS corrected birth rates given in Table 8, the differences as noted earlier could be explained fairly convincingly in the case of the three rural zones and Bangalore City. In the case of 'towns' the difference cannot be explained so easily.

(iv) *Estimates of Death Rates*

Turning to estimates of mortality our discussion will relate to those obtained from the linked life tables. The death rates obtained by using this method were higher than the MPS corrected rates in all the areas—the rural areas, 'towns' and Bangalore City. It should, however, be remembered that the linked life tables refer to a period in the past centred roughly some six years prior to MPS i e around 1944 and would cover the mortality conditions which prevailed over a period of six years on either side of 1944. Using the death rates estimated by the linked life tables the average death rate during 1938-50 for the area surveyed by the MPS was 21 2 per 1000. This does not compare unfavourably with the average death rate of 19 per 1,000 for 1941-51 given by the Census Actuary for the entire state of who«e population the MPS covered 61 per cent.

The death rates obtained by the MPS cannot be checked directly against the ones provided by the linked life tables as they refer to different periods. However, in view of the rapid decline in mortality reported because of the public health measures undertaken after 1945, the MPS rates corrected by the cross-check method seem quite plausible especially for the rural areas. The weighted corrected death rate for the rural areas in 1950-51 as given by the MPS was 18 3 per 1000 while the rate given for 1938-50 centred at 1944 given by the linked life table was 21.7.

6. Concluding Remarks

This paper was primarily an attempt to assess the effectiveness of the cross-check method by comparing the estimates of birth and death rates obtained by MPS—which used this method to provide correction factors-with those obtained by using Brass techniques in the five areas selected for the MPS. Alto of interest was the additional information which could be elicited by using some of the Brass techniques by applying them to the MPS data.

Among the Brass techniques, the P/F method devised primarily to assess the accuracy of retrospective data on births could not provide any correction for the birth data recorded by MPS except in the case of 'towns' as the P/F values for the age-group 15-25 in the other areas were near to or much below unity. The correction factor provided by the P/F method for 'towns' was exactly the same as that given by the cross-check method. The likelihood of an increase in fertility in the rural areas and of a decrease in fertility in Bangalore City and possibly in 'towns' was shown by P/F method although, in general, it precluded any definite statement on the accuracy of the recording of births.

In respect of mortality, the Brass techniques gave indications of trends which seemed to fit well with those expected from a knowledge of public health

measures taken in Mysore state. But without making assumptions to extrapolate the estimates obtained by these techniques, they could not give mortality rates for very recent periods which the MPS could. It was further evident that when dealing with small areas within a state where population growth rates are affecteted by migration, the mortality estimates obtained by using indirect methods could be in error, especially as it is often difficult to estimate migration rates.

In contrast to the ambiguity of the findings of the P/F method and its failure to determine the extent of under-enunuration of births except in 'towns' on the one hand and the inability of the 'indirect method' to provide correction factors for death rates, the cross-check method used in the MPS gave adjusted birth rates, which along with the corrected death rates gave an extremely plausible natural increase rate for the areas surveyed as a whole.

On the whole, the procedures used in the MPS, which relied mainly on the cross-check method for adjustment of the recorded rates, appear to have done well in the Rural Areas both with respect of births and deaths. In the urban areas the MPS provided reasonably accurate birth rates but not of the death rates, particularly in Bangalore City. It is reasonable to expect that prospective surveys like the SRS (Sample Registration System) of India with proper cross-check methods might do quite well to provide estimates of current birth and death rates. However, such surveys have to be repeated periodically to provide levels as well as trends in fertility and mortality rates in the future.

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APPENDIX

The procedure used in this paper for calculating Brass's multipliers to adjust the synthetic cumulated fertility to compare with mean parity in the use of the P/F techniques is described below.

Brass's multipliers for adjusting *Fths* current cumulated fertility using the age specific fertility rates obtained from a survey to make it comparable to P the mean parity given by the survey are readily available when the following data are known (United Nations, 1967):

(1) the age specific fertility rates as obtained from the survey are given in five-year age groups 15-20, 20-25, . . . 45-50;

(2) the age-specific fertility rates based on births which occurred either during the oae-year preceding the survey and the age of the mother as recorded at the time of the survey are known or alternatively the age-specific fertility rates calculated using the time of birth and mother's age at that time as in the case of vital statistics registration data are given; and

(3) the average number of children ever born is available by the age of the mother at the time of survey.

In our case the births were recorded during a fixed one-year period for the entire survey, while the mother's age was recorded as at the time of survey. Further we were required to obtain *F* in ten-year age-groups although they were also available in five year age groups, as *P's* were available only in tea-year age-groups.

We made use of Brass's fertility polynominal

$$f(x) = c(x - s)\,(s + 33 - x)^3, \quad \text{where } s < x < s + 33 \qquad \text{(i)}$$

and s is the age at which child-bearing starts, x is the age of the woman and c is a scale factor d-terming the level of fertility. It is also to be recognised that the mean age at fertility m as given by the polynominal is $s + 13.2$. As such the value of s can obtained if m is known.

Putting $x / s - T$, equation (i) gives

$$f(T) = cT\,(33 - T)^2 \quad \text{for } 0 < T < 33 \qquad \text{(ii)}$$

Integrating f(T) once we get $F(T)$ and integrating $F(T)$ once again we get

$P(T)$ given by the equations (iii) and (iv) respectively :

$$F(T) = c\left[\frac{T^4}{4} - 22T^3 + \frac{1089}{2}T^2\right] \quad \text{(iii)}$$

$$P(T) = c\left[\frac{T^5}{20} - \frac{11}{2}T^4 + \frac{1089}{6}T^3\right] \quad \text{(iv)}$$

F(T) gives the total number of children born to a woman upto age *T,* while the difference of *P(T)* taken over an interval and divided by the length of the interval gives the mean parity for that interval.

We have followed the recommendation of Brass that the value of $\bar{m}$ the mean age at fertility required for the assessment of multipliers for younger age groups should be based on the values of f_1/f_2 where f_1 and f_2 are the fertility rates of the 15-19 and 20-24 age groups and have estimated *m* as applicable to the 15-25 age group on the basis of f_1/f_2 for the other two age groups 25-35 and 35-45 the value of *m* used was based on the age-specific fertility rates given by the Mysore Study for the area concerned.

The displacement *d*—the interval between the date of survey and the time at which birth occurred—was taken as the interval between the mid point of the period over which the survey extended and the mid-point of the 12-month interval during which the births which occurred were to be recorded. The value of *s* obtained by deducting 13.2 from the mean age at fertility as obtained directly from the Mysore Survey had to be reduced by *d* the displacement, in order to get the true value *of s. As* such since 26.61 was the mean age at fertility as obtained directly from the Survey (birth in the fixed 12-month period and the age of the mother as at the time of survey were used to obtain the specific fertility rates) for Zone III and *d* the displacement for the zone was 1.0 year, the starting point of the fertility curve for this zone is 26.61 — 13.2 — 1.0 = 12.41 years. For the age range 25 to 35 for instance, the range of *T* for ta« calculation of *P(T)* will vary from 12.59 to 22.59. As the age of the mother at the birth of the child is affected by displacement, the corresponding range of *T* for the calculation of *F(T)* will vary from 11.59 to 21.59. The multiplier k(25, 35) in this case will be given by

$$k(25, 35) = \frac{\frac{P(22.59) - P(12.59)}{10} - F(11.59)}{\frac{F(21.59) - F(11.59)}{10}} \quad \text{(v)}$$

In general, if—

s is the age at which child-bearing started (obtained by using $\bar{m}$ as given directly by the survey)

d ig the displacement
a is the lower end of the age group and *b* the upper end of the age group for adjusting whose age-specific fertility rate the multiplier is required,

the value of the multiplier *k(a, b)* is gives by the formula

$$k(a, b) = \frac{\frac{P(b - s + d) - P(a - s + d)}{b - a} - F(a - s)}{\frac{F(b - s) - F(a - s)}{b - a}} \qquad \text{(vi)}$$

It is usual to assume $F(a - s)$ to be zero for all values of $(a - s) \leq 15$. In other words, it is usual to assume cumulative fertility at age 15 as zero and to include fertility under 15 in the age-group 15 19 years,

As an illustration, the procedure followed in the case of Zone III is given below :

BASE DATA : $(f_1/f_2) = .788$; m = 26.61; DISPLACEMENT ONE YEAR

Particulars	*Age-group*		
	15-24	*25-34*	*35-44*
m	25.063	25.61	25.61
(after allowing for displacement) *s*	11.863	12.41	12.41
Range of *T* for calculating *F*	2.137-12.137	11.59-21.59	21.59-31.59
Range of *T* for calculating *P*	3.137-13.137	12 59-22.59	22.59-32 59
Area Below *T* for calculation of *P*	2277.1175 to 46300.387 (F_1)	43401.681 to 86724.077 (F_2)	86724.077 to 98796.903 (F_3)
Area below T for calculation of *P*	5085.56 to 267246.66 (P_1)	239834.06 to 954165.64 (P_2)	954165.64 to 1916250.8 (P_3)
Multiplying factor	$\frac{\frac{P_1}{10} - 0}{\frac{46300.387 - 0}{10}} = 5.6622$	$\frac{\frac{P_2}{10} - 43401.681}{\frac{F_2}{10}} = 6.4704$	$\frac{\frac{P_3}{10} - 86724\,077}{\frac{F_3}{10}} = 7.8560$