SAMPLING ERRORS IN THE ESTIMATION OF FERTILITY RATES

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SUMMARY. In this paper, variability of some of the fertility indicators and of their changes over a short period of time have been studied. Model sampling of data collected through a complete enumeration of all couples in a selected area reveals that pregnancy indicators as well as their changes have a larger variability than in the case of live-birth rates. It seems that ascertainment of pregnancies, in spite of close investigations with repeated visits, is subject to a large error.

1. INTRODUCTION

The present study is an attempt to determine the magnitude of sampling errors in estimated fertility rates, and hence to appraise the sensitivity of different indicators in so far as they can detect small changes in them. Since, such changes would necessarily be small, the sampling errors of their estimates should have to be smaller still to acquire a statistical significance. On the other hand, the estimated rates themselves and specially the changes in them are likely to be subject to large sampling errors. It will be useful therefore if some idea about the reliance of the estimates based on a sample survey can be obtained from the available material.

2. NATURE OF THE MATERIAL AT DISPOSAL

The data available for this study relates to a Family Planning Action Research Project which was taken up by the Indian Statistical Institute in February 1963 in the City of Calcutta. Two centres in the shape of compact blocks, roughly half a square mile in area each and consisting of nearly 3000 households were completely enumerated and all married couples within an active age (couples with wives' age 15-45 years) with the husband and wife living together were listed. A total of 3002 coulpes were thus listed from the two centres, who were interviewed in an initial base-line survey and schedules were filled in for each. They were then revisited after an interval of twelve months.

Intermediate visits. In the initial survey the couples were individually contacted and as far as possible both husband and wife were interviewed. In specially difficult cases, women investigators were employed to interview the wife where the male investigators failed to obtain cooperation. Among various other items of information a couple was asked to recall the date of their last child-birth and the same for the previous one. Thus, even in the initial survey, data was collected from which birth-rate during 12 months prior to the date of visit could be computed. Before a revisit which was taken up at the end of one year, each couple was contacted during the mid-year also, so as to keep them under constant observation during the whole term of twelve months. With the incidences of child-birth during these twelve months of close observation, it was thus possible to obtain a second set of birth-rates and other like indicators of fertility were available for two successive years.

Casualties and effective material for tabulation. The following table gives the original number of couples initially surveyed and accepted for tabulation, the number of couples who had not yet completed one year of married life at the time of initial survey, couples who had left the area during the 12 months between the two surveys and the effective number of couples available for the initial and resurvey tabulations.

TABLE 1. NUMBER OF COUPLES SURVEYED AND TABULATED

centre	initial survey schedules			resurvey schedules	
	total surveyed	number with married life < 1 year	number tabulated (2)−(3)	number left during the year	number tabulated (2)−(5)
(1)	(2)	(3)	(4)	(5)	(6)
1	1501	58	1443	143	1358
2	1501	75	1426	119	1382
total	3002	133	2869	262	2740

It will be seen that a considerable proportion of couples, nearly 8.7% had left, i.e., changed their residence, died or were invalidated. It was not practically possible to follow them up at their new addresses and collect the data. On the other hand, new couples who had taken up their residence in this area within this period of one year, have also been left out, owing to obvious difficulties. The number of couples who had left were automatically missing in resurvey sample, while women, who had not completed one year of married life, although excluded from the initial sample, were included in the resurvey sample. Thus, the fertility rates were based on couples qualifying for admission and staying there throughout the entire period of observation, and who thus do not strictly represent the total population resident in that area at the respective points of time. As a result of these transfers, the age-composition of the resurvey sample may or may not have seriously differed from that of the original sample with which we started during the base-line survey.

Basic data. The basic data relating to the two visits, initial and resurvey are given below.

TABLE 2. BASIC DATA COLLECTED IN THE TWO SURVEYS

centre	surveys	active couples	number of		
			live-births	pregnancies	susceptible woman-months
(1)	(2)	(3)	(4)	(5)	(6)
1	initial	1443	232	175	14935
	resurvey	1358	189	156	13118
2	initial	1426	226	181	14740
	resurvey	1382	170	140	13826

The data refers to the respective 12-month periods preceding the initial survey and resurvey, and was collected by personal interviews at six-month intervals. The information sought for was (i) incidence of last termination of pregnancy, if any, along with the dates of its termination and re-start of menstruation (ii) whether now pregnant or not, and (a) if pregnant, the number of months of pregnancy and (b) if not pregnant, the date of last menstruation.

The pregnancies are likely to be under-reported specially at its early stages as it is difficult to confirm a pregnancy even if menstruation has discontinued for six weeks or more. But this could be verified and determined fairly accurately as the survey was repeated every six months. The state of pregnancy was thus determined on the informant's own report and verified at subsequent visits, without any attempt for medical examination.

The susceptible woman-months given in Table 2, were calculated as the total exposure period over all the women in the sample intercepted within the accounting year under review. If a woman was currently menstruating she was considered to be susceptible to pregnancy. When a woman was pregnant during the period under reference, the woman-months contributed by her were excluded. Also if a woman had a termination of pregnancy, ending either in live-birth, still birth or abortion, the non-susceptible period was reckoned to continue up to the re-starting of menstruation and the relevant months included within the accounting year were counted as non-susceptible months.

Characters chosen as fertility indicators. It was intended to try out a number of indicators which measure the marital fertility rates directly or indirectly. The four characters selected for this purpose are :

(i) gross pregnancies per (000) of couples;

(ii) pregnancies per (00) of "exposure" years ;

(iii) live-births per (000) of couples ;

(iv) "engaged"-months, i.e., non-susceptible months per (00) of woman-months.

The first of these characters, namely, pregnancies per (000) couples is a simple and gross rate of the number of total pregnancies (ending in live-birth or not) per (000) of active couples. The second one refers to the number of pregnancies originating within an one-year period per hundred of "exposure"-years, i.e., the number of total woman-months less those covered by pregnancies (inclusive of the post-natal gap) and divided by 1200. This does not of course take any account of temporary separations from the male cohort or temporary menostops.

The computation of "live-birth pregnancy rates" (Chandrasekaran and Freymann, 1964) i.e., number of conceptions occurring within the year and terminating in live-births per hundred years of exposure calls for a follow-up of the survey for another ten months and was not therefore attempted. In a sense, it is a reduction in the gross number of conceptions irrespective of their ultimate outcome which is the real measure of any family control programme. The ratio of live births per gross conception would depend on the standard of pre-natal care and medical facilities. If pregnant women do not get adequate care and there is a consequent fall in live-births per conception, that would not reflect the merits of a particular F. P. programme.

The third refers to the number of live-births per (000) of active couples and the fourth character gives the percentage of "engaged" i.e., non-susceptible woman-months to the total of all woman-months.

3. Results

Mean rates. Estimated mean values for each of the four characters taken up for this study were computed for each centre separately for the initial survey and resurvey, and is shown below in Table 3.

It will be seen that there is a fall in all of them at the time of resurvey except in the fourth compared to the initial survey estimates, and the changes are usually in the same direction in both the centres, as will be seen from cols. (5) of Table 3. It is also evident that the so-called control Centre-2 has, if any, shown a greater decline in live-birth rates. For our

TABLE 3. FERTILITY RATES AS OBSERVED DURING THE TWO SURVEYS BY CENTRES

characters	centre	initial survey	resurvey	difference, (resurvey − initial)
(1)	(2)	(3)	(4)	(5)
(i) pregnancies per (000) of couples	1	120.9	114.0	− 6.0
	2	126.8	101.5	−25.3
	comb.	124.0	108.2	−15.8
(ii) pregnancies per (00) of exposure-years	1	14.04	14.29	0.25
	2	14.85	12.35	− 2.50
	comb.	14.42	13.75	− 0.67
(iii) live-birth per (000) of couples	1	160.8	139.2	−21.6
	2	158.5	122.9	−35.6
	comb.	159.7	131.0	−28.7
(iv) 'engaged'-months per (00) of woman-month	1	13.7	19.5	5.8
	2	13.8	16.6	2.8
	comb.	13.8	18.1	4.3

present studies, the two centres have been combined and treated as constituting a single population. The question is now to ascertain the errors of these estimates and to test how far these differences, i.e., changes in the above four indicators of fertility are statistically significant.

Errors of estimation. It may be remembered that the data has been collected from all couples resident in the area exhaustively, and not on a random sampling basis. It is not therefore possible directly, to work out the sampling errors on which we can judge the precision of the estimated rates or if changes in these rates from one year and another have a statistical significance.

Model sampling. We may however take recourse to a procedure of model sampling by splitting up the total population artificially into a number of small samples. For this purpose, all couples having its serial number ending in 0, 1, 2, ... or 9 were separated and grouped together to constitute ten systematic samples. Ten independent estimates for each of the above four characters could then be worked out from these ten sub-samples. It should be noted here that these variabilities refer to sub-sample units comprised of a given number of couples each. The number of couples in the different sub-sample units sometimes vary a little, but this has been ignored and these units are considered to have a more or less uniform size for all practical purposes.

The distribution of couples by these ten sub-samples have been given in Table 4 below.

TATLE 4. NUMBER OF COUPLES CONSTITUTING THE ARTIFICIAL SUB-SAMPLES RELATING TO (a) ONE YEAR PREVIOUS TO THE INITIAL VISIT (b) ONE YEAR PRECEDING RESURVEY

sub-sample	total couples analysed		number left during the year after initial survey[1]	number with married life < 1 year at the time of initial survey[2]	common couples = (2)–(4) = (3)–(5)
	initial	resurvey			
(1)	(2)	(3)	(4)	(5)	(6)
0	288	265	32	9	256
1	292	287	17	12	275
2	284	270	29	15	255
3	283	284	16	17	267
4	281	276	22	17	259
5	286	276	22	12	264
6	283	269	26	12	257
7	290	272	29	5	267
8	287	272	25	10	262
9	289	269	28	8	261
total	2869	2740	246	117	2623

[1] excluding 16 who had not completed one year of married life, initially.
[2] excluding 16 who had left in the meantime.

From these sets of replicated estimates, standard errors for the overall mean have been worked out. Table 5 below gives the mean, coefficients of variation and the percentage errors of the overall mean for all these characters separately for the initial year and for the resurvey year. The variabilities of all these characters although quite high are found to be consistent between both the years.

TABLE 5. VARIABILITY OF THE DIFFERENT CHARACTERS INDICATING BIRTH RATES, AS IN THE TWO SURVEYS WITH A GAP OF ONE YEAR BETWEEN THEM, IN TWO SELECTED CENTRES OF CALCUTTA, BASED ON ARTIFICIAL SUB-SAMPLES (280.9 COUPLES IN THE INITIAL AND 274.0 COUPLES IN RESURVEY PER SUBSAMPLE)

characters	survey	mean	coefficeint of variation	percentage variability	size of sample (couples) required to give 5% error
(1)	(2)	(3)	(4)	(5)	(6)
(i) pregnancies per (000) of couples	initial	124.0	19.0	6.00	4143
	resurvey	108.2	22.7	7.18	5548
(ii) pregnancies per (00) of susceptible years	initial	14.4	21.2	6.70	5061
	resurvey	13.8	24.6	7.78	6579
(iii) live-births per (000) of couples	initial	159.7	17.6	5.56	3515
	resurvey	131.0	11.8	3.75	1578
(iv) 'engaged' month per (00) of women-months	initial	13.8	17.6	5.56	3515
	resurvey	18.1	13.0	4.11	1863

The coefficients of variation for the first two characters lie between 19.0% to 24.6% and between 11.8% to 17.6% for the latter. These coefficients, it should be remembered, refer to the sub-sample units comprised of about 287 couples in the initial and of 274 couples in the resurvey.

The variability for the two characters (i) and (iii) can also be worked out on purely binomial assumptions. These were obtained as $100\sqrt{\frac{8760}{1240\times286.9}} = 15.5\%$ and $100\sqrt{\frac{8403}{1597\times286.9}} = 13.5\%$ in the initial sample. These are quite close to the observed variations given in col. (4).

It is obvious that a larger sample size is called for to estimate them with a reasonably small margin of sampling error. Col. (6) in Table 5 gives the approximate size of unistage sample in terms of the number of ultimate units, namely 'couples', which would give an error of 5% to these characters, based on the coefficients of variation as observed in the respective surveys. The variabilities are however expected to be higher when an extensive area is to be sampled. The size of sample would thus have to be somewhat larger than indicated here.

Measurement of the changes in the fertility rates. In measuring the changes in the fertility rates that have occurred during this period of one year, it has to be kept in mind that an exact correspondence between the couples in the initial survey material and resurvey, does not exist, although most of the couples are common. While in the initial survey, couples who had not yet completed one year of married life were excluded, the same were accepted during the resurvey tabulations. On the other hand, quite a large number of couples had left the area and were automatically excluded in the resurvey. Table 4 discussed earlier has given the distribution of couples in each category for individual sub-samples while the number of couples common to both is shown in col. (6) of the same table.

Mean differences. In computing the mean differences, i.e., changes in the different rates, this 'common' material has been utilised so as to be able to work out the standard errors of the differences in individual sub-samples between the two surveys and make them amenable to tests of significance by Student's t. The results have been given in Table 6. Variabilities in the different characters based on the common couples are found to be of the same order as on the full data given in Table 5 earlier. The variabilities in the differences of all the rates are higher as might have been expected. The percentage errors of the overall mean differences work out to be 44.3% for pregnancies per (000) couples, 62.8% for pregnancy per (00) of exposure-years and 19.1% for live-births per (000) couples. The differences in the third character, namely, that of live-births per (000) couples has come out as statistically significant. The unusually high variability in pregnancies per (000) couples have perhaps been caused by the incidence of larger errors in reporting pregnancies than live-births. The size of unistage sample in terms of ultimate couples expected to give a margin of error of 10% for estimating the mean differences have been given in col. (6) of Table 6.

It appears that live-births per (000) couples has the lowest variability both in respect of its absolute mean value as also in its difference. It is of course true that this mean difference refers to a population as at two different points of time, the effect of a shifting of the ages by one year i.e., an ageing by one year of all individuals thus being ignored. Two different samples, chosen independently in the two years, would furnish

TABLE 6. SAMPLING ERROR OF THE ESTIMATED CHANGES IN THE INDICES MEASURING BIRTH-RATES, AS OBSERVED BETWEEN TWO SURVEYS CONDUCTED ONE YEAR APART BASED ON ARTIFICIAL SUBSAMPLES OF COUPLES COMMON TO BOTH (262.3 COUPLES PER SUBSAMPLE)

characters	surveys	mean ± s.e.	coefficients of variation	percentage variability	size of sample (couples) for estimating mean difference with 10% error
(1)	(2)	(3)	(4)	(5)	(6)
(i) pregnancies per (000) couples	initial	120.0±7.1	18.8	5.03	—
	resurvey	99.9±8.4	26.6	8.40	—
	difference	−20.1±8.90	140	44.3	51411
(ii) pregnancies per (00) susceptible-years	initial	13.0±0.03	21.2	6.70	—
	resurvey	12.1±1.12	29.3	9.27	—
	difference	−1.80±1.13	199	62.8	103873
(iii) live-births per (000) couples	initial	158.0±9.1	18.3	5.78	—
	resurvey	121.2±4.7	12.3	3.89	—
	difference	−36.8±7.02	61	19.1	9760
(iv) 'engaged' months per (00) woman-month	initial	13.3±0.80	19.0	6.02	—
	resurvey	16.9±0.86	16.1	5.09	—
	difference	+3.61	—	—	—

us with a comparison not between identical couples, but between two different populations representing all the age-groups in their due proportions. On those conditions, a Fisher's t would have been appropriate for measuring the changes.

An attempt to follow up the identical couples for a sample of considerable size, for any length of time would obviously be a difficult one and even if it could be done, would not represent the population at large at any point of time. A more practical approach seems to be in sampling independently over a large area, so as to minimise inter-regional transfers and collect information, as in a census, from couples resident at different points of time.

It will be seen that not only the live-birth rates, but the pregnancy rates also have fallen during this one year interval. On the other hand, percentage of 'engaged' i.e., 'non-susceptible' months has shown some increase, and conversely susceptible months per woman-month has somewhat gone down. This anomaly seems to have resulted from a faulty accounting of 'engaged-month' in respect of the 12 months preceding the initial survey because of the general tendency to supress non-live-births, specially the premature ones, which unlike resurveys could not be verified. Moreover the dates of re-start of menstruation after termination of pregnancies could not often be furnished by informants at the initial survey but could be kept under observation in the resurveys. This naturally would tend to lower down the computed 'engaged-month' (and consequently raise the total of susceptible

months) for the initial period, while in the resurvey period ascertainment of 'engaged months' was more complete and accurate. Thus 'engaged-month' underestimated in the initial period may appear to have gone up relative to that in resurvey when it was no more underestimated. For this reason the error of difference has not been calculated in case of 'engaged-months'.

A lowering of pregnancy rates is expected to increase the susceptible period, and thus to have an effective reduction in the number of total pregnancies, pregnancies per susceptible woman-year should have to be disproportionally reduced, such that the product of an enhanced susceptible period with the reduced pregnancy rate per unit of susceptible period, might show a decline.

4. Estimation of total births in a given population, either directly or indirectly through other concommittant characters

It is believed that pregnancies are usually under-reported, specially at their early stages or in those terminating in abortions. The calculation of susceptible-months is consequently subject to considerable inaccuracies. The number of pregnancies per (00) susceptible-years or the number of 'engaged'-months per (00) woman-months are thus more or less 'laboratory' rates which can be correctly ascertained only under ideal circumstances. Even though they may be more sensitive in measuring changes, they are hardly suitable as concommittant characters for indirectly measuring the absolute rates of births.

If our object is to estimate number of births in a given population during a particular time-interval, the direct procedure would be in counting up the total incidence of live-births (or for that matter all births, a technological ratio of live-births to all births being determined in a separate enquiry) in the sample under observation within the given period of time. In large scale surveys, where deep probing is impossible and where everything will have to be ascertained in one or two ad-hoc interviews, it is the number of births which is likely to possess some degree of reliance.

Again, an efficient estimation of birth-rates (all or 'live' alone) per active couple calls for a sampling frame of all couples for the entire coverage, unless we introduce another stage of sampling, say households, which will mean some loss of efficiency. The birth rates may therefore be made to refer to 'individuals', i.e., gross population, rather than to couples as the ultimate units.

Reference

Chandrasekaran, C. and Freymann, M. W. (1964) : Evaluation of family planning programmes (mimeographed). Presented at the Family Planning Communications Research Seminar.

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