

Sensitivity Analysis of Birth Intervals through Computer Simulation

IN this article an attempt is made to investigate the relative sensitivity of birth intervals, the closed as well as the open intervals as indices of fertility. The multivariate analysis of variance technique (MANOVA) has been employed to the simulated data on birth intervals by taking four biological components, viz., fecundability, post-partum amenorrhea, incidence of fetal wastage and age at marriage, which are considered to be the most important determinants of fertility. The impact of these factors on birth intervals has also been examined. Another index of fertility designated as I , obtained as a linear combination of the closed and open intervals with minimum variance, has been introduced and its potential advantages over the other two analysed. The investigation showed that open interval is able to reflect changes relatively sharply for even smaller changes in fecundability. However, open interval is unable to record sensitively changes in the level of either post-partum amenorrhea or fetal wastages. On the other hand, closed interval demonstrates a relatively much closer association with both these factors. Index I appears to be better for reflecting changes in fertility caused by changes in all the influencing factors put together. It is interesting but not surprising to find that the conventional analysis of variance technique (ANOVA) also yield similar results.

I

The feasibility of utilising birth intervals, closed and open, as indices of fertility has been under discussion during the last few years. The techniques used in the investigation of the problem have included analysis of empirical data (Henry, 1958 and Srinivasan, 1967), analytical methods through deterministic and stochastic models (Dandekar, 1959; Pathak, 1970; Potter, 1963; Sheps and Perrin, 1964 and Srinivasan, 1966a) and computer simulation (Venkatacharya, 1969). The specific problem of assessing the relative sensitivity of the open and closed intervals as indices of fertility has also been investigated to some extent (Srinivasan, 1970).

The problem of studying the sensitivity of the fertility index appears to have two dimensions. The first, one is concerned with the tautological problem of defining the term sensitivity as applied to fertility measures; the second one relates to the identification of factors influencing fertility measures and the relative effect of each of the factors on the measures. The problem of defining sensitivity seems to have received very little attention in the literature. However, two approaches to the definition of sensitivity have been implicitly suggested in earlier works. If one presupposes that the ultimate measure of current fertility among married women is the fecundability, that is, the probability of a married woman in the susceptible status conceiving in a month, any fertility measure which approximates more closely to fecundability can be considered to be more sensitive. Since fecundability is a probabilistic concept and cannot be measured exactly, sensitivity of an index can be estimated only through analytical models or computer simulation. The problem in defining sensitivity in this manner is that a fertility measure that is sensitive according to this definition need not necessarily reflect changes in the conventional marital fertility measures of the population such as general marital fertility rate or age specific marital fertility rate. The fertility rate of married women is influenced not only by the fecundability but also by the proportion of women in the susceptible status, which, in turn, is influenced by a host of factors, social and biological. Important among these factors are age distribution of population, age at marriage, length of post-partum amenorrhea and the incidence of fetal wastage.

The second concept of sensitivity which takes into account these factors attempts to study through analysis of empirical data the correlation between the conventional measure such as general or age specific marital fertility rate and the index under consideration. The higher the correlation coefficient, the more sensitive is the index under consideration. Srinivasan (1970) has used this concept in the study of relative sensitivity of closed and open intervals and has come to the conclusion that open interval is more sensitive than closed interval. On the basis of correlation analysis of average age of women at a given parity and open and closed intervals, he has argued that open interval is a better index of fertility because of its higher correlation coefficient with the average number of children ever born for a given marital duration. He has concluded that addition of the closed interval (by forming linear combination of the two) does not improve the index.

The objective of the present study is to investigate through computer simulation the sensitivity of the closed interval, open interval and a linear combination of the two as a measure of fertility. The sensitivity concept used in the analysis is the first one, namely, the effect of changes in the measure caused by a specific change in the level of fertility. In order to study the extent of influence of other social and biological factors, commonly being termed as fertility determinants, different levels of the distribution of age at marriage, post-partum amenorrhea and incidence of fetal wastage have been assumed.

II

The model utilised in the present study has been a micro simulation model which reproduces fertility histories of different cohorts of married women starting from their age at marriage to the current age. This is accomplished through the use of following input parameters:

- (a) distribution of age at marriage of currently married women;

- (b) age distribution of a group of currently married women;
- (c) distribution of women by their ages at onset of menstruation;
- (d) distribution of women by their ages on the occurrence of secondary sterility;
- (e) monthly chance of conception (fecundability) of women by age;
- (f) proportion of conceptions terminating in live birth, still birth and abortion;
- (g) period of gestation preceding a particular type of termination;
- (h) post-partum amenorrhea period following a particular type of termination; and
- (i) probability of primary sterility.

Once the values of these parameters, which characterize a particular population in terms of its fertility level, are specified, the model generates fertility histories of women and enables one to obtain samples of average closed and open intervals for a group of currently married women from the population. The unit of simulation for the model has been kept as one month.

A statistical analysis, like the one indicated by Venkatacharya *et al* (1972) and Kirk (1969), revealed that a size of 200 currently married women for obtaining samples of the average closed and open intervals would be sufficient for the present analysis, if the experiment has approximately 12 replicates. The following four factors at different levels have been considered to assess the relative changes in birth intervals as indices of fertility for a specific change in the factors.

- (1) Fecundability (F),
- (2) Post-partum amenorrhea following a live birth (P),
- (3) Proportion of conceptions ending in live birth (W), and
- (4) The distribution of married women by their age at marriage (A).

The levels of other input parameters, apart from the above four, were kept constant throughout the experiment. The levels for each of the three factors F, P and W have been considered and samples of the two intervals were generated in 12 replicates corresponding to each possible combinations of these factors. Thus we have eight distinct treatment (factor) combinations (T_i $i=1,2, \dots, 8$) of a 2^3 factorial experiment. The level of the fourth factor (A) was held constant for all these combinations. Another set of observations on the two intervals (in 12 replicates) were obtained by forming a separate treatment combination (T_9) incorporating a different level of the factor A. Table 1 describes the different treatment combinations.

Table 1—Treatment combinations formed by different combinations of the four factors

Treatment combinations	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Levels of different factors	$F_0P_0W_0$	$F_1P_0W_0$	$F_1P_1W_1$	$F_0P_1W_1$	$F_0P_0W_1$	$F_1P_1W_0$	$F_0P_1W_0$	$F_1P_0W_1$	$F_1P_0W_0A$

The suffixes 0 and 1 indicate the lower and higher levels of the corresponding factors. The distribution used at different levels of these factors as well as for other input parameters have been presented in Appendix I. The two levels for the factor F have been so taken as to yield a model fecundability value of 0.05 and 0.10 respectively. A set of 108 observations on each of average closed and open intervals, obtained under nine different treatment combinations with 12 replicates each, have been shown in Appendix II.

III

In order to achieve the objective set fourth in the investigation of the problem, a multivariate analysis of variance was thought of as a plausible line of approach in assessing the relative sensitivity of birth intervals for a specific change in the factor under consideration. This analysis enables one to have a better comparison of the relative ability of the two responses in reflecting a change in a given treatment combination. This is obtained by calculating the simultaneous confidence intervals for the two responses for various treatment differences.

Let X_{ijk} ($i=1, 2, \dots, N_j; j=1, 2, \dots, k$ and $l=1, 2, \dots, p$) denotes the i th observation of the l th response corresponding to j th treatment combination. Then we proceed first to test the hypothesis of equal treatment effects on the basis of the two responses. This amounts to testing whether a change in the level of fertility of the population, obtained by the different treatment combinations, is indicated by either closed interval or open interval or both. To facilitate the test two matrices H and E are to be obtained (Morrison, 1967) whose (rs) th elements are given by

$$h_{rs} = \sum_{j=1}^k \frac{1}{N_j} T_{jr} \quad T_{js} - \frac{1}{N} G_r G_s$$

$$e_{rs} = \sum_{j=1}^k \sum_{i=1}^{N_j} x_{ijr} x_{ijs} - \sum_{j=1}^k \frac{1}{N_j} T_{jr} T_{js}$$

where $T_{jr} = \sum_{i=1}^{N_j} x_{ijr}$; $G_r = \sum_{j=1}^k T_{jr}$ and $N = \sum_{j=1}^k N_j$

The greatest root C_s of the matrix HE^{-1} provides the required test criterion and the quantity

$$Q_s = \frac{C_s}{1 + C_s}$$

is referred to the appropriate Heck percentage point

chart (Heck, 1960) to test the above hypothesis. The different parameters for fixing the level of significance from the Hecks chart are :

$$s = \text{minimum of } (k-1, p); \quad m = \frac{|k-p-1|-1}{2}; \quad n = \frac{N-k-p-1}{5}$$

If the test led to the rejection of the hypothesis then simultaneous confidence intervals for the two responses under various treatment differences could be obtained to see which treatment differences and responses have contributed to this rejection. If the means of the responses under treatment j are denoted

$$[\bar{x}_{j1}, \bar{x}_{j2}, \dots, \bar{x}_{jp}], \text{ the } 100(1-\alpha) \text{ per cent simultaneous confidence}$$

intervals for all non-null linear compounds of the difference of the j 'th and $(j+1)$ th treatment effect vectors are given by

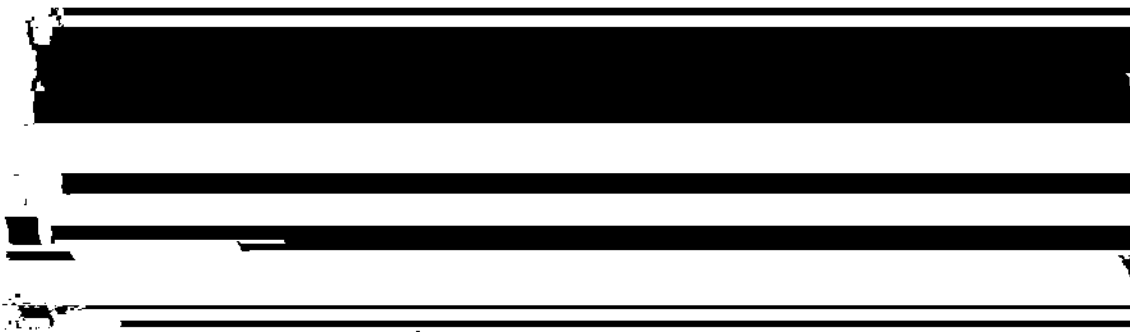
$$\sum_{h=1}^p a_h (\bar{x}_{jh} - \bar{x}_{j+1, h}) - \sqrt{\frac{x\alpha}{1-x\alpha}} a E a \left(\frac{1}{N_j} + \frac{1}{N_{j+1}} \right)$$

$$\leq a_h (T_{jh} - T_{j+1, h}) \leq \sum_{h=1}^p a_h (\bar{x}_{jh} - \bar{x}_{j+1, h}) + \sqrt{\frac{x\alpha}{1-x\alpha}} a E a \left(\frac{1}{N_j} + \frac{1}{N_{j+1}} \right)$$

$\alpha = (1, 1, \dots, p \text{ times})$. The parameters of the critical value $X = xy$; s, m, n are s, m and n as defined earlier (Morrison, 1967). If the confidence intervals contain zero, we say that the particular linear compound of the response effects is not significantly different for j th and $(j+1)$ th treatments. Greater the value of the lower confidence limit for a particular response under a specific treatment difference, more significant it will be to show the difference.

In order to substantiate some of the findings of the above multivariate analysis, the two responses have been analysed independently through conventional ANOVA technique. This was however, done by including the first eight treatment combinations T_{-1} to T_8 and considering the experiment as a 2^3 factorial experiment. Results discussed in the subsequent sections, revealed that it was not possible to grade any of the two indices as a more sensitive index of fertility over the other. This is an important finding because open interval, though highly sensitive in discerning a change in fecundability, remains almost unchanged even if the fertility of the population changes due to a change in the level of either the factor P or W or both.

An attempt was, therefore, made to construct another index, denoted by I as a linear combination of the two intervals. It is a well established fact that the open interval has a much larger variance than the closed interval. This reduces the potential advantages of open interval to some extent, because larger the variance of an index, more will be the sample size required for its study. The index I has, therefore, been developed with a view to minimize its variance.



IV

An attempt is made first to test the hypothesis of equal treatment differences for the two responses through the MANOVA technique. The statistic required for the test with the parameters for its distribution are indicated in the following table.

Table 2

Value of the test statistic, its parameters and the upper 100 percentage point from Heck chart

Test statistic ϕ_c	s	m	n	$X_{.05; s, m, n}$
.981	2	2.5	48	.180

The test leads to the rejection of the hypothesis and thus helps to conclude that the difference in these treatment combinations makes significant impact on the two intervals in general. This, in other words, supports the general opinion that both the intervals, closed and open, are qualified to be considered as fertility indices because changes in the level of fertility accomplished by varying the treatment combinations alter the values of these intervals. The confidence intervals of the indices for various treatment differences are presented in Table 3.

Table 3

Lower and upper limits of the 95% simultaneous confidence intervals for the three different indices for various treatment differences

Treatment difference	Comparison to be made from the corresponding treatment difference	Closed Interval		Open Interval		I	
		Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
T1—T2	Effect of F at P ₀ W ₀	4.88	9.48	21.29	34.29	7.22	11.26
T4—T3	„ „ F „ P ₁ W ₁	3.04	7.64	22.58	35.58	5.70	9.74
T5—T8	„ „ F „ P ₀ W ₁	5.06	9.66	23.09	36.09	7.56	11.60
T7—T6	„ „ F „ P ₁ W ₀	4.08	8.68	22.02	35.02	6.57	10.61
T7—T1	„ „ P „ F ₀ W ₀	3.05	7.65	—3.05	9.95	3.14	7.18
T4—T5	„ „ P „ F ₀ W ₁	1.33	5.93	—4.25	8.75	1.48	5.52
T6—T2	„ „ P „ F ₁ W ₀	3.85	8.45	—3.78	9.22	3.79	7.83
T3—T8	„ „ P „ F ₁ W ₁	3.35	7.95	—3.74	9.26	3.34	7.38
T5—T1	„ „ W „ F ₀ P ₀	0.28	4.88	—2.53	10.47	0.70	4.74
T4—T7	„ „ W „ F ₀ P ₁	—1.44	3.16	—3.73	9.27	—0.96	3.08
T8—T2	„ „ W „ F ₁ P ₀	0.10	4.70	—4.33	8.67	0.36	4.40
T3—T6	„ „ W „ F ₁ P ₁	—0.40	4.20	—4.29	8.71	—0.09	3.95
T2—T9	„ „ A „ F ₁ P ₀ W ₀	—0.91	3.69	—4.78	8.22	—0.59	3.45

Table 3 brings out certain interesting findings. Both the intervals show a significant change in the presence of a change in the level of fecundability. However, the open interval stands out as more significantly different. But open interval fails to exhibit any change in its value for a change in the level of either the factor P or W. Closed interval demonstrates a relatively much closer association with both the factors P and W. In other words the closed interval should be preferred to the open interval as an index in order to discern a possible change in the level of fertility due to a change in the level of either post-partum amenorrhea or fetal wastage that might occur in the population. However, both these intervals are ineffective in measuring a change due to a change in the age at marriage distribution of the population.

The confidence interval for the index I, which was obtained as equal to $I = 0.90(C) + 0.10(O)$ where C and O are the closed and open intervals, and subsequently included in the analysis (shown in Table 3), produces a slightly better picture. This index, like the closed interval, is able to measure a change in the level of the three factors, F, P and W (excepting for the three comparisons $T_4 - T_7$, $T_3 - T_6$ and $T_2 - T_9$). But at the same time it becomes more sensitive than closed interval in the sense that it could reflect a lesser change in the level of the three factors F, P (with the exception of the comparisons $T_6 - T_2$ and $T_3 - T_8$) and W.

The analysis of variance table (Table 4) depicts similar results as obtained in the case of MANOVA.

It is evident from Table 4 that almost 94% of the variability in the open interval is explained by a change in the level of fecundability alone. The contributions of the other two factors P and W are nearly zero. In the case of closed interval even though the factor F explains the largest chunk of its variability, the factors P and W are able to contribute significantly to the variability.

This study of the relative sensitivity of the closed and open intervals and a linear combination of the two is conducted through an application of multivariate analysis of variance technique to the simulated data on birth intervals. It is found that open interval is a better predictor of fertility change caused by change in the fecundability parameter. Srinivasan (1966) has also observed that open interval is more sensitive to fecundability and in a population where change in the level of fertility occur mainly because of changes in the fecundability parameter, open interval would be preferred to closed interval as an index of fertility. But if one wants to assess the changes in the level of fertility due to changes in the level of post-partum amenorrhea and incidence of fetal wastage closed interval fares better than the open interval. However, the index I, which is constructed as a linear combination of the closed and open intervals, appears to be slightly better in situations where fertility changes take place due to changes in all the influencing factors put together.

VI

The study is limited to only four fertility determinants and that too only two different levels of them could be considered to assess their impact on the three indices. The effect of truncation error on birth intervals has not been considered in the present problem. It is found that the quantum of truncation error on the closed and open birth intervals largely depends on

Table 4 Analysis of variance table for closed and open intervals and

index I

<i>Sources of Variation</i>	<i>Closed</i>			<i>Open</i>			<i>I</i>		
	<i>Sum of squares</i>	<i>Degree of freedom</i>	<i>Variations explained by each source of variation %</i>	<i>Sum of squares</i>	<i>Degrees Of freedom</i>	<i>Variation explained by each source of variation %</i>	<i>Sum of squares</i>	<i>Degrees of freedom</i>	<i>Variation explained by each source of variation %</i>
W	90.23	1	4.76	185.48	1	0.88	98.21	1	3.73
P	647.87	1	34.19	187.99	1	0.89	589.45	1	22.37
PW	7.35	1	0.39	1.97	1	0.01	6.69	1	0.25
F	1034.18	1	54.56	19831.18	1	94.19	1851.70	1	70.26
FW	1.12	1	0.06	8.32	1	0.04	0.45	1	0.02
FP	11.87	1	0.63	0.08	1	0.00	9.44	1	0.36
FPW	2.21	1	0.12	2.36	1	0.01	2.22	1	0.08
Error	100.34	88	5.29	837.49	88	3.98	77.19	88	2.93
Total	1895.17	95		21054.87	95		2635.35	95	

the length of marital duration. In the present problem, since the average marital duration is constant for all the combinations except for a change in the age at marriage distribution, it is presumed that the inferences drawn in this paper may not get vitiated due to the presence of truncation errors. However, the impact of truncation errors on the sensitivity of birth intervals is worth investigating. The study could be extended for other fertility determinants and inclusion of a few additional levels of these factors would provide better understanding of the various effects and interactions of these factors. The technique adopted here for investigating the effect of these four factors on the birth intervals can be extended to all the fertility measures, both period and cohort measures, in order to understand the relative sensitivity of each over the other.

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Distribution for the Different Levels of the Four Factors

Age	Fecundability (F)					Post-partum Amenorrhea (P)					
	F_0	F_1	Age	F_0	F_1	Months	P_0	P_1	Months	P_0	P_1
15	.02886	.04011	33	.01019	.04769	1	0.04	0.0039	19	0.02	0.0353
16	.03833	.05887	34	.00779	.04074	2	0.04	0.0066	20	0.01	0.0342
17	.04518	.07248	35	.00578	.03415	3	0.05	0.0098	21	0.01	0.0329
18	.04932	.08290	36	.00418	.02810	4	0.05	0.0133	22	0.01	0.0315
19	.05112	.09056	37	.00289	.02253	5	0.05	0.0169	23	0.01	0.0300
20	.05118	.09573	38	.00192	.01723	6	0.06	0.0205	24	0.01	0.0285
21	.05005	.09892	39	.00117	.01283	7	0.06	0.0239	25	0.01	0.0269
22	.04765	.10015	40	.00066	.00899	8	0.07	0.0271	26	0.01	0.0253
23	.04466	.09912	41	.00034	.00579	9	0.07	0.0299	27	0.01	0.0237
24	.04070	.09712	42	.00015	.00344	10	0.06	0.0322	28	0.01	0.0222
25	.03684	.09356	43	.00005	.00176	11	0.06	0.0341	29	0.01	0.0207
26	.03280	.08894	44	.00001	.00067	12	0.05	0.0356	30	0.01	0.0192
27	.02856	.08373				13	0.05	0.0367	31	—	0.0178
28	.02460	.07757				14	0.04	0.0373	32	—	0.0164
29	.02069	.07258				15	0.04	0.0375	33	—	0.0151
30	.01656	.06283				16	0.03	0.0374	34	—	0.0151
31	.01606	.06169				17	0.03	0.0370	35	—	0.0127
32	.01289	.05479				18	0.02	0.0363	36	—	0.1157

Source: Both the distributions are arbitrary.

Source: Distribution P_0 is based on the mean and variance of postpartum amenorrhea for an Indian population as reported by Potter *et.al* (1965). Distribution P_j is based on mean and variance of PPA used by Sheps *et.al* (1965).

Appendix I—A (Contd.)

Proportion of Conceptions terminating in
live birth, still birth and abortion (W)

Probability of marrying at different ages (A)

Age group	W_0			W_1			Age	A_0	A_1	Age	A_0	A_1
	L.	S.	A.	L.	S.	A.						
15-19	0.806	0.078	0.116	0.750	0.100	0.150	15	0.42564	0.21261	26	0.00316	0.00212
20-24	0.879	0.048	0.073	0.750	0.100	0.150	16	0.21261	0.13286	27	0.00212	0.00213
							17	0.13286	0.05332	28	0.00213	0.00107
							18	0.05332	0.03931	29	0.00107	0.00106
25-29	0.895	0.042	0.063	0.750	0.100	0.150	19	0.03931	0.03206	30	0.00106	0.00104
							20	0.03206	0.02659	31	0.00104	0.00109
							21	0.02659	0.16278	32	0.00109	0.00108
30-34	0.875	0.050	0.075	0.750	0.100	0.150	22	0.02124	0.16285	33	0.00108	0.00196
							23	0.02132	0.15749	34	0.00106	0.00104
							24	0.01596	0.00424	35	0.00104	0.00104
40-44	0.700	0.096	0.144	0.750	0.100	0.150	25	0.00424	0.00316	Mean	16.8	19.3

Source: Distribution W_0 is taken from Potter *et.al.* (1965). Distribution W_1 is taken arbitrarily by assuming 25% fetal wastage for all ages (Ridley *et. al.*, (1966).

Source: A_0 obtained from Sheps *et.al* (1965)
 A_j is taken arbitrarily.

APPENDIX I-B

Means and Variances of the Various Input Parameters of the Model

Parameters	<i>Mean</i>	<i>Variance</i>
1. Probability of primary sterility	0.06	—
2. Gestation period leading to live birth	9.60	0.46
3. Gestation period leading to still birth	8.15	0.60
4. Gestation period leading to abortion	3.67	1.44
5. PPA following a still birth	2.95	1.25
6. PPA following an abortion	1.50	0.45
7. Age at menarche	13.50	2.46
8. Terminal age of fecundity	41.50	21.51
9. Age of currently married women	29.40	88.87

Source: (1) Ministry of Health, Government of India, 1964, p.30; (2-4) Suggested by Dr. R.P. Soonawala, Naoroji Wadia Hospital, Bombay, (5) Suggested by C. Tietze; (6-8) Venkatacharya (1971); (9) Sebastian (1970)

APPENDIX—II

Values of Average Closed and Open Interval and Index I

<i>Closed</i>	<i>Open</i>	<i>I</i>	<i>Closed</i>	<i>Open</i>	<i>I</i>	<i>Closed</i>	<i>Open</i>	<i>I</i>
	T_1			T_2			T_3	
40.00	69.50	42.95	34.14	47.26	34.45	41.66	52.79	42.77
42.86	68.81	45.46	33.89	44.22	34.92	42.23	52.86	43.29
40.37	71.38	43.47	34.45	46.24	35.63	41.60	50.17	42.45
42.10	73.89	45.28	33.58	44.21	34.64	42.30	50.80	43.15
41.55	74.36	44.83	34.97	42.96	35.76	41.63	50.54	42.52
41.10	76.35	44.71	34.19	42.02	34.07	43.81	53.44	44.77
41.06	72.55	44.21	33.99	44.61	35.05	42.58	47.85	43.10
41.02	70.53	43.97	34.48	48.48	35.86	42.00	50.26	42.83
40.93	74.47	44.28	33.62	46.49	34.91	42.43	47.23	42.91
41.24	73.20	44.44	34.17	45.38	35.29	41.17	46.00	41.65
41.50	77.49	45.10	34.02	43.93	35.10	42.58	52.29	43.55
42.61	73.31	45.68	34.78	46.65	35.97	42.92	47.41	48.37

Appendix — II Contd.

<i>Closed</i>	<i>Open</i>	<i>I</i>	<i>Closed</i>	<i>Open</i>	<i>I</i>	<i>Closed</i>	<i>Open</i>	<i>I</i>
<i>T₄</i>			<i>T₅</i>			<i>T₆</i>		
46.05	84.74	49.92	42.68	72.78	45.69	40.67	46.47	41.25
48.86	82.88	52.26	42.37	78.91	46.02	40.24	49.76	41.19
47.45	78.94	50.60	43.13	83.68	47.19	40.30	41.05	40.38
46.56	74.53	49.38	45.29	75.72	48.33	39.42	47.37	40.22
44.67	83.98	48.60	44.07	75.31	47.19	40.43	47.42	41.13
48.83	81.47	52.09	44.79	83.24	48.64	40.43	47.75	41.16
50.24	77.25	52.94	41.83	81.99	45.85	39.63	48.71	40.54
46.59	75.06	49.44	43.15	74.12	46.25	40.41	51.75	41.54
47.30	80.74	50.64	43.82	73.02	46.74	41.34	51.68	42.37
46.16	81.77	49.72	45.86	78.21	49.10	40.35	47.98	41.11
48.73	73.25	51.18	43.99	75.52	47.14	40.27	49.11	41.15
49.57	75.95	52.21	46.40	70.96	48.86	40.56	45.93	41.10
<i>T₇</i>			<i>T₈</i>			<i>T₉</i>		
45.98	81.45	49.53	38.05	45.07	38.75	32.84	45.95	34.15
48.41	76.61	51.23	36.40	42.98	37.14	31.71	41.31	32.66
47.25	80.91	50.62	36.23	49.91	37.60	31.82	43.82	33.02
45.30	75.14	48.37	37.18	45.25	37.99	34.11	40.68	34.77
45.03	78.97	48.42	34.95	52.27	36.68	32.50	43.94	33.64
44.00	80.07	47.61	36.25	50.52	37.68	33.01	42.58	33.97
47.61	75.57	50.41	36.23	46.97	37.30	32.43	43.56	33.54
47.02	71.11	49.43	37.51	47.99	38.56	33.61	45.85	34.83
48.60	75.77	51.32	36.71	46.92	37.73	32.17	41.65	33.12
46.27	71.29	48.77	37.43	45.93	38.28	32.19	45.42	33.51
48.12	75.35	50.84	36.02	47.49	37.17	34.58	42.59	35.38
46.94	75.09	49.76	36.08	47.10	37.18	32.58	44.55	33.78

References

- Datidekar, K. (1959) — Intervals Between Confinements, *Eugenics Quarterly*, 6.
- Heck, D. L. (1960) — Cahrts of some Upper Percentage Points of the Distribution of the Largest Characteristic Root, *The annals of Methemathical Statistics*, Vol. 31.
- Henry, L. (1960) Kirk, — Intervals Between Confinements in the absence of Birth Control, *Eugenics Quarterly*, 5.
- Roger, E. (1969) — *Experimental Design: Procedures for the Behavioral Sciences*, Brooka/Cola Publishing Co., Belmont, California.

- Ministry of Health — Report on the Sub-group on "Demographic and Social Studies" of the Family Planning Programme Evaluation and Planning Committee.
- *Multivariate Statistical Methods*, Mcgraw-Hill Inc.
- Government of India (1964)
- Morrison, D. P. (1967) — Observations on "Open Interval" and "Open Status" as Indicators of Fertility Change, *Journal of Family Welfare*, Vol. 16. No. 3.
- Pathak, K.B. (1970) — Birth Intervals; Structure and Change, *Population Studies*, 17, 2. Fetal Westage in eleven Punjab Villages, *Human Biology*, Vol. 37.
- Potter, R.G. (1963) —
- Potter, R.G., J.E. Gordon, — A case study of Birth Interval Dynamics, *Population Studies*, Vol. 19.
- M. Parker, and J.B. Wyon (1965) — Marriage Patterns and Natality: Preliminary Investigations with a Simulation Model, Paper presented at the annual meeting of the Population Association of America, Chicago.
- An Analytic Simulation Model of Human Reproduction with Demographic and Biological Compounds, *Population Studies* Vol.19, No.3.
- Sebastian, A. (1970) — Methods of Assigning Age, Sex and Marital Status to the Initial Population and the Ages of Husband, *Population Simulation Models*, Research Papers Series No. 31, International Institute for Population Studies, Processed.
- Sheps, M.C. and Perrin, E.B.— The Distribution of Birth' Intervals, under a class of Stochastic Fertility Models, (1964) *Population Studies*, Vol. XVII, No. 3,
- Srinivasan, K. (1966a) — An Applibation of a Probability Model to the Study of Inter-live-birth Intervals, *Sankhya*, B, Vol. XXVIII.
- (1966b) — The 'Open Birth Interval' as an index of fertility, *Journal of Family Welfare*, Vol. 13, No.2.
-(1967) - A Probability Model Applicable to the Study of Inter-live-birth Intervals and Random Segments of the Same, *Population Studies*, Vol. XXI, No.1.
- (1967) — Analytical Models for Two Types of Birth Intervals with Applications to Indian Population, unpublished Ph. D. thesis submitted to Kerala University, India.
- (1970) — Findings and Implications of a Correlation Analysis of the Closed and the Open Birth Intervals, *Demography*, Vol.7, No.4.
- Venkatacharya, K. (1969) — Some Recent Findings on 'Open Birth Intervals', *Artha Vijnana*,\o\, **XI**, No.3.
- (1971) - Fertility and Fecundability, *Social Biology*, Vol.18, No.4.
- Venkatacharya, K. and — Determination of Sample Size in the Simulation Models of Human Reproduction
- T.K. Roy (1962) — *OPESARCH* Vol.9, No.1.