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Survivorship Probabilities Under Different Policies of Population Control— A Simulation Model

Introduction

A PROGRAMME of insisting on sterilisation, or of intensive campaign to that effect, encounters a conflict between two premises :

- (a) It is the Government's duty to intervene for correcting the situation, in which irresponsible parenthood by a section of the people is the main cause of slow economic development; those who have already adopted small family norm in the expectation of faster improvement of their living standards, may be frustrated by the Government's inaction.
- (b) Every citizen has got the right of having children according to his choice. Rights may not be considered absolute and a license for irresponsible parenthood, but there should not be any restraint on action based on genuine aspirations, like the actions for ensuring survival through the descendants.

So we should assess the degree of conflict, if any, and try to formulate a programme with a view to minimising the conflict between personal interests of couples enumerated at (6) above with the social aim mentioned at (a). Parents want children for old age security, other economic reasons, psychological reasons

including immortality syndrome, and requirement of performing religious rituals at death. By policy decisions and elaborate social security measures, effects of some of the factors, particularly the economic ones, may be nullified. But it is very difficult to do anything in respect of the psychological factors and the requirement of performing religious rituals. So we see that the population policy should be such that the genuine interests of the couples are affected as little as possible.

It has been shown elsewhere [2] that survivorship probability is likely to increase in the coming years, since in developing countries like India, infant mortality is likely to decline faster. The attempt here is to find the probability of survival of children upto the death of the parent dying first; this has been done under different assumed strategies of population control. The main objective is the calculation of percentage of parents survived by at least one child. We have tried to anticipate the actual situation that may arise in the Indian society due to adoption of either of the policies,

Methodology

A base-line distribution of currently married women by age and number of living children of different ages has been taken and they have been followed till the death of either of the parents. During the subsequent years, new couples, entering into marital status, will be subject to relevant fertility and mortality schedules. Assuming that the contribution of the newly married couples in the pool of 'all married couples' in any year will be 5 per cent [3] fertility and mortality histories of these new entrants have also been generated separately, year after year, upto the point of death of either spouse. At the point of death of the couple, it has been shown whether the couple has been outlived by one or more children. In any year, out of the couples dying, some are survived by one child and some are survived by 2 children ... etc. and the number belonging to each category has been worked out.

Decision about occurrence of each event is made using a computerised technique of a drawing random number and comparing it with appropriate probability. If the random number drawn is less than the probability of occurrence, the event is assumed to have occurred. The father is assumed to have died after T_1 years, where the probability of dying within T_1 years is less than the random number drawn but the probability of dying within $(T_1 - 1)$ years is not less than the random number drawn.

A father aged x in the K -th calendar year means that he has completed x ; and the probability of survival in the next year is $= p_x = l_{x+1}^k/l_x^k$ where l_x^k values refer to the male life table values corresponding to the k -th calendar year. The probability that the father aged x will survive for T_1 years is given by :

$$AMR = \frac{l_{x+1}^k}{l_x^k} * \frac{l_{x+2}^{k+1}}{l_{x+1}^{k+1}} * \frac{l_{x+3}^{k+2}}{l_{x+2}^{k+2}} * \dots * \frac{l_{x+T_1}^{k+T_1-1}}{l_{x+T_1-1}^{k+T_1-1}}$$

If the random number drawn is AR , the computer is required to compare AR with AMR and if AR is less than AMR , the death is assumed to have occurred. Similarly, the probability of survival of the mother upto T_2 years is determined by taking relevant values from female life tables. Number of years survived by the couple is T years, where $T = \text{Minimum of } T_1 \text{ and } T_2$.

The next part of the programme is testing for survival of children upto the point of death of the couple; and this has been done separately for each of the existing children as well as those born in subsequent years. Survival of children is tested by drawing a random number and comparing it with the relevant probability for the child; this has been done with due consideration to the sex of the child determined on the basis of sex ratio at birth. The calculated value of the probability that a child born in the K -th calendar year will survive for t years may be seen in appendix Table-8.

If it is found that one or more children are surviving, the couple is considered to have been survived by the said number of children.

Decision about occurrence of births also has been taken similarly by drawing a random number and comparing it with the relevant probability of giving birth. The testing for occurrence of births has been done annually assuming that no woman can give birth in two consecutive years and inflating the probability to $f_x = f_x/1 - f_{x-1}$, if she has not given birth last year. This is because:

$$\begin{aligned} f_x &= \text{probability of giving birth at age } x \\ &= \text{probability that she gave birth at age } (x-1) * 0 \\ &+ \text{probability that she did not give birth at age } (x-1) * f_x/1 - f_{x-1} \end{aligned}$$

The generated distribution of proportion of women given birth last year is given in appendix Table-5.

Those entering into marital status in subsequent years are not having any children to start with, and can get children only in subsequent years. So tests were made for survival of the couple, number of children born and survival of those upto the point of death of the couple. Number of new entrants has been taken as equal to 5% of the number of currently married women at the end of the previous year [3].

Four runs of simulation have been used in the paper, one is the control run and the other three are under different assumptions of family welfare programmes. Assumptions about improvement of mortality and increase in expectation of life have been taken as those of Coale and Demeny Model (West) life tables. Assumed values of e_g shown in appendix Table 2.

In all the cases, before generating the future fertility history of any couple, it was tested whether either of them has already been sterilised due to ongoing programme since 1956. Sample size of each of the runs were of the order of 5,500 comprising of 2,000 currently married women of different ages in 1976 and 5% new entrants in each year during the period 1977-2000 A.D.

Data Used

Inputs are age specific fertility and mortality rates in different periods of time, age distribution of currently married women, conditional distribution of getting married at a particular age etc. Mortality has been changed at intervals of 5 years and l_x values have been taken from complete life tables based on Coale and Demeny Model (West) life tables [5]. Relevant set of e'' values are shown in appendix Table 2. Age specific fertility rates have been taken from Sample Registration Bulletin (July, 1975) [6]; the calculated age specific marital fertility rates are shown in appendix Table I. Appendix Table 3 shows the distribution of married women obtained from the census (1971) data, and the conditional probability of getting married at afferent ages.

For making the model as realistic as possible, we have started with a set of currently married women and many of them are already married and having a number of living children in the base period. So we need distribution of currently married women in reproductive period by number of living children and ages of these children. These, and the data on proportion of women giving birth last year have been simulated separately on the basis of a sample of 5,000 Nos. 1 & 2 1979 Demogr

currently married women. These are shown in appendix Tables 4, 5, 6 and 7. For this part of the computer programme we used e_0^m values for the years 1946-76 and A.S.M.F.R. corresponding to a period around 1960. These are shown in appendix Tables 2A and 1A respectively. The basic steps in this part of the simulation are determination of age at marriage and hence the year of marriage, and then generation of fertility history of the couple and mortality histories of the children.

Validation of the Model

Simulation amounts to drawing a random sample from the population and hence there will be fluctuations. For testing whether these fluctuations are within reasonable limits, a replicate was taken for the control run. The test statistic

$$\chi^2 = \sum_{i=1}^2 \sum_{j=1}^c \left(n_{ij} - \frac{n_i m_j}{n} \right)^2 \frac{n}{n_i m_j}$$

where n_{ij} is the frequency in the j -th class of i -th sample and $n = \sum_{i=1}^2 n_i$;

$m_j = \frac{2}{n} \sum_{i=1}^2 n_{ij}$ [11] was calculated to test that these two distributions of number of couples survived by different combinations of sons and daughters do not differ significantly. Below is given the data on the two replicates:

<i>Percentage of couples survived by</i>	<i>1st replicate</i>	<i>2nd replicate</i>
At least one child	92.2	92.2
At least one son	76.9	77.7
At least one daughter	79.6	78.7
Children of both sexes	64.3	64.2

$\chi^2 = 0.007663$. This value being insignificant at 1% level, we can say that the distributions are not significantly different.

Some other expected value checks, like the comparison of the number of

births and deaths with the corresponding expected values have also been made for validating the model.

Results

The following table shows the percentage of couples survived by different combinations of sons and daughters upto 2000 A.D. separately for each of the programmes.

TABLE 1—PERCENTAGE OF COUPLES SURVIVED BY CHILDREN

<i>Programme</i>	<i>Percentage of couples survived by</i>			
	<i>At least one child</i>	<i>At least one son</i>	<i>At least one daughter</i>	<i>Children of both sexes</i>
Sterilisation after two children	92.4	66.8	71.2	45.6
Sterilisation after 3 children	92.9	70.6	74.9	52.6
Sterilisation after 4 children	91.1	72.8	77.3	59.0

No appreciable change in chances of being survived by at least one child is observed. Probability of being survived by a child of specified sex falls to some extent with stringency of the programme and chances of being survived by children of both sexes fall faster.

The above results relate to the totality of the population including those who are already married and having children as well as those who will be entering into marital status subsequently. Below is given the relevant data for those who will be entering into marital status during the period 1977-2000 A.D.

TABLE 2—SHOWING THE PERCENTAGE OF NEWLY ENTERING COUPLES SURVIVED BY DIFFERENT COMBINATIONS OF SONS AND DAUGHTERS

<i>Programme</i>	<i>Percentage of couples survived by</i>			
	<i>At least one child</i>	<i>At least one son</i>	<i>At least one daughter</i>	<i>Children of both sexes</i>
Sterilisation after 2 children	74.6	43.3	47.4	16.3
Sterilisation after 3 children	78.9	51.0	55.7	27.8

It is seen that the proportion of couples survived by at least one child goes down to some extent with the programme of sterilisation after 2 children, and the probability of being survived by at least one son etc. registers a sharper fall. While interpreting the table above, it is to be borne in mind that this sample of new entrants is not a representative sample of the population.

Limitations and Prospects

Input data have got their limitations and more experimentation with better data will help in appraising the situation more clearly. In the model, we could not take into account of divorce and remarriage. Also due to non-availability of relevant data, some connected data have been adapted under broad assumptions. For example, in respect of the data on the distribution of proportion of already sterilised couples by the number of living children, we had to use the age distribution of those sterilised since 1956 for surviving them over the relevant period to get the total number of sterilised couples in reproductive ages. Using the present day distribution of sterilisation by number of living children, we have allocated this total number of sterilised couples into different number of living children groups.

Three variants of sterilisation programme have been considered. Some other alternative programmes, particularly, one introducing spacing till the child crosses the infant mortality period could be considered also. In those cases, survivorship probability will improve.

The results worked out refer only to those who could have children; we have not eliminated a percentage of couples for primary sterility. In the case of an assumption of about 5% primary sterility, a corresponding proportion can not have any children at all and there will be a decrease in the absolute value of the proportion of couples survived by no child.

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Appendix

TABLE 1—SHOWING AGE-SPECIFIC MARITAL FERTILITY RATES

Age	Age specific marital fertility rates**
15	0.10270
16	0.14245
17	0.17680
18	0.20595
19	0.23020
20	0.24990
21	0.26520
22	0.27645
23	0.28395
24	0.28795
25	0.28895
26	0.28740
27	0.28255
28	0.27440
29	0.26375
30	0.25130
31	0.23665
32	0.22370
33	0.21435
34	0.20695
35	0.19760
36	0.18665
37	0.17470
38	0.16145
39	0.14675
40	0.13000
41	0.11125
42	0.09020
43	0.06655
44	0.04000

**Computed from : (i) R. G. India, *Sample Registration Bulletin*, Vol-IX, No. 3, July, 1975 and (ii) Census of India *Pocket Book on Population Statistics*, 19.

TABLE 1A—SHOWING AGE-SPECIFIC MARITAL FERTILITY RATES USED FOR GENERATING FERTILITY HISTORIES RETROSPECTIVELY FROM YEAR OF MARRIAGE UPTO BEGINNING OF 1976

<i>Age group</i>	<i>Age specific marital fertility rates</i>
15-19	0.22399
20-24	0.31021
25-29	0.28039
30-34	0.22261
35-39	0.15871
40-44	0.06900

SOURCE : Rao, S. L. N., Differential fertility in India by State, Seminar paper submitted to D. T. R. C., Bombay, (*Mimeographed*), 1967.

TABLE 2—ASSUMED VALUES OF e_g FOR GENERATING MORTALITY HISTORIES OF COUPLES AND CHILDREN FROM 1976 ONWARDS

<i>Year</i>	<i>Expectation of life at birth e_{00}</i>	
	<i>Male</i>	<i>Female</i>
1976-1980	49.58	50.03
1981-1985	51.86	52.53
1986-1990	54.17	55.04
1991-1995	56.51	57.54
1996-2000	58.88	60.05

**Corresponding l_x values have been taken from Sinha, U. P., Complete life tables based on Coalc and Demeny's Model (West) life tables, I. I. P. S., Bombay, (*Mimeographed*), 1972.

**TABLE 3A—EXPECTATION OF LIFE AT BIRTH (e^0) IN DIFFERENT PERIODS
OF TIME USED FOR, GENERATING MORTALITY OF CHILDREN BORN
SINCE 1946**

Year	Expectation of life at birth (e^0)	
	Male	Female
1941-51 (1)	32.48	32.49
1953-61 (2)	38.99	38.57
1961-71 (2)	44.61	44.78
1971-76 (2)	48.31	48.89

N.B.

(1) Corresponding l_x values have been obtained from Sinha, U. P., Complete life tables based on Coale and pemeny's Model (West) life tables, I.I-P.S., Bombay, 1972. (*Mimeographed*).

(2) Corresponding l_x Values obtained from Immerwahr, G. E. and Sinha, U. P., Mortality rates for India, 1951-81 for use of computer simulation model COMPSIM, I.I.P.S., Bombay, (*Mimeographed*).

TABLE 5—SHOWING AGE DISTRIBUTION OF CURRENTLY MARRIED **WOMEN**
AND THE CONDITIONAL PROBABILITY OF GETTING MARRIED AT
DIFFERENT AGES

Age	Proportion of currently married Women(1)	Conditional probability of getting married(2)
	0.022	0.42564
16		0.21261
17	0.027	0.13286
18	0.029	0.05332
19	0.033	0.03931
20	0.037	0.03216
21	0.039	0.02659
22	0.041	0.02124
23	0.042	0.02132
24	0.043	0.01596
23	0.044	0.00424
26	0.043	0.00316
27	0.042	0.00212
28	0.040	0.00213
29	0.039	0.00107
30	0.039	0.00106
31	0.037	0.00104
32	0.036	0.00109
33	0.035	0.00108
34	0.033	0.00106
35	0.033	0.00104
36	0.032	—
37	0.031	—
38	0.029	—
39	0.028	—
40	0.027	—
41	0.025	—
42	0.024	—
43	0.023	—
44	0.022	—

1. Computed from data in Census of India, *Pocket Book on Population Statistics*, 1972.

2. Taken from Mukherjee, S. and Venkatacharya K., *Effect of P.A. on natality*, I.I.P.S.

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**TABLE 4—SHOWING PROPORTION OF CURRENTLY MARRIED WOMEN
HAVING < X NUMBER OF LIVING CHILDREN SEPARATELY FOR
EACH AGE**

Age	Proportion of couples having number of living children less than or equal to (X)										
	0	1	2	3	4	5	6	7	8	9	10
15	1.00										
16	0.93	1.00									
17	0.78	1.00									
18	0.63	0.99	1.00								
19	0.49	0.97	1.00								
20	0.36	0.85	1.00								
21	0.28	0.73	0.99	1.00							
22	0.24	0.68	0.93	1.00							
23	0.12	0.49	0.86	0.98	1.00						
24	0.11	0.37	0.78	0.97	1.00						
25	0.09	0.40	0.73	0.95	0.99	1.00					
26	0.06	0.30	0.64	0.93	0.99	1.00					
27	0.06	0.25	0.56	0.88	0.99	1.00					
28	0.06	0.24	0.54	0.82	0.98	1.00					
29	0.03	0.15	0.46	0.76	0.93	0.99	1.00				
30	0.03	0.14	0.37	0.69	0.91	0.98	1.00				
31	0.03	0.14	0.37	0.63	0.91	0.99	1.00				
32	0.03	0.12	0.29	0.59	0.84	0.96	0.99	1.00			
33	0.02	0.07	0.29	0.62	0.87	0.96	1.00				
34	0.01	0.07	0.28	0.55	0.83	0.94	0.99	1.00			
35	0.03	0.10	0.27	0.50	0.81	0.95	0.99	1.00			
36	0.01	0.05	0.19	0.46	0.76	0.91	0.98	0.99	1.00		
37	0.01	0.10	0.24	0.48	0.77	0.92	0.97	0.99	1.00		
38	0.00	0.10	0.23	0.41	0.69	0.76	0.76	1.00			
39	0.03	0.10	0.28	0.52	0.70	0.88	0.96	0.98	1.00		
40	0.02	0.10	0.25	0.46	0.70	0.85	0.94	0.98	1.00		
41	0.01	0.04	0.17	0.38	0.60	0.86	0.96	0.99	1.00		
42	0.02	0.08	0.13	0.37	0.59	0.82	0.94	0.98	0.99	1.00	
43	0.00	0.05	0.20	0.38	0.63	0.84	0.91	0.98	0.99	1.00	
44	0.00	0.05	0.18	0.43	0.61	0.84	0.95	0.99	1.00		

SOURCE :—Computed from Simulation of Fertility Histories (Retrospectively) of 5000 currently married women.

TABLE 5—PROPORTION OF WOMEN GIVING BIRTH LAST YEAR

<i>Age</i>	<i>Proportion of women giving birth last year</i>
15	0.000
16	0.096
17	0.156
18	0.269
19	0.218
20	0.265
21	0.318
22	0.297
23	0.367
24	0.367
25	0.327
26	0.377
27	0.324
28	0.295
29	0.297
30	0.287
31	0.286
32	0.333
33	0.297
34	0.242
35	0.194
36	0.231
37	0.129
38	0.138
39	0.128
40	0.148
41	0.176
42	0.150
43	0.122
44	0.064

SOURCE. Computed from simulation of fertility histories retrospectively of 5,000 currently married women.

TABLE 6—SHOWING THE AVERAGE AGES OF CHILDREN BY AGE OF MOTHER AND NUMBER OF LIVING CHILDREN SHE IS HAVING

Age(s)	Average ages ($a_{1j}, a_{2j}, \dots, a_{ij}$)* when the number of living children (j) is :						
	1	2	3	4	5	6	...
16	0	—	—	—	—	—	.....
17	1	—	—	—	—	—	.....
18	1	1,2	—	—	—	—	.....
19	1	2,3	—	—	—	—	.....
20	1	2,4	—	—	—	—	.....
21	0	1,3	2,4,5	—	—	—	.....
22	1	1,3	2,4,5	—	—	—	.....
23	0	1,2	1,4,4**	2,4,6,7	—	—	.....
24	1	1,3	2,4,5	3,5,7,8	—	—	.....
25	0	1,2	2,3,4	2,4,6,7	3,6,7,7,9	—	.....
26	1	1,3	1,4,5	2,4,6,7	3,6,8,9,9	—	.....
27	1	1,2	2,4,5	3,5,7,7	4,7,8,9,9	—	.....
28	1	2,3	2,4,6	4,5,7,8	5,7,8,10,10	—	.....
29	1	1,3	2,3,5	2,4,6,7	3,6,8,8,10	5,7,9,11,11,13	.....
30	1	1,3	2,4,5	2,4,7,7	3,6,7,9,10	5,9,10,11,12,12	.....
31	0	1,2	2,5,5	3,5,7,9	3,6,8,9,11	5,8,11,12,12,15	.....
32	0	1,2	2,3,5	2,4,6,8	3,5,7,9,10	4,7,9,10,11,11	.....

33	1	2,3	2,5,6	3,5,8,9	5,7,9,11,12	7,11,12,13,14,14
34	2	1,4	2,5,8	2,5,8,10	3,6,8,11,12	4,7,10,11,14,14
35	0	3,2	3,5,6	3,6,8,8	3,6,9,9,11	6,9,10,12,15,13
36	1	1,4	2,6,8	2,5,8,10	3,6,9,10,12	5,7,9,11,13,14
37	2	1,5	2,5,7	3,4,8,9	4,7,7,11,12	4,8,10,11,14,14
38	1	4,6	3,7,10	3,8,10,12	6,8,11,12,15	5,11,13,14,15,18
39	2	5,5	3,8,7	4,6,9,10	4,8,10,12,13	5,9,11,13,14,15
40	3	2,7	3,5,10	5,6,9,12	4,9,11,11,15	5,9,13,14,14,18
41	4	3,6	3,7,8	4,8,10,11	4,8,11,12,13	6,9,12,14,14,15
42	8	3,10	4,7,12	4,7,9,15	5,7,11,12,16	6,10,11,14,15,18
43	3	1,6	5,6,9	4,8,12,11	5,8,11,15, 16	6,10,13,14,16,18
44	2	4,7	5,8,10	6,9,12,12	7,10,13,13,14	8,13,15,16,17,17

SOURCE : Computed from simulation of fertility histories retrospectively of 5000 currently married women.

* $a_{i1}, a_{i2}, \dots, a_{ij}$ are the ages of the j living children in ascending order.

**The average age a_{ijk} is over the K th living children (not average age of children of K th order birth) of all mothers aged i and having j children living.

TABLE 7—SHOWING DISTRIBUTION OF 5000 CURRENTLY MARRIED WOMEN ACCORDING TO THEIR AGE AND NUMBER OF LIVING CHILDREN IN 1976.

Age group	Number of mothers having living children							Total
	0	1	2	3	4	5	6+	
15-19	504	169	7	—	—	—	—	680
20-24	218	405	295	83	9	—	—	1010
25-29	63	220	330	295	108	22	2	1040
30-34	22	78	192	266	229	84	29	900
35-39	12	56	116	177	212	127	65	765
40-44	6	33	75	131	136	128	96	605
Total	825	961	1015	952	694	361	192	5000

SOURCE : Computed through simulation of fertility histories of 5,000 currently married women retrospectively.

TABLE 8—SHOWING THE PROBABILITY ACM (K, T) THAT A MALE CHILD BORN IN K th CALENDAR YEAR WILL SURVIVE FOR T YEARS

Years of birth (K)	Probability of Survival upto (T Years)											
	1	2	3	4	5	6	7	8	9	101112		
1976	.87547	.84833	.83644	.82866	.82287	.81941	.81647	.81375	.81176	.80980	...	...
1977	.87547	.84833	.83644	.82866	.82378	.82032	.81738	.81486	.81267	.81097	...	...
1978	.87547	.84833	.83644	.83005	.84518	.82171	.81876	.83624	.81434	.81264		
1979	.87547	.84833	.83828	.83169	.82651	.82332	.82037	.81818	.81627	.81457		
1980	.87547	.85241	.84231	.83569	.83077	.82727	.82469	.82249	.82057	.81886		
1981	.88864	.86523	.85498	.84826	.84327	.84018	.83756	.83532	.83338	.83164		
1982	.88864	.86523	.85498	.84826	.84408	.84099	.33837	.83613	.83418	.83269		
1983	.88864	.86523	.85498	.84938	.84519	.84230	.83947	.83723	.83557	.83408		
1984	.88864	.86523	.85667	.85106	.84687	.84377	.84114	.83922	.83756	.83606		
1985	.88864	.86891	.86069	.85506	.85066	.84754	.84530	.84337	.84169	.84019		
1986	.90143	.88164	.87292	.86720	.86293	.86022	.85794	.85598	.85429	.85276		
1987	.90143	.88164	.87292	.86720	.86351	.86079	.85851	.85656	.85486	.85358		
1988	.90143	.88164	.87292	.86807	.86437	.86166	.85937	.85741	.85599	.85471		
1989	.90143	.88164	.87443	.86957	.87469	.86315	.86086	.85922	.85779	.85652		
1990	.90143	.88575	.87851	.87363	.86991	.86718	.86525	.86359	.86217	.86088		
1991	.91379	.89790	.89056	.88561	.88184	.87952	.87756	.87588	.87443	.87313		
1992	.91379	.89790	.89056	.88561	.88247	.88015	.87819	.87651	.87506	—		
1993	.91379	.89790	.89056	.88649	.88335	.88102	.87906	.87738	—	—		
1994	.91379	.89790	.89202	.88794	.88479	.88217	.88049	—	—	—		
1995	.91375	.90159	.89569	.89159	.88843	.88362	—	—	—	—		
1996	.92570	.91334	.90736	.90321	.90001	—	—	—	—	—		
1997	.92570	.91334	.90736	.90321	—	—	—	—	—	—		
1998	.92570	.91334	.90736	—	—	—	—	—	—	—		
1999	.92570	.91334	—	—	—	—	—	—	—	—		
2000	.92570	—	—	—	—	—	—	—	—	—		

SOURCE : Computed from l_x values (vide methodology)
N.B. Only a portion of the data shown.