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A Simulation Model to Study the Effect of Sex Preferences on Current Fertility

The impact of sex preferences on fertility has been well documented in various countries (Bumpass and Westoff 1970; Markle and Nam 1971; Gray 1972; Gray and Morrisori 1974; Srinner and Mader 1975; Coombs and Sun 1978; Cleland et al. 1983; Sloane and Lee 1983; Arnold 1985; Das 1986; Das 1987a; United Nations 1987), although there exist conflicting results even within the same country (Cutright et al. 1974; Freedman and Coombs 1974; Waller 1976; Ben-Porath and Welch 1976; McClelland and Hackenberg 1978; Pebley and Westoff 1982). Nevertheless, the evidence leaves no doubt that, at least in many developing countries the sex of a child is important to parents in their fertility decisions. In certain countries sex preference is now having a greater effect on fertility because family size norms have gone down and contraceptive use has gone up (Das 1987a). In other words, sex preference may not have much impact at high fertility levels, but as average family size norm declines, sex preference will become a more important factor in fertility decisions. If so, it would be interesting to understand the changes in the birth rate and other current fertility indices of a population if all couples proceed to attain the desired sex composition of their children but stop reproduction as soon as they attain this. Although a number of mathematical studies have examined the effect of sex preference on fertility and sex ratio (e.g., Sheps 1963; Mitra 1970; Pathak 1973; Krisnamoorthy 1974; Keyfitz 1977; McClelland 1983; Talwar 1975), the effect of increasing preference for one sex over the other on current fertility is not clearly known. In this regard, the author has recently developed a stochastic model and has shown that sex preference affects current fertility of a population. If sex preference is stable, the expected fertility will increase with increasing preference for one sex over the other (Das 1987b; Das 1989). The importance of the development of such mathematical or stochastic models for the proper study of these problems cannot be undermined, although these models sometimes involve some rigid assumptions which may or may not influence the results. Many complex situations which are not amenable to mathematical modelling can be analysed easily by simulation techniques. Moreover, the development of simulation models does not require the simplifying assumption of stationarity (parameters do not change with age) or even of homogeneity (all couples share the same parameter values) which many reproductive models presuppose (Bongaarts and Potter 1983). The purpose of this research is, therefore, to develop a simulation model which may help to study the effects of sex preference on current fertility, without involving much mathematical intricacy. To illustrate the model, Indian data have been considered.

THE MODEL

The model to study the effect on current fertility, of allowing couples to satisfy their desired sex composition, can be looked upon as a controlled experiment. *The* analysis would be done in two segments. One segment is a cohort simulation model of human fertility which is very similar to the model of Ridley and Sheps (1965) and Venkatacharya (1972). This could provide estimates of birth probabilities $f(x,y)$ for a given current age (x) and age at marriage (y) of woman, once assuming usual reproductive behaviour (control set), and the other with specific rules for stopping after achieving a specific family size composition (experimental set). All the input values except those of stopping rules are identical for the two sets. The second segment involves estimation of various current fertility rates from the age-specific and age-at-marriage-specific birth matrices $f(x,y)$ derived in the first segment for the control set and experimental set. To estimate fertility rates in the second segment, a simple population projection technique was used, details of which have been considered later in the relevant section. A difference in the fertility rate of the two sets in each case is a measure of the impact of allowing couples to attain specified family size composition on fertility.

The Monte Carlo Model to Obtain Age-specific and Age-at-marriage-specific Birth Probabilities

In the Monte Carlo model the sequence of events such as marriage, pregnancy, stay in various pregnancy periods, outcome of a conception, stay in post-partum non-susceptible period are worked out with the help of a set of pseudo-random numbers. Let us consider an example where we are interested in simulating the age at marriage of a woman on the basis of a certain probability distribution. Let the chance of a single woman aged x marrying before $x+1$ be $m(x)$. A random number, with values between 0 and 1 generated in the computer, is drawn and it is tested whether this random number is less than or equal to $m(x)$. If the random number is less than or equal to $m(x)$, the marriage takes place at age x , otherwise not and a similar procedure is adopted to decide her marriage at age $x+1$. The same technique can be followed to determine other events. For each female partner, the successive reproductive states entered are determined. Repeating this process many times produces a collection of reproductive histories, for which as many details as desired may be retained. Thus in order to determine the event we use the probability of its occurrence. The detailed procedure for simulating a woman's fertility history has been described by Venkatacharya (1970a). Simulation models are very widely used because of their flexibility and ease due to the advent of high-speed electronic computers.

The present model simulates fertility histories of married women from their entry into marital union to the end of their reproductive life, and records all the events necessary for the computation of various current fertility indices. The sequence of events that can take place while simulating the fertility history of a married woman under the control set and experimental set, is shown in Figures 1 and 2. All the events are generated on the basis of the input probability density functions corresponding to the specific event. In the following section the assumptions and input parameters underlying the Monte Carlo model are discussed.

Assumptions:

1. Fertility is simulated from age at marriage to 44 years of age. No woman starts her reproduction before age 15. This is an arbitrary assumption and the model can be used for any age other than 15 years as the initial age of fertility. The age at menopause for all women is taken to be 45 years.

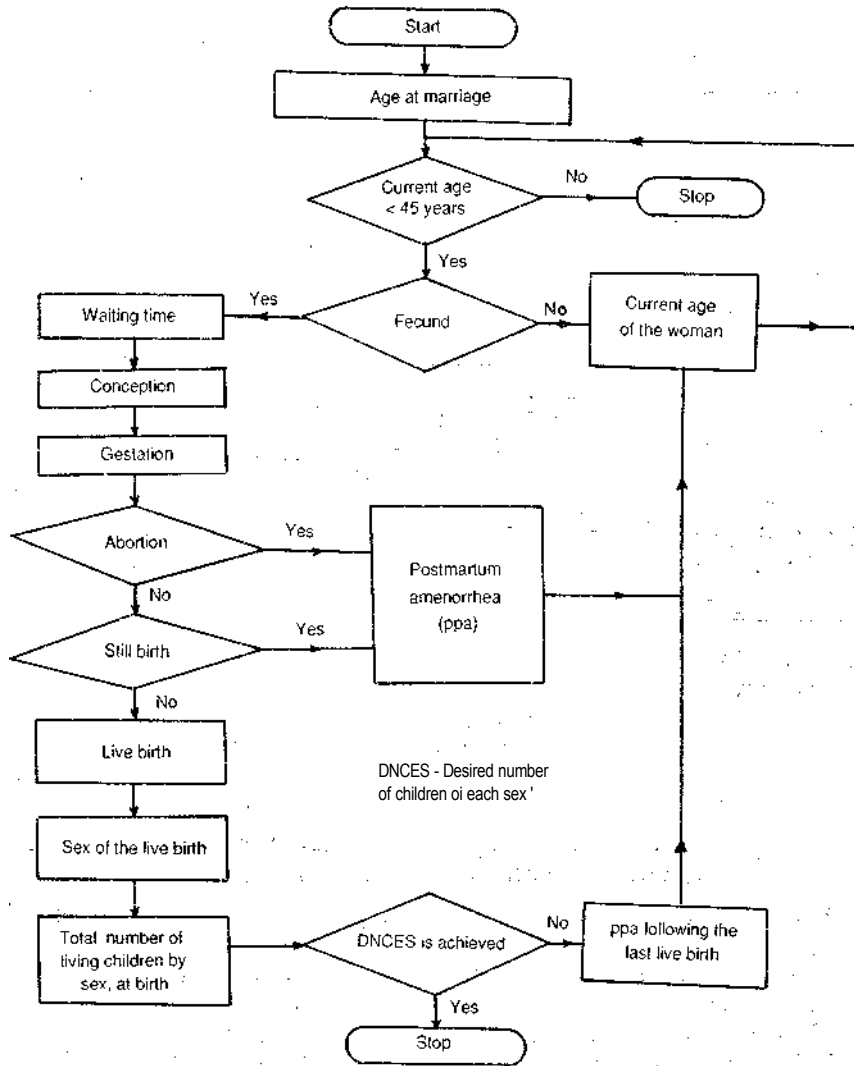


Figure 1. Flow Chart showing the sequence of events that can take place while simulating the fertility history of a married woman under control set

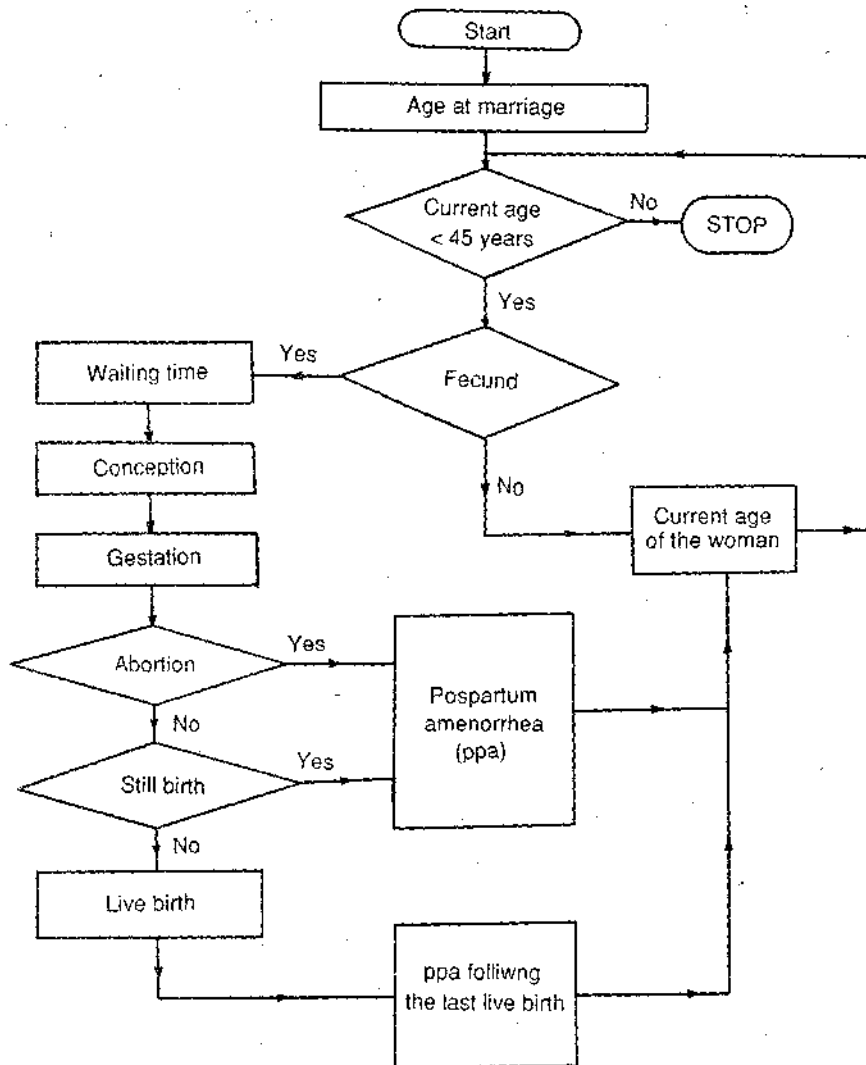


Figure 2. How Chart showing the sequence of events that can take place while simulating the fertility history of a married woman under the experimental set

2. The unit of time is considered as a month, which is nearly equal to the mean inter-menstruum.
3. Women are assumed to have identical biological parameters, i.e., they are homogeneous.
4. Mortality of the woman has been ignored (it is taken care of separately).
5. Probability of a woman becoming sterile is assumed to vary with her age.
6. Fecundability is assumed to vary with age of a woman, although it does not change with parity.

7. A conception is assumed to terminate either in a live birth, a stillbirth or an abortion, and the probability of the occurrence of each is assumed to vary over age.
8. The termination of gestation periods leading to a live birth, stillbirth or abortion, are assumed to occur according to specified discrete probability distributions which are assumed to be constant for all ages and parities. Similarly, post-partum amenorrhoea periods are assumed to follow specified probability distributions.
9. Probability of a male and female birth to survive at a point of time depends on his/her age, at that point of time.
10. Birth control is complete. Couples stop reproduction as soon as the desired sex composition and/or size (in terms of b surviving sons and g surviving daughters and/or a total of s surviving children) is achieved.

Assumption (10) is meant for the experimental group where it is assumed that a couple has a preference for a fixed minimum number of boys and a fixed minimum number of girls. The expected fertility is obtained under the assumption that sex preference can only increase, not decrease, fertility. The accuracy of the results depends on the validity of this assumption, in a population under study. In any case, the present measure is useful to know the maximum possible impact of sex preference on fertility.

Input

To simulate fertility history at micro level, it is necessary to obtain age-specific sterility rate, age-specific fecundability, age-specific probabilities of conception terminating in a live birth, a stillbirth, or an abortion, probability of termination of pregnancy periods and post-partum amenorrhoea periods associated with each conception termination and the survival probability of a birth to a particular age by sex. Each of these input probabilities used in the simulation model are summarised in Appendix Table 1.

The current age and age-at-marriage-specific birth probabilities are obtained on the basis of 100 women simulated at each of the single years 15,16,..., 35. That is, 2,100 women histories are used to yield one birth matrix ($f_{xy}, x = 15,16,\dots, 44, y = 15,16,\dots, 35$ where $x \geq y$). This set of 2,100 women forms one replicate. Fertility histories were generated in two replicates of 2,100 women in each. Replications were mainly for testing internal consistency of the output. Between the replicates the differences in important rates were not much. Therefore, the results are presented for the pooled data. The matrix of birth probabilities ($f_{x,y}$) obtained by assuming usual reproductive behaviour (where reproduction is, by and large, at the observed level, i.e. unaffected by any specific planning) gives the age-specific and age-at-marriage-specific birth probabilities corresponding to the control assumption. Using the same simulation model and all the input values, and adding an assumption for stopping after achieving certain specified family size composition, the matrices of birth probabilities ($f^s_{x,y}$) corresponding to each specific stopping rule under experimental set are obtained. The 12 hypothetical cases under the experimental set, giving the rules when a couple would stop, have been considered. They are framed based on

empirical data to make them more realistic for India.¹ Several other stopping rules may be framed, and the birth matrix can be computed. The 12 stopping rules considered here are described below.

Couples stop reproduction as soon as they have:

- Rule 1 : two living children;
- Rule 2: three living children;
- Rule 3 : four living children;
- Rule 4 : one living son and one living daughter;
- Rule 5: two living sons;
- Rule 6: one living son and two living daughters;
- Rule 7: two living sons and one living daughter;
- Rule 8 : two living sons and two living daughters;
- Rule 9 : three living sons and one living daughter;
- Rule 10 : one living son and one living daughter or three living children;
- Rule 11: two living sons and one living daughter or four living children;
- Rule 12: two living sons or three living children.

It is seen that Rules 1 to 3 are framed without any allowance for sex preference. Rules 4 to 9 are meant for those couples who wish to continue reproduction until a desired minimum number of children by sex is achieved. The remaining three stopping rules (Nos. 10 to 12) regarding sex preference are framed considering that it may be unrealistic to assume that couples will continue reproduction until they achieve the desired minimum number of children of each sex.

Derivation of Current Fertility Rates

Having obtained the estimates of age at marriage and age-specific birth probabilities under control and various sex preference assumptions, the corresponding fertility rates during 1981 and their trends in the next 15 years could be derived. The current fertility indices mainly considered are age-specific marital fertility Rate (ASMFR), total marital fertility rate (TMFR), general marital fertility rate (GMFR) and crude birth rate (CBR). For this purpose, it is necessary to derive the currently married women by their current age at each future year. This is done by projecting the single-year currently married women in 1981 into future years, by making use of appropriate joint survival ratio and taking into account new entrants through marriage at each year. The details of obtaining currently married women by current age in a given year are described below.

¹ In an all-India survey carried out by ORG, Baroda, during 1980, it was found that the most frequently preferred combination of children is two sons and one daughter (34 per cent), followed by one son and one daughter (28 per cent). The next important combination of children appears to be two sons and two daughters (17 per cent). About 6 per cent of the couples indicated a preference for three sons and one daughter, while another 6 per cent preferred two sons only. The remaining 9 per cent of the couples perceived ; other than the above, as best combination of children (Khan and Prasad 1983).

To project the currently married women (aged 15-44) the following assumptions are made:

1. Marriage is assumed to be universal and no remarriage is considered. The age-specific marriage probabilities (m_y) are assumed to correspond to the pattern shown in Appendix Table 2.
2. The level of mortality for males and females is assumed to correspond to the e_0° shown in Appendix Table 3.
3. To obtain the joint survival ratio of a woman in married state, it is assumed that age differential between husband and wife is five years. Making use of e_0° for the period concerned (see assumption 2), the single-year survival ratios for males and females (S^m_x and S^f_x) are first obtained from the results of a paper by Sinha (1972) which provides complete life tables based on Coale and Demeny's Model (West) Life Tables. Appropriate joint survival ratio (S^{mf}_x) is obtained as $S^{mf}_x = S^f_x S^m_{x+5}$ ($x = 15, 16, \dots, 44$).
4. The ratio of newly married women in a year to the currently married women of the age group 15-44 in the preceding year, is assumed to be constant throughout the projection period. This ratio is estimated to be around 5.5 per cent from the census data of 1971 and 1981 (based on the method followed by Venkatacharya 1972:357),
5. The proportion m_y of women marrying at a particular age y in a year to all women that got married during the same year, is assumed to be constant throughout the projection period. Under this assumption, in the year J $m^j_y = P$
(a newly wed woman in the year j is of age y)
 $= m_y$.

The 1981 census has revealed that the population of India is 685.185 million as on 1 March 1981, Further, the total number of currently married females in the age group 15-44 is reported to be about 115.776 million. The quinquennial age distribution of the currently married females based on 5 per cent sample data (Government of India 1983) is used to derive single-year age distribution.

To project the 1981 single-year currently married females (in the age group 15-44) at each future year, the following procedure is adopted.

Let W^j_x = the number of currently married women aged x in the J^{th} year ($J = 1981, 1982, \dots, 1996$)

W^j - the total number of currently married women in the age group 15-44 in the J^{th} year

$$\left(W^j = \sum_{x=15}^{44} W^j_x \right)$$

and E^j_x = the number of new entrants through marriage into the currently married group at age x in the J^{th} year.

In view of assumptions 4 and 5 mentioned earlier, we have

$$E_x^J = (0.055) W_x^{J-1} m_x$$

Therefore, the number of currently married women age x in the J^{th} year is given by

$$W_x^J = W_x^{J-1} S_x^{mf} + E_x^J$$

This procedure is repeated from 1981 onward to obtain age-specific currently married women for each year during 1981-96.

Computation of Various Fertility Indices

Given the constancy of birth probabilities or $f_{x,y}^e$ over the time as well as of the corresponding probabilities (m_y) of marriage (under assumption 5), the single-year age-specific marital fertility rate (F_x) is not supposed to show variation over the years and is therefore independent of J . So is the total marital fertility rate (T). However, the ASMFRs by five-year age groups, the GMFR (G^J) or crude birth rate (derived later in the section) may be expected to vary, depending on the extent of changes in the population age-composition over time. The single-year ASMFRs (F_x) as well as TMFR (T), derived from F_x^J are independent of J and can be obtained by

$F_x =$ P (A married woman of age x gives birth to a child)

$$= \sum_{y=15}^{35} P \text{ (A woman of age } x \text{ gives birth to a child and the woman was married at age } y \text{)}$$

$$\sum_{y=15}^{\min(x,35)} f_{x,y} m_y \quad (x = 15, 16, \dots, 44) \text{ and } T = \sum_{x=15}^{44} F_x$$

where $m_y =$ Probability of a single woman marrying at age y

$f_{x,y} =$ Probability of occurrence of a birth to a woman given that she is aged x and is married at age y .

Note that $f_{x,y}$ is either $f_{x,y}^c$ or $f_{x,y}^e$ depending on the group (control or experimental) for which the fertility rates are to be obtained.

It is now possible to derive various other measures of current fertility. The absolute number of births to the currently married women aged x in the J^{th} year can be obtained as

$$b_x^J = W_x^J F_x \quad (J = 1981, 1982, \dots, 1996)$$

and the absolute number of births to the women in the age group 15-44 in the j th year can be obtained as

$$b^j = \sum_{x=15}^{44} b_x^j = \sum_{x=15}^{44} W_x^j F_x$$

where,

$$W_x^j = \text{Number of currently married women aged } x \text{ in the year } J.$$

Relating these births to currently married women, general marital fertility rate (G^j) as well as ASMFRs in the conventional five-year age groups ($5F_x^j$) for the control and experimental set in a given year J can be obtained.

$$G^j = \frac{b^j}{W^j} = \frac{\sum_{x=15}^{44} b_x^j}{\sum_{x=15}^{44} W_x^j}, \quad (J = 1981, 1982, \dots, 1996)$$

$$5F_x^j = 5b_x^j / 5W_x^j, \quad (x = 15, 20, 25, 30, 35, 40)$$

where,

$$5b_x^j = \sum_{i=0}^4 b_{x+i}^j$$

and

$$5W_x^j = \sum_{i=0}^4 W_{x+i}^j.$$

Remarks: The above results can also be used to estimate Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR). GRR is a slight modification of the total fertility rate. The only distinction is that the numerator of the GRR is based on female births instead of total births. The NRR also uses the age-specific female birth rates; however, it is based on the survivors of a cohort rather than on a cohort without mortality (The cohort is taken directly from a Life Table).

It is also possible to estimate the birth rate of the population under the different sex preference and stopping rule assumptions for the J th year is already known. In other words, the mid-year population for each year 1981, 1982, ..., 1996 is required. For this the derivation of total population at each future year during 1981-97 is necessary. This is done by simply projecting the 1981 census population by age and sex into future years, by making use of appropriate survival ratios which are again selected with the help of the assumed level

of male and female e°_0 of the respective period (see assumption 2). Further, in future years, the births which take place during a year under a particular fertility assumption, are to be added to survivors of the previous year's population. For this, the use is made of the absolute number of births in each calendar year obtained through the present birth probability matrices, and they are distributed by sex assuming the sex ratio at birth to be 105 males per 100 females. The enumerated population of the 1981 census is taken to be the population at the beginning of 1981. Therefore, after knowing the population the beginning of each year during 1981-97, the mid-year population during each of the years 1981-96 can be obtained and hence the birth rate. Denoting by P^T and P^1 the population at the beginning and the middle of calendar year T , we have

$$P^T = (P^T + P^{T+1})/2 \quad (T = 1981, 1982, \dots, 1996).$$

Then the birth rate can be obtained as

$$B^T = b^T/T^T$$

Where b^T is the number of births in calendar year T .

RESULTS

Having obtained the estimates of age-specific and age-at-marriage-specific birth probabilities under control and various stopping rule assumptions, the corresponding birth rates and other measures of current fertility and their trends during 1981-96 are derived by the method discussed earlier. The results are summarised in Table 1-5. It may be noted that the results are based on the pooled results of the two independent calculations made with the two birth-probability matrices. As mentioned earlier, each of the two matrices for the control and experimental sets, is obtained on the basis of 2,100 simulated cohort fertility histories. To indicate the amount of sampling error one can expect if the fertility rates are based on only one birth probability matrix, TMFRs are computed for the two independent sample matrices for the control set and for all the stopping rules under the experimental set, and are presented in Table 1. It is evident from this table that the differences in TMFRs between sample I and II are not large for each of the stopping rules and control assumptions, indicating that the above analysis could have been made without any serious error on the basis of only a single birth-probability matrix.

To understand the likely effect of sex preference on the current fertility of a population, each of the current fertility indices derived through simulation model under control and experimental set are examined. The interpretation of the results in Tables 1 to 5 is more or less similar.

TABLE 1 : TOTAL MARITAL FERTILITY RATES OBTAINED FOR THE CONTROL SET AND FOR DIFFERENT STOPPING RULE ASSUMPTIONS UNDER THE EXPERIMENTAL AGE-SPECIFIC AND AGE-AT-MARRIAGE-SPECIFIC BIRTH PROBABILITY MATRICES DERIVED BY SIMULATING 2100 COHORT FERTILITY HISTORIES FOR EACH MATRIX

	<i>Total Marital Fertility Rate*</i>		
	<i>Sample I</i>	<i>Sample II</i>	<i>Combined</i>
Control Set	5.30	5.37	5.34
Experimental Set			
Rule 1	2.11	2.11	2.13
Rule 2	3.21	3.24	3.22
Rule 3	4.13	4.21	4.17
Rule 4	2.84	3.01	2.93
Rule 5	3.64	3.64	3.64
Rule 6	4.15	4.31	4.23
Rule 7	4.05	4.22	4.13
Rule 8	4.80	4.91	4.85
Rule 9	4.96	4.97	4.97
Rule 10	2.63	2.70	2.67
Rule 11	3.83	4.02	3.92
Rule 12	2.96	3.01	2.98

* Based on single-year age-specific marital fertility rate which remains the same during the period 1981-96.

Total Fertility

Table 1 also shows the pooled Total Marital fertility Rate (TMFR) for the control set and the experimental set. Since TMFRs for the period 1981-96 remain stable under the control set and under each stopping rule (for details refer to the previous sections), they are presented for a year. The effect of sex preference on current fertility is clearly evident when TMFRs under different stopping rules are compared in Table 1. For a given size of family

(number of total living children desired) the lowest fertility would be achieved if there was no sex preference. The next lowest TMFR is when the preference is for equal number of each sex. Similarly, when the desired number of surviving sons is greater than the desired number of surviving daughters the corresponding TMFR is greater than when the preference is for equal number of each sex. The maximum is reached when the desired minimum family size consists of one sex only (all combinations are not shown in the Table). Thus, the level of TMFR increases with the increasing preference for one sex over the other, indicating that the results are basically consistent with those obtained through probability models (Das 1987b, 1989).

The TMFRs obtained here under the control set and under different stopping rules are compared to understand the implications of allowing couples to attain the desired size and/or its sex composition, on the level of current fertility. It is evident from Table 1 that the level of fertility prevailing at present in the country, can substantially be reduced even if all couples are allowed to have one living son and one living daughter (Rule 4) or two living sons and one living daughter (Rule 7). The expected TMFR under stopping Rules 4 and 7 is estimated to be 2.93 and 4.13 respectively, while it is as high as 5.34 under the control set. In other words, the current level of fertility can be reduced by about 45.1 per cent even if couples wish to have one living son and one living daughter and continue to have children until they achieve this desired composition. Even under Rule 7, where couples cease child bearing as soon as they have two living sons and one living daughter, the total fertility rate of the population is expected to reduce by about 22.7 per cent. The corresponding reduction in total fertility is obviously expected to be much higher in case of Rule 1 (60.1 per cent) and Rule 2 (39.7 per cent; where couples cease childbearing at two and three living children respectively, without regard to the sex composition). It can, however, be seen from Table 1 that the TMFR under Rule 9 (three living sons and one living daughter) is as high as 4.97. It is more than that obtained under any of the other hypothetical cases illustrated here since greater preference for size and sex (boys) is shown. For Rule 8, where a couple gives equal preference for sex (two living sons and two living daughters), the TMFR is still less (4.85) than that obtained under Rule 9. It is only for Rule 5, that the desire for one sex only is shown. The total fertility rate is expected to be relatively very high if couples wish to have children of one sex only and are allowed to have this desired minimum, without any limit on the number of total living children.

If couples are allowed to satisfy their desired family size composition subject to a certain limit on their total children, the total fertility is expected to be relatively low (see Table 1). This is shown under Rules 10 to 12 where couples are allowed to satisfy their sex preferences subject to a maximum of three or four living children. Hence the expected TMFRs under Rules 10,11 and 12 are relatively less than the corresponding TMFRs under Rules 4,7 and 5 respectively, where the couples are otherwise allowed to satisfy the same sex preference without any upper limit on their total living children.

Net Reproduction Rate

Table 2 shows the Net Reproduction Rate (NRR) for the control set and for the various stopping rules under the experimental set during the period 1981-96. The NRRs are, however, not presented for each year of the period of projection, but are given for each year

that falls at an interval on five years during 1981-96. The estimates of NRRs during this period are as such more or less stable except for a tendency to increase slightly over a period of time as a result of changes in the level of mortality. The interpretation of Table 2 is facilitated by having evaluated the results based on TMFRs (Table I). The effect of sex preference on NRR is clearly evident when NRRs obtained under different stopping rules are compared. It is quite satisfying to note that the changes in the values of NRR are in conformity with the changes in the values of TMFR.

TABLE 2: NET REPRODUCTION RATE FOR THE CONTROL SET AND FOR THE DIFFERENT STOPPING RULE ASSUMPTIONS UNDER THE EXPERIMENTAL SET, 1981-96

	<i>Net Reproduction Rate*</i>			
	1981	1986	1991	1996
Control Set	2.12	2.19	2.27	2.34
Experimental Set				
Rule 1	0.88	0.91	0.94	0.96
Rule 2	1.31	1.35	1.39	1.43
Rule 3	1.68	1.74	1.80	1.85
Rule 4	1.19	1.23	1.27	1.30
Rule 5	1.47	1.52	1.57	1.61
Rule 6	1.69	1.75	1.81	1.86
Rule 7	1.66	1.72	1.77	1.82
Rule 8	1.93	2.00	2.06	2.12
Rule 9	1.96	2.02	2.09	2.16
Rule 10	1.09	1.13	1.16	1.19
Rule 11	1.58	1.63	1.68	1.73
Rule 12	1.22	1.26	1.30	1.33

* The net reproduction rate is defined as $\sum_{x=1}^{\infty} 5b^f_x (5Lx/l_0)$.

Where $5b^f_x$ represents the rate of female births during a year, to women of age x , where x is an interval of five years, and $5Lx/l_0$ is the number of person years lived per woman (from life table).

Table 2 further reveals that the long-term demographic goal of NRR equal to 1 by 1996-2001, as spelt out in the National Population Policy (Government of India, 1981), cannot be achieved if couples are allowed to have a minimum of one living son and one living daughter. Under this pattern of reproduction (Rule 4), the level of NRR by 1996 can be expected to be about 130 in India. The level of NRR equal to 1 would be achieved if there was no sex preference and a couple would stop reproduction as soon as a family size of two living children is attained (Rule 1).

Age-Specific Marital Fertility Rate

The age-specific marital fertility rate (ASMFR) in the conventional quinquennial age groups is shown in Table 3. This is presented corresponding to the control set and experimental set for 1986. This is because the pattern of ASMFR for any other year within 1981-96 is quite close to that of 1986, for the control set and for each of the stopping rules under the experimental set. The impact of adopting stopping rules on ASMFR is clearly evident, especially in the later age groups. It is seen that all the ASMFRs under the experimental set are smaller than or equal to those of the control set for any age group. The ASMFRs for the later age group, in case of each of the stopping rules under the experimental set, are particularly much smaller than the corresponding ASMFR of the control set, the chances of satisfying the desired sex composition being relatively much higher by the time couples reach the later age groups. Thus the greater reduction in total fertility is obtained because of reduction in fertility in the middle and older age groups.

TABLE 3. AGE-SPECIFIC MARITAL FERTILITY RATE (ASMFR) FOR THE CONTROL SET AND FOR THE DIFFERENT STOPPING RULE ASSUMPTIONS UNDER THE EXPERIMENTAL SET FOR 1986.

	<i>ASMFR (Births per 1000 Married Women) under Age Group</i>					
	15-19	20-24	25-29	30-34	35-39	40-44
Control Set	123.85	277.45	274.34	204.85	145.12	76.93
Experimental Set						
Rule 1	114.23	212.40	93.31	19.18	5.26	1.81
Rule 2	117.35	267.41	185.27	68.65	23.01	6.20
Rule 3	118.48	272.16	260.10	135.33	55.44	25.14
Rule 4	116.02	240.84	149.59	64.59	25.48	10.25
Rule 5	125.22	243.66	198.91	111.96	48.48	26.69
Rule 6	122.17	264.19	237.91	146.09	71.86	29.72
Rule 7	121.14	254.12	239.22	139.18	66.40	33.77
Rule 8	122.48	261.69	270.91	188.83	105.15	50.73
Rule 9	123.44	269.25	265.05	194.84	105.04	61.73
Rule 10	110.94	237.92	142.24	44.38	14.51	4.21
Rule 11	112.22	257.29	237.03	122.99	60.83	20.60
Rule 12	122.18	242.72	169.59	60.20	18.48	6.35

General Marital Fertility Rate and Crude Birth Rate

Table 4 shows general marital fertility rates (GMFR), while Table 5 shows crude birth rates (CBR) during the period 1981-96. This is shown for the control set and for each of the

TABLE 4 : GENERAL MARITAL FERTILITY RATE (GMFR) FOR THE CONTROL SET AND FOR THE DIFFERENT STOPPING RULE ASSUMPTIONS UNDER THE EXPERIMENTAL SET, 1981-96

<i>GMFR (Births per 1000 Married Women)</i>				
	<i>1981</i>	<i>1986</i>	<i>1991</i>	<i>1996</i>
Control Set	198.57	188.25	188.96	191.95
Experimental Set				
Rule 1	82.50	77.17	83.77	86.93
Rule 2	126.01	117.50	122.33	127.45
Rule 3	160.32	151.26	152.55	157.85
Rule 4	112.91	106.19	110.89	114.82
Rule5	139.06	131.25	133.95	138.19
Rule 6	161.31	152.12	154.25	158.60
Rule7	157.79	148.67	150.25	155.12
Rule8	183.15	173.47	173.53	177.67
Rule 9	186.27	176.69	176.92	180.64
Rule 10	104.07	97.08	102.17	106.65
Rule 11	151.38	141.88	143.99	149.03
Rule 12	115.87	108.60	113.18	118.34

TABLE 5. BIRTH RATE FOR THE CONTROL SET AND THE DIFFERENT STOPPING RULE ASSUMPTIONS UNDER THE EXPERIMENTAL SET, 1981-96

<i>Crude Birth Rate per 1000 Population</i>				
	<i>1981</i>	<i>1986</i>	<i>1991</i>	<i>1996</i>
Control Set	33.52	31.80	31.97	30.60
Experimental Set				
Rule 1	14.21	13.29	14.43	15.03
Rule 2	21.53	20.09	20.93	21.89
Rule 3	27.24	25.71	25.97	26.96
Rule 4	19.34	18.12	19.08	19.76
Rule5	23.71	22.39	22.88	23.68
Rule 6	27.32	25.86	26.25	27.09
Rule 7	26.82	25.29	25.59	26.51
Rule 8	31.00	29.38	29.44	30.25
Rule 9	31.51	29.90	29.99	30.73
Rule 10	17.85	16.66	17.56	18.38
Rule 11	25.76	24.16	24.55	25.50
Rule 12	19.84	18.60	19.40	20.31

stopping rules, considered under the experimental set. It can be seen from Tables 4 and 5 that the GMFR/CBR for the period 1981-96 are more or less stable, except for a tendency to decrease slightly in the initial years and then to increase slightly in the later years. This is due to the interaction between the changing age structure of the population and fertility rates. The interpretation of the results in Table 4 and 5 is more or less similar to that of Table 1. The impact of sex preference on current fertility is clearly evident from Tables 4 and 5 for a given family size, the lowest GMFR/CBR would be achieved if there were no sex preferences. It is also evident from these tables that the level of GMFR/CBR in India could be greatly reduced by an effective campaign of limiting family size to three or less. For example, in 1986, a birth rate of 31.80 per 1,000 population reduces by 58.2 per cent under Rule 1 where couples interrupt their childbearing at two living children, and by 36.8 per cent under Rule 2 where couples cease childbearing as soon as they have three living children, without regard to the sex composition. Similarly, the level of GMFR which is observed to be 188.25 per 1,000 currently married women under the control set during 1986, is expected to reduce by about 59.0 per cent under Rule 1 and 37.6 per cent under Rule 2. Considering the degree of sex preference that prevails in a developing country like India, even if those couples who are not satisfied with the sex composition of their two or three living children, are allowed to continue reproduction until they achieve the desired minimum of each sex, the current level of GMFR/CBR can still be reduced significantly. For example, if all couples are allowed to have one living son and one living daughter but stop reproduction as soon as they achieve this desired composition (Rule 4), the same GMFR (188.25)/CBR (31.80) would still decline by about 43-44 per cent, while the corresponding reduction is about 20-21 per cent under Rule 7 where couples cease childbearing when they have two living sons and one living daughter. Similarly, the implications of allowing couples to have four living children and/or its various sex composition on the GMFR/CBR can be seen from Tables 4 and 5. The results further reveal that if each couple is allowed to have two living sons and one living daughter subject to a maximum of four living children (Rule 11), the GMFR/CBR is lower than that obtained under its corresponding stopping rule (Rule 7), which has no upper limit on the total number of children. Thus the expected reduction in GMFR/CBR, from its current level in a population, is more in the case of Rule 11 than that obtained under Rule 7. Similarly, the reduction under Rules 10 and 12 would be higher than that under their corresponding Rules 4 and 5, respectively.

Overall Effect of Sex Preference on Current Fertility

So far, the implications of adopting a particular stopping rule regarding sex preference on the level of current fertility in a population like India, have been examined. In other words, if the sex preferences within the population are homogeneous and all the couples are allowed to achieve this desired minimum, its effect on current fertility can be seen from the results presented in the previous sections. However, since sex preferences do differ even within a population, an attempt is made here to estimate the overall effect of these varied sex preferences on the level of current fertility in the country. This is done by the following procedure.

Basically the approach is similar to that used earlier (see Section 2). Apart from the current level of fertility obtained under the control set, two sets of fertility rates are obtained

under the experimental set, one allowing couples to satisfy their respective desired sex composition and the other allowing couples to satisfy their respective desired family size.

Based on an all-India survey carried out by ORG, Baroda during 1980 (see Khan and Prasad, 1983, for details) it is assumed that Indian couples have the following sex preference patterns: (a) one son (desired by 2.11 per cent of the couples), (b) one daughter (0.71 per cent), (c) one son and one daughter (25.55), (d) two sons (6.44), (e) two sons and one daughter (34.41), (f) one son and two daughters (5.13), (g) three sons (2.41), (h) three sons and one daughter (6.04) and (i) two sons and two daughters (17.20).²

Assuming that the above sex preferences are stable, nine stopping rules (R_1, R_2, \dots, R_9) are accordingly framed. It is assumed that stopping rules R_1, R_2, \dots, R_9 are followed by $P(R_1), P(R_2), \dots, P(R_9)$ proportion of the couples respectively to satisfy their individual sex preference.

Then

$$P(R_1) + P(R_2) + \dots + P(R_9) = 1$$

Having obtained, by the same procedure, simulated current- age-specific (x) and age-at-marriage-specific (y) birth matrix ($f_{x,y}$, $x = 15, 16, \dots, 44$, $y = 15, 16, \dots, 35$ where $x \geq y$) corresponding to each of these stopping rules (R_1, R_2, \dots, R_9) under the experimental set, the pooled birth matrix can be obtained by

$$\begin{aligned} f_{x,y}^p &= f_{x,y}^{R_1} P(R_1) + f_{x,y}^{R_2} P(R_2) + \dots + f_{x,y}^{R_9} P(R_9) \\ &= 0.0211 f_{x,y}^{R_1} + 0.0071 f_{x,y}^{R_2} + 0.2555 f_{x,y}^{R_3} + 0.0644 f_{x,y}^{R_4} + 0.3441 f_{x,y}^{R_5} \\ &\quad + 0.0513 f_{x,y}^{R_6} + 0.0241 f_{x,y}^{R_7} + 0.0604 f_{x,y}^{R_8} + 0.1720 f_{x,y}^{R_9} \end{aligned}$$

Similarly, the corresponding birth matrix in the absence of sex preference is derived for the same experimental group as follows. Since the sex of children would no longer be important, couples will stop reproduction as soon as their respective family size in terms of total living children desired is achieved. The distribution of couples, by their reported sex preference pattern will therefore take the following form in the absence of such a preference: (a) one child, 2.82 per cent (2.11+0.71), (b) two children, 31.99 (25.55+6.44), (c) three children, 41.95 (34.41+5.13+2.41) and (d) four children, 23.24 (6.04+17.20), assuming that the sum of the desired number of sons and daughters is the total family size desired by the couples.

2 Any other categories of sex preference which consist of less than half percentage excluded from the total cases to obtain percentage distribution of these categories.

3 These stopping rules imply that a couple will stop reproduction as soon as the specified number of living children by sex is achieved. The nine stopping rules are as follows: R_1 : 1 son; R_2 : 1 daughter; R_3 : 1 son and 1 daughter, R_4 : 2 sons; R_5 : 2 sons and 1 daughter, R_6 : 1 son and 2 daughters; R_7 : 3 sons; R_8 : 3 sons and 1 daughter, R_9 : 2 sons and 2 daughters.

Accordingly, another set of four stopping rules $R1, R2, R3$ and $R4$ are framed under the experimental group.⁴ It is assumed that stopping rules $R1, R2, R3$ and $R4$ are followed by 2.82, 31.99, 41.95 and 23.24 per cent of the couples, respectively. Having obtained the simulated birth matrices corresponding to each of the four stopping rules under the experimental set, the pooled birth matrix can similarly be obtained by

$$f_{x,y}^p(2) = .0282 f_{x,y}^{R1} + .3199 f_{x,y}^{R2} + .4195 f_{x,y}^{R3} + .2324 f_{x,y}^{R4}$$

The estimates of $f_{x,y}(1)$ and $f_{x,y}(2)$ are used to derive the corresponding birth rate and other measures of current fertility for the experimental sets by the method discussed earlier. The fertility rates based on $f_{x,y}(1)$ refer to stopping rules regarding sex preference (experimental set I), while those based on $f_{x,y}(2)$ refer to stopping rules in the absence of sex preference (experimental set II). A difference in the fertility rates of the two sets is a measure of the overall effect of sex preference on current fertility in the population under study. On the other hand, a difference in the fertility rates between the control set and the experimental set is a measure of the impact of allowing all couples to attain their respective desired family size or its sex composition on fertility. The results of these analyses are summarised in Table 6.

TABLE 6. THE OVERALL EFFECT OF SEX PREFERENCE* ON THE BIRTH RATE AND OTHER CURRENT FERTILITY INDICES IN INDIA, 1981-96

Fertility Indices/Year	Control Set	Experimental Set-I (Based on Sex Preference)	Experimental Set-II (In the Absence of Sex Preference)
TMFR*	5.34	3.92	3.03
NRR			
1981	2.12	1.57	1.23
1986	2.19	1.63	1.27
1991	2.27	1.68	1.32
1996	2.34	1.73	1.35
CBR			
1981	33.52	25.40	20.08
1986	31.80	23.97	18.83
1991	31.97	24.40	19.63
1996	32.60	25.22	20.46
GMFR			
1981	198.57	149.40	117.52
1986	188.25	141.01	110.14
1991	188.96	143.23	114.70
1996	191.95	147.49	119.11

+ The distribution of the couples by their desired family size composition is as follows: one son (2.11 percent), one daughter (0.71), one son and one daughter (25.55), two sons (6.44), two sons and one daughter (34.41), one son and two daughters (5.13), three sons (2.41), three sons and one daughter (6.04) and two sons and two daughters (17.20)

* It is shown for a year, as it is independent of the year and remains stable during the period of projection. TMFR presented here is based on single-year ASMR.

4 Each of these four stopping rules implies that a couple will stop reproduction as soon as a specified number of living children, irrespective of their sex, is achieved. The four stopping rules specifically refer to having: (a) One Living Child $R1$, (b) two living children $R2$, (c) three living children $R3$ and (d) four living children $R4$.

It is evident from Table 6 that sex preference in India seems to have a significant effect on current fertility. In the light of the present pattern of sex preferences in India, if all couples continue reproduction in order to satisfy their respective desired family size composition but stop as soon as their desired minimum is achieved, the total marital fertility of the population is expected to be 3.92 per woman (under experimental set I). In the absence of sex preference, it is estimated that this figure would decrease to 3.03 (under experimental set II). In other words, if couples cease childbearing as soon as their minimum desired family size (irrespective of sex) is achieved, TMFR is expected to be 3.03 only. Thus the overall effect of sex preference is to increase total fertility by about 29 per cent. An almost similar increase is also noted when considering other measures of current fertility (see Table 6). Considering the aggregate effect of sex preference on fertility it appears that a significant decrease in fertility could be achieved in the complete absence of any sex preference, which is an unlikely circumstance in the near future. Nevertheless, the results further reveal that even if all couples are allowed to satisfy their respective sex preferences but stop reproduction as soon as the desired minimum is achieved, the level of fertility in India could still be reduced by about one-fourth from its current level. For example, a TMFR of 5.34 as observed under the control set, reduces to 3.92 as observed earlier under the experimental set I. Similarly in 1986 the birth rate of 31.80 per 1,000 population is expected to reduce to 23.97 while GMFR of 188.25 per 1,000 married women reduces to 141.01 under the same strategy. The corresponding values of NRR are 2.19 and 1.63 respectively.

SUMMARY AND CONCLUSIONS

Despite the keen interest that has been shown in the study of sex preference and fertility, surprisingly little is known about its effects on current fertility of a population. It is needless to emphasise that such an understanding has important policy implications, especially in the developing countries where it is expected that as average family sizes begin to fall, sex preference will become more important factor in fertility decisions. Much of the research done in this area has examined the effects of sex preference on family size and sex ratio through probability models. Recently a stochastic model has been introduced by the present author to study its likely effect on birth rate and other current fertility indices and has shown that if the sex bias is stable, the expected fertility will increase with increasing preference for one sex over the other. These mathematical or stochastic models however sometimes involve some rigid assumptions which may or may not influence the results. The same problem has therefore been studied through development of a simulation model, the underlying assumptions for which are sufficiently general and realistic. In other words, the main purpose of this research was to develop a model of fertility decision-making with respect to sex preferences, so as to provide a suitable tool for consideration for policy-makers and planners in assessing the likely implications of allowing couples to attain the desired family size and composition, on the current fertility. For illustration, the model was applied to Indian data.

The results suggest that sex preference affects the current fertility of a population. If sex preference is stable, current fertility as measured through TMFR, GMFR or CBR, increases with increasing preference for one sex over the other. For a given size of family, the lowest fertility is achieved if there is no sex preference, while the maximum is obviously reached when the desired minimum consists of one sex only. Even if couples wish to have a minimum of one living son and one living daughter and keep having children to attain this, the total fertility or the birth rate of a population would always be higher than it would be if they stop at two children, irrespective of the sex. Nevertheless, in a population like India, the current fertility can be greatly reduced even if couples are allowed to have one child of each sex, but stop reproduction as soon as they attain this minimum. For example, a birth rate of 32 per 1,000 population, which is observed during 1986, under the control set, reduces by more than two-fifths (43 per cent) under such a strategy. Even if Indian couples wish to have two living sons and one living daughter (the most preferred combination), but stop reproduction as soon as they attain this, the birth rate in the country could still be reduced by about one-fifth from its current level.

It is further evident from the present analysis that the long-term demographic goal of the country, i.e. NRR equal to one by 1996-2001, cannot be achieved even if couples are allowed to have a minimum of one living child of each sex. The same can be achieved only if there were no sex preference and couples stop reproduction as soon as a total of two living children is attained. But in a society where the sex of the children is still important to parents and suitable sex selection technology is not available for mass use, it is difficult to imagine a condition where couples would adhere to the two-child norm and cease childbearing at two children irrespective of their sex. The achievement of the long-term demographic goal of NRR equal to unity even to the revised date of 2006-11 (Government of India 1985) still appears to be an unrealistic proposition.

In view of the varied size and sex preferences that prevail in India, an attempt has been made to estimate the aggregate effect of sex preference on current fertility. It is observed that the overall effect of sex preference is likely to increase total fertility or the birth rate of the population by as much as one-fourth. Considering the extent of the aggregate effect of sex preferences, it seems that a significant decrease in fertility could be achieved in the complete absence of sex preference, which is an unlikely circumstance in the near future. It is, however, interesting to note that even if all couples are allowed to satisfy their respective sex preference, but stop reproduction as soon as the desired minimum is achieved, India could still reduce its current level of fertility by about one-fourth. For example, a birth rate of 32 which is observed under the control set during 1986, is expected to reduce to 24 under this strategy. It may be noted that such a reduction is likely to be achieved under the present family planning programme, as it does not involve any additional efforts to alter the prevailing norm regarding size and sex preferences in India.

Considering this, it is recommended that the immediate goal of the country should be to aim for a birth rate of 24 which could be easily achieved under the present family planning programme. It does, however, call for a revitalisation of the family planning programme whereby couples are motivated to adopt contraception as soon as they have achieved their

desired family composition. The reduction in fertility beyond this level can be attained only through mass use of sex selection techniques which is an unlikely circumstance in the near future in a developing country like India.

Further reduction in fertility can therefore be brought about only by an effective campaign of limiting family size to three or less. This would involve approaches beyond family planning which promote the small family size norm and reduce son preference. Such approaches, however, can see fruition in the long run since they involve fundamental structural and ideological changes to reduce fertility.

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APPENDIX

TABLE 1 : VALUES OF VARIOUS INPUT PARAMETERS USED IN THE MONTE CARLO MODEL TO ESTIMATE AGE-SPECIFIC AND AGE-AT-MARRIAGE-SPECIFIC BIRTH PROBABILITIES

<i>Age group</i>	<i>Fecund ability</i>	<i>Sterility rate</i>	<i>Probability of a conception ending in a</i>		
			<i>Live birth</i> <i>(θ1)</i>	<i>Still birth</i> <i>(θ2)</i>	<i>Abortion</i> <i>(θ3)</i>
	<i>(P)</i>	<i>(β)</i>			
15-19	.027	.111,	.7888	.0625	.1487
20-24	.057	.032	.8667	.0207	.1126
25-29	.050	.052	.8841	.0201	.0958
30-34	.035	.110	.8618	.0131	.1251
35-39	.027	.269	.8110	.0473	.1417
40-44	.022	.507	.7349	.0106	.2545
<i>Gestation period associated with a</i>		<i>Mean (in months)</i>		<i>Variance</i>	
live birth (θ1)		9.64		0.46	
Stillbirth (θ2)		8.15		0.60	
abortion (θ3)		3.67		1.44	
<i>Postpartum amenorrhea following</i>		<i>Mean (in months)</i>		<i>Variance</i>	
a. livebirth (W ₁)		10.80		46.09	
a still birth (W ₂)		2.95		1.25	
an abortion (W ₃)		1.50		0.45	
<i>Probability of a birth to survive to exact age x (S_x)</i>		<i>Males</i> <i>(e⁰₀ = 54.6)</i>		<i>females</i> <i>(e⁰₀ = 55.2)</i>	
Age (in years)	1	.90143		.90661	
	2	.88164		.88354	
	-	-		-	
	-	-		-	
	10	.85103		.84989	
	-	-		-	
	-	-		-	
	20	.82912		.82284	
	-	-		-	
	-	-		-	
	-	-		-	
	-	.79128		.78333	

TABLE 2 : PROBABILITY OF A WOMAN MARRYING AT AGE x (in years)

x	m_x	x	m_x	
15	.4650	26	.0030	
16	.1100	27	.0025	
17	.0995	28	.0025	
18	.0810	29	.0025	
19	.0805	30	.0005	Mean = 16.965
20	.0640	31	.0005	Variance = 6.875
21	.0505	32	.0005	
22	.0145	33	.0005	
23	.0097	34	.0003	
24	.0073	35	.0002	
25	.0050			

Source: Computed from Government of India, 1983. *Report and Tables*. Based on 5 per cent Sample Data. Census of India, 1981: Series I, Part U Special Office of the Registrar General, New Delhi, India: 360-68

TABLE 3 : EXPECTATION OF LIFE AT BIRTH (e_l) FOR MALES AND FEMALES FOR THE PERIOD 1981-96

<i>Period</i>	<i>Male e_0</i>	<i>Female</i>
1981-86	55.6	56.2
1986-91	58.1	58.7
1991-96	60.6	61.2

Source: Government of India, 1984. *Population Projections for India 1981-2001*. Census of India, 1981. Series-I, India, Office of the Registrar General, New Delhi:9.