Model for First Birth Interval and Some Social Factors

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ABSTRACT

A probability distribution for describing the time of first live birth is developed which is more suitable for traditional societies where the age at marriage is low. The model takes account of temporary separation between husband and wife just after marriage and indirectly incorporates adolescent sterility and the restriction on sexual union imposed on younger couples. The model is applied to the data collected in the large scale sample survey entitled "Rural Development and Population Growth—A Sample Survey 1978" conducted by Centre of Population Studies, Banaras Hindu University, India.

1. INTRODUCTION

Estimation of parameters of reproduction is an important part of fertility studies. Demographers have, for long past, shown keen interest in the period between marriage and first conception or first birth for the estimation of fecundability [5, 7]. Owing to its importance in the study of human fertility, several probability models relating to this interval have been proposed under different sets of assumptions (e.g. [15, 18, 20, 4, 24]). The common assumptions in deriving these models are that the women under study are susceptible to conception at the time of marriage and that fecundability is constant for a single woman until the occurrence of first live birth conception. Fecundability may vary among women, and they are observed until the last woman conceives.

In traditional societies, the length of first conceptive delay is greatly influenced by sociocultural practices and certain physiological constants. Especially in those parts of the world where the age at marriage is low, as in

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some rural parts of India, some women may be in the stage of adolescent sterility at the time of return marriage[1] (RM). A number of sociocultural practices and taboos associated with the early part of married life also govern the timing and frequency of intercourse. For example, in some rural areas of Northern India, women, after a short stay with in-laws after RM, return to their parents for a considerable period. Further, they make frequent short visits to their parents in the following years. Older women in the family customarily isolate younger women from their husbands during the initial marital days.

Pathak and Prasad [14], Pathak [13], and Nair [11, 12] have considered adolescent sterility in their models for the first conceptive delay. On the other hand, Singh and Singh [22], in their model, took account of the period of a woman's first stay with her parents after RM.

As mentioned above, the early part of married life is governed by a large number of sociocultural variables apart from those considered by previous workers. Thus, it becomes difficult to incorporate all these factors separately, as that may lead to a complex model whose suitability is difficult to evaluate.

In this paper we have developed a probability model for the first live birth interval which takes account of the situation where women may not be exposed to the risk of conception just after the RM. Further, fecundability is considered to be time-dependent during the early part of cohabitation, an assumption which indirectly incorporates adolescent sterility, short visits to parents, restrictions on frequent sexual union, and other sociocultural factors. The application of the model is illustrated through real data.

2. MODEL

Let us consider a cohort of married women, all of the same age at RM and married for T years. Information about the time of first birth is available for those giving birth in first T years of RM, and for the rest, the time of first birth is known to be more than T years. The distribution of time between RM and first birth is derived under following assumptions:

(i) The duration of a woman's first visit to her parents immediately after RM, say Z, is a nonnegative random variable having distribution function $H(t)$. The woman is fecund when she returns to her husband.

(iia) The coital frequency of a couple is low during the early part of cohabitation and gradually increases with time during $(0, T]$. The conditional probability that a woman has coition during the interval $(t, t + \Delta t)$, given that the duration of first stay is of length Z and she has not yet had a

[1] Return marriage (*gauna*) provides a social sanction for married couples to live together. In a society where early marriages are customary, marriage only establishes the ritual union of the couple. The consummation occurs only after return marriage.

conception, is $m'(t/z)\,\Delta t + O(\Delta t)$, where

$$m'(t/z) = \begin{cases} 0 & \text{for} \quad t \leq z, \\ m'(t/z) & \text{for} \quad z < t \leq T, \quad m'(t/z) > 0. \end{cases}$$

(iib) The coitions are mutually independent, and the probability p that a coition results in a conception to a fecund woman who has not yet had a conception is constant. It is easy to see that the conditional instantaneous risk of first conception for a woman at time t with $Z = z$ is

$$m(t/z) = \begin{cases} 0 & \text{for} \quad t \leq z, \\ pm'(t/z) & \text{for} \quad z < t \leq T. \end{cases}$$

(iii) Each conception results in a live birth. The period of gestation associated with a live birth, say g, is 0.75 years.

(iv) The women belong to two distinct groups: the first consists of women who are primarily sterile, and the second consists of women who are fecund at the start of cohabitation and remain fecund until the birth of the first child. Let $1 - a$ and a be the proportions of women belonging to the first and second groups, respectively.

For a woman of the second group, the interval between RM, and first birth, say T_0, in the absence of risk of fetal wastage, is the sum of the following three components:

(a) Z, the duration of first stay of the woman with her parents,

(b) Y, the interval between time of first conception and the time of return to husband after first visit, and

(c) g, the period of pregnancy associated with the first live birth.

Thus

$$T_0 = Z + Y + g.$$

The derivation of the distribution of T_0 is similar to that of a closed birth interval without fetal wastage if the period of first visit is considered as the duration of postpartum amenorrhea [23].

Under assumptions (i) to (iii) the distribution of Y given $Z = z$ becomes

$$F_Y(t/z) = 1 - \exp\left\{ -\int_z^{t+z} m(x/z)\,dx \right\}, \qquad t > 0, \tag{2.1}$$

and the distribution of T_0, say $K(t)$, is

$$K(t) = \int_0^{t-g} \delta H(z)\, F_Y((t - g - z)/z), \qquad t > g. \tag{2.2}$$

Since a woman of the first group can never conceive, i.e. $T_0 = \infty$, the distribution of T_0 for a woman selected at random from the population is

$$\begin{aligned} P[T_0 \leqslant t] &= aK(t) \qquad \text{for} \quad g < t \leqslant T, \\ P[T_0 > T] &= (1-a) + a[1 - K(T)]. \end{aligned} \tag{2.3}$$

We now specify assumptions (i) and (ii) as follows:

(i) Z is a discrete random variable, and b_i is the probability that the duration of first stay with parents is of length τ_i ($0 \leqslant \tau_1 < \tau_2 < \tau_3 < \cdots$), with $\sum_i b_i = 1$, and

(ii) $m(t/z)$ is a polynomial of degree r in t and is of the form

$$m(t/z) = \sum_{j=0}^{r} q_j (t-z)^j \tag{2.4}$$

(i.e., the instantaneous risk of conception at time t depends on the distance between the start of cohabitation and t).

Then the expression (2.2) reduces to

$$K(t) = \sum_{i/h_i < t} b_i \left[1 - \exp\left\{ - \int_{\tau_i}^{t-g} m(x/\tau_i)\, dx \right\} \right], \qquad h_1 < t \leqslant T, \tag{2.5}$$

where

$$h_i = \tau_i + g,$$

$$\int_{\tau_i}^{t-g} m(x/\tau_i)\, dx = \sum_{j=0}^{r} q_j \frac{(t-h_i)^{j+1}}{j+1}, \qquad t > h_i.$$

3. ESTIMATION

A procedure to obtain maximum likelihood (m.l.) estimates of the parameters in the distribution (2.3) when $m(t/z)$ is a polynomial of degree two in t, for a known discrete form of the distribution of the duration of the first stay of the woman with her parents, is outlined below for grouped data. In this case, the distribution involves four unknown parameters: q_0, q_1, q_2, and a.

Let the range of the first birth interval be partitioned into k intervals: t_1 or less, $(t_1, t_2], (t_2, t_3], \ldots, (t_{k-1}, t_k]$, where $t_1 > h_1$ and $t_k = T$. The probability that the time of first live birth to a woman falls in the interval $(t_{j-1}, t_j]$ is

$$P_1 = aK(t_1),$$

$$P_j = a\{K(t_j) - K(t_{j-1})\}, \qquad j = 2, \ldots, k,$$

and the probability that the time of first live birth exceeds T, say P_{k+1}, is

$$P_{k+1} = 1 - aK(T).$$

In a sample of N women, $n_1, n_2, \ldots, n_k$ women are observed to deliver the first child during intervals $1, 2, \ldots, k$, respectively, and $\sum_{i=1}^{k} n_i = n$. The remaining $n_{k+1} = N - n$ women did not have their first child by the time T. The observed number of women classified in this manner follows a multinomial distribution given by

$$L = \frac{N!}{\prod_{j=1}^{k+1} n_j!} \prod_{j=1}^{k+1} P_j^{n_j}.$$

The m.l. estimates of the parameters are the solutions to the following equations:

$$\sum_j \frac{n_j}{P_j} \frac{\partial P_j}{\partial \theta_u} = 0 \qquad (u = 1,2,3,4), \tag{3.1}$$

where $\theta_1 = q_0$, $\theta_2 = q_1$, $\theta_3 = q_2$, and $\theta_4 = a$.

The equation (3.1) does not provide explicit expressions for the m.l. estimates. However, m.l. estimates of the parameters may be computed by a scoring method (see [17]). Pilot values of unknown parameters are required for scoring. The m.l. estimates of parameters in $m(t)$ obtained by fitting the truncated form of the distribution, defined as

$$K^*(t) = \frac{K(t)}{K(T)}, \qquad 0 < t \leq T, \tag{3.2}$$

to the observed distribution of time of first live birth in $(0, T]$, and the estimate of a obtained from the equation

$$\hat{a} = \frac{n/N}{\hat{K}(T)} \tag{3.3}$$

can be used as the pilot estimates.

Using the scoring method, the m.l. estimates of the parameters of (3.2) are solutions to

$$I\delta\theta = S, \tag{3.4}$$

where

$$I = \{I_{st}\}, \qquad s, t = 1,2,3,$$

$$I_{st} = (N - n) \sum_{r=1}^{k} \frac{1}{P_r^*} \left(\frac{\partial P_r^*}{\partial \theta_s} \right) \left(\frac{\partial P_r^*}{\partial \theta_t} \right),$$

$$\delta\theta' = (\delta\theta_1, \delta\theta_2, \delta\theta_3), \qquad S' = (S_1, S_2, S_3),$$

$$S_s = \sum_{r=1}^{k} \frac{n_r}{P_r^*} \frac{\partial P_r^*}{\partial \theta_s} \quad \text{and} \quad P_r^* = \frac{P_r}{K(T)}.$$

When $m(t/z)$ is a constant, the above model involves only one parameter, viz. q_0. Hence q_0 may be estimated from the matrix equation (3.4) by deleting the last two rows and the last two columns of the matrix I, and deleting the last two rows of both the matrices $\delta\theta$ and S. The pilot value of q_0 can be obtained by equating $\overline{X}$, the mean length of the first birth interval of those giving birth in $(0, T)$, to its theoretical expression

$$\overline{X} = \frac{1}{q_0} \frac{\sum_{i/h_i < T} b_i\left[h_i - T\exp\{-q_0(T - h_i)\}\right]}{\sum_{i/h_i < T} b_i\left[1 - \exp\{-q_0(T - h_i)\}\right]}.$$

The equation may be solved by Newton-Raphson iteration procedure.

When $m(t/z)$ is a polynomial of degree one, there are two parameters, viz. q_0 and q_1. The m.l. estimates of these parameters can be obtained by deleting appropriate rows and columns of the matrices I, $\delta\theta$, and S. The pilot values for q_0 and q_1 may be taken as the m.l. estimates of q_0 obtained by taking $m(t/z)$ to be constant and zero, respectively. Similarly when the form of $m(t/z)$ is quadratic, the m.l. estimates of q_0 and q_1 obtained above and zero may serve as the pilot values of q_0, q_1, and q_2, respectively. It should, however, be noted that alternative methods for finding pilot estimates may be used [3].

4. APPLICATION

4.1. *THE DATA*

The data used for illustration of the model are taken from the survey entitled "Rural Development and Population Growth—A Sample Survey 1978." The survey was conducted by the Centre of Population Studies, Banaras Hindu University, in 1978. In accordance with the objectives of the survey, a stratified random sample of 19 villages was selected from the Varanasi district and adjoining areas. The survey included all the households, numbering 3514, of these 19 villages.

A couple was defined as eligible if both the partners were alive and the wife was less than 50 years old on the reference date (25 March 1978, the Holi festival). For each eligible wife, the following data were obtained: the number of times married and, for the current marriage, the date and age at marriage and at RM, the duration of stay with the husband after RM, the period of first visit to parents, the intervals between RM and first birth and between consecutive births, use of family planning methods, etc.

4.2. *ILLUSTRATION OF THE MODEL*

The present study takes into account the reproductive history of eligible couples whose RM took place either at least eight or at least seven years prior to the reference date of the survey, and when the woman's age at RM was twelve or more than twelve years, respectively. Only those eligible couples are considered in the study who did not practice any family planning method; both the partners were regular residents of the village, and the woman had been married only once. Table 2, below, presents the distribution of women who had given birth during the first seven years of RM (eight years for women of age 12 years at RM) according to the time of first birth, and the number of women who did not deliver during the aforementioned period by age at RM. Women of age below 12 years and those of age 20 years or more at the time of RM are excluded from the analysis, being few in number.

In the area under study, after RM, the women stay with in-laws, usually for a very short time, and then return to their parents and stay for a longer time. During this first stay with in-laws, couples usually have small opportunity for sexual relations. This fact was shown empirically: a very small incidence of conception was found during the first stay of women with in-laws. Thus *the total duration of the first stay with in-laws and the duration of the subsequent visit to parents is taken as the duration of the woman's first stay with parents and is termed the "first stay" hereafter.* Of course, some women visit their parents only a long time after the RM; the duration of first stay of such women is considered to be zero. Table 1 presents the distribution of women according to duration of first stay separately for each age at RM. To avoid truncation effects, only women having marriage duration of five or more years are considered. For the application of the model, it is assumed that conception cannot occur before the age of 13 years. Thus, for women 12 years of age at RM, the duration of first stay is taken to be zero for those having actual durations smaller than 12 months, and for the others, 12 months is subtracted from the actual duration for use as given in Table 1.

Assuming the distribution of first stay is as given in Table 1, the distribution (2.3) with $K(t)$ given in (2.5), taking $m(t/\tau_k)$ to be constant,

TABLE 1

Distribution of Duration of First Stay of Women by Age at Return Marriage

Duration of first stay (months)	i	τ_i (years)	$h_i = \tau_i + g$ (years)	Proportion of women with $h = h_i$ having age at return marriage 12	13	14	15	16	17, 18, 19
0	1	0	0.750	0.50	0.03	0.05	0.07	0.10	0.14
0–5	2	0.208	0.958	0.35	0.15	0.18	0.17	0.14	0.12
5–10	3	0.605	1.375	0.04	0.30	0.34	0.32	0.32	0.25
10–20	4	1.250	2.000	0.04	0.43	0.35	0.34	0.34	0.36
20–30	5	2.083	2.833	0.03	0.05	0.05	0.07	0.07	0.09
> 30	6	2.917	3.667	0.04	0.03	0.03	0.03	0.03	0.04
Total	—	—	—	179	414	541	676	491	551

TABLE 2

Distribution of Women Giving Birth in the First Seven Years of RM[a]

Interval between RM and first live birth (years)	Number of women having age at RM[b]											
	12[c]		13		14		15		16		17–19	
	O	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*
0 –1.75	12	13.1	7	8.3	17	19.2	45	42.1	49	46.2	69	67.4
1.75–2.75	36	32.3	49	48.5	98	93.6	123	130.2	102	108.2	136	142.3
2.75–3.75	39	36.5	96	86.1	143	138.6	163	154.3	113	105.9	128	128.3
3.75–4.75	22	28.8	75	83.9	104	111.2	113	121.8	67	75.1	73	78.2
4.75–5.75	16	17.5	52	56.7	56	59.3	79	72.7	49	42.5	34	35.0
5.75–7.00	13	9.8	37	32.5	29	25.1	37	38.9	21	23.1	15	13.8
No birth in first 7 years	23	23.0	58	58.0	47	47.0	60	60.0	35	35.0	48	48.0
Total	161	161.0	374	374.0	494	494.0	620	620.0	436	436.0	513	513.0
χ^2	3.502		3.305		1.844		2.353		3.072		1.528	
Estimates												
q_0	0.012		0.019		0.028		0.176		0.334		0.444	
q_1	0.224		0.258		0.342		0.208		0.160		0.239	
a	0.882		0.876		0.916		0.925		0.941		0.913	

[a]According to time of first live birth and number of women with no birth in the period by age a RM.

[b]O = observed frequency; E = expected frequency.

[c]Interval length is measured from age 13.

linear, or quadratic in t, is applied to the data given in Table 2. In all cases the assumption that $m(t/\tau_k)$ is constant gives a poor fit. When $m(t/\tau_k)$ is taken as a linear function of time, a better fit is obtained. However, for a quadratic form of $m(t/\tau_k)$ the improvement in fit is negligible. Also, the likelihood ratio criterion for testing the null hypothesis $q_2 = 0$ against the alternative hypothesis $q_2 \neq 0$ has been calculated for each set of data and is found to be insignificant. The expected distribution of women according to the length of first live birth interval and the estimates of the parameters, for the case when $m(t/\tau_k)$ is linear, are also presented in Table 2. The variances of estimators and correlation coefficient between the estimators are given in Table 3.

The estimate of the conception rate at the start of cohabitation, $\hat{q}_0$, is near zero for women 12–14 years old at RM. It is 0.18, 0.33, and 0.44 for women 15, 16, and 17–19 years old, respectively, at RM. q_1, a measure of the rate of increase, is maximum for women with age at RM of 14 years, more or less the same for women with ages at RM of 12, 13, and 17–19, and smaller for women with ages at RM of 15 and 16 years. However, $m(t/\tau_k)$ for any

TABLE 3

Estimates of Variances and Correlation Coefficients between Estimators under Linear Form of Risk Function

Age at RM	$10^4 \times$ Var(q_0)	$10^4 \times$ Var(q_1)	$10^4 \times$ Var(a)	Corr(q, q_1)	Corr(q_0, a)	Corr(q_1, a)
12	20	19	9	−0.781	0.173	−0.312
13	13	15	5	−0.805	0.253	−0.421
14	14	16	2	−0.812	0.133	−0.219
15	14	12	2	−0.810	0.265	−0.453
16	34	30	3	−0.818	0.320	−0.539
17–19	61	61	2	−0.852	0.140	−0.215

given t and τ_k increases with increasing age at RM. Thus, the smaller values of $\hat{q}_0$ at the start, for younger women, may be attributed to adolescent subfecundability, strict traditional coitus regulation, etc., and with the passage of time the attainment of fecundable state, gradual withdrawal of sexual restrictions, etc., may be responsible for higher values of q_1. On the other hand, a major proportion of women married at ages 15 and above are expected to be fecund when they are exposed to sexual union; and social forces that oppose the sexual relations also become weaker at higher ages. These may be reasons for the higher values of $\hat{q}_0$ and lower estimates of q_1 for such women. The slightly higher value of q_1 for women with age at RM of 17–19 years than for women with age at RM of 15 or 16 years may be because of the traditional expectation by elderly members of the family of early birth and mental and physical maturity of couples, causing women to wish to have an early pregnancy.

Define $\overline{m}(y+t)$, the average risk of first live-birth conception at age $y+t$ for women having age at RM y, as the weighted average of $m(t/\tau_k)$ in which the weight is the ratio of the number of fecund women having $Z=\tau_k$ who did not conceive by time t, to the total number of fecund women who did not conceive by time t:

$$\overline{m}(y+t)=\frac{\sum_k b_k\left[\exp\left\{-\int_{\tau_k}^{t} m(x/\tau_k)\,dx\right\}\right]m(t/\tau_k)}{\sum_k b_k\left[\exp\left\{-\int_{\tau_k}^{t} m(x/\tau_k)\,dx\right\}\right]},$$

where

$$\int_{\tau_k}^{t} m(x/\tau_k)\,dx=0,\qquad t<\tau_k.$$

TABLE 4

Average Risk of First Live-Birth Conception According to Age at RM

Age at RM (years)	Average risk of first birth conception at ages										
	14	15	16	17	18	19	20	21	22	23	24
12	0.19	0.38	0.57	0.74	0.90	1.05	1.20	—	—	—	—
13	0.07	0.27	0.49	0.72	0.94	1.15	1.36	—	—	—	—
14	—	0.12	0.38	0.66	0.94	1.21	1.46	1.72			
15	—	—	0.15	0.39	0.58	0.77	0.96	1.14	1.33		
16	—	—	—	0.21	0.44	0.62	0.77	0.91	1.05	1.20	
17*	—	—	—	—	0.25	0.54	0.82	1.02	1.22	1.41	1.61

*Computation is based on the estimates of instantaneous risk of conception obtained for women with age at RM of 17–19 years.

The values of $\overline{m}(y+t)$ are obtained for $t=1,2,\ldots,7$ for each age at RM and are given in Table 4. $\overline{m}(a)$ is found to decrease with increasing age at RM, which also indicates that the increase in conception rate with time may be due to weakening of social restrictions on sexual union.

It is difficult to identify inability of a couple to procreate, as sterility is only suspected if, in the absence of deliberate efforts to control fertility, a woman is unable to have any recognizable conception during a sufficiently long period after marriage. Here, the estimates of the proportion of primarily sterile couples, $1-\hat{a}$, are obtained according to the age at RM of women. The estimate is about 9 percent—a little higher for women with age at RM of 12, 13, 14, 15, and 17–19 years than for those with age at RM of 16 years, for whom it is 6 percent. The higher values of $1-\hat{a}$ for women with lower age at RM may be because b_i, the proportion of women exposed to the risk of conception at time τ_i $(i=1,2,\ldots)$ following RM, as considered here (see Table 1), is smaller for lower values of τ_i because of factors such as nonattainment of menarche, adolescent sterility, or social customs imposing restriction on sexual union at younger ages. On the other hand, the age at marriage is high in the upper castes, where the joint family system, level of education, migration of men to urban areas for employment, etc., are more prevalent. Thus, a significant proportion of men to women with age at RM of 17–19 years may be either students or in search of employment, causing delay in conception for a considerable period. This may be the reason for the higher values of $1-\hat{a}$ for such women.

The findings of other studies in India are that the proportion of primarily sterile couples lies roughly between 2.4 and 10.5 percent [1, 8, 16]. Singh and associates, based on the data of the present survey and others conducted in the same locality, reported that about 5 percent of couples are primarily sterile (e.g. [2, 21]). Thus the estimates of $1-a$ obtained for women having age at RM of 15 or 16 years may be considered to be closer to the true value. The model can easily be extended by incorporating fetal wastage. Further, some other functional form of $m(t)$ may give suitable results.

Here the conception rate is age dependent, but for simplicity the variation among women is ignored. An extensive literature on the distribution of time of first birth for a heterogeneous population has been summarized in [9, 10, 19]. Heterogeneity may be introduced by assuming the conception rate is of the form $\theta m(t)$ and choosing a suitable form of distribution of θ in the population, or by specifying the conception rate as a product of $m(t)$ and a multiplier which is a function of the explanatory variables. The present model may be extended in light of the above factors (see [6]).

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