Approaches to Study Parity Progression of Fertility with illustrative application to India's National Family Health Survey

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Background: Among several approaches, analysis of closed and open birth intervals is taken as the simplest to study the degree of transition from one specific-parity to next higher parity (parity progression ratios). They are dependent of certain assumptions and broadly categorized into stochastic models or life table framework.

Objectives: The aim of this paper is to provides estimates of the parity progression ratios (PPRs) from the truncated distribution of birth intervals and the life approach as the probability of transition for women from one specific parity to next higher parity. It also aims used to study the level and determinants of fertility in India's population.

Method: It evolved two models, one that considers the distribution of closed birth intervals and open birth interval truncated as a specific time to estimate the parity progression ratios. The life table approach has been adopted as second model to combine the data on closed and open birth intervals in life table format and estimates parity progression ratio as the complements of the survival probability after a specific time point after the last birth. The latter approach under the multivariate is subsequently considered to study the impact of intermediate variables on fertility.

(1) Stochastic model

Srinivasan (1968) propounded the method of estimating instantaneous parity progression ratios (IPPR) as:

$$E(U_i) = \alpha_i \frac{E(T_i^2)}{2E(T_i)} + (1-\alpha_i) \frac{E(V_i^2)}{2E(V_i)} \qquad \dots (1)$$

Where, $E(U_i)$ is the mean of open birth interval and, $E(T_i)$ and $E(T_i^2)$ are mean and second moment of T_i (inter-live birth interval between i^{th} and $(i+1)^{th}$ birth). V_i is the interval between the date of birth of last child (for parity "i" women) and end of reproductive age, say 45 years. α_i be the proportion of women who go for the next higher order $(i+1)^{th}$ birth and $(1- \alpha_i)$ do not go for the next birth

As the data on V_i are seldom available in fertility surveys and even if available, they suffer from various types of biases, Yadav et al. (1992, 2013) addressed considered only those OBI which were less than a specified value, say, C such that $P[T_i \geq C] \approx 0$.

If α_i^* be the probability that the woman after i^{th} birth go for the next higher order $(i+1)^{th}$ birth and $(1 - \alpha_i^*)$ do not go for the next birth. Considering only those OBI which are less than C, the total number of fecund women having OBI<C will be:

$$\int_0^C \alpha_i^* B_i [1 - F_i(u)]\, \mathrm{d}u = \alpha_i^* B_i\, E(T_i) \text{ and} \qquad \ldots (2)$$

the total number of infecund women with OBI<C will be:

$$\int_0^C (1 - \alpha_i^*)\, B_i\, \mathrm{d}u = (1 - \alpha_i^*)\, B_i\, C \qquad \ldots (3)$$

So, the total number of women at the time of survey with OBI<*C* will be

$$\alpha_i^* B_i\, E(T_i) + (1 - \alpha_i^*)\, B_i\, C.$$

Thus, the proportion of women in the sample at the time of the survey with OBI < C who will go for the next higher order $(i+1)^{th}$:

$$\alpha_i = \frac{\alpha_i^* E(T_i)}{\alpha_i^* E(T_i) + (1 - \alpha_i^*) C} \qquad \ldots (3)$$

The mean OBI of women whose OBI<*C* is given by,

$$E(U_i^c) = \alpha_i \frac{E(T_i^2)}{2E(T_i)} + (1 - \alpha_i) \frac{C}{2} \qquad \ldots (4)$$

After solving the above, we get,

$$\alpha_i^* = \frac{C^2 - 2CE(U_i^c)}{C^2 - 2[E(T_i^2)] - \{C - E(T_i)\} E(U_i^c)]} \qquad \ldots (5)$$

Thus, with the knowledge of $E(U_i^c)$, $E(T_i)$, $E(Ti^2)$, and C, we can estimate both α_i(IPPR) as well as α_i^*(PPR). The above concept of introducing C (a specified value) and using mean of open birth interval truncated at C, can be tried under the life table framework as well.

(2) Life table combining closed and open birth intervals to estimate parity progression ratios

We combine closed birth intervals of women who have had a birth of a particular order and open birth interval for women who have not experienced the birth of same order at the time of survey. We define the time interval ($t_{ij} \leq t < t_{i,j+1}$] during which an individual woman, having had i^{th} birth, experience either her $(i+1)^{th}$ birth or do not experience a birth but the survey remaining in the same state. In latter situation, the interval is open birth interval and called censored times for the specific i^{th} birth. Aggregate them into intervals given by t_{ij}, j = 1, …, n with each interval containing counts for $t_{i,j} \leq t < t_{i,j+1}$. Suppose that d_j and m_j respectively be the number of births (event) and censored (failures) observations during the interval. Let N_{ij} be the number of women at the start of the interval with specific parity i. Define $n_{ij} = N_{ij} - \frac{m_{ij}}{2}$ as the adjusted number at risk at the start of the interval. The product-limit estimate of the conditional survivor function is:

$$S_{ij}=\prod_{k=1}^{j} \frac{n_{ik}-d_{ik}}{n_{ik}} \qquad \text{… (6)}$$

Then, 1- S_{ic}, would approximate as the parity progression ratio p_i for a priori value of $T_{ij}=C_i$.

We can further examine the net effect of the variables on the timing of births through the development of multivariate life table. The basic model is proportional hazard model which expresses the logarithm of the hazard rates as a linear function of a set of independent variables or covariates as follows:

$$\lambda(t, x) = \lambda_0(t)e^{\beta x} \qquad \text{… (7)}$$

Where, λ(t, x) is the hazard rate at time t, λ_0(t) is the baseline hazard function, X is a vector of covariates and β is a vector of the corresponding regression coefficients. In subsequent researches, time dependent covariates were also followed.

Data: It uses data the data from the National Family Health Survey, 2005-06 (NFHS-3).

Results and conclusion:

Based on all India data on birth intervals in third round of National Family Health Survey, 2005-06 (NFHS-3), the mean and second moment of T_i (closed birth interval between i^{th} and $(i+1)^{th}$ and U_i for all ever married women age 15-49 are presented respectively for first four columns of Table 1. The estimates of parity progression ratios based on life table denoted are consistently greater than the estimates based on direct use of mean closed and open birth intervals are same in the beginning, e.g., from marriage to first birth and from first to second birth. However, the estimates of PPR based on the life table as compared to the other model are consistently greater for higher parities after parity 2.

The implied estimate the total marital fertility rates (TMFR) derived from the estimates of PPR based on life table approach is close to its direct estimate. The latter approach when used under multivariate framework found there is impact of the place of residence and education of mothers as two important intermediate variables affecting fertility in India (Table 2).

Table 1: Estimates of PPR & IPPR for ever-married women aged 15-49 years NFHS-3, India (2005-06)							
Parity	$E(T_i)$	$E(T_i^2)$	$E(U_i)$	$E(U_i^2)$	α_i	α_i^*	KM α_i^*
P_{0-1}	27.6	1207.56	28.2	1578.99	0.83	0.96	0.96
P_{1-2}	36.8	1740.78	30.8	1717.07	0.80	0.93	0.94
P_{2-3}	35.4	1610.36	44.6	3118.75	0.41	0.70	0.76
P_{3-4}	34.4	1514.91	50.9	3839.1	0.24	0.52	0.67
P_{4-5}	34.1	1471.74	51.8	3900.06	0.21	0.49	0.65
P_{5-6}	33.4	1432.35	52.6	3995.63	0.19	0.46	0.63
P_{6+}	32.6	1336.75	52.0	3967.01	0.20	0.48	0.63
Implied TFR for p_B= 0.96					1.85	2.05	2.74

Table 2: Estimated relative position of 1-S(c; **x**) by place of residence, India, NFHS-3 (2005-06)					
Parity→	0-1	1-2	2-3	3-4	4-5
Place of residence					
Rural	1.00	1.00	1.00 for	1.00	1.00
Urban	1.14*	0.80*	0.71**	0.74**	0.78**
Mother’s education					
<Primary	1.00	1.00	1.00	1.00	1.00
Primary	1.08*	0.95*	0.72**	0.65**	0.67**
Secondary	1.20*	0.78**	0.45**	0.45**	0.48**
Higher	1.23*	0.45**	0.17**	0.21**	0.29**
*Significant at 5% level of significance, ** Significant at 1% level of significance					

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