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## Models to Study Birth Intervals & Parity Progression Ratios

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# 1. Introduction

- Study of the human reproductive patterns has been of interest to demographers, social scientists and public health researchers to understand the family building process and the life course.
- Data on birth intervals are taken as the sensitive measure of human fertility particularly for detecting the current changes in natality patterns of women who are still in the reproductive ages.
- Conventional measures used for studying fertility do not always provide a clear description of the conditions underlying the observed fertility trends and are not sensitive to small and short-term changes in the reproductive patterns, especially when fertility is highly controlled.

# 1. Introduction

- In fact, the initial stages of fertility transition occur mainly as a result of earlier cessation of child bearing and afterwards as a consequence of the changes in the spacing between births.
- Moreover, the spacing pattern can affect the intrinsic growth rate as well as the mean generational length of any population (Srinivasan, 1980).
- Thus, the timing of births can be viewed as a major determinant of population change that can provide insight into the mechanisms underlying the fertility behaviour of a population by disaggregating the reproductive process.

## 1. Introduction

- In fact, human fertility is governed by its two components:

  (1) The pace with which the women are bearing children, i.e., the age at which women begin childbearing and have subsequent births; and

  (2) the degree of transition of women from one specific-parity to next higher parity, i.e., parity progression ratios (PPR).

- ❖While former is estimated and analysed based on the birth history data on inter-live birth intervals, the later requires data on both closed and open birth intervals.

- ❖There have been efforts to use birth order statistics as well to estimate PPR.

# 1. Introduction - Type of Birth Intervals

- Let us give a look at the following sequence of events to visualize the types of birth intervals.

←----- $T_0$ ------→ ←-----$T_1$ -----→ ……………………………………………… ←---- $T_{(i-1)}$ ------→ ←----- $U_i$ ------→ ←----- $Z_i$ -----→

↓------------------- ↓ ----------------↓ ------------------------------------ ↓ ------------------- ↓ ------------------↓ --------------- ↓

Marriage 1st birth 2nd birth (i-1)th birth ith birth Survey (i+1)th birth

1) *First birth interval*- the interval between marriage and the first birth is called first birth interval.
2) *Inter-live closed birth interval* - the interval between two consecutive births is called closed birth interval.
3) *Open birth interval* - the interval between the date of birth of last child and the survey date is called open birth interval.

## 1. Introduction - Type of Birth Intervals contd. …

4) *Straddling birth interval* – any closed birth interval that straddles the survey date is said to be straddling birth interval. In this case, one birth occurs before that age / time point (e.g., survey date) and the other birth occurs after the survey date.

   The closed birth interval that begins and ends in any segment of time (age-group or the marital duration or interval between two survey dates) is called *interior closed birth interval*.

5) *forward birth interval* - the interval between survey date and the date of next live birth after the survey is called forward birth interval.

## 1. Introduction contd. …

- ❖As such, the data on birth intervals are governed by the ascertainment plans (retrospective, prospective or straddling).
- ❖Most surveys produce cross-sectional data, where the information pertains to the experience up to the date of the survey and thereby researchers are confronted with the following issues:
  a) selectivity,
  b) censoring, and
  c) truncation

## 1. Introduction contd. …

(a) Selectivity –

- If we consider a sample of recently married women and follow them month by month to observe the duration of first birth or consecutive births, we can see that those who are more fecund would conceive sooner and less fecund conceive latter. Thus, the summary statistics based on such sample would be over represented by greater fecund women and thereby will exaggerate the rate of conception.
- This kind of over representation of highly fecund women is called selection bias.
- If everyone had the same conception rate, then the selection effect would not exist.
- This issue is discussed in detail in a classical paper by Singh, Bhattacharya & Yadav (Jr of American Statistical Association, 1979)

## 1. Introduction contd. …

(b) Censoring –

- In surveys, we are met with the complete and incomplete (censored) information

  (Cox, 1972; Rodriguez, 1988; Namboodiri and Suchindran, 1988 etc.)

(c) Truncation -

- In surveys, there could be nonavailability of sufficient exposure period (marital duration) for having at least ‘i’ ($i \geq 1$) births.
- The issue is described in detail
  - based on simulation Venkatacharya and Roy 1969); Sheps et al. (1970), Sheps and Menken, (1972, 1973); and Poole, 1973;.
  - Based on explicit models Singh, Yadav, Pandey (1979), Pathak and Shastry (1984) etc.

# 1. Introduction example

contd. …

- For this, let us consider an example of the interval between 1st and 2nd birth in NFHS-3 (UP) data (tabulated by Yadav and Rai, 2019):
- We find that the mean is 29 months for women with marriage duration 5-9 year and 34 months for women over 20+ years marriage duration.
- Then the natural question arises whether 29 months to be considered as the true mean of first order closed birth interval?
  - The answer is no!
- Because all women who conceive late and give birth latter, did not get sufficient time to give at least 2 births in a marital duration of 5–9 years and thereby larger birth intervals could not be included in the study resulting into lower observed mean.

## 1. Introduction example contd. …

- On the other hand, the mean interval between 1st and 2nd birth is almost constant for the marital duration 10+
- This suggest that the chance of including all women who are to give at least two births for marital duration 10+ years is almost one, and hence the interval between 1st and 2nd birth of these women can be considered as reasonable estimates of the mean of the first order CBI.
- In fact, former was the situation of excluding larger proportion of longer birth intervals. The issue is precisely known to cause truncation effect which has been described by Sheps et al. (1970), Pathak and Pandey (1990); Sheps and Menken (1972, 1973).

## 1. Introduction example contd. …

- There is another issue of ascertainment plan as follows:
- In the same data set, there were 136 women who had given 4 births, and among them the mean of the interval between 1st and 2nd birth, and, between 2nd and 3rd birth were **34** months, but mean interval between 3rd and 4th birth was 38 months.
- Similarly, there were 138 women who had given 5 births; the mean of the most recent closed birth interval (CBI) is significantly greater than the means of other usual CBI.
- Hence, we can say that the mean of the most recent closed birth interval is significantly greater than the means of other previous CBI.
- This suggest dealing the two, differently in analysis.

## 2. Modelling as a suitable approach

- These kinds of problems are said to be handled by appropriate models.
- In fact, modelling is an abstraction of the process indicating the relevant relations among different elements and when expressed mathematically, called mathematical models.
- Initial efforts to study the birth intervals seem to be in French by Gini, Louis Henry, Norman Ryder and some others, and became known when some of the works were translated into English by Mindel Sheps in 1972.
- First model appears to have been on the time of first conception.

## 3.1 Modelling time to first conception

If ‘p’ be the monthly chance of conception (fecundability) and conception is the outcome of a sequence of Bernoulli trials, the time of first conception after marriage consummation (X) follows a geometric distribution, i.e.,

$$P(X = x) = q^{x-1}p,\ x = 1, 2, \ldots, 0 < p < 1, q = 1 - p). \quad \ldots (1)$$

$$E(X) = \sum_{x=1}^{n} x\, q^{x-1} p = \frac{1}{p}; \text{ and} \quad \ldots (2)$$

$$Var(X) = \frac{q}{p^2}. \quad \ldots (3)$$

Hence, one can estimate ‘p’ from the data on time to first conception/birth. Gini (1911) and a study of 24 Women in Crulai.

## 3.1 Modelling time to first conception

If we incorporate the provision that the population of women is heterogeneous w.r.t. to fecundability p, we shall have,

$$P(X = x) = \int q^{x-1} p\, f(p)\, dp \qquad \dots (4)$$

Potter & Parker (1964) and Sheps (1964) assumed f(p) to be Beta distribution.

If time is treated as a continuous random variable and 'm' is the conception rate, the probability model of $T_0$ is given by,

$f_0(x)$ = m $e^{-mx}$ for homogeneous population of women,

= $\int m\, e^{-mx} f(m)\, dm$ for heterogeneous population of women. … (5)

Singh (1964) considered f(m) to be a type III Gamma distribution.

### 3.1 Modelling time to first conception

- Note that the above models were under the assumption that the we could observe the outcome for a long time which is not always feasible.
  - Hence, Suchindran and Lachenbruch (1974) Singh et al. (1972, 1976) developed truncated version of the model and estimate the parameters.
  - Efforts were also made to incorporate the chance of foetal losses before the occurrence of first live birth and methods to estimate the parameters from the truncated data.
- Pathak and Prasad (1977) included and estimated the extent of adolescent sub-fecundity/infertility for the population where consummation of marriage used to take place early before the maturation of couples.

### 3.2 Modelling inter-live birth intervals

The model was further extended to analyze inter-live birth intervals by Srinivasan (1966) by incorporating the period of post-partum amenorrhoea (PPA) after a birth,

Accordingly, probability density function $f_i(x)$ the inter-live birth interval $T_i$ is given by

$f_i(x) = m\, e^{-m(x-h)}$ for homogeneous population of women, ... (6)

$= \int m\, e^{m(x-h)} f(m)\, dm$ for heterogeneous population of women.... (7)

Where "$m$" is the conception rate and h = gestation period + PPA.

The discrete-time model of (6) was first used by Srinivasan (1966) while

Singh & Bhaduri (1972) used the continuous time model (7) to study the birth intervals.

## 3.2 Modelling inter-live birth intervals

- Several researchers analyzed birth interval data in different parts of the world, e.g.,
  - Jain (1969), analyzed data on birth intervals from Taiwan;
  - Chakraborty (1974) from Varanasi Survey;
  - George (1977) from Kerala Fertility Survey etc.
- However, they did not visualize the kind of problems stated above.
- It is Sheps et al. (1970) who first visualized the problem of truncation and distinguished the difference between birth intervals of,
  - those women who have given at least (i+1), and
  - those who have given exactly “(i+1)” births, prior to the survey.

## 3.2 Modelling inter-live birth intervals

- The model of the interval between $i^{th}$ and $(i+1)^{th}$ birth for women who have given <u>at least</u> (i+1) birth in (0,T),) is give by,

$$h_i(x/T) = \frac{G_i(T-x)f_i(x)}{G_{i+1}(T)},\ i\geq 0,\ x\leq T \qquad \ldots (8)$$

Where $G_i(T)$ is the waiting time distribution function for $i^{th}$ birth.

The model for the interval between $i^{th}$ and $(i+1)^{th}$ birth for women who have given <u>exactly</u> (i+1) birth in (0, T) is give by,

$$h_{iL}(x/T) = \frac{P_i(T-x)f_i(x)}{P_{i+1}(\bar{l})},\ i\geq 0,\ x\leq T \qquad \ldots (9)$$

## 3.2 Modelling inter-live birth intervals in a marriage cohort

Where, $P_i(T)$ is the probability distribution of "i" births and given by the difference of two consecutive distribution functions, i.e.,

$$P_i(T) = G_i(t) - G_{i+1}(t),\ i>0. \qquad \dots (10)$$

Note that the above model remains inside the simulation lab ands appreciated by limited researchers.

If we take $f_0(x)$ and $f_i(x)$ as (5) and (6) and one-to-one correspondence between a conception and a birth, $G_i(T)$ and $P_i(T)$ are given by,

$$G_i(t) = 1 - e^{-m(T-(i-1)h)} \sum_{j=0}^{i-1} \frac{[m(T-(i-1)h)]^j}{j!} \text{ and} \qquad \dots (11)$$

## 3.2 Modelling inter-live birth intervals in a marriage cohort

$P_0(T) = 1 - \alpha\, e^{-mT}$; ... (12)

$P_i(T) = \alpha\, [e^{-m(T-ih)} \sum_{j=0}^{i} \frac{[m(T-ih)]^j}{j!} - e^{-m(T-(i-1)h)} \sum_{j=0}^{i-1} \frac{[m(T-(i-1)h)]^j}{j!}]$ ... (13)

Where, α be the probability that the woman under study is susceptible.

Hence, corresponding mean and variances of $X_i$ and $X_{iL}$ could be derived.

With the help of these models we can analyze the data on birth intervals and get reliable estimate of the parameters that accounts for the ascertainment plan and truncation effects.

## 3.2 Modelling inter-live birth intervals - Remarks

- While Indian researchers like Singh et al. (1979), Pathak and Shastry (1984), Pandey et al. (1988; 1989) etc. propounded these models with application to sample survey data;
- Recently, Yadav and Rai (1019) have reviewed and analysed birth intervals from NFHS data and estimated various parameters.
- It is concluded that one may prefer to analyse most recent closed birth intervals which are relatively easy to ascertain and correlate to the current fertility of women, but by proper method (right model).

### 3.3 Modelling open birth interval

- Srinivasan (1967, 1968) introduced the concept of open birth interval.
- Sheps et al. (1970) presented a general model of open birth interval of women of parity "i", $k_i(u|T)$ as follows:

$$k_i(u|T) = \frac{g_{i-1}(T-u)\, Q_i(u)}{P_i(T)}, \quad \dots (14)$$

- where, $g_{i-1}(T-u)$ is the cumulated time density function, $Q_i(x)$ is the probability of "no birth" in an interval of length "u" after the $i^{th}$ birth, and $P_i(t)$ is the probability of exactly "i" births in time (0, T).
- For large T, the model is quite simple as:

$$u_i(x) = \frac{Q(x)}{E(T)} = \frac{1-F(x)}{E(T)} \quad \dots (15)$$

Pathak (1971), Singh et al. (1982) and Pandey (1985) etc. derived explicit models of open birth interval and estimated fertility parameters fecundability and sterility.

# 3.4 Modelling straddling birth intervals

## 3.4 Straddling Birth Interval

Srinivasan (1967) while introducing the concept of open birth interval presented following figure:

←<<<<<<<<<<<<<<<<<<< $T_{1(i-1)}$ >>>>>>>>>>>>>>>>>>→ ←<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< $T_{1i}$ >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>→

↓---------------------------------------------- ↓ ---------------------------- ↓ ......................................................↓

(i-1)th birth     ith birth ←<<<<<<<<<<<<<< $T_{2i}$ >>>>>>>>>>>>→Survey date     (i+1)th birth

$T_{2i}$ (open birth interval) was taken as a random segment of $T_{1i}$ which is same as $T_{1(i-1)}$ and if births are uniformly distributed, $E(T_{2i}) = ½ E(T_{1i})$.

- Leridon (1969) having questioned Srinivasan's results, suggested that the interval $T_{1i}$ which includes the survey date is proportional to the length of $T_{1i}$.

## 3.4 Models of Straddling Birth Intervals

- i.e., larger intervals of $T_{1i}$ have more chance of inclusion of a survey than the smaller intervals and it is a straddling closed birth interval.
- Hence, the model for straddling birth interval, $k_i(t)$, will be proportional to the length and distribution of usual closed birth intervals, i.e., $k_i(t) \alpha \; t \; f_i(t)$ and

Hence, $k_i(t) = \frac{tf(t)}{E(T)}$ … (16)

where E(T) is the mean of $T_{1(i-1)}$. (Same was earlier found by Henry).

- Specific models were developed by Yadav and Pandey (1989) and used with real data to estimate the parameters.
- This feature is also called as length biased sampling because the intervals of larger lengths have larger probability of inclusion in the study.

## 4 Parity progression ratios

French demogrphers Luis Henry (1953) and Norman Ryder (1953) introduced the concept of parity progression ratios (PPR) as the probability that a woman after delivering her $i^{th}$ birth will ever proceed to the next birth ($p_i$).

$$p_i = \frac{\text{Number of women who have (i+1) birth}}{\text{Number of women who have i birth}}, \; i \geq 0.$$

It is a conditional probability, and the cumulative probability would give the estimate of total fertility rate:

$$TFR = p_0 + p_0\, p_1 + p_0\, p_1\, p_2 + p_0\, p_1\, p_2\, p_3 + \ldots$$

This concept, however, did not gain wide application due to:

- the issues related to its measurement, data needs, and
- conceptualization with respect to cohort and period measures.

## 4 Parity progression ratios

- In this context, let us recall the model of open birth interval (15) as:

$$u_i(x) = \frac{Q(x)}{E(T)} = \frac{1-F(x)}{E(T)}$$

Wherein Srinivasan (1967, 68) presented that mean of $U_i$ as:

$$E(U_i) = \frac{E(T_i^2)}{2E(T_i)} \quad \dots (17)$$

- Where, $E(U_i)$ is the mean and second moment of open birth interval, $E(T_i)$ 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).

- The above results are true only for those women who continue to reproduce at least up to $(i+1)^{th}$ birth.

## **4. Modelling open birth interval to estimate ppr** contd. …

- For those women who gave birth to their $i^{th}$ child between "u" time prior to the survey (open birth interval) and that $i^{th}$ birth happen to be the last birth, the mean open birth interval is:

$$E(U_i) = \frac{E(V_i^2)}{2E(V_i)} \qquad \dots (18)$$

  - Where, $V_i$ is the interval between the date of birth of last child (for parity "i" women) and end of reproductive age, say 45 years.

- If $\alpha_i$ proportion go for the next higher order $(i+1)^{th}$ birth and do <u>not go</u> for the next birth, the final expression of mean open birth interval would be:

$$E(U_i) = \alpha_i \frac{E(T_i^2)}{2E(T_i)} + (1-\alpha_i) \frac{E(V_i^2)}{2E(V_i)} \qquad \dots (19)$$

## 4. Modelling open birth interval to estimate ppr contd. …

- With knowledge of mean open birth interval, $E(U_i)$, $E(T_i)$ $E(T_i^2)$, $E(V_i), and\ E(V_i^2)$ we can estimate $\alpha_i$.
- Srinivasan (1967, 1968) called this $\alpha_i$ as the instantaneous parity progression ratio (**IPPR**$_{i \to i+1}$).
- Then two question arose:
  (1) What would be PPR?
  (2) Where to get data on $V_i$? Which are seldom available in fertility surveys and even if available, they suffer from various types of biases.

## 4. Modelling open birth interval to estimate ppr contd. …

In this context, Yadav and Saxena (1989) and Yadav et al. (1992, 2013) addressed both the issues and considered only those OBI which were less than a specified value, say, C such that $P[T_i \geq C] \approx 0$.

Let $\alpha_i^*$ 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:

$$\int_0^C \alpha_i^* B_i [1 - F_i(u)]\, du = \alpha_i^* B_i\, E(T_i) \text{ and} \quad \ldots (20)$$

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

$$\int_0^C (1 - \alpha_i^*)\, B_i\, du = (1 - \alpha_i^*)\, B_i\, C \quad \ldots (21)$$

## 3.3 Modelling open birth interval to estimate parity progression ratios contd. ...

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:

$$\alpha_i = \frac{\alpha_i^* E(T_i)}{\alpha_i^* E(T_i) + (1 - \alpha_i^*) C} \qquad \text{... (22)}$$

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

$$E(U_i^c) = \alpha_i \frac{E(T_i^2)}{2E(T_i)} + (1 - \alpha_i)\frac{C}{2} \qquad \text{... (23)}$$

After solving the above, we get,

$$\alpha_i^* = \frac{C^2 - 2CE(U_i^c)}{C^2 - 2[E(T_i^2)] - \{C - E(T_i)\}E(U_i^c)]} \qquad \text{... (24)}$$

## 3.3 Modelling open birth interval to estimate parity progression ratios contd. ...

Thus, with the knowledge of E($U_i^c$), E($T_i$), E(Ti$^2$), and C, we can estimate both $\alpha_i$(IPPR) as well as $\alpha_i^*$(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.

## 3.3 Modelling closed and open birth interval to estimate PPR : Life table approach

Life table approach

- The data on closed birth interval and open birth interval may be treated as complete and censored and could be combined into one.
  - Life table method combines 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.
- The parity transition is the proportion of women who have had birth within a given period.
  - The case of first transition from woman's own consummation of marriage to the occurrence of her first order birth, and from first birth to second order birth and so on. In general, starting event is consummation of marriage or a birth of a particular order, say, $i^{th}$ birth and next event is $(i+1)^{th}$ order birth or the survey date.

## 3.3 Modelling closed and open birth interval to estimate PPR : Life table approach …

- 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:

$$S_{ij} = \prod_{k=1}^{j} \frac{n_{ik} - d_{ik}}{n_{ik}} \quad \text{… (26)}$$

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

## Table 1: Estimates of PPR & IPPR for ever-married women aged 15-49 years NFHS-3, India (2005-06).

| Parity | $E(T_i)$ | $E(T_i^2)$ | $E(U_i)$ | $E(U_i^2)$ | $\alpha_i$ (IPPR) | $\alpha_i^*$ (PPR) | PPR (KM) |
|---|---|---|---|---|---|---|---|
| $P_{0-1}$ | 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 | | | | | | 2.05 | 2.74 |
| | *TFR = $p_B p_0 + p_B p_0 p_1 + p_0 p_1 p_2 + p_0 p_1 p_2 p_3 +$ ------ $+ p_B p_0 p_1 p_2 p_3 p_4 p_5 p_6/(1-p_6)$ with $p_B = 0.96$ | | | | | | |

**Summary measures are based on ungrouped data and C=120 months.**

## 3.3 Modelling closed and open birth interval to estimate PPR: Multivariate Life table approach

- ❖Suppose m(t; x) be the hazard at time t for a woman with explanatory variables $x_1, x_2, x_3, \ldots$ as vector **x**, then according to Cox (1972) and Kalbfleisch and Prentice (2002), Rodriguez (1988) etc.

$$m(t; \mathbf{x}) = m_0(t)\, e^{\beta X}$$

  - where, m(t; **x**) is the hazard rate at time t with fixed covariates **x,**
  - $m_0(t)$ is the baseline hazard for which no specific function is assumed and represents the hazards of individuals for whom all the variables are set at 0, and
  - $\beta = (\beta_1, \beta_2, \beta_3, \ldots)$ a vector of regression coefficients corresponding explanatory variables $x_1, x_2, x_3$.

- ❖1-S(c;**x**) - the cumulative survival to a fixed value c - gives the estimates of PPR (Gandotra et al. 1999, Retherford et al., 2013). … (27)
- ❖Use MCA over the estimates of relative position of 1-S(c;**x**) to estimate PPR in different sub-groups of the population under study.

**Table 2: Estimated relative position of 1-S(c; x) PPR 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 | 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** |

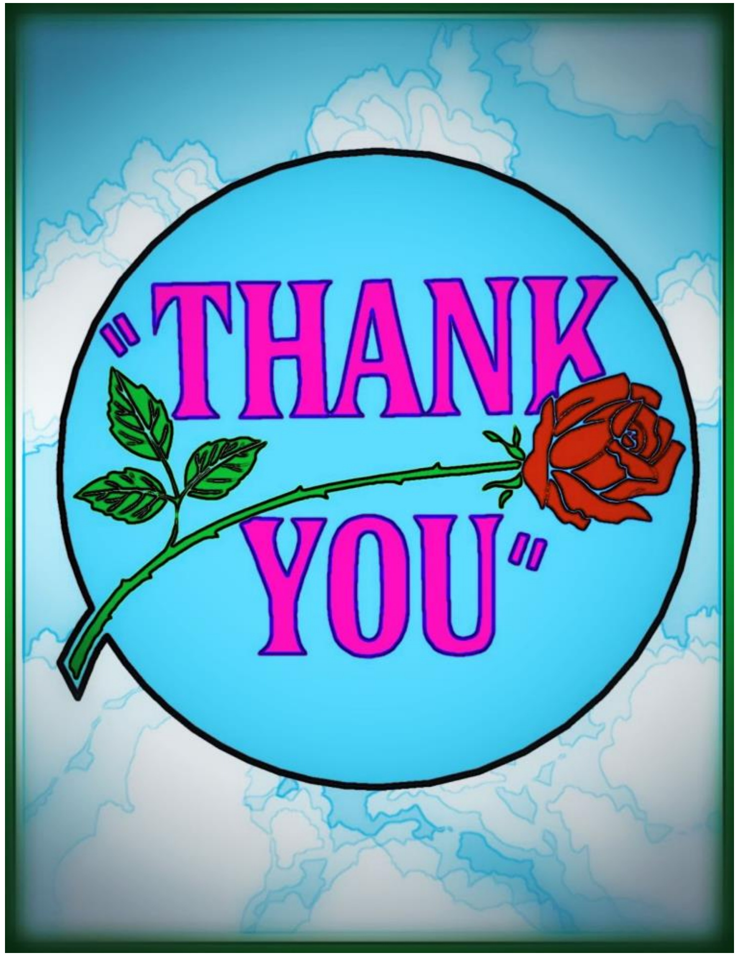
## Remarks: Other methods of estimation of PPR

❖ <u>Use of birth order statistics</u>:

- Bhrolchain (1987), Feeney and Yu (1987) Lutz and Fitchimger (1985), Ram and Pathak (1989); Pandey et al. (1994); Ram and Pathak (1989); etc. have made use of birth order statistics to estimate PPR.

❖ Vital statistics e.g. age-parity-specific probability table as force of fertility.

  - The model was used with the data from US as such data existed over there (Pandey, 1995; 1997).
  - Rajaram (1996) used above to estimate PPR from the Census 1981.
  - Sreenivasan (2002) used NFHS-1 data examining the impact of including the period on non-susceptibility (PPA) into the model.


"THANK
YOU"