A Model Base Approach to Study the Age at First Cesarean Delivery in Uttar Pradesh, India

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Abstract. The cesarean delivery is a common practice in present scenario in most of the developed as well as many developing countries including India. Cesarean birth has increased noticeably over the last years especially in countries with high or middle income. The present study is based on analysis of data from National Family Health Survey third round in India, which investigate the role of age at marriage and age at first delivery on cesarean cases of first birth. Finding suggests that proposed distribution is appropriate for the age at marriage and first birth of the women, whose first birth is cesarean. Maximum likelihood estimates obtained for the parameters of the distribution. The model suggests the modal age at marriage and first birth in case of first cesarean birth in Uttar Pradesh is 18.41 and 20.56 years.

Keywords: Cesarean delivery, age at marriage and first birth, type I extreme value distribution, K-S test.

1 Introduction

Cesarean delivery (here after CD) is a surgical intervention which is carried out to ensure safety of mother and child when vaginal delivery is not possible (emergency CD) or when the doctors consider that the danger to the mother and baby would be greater with a vaginal delivery (planned CD). Proportion of CD to the total births is considered as one of the important indicators of emergency obstetric care. CD was introduced in clinical practice as a life saving procedure both for the mother and the baby which is in under use in low income settings, and adequate or even unnecessary use in middle and high income settings (Althabe and Belizan, 2006). A figure below 5 percent implies that a substantial proportion of women do not have access to surgical obstetric care; on the other hand a rate higher than 15 percent indicates over utilization of the procedure for other than life saving reasons (WHO, 1985). Rapid increase of CD rate throughout the world has emerged as a serious public health issue, also the high rate of CD does not necessarily contribute to an improved maternal health and pregnancy outcome. Birth, a normal human physiological process was once a high mortality event causing both serious maternal and newborn losses. Medical technology and public health measures were introduced to prevent childbirth complications including CD. With the advancement in medical technologies, CD safety has been increasing, leading to a rapid increase in CD rate. But, surgical interventions during pregnancy should be performed to ensure safety of the mother and child under conditions of obstetric risk (Mishra et al. 2002) thus, it is justified under certain circumstances of medical complication and the intervention necessary only in high risk groups, should not be used normally (Bruekens 2001). Morbidity and mortality caused by unnecessary interventions is a serious problem, and worldwide epidemic of obstetrical interventions could have a negative health impact on women and her child. CD should be undertaken only when indicated to enhance the well being of mothers and babies and improves outcomes.

In case of the developing countries like India, it is still unclear about motivation behind the increasing flow of CD. In general, besides the medical factors, physician interest determines the choice of CD. The physician factors that influence CD incidence comprise physicians practice style, clinical attitude and at the same time, the place of delivery i.e., whether it was a private or public sector institutions suggested by several social scientists. Also women's fear of the physiological consequences of normal delivery and, also cesarean section is less painful and less time consuming. In India giving birth in an auspicious day is driving the women to go for a cesarean section (Mishra et al. 2002). Increasing CD everywhere in the world, raising the question of the appropriateness of the selection of CD for the procedure of delivery of a child and it also indicates growing access to gynecological and obstetric care as well. CD has increased noticeably over the last years especially in countries with high or middle income (Puentes-Rosas, et al., 2004). CD has other serious implications for the health of women undergoing them. Therefore the performance of a CD is justified only when obstetric risks outweigh the risks of normal procedure itself. There are numerous factors such medical, social-demographic and institutional factors associated with cesarean birth rates. The important among them include rising maternal age, high level of maternal education, previous CD, obstetric complications, maternal wish and high income level of social class (Lyter, 1986; Braveman et al., 1995; DiMatteo et al., 1996; Schimmel et al., 1996; Woolbright, 1996; Crane et al., 1997; Perez Eschimmel et al., 1997 and Mossialos et al. 2005). The previous literature suggests the same about the advanced maternal age is itself may be an independent risk factor for CD, due to physician's and patient's concern over pregnancy outcome for an older women (Gordon et al., 1991; Peipert et al.,1993; Parrish et al., 1994; Taffel, 1994; Irwin et al., 1996; Mc Closky, 1988). Thus in the light of above discussion, the pattern of age at marriage and age at delivery especially in relation to first order of birth by surgical intervention may be one of the major demographic concerns of the investigation in any society. Singh et al. (2015) used a polynomial to understand this. The probability models provide real representations of extensive data sets in a concise way, so we are describing the distribution here by probability model. For the lack of data at national level as well as lack of interest among the social scientists and demographers, no previous study has been carried out to examine the distribution of delivery of first birth by the surgical intervention in association with age at marriage and age at first delivery in India. Therefore this study is important to get a clear picture of the pattern of age at marriage and age at first birth in relation to CD using probability model. Extreme Value distributions arise as limiting distributions for maximums or minimums (extreme values) of a sample of independent, identically distributed random variables, as the sample size increases. Extreme Value Theory (EVT) is the theory of modeling and measuring events which occur with very small probability. This implies its usefulness in risk modeling as risky events per definition happen with low probability.

2 Conceptual Framework

Let F be a female subject who starts her marriage life at age A_1, after certain period of time T_1, she produces a live birth say B_1, corresponding to maternal ages $A_{1.1}$. Here we assume that the order of first birth B_1 is by cesarean B_C and non cesarean $B_{NC.}$ And here we would like to investigate the inter link between age at marriage and the Age at first birth with cesarean cases only of first order. Therefore, according to figure 1, the desired relationship may be traced by starting with the age at marriage A_1 and age at first birth $A_{1.1}$ which is followed by delivery cases of first order by cesarean B_C.

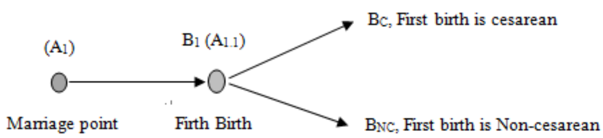

Figure 1. The framework of current study

3 Probability Model

Since probability models provide concise and clear representations of extensive data sets in a better way thus in order to describe the distribution of female age at marriage and age at first birth corresponding to CD, Type I extreme value distribution or Gumbel distribution has been found a suitable probability model in the present study. The Gumbel distribution, named after one of the pioneer German mathematician Emil J. Gumbel (1891-1966), has been extensively used in various fields including hydrology for modeling extreme events. Gumbel applied EVT on real world problems in engineering and in meteorological phenomenon. Further, in demography Nath and Talukdar (1992) used Type I extreme value model to describe the pattern of female age at marriage in a traditional society (a society where females marry at early ages and all births occur within the marital context) of India. In brief, the Type I extreme value distribution is discussed below:

Suppose the age at first marriage or age at first birth by CD for females be denoted by x. The Type I extreme value distribution is given by

$$f(x) = \exp\left[-(z) - \exp\{-(z)\}\right] / \beta \qquad x > 0 \tag{1}$$

where $z = \left(\frac{x-\alpha}{\beta}\right)$ and α is mode of the distribution called location parameter and β is the scale parameter of the distribution. The cumulative distribution function of x is given by

$$F(x) = p(X \le x) = \exp\left[-\exp\{-(z)\}\right] \tag{2}$$

4 Estimation and Application

Let X_i (i = 1,2, ..., N) be a random sample of size N from the distribution (1), where X_i denotes the age at marriage/first birth of the i^{th} female whose delivery becomes cesarean. Let N_j (j=1,2, ..., n) be the number of delivery cases (observed frequencies) of female whose first birth is cesarean. This is corresponding to age at marriage/first birth i.e. exactly 'j' years. Therefore,

$$\sum_{j=1}^{n} N_j = N$$

The likelihood function is given by,

$$\mathrm{L}(\alpha, \beta) = \frac{\mathrm{N}!}{\left(\prod_{\mathrm{j}=1}^{n} N_j!\right)} \prod_{\mathrm{j}=1}^{n} p_j^{N_j} \tag{3}$$

where $p_j = \frac{1}{\beta}\exp\left[-\left(\frac{x_j-\alpha}{\beta}\right) - \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\}\right]$

Taking logarithms on both sides,

$$Log\ L = \log N! - \sum_{j=1}^{n} \log \lfloor N_j - \sum_{j=1}^{n} N_j\left[\log\beta + \left(\frac{x_j-\alpha}{\beta}\right) + \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\}\right]$$

$$Log\ L = \log \lfloor N - \sum_{j=1}^{n} \log \lfloor N_j - N\log\beta - \frac{1}{\beta}\sum_{j=1}^{n} N_j x_j + \frac{N\alpha}{\beta} - \frac{1}{\beta}\sum_{j=1}^{n} N_j \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\}$$

Equating $\frac{\partial}{\partial\alpha}\log L = 0$, (4)

$$\frac{1}{\beta}\left[N - \sum_{j=1}^{n} N_j \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\}\right] = 0$$

$$\Rightarrow \sum_{j=1}^{n} N_j \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\} = \mathrm{N}$$

Taking logarithmic;

$$\log\left[\sum_{j=1}^{n} N_j \exp\left\{-\left(\frac{x_j}{\beta}\right)\right\}\exp\left(\frac{\alpha}{\beta}\right)\right] = \log N$$

$$\Rightarrow \frac{\alpha}{\beta} = -\log\left[\frac{\sum_{j=1}^{n} N_j \exp\left(\frac{-x_j}{\beta}\right)}{N}\right]$$

Thus the estimated parameter α is defined by,

$$\hat{\alpha} = -\beta \log\left[\frac{\sum_{j=1}^{n} N_j \exp\left(\frac{-x_j}{\beta}\right)}{N}\right] \tag{5}$$

Equating $\frac{\partial}{\partial\beta}\log L = 0$,

$$\Rightarrow -\sum_{j=1}^{n} N_j \left[\frac{1}{\beta} - \frac{(x_j-\alpha)}{\beta^2} + \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\}\frac{(x_j-\alpha)}{\beta^2}\right] = 0$$

$$\Rightarrow \beta\left\{\sum_{j=1}^{n} N_j - \frac{1}{\beta}\sum_{j=1}^{n} N_j\left(x_j - \alpha\right)\right\} = -\sum_{j=1}^{n} N_j x_j \exp\left(\frac{-x_j}{\beta}\right)\exp\left(\frac{\alpha}{\beta}\right) + \alpha\sum_{j=1}^{n} N_j \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\}$$

Since, $N - \sum_{j=1}^{n} N_j \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\} = 0$

$$\therefore N = \sum_{j=1}^{n} N_j \exp\left\{-\left(\frac{x_j-\alpha}{\beta}\right)\right\}$$

$$\Rightarrow \beta\left\{\sum_{j=1}^{n} N_j - \frac{1}{\beta}\sum_{j=1}^{n} N_j\left(x_j - \alpha\right)\right\} = -\sum_{j=1}^{n} N_j x_j \exp\left(\frac{-x_j}{\beta}\right)\exp\left(\frac{\alpha}{\beta}\right) + \alpha N$$

$$\Rightarrow \beta\left\{\sum_{j=1}^{n} N_j - \frac{1}{\beta}\sum_{j=1}^{n} N_j x_j\right\} = -\frac{\sum_{j=1}^{n} N_j x_j \exp\left(\frac{-x_j}{\beta}\right)}{\exp\left(-\frac{\alpha}{\beta}\right)}$$

Since, $\frac{\alpha}{\beta} = -\log\left[\frac{\sum_{j=1}^{n} N_j \exp\left(\frac{-x_j}{\beta}\right)}{N}\right]$

$$\therefore \exp\left(-\frac{\alpha}{\beta}\right) = \frac{\sum_{j=1}^{n} N \exp\left\{-\left(\frac{x_j}{\beta}\right)\right\}}{N}$$

$$\Rightarrow \beta\left\{\sum_{j=1}^{n} N_j - \frac{1}{\beta}\sum_{j=1}^{n} N_j x_j\right\} = -\frac{N\sum_{j=1}^{n} N_j x_j \exp\left(\frac{-x_j}{\beta}\right)}{\sum_{j=1}^{n} N \exp\left\{-\left(\frac{x_j}{\beta}\right)\right\}}$$

$$\therefore \beta + \frac{\sum_{j=1}^{n} N_j x_j \exp\left(\frac{-x_j}{\beta}\right)}{\sum_{j=1}^{n} N \exp\left\{-\left(\frac{x_j}{\beta}\right)\right\}} - \frac{\sum_{j=1}^{n} N_j x_j}{N} = 0 \quad (6)$$

From equation (6), the parameter β can be estimated by Newton-Raphson iterative procedure. The parameter α then easily can be estimated from equation (5). The mean of the distribution can be estimated by

$$Mean = \alpha + \gamma\beta \ \ where\ \gamma\ is\ Euler\ cons\tan t\,(0.5772156649....) \quad (7)$$

Since the value of α and β is positive so that from the above equation it is clear that the mean is more than the mode (α) of the distribution so that the distribution is positively skewed distribution. The model is applied to the real data of age at marriage and age at first birth by CD for females of Uttar Pradesh. The data have been taken from third round of National Family Health Survey (NFHS-III) for Uttar Pradesh a most crowded and traditional state of India. The distribution of females according to their age at first marriage and according to their age at first birth is in table 4 along with the value of estimated parameters respectively and test of goodness statistics.

5 Goodness of Test Statistics

A random sample $X_1, X,\ldots, X_n$ of size n is drawn from an unknown population having the cumulative distribution function F(x). Let the ordered values be $x_{(1)}, x_{(2)},\ldots, x_{(n)}$. The K-S test is based on the Glivenko-Cantelli theorem which states that the step function $S_n(x)$, with jumps occurring at the values of the ordered statistics $x_{(1)}, x_{(2)},\ldots, x_{(n)}$ for the sample, approaches the true distribution for all x. Using this theorem, the comparison of the empirical distribution function $S_n(x)$ of the sample for any value x is made by defining the distance between the two cumulative distribution functions which is taken as the supremum of the absolute deviations i.e. $Sup|S_n(x)-F_0(x)|$ over all x. The hypothesis for the test of goodness of fit is,

H_0: $F(x)=F_0(x)$ vs. H_1: $F(x)\neq F_0(x)$, where, F_0 is a completely specified continuous distribution. To test H_0, the actual numerical difference $|S_n(x)-F_0(x)|$ is used in K-S test. Since this difference depends on x, the K-S statistics is taken to be the supremum of such differences, i.e.

$$D_n = \underset{x}{Sup}\left|\mathrm{S_n}(x) - F_0(x)\right|$$

where, D_n is known as the K-S statistics. Under H_0, the statistics D_n has a distribution which is independent of the cdf $F(x)$ that defines H_0. The statistics D_n is distribution free. To decide about H_0, the test criterion is, reject H_0 if D_n ,($\max|S_n(x)-F_0(x)|$), exceeds the tabulated value for given n and prefixed significance level α. Otherwise, H_0 is not rejected.

6 Results

Table 1 reveals that the prevalence of CD in India is about 12 percent. In all the southern states of India the occurrence of CD is higher than all other states of India. About one third of the total deliveries are cesarean in Kerala and 28.6 percent in Andhra Pradesh. In northern states of India percentage of CD is low. In Madhya Pradesh it is 8.3 percent however in Uttar Pradesh it is 6.7 percent. In Bihar and Rajasthan the CD is about 5 percent. In Maharashtra and West Bengal the prevalence of CD is same. Table also reveals that in rural areas the prevalence of CD is quite low in comparison to its urban counterparts in all states of India here in this study. In urban West Bengal the prevalence of CD is unexpectedly high. Table 2 explains the percent distribution of CD in Uttar Pradesh according to the age of female and the birth order for their last child and reveals that the first order birth has the high prevalence of CD in each and every age group whereas it falls lower as we go for the higher order births. The first order birth it is about 15.7 percent and falls down to 10 percent for the second order births. The table shows the prevalence of CD in India is higher in females of lower age group in comparison with the higher age group of females in total. On the contrary if we concentrate on the birth order, the first order birth for the females of the lower age groups has the lower prevalence for the CD in comparison to the higher age group females and the tendency goes similar for the rest of the birth orders. Table 3 reveals the facts about the progression to the next birth according to the age of females in Uttar Pradesh and explains that the percentage for the CD decreases substantially as with the parity progression. The parity progression is found lower in case of NCD than CD in all age group in Uttar Pradesh due to some medical reason.

Table 1. Region wise percent distribution of cesarean delivery in India

States	**NFHS-III**		
	Total	**Urban**	**Rural**
Northern			
Uttar Pradesh	6.7	14.1	2.9
Bihar	5.0	9.5	2.9
Madhya Pradesh	8.3	16.0	2.0
Rajasthan	4.8	11.1	2.5
Southern			
Andhra Pradesh	28.6	33.9	20.0
Karnataka	17.1	24.6	12.8
Kerala	31.0	34.5	29.3
Tamil Nadu	25.0	27.8	21.8
Eastern			
West Bengal	17.2	32.4	6.6
Orissa	7.0	14.9	4.2
Western			
Maharashtra	17.2	21.6	8.5
Gujarat	10.1	16.1	6.3
India	**12.1**	**19.6**	**7.2**

Table 2. Percent distribution of cesarean delivery in Uttar Pradesh according to the age of female and birth order of last child

Age of female	**Birth order of last child**					**Total**
	1	**2**	**3**	**4**	**5+**	
15-20	9.6	0.0	0.0	0.0	0.0	7.4
20-30	16.2	7.7	2.3	2.0	0.6	6.8
30+	44.1	27.5	10.5	2.4	2.2	6.4
Total	15.7	10.0	4.0	2.2	1.8	6.7

The proposed model has been applied to the data taken from NFHS-III, for the number of CD cases at first birth for females of Uttar Pradesh. The distribution of females according to their age at marriage and first birth by cesarean section is given in the following table 4. The estimated values of α and β are found as 18.405 and 2.822 respectively for age at marriage of females whose first birth is cesarean while they are 20.563 and 2.617 for age of females at first cesarean birth. Here α is the location parameter which provides the model value of the distribution thus 18.405 and 20.563 years are the most plausible value of age at marriage whose first birth is cesarean and age at first cesarean birth respectively and the mean (from eq. 7) is obtained as 20.03 and 22.07 years for the two data sets considered here and the difference is almost 2 years which may be considered as an estimate of average first birth interval. The results of Kolmogrov-Smirnov test statistics D are found to be 0.0967 and 0.0878 for both the data sets respectively. The tabulated value of D is 0.1136 and 0.1366 (from statistical tables) at 5% and 1% level of significance respectively indicate that the data follow the distribution i.e. there is no significant difference between observed and expected proportions for number of females with cesarean birth.

Table 3. Progression to the next birth according to the age of female in Uttar Pradesh

Progression to birth order	Age of female						Total	
	15-20		20-30		30+			
	NCD	CD	NCD	CD	NCD	CD	NCD	CD
1-2	0.25	0.00	0.76	0.44	0.96	0.80	0.75	0.51
2-3	0.16	0.00	0.57	0. 36	0.78	0.37	0.60	0.31
3-4	0.10	0.00	0.39	0. 26	0.57	0.22	0.43	0.29

Table 4. Observed and expected number of females whose first birth is cesarean according to age at marriage/age at first birth in Uttar Pradesh

Age at marriage (x)	Number of females whose first birth is cesarean		Age at first birth (x)	Number of females whose first birth is cesarean	
	Observed	Expected		Observed	Expected
14	2	1.77	14	0	0.00
15	14	5.57	15	1	0.05
16	21	12.56	16	2	0.64
17	23	20.17	17	13	3.53
18	18	25.40	18	14	10.34
19	26	26.92	19	22	19.35
20	19	25.26	20	18	26.48
21	18	21.74	21	25	28.10
22	12	17.61	22	33	28.64
23	15	13.67	23	11	23.57
24	17	10.29	24	18	18.75
25	7	7.59	25	17	14.21
26	3	5.52	26	8	10.42
27	6	3.97	27	6	7.46
28	0	2.83	28	9	5.27
29	0	2.00	29	5	3.68
30	2	1.42	30	3	2.51
31	2	1.00	31	1	1.80
32	1	0.71	32	0	1.21
Total	**206**	**206.00**	**Total**	**206**	**206.00**
Parameters	$\alpha = 18.405$, $\beta = 2.822$		Parameters	$\alpha = 20.563$, $\beta = 2.617$	
K-S Statistics	$D_{cal}=0.0967$ $D_{0.05}=0.1136$, $D_{0.01}=0.1366$		K-S Statistics	$D_{cal}=0.0878$ $D_{0.05}=0.1136$, $D_{0.01}=0.1366$	

7 Discussion

In the present study finding suggests that cesarean birth decreases with birth order increases in each and every age group of females. Reason may be increased possibility of obstetrics complications after the cesarean birth therefore it may be stated that as the number of CD increases, restrict the future fertility. In addition, this study suggests that the distribution of female in cesarean cases according to their age at marriage/first birth in Uttar Pradesh can be described suitably by the Type I extreme value distribution, indicating that the model age at cesarean birth is quite low, which is itself responsible for reproductive complications. Webster et al., (1992) concluded that women with obstetrics complications near delivery are more likely to undergo CD in order to improve the survival prospects of their newborns and selves. Gould et al., 1989; Signorelli et al., 1995; Cnattingius et al., 1998; suggest some maternal factors (clinical) such as long labour (⩾12 hours), fetal distress, multiple births, abdominal operation, length or weight of babies and so on were considered as primary independent variables in their respective studies. To identify the high risk group, we are developing a methodology including some covariates under this model.

8 Conclusion

In this paper a proposed model has been applied to the data taken from NFHS-III, for the number of deliveries at first birth for females according to their age at marriage and first birth by cesarean section. The Extreme value distribution has been fitted to the data and gives an exact fit for the phenomenon and further can be applied in other places of similar environment. Some other models can also be applied to the cesarean section for the number of deliveries at first birth for females according to their age at marriage and first birth.

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