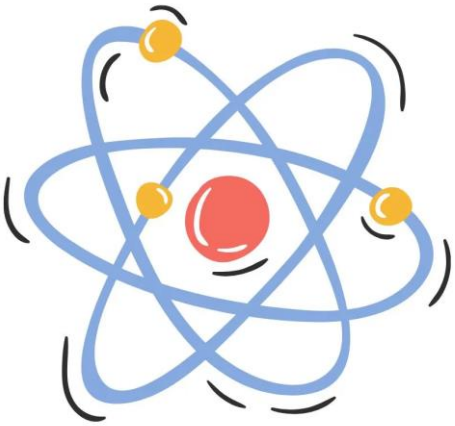

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RIGHT-CENSORED NEGATIVE BINOMIAL REGRESSION MODEL FOR FERTILITY COUNT DATA AND ITS APPLICATIONS

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Abstract: *The research examines the primary determinants of caesarean deliveries in the Indian state of Andhra Pradesh. Estimating characteristics and identifying important factors impacting the number of caesarean section deliveries among women in Andhra Pradesh, India, between the ages of 15 and 49, is the primary goal of the research. The right-censored negative binomial and the right-censored Poisson will be used in the study to achieve this. The fertility count data set, real-world Demographic and Health Surveys phase VII input, and National Family Health Survey, 2019–2021 input are all used in the analysis. Investigating the methods used by expectant mothers to give birth. This study was based on the fitting of the model right-censored number of caesarean section deliveries in right-censored Poisson and right-censored negative binomial utilizing Generalized Additive Models for Location Scale and Shape. The analysis makes use of the R packages survival as well as the add-on package Generalized Additive Models for Location Scale and Shape. The parameters are estimated using both right-censored Poisson and right-censored negative binomial; that are Intercept (-1.7416), "Breech Presentation" ("Yes and Don't know") (-0.3211 and 0.5282), "Currently has heart disease" ("Yes") (-0.8697), "High blood pressure" ("Yes and Don't know") (0.0323 and 0.0305), "Prolonged labour" ("Yes and Don't know") (-0.0707 and -0.6817), "Child is twin" ("1st multiple, 2nd multiple, 3rd multiple") (0.1565, 0.1288, -8.0569), "Age" (0.0226), "Educational level" ("Primary, Secondary, Higher") (0.0678, 0.4528, 0.6496) of both right-censored Poisson and right-censored negative binomial. According to the outcomes of applying the Akaike Information Criterion and Schwarz Bayesian Criterion, (4456.177) and (4545.413); (4458.177) and (4553.362) are of right-censored Poisson and right-censored negative binomial, respectively. In the model fitted using right-censored Poisson and right-censored negative binomial, the parameters "Breech presentation" ("Yes and don't know"), "Prolonged labour" ("Don't know"), "Age," and "Educational level" (Secondary and Higher) had an impact on the number of caesarean section deliveries. The government agencies responsible for formulating policies pertaining to women's welfare must prioritize the health of women, defined as those between the ages of 15 and 49. Compared to the right-censored negative binomial, the right-censored Poisson shows a comparatively better match with number of caesarean section deliveries. To undertake further research, it is recommended to compare right-censored Poisson with several models that predict over-dispersion in count data.*

Keywords: count data, caesarean section deliveries, right-censored Poisson, right-censored negative binomial

1. Introduction

Emerging nations have delicate health circumstances that have raised serious concerns and made achieving universal health, especially for women and children,

problematic due to resource shortages and the medicalization of health issues. As a result, by developing a sound strategy and carrying out the required treatments when required, we may improve and safeguard the maternal health care system. Giving birth is a perfectly normal process—it is not a disease. The usage of obstetrical procedures has increased recently on a global scale [1]. A West Bengal study found that the number of caesarean deliveries has increased dramatically over time worldwide, particularly in high-income and developing countries. However, a number of detrimental short- and long-term impacts of caesarean delivery on childbirth and reproductive health have been shown in studies [2]. According to a study conducted in Uttar Pradesh, there is a very high probability of caesarean section for women who give birth in private hospitals with distinct clinico-social profiles and live in urban regions [3].

Count data displays the number of times an event happens during a specified time interval [4, 5]. As an example, the number of caesarean sections [6] that a woman has had over her lifetime. Count data are used in almost all academic disciplines, such as management, industrial organizations, economics, health, and so forth [7]. Numerous fields, such as marketing, public health, and biological sciences, frequently employ count data. Poisson models are widely used as the basis for regression analysis of count data and for count data analysis [8, 9, 10, 11]. Poisson regression is one of the most widely used techniques for counting data analysis [10, 12]. Negative binomial regression extends Poisson regression model when generously assuming variance, and it can converge to Poisson regression model when the dispersal parameter approaches zero [13]. In practical situations, count data sometimes shows over-dispersion and excess zeroes. When dealing with over-dispersed count data, negative binomial regression model is utilized; yet, Hurdle [14] and Zero-inflated [15, 16] regressions address the extra zeroes in the data. Modelling of the number of caesarean section deliveries ("NCSD") is done with National Family Health Survey, 2019–2021 (NFHS-5) fertility count data. The NFHS-5 provides estimates for women's health and children's nutrition, as well as estimates for adult, child, and maternal health, fertility, and mortality. Most of these estimates project significant things regarding well-being of Indian families. Knowledge of estimates found in the “Sustainable Development Goals (SDGs)”, is provided by NFHS-5. To fulfill SDG-3, "Ensure healthy lives and promote well-being for all at all ages," by 2030 (NFHS-5, 2019–2021), is a prerequisite [11, 17, 18].

2. Methods

The NFHS-5, the fifth survey in the line, gives data on nutrition, health, and population in India. Phase-I, which included 17 states and 5 union territories (UT), went from June 17, 2019 to January 30, 2020; Phase-II, which covered 11 states and 3 UTs, ran from January 2, 2020 to April 30, 2021. This survey in India held in two slots. A 97 percent response rate was obtained from 7,24,115 women who were contacted by 17 Field Agencies [11, 17, 18]. Sigma Research and Consulting Pvt. Ltd. conducted the fieldwork for NFHS-5 in Andhra Pradesh between July 2, 2019, and November 14, 2019. 10,975 female informants [11, 18, 19] were provided. The research invistigators employed the approach of purposive sampling. 7, 24,115 women are considered in the first phase. In the 2^{nd} phase of the purposive sampling process, 18,538 women from Andhra Pradesh were involved, of whom 7,563 women were questioned. Ultimately, 2,833 females aged 15 to 49 are included through the purposive sampling technique. Secondary data from the NFHS-5 are used in the analysis. 50.5% and 39.3% of deliveries in urban and rural areas, respectively, resulted in a caesarean section; the overall number of births that happened five years before to the study is 42.4%. In urban and rural areas, the proportion of caesarean

section deliveries that occur in private health facilities is 66.1% and 61.4%, respectively, although the total number of births that took place five years before to the study is 63.0%. The rates of caesarean sections for newborns in urban and rural public health institutions are 30.9%, 25.2%, and 26.6%, respectively, for births that took place five years before the survey [11, 18, 19].

Table 1 provides a summary of the variables that are both primary and secondary to the study of "NCSD" in Andhra Pradesh, India.

Table 1: An Inventory of the Variables Studied in the Research

"Variable"	"Type"	"Value Description"
"Number of caesarean section deliveries"	"Categorical"	0 = "No caesarean section delivery", 1 = "One caesarean section delivery", 2 = "Two caesarean section deliveries"
"Breech Presentation"	"Categorical"	1 = "No", 2 = "Yes", 3 = "Don't know"
"Currently has heart disease"	"Categorical"	1 = "No", 2 = "Yes", 3 = "Don't know"
"High blood pressure"	"Categorical"	1 = "No", 2 = "Yes", 3 = "Don't know"
"Prolonged labour"	"Categorical"	1 = "No", 2 = "Yes", 3 = "Don't know"
"Child is twin"	"Categorical"	1 = "Single birth", 2 = "1st of multiple", 3 = "2nd of multiple", 4 = "3rd of multiple", 5 = "4th of multiple", 6 = "5th of multiple"
"Age"	"Interval"	15,16,…….,49
"Educational Level"	"Categorical"	1 = "No education", 2 = "Primary", 3 = "Secondary", 4 = "Higher"
"Type of place of residence"	"Categorical"	1 = "Urban", 2 = "Rural"

"0," "1," and "2" or more "NCSD" is the definition of the explained variable "NCSD" [11]. The variables "High blood pressure" and being informed by a doctor or other health professional that they had high blood pressure on two or more occasions combine to form x_3, while the variables "Prolonged labour" and being asked if they had experienced prolonged labour during delivery combine to form x_4. These variables together transform "NCSD." Below is an explanation of the other factors. In addition, the absent integers are substituted by "3 = Do not know".

One caesarean section delivery, modelled to match the right-censored Poisson regression model (RCPRM) [8, 20, 21], is the count data outcome variable, which is right-censored [22] at 1. First, RCPRM and then right-censored negative binomial regression model (RCNBRM) are fitted to the model. Although more usually referred to as simply over-dispersed, data with a higher variance than the mean are called Poisson over-dispersed [23]. According to references [10, 24], a response variable is considered over-dispersed if its variance exceeds the mean, while it is considered under-dispersed otherwise. Right-censored NCSD in RCPRM and RCNBRM is fitted using Generalized Additive Models for Location, Scale, and Shape (GAMLSS) [25]. The analysis makes use of the R packages survivability, surv [22], and gamlss.cens [25], which are add-on packages to GAMLSS. y is the right-censored outcome, β_0 and β_p are numerical coefficients; β_0 is the intercept; and x is the covariate in the basic structure of RCPRM, which is $log(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p$. Examine the following equation, which has one predictand variable and seven predictor variables:

$$\log(y) = \beta_0 + \beta_p x_p \text{ , where } p = 1,2, \ldots ,7 \quad (1)$$

$$\log(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 \quad (2)$$

Where

$$y = \text{“Number of caesarean section deliveries”}$$

$$x_1 = \text{“Breech presentation”}$$

$$x_2 = \text{“Currently has heart disease”}$$

$$x_3 = \text{“High blood pressure”}$$

$$x_4 = \text{“Prolonged labour”}$$

$$x_5 = \text{“Child is twin”}$$

$$x_6 = \text{"Age"}$$

$$x_7 = \text{“Educational level”}$$

$$\text{Similar in: } y = e^{(\beta_0 + \beta(x))} = e^{\beta_0} + e^{\beta_p * x_p} \quad (3)$$

Negative binomial regression is the extension of Poisson with a more liberal variance assumption and could collapse into Poisson regression with the dispersion parameter equal to 0[13, 26]. The PRM is the format of the NBRM model equation. A linear combination of variables is used to predict the outcome's log [27]. The censored negative binomial (CNB) distribution converges to the censored Poisson (CP) distribution if the dispersion parameter equal to 0 [28]. In the same way, the RCNB distribution converges to the RCP distribution if the dispersion parameter tends to 0. Thus, for RCNBRM, equations 1, 2, and 3 are obtained. Next, based on equation 3, the subsequent equations are

$$y = e^{(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7)} \quad (4)$$

$$y = e^{\beta_0} * e^{\beta_1 x_1} * e^{\beta_2 x_2} * e^{\beta_3 x_3} * e^{\beta_4 x_4} * e^{\beta_5 x_5} * e^{\beta_6 x_6} * e^{\beta_7 x_7} \quad (5)$$

3. Results

The research considers the demographic information provided by the participants, encompassing their "Type of Residence," "Age," and "Educational Level." The results of a research study on women in the NFHS-5 data who were between the ages of 15 and 49 in Andhra Pradesh, India, vary. The descriptive information from the respondents is as follows.

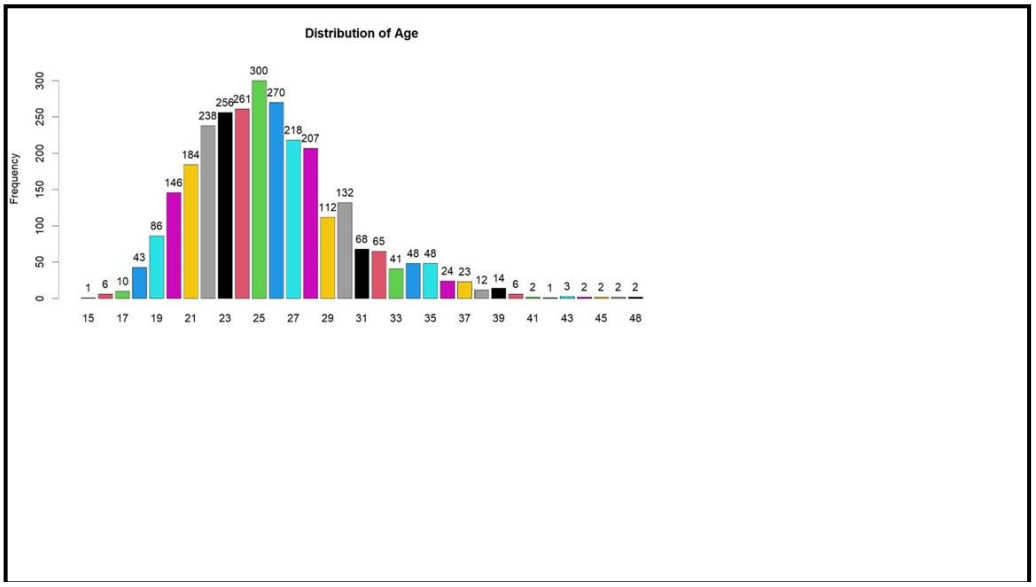
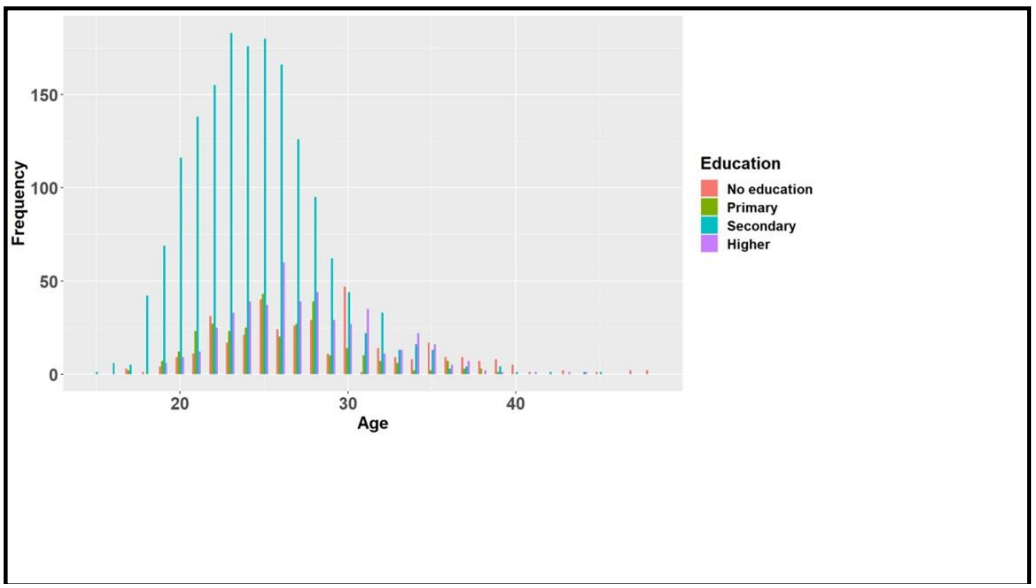


Figure 1: Age Distribution

The age distribution of the respondents is shown in Figure 1. It demonstrates that women of 25 years old are more, followed by 26 years old respondents.



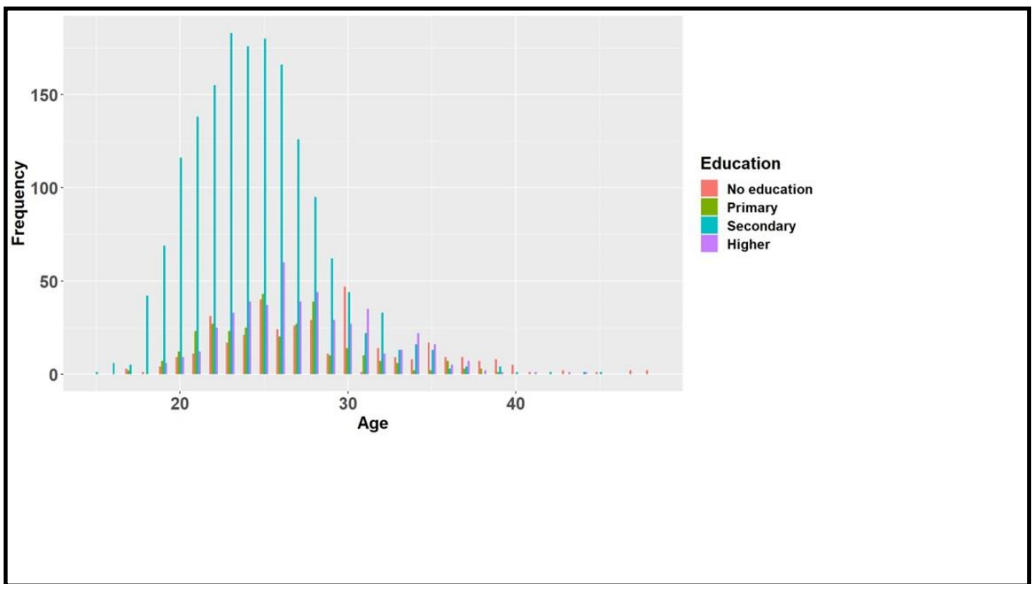


Figure 2: Education with Age

The information of women can be seen that majority of the respondents have completed their secondary education is shown in Figure 2.

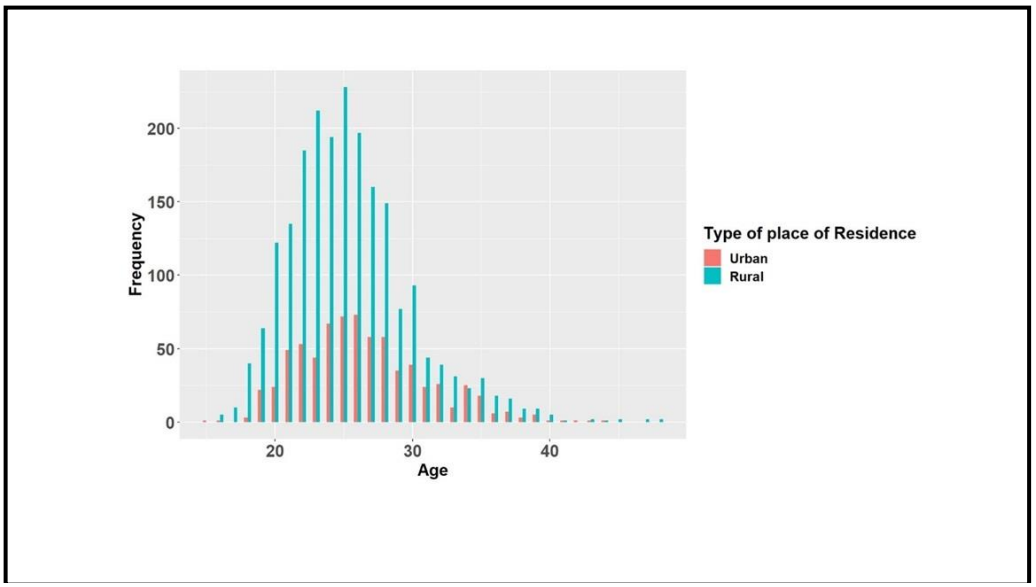


Figure 3: Type of Place of Residence with Age

Figure 3 portraits "Type of Place of residence" with respondent's age. It is clearly vivid that many respondents of different age group are from rural area.

The right-censored **"**NCSD" model is fitted in RCPRM using gamlss.cens and Surv. The outcome is displayed below:

Table 2: RCPRM Values Synopsis - Coefficients Study:

Variables	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	-1.7416	0.2250	-7.742	0.0000***
Breech Presentation				
Yes	-0.3211	0.0990	-3.243	0.0012**
Don't know	0.5282	0.1612	3.277	0.0011**
Currently has heart disease				
Yes	-0.8697	0.7086	-1.227	0.2198 @
High blood pressure				
Yes	0.0323	0.0860	0.376	0.7067 @
Don't know	0.0305	0.2057	0.148	0.8821 @
Prolonged labour				
Yes	-0.0707	0.0892	-0.793	0.4277 @
Don't know	-0.6817	0.2626	-2.596	0.0095**
Child is twin				
1st of multiple	0.1565	0.2947	0.531	0.5954 @
2nd of multiple	0.1288	0.2904	0.444	0.6573 @
3rd of multiple	-8.0569	116.9606	-0.069	0.9451 @
Age	0.0226	0.0066	3.424	0.0006***
Educational Level				
Primary	0.0678	0.1396	0.486	0.6269 @
Secondary	0.4528	0.1052	4.303	0.0000***
Higher	0.6496	0.1125	5.771	0.0000***

The RCPRM values are summarized in Table 2. In the model the variables, “Breech Presentation” (“Yes and Don't know”) and “Prolonged labour” (“Don't know”) are significant at 0.01 LOS in the model fitted. The variables “Age” and “Educational Level” (“Secondary and Higher”) are significant at 0.001 LOS.

Table 3: Summary of RCPRM Values of GD, AIC and SBC

	GD	AIC	SBC
RCPRM	4426.177	4456.177	4545.413

The values of Global Deviance (GD) [25], Akaike's Information Criterion (AIC) [29] and the Schwarz Bayesian Criterion (SBC) [30] are summarized in Table 3. RCPRM's AIC is 4456.177, whereas SBC is 4545.413. RCPRM's GD is 4426.177.

The RCNBRM gamlss.cens and Surv models are supplied with the right-censored “NCSD”. The outcome is as follows:

Table 4: RCNBRM Values Synopsis – Coefficients Study:

Variables	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	-1.7416	0.2250	-7.741	0.0000***
Breech Presentation				
Yes	-0.3211	0.0990	-3.242	0.0012**
Don't know	0.5282	0.1613	3.276	0.0011**
Currently has heart disease				
Yes	-0.8697	0.7097	-1.225	0.2205 @

High blood pressure				
Yes	0.0323	0.0860	0.376	0.7068 @
Don't know	0.0305	0.2059	0.148	0.8822 @
Prolonged labour				
Yes	-0.0707	0.0892	-0.793	0.4278 @
Don't know	-0.6817	0.2627	-2.595	0.0095**
Child is twin				
1st of multiple	0.1565	0.2945	0.531	0.5952 @
2nd of multiple	0.1288	0.2904	0.444	0.6574 @
3rd of multiple	-8.0569	70.9885	-0.113	0.9096 @
Age	0.0226	0.0066	3.423	0.0006***
Educational Level				
Primary	0.0678	0.1396	0.486	0.6270 @
Secondary	0.4528	0.1052	4.303	0.0000***
Higher	0.6496	0.1125	5.773	0.0000***

The RCNBRM value summary is explained in Table 4. The elements in the model fitted indicates that the variables, “Breech Presentation” (“Yes and Don't know”) and “Prolonged labour” (“Don't know”) are significant at 0.01 LOS in the model fitted. The variables “Age” and “Educational Level” (“Secondary and Higher”) are significant at 0.001 LOS.

Table 5: Summary of RCNBRM values of GD, AIC and SBC

	GD	AIC	SBC
RCNBRM	4426.177	4458.177	4553.362

The NBRM's GD, AIC, and SBC values are displayed in Table 5 with clarity. AIC of NBRM is 4458.177 and SBC is 4553.362. The GD of is 4426.177.

Table 6: Summary of values of GD, AIC, and SBC

Model	Model selection criteria		
	GD	AIC	SBC
RCPRM	4426.177	4456.177	4545.413
RCNBRM	4426.177	4458.177	4553.362

The GD, AIC, and SBC summary values are explained in detail in Table 6. RCPRM's 4456.177 AIC and 4545.413 SBC are both fewer than RCNBRM's 4458.177 and 4523.554 4553.362, respectively. As a result, RCPRM fits the model right-censored “NCSD” better. In comparison to RCNBRM, the AIC and SBC values of RCPRM are lower. Thus, there is vivid proof that RCPRM is the appropriate and superior to RCNBRM.

4. Discussion

4.1. Findings

The parameters are estimated using RCPRM and RCNBRM for the “NCSD” model, NFHS-5, 2019–2021 data, that is available at DHS program. The intercept coefficient of RCPRM is (-1.7416) and is significant at 0.001 LOS. The coefficient of “Breech presentation” (“Yes and Don’t know”), is (-0.3211 and 0.5282) and is significant at 0.01 LOS. The coefficient of “Prolonged labour “(“Don’t know) is (-0.6817) and is significant at 0.01 LOS. The coefficient of “Age” is (0.0226) and is significant at 0.001 LOS. The coefficient of “Educational level “(Secondary and Higher) is (0.4528 and 0.6496) and is

significant at 0.001 LOS. Therefore, it is concluded that these elements "Breech presentation" ("Yes and Don't know"), "Prolonged labour "("Don't know"), "Age" and "Educational level "(Secondary and Higher) are affecting "NCSD". GAMLSS and Surv is used to model "NCSD" in Andhra Pradesh, India, between 2019 and 2021. It is possible to compare the "NCSD" model with different regression models. The coefficient of "Currently has heart disease" ("Yes") is (-0.8697) and is not significant. The coefficient of "High blood pressure" ("Yes and Don't know") is (0.0323 and 0.0305) and is not significant. The coefficient of "Prolonged labour" ("Yes") is (-0.0707) and is not significant. The coefficient of "Child is twin" ("1st multiple, 2nd multiple, 3rd multiple") is (0.1565, 0.1288, -8.0569) and is not significant. The coefficient of "Educational level" ("Primary") is (0.0678) and is not significant.

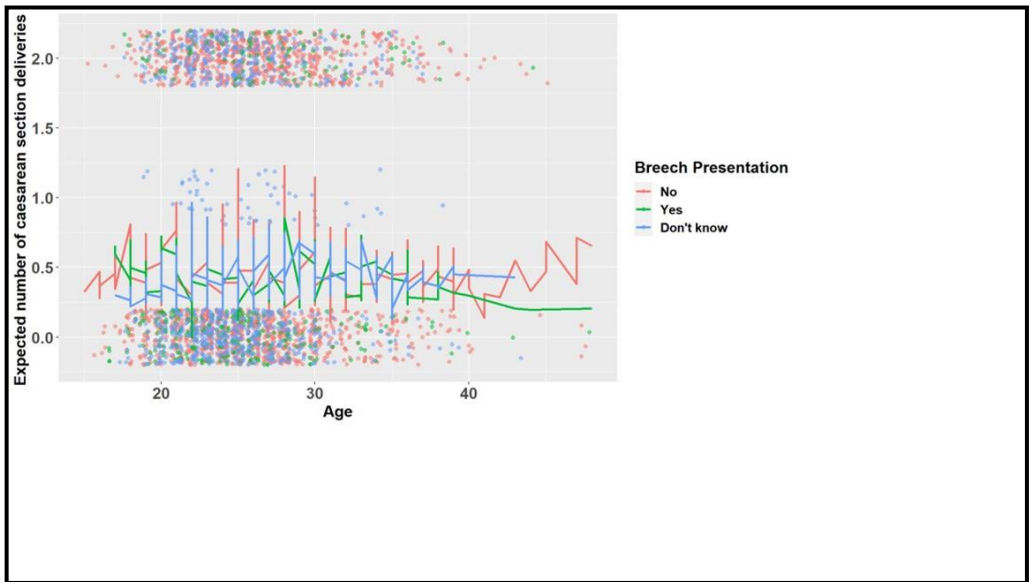


Figure 4: RCPRM's Predicted "NCSD"

Figure 4 indicates the predicted "NCSD" for those respondents who have "Breech presentation" based on their present "age" using RCPRM.

The intercept coefficient of RCNBRM is (-1.7416) and is significant at 0.001 LOS. The coefficient of "Breech presentation" ("Yes and Don't know"), is (-0.3211 and 0.5282) and is significant at 0.01 LOS. The coefficient of "Prolonged labour "("Don't know") is (-0.6817) and is significant at 0.01 LOS. The coefficient of "Age" is (0.0226) and is significant at 0.001 LOS. The coefficient of "Educational level "(Secondary and Higher) is (0.4528 and 0.6496) and is significant at 0.001 LOS. Therefore, it is concluded that these elements "Breech presentation" ("Yes and Don't know"), "Prolonged labour "("Don't know"), "Age" and "Educational level "(Secondary and Higher) are affecting "NCSD". The coefficient of "Currently has heart disease" (Yes) is (-0.8697) and is not significant at 0.001 LOS. The coefficient of "High blood pressure" ("Yes and Don't know") is (0.0323 and 0.0305) and is not significant. The coefficient of "Prolonged labour" ("Yes") is (-0.0707) and is not significant. The coefficient of "Child is twin" ("1st multiple, 2nd multiple, 3rd multiple") is (0.1565, 0.1288, -18.4904) and is not significant. The coefficient of "Educational level" ("Primary") is (0.0678) and is not significant.

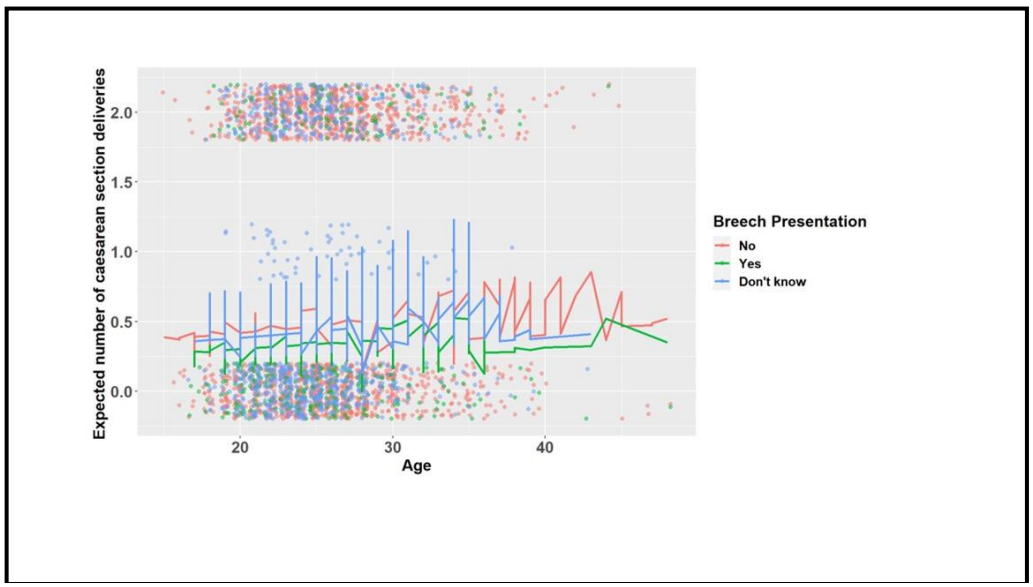


Figure 5: RCNBRM's predicted "NCSD"

Using RCNBRM, Figure 5 predicts the "NCSD"; for respondents who have "Breech presentation" based on their present "age".

The study does not account for the respondents' socioeconomic status; their demographics are not proportionate; the respondents' caste and religion are not included in the model; and a comparative analysis with other Indian states is not carried out, among other research limitations. This would have required an extensive study with many variables considered in different scenarios. Future research can consider these aspects in an effort to reduce the "NCSD."

4.2. Conclusion

According to our study, respondents who are 25 years old and live in rural areas are more likely to give birth by caesarean section. Local medical officers and government health policymakers should create well-equipped public healthcare facilities, increase public awareness, and—above all—appoint medical professionals to counsel expectant mothers about normal vaginal deliveries in order to lower the number of caesarean section births. The government agencies that are in charge of creating health policies related to women's welfare must give priority to the health of women, who are defined as those who are between the ages of 15 and 49. This will help to lower the "NCSD" by increasing maternal health literacy and awareness among women and the community. The variables "Breech presentation" ("Yes and Don't know"), "Prolonged labour" ("Don't know"), "Age," and "Educational level" ("Secondary and Higher") have an effect on the "NCSD" in the model fitted using RCPRM and RCNBRM. The RCPRM displays a somewhat better match with "NCSD" than the RCNBRM. It is found that "NCSD" fits best with the RCPRM. Comparing RCPRM with several models that forecast over-dispersion in count data suggests more investigation.

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