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Statistical Analysis of Factors Associated with Maternal Mortality in Nepal

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Abstract

A four year district level data including all the districts of Nepal observed between 2003/04 till 2006/07 has been compiled from Annual Health Reports published by the Department of Health Services, Kathmandu on maternal mortality and several factors likely to be associated with it. The compiled data is used for some descriptive analyses and statistical modeling. The generalized linear model with Poisson log link is applied for establishing linkage between maternal deaths with some relevant predictors. The model is found to be suitable only after deletion of substantial number of extreme values from reported data so that assumption of Poisson distributed dependent variable is retained. Statistical significance of estimated regression coefficients are assessed from their adjusted standard errors since slight overdispersion is still present in the final model. Estimated model coefficients showed that on the average and at the district level of Nepal, increment of 1 antenatal care visits per pregnant woman and 1% delivery conducted by health workers at health institute as % of expected pregnancies are associated with decline in 31.61% and 2.27% maternal deaths, respectively. On the contrary, increment of 1% delivery conducted by trained traditional birth attendant as % of expected pregnancies, 1% post natal care visits as % of expected pregnancies, and 1000 expected pregnancies are associated with increase in 1.11%, 1.61%, and 3.84% maternal deaths, respectively. In the scenario of high maternal mortality prevalent in Nepalese population and the country committed to a three fourth reduction in maternal mortality by the year 2015 as set in Millennium Development Goals, the analysis done in the paper is likely to be informative as well as helpful to all those concerned.

Keywords and Phrases: Maternal Mortality, Nepal, Dispersion Parameter, Poisson Model, Overdispersion, Model Adequacy Tests, Outliers.

AMS Classification: 62J12.

1 Introduction

Since the launch of the Safe Motherhood Initiative in 1987, awareness to reproductive health has increased globally and today, it is recognized as the crucial part of overall health status of human population. Maternal health is one of the major components of reproductive health whose concern is gaining importance day by day. The tenth revision of international classification of disease defines maternal death as the death of a woman during her pregnancy or within 42 days of termination of pregnancy irrespective of the duration and site of the pregnancy from any cause related to, or aggravated by the pregnancy or its management but not accidental or incidental causes [see WHO (1993)][1]. Pregnancy and delivery related causes are among the top ten reasons for death among women of reproductive age in almost all developing countries [see Winikoff and Sullivan (1987)].

The cause of maternal mortality is classified as direct or indirect. The main direct causes are hemorrhage, sepsis, toxaema, obstructed labor and septic abortion [see WHO and UNICEF (1996)]. Indirect causes accounts for 20% to 25% of maternal death and attributed to illness aggravated by physiologic effects of pregnancy. They include anemia, malaria, HIV/AIDS, heart diseases, ectopic pregnancies, etc. [see WHO (1996)]. Maternal death is one of the leading causes of healthy life year lost for developing country women of reproductive age, accounting for 28 million disability adjusted lost life years (DALY's) as reported by WHO in 2005. [see WHO (2005)].

Estimation of maternal mortality level is complicated, especially in a country such as Nepal where reliable registration system of deaths or causes of deaths are not available. The Nepal family health survey (NFHS), 1996 estimates maternal mortality ratio as 539 per 100,000 live births (alternatively 5 deaths per 1000 live births), which was the highest among the south Asian countries at that time. The ratio in 2000 was 415 deaths per 100,000 live births, estimated by Nepal Planning Commission. The most recent available figure is the Nepal Demographic and Health Survey estimation of 281 in 2006 (3 deaths per 1000 live births). From these figures it can be said that maternal mortality has declined substantially in Nepal in the past decade [see NDHS (2007)]. There are many factors which may have contributed to this decline. In this paper relevant literature is reviewed and the available reported data is analyzed to examine the differential in maternal mortality by various factors which are likely to be associated and estimating the coefficients of statistically significant factors.

Studies in different countries including Nepal have demonstrated that the majority of these deaths could be prevented if problems are recognized early and timely access to appropriate maternal health care occur [see Pathak et. al. (1998) and Gelbandd et. al. (2001)]. According to Nepal Demographic and Health Survey (NDHS), 2006 44% receiving ANC from skilled birth attendant (SBA) there has been significant improvement over a past ten years in the proportion of mothers who get ANC from SBA'S (Doctor, Nurse, Midwife), increasing from 24% in 1992 to 28% in 2001, and 44% in 2006. About 57% of mother who receive ANC showed the signs of pregnancy complications [see NDHS (2007)].

Most studies have emphasized that ANC is essential to reduce complications related to poor health status. Kinshasa and Ojengbede et. al., 1987, in a study has shown that mother who utilizes ANC service have low chance of experiencing morbidity and mortality, however Acharya (1995) in the review paper challenged this notion and concluded that ANC alone can't prevent obstetric complications like hemorrhage or obstructed labor. There is need to supplement ANC with establishment of Essential Obstetric Care (EOC) center in all regions. Researchers are also studying the factors associated with use of ANC [see WHO and UNICEF (2003), and Magadi et. al. (2000)]. A study in rural Nepal found that lack of quality of services at the health post and its remoteness out reach workers, and therefore quantity of facilities is not the strongest determinant of use of ANC services [see Acharya and Cleand (2001)].

Proper medical attention and hygienic condition during delivery can reduce the risk of complications and infection that may lead to death or serious illness to the mother and baby. According to NDHS, in Nepal 81% births take place at home [see NDHS (2007)]. The percentage of birth taking place in health institute has doubled in last five years (9% in 2001 and 18% in 2006). This is impressive because between 1996 and 2001 there was little change in facility based delivery. It is also now recognized that the context within which a provider works has a large effect on the outcome of the delivery [see MacLean (2003)]. The broader concept of "Skilled Attendance" has been developed to describe the presence of a skilled provider with a supportive environment. It is defined as the process by which a woman is provided with adequate care during labor, delivery, the post partum, and immediate periods. In order for this process to take place, the attendant must have the necessary skills and must be supported by an enabling environment, which includes adequate supplies, equipment and infrastructure as well as an efficient and effective system of communication and referral transport [see Safe motherhood IAG (2003)]. There is also great risk of complication for both the mother and new born in the immediate post partum period. In addition, the first two days following delivery are critical for monitoring complication arising from the delivery. According to NDHS only one third of women receive post natal care [see NDHS (2007)] in Nepal.

2 Method

The adopted methodologies are described in the following sections.

2.1 Data and Variables

A set of district level data has been compiled for all districts of Nepal from the Annual Health Reports published by the Department of Health Services (DoHS), Kathmandu, Nepal [see DoHS (2005 - 2008)]. Data is compiled for 4 consecutive years on several key variables containing both cross-sectional as well as annual time series data. The analysis is based upon a series of annual data generated from 75 districts of Nepal consisting of 300 data points observed for 4 years between 2003/04 till 2006/07.

The study variables included maternal deaths (MD), the number of hospitals, health posts (HP), sub health posts (SHP), primary health care (PHC) centers, average antenatal care (ANC) visits, post natal care (PNC) visits, expected pregnancy (EP), female population (FP), deliveries conducted by different categories of health personnel, etc. The survey data of NDHS, 2006 was also examined but the sample coverage was found to be inadequate for estimating maternal deaths at the district level, and therefore left out from the current analysis. The description of the variables used is given below (Table 1). The variables are defined for a given year and district.

Table 1: Variable description

Name	**Label**
Maternal Deaths	Total reported maternal deaths
Expected pregnancies	Number of expected pregnancies
ANC Visits	Average antenatal care visits per pregnant woman
PNC Visits as % EP	Post natal care visits as percentage of expected pregnancy
Deliveries at HI as % EP	Deliveries conducted by health worker at health institute as % of expected pregnancies
Deliveries by TTBA as % EP	Deliveries conducted by TTBA as % of expected pregnancies

2.2 Statistical Analysis

Some descriptive analyses are done and a statistical model capable of establishing linkage between maternal mortality and some differential factors is developed. In the process of the development of the model different types of statistical models including linear as well as nonlinear models were explored. Finally, a nonlinear model with count dependent variable and qualitative or quantitative explanatory variables is selected for establishing linkage between maternal deaths and several key variables. The model is the generalized linear model with log link which is a member of exponential family of distributions having different link functions [See Montgomery et. al. (2003, 2004)].

The density of the exponential family of distributions is

$$f(y_i) = e^{\left(\frac{y_i\theta_i - b(\theta_i)}{\phi}\right)p_i + c(y_i;\phi)} \tag{1}$$

where θ_i and ϕ are parameters, $b(.)$ and $c(.)$ are known functions and p_i are prior weights (generally 1). The mean and variance are

$E(y_i) = b^{'}(\theta_i)$ and $V(y_i) = b^{''}(\theta_i)a_i(\phi)$ where $a_i(\phi) = \frac{\phi}{p_i}$. ϕ is known as the dispersion parameter.

Relating the distribution with the density of the Poisson distribution given by

$$f(y_i) = \frac{e^{-\mu_i}\mu_i^{y_i}}{y_i!} \tag{2}$$

$y_i = 0, 1, 2, 3, \cdots$, we find the following identities.
$\theta_i = Log(\mu_i)$; $b(\theta_i) = \mu_i$; $\phi = 1$; $p_i = 1$ and $c(y_i; \phi) = -Log(y_i!)$ which means that if we replace these identities in equation 1, we get density of Poisson distribution given in equation 2.
The Poisson model specifies that Y is drawn from a Poisson distribution with the parameter μ which is related to the regressors through log linear relation as follows.

$$\mathrm{Y} = \mathrm{E}(\mathrm{Y}/\mathrm{X}_1,\mathrm{X}_2,\cdots,\mathrm{X}_\mathrm{p}) + \varepsilon \tag{3}$$

where $\mathrm{E}(\mathrm{Y}/\mathrm{X}_1,\mathrm{X}_2,\cdots,\mathrm{X}_\mathrm{p}) = \mu$. There exists a function g that relates the mean μ to a linear predictor as follows

$$\mathrm{g}\,(\mu) = \eta = \mathrm{X}^\mathrm{t}\beta \tag{4}$$

If the link function is log then

$$\mathrm{g}\,(\mu) = \mathrm{Log_e}(\mathrm{Y}) = \mathrm{X}^\mathrm{t}\beta = \beta_0 + \sum_{\mathrm{k}=1}^{\mathrm{p}} \beta_\mathrm{k}\mathrm{X}_\mathrm{k} \tag{5}$$

where X_k is the K^{th} independent variable, β_k is the K^{th} parameter. The estimation of model parameters is done by what is known as Iteratively Re-weighted Least Squares (IRWLS) which is identical to the algorithm of Fisher Scoring and leads to maximum likelihood estimates as shown by McCullagh and Nelder (1989). The relative risk (RR) of the dependent variable for increase in the value of the explanatory variable X_k from X_{k1} to X_{k2} making the values of the other explanatory variables constant is given by

$$\mathrm{RR} = \mathrm{e}^{\hat{\beta}_\mathrm{K}(\mathrm{X}_{\mathrm{K}2} - \mathrm{X}_{\mathrm{K}1})} \tag{6}$$

Where $\hat{\beta}_k$ is the partial regression coefficient and estimate of β_k. The calculation of RR assumes that it is constant across the levels of the covariates in this model. A brief discussion on stepwise Fisher scoring algorithm used for estimation of parameters in generalized linear models is given below.

Step 1: For a trial estimate of $\hat{\beta}_i$, $\hat{\eta}_\mathrm{i} = \mathrm{x}_\mathrm{i}^\mathrm{t}\hat{\beta}$ is computed.

Step 2: The initial fitted values are computed, $\hat{\mu}_\mathrm{i} = \mathrm{g}^{-1}(\hat{\eta}_\mathrm{i})$.

Step 3: The working dependent variable is computed, $\mathrm{Z_i} = \hat{\eta}_\mathrm{i} + (\mathrm{y_i} - \hat{\mu}_\mathrm{i})\frac{\partial \eta_\mathrm{i}}{\partial \mu_\mathrm{i}}$
where $\frac{\partial \eta_\mathrm{i}}{\partial \mu_\mathrm{i}}$ is the derivative of the link function evaluated at the trial estimate.

Step 4: The iterative weights are calculated, $W_i = \frac{1}{b''(\theta_i)\left(\frac{\partial \eta_i}{\partial \mu_i}\right)^2}$
where $b''(\theta_i)$ is the second derivative of $b(\theta_i)$ evaluated at the trial estimate.

Step 5: Updated estimate of β is computed by regressing the working dependent variable on the predictors x_i using the weights W_i i.e. the weighted least square estimate is calculated.

Step 6: Step 1- step 5 are repeated until $\hat{\beta}$ attains approximately the same value or successive estimates change by less than a specified small value.

2.3 Accounting for Overdispersion

The variance function of the Poisson distributed variable is equal to its mean. This is often violated when the variance is higher than the mean for a given data set resulting in what is known as overdispersion. The opposite situation when the variance is smaller than the mean is known as underdispersion. Even though in the Poisson model valid statistical inference using computed maximum likelihood standard errors requires correct specification of the conditional mean and variance and therefore equidispersion, the problem of overdispersion (or underdispersion) condition is usually handled in the following manner unless the problem is severe.

The variance can be expressed by the following function assuming that it is a multiple of the mean

$$\mathrm{V(y_i)} = \phi\mu \tag{7}$$

where ϕ is a scalar capturing the extent of overdispersion or underdispersion and known as the dispersion parameter. An estimate of ϕ is given by the ratio of Pearson χ^2 statistic and the corresponding degrees of freedom, $n - p$ as follows:

$$\hat{\phi} = \frac{\sum\limits_{\mathrm{i=1}}^{\mathrm{n}} \tau_\mathrm{i}^2}{\mathrm{n - p}} \tag{8}$$

Overdispersion occurs if $\hat{\phi} > 1$ and under-dispersion if $\hat{\phi} < 1$.
The problem of overdispersion or underdispersion is tackled by consideration of the following consequences.

- The parameter estimates of the model are unchanged.
- The estimated variances and covariances are multiplied by $\hat{\phi}$.

- Log likelihood and scaled deviance are divided by $\hat{\phi}$.
- Wald confidence intervals of the estimated coefficients are corrected by multiplying the width of the interval by $\sqrt{\hat{\phi}}$. This implies that the standard error is also multiplied by $\sqrt{\hat{\phi}}$.

2.4 Model Adequacy Tests

The adequacy of the developed model is verified through standard statistical means such as checking for distributional assumption of dependent variable including overdispersion, overall goodness of fit, statistical significance of estimated parameters, homogeneity of deviance and Pearson residuals, mulicollinrearity, and autocorrelation.

3 Results

Results are presented in the following two sections.

3.1 Descriptive Analysis

A series of descriptive analyses were done after cross examination of annual time series data on several key variables with regard to ecological belts and development regions of Nepal. Results are described as follows.

On Maternal Mortality

The reported maternal deaths per hundred thousand female population aged 15-49 (Table 2 & 3):

- Has remained almost the same (5) between the period 2003/04 till 2006/07 except for the year 2004/05 during which it was relatively higher (6.5) for Nepal even though maternal mortality rate (MMR) is found to be decreasing significantly during the past decade. The maternal mortality ratio obtained from the 1996 NFHS is 539 deaths per 100,000 live births. The 95 percent confidence interval ranges between 392 and 686. The true MMR for 2006 is between 178 and 384, indicating no overlap in the confidence intervals for the two ratios suggesting statistically significant decrease in MMR.
- Is very high (more than double, 11.7) in the mountain region as compared to hills (5.13) and the Terai (4.74) region of Nepal. The values are consistently higher over the past 4 years in the mountain region.
- Has remained almost same in the hills and the terai over the past 4 years.

- Is highest (8.46) in mid western region and lowest in the western region of Nepal and has steadily increased over the recent past from 6.8 to 11.7. Conversely, it has decreased from 5.8 to 2.8 in the central region of Nepal.

Table 2: Maternal Deaths per 100 thousand female population aged 15-49 by ecological belts

Year	Ecological Region			Nepal
	Mountain	Hill	Terai	
2003/04	6.47	5.08	4.55	4.94
2004/05	14.95	5.66	5.98	6.47
2005/06	11.51	5.23	4.07	5.16
2006/07	13.65	4.59	4.40	5.15
4 year	11.69	5.13	4.74	5.43

Table 3: Maternal deaths per 100 thousand female population aged 15-49 by development regions

Development region	2003/04	2004/05	2005/06	2006/07	4 year
Eastern	3.95	8.31	6.83	6.08	6.30
Central	5.79	4.61	3.95	2.76	4.25
Western	2.84	6.26	3.13	4.38	4.16
Mid western	6.82	7.55	7.60	11.69	8.46
Far western	6.17	7.76	6.37	4.24	6.11
Nepal	4.94	6.47	5.16	5.15	5.43

On factors assumed to be associated with maternal deaths (Table 4):

- Government hospitals have increased from 79 to 89, and increase of 12.6% but other health institutions including health posts, sub health posts and primary health care centers have more or less remained the same (around 4000).
- Average ANC visits per pregnant woman have increased only slightly over the past 4 years from 2 to 2.3.
- Deliveries conducted by health workers at health institute as % of expected pregnancies has increased steadily from 7.5 to 11.8 during the same period.
- Similarly, PNC visits as % of expected pregnancies has also increased steadily from 25.9 to 37.8.
- Female population in the reproductive age increased from 6 million to 6.5 million.

- Expected pregnancies increased from 0.9 million to 0.99 million during 2060/61(BS) to 2061/62(BS) and then decreased to 0.96 million in 2063/64(BS).

Table 4: Annual data on various factors assumed to be associated with maternal death

Year	Hospitals	HP, SHP & PHC	Average ANC visits	Delivery at HI	PNC visits	Female Population	Expected Pregnancies
2003/04	79	4027	1.98	7.49	25.89	6031500	899106
2004/05	84	4026	2.05	8.15	28.48	6149664	990328
2005/06	89	4013	2.21	10.31	35.32	6301779	937077
2006/07	89	3999	2.26	11.77	37.77	6467378	960735

3.2 Statistical Model

In the present model building, Poisson model is used to associate maternal deaths at the district level of Nepal with several differential factors likely to be associated with it. The underlying motivations for using Poisson regression model are stated below:

(a) Dependent variable is a count variable likely to be Poisson distributed.

(b) Association between the dependent variable and the explanatory variables is also likely to be nonlinear rather than linear.

(c) Use of linear model did not fit the data as good as with the Poisson model. For instance, using the dependent variable as average maternal deaths for different years rather than total maternal deaths did not produce better results with linear model.

The initial process of model building was characterized by violation of the assumption of the dependent variable distributed as Poisson when all 300 data points were used. The presence of high overdispersion was detected with estimated dispersion parameter taking the value around 3. Although, overdispersion corrected Poisson model can still be fitted by adjusting standard errors and p values for the estimated regression coefficients (found statistically significant) but the fundamental distributional assumption of the dependent variable distributed as Poisson distribution is nevertheless violated. This led to the search for outliers in the model built from all the 300 data points and also to assess whether these outliers were responsible for denying the distributional assumption. It was found that indeed there were a significant number of outliers in the observed values which affected the dispersion parameter causing overdispersion. Consequently, these outliers (29 which is about 10% of all data points) were deleted from data analysis. As expected, this resulted in the model with overdispersion almost eliminated ($\hat{\phi}$ =1.028). Moreover, when the distributional assumption of the observed values of the maternal deaths was tested using one sample Kolmogorov-Smirnov test, it was found that the dependent variable can be assumed as Poisson distributed since the test statistic value was found to be insignificant with p value equal to 0.11. Finally, the Poisson model with 271 data points was used. The estimated standard errors were corrected for the slight overdispersion still present in the model.

The fitted model consisted of MD as the dependent variable and average ANC visits (average / pregnant woman), deliveries conducted by health workers at health institute as % of expected pregnancies, deliveries conducted by trained traditional birth attendants (TTBA) as% of expected pregnancies, PNC visits as % of expected pregnancies, and expected pregnancies as the explanatory variables with Akaike information criterion value equal to 1102. The fitted model showed negative associations with average ANC visits and deliveries conducted by health workers at health institute as % of expected pregnancies while rest of the variables showed positive associations (Table 6). The model parameter estimates, standard errors, p values, relative risks, % increase in MD are shown in table 6. The estimated parameter coefficients suggest that on the average at district level: increment of

- 1 ANC visits per pregnant woman is associated with decline in 31.61% maternal deaths.
- 1% Delivery conducted by health workers at health institute as % of expected pregnancies is associated with decline in 2.27% maternal deaths.
- 1% Delivery conducted by TTBA as % of expected pregnancies is associated with increase in 1.11% maternal deaths.
- 1% PNC as % of expected pregnancies is associated with increase in 1.61% maternal deaths.
- 1000 expected pregnancies are associated with increase in 3.84% maternal deaths.

It is to be noted that the model coefficients is generally applicable in between the data observed for the explanatory variables and will be obviously questionable for data beyond the minimum and the maximum observed values at the district level as shown in the table 5. Moreover, model is built based upon the data obtained in the context of districts of Nepal and therefore it is best suitable for Nepal rather than other countries of the world. However, it may be used in the countries with prevalence of similar conditions as observed in Nepal with regard to the variables under investigation.

3.3 Model Adequacy Tests

- The distributional assumption of dependent variable i.e. maternal deaths distributed as Poisson is maintained since the estimated dispersion parameter measuring overdispersion (or underdispersion) is only slightly greater than unity

Table 5: Descriptive measures of the model variables after deletion of outliers

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Maternal deaths	271	0.0	13	3.89	2.602
ANC visit	271	1.0	4.9	2.122	.4660
Deliveries at HI as % EP	271	0.7	62.9	9.501	11.2700
Deliveries by TTBA as % EP	271	0.0	39.5	6.797	7.0672
PNC Visits as % EP	271	6.4	66.3	31.458	11.9408
Expected pregnancies	271	391	36700	1.21E4	7713.752

Table 6: Model parameter estimates

Variables	Estimate	Standard Error	Chisquare	Pr > Chisquare	RR	% Increase	
						%	Per
Intercept	1.254	0.190107	43.5109	< 0.0001	-	-	-
Average ANC	-0.380	0.106158	12.8139	0.0034	0.6839	-31.61	1
Delivery at HI as % EP	-0.023	0.004258	28.6108	< 0.0001	0.9773	-2.27	1%
Delivery by TTBA as % EP	0.011	0.004765	5.3284	0.0210	1.0111	1.11	1%
PNC as % of EP	0.016	0.003346	22.8672	< 0.0001	1.0161	1.61	1%
Expected Pregnancies	0.0000377	0.0000053	50.0828	< 0.0001	1.0384	3.84	1000

(1.028). Moreover, one sample Kolmogorov-Smirnov (KS) test statistic is statistically insignificant with p value 0.11 when used to test whether the variable is Poisson distributed or not.

- The overall goodness of fit of the model is assessed by deviance and Pearson residuals. The deviance residual is found to be 292.5 for 265 degrees of freedom which is just insignificant at p value 0.12. Similarly, the Pearson residual is found to be 272.36 for 265 degrees of freedom which is also insignificant at p value 0.36. The log likelihood of the model is -544.89.

- The likelihood ratio chisquare value is 198.03 at 5 degrees of freedom using omnibus test which is highly significant with p value less than 0.0001. This shows that addition of explanatory variables in the model after the intercept term is statistically significant.

- The coefficients of the independent variables are found to be statistically significant with p values less than 0.03.

- Deviance and Pearson residuals are found to be normally distributed since KS tests shows insignificant p values equal to 0.50 and 0.42 for deviance and Pearson residuals, respectively.

- The standardized deviance and Pearson residuals are found to be homoscadastic with no outliers seen. All the residuals are in between -2.35 and 2.35 for standardized deviance residual and in between -2.6 and 2.6 for Pearson residual.

- The presence or absence of multicollinearity is examined through the computation of variance inflation factors which shows that the values are less than 2.0 and demonstrates the absence of multicollinearity in the developed model.

- As far as serial correlation is concerned, autocorrelations and partial autocorrelations are computed up to lag 16 for both deviance and Pearson residuals which show that the correlations are small and insignificant for both deviance (<0.09) as well as Pearson residuals (<0.11).

4 Conclusions

According to NDHS, maternal mortality even though decreasing in the recent times is still high in Nepal. It estimated maternal mortality as 0.33 per 1000 female population aged 15-49. Reduction of the maternal death (by 3 quarter during the period 1990-2015) was set as a target for monitoring the achievement of the Millennium Development Goal (MDG) No.5, which seeks to improve maternal health. Despite the fact that MMR is decreasing in Nepal, the annual data published by DoHS shows that the reported maternal deaths per thousand female population aged 15-49 has remained almost the same during the last 4 years. Moreover, the deaths are grossly under reported since only around 16.5% of NDHS estimate has been found reported. A cross examination between the ecological belts of Nepal reveal that the reported maternal deaths per thousand female population aged 15-49 is more than double in the mountain region as compared to other regions.

In order to assess the differential in maternal mortality across Nepal at district level and the factors associated with these differences, a 4 year data is collected from DoHS annual reports and analyzed. The statistical analysis showed that various factors were associated with maternal deaths in Nepal. These included ANC visits, PNC visits, mode of delivery, and expected pregnancies among other variables taken under consideration for analysis. While ANC visits and the delivery conducted at health institute were negatively associated, rest of the variables was positively associated with maternal death. It is also important to note that delivery by TTBA was found positively associated with maternal deaths.

Since the model with all 300 data points included was characterized by the violation of the Poisson distributed dependent variable, altogether 29 (nearly 10%) outliers were detected and deleted from the final model. This effectively resulted in near equidispersion of the dispersion parameter and Poisson distribution of the dependent variable. The question of existence of substantial number of outliers in the observed data for maternal deaths at the district level is indeed a vital question. There may be several reasons behind this observation such as due to the presence of errors in the reported data itself, presence of unknown factors whose influences resulted in overdispersion, etc. These scenarios obviously call for further research in this area. However, what is suspected and believed true is that maternal deaths are usually under reported in Nepal. In this situation the presence of outliers particularly with high values of maternal deaths is surprising and may be due errors in recording of data. On the contrary, outliers with zero or low maternal deaths may be explained as the consequence of under reporting. In the current model building process the outliers are deleted primarily because it is believed that these are basically generated through errors occurred during data recording. The existence of outliers due to other reasons is also possible and to explore these reasons warrants further research in this area.

Finally, in order to achieve the MDG goals regarding the reduction of maternal deaths in Nepal, efforts at the governmental level will have to be intensified to formulate and implement national policies suitable for the reduction of maternal deaths particularly in rural area of Nepal. Consequently, the factors discussed in the paper and found statistically significant in the model have to be closely monitored in the coming years.

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