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ASSESSING THE EFFECTS OF SOCIO-ECONOMIC DETERMINANTS ON INFANT MORTALITY IN NORTH-EASTERN INDIAN STATES BASED ON AREAL DATA MODELLING

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Abstract

Socio-economic determinants have been identified as the most important set of factors affecting the prevailing Infant Mortality (IM) scenario in a region. The present paper analyses the district level information on the socio-economic determinants and the existing infant mortality scenario in North-Eastern Indian states in order to explain the existing infant mortality. The district level raw data on infant mortality for the seven North-Eastern Indian states exhibit a high degree of intra-class (state) correlation as well as high degree of inter-districts spatial correlation. A Generalized Liner Mixed Model approach has been used to analyse the data which successfully was able to model both of the intra-class as well as spatial correlations. The results on district level infant mortality rate and the infant mortality risk had also been computed and mapped for the study region. It has been observed that out of

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the five socioeconomic categories the existing combined lowest two categories population and the number of under-age married girls in a district are positively associated with the IM rate of the district to an extent that an increase of 1,000 house hold in the combined two lower income group quintiles increases the IMR by 0.4087 per cent while an increase of 100 under-age married girls increases the IMR by 0.1026 per cent. The higher income group population and the availability of number of Primary Health Centres (PHC) are negatively associated with the IMR. The highest negative association was observed between the middle socioeconomic quintile with the IMR as an increase of 1,000 HH in this category decreases the IMR by 0.6626 per cent.

Key Words: Socio-economic determinants, infant mortality rate, risk surface, spatial correlation and generalized linear mixed model.

1. Introduction

The Millennium Development Goal-4 (MDG-4), set by WHO, calls for reducing under 5 (U-5) mortality rate by two-third between 1990 and 2015 ("Levels & Trend", 2014). In case of India, the MDG-4 requires to bring infant mortality rate (IMR) to less than 39 per 1,000 live births by the end of 2015 ("India unlikely", 2015). However, the current IMR in India is 40 and it may not achieve the goal set by MDG-4 by the end of 2015. Assam together with Madhya Pradesh tops the list with an IMR of 54 per 1,000 live births and Meghalaya ranks third with 47 (Office of the Registrar General, 2013). The Saiha district of Mizoram has an IMR of 93 per 1,000 live births (MoHFW). India may be very near to achieving the target at the national level by the end of 2015, however, the target seems to be far away at some states as well as some district levels.

Infant mortality is a complex and multifaceted problem and it is associated with a variety of factors such as premature age of mother, maternal health, quality and access to medical care, public health practices and socio-economic conditions. The socio-economic conditions control most of the endogenous and exogenous factors. A

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lowered level of these determinants have been identified as being the most influential factors for increased level of infant mortality, globally. Countries with high income inequality have higher infant mortality than countries with similar level of income distribution and income and infant mortality have negative relationship (Flegg, 1982; You, Hug, et al., 2015; Wang, et al. 2014). IMR among poor families in India has been observed to be twice as high as in better-off families (IIPS & ORC, 2007). In India, 69 percent of total population lives in rural India and out of these 92 percent households (HH) have a monthly income of less than Rs.10,000. In urban India, 3,500,000 HHs have no sources of income (Subodh, 2015).

Areal data are aggregated quantities for each non-overlapping polygon with defined boundaries (Roger, Bivand, et al., 2008). These areal entities may themselves constitute the units of observation, for example when studying the population sizes of countries, population of each country is taken as a unit. These data are useful in ecological studies relating area characteristics to morbidity and mortality rate (Townsend, 1998; Carstairs, 1991; Wing, et al., 1992). Area based measures can be proposed as alternative indicators for socio-economic condition of individuals when individual level measures are not available (Krieger N, 1991, 1992). There has been growing interest in the use of areal data which is available in public and private organizations of socio-economic characteristics in studies of social inequalities and health.

The article presents atlas of infant mortality in terms of relative risk, usually standardized mortality ratios (SMR) and IMR in the North-Eastern Indian states, namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram and Tripura. The study region is divided into 71 non-overlapping administrative units called districts. As the covariate information for Nagaland was not available, therefore, Nagaland could not be considered in the present analysis. Also, it estimates the effects of some covariates on infant mortality risks. The article is divided into 6 sections. Section 1 is introductory in nature and section 2, presents the literature review and data description. Section 3, presents the modelling aspect for correlated data. The results of the analysis, discussions on the findings and conclusions are presented in sections 4, 5 and 6 respectively.

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2. Literature Review and Data:

2.1. Literature Review:

Ecological regression studies to identify the causal factors affecting IMR and measure the effects of various covariates on IMR have been performed by some of the researches in India. Dixit et al. (2006) used multiple regression modelling approached to examine socio-economic characteristics physical amenities and health care at district level and attempted to identify factors that influence IMRs and life expectancy (LE) in the Indian Thar desert. They identified the number of health institution and percentage of households visited by health worker in the last three month as most important factors affecting IMR and LE.

Kapoor, 2010, used district level data on IMR for 666 districts in India and applying Quantile regression approach identified the women literacy and women's labour force participation as influencing factors in reducing IMR.

Singh et al., 2011, applied the geo-statistical techniques like Moran's I, univariate local indicators of spatial association (LISA), bivariate LISA, spatial error regression and spatiotemporal regression on National Family Household Survey (NFHS) 1992-1993, NFHS 1998-1999 and District Level Household Survey (DLHS) 2002-2004 data. Based on, natural geographic regions as unit of observation, obtained that regions which were underprivileged in terms of female literacy or child nutrition were also disadvantaged in terms of the two indicators of mortality during early childhood. Moreover, the effect of poverty on infant and under-five mortality reduced with time, whereas, female literacy had a consistently increasing effect. Urbanization and coverage of safe delivery were not associated with either infant or under-five mortality.

Singariya, 2013, based on state level data, explored social economic factors associated with IMR using regression analysis and principal component analysis. He concluded that women empowering indicators like percent female engaged in salaried works and female literacy rate had negative relationship but female work participation rate and percent female cultivator have positive association with IMR in India.

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Barma et al., 2014, had examined the trend of IMR in Assam between 1998 and 2012 and concluded that IMR in Assam is declining in both of the rural and urban Assam. They also report that education among the female, gap between two births, vaccination of babies and hygienic conditions, reduces IMR. Whereas, absence of doctors and nurses, under-age and over-age marriage, low income group were observed to be positively associated with IMR.

2.2. Data:

The district level Infant Mortality and birth are reported by the Ministry of Health & Family Welfare (MoHFW), Government of India, available at the URL: https://nrhm-mis.nic.in/hmisreports/frmstandard_reports.aspx, have been used for the analysis. Sum of infant mortality for two consecutive years 2013-14 and 2014-15 is used as a response variable. The five economic classes based on wealth index and number of under-age marriage girls from District Level Household and Facility Survey (DLHS-3) conducted by International Institute of Population Sciences (IIPS), Mumbai in collaboration with MoHFW, Government of India, and district level number of public health centre (PHC) from National Rural Health Mission (NRHM) are taken as regressors. Wealth index is prepared by IIPS at national level by combining household amenities, assets and durable goods and has divided the household (HH) into five groups on the basis of quintiles. However, for the analysis, percentage of district level socio-economic classes are converted into number of 100,000 HH in a socio-economic class in district level on the basis of 2011 census will be used. Similarly, remaining regressors, number of under-age marriage girls and number of PHC in a district are converted into number of 10,000 under-age marriage girls and number of PHC per 10,000 HH respectively and used as regressors in the analysis.

2.3. Infant Mortality Risk and Infant Mortality Rate:

The infant mortality risk is the ratio of observed number of infant mortality to the corresponding expected number of infant mortality in a district. In the present paper

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the expected number of infant mortality is estimated by internal standardisation method. Figure 1(a) presents the spatial pattern of infant mortality risk based on raw data. Except the state of Assam the infant mortality risk is more or less similar within a state. Barring the West Kameng and Churchanpur districts of Arunachal Pradesh and Manipur respectively, the infant mortality risks for other districts of these two states are 0.5, that is, have low risk. The Dhalai district of Tripura is the only district in the state which has elevated risk and lies between 1 and 2. Cachar, Morigaon, Bhubri, Baksa, Udalguri, Golaghat, Lakhimpur and Dhemagi districts of Assam also have risk of infant mortality in the range 1 to 2. The entire districts of Mizoram, except Ri-Bhoi district of Meghalaya and three districts of Assam namely, Dima Hasao, Bongaigaon, Hailakandi are the districts which have highest elevated risk of infant mortality in this study region.

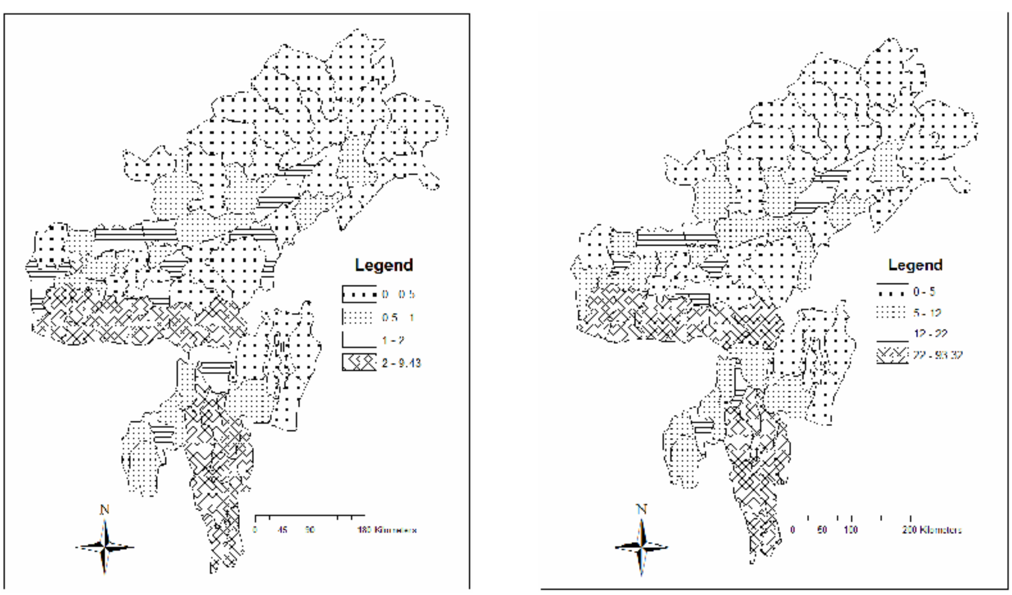

Figure 1: Map of District Level Raw Infant Mortality Risk (a) and Infant Mortality Rate (b) in Six North-Eastern Indian States.

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Figure 1 (b) presents the spatial pattern of raw IMR in the district level. Its surface shows the similar pattern of surface with Figure 1 (a) in term of IMR. In these two surfaces, those districts which occur the low risk are occupied by low IMR. Similarly, it happens in those high IMR districts also.

2.4. Correlations in Raw Infant Mortality:

The states form a natural grouping for districts within it. Further, the spatial contiguity of districts is expected to introduce some spatial association between neighbouring districts. These considerations may lead to the district level observations being dependent. To have an idea of the grouping effect due to states as well as the strength of spatial association, intra-class (state) correlation and Moran's I, the measure of correlation are computed together with their significance values and presented in Table 1.

Table 1: Correlations in District Level Raw IMR data.

	Parameter	Estimated value	p-value
Spatial correlation	Moran's I	0.2525	0.0005
Intra-state correlation	ρ	0.6698	<0.0001

The intra-class correlation and spatial correlation in the raw infant mortality data obtained as 0.6698 and 0.2525 respectively, and are significant at most of the values.

The distribution of state wise population proportion, in term of socio-economic classes together with the same for the whole study region is presented in Figure 2. The percentage of 'poor' is nearly negligible in Mizoram, very small in Tripura, Meghalaya and Assam. The percentage of poor is less than 10 percent in the entire North-eastern region taken together.

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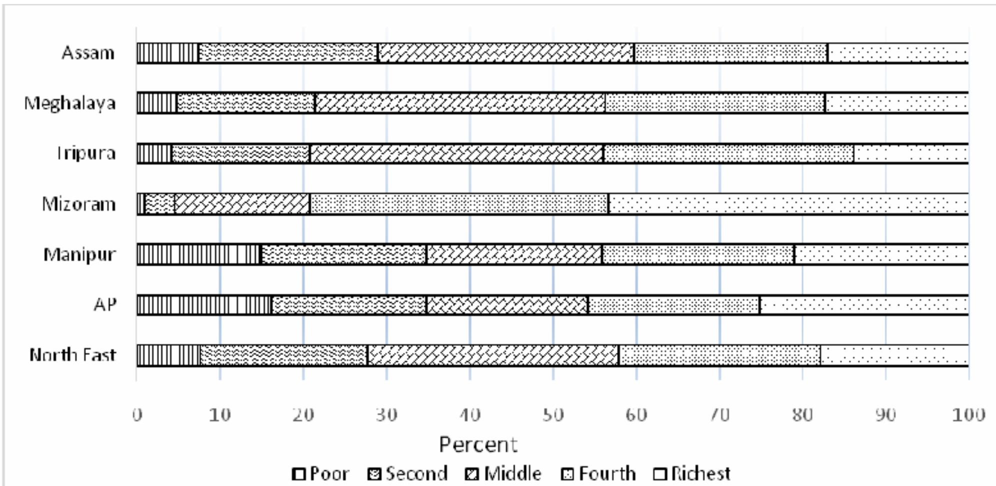

Figure 2: Socio-Economic Classes in North Eastern Indian.

3. Areal Data Modelling:

The correlations present in the infant mortality make the multiple linear regression analysis inappropriate for the analysis. Therefore, it was required to use a suitable model which can capture both intra-class correlation as well as spatial correlation simultaneously in the data. Initially, Conditional autoregressive (CAR) model was used to analyse the data (Besag et al., 1991; Clayton et al., 1987). The CAR model was not able to explain the correlations present in the data as both the types of correlations were significantly present in the model residuals. Next, the Generalized Linear Mixed Model (GzLMM) was tried which could successfully explain the variability and was able to provide stable estimates of parameters. For GzLMM the response variable was the observed number of infant mortality in a district and the regressors were the number of socio-economic classes, number of PHC per 10,000 HH and number of under-age married girls in the corresponding districts.

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The data used to quantify infant mortality are denoted by y_{ij}, the number of infant mortality cases observed in each of the non-overlapping j^{th} district coming from i^{th} state within a specified time frame. A general Poisson GzLMM with mean μ_{ij} is given by

$$y_{ij} \mid u_i \sim Poisson\ (\mu_{ij})$$

$$\log(\mu_{ij}) = offset + x'_{ij}\beta + u_i \ \ i = 1, 2, \ldots, n_i; \qquad (1)$$

$$u_i \sim i.i.d\ N(0, \sigma_u^2),$$

and x'_{ij} are vector of explanatory variables of j^{th} district in i^{th} state. u_i is the random effects coming from i^{th} state and β is a vector of regression coefficients.

Offset in this model depend on the size and demographic structure of the population living in the study area. Different offset allowed estimation of infant mortality risk and of infant mortality ratio.

Results:

The data are analysed by the above model using R-software with two different types of offsets. Best results in terms of deviance measures were obtained on taking the regressors combination as 'poor & second', 'middle', 'fourth', 'richest', PHC and the number of under-age married girls. Therefore, these six regressors were considered in the present analysis and the results are presented in Table 2. Part 'A' of Table 2, presents the results for the analysis based on infant mortality risk whereas part 'B' presents the results based on IMR. In the table the estimated intercepts and slopes were presented in the exponentiated forms. The estimated spatial and intra-class correlations in the model residuals are also presented in the table.

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Table 2:

		A. Infant Mortality Risk		B. Infant Mortality Rate	
	Parameters	Estimated value	p-value	Estimated value	p-value
Intercept	$Exp\ (\beta_0)$	1.4353	0.4970	14.2069	<0.0001
Poor & Second	$Exp\ (\beta_1)$	1.4087	<0.0001	1.4087	<0.0001
Middle	$Exp\ (\beta_2)$	0.3374	<0.0001	0.3374	<0.0001
Fourth	$Exp\ (\beta_3)$	0.8380	0.0319	0.8380	0.0270
Richest	$Exp\ (\beta_4)$	0.7884	<0.0001	0.7884	<0.0001
Under age marriage girls	$Exp\ (\beta_5)$	1.1026	<0.0001	1.1026	<0.0001
Public health centre	$Exp\ (\beta_6)$	0.8560	<0.0001	0.8560	<0.0001
Spatial correlation in model residuals	Moran's I	-0.0966	0.8774	-0.0966	0.8717
Intra-state correlation in model residuals	ρ	0.0000	1.0000	0.0000	1.0000

The part A of Table 2 presents the estimated overall mean risk for the study region as 1.4353 with a p-value of 0.4970. The overall risk was insignificant and can be inferred that the overall mean risk scenario for the study region is good as it did not have elevated risk. The estimated exponentiated slope values for all the regressors have significant effects on the district level infant mortality risks. However, 'poor & second' socio-economic class and the number of under- age married girls have positive effects on infant mortality risk whereas 'middle', 'fourth' and 'richest' socio-economic classes and PHC per 10,000 HH have negative effects on infant mortality risk. An increase of 100,000 HH in 'poor & second' socio-economic classes, increases the existing district level infant mortality risk by 40.87%. This translates into increasing 1 HH in 'poor & second' socio-economic class, increases the existing district level infant mortality risk by 0.00041% and the estimated value is significant at most of the ? values. Whereas, with an increase of 100,000 HH in the 'middle' socio-economic class, the district level infant mortality risk decreases by 66.26% of the existing value. Similarly, for an increase of 100,000 HH in the 'fourth' and 'richest' socio-economic classes, the district level infant mortality risk decreases by 16.20% and 21.16% respectively, of the existing risk values. Again an increase of 10,000 under age married girls in a district increases the infant mortality risk by 10.26% of the existing value. Finally, an increasing a PHC per 10,000 HH in a district decreases the infant mortality risk of the district by 14.40% of the existing risk value. The estimated spatial and intra-class correlations in the model residuals are -0.0966 and 0 respectively, with p-values of 0.8774 and 1.0000, indicating

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absence of significance correlations in residuals. The district level estimated infant mortality risk for the study region were mapped and presented in Figure 3 (a).

Part 'B' of Table 2 presents the estimated overall average IMR for the study region as 14.21, obtained using the model. The estimated overall average IMR for the study region was significant at most of the values. The present article estimates infant mortality risk and IMR based upon the same covariates but with different offsets. Therefore, these two measures differ for intercept values only. The slopes were same for both the infant mortality risk and IMR. Therefore the interpretation is that an increase of 100,000 HH in 'poor & second' socio-economic classes, increases the existing district level infant mortality rate by 40.87%. This translates into increasing 1 HH in 'poor & second' socio-economic classes increases the existing district level infant mortality rate by 0.00045%. Similar explanation holds for other regressors in the model. The district level estimated IMR for study region are mapped and presented in Figure 3 (b).

3.1. Infant mortality surface:

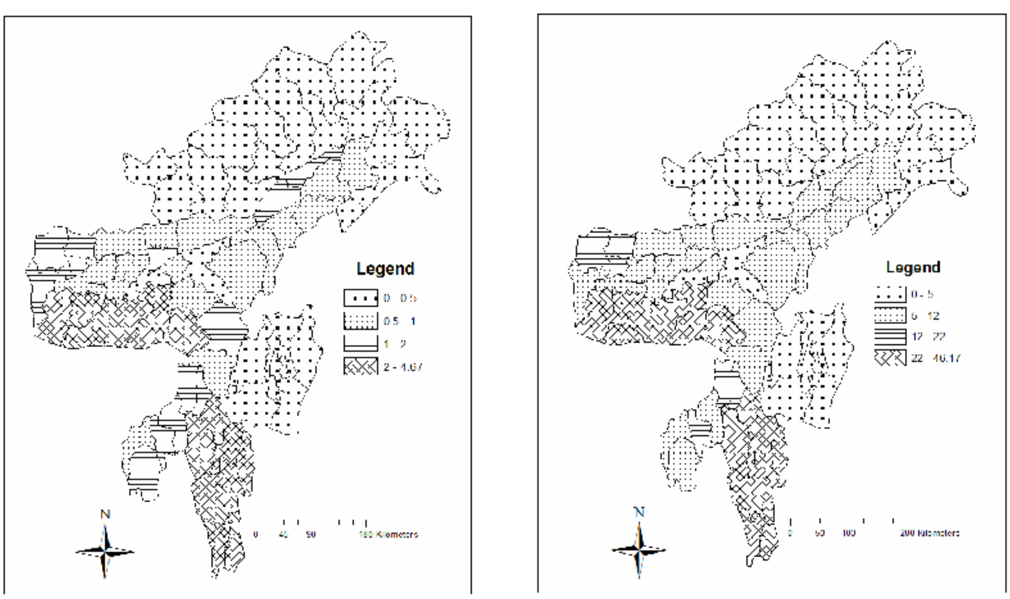

Figure 3: Map Showing District Level Estimated Infant Mortality Risk (a) and Infant Mortality Rate (b) using GzLMM for six North-Eastern Indian states.

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Figure 3 (a) and (b) present respectively, the estimated infant mortality risks as well as IMRs obtained through the use of GzLMM. The map of estimated values for infant mortality risk and IMR are smoother than the raw maps as the maximum values for infant mortality risk and IMR in raw data were 9.43 and 93.3, while the corresponding model estimates were 4.67 and 46.17 respectively. Also, the estimated surfaces exhibit a relatively more similar pattern within the states as compared to the raw data surfaces presented in Figure 1. However, the estimated infant mortality surfaces exhibit a similar spatial pattern to the raw infant mortality maps, with the highest infant mortality for both the maps being observed in the state of Mizoram and Meghalaya. All the districts of Arunachal Pradesh and Manipur fall in the lowest category of infant mortality risk and IMR level.

4. Discussion:

In raw data the most influential observation for the study region were the infant mortality risk and IMR values for Saiha district of Mizoram with values 9.42 and 93.3, respectively. Analyses were performed by including as well as excluding Saiha district value and in both the cases the results obtained were quite similar. Therefore, the results presented here include the value from Saiha district. Again, grouping of socio-economic classes into four groups i.e., 'poor & second', 'middle', 'fourth' and 'richest' were obtained from various combination of socio-economic classes on the basis of measures like AIC and deviance in order to obtain the best results.

The presence of a high degree of intra-state correlation as well as high degree of inter-district spatial correlation makes analysis such as multiple linear regression, unsuitable for this kind of data. Therefore, the present data set was modelled using GzLMM which was able to capture both the correlation as well as estimate the parameters precisely.

The overall mean infant mortality risk and IMR for the study region obtained using GzLMM are 1.4353 and 14.21 respectively, are larger than the overall means of

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the raw data 1.15 and 11.55. However, the conclusion of overall mean of infant mortality risk has an inconvenient. The regression results indicate that an increase of 100,000 HH in the lowest two quintiles of socio-economic category of 'poor &second' in a district increases the mean infant mortality risk and IMR value of the district by 40.87%. An increase of 100,000 HH in the 'middle', 'fourth' and 'richest' socio-economic category in a district decreases the mean infant mortality risk and IMR values of the district by 66.26%, 16.20% and 21.16% respectively. Fifthly, the increase of 10,000 under age marriage girls in a district, increases the mortality risk and IMR by 10.26% of the existing value. Lastly, an increase of one PHC per 10,000 HH in the district decreases the district level infant mortality risk by 14.40% of the existing value. All the six results reported here accompanied a high level of confidence. The study region has 27.73% of population under 'poor & second' socio-economic class, 30.12% of population in 'middle' socio-economic class, 24.23% of population in 'fourth' socio-economic class and 17.92% of population in 'richest' socio-economic class.

These results also indicate upon the effects of the different socio-economic classes in a district in North-eastern India on the infant mortality. The 'poor & second 'socio-economic group has positive effect on district level infant mortality risk and IMR, while the 'middle', 'fourth' and 'richest' socio-economic classes together has a negative effect with the same. The 'middle' socio-economic class of the society is the most effective class in reducing IMR. Also, the 'fourth' and 'richest' socio-economic classes have impact on reducing infant mortality. While, the effect of socio-economic classes are reducing from 'middle' to 'richest'.

5. Conclusion:

The present overall results support the findings as reported in literature that the infant mortality risk and IMR are relatively higher in the lower income group families. However, surprisingly the districts from the states of Arunachal Pradesh and Manipur have a relatively higher concentration of lower income group HHs, but the infant mortality risk and IMR are the lowest. Again, the districts of Meghalaya and Mizoram have

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relatively lower concentration in lower income group families but have the highest infant mortality risk and IMR levels within the study region. This issue needs further investigation. Also, this analysis shows that under-age marriage girls have positive effects on infant mortality. At last, it explained the importance of PHC which help in controlling the infant mortality.

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