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An investigation of spatial determinants of the birth size of child in the last two decades in India

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ABSTRACT: *The study examines the clustering of birth size and investigates the potential effect of geographical areas on birth size after adjusting for socioeconomic and demographic risk factors in the last two decades in India. The study used the data from the first, second, and fourth rounds of the National Family Health Survey (NFHS) conducted in 1992-93, 1998-99, and 2015-16 respectively, in India. The study divides India into 74 natural zones for analytical purposes and used various geospatial techniques to analyze data. High-high clustering of smaller than average birth size was observed in western and south-western India in 1992-93, south-western and central India in 1998-99 and north-eastern India in 2015-16. The univariate Moran's-I of the smaller than average birth size increased from 0.333 in 1992-93 to 0.456 in 2015-16. The spatial error regression model reveals unplanned pregnancies (%), unimproved toilet facilities (%), and solid cooking fuels (%) were significantly and positively associated with smaller-than-average birth size. The study concludes there is a significant shift in the spatial clustering and unplanned pregnancies (%), unimproved toilet facilities (%), and solid cooking fuels (%) emerged as significant spatial determinates of smaller than average birth size in the last two decades in India.*

KEYWORDS: Spatial, birth size, clustering, National Family Health Survey (NFHS), India

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I. INTRODUCTION

Low Birth Weight (LBW) is a significant public health problem globally; the prevalence has been consistently higher in Southasian and Sub-Saharan countries in the last decade. It is estimated that more than 20 million births (15-20% of all births) are LBW in the world in 2014. There is a significant variation in the prevalence of LBW across and within countries. It varies from 28% in South Asia and 13% in Sub-Saharan Africa to 9% in Latin America. In particularly, 30-35% of births are full-term LBW in India. The country alone contributes to 40% of LBW births in all developing countries and nearly half of those born in Asia.

The recent National Family Health Survey-4 (NFHS-4) estimates suggest that the prevalence of LBW varies from the lowest 6% in Mizoram to the highest 27% in Delhi 2015-16 in India. India consists of 28 states and 8 union territories (UT), and clearly, there is a significant within and between states variation in the prevalence of LBW. On the other hand, the classical demographic, clinical, epidemiological studies examining prevalence and risk factors of LBW have majorly focused on bio-demographic individual risk factors and completely ignored a geographical space as an independent factor affecting levels and determinants of LBW in India.

It is noteworthy that there is evidence in developed countries suggesting linkages between LBW and geographical space, and these studies also identified factors affecting the spatial pattern of LBW. Given the complete dearth of studies examining spatial patterns and associated factors of LBW, the present study aims to examine the clustering of birth size and to investigate the potential effect of geographical areas on birth size after adjusting for socioeconomic and demographic risk factors in the last two decades in India. Many research studies have suggested 'birth size of child' is a relatively good indicator of 'birth weight' in underdeveloped and developing countries, including India, where reliable, accurate and complete data of 'birth weight' is not available.

II. METHODOLOGY

The study is cross-sectional and based on the data from the first, second, and fourth rounds of a nationally representative population-based cross-sectional National Family Health Survey (NFHS) conducted in 1992-93, 1998-99, and 2015-16 respectively in India (Demographic and Health Surveys (DHS) are known as NFHS in India). The analysis in the study includes only the youngest under-five live and singleton children born in the reference time of the respective rounds of the survey.

In the study, the outcome variable is the 'proportion of smaller than average birth size of child.' To get details about the birth size of a child in NFHS, mothers of children below age five years are asked, "When (NAME) was born, was (he/she) very large, larger than average, average, smaller than average, or very small?" The response categories to this question are 'very large,' 'larger than average,' 'average,' 'smaller than average,' 'very small,' and 'don't know.' The outcome variable 'birth size of child' has two categories. The responses 'smaller than average' and 'very small' are combined as 'smaller than average.' The other responses are combined as 'average and larger.' Further, the study utilized female illiteracy (%), unplanned pregnancies (%), less than four antenatal care (ANC) visits (%), use of unimproved toilet facilities (%), use of solid cooking fuels (%), and poverty (%) in natural zones as exposure variables.

III. DISCUSSION

We analyzed the spatial clustering and associated risk factors by applying Moran's I Index, univariate and bivariate local indicators of spatial association (LISA), and spatial regression. The spatial clustering was examined at 76 natural regions based on the agro-climatic scheme proposed by Bhat and Zavier (1999) because the DHS 1992-93 and 1998-99 rounds data were not district representative. The analysis at the natural region level helped to study the changes in spatial clustering of birth size in the last two decades in India.

To examine the spatial clustering of the birth size of child across regions, Moran's I Index is computed to measure the extent of the autocorrelation among the neighboring regions. Spatial autocorrelation is used to investigate the correlation of a variable with itself over space.

Moran's I: It is applied to examine spatial autocorrelation. There are two forms of Moran's I, Global Moran's I and Local Moran's I. The Global and Local Moran's I are used to measure spatial autocorrelation for the entire global region and each local region. The Global Moran's I is calculated as,

$$\mathbf{I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\,(y_i - \bar{y})\,(y_j - \bar{y})}{\sum_{i=1}^{n}(y_i - \bar{y})}}$$

here,
n = number of regions i and j;
yi = proportion of children born with smaller than average size in the ith region;
ȳ = mean proportion of children born with smaller than average size;
wij = spatial weight where j denotes the region adjacent to the ith region.

The value of Moran's I ranges from – 1 (perfect dispersion) to + 1 (perfect correlation). Negative (positive) values indicate negative (positive) spatial autocorrelation. If its value is zero, it denotes no or random spatial clustering. A positive value denotes spatial clustering with regions that are likely to have similar values, while a negative value denotes the regions that are more likely to have dissimilar values.

Univariate LISA: It measures the correlation of neighborhood values around a particular spatial location. It determines the extent of spatial nonstationary and clustering present in the data. It is given as,

$$\mathbf{I_i = Z_i \sum_{j} w_{ij}\; z_i}$$

Bivariate LISA: It measures the local correlation between an outcome variable and the weighted average of the exposure variable in the neighborhood. The bivariate LISA is calculated as,

$$\mathbf{I_i = n_i \sum_{j} w_{ij}\; z_i}$$

Spatial regression: It is applied to examine the spatial effect on an outcome variable in two ways,

Spatial lag model: If the dependent variable, Y, is correlated with a weighted average of its value in its neighborhoods and other locations, the relationship can be expressed as,

$$Y = \rho WY + \beta X + \varepsilon$$

here,

ρ = spatial lag parameter;

W = spatial weight matrix;

X = vector of explanatory predictors;

β = corresponding coefficient vector;

ε = error term.

In the spatial lag model, it is assumed that the error terms ε's are identically and independently distributed (iid's), although one can correct for heteroscedasticity. The ordinary least square (OLS) would provide biased and inconsistent estimates of the model parameter due to simultaneity bias.

Spatial error model: If the spatial dependence enters the model through the error term, ε, the spatial model can be given as,

$$Y = \beta X + \varepsilon \text{ and } \varepsilon = \lambda W\varepsilon + \mu$$

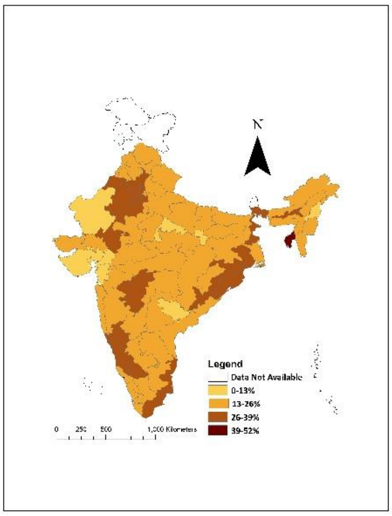
here,

λ = spatial autoregressive parameter;

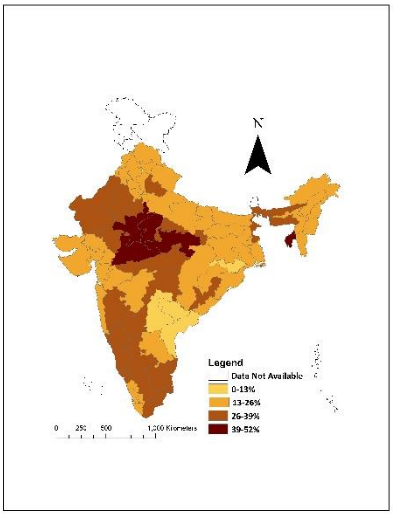
μ = iid's.

A spatial error model is a special form of regression with a non-spherical error term, and OLS, although unbiased, is insufficient. In this way, the spatial regression considers proximity among geographical units through weight matrix W.

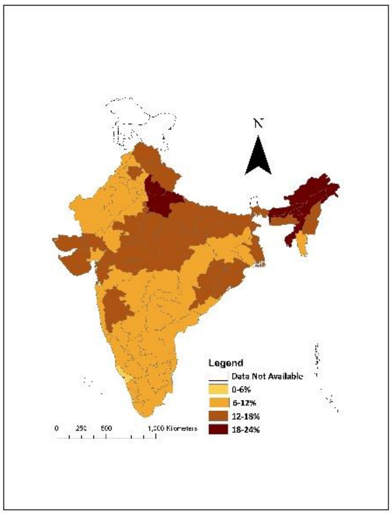
IV. FINDINGS



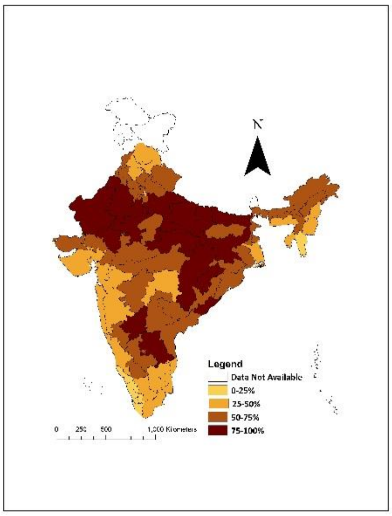
Ssmaller than average birth size (%), India, 1992-93



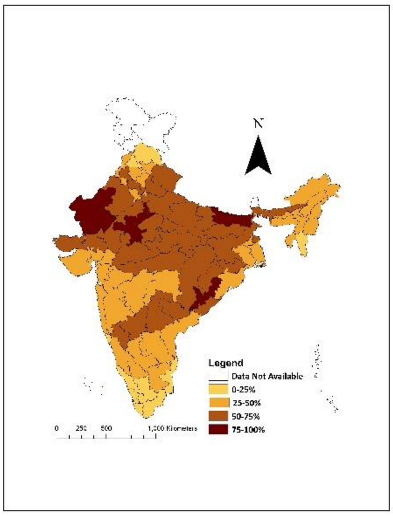
Smaller than average birth size (%), India, 1998-99



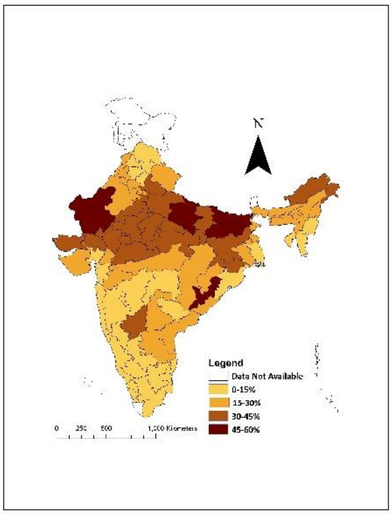
Smaller than average birth size (%), India, 2015-16



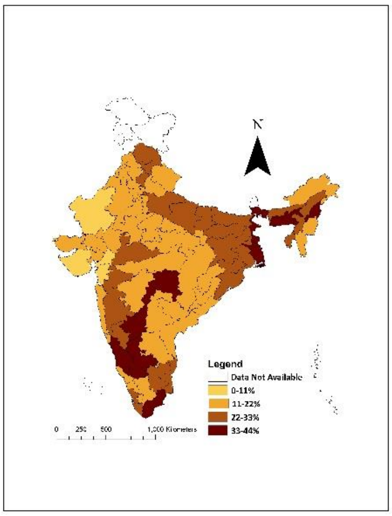
Female illiteracy (%), India, 1992-93



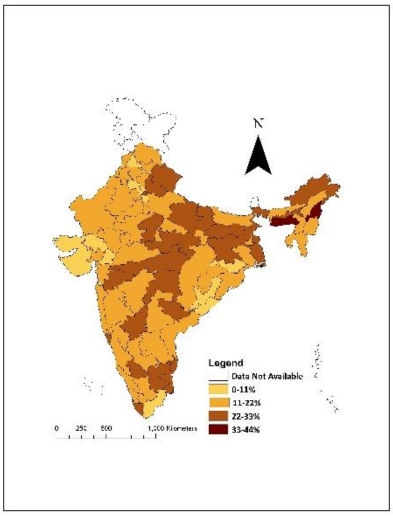
Female illiteracy (%), India, 1998-99



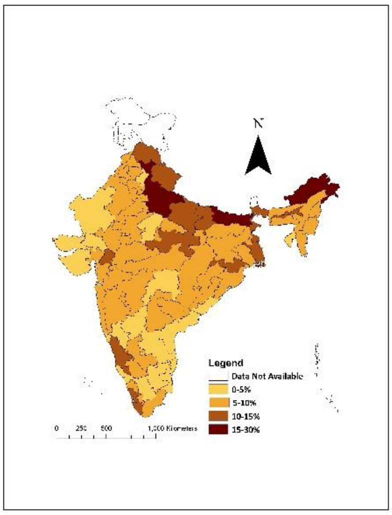
Female illiteracy (%), India, 2015-16



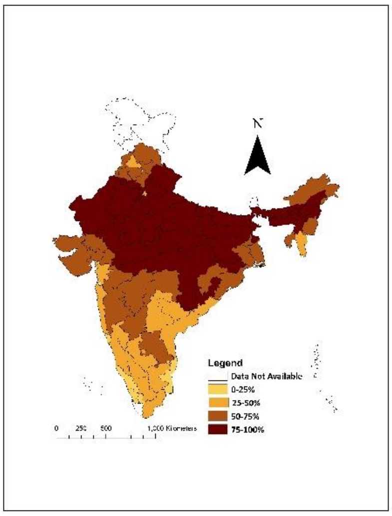
Unplanned births (%), India, 1992-93



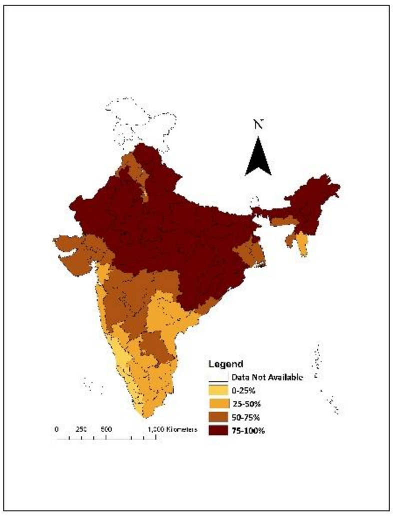
Unplanned births (%), India, 1998-99



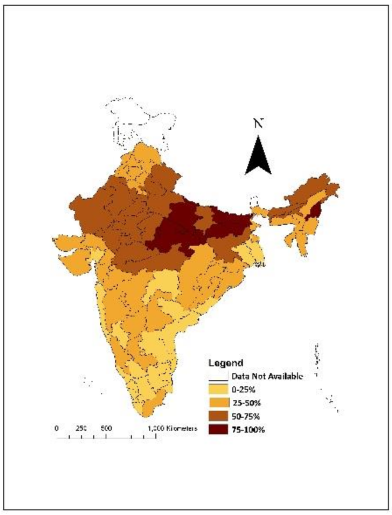
Unplanned births (%), India, 2015-16



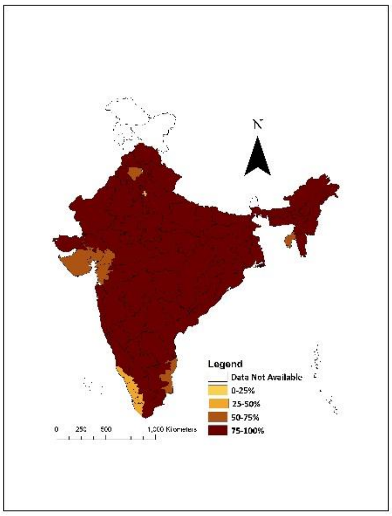
ANC underutilisation (%), India, 1992-93



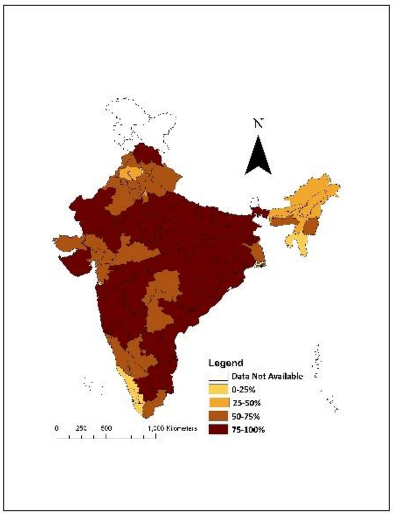
ANC underutilisation (%), India, 1998-99



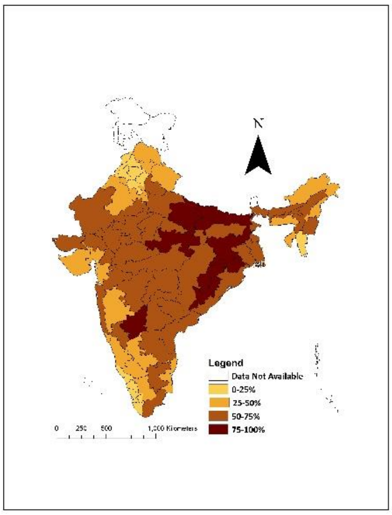
ANC underutilisation (%), India, 2015-16



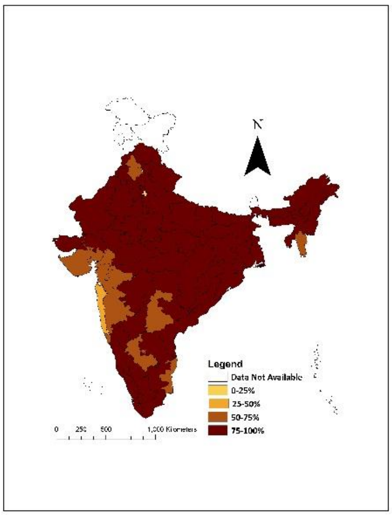
Use of unimproved toilet facilities (%), India, 1992-93



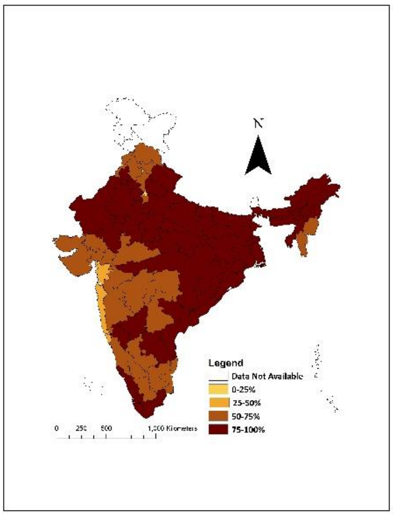
Use of unimproved toilet facilities (%), India, 1998-99



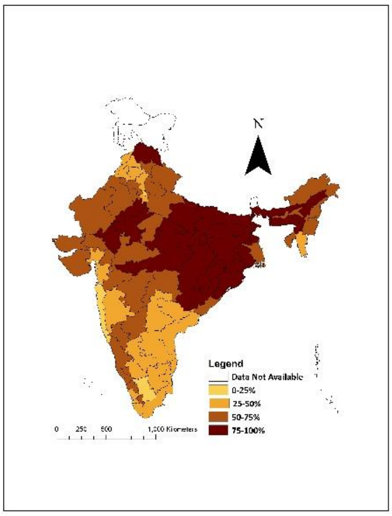
Use of unimproved toilet facilities (%), India, 2015-16



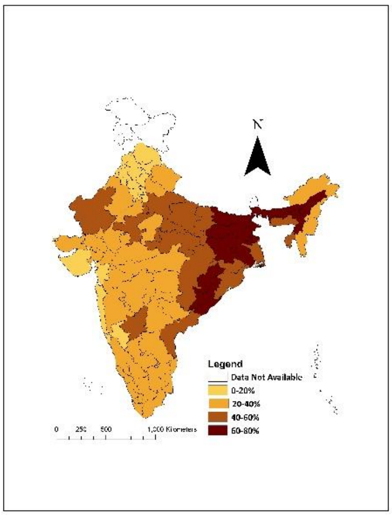
Use of solid cooking fuels (%), India, 1992-93



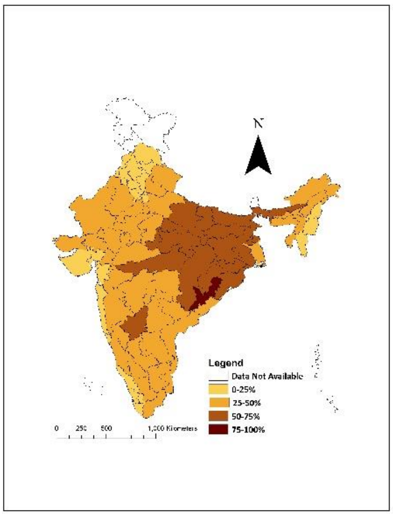
Use of solid cooking fuels (%), India, 1998-99



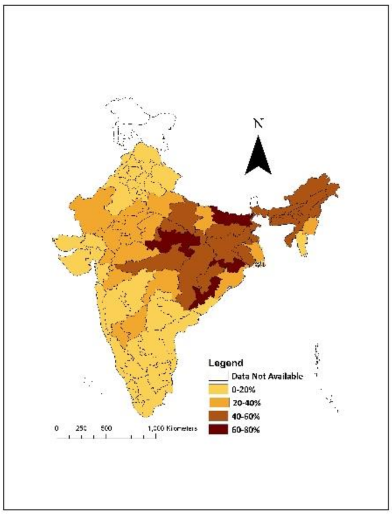
Use of solid cooking fuels (%), India, 2015-16



Poverty (%), India, 1992-93



Poverty (%), India, 1998-99

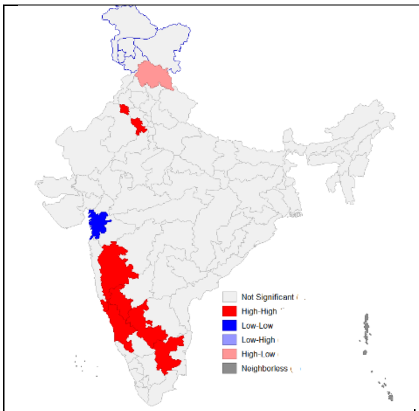


Poverty (%), India, 2015-16

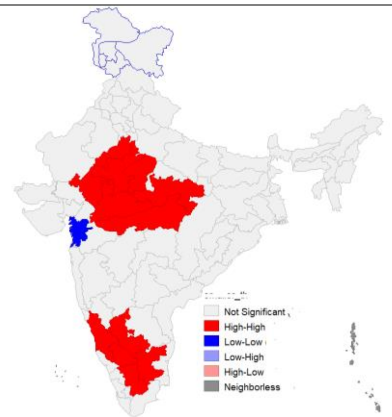
Figure 1: Trends of smaller than average birth size (%), female illiteracy (%), unplanned births (%), ANC underutilization (%), use of unimproved toilet facilities (%), use of solid cooking fuels (%), and poverty (%) in 76 regions, India, 1992-2016

The Figure 1 shows that the smaller than average birth size (%), female illiteracy (%), unplanned births (%), ANC underutilization (%), the use of unimproved toilet facilities (%), use of solid cooking fuel (%), and poverty (%) declined over time across 76 regions but with large regional disparities hidden below national and state-level average in India. The trends indicated Tripura consistently reported the highest prevalence of smaller than average birth size, and there were five regions with higher than 20% of smaller than average size births during 1992-2016. Female illiteracy was invariably above 50% in the South Plateau region in Odisha and Bihar. The South West Plain region in Uttar Pradesh continuously reported more than 20% of unplanned births in all survey years. The ANC underutilization had a one-third decline, but there were regions, namely Arunachal Pradesh, Bihar, South East Plain region in Haryana, Jharkhand, North East Uplands region in Madhya Pradesh, Nagaland, and Uttar Pradesh (excluding North East Plain) reportedly had above 70% of the percentage of ANC underutilization.

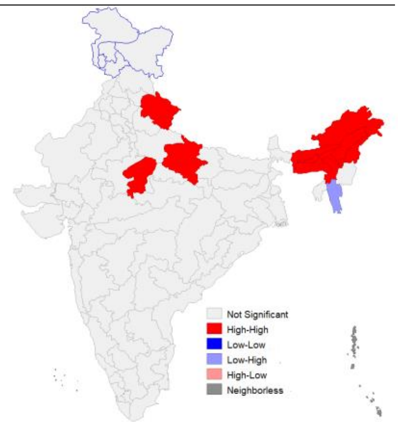
The use of unimproved toilet facilities recorded a 25% decline over the years. Still, the usage was more than 75% in the North Plain region in Bihar, Jharkhand, North East Plateau region in Karnataka, and North East Uplands region in Madhya Pradesh, Odisha (except for Coast and Delta region), Oudh Plain and Bhojpur Plain regions in Uttar Pradesh. The use of solid cooking fuels reported a sluggish decline during 1992-2016. The regions, namely East Valley and Cachar and South West Valley regions in Assam, North and West Plain regions in Bengal, Bihar, Chhattisgarh, Jharkhand, North East Uplands regions in Madhya Pradesh, Meghalaya, Odisha (excluding Coast and Delta region), and Southern Uplands region in Uttar Pradesh had higher than 80% of the use of solid cooking fuels during all survey years. Poverty was above 50% in regions like the West Plain region in Bengal, the North Plain region in Bihar, and North Hills and South Plateau regions in Odisha.



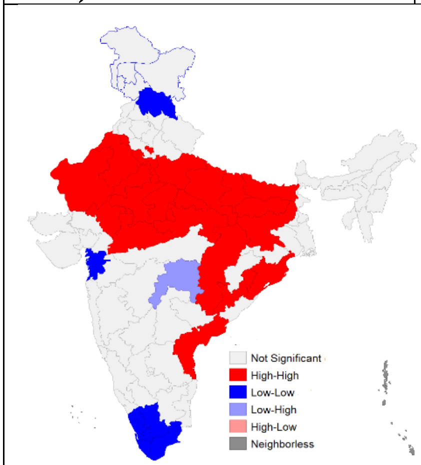
Smaller than average birth size (%), India, 1992-93 (Moron's I = 0.326)



Smaller than average birth size (%), India, 1998-99 (Moron's I = 0.349)

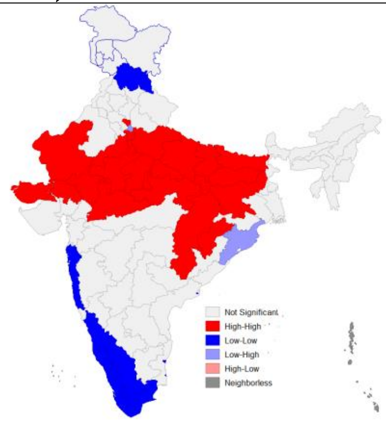


Smaller than average birth size (%), India, 2015-16 (Moron's I = 0.456)

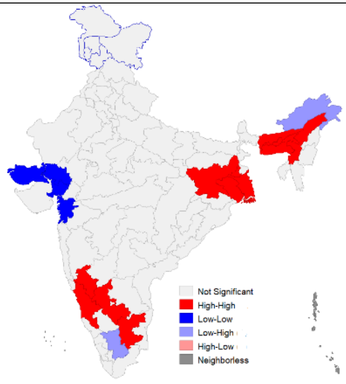


Female illiteracy (%), India, 1992-93 (Moron's I = 0.586)

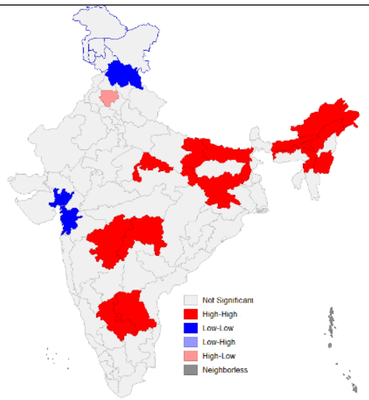
Female illiteracy (%), India, 1998-99 (Moron's I = 0.619)



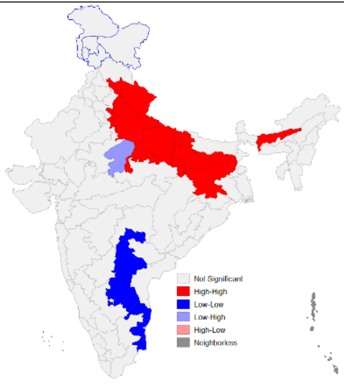
Female illiteracy (%), India, 2015-16 (Moron's I = 0.588)



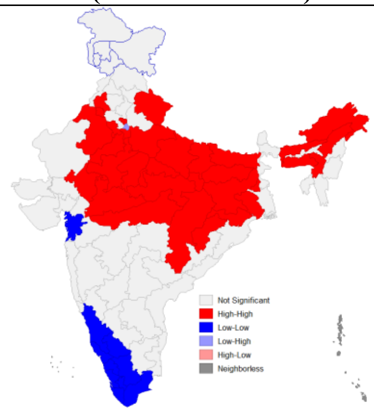
Unplanned births (%), India, 1992-93 (Moron's I = 0.375)



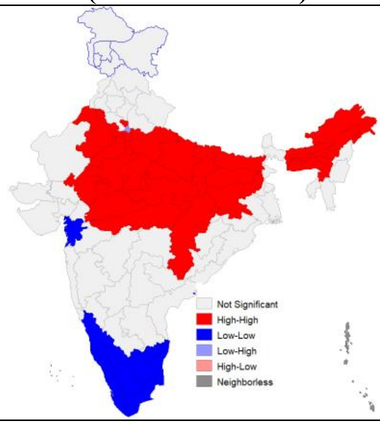
Unplanned births (%), India, 1998-99 (Moron's I = 0.376)



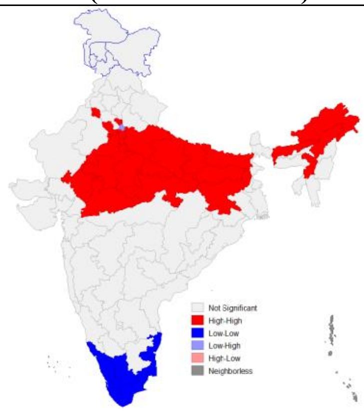
Unplanned births (%), India, 2015-16 (Moron's I = 0.372)



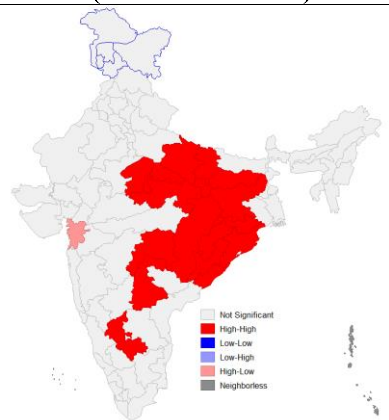
ANC underutilisation (%), India, 1992-93 (Moron's I = 0.667)



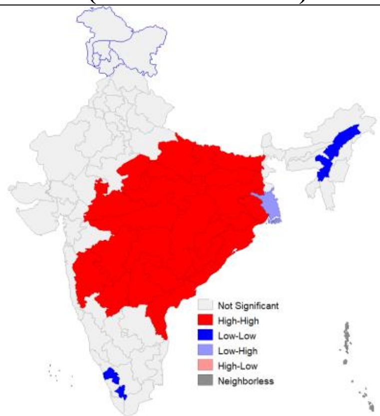
ANC underutilisation (%), India, 1998-99 (Moron's I = 0.657)



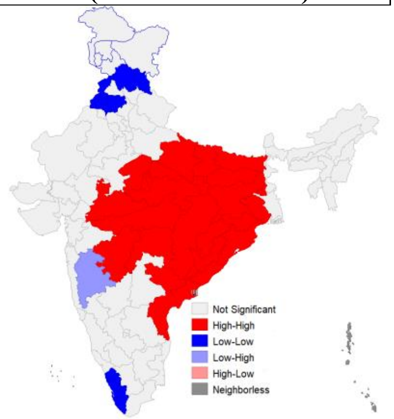
ANC underutilisation (%), India, 2015-16 (Moron's I = 0.655)



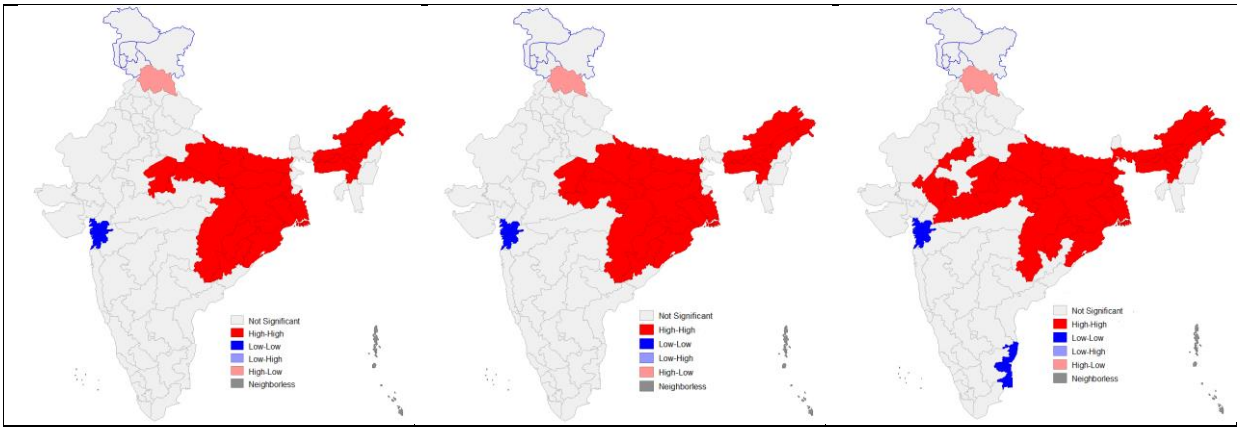
Use of unimproved toilet facilities (%), India, 1992-93 (Moron's I = 0.476)



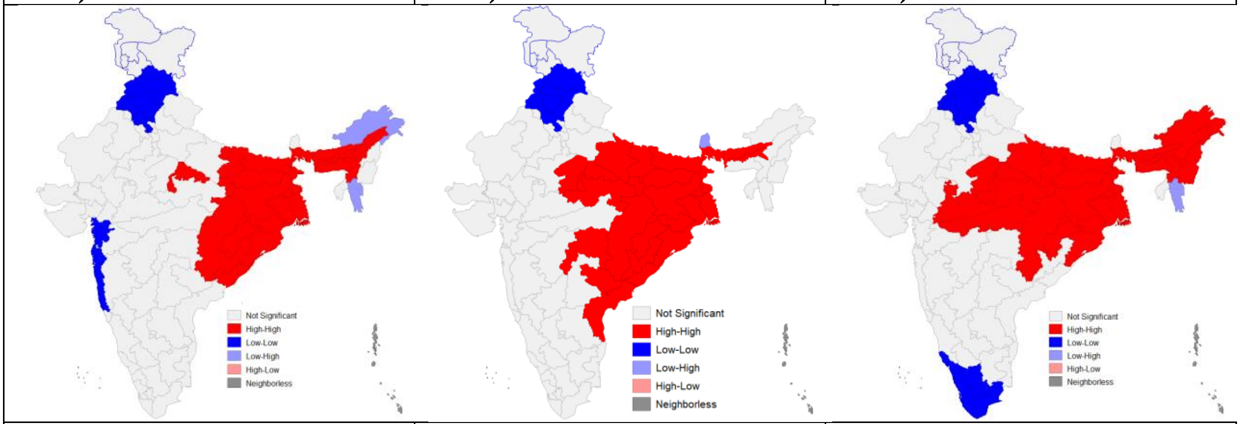
Use of unimproved toilet facilities (%), India, 1998-99 (Moron's I = 0.539)



Use of unimproved toilet facilities (%), India, 2015-16 (Moron's I = 0.636)



Use of solid cooking fuels (%), India, 1992-93 (Moron's I = 0.474)	**Use of solid cooking fuels (%), India, 1998-99 (Moron's I = 0.491)**	**Use of solid cooking fuels (%), India, 2015-16 (Moron's I = 0.544)**



Poverty (%), India, 1992-93 (Moron's I = 0.659)	**Poverty (%), India, 1998-99 (Moron's I = 0.667)**	**Poverty (%), India, 2015-16 (Moron's I = 0.709)**

Figure 2: Univariate LISA maps showing spatial clustering and Univariate Moron's I of smaller than average birth size (%), female illiteracy (%), unplanned births (%), ANC underutilization (%), use of unimproved toilet facilities (%), use of solid cooking fuels (%), and poverty (%) in 76 regions, India, 1992-2016

Figure 2 indicates the univariate LISA maps showing the 'high-high' clustering of smaller than average birth size (%) in the South Plain region in Haryana, Goa, Karnataka (except for North East Plateau), Desh region in Maharashtra, East Uplands region in Tamil Nadu in 1992-93. At the same time, 'low-low' clustering was reported in the South Plain region in Gujarat. In 1998-99, smaller than average birth size had 'high-high' clustering in Karnataka (except for North East Plateau), Madhya Pradesh, Arawali and Banas, and Chambal Basin regions in Rajasthan, Kongunad and Nilgiris, and East Uplands region in Tamil Nadu. On the other hand, the South Plain region in Gujarat reported 'low-low' clustering. Further trends suggested the 'high-high' clustering completely shifted to Assam, Arunachal Pradesh, North West Uplands region in Madhya Pradesh, Meghalaya, Nagaland, Oudh region in Uttar Pradesh, and Uttarakhand in 2015-16.

Over the period, the 'high-high' and 'low-low' clustering of female illiteracy (%) did not change much. Bihar, Chhattisgarh, Jharkhand, Odisha, Madhya Pradesh (excluding Narmada Range), and Uttar Pradesh (excluding North East Plain) reported 'high-high' clustering of female illiteracy during 1992-2016. Similarly, the low-low clustering was more prominent in Kerala, the North region in Himachal Pradesh and Kongunad and Nilgiris, and the South East Coast regions in Tamil Nadu. The 'high-high' clustering of unplanned births (%) was constantly observed in Jharkhand and South West Valley in Assam and many other regions over the years.

The univariate LISA maps also showed that the spatial clustering of ANC underutilization (%), use of unimproved toilet facilities (%), and use of solid cooking fuel (%) and poverty did not have gone significant changes during 1992-2016. The Eastern, Central, and North-Eastern regions in India emerged as 'high-high' clusters of ANC underutilization (%), use of solid cooking fuel (%), and poverty (%). While, Kerala and Tamil Nadu, and the South Plain region in Gujarat reported 'low-low' clustering of ANC underutilization and use of solid cooking fuels, respectively. The 'low-low' clustering of poverty (%) was prominently observed in

Haryana, Himachal Pradesh, NCT of Delhi, and Punjab. The use of unimproved toilet facilities (%) had 'high-high' clustering in Eastern, Central, and South Eastern regions and 'low-low' clustering in Kerala.

All selected socioeconomic and household environmental characteristics had a substantial amount of geospatial clustering in each survey round. Interestingly, the Moron's I statistics value increased for all variables indicating the increase in geospatial clustering of variables over time except for unplanned births (%). Poverty (%) showed the highest geospatial clustering, followed by ANC underutilization (%), while it was the lowest in unplanned births (%).

Socioeconomic and household environmental variable	Year of Survey					
	1992-93		1998-99		2015-16	
	Aspatial OLS for smaller than average birth size	LM Spatial for smaller than average birth size	Aspatial OLS for smaller than average birth size	LM Spatial for smaller than average birth size	Aspatial OLS for smaller than average birth size	LM Spatial for smaller than average birth size
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Female illiteracy (%)	-0.022	-0.037	-0.047	-0.087	-0.066	-0.031
Unplanned births (%)	**0.351**	**0.339**	0.223	**0.249**	**0.432**	**0.457**
ANC underutilization (%)	-0.062	-0.042	0.011	0.098	0.046	0.010
Use of unimproved toilet facilities (%)	**0.142**	**0.132**	0.084	0.026	0.034	**0.072**
Use of solid cooking fuel (%)	**0.098**	**0.096**	**0.209**	**0.163**	**0.070**	**0.061**
Poverty (%)	-0.038	-0.013	-0.084	0.058	0.032	0.023
Constant	0.554	0.520	2.260	1.036	1.442	0.932
Number of observations	76	76	76	76	76	76
Log likelihood	-268.148	-267.169	-301.141	-290.712	-221.729	-214.604
AIC	550.295	548.338	616.218	595.425	457.459	443.209
R square	0.685	0.690	0.508	0.653	0.697	0.759
Lag coefficient (Lambda)		**0.248**		**0.640**		**0.501**
Highlighted values indicate significant finding at p-value < 0.05.						

Table 1: Results of OLS and Spatial Error Model assessing the association between socioeconomic and household environmental variables and spatial clustering of birth size in 76 natural regions, India, 1992-2016

Table 1 indicates the presence of geospatial clustering of birth size, and so we estimated the aspatial OLS and Spatial Error model to assess its association with socioeconomic and household environmental variables in 76 regions in India during 1992-2016. The higher log-likelihood values and lower AIC values for the spatial error model indicated it was the best-fitted model than the aspatial OLS model. The results of the spatial error model indicated the proportion of unplanned births was statistically and positively associated with the prevalence of smaller than average birth size in all survey rounds. However, its magnitude decreased from 0.339 in 1992-93 to 0.249 in 1998-99 and increased to 0.457 in 2015-16. The proportion of the use of unimproved toilet facilities had a statistically significant and positive association with the prevalence of smaller than average birth size in 1992-93 and 2015-16. However, the magnitude of the use of unimproved toilet facilities decreased from 0.132 in 1992-93 to 0.072 in 2015-16. Similarly, the use of solid cooking fuels was statistically and positively associated with the prevalence of smaller than average birth size in all years of the survey. First, the magnitude of the use of solid cooking fuels increased from 0.096 in 1992-93 to 0.163 in 1998-99 and then decreased to 0.061 in 2015-16

V. CONCLUSION

This study is the first, perhaps, to investigate the spatial determinants of smaller than average birth size in the last two decades in India. The study uses three rounds of data from large-scale nationally representative population-based NFHS for this purpose. There is a striking shift in the high-high clustering of the prevalence of smaller than average birth size during 1992-93 and 2015-16. An increase in the univariate Moran's I suggest a spatial correlation in smaller than average birth size increased over time. The natural zones characterized by a higher percentage of unplanned pregnancies, use of unimproved toilet facilities and use of solid cooking fuels are also characterized by a higher prevalence of smaller than average birth size. The significant reduction in the prevalence of smaller than average birth size can be achieved through the programs and interventions addressing the unplanned pregnancies, use of unimproved toilet facilities and use of solid cooking fuels in India.

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