Understanding the Geographical heterogeneity of children undernourished and its risk factors across the districts of India: Geographically Weighted Regression Analysis

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Background

Undernutrition among children always has been and continues to be one of the critical development issues globally. And India has been identified as one of the countries among the Low- and Middle-Income countries where prevalence of undernutrition is alarmingly high. Even though the recent evidence shows a nominal reduction in the rates in India, the goals are far to be reached. Hence, fresh approaches are necessary to analyse the problem and its risk factors in order to produce robust evidence to find solutions. And the improved spatial analytical methods and models entrenched into the Geographic Information Systems (GIS) facilitate more in-depth examination of the causes and consequences behind the problem of undernutrition among children. These applications have significant policy implications because they aid in understanding the relationships between geography and child undernutrition and its various determinants, and are particularly important in planning impactful programmes to help address such issues. Drawing on which, the objective of the present study is to unravel the location-specific (local) spatial heterogeneity and spatial dependency, in associations between children undernourished and its selected risk factors across the districts of India.

Data & Methods

The latest 2019-20, the fifth round of the National Family Health Survey, was utilised in the current study. The prevalence of children stunted, children underweight and children wasted were the three outcome variables studied.

Analytical Approach

Firstly, Principal Component Analysis (PCA) was applied on the selected 22 independent households, maternal and child related variables. Principal Components (PCs) with eigenvalues larger than one were considered. The Kaiser–Mayer–Olkin (KMO) sampling adequacy test value with 0.82, suggested that the variables were suitable for the PCA analysis. Once the complexity of the data set was reduced to its principal components, the scores were predicted and the bivariate, multivariate geo-spatial techniques and models were applied on the principal components with the outcome variables to identify the association and the regional patterns of the magnitude of association across the 705 districts of India.

Local Indicators of Spatial Association (LISA) statistics, Univariate and Bivariate Local Moran's I, were employed to confirm the spatial clustering and dependency in the nutritional status of children along with their risk factors. The stationary regression models like the Ordinary Least Square (OLS), and various spatial econometric models like the Spatial lag and spatial error models, Geographically Weighted Regression (GWR), were applied to check for spatial dependency and examine the spatial influence of various correlates on the health of the child, across the geographical space, after adjusting for the endogeneity. GWR, a non-stationary regression model, was utilised to study the local relationships between these variables, their direction and magnitude, location-specific, across all 705 districts. The spatial influences between neighbourhoods by considering local regression parameters rather than global regression parameters were estimated independently for each location.

Results

While the first principal component had a significant loadings of IFA supplementations, antenatal care visits, and postnatal care given to both mother and child, the second component had a heavy load of the mother's BMI below normal, adequate diet of the child and anaemia among children, third component with loadings of early marriages and pregnancy, and the fourth with clean fuel usage for cooking in the households and improved drinking water. Based on these characteristics of the respective components, the indices were constructed by predicting the scores as the parameters having a high influence. Hence, the five components can broadly be described as: PC1: service delivery during pre & post pregnancy, PC2: Poor maternal and child nutritional status, PC3: Early marriage and pregnancy, and PC4: Household Environment. Additionally, to study the economic affordability of the households, an economic-status index was also constructed, taking into account a total of 26 commodities the households possessed (including items such as TV, fridge, mattress, and others), quality of the housing, ownership of land and house, number of members sleeping per room and domestic staff. The approach utilised for constructing the wealth index in this study was consistent with the methodology employed in the NFHS dataset. However, certain variables, such as households' access to clean drinking water, toilets, and clean cooking fuel, among others, which were considered during the development of the NFHS wealth index, were excluded from the index construction of this study.

The aspatial, OLS, Spatial Lag and Spatial Error models were applied. The model diagnostics test estimates denoted SEM as a better fit than SLM, based on the lower AIC scores and a better R-squared value. Hence, the results of SEM have been utilised (presented in Table 1). Model 1 presents the bivariate regression results of all four components with the three outcome variables. Model 2 illustrates the multivariate regression outcomes of the association of all the extracted components together on the undernutrition parameters. Model 3 presents the multivariate regression results of the association of all four components together, along with the economic conditions, on the undernutrition parameters.

When poverty was not accounted for, significant predictors of child stunting included maternal and child nutrition, service delivery during pre- and post-delivery periods, and early marriage and pregnancy. A one-unit decline in maternal and child nutrition (child's diet adequacy, anaemia prevalence, mother's low BMI) increased stunting prevalence threefold. Effective maternal service delivery reduced stunting risk, highlighting the intergenerational impact. Early marriage and pregnancy also increased stunting prevalence, but lost significance once economic conditions were considered.

Child wasting was consistently associated with poor maternal and child nutrition and household environment (clean water, clean cooking fuel), regardless of poverty status.

Underweight, a composite indicator combining stunting and wasting, correlated strongly with poor maternal and child nutrition, early marriage and pregnancy, and household environment when poverty was not considered. After controlling for poverty, maternal and child nutrition remained significant along with poverty itself.

Table 1: Results from the Spatial Error Models, district-wise, India, 2019-21

Variables (Components)	Stunted			Wasted			Underweight		
	Model-1	Model-2	Model-3	Model-1	Model-2	Model-3	Model-1	Model-2	Model-3
Service Delivery during pre and post delivery	-1.66***	-1.41***	-0.92***	-0.11	0.14	0.17	-0.83**	-0.31	0.12
Poor Maternal and Child nutrition	3.52***	3.21***	2.69***	1.56***	1.48***	1.46***	3.57***	3.17***	2.94***
Early marriage and pregnancy	2.44***	1.4***	0.57	0.3	0.06	0.01	2.17***	1.51***	0.72
Household Environment	-1.4***	-0.52	0.63	-0.89**	-0.80**	-0.73*	-1.7***	-1.14***	-0.13
Poor Economic Status	0.25***	-	0.17***	0.05*	-	0.01	0.22***	-	0.17***
Lambda Value (Lag Coefficient)		0.49***	0.47***		0.59***	0.58***		0.72***	0.68***
R-squared		0.51	0.53		0.39	0.39		0.68	0.69
Log likelihood		-2275.68	-2256.07		-2170.29	-2170.5		-2243.6	-2227.27
Akaike info criterion		4561.36	4524.15		4350.6	4348.99		4497.2	4466.55

* P<0.05 ** P<0.01 *** P<0.001 level of significance

Results: Geographically Weighted Regression

Geographically Weighted Regression (GWR), extending standard regression by estimating local rather than global parameters, captured district-level geographic variations. The significant local coefficients derived from GWR are mapped below for each undernutrition indicator, using quintile scales, clearly highlighting regional differences.

A positive local coefficient indicates a reduction in undernutrition with higher values of predictor variables, and higher the value of the coefficient, stronger the association in those locations.

Service delivery (PC1) showed a strong negative, region-specific association with child stunting, especially in northeast districts, southern Maharashtra, northern Karnataka, and a belt covering Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, and Chhattisgarh, indicating improved services could reduce stunting here.

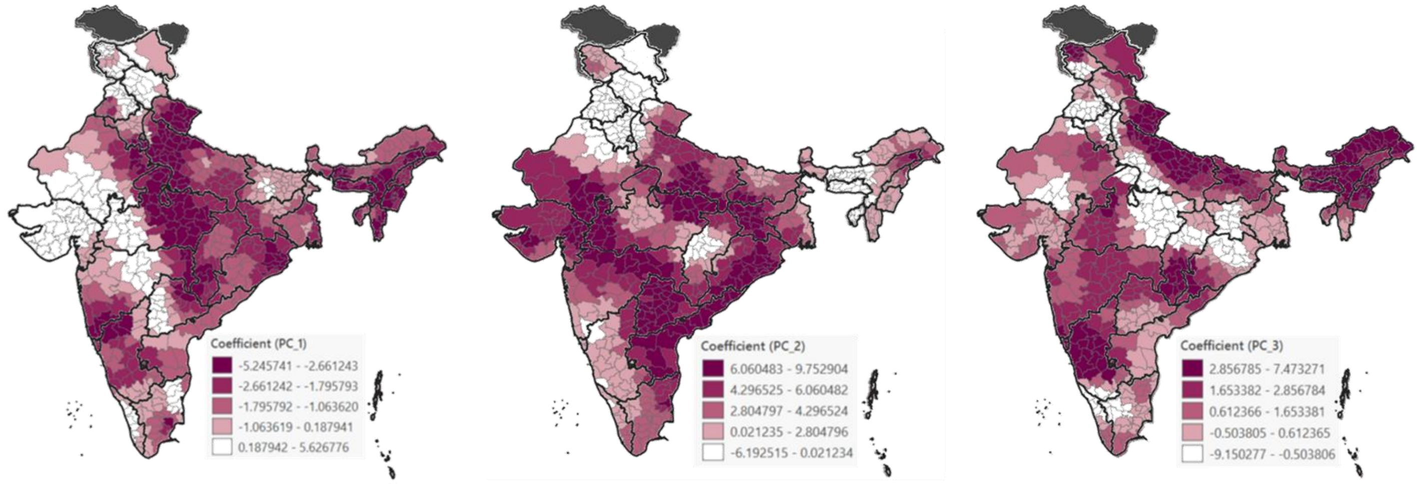
Poor maternal and child nutrition strongly correlated positively with stunting in central states (Madhya Pradesh, Rajasthan, Chhattisgarh, Jharkhand, Telangana, eastern Maharashtra), western India, and coastal Odisha to Andhra Pradesh. Early marriage and pregnancy showed strong positive associations in selected districts of UP, Bihar, northeastern states, southern Chhattisgarh, Karnataka, and Maharashtra.

Including poverty (Model 3) shifted clusters slightly. Negative associations between service delivery and stunting concentrated mainly in Madhya Pradesh and adjoining UP, Chhattisgarh, and Jharkhand. Economic status positively correlated with stunting along coastal Maharashtra, Goa, Karnataka, and Kerala, and northern states like Punjab, Haryana, and Rajasthan, highlighting regional economic inequalities.

Negative associations between child wasting and household environment appeared strong in coastal Odisha, northeastern states, Maharashtra, Karnataka, Telangana, and Kerala. Conversely, child wasting strongly positively correlated with poor maternal and child nutrition in districts of Rajasthan, Gujarat, Odisha, eastern

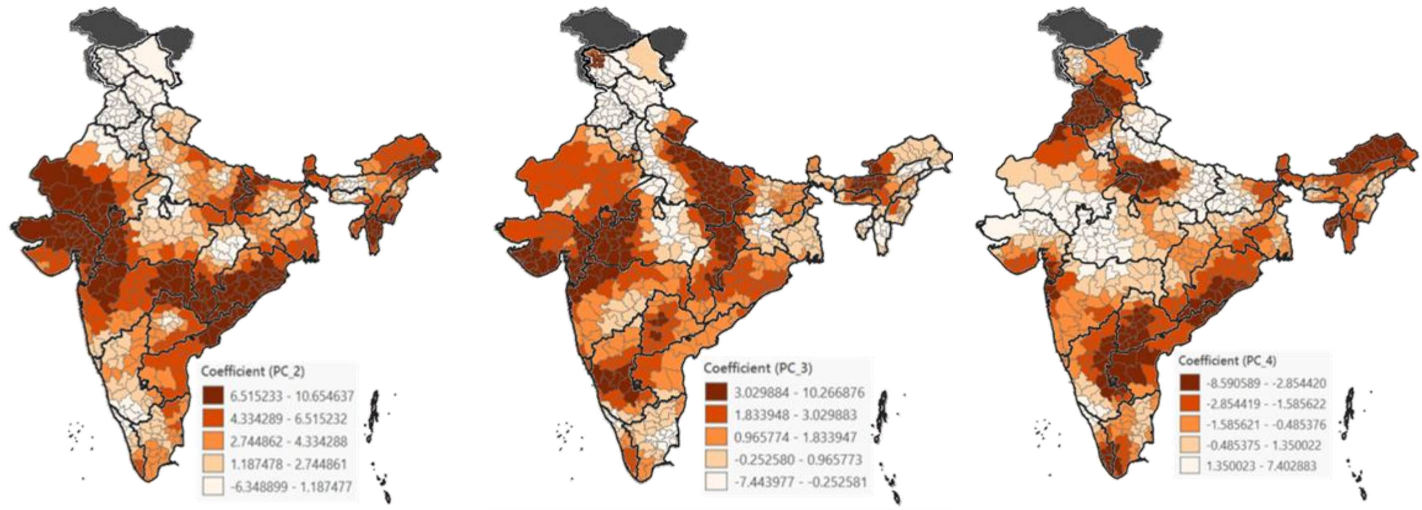
Maharashtra, border areas of UP-Bihar, Tripura, Manipur, and Mizoram. Similar regional clustering patterns emerged for underweight children.

Local coefficient maps from GWR illustrating these associations follow below.



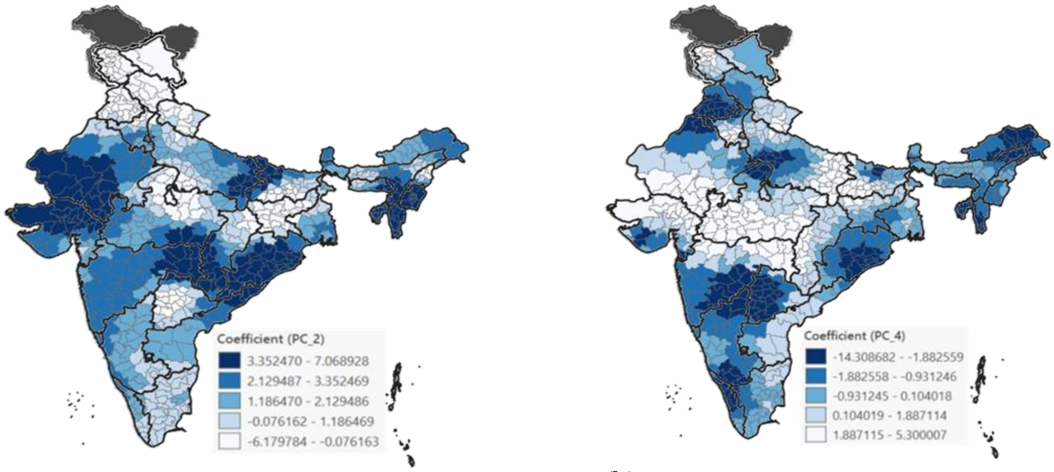
(a) PC1: service delivery during pre & post pregnancy (b) PC2: Poor maternal and child nutrition (c) PC3: early marriage and pregnancy

Figure 1: GWR Model Results: Spatial pattern of local coefficients of significant predictors from Model 2: children stunted with a) PC1, b) PC2, c) PC3., India, 2019-21



(a) Poor maternal and child nutrition (b) early marriage and pregnancy (c) Household environment

Figure 3: GWR Model Results: Spatial pattern of local coefficients of significant predictors from Model 2: children underweight with a) PC2, b) PC3, c) PC4. India, 2019-21



(a) Poor maternal and child nutrition (b) Household Environment

Figure 5: GWR Model Results: Spatial pattern of local coefficients of significant predictors from Model 2: children wasted with a) PC2, b) PC4. India, 2019-21

Conclusion

The GWR findings revealed that the geographical variability in correlations between undernutrition among children and its risk factors across the districts were substantially region-specific, with the direction and strength of these relationships varying between districts, thus allowing for a more nuanced understanding of the potential local determinants of the problem that may otherwise be hidden over the examined space. Within a state itself the association between the variables vary. Thus, the identification of geographical hot spots, and the contributing factors to the high undernutrition levels across and specific to the regions, can assist policymakers in developing robust programs and interventions specific to nutrition in order to tackle the problem and produce undernutrition-free enclaves. These results from the analysis facilitates the allocation of resources effectively to reduce health inequities between and within districts.

While child nutrition in India is a major development agenda, special focus is arguably required on the poorly performing regions, especially by addressing the maternal health care needs, improvement of sanitation facilities, better health care services, improving educational levels of women, and enhancing women empowerment. Only by addressing these causes and consequences, the SDG goals in terms of addressing health and wellbeing and the National Nutrition Mission goals will be achieved. The evidence gathered from this study can be used by decision-makers for developing better strategies at the micro-level and long-term planning to find solutions to mitigate the problem of undernutrition in India and can also be used as a case study for other LMICs.