INDIAN JOURNAL OF POPULATION AND DEVELOPMENT
Volume 1(2), July 2021: 185-208

A Non-parametric Approach to Small Area Estimation with Application to Madhya Pradesh, India

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Abstract

This paper proposes a simple approach to extrapolate demographic indicators at the local level to a recent date for which estimate of the demographic indicator is available at the aggregate level through the application of data mining technique. The approach has been applied to estimate the probability of death in the first five years of life in the districts of Madhya Pradesh, India for the year 2017 corresponding to the estimate of under-five mortality rate for Madhya Pradesh for the year 2017 available through India's official sample registration system.

Introduction

There is a long-standing demand for district level estimates of key demographic indicators to facilitate decentralised district development planning in India. There is, however, little progress in this direction. Estimates of key demographic indicators in India are not available below the district level on a regular basis. The registration of births and deaths in India is compulsory under the Registration of Birth and Death Act of 1969 (Government of India, 1969), but birth and death registration in the country is not satisfactory to provide reliable estimates of key demographic indicators at the district level. To improve the civil registration system, the sample registration system was launched in 1965-65 and introduced throughout the country in 1969-70 (Padmanabha, 1982). However, the system hardly contributed to improving the civil registration data and remained confined to providing estimates of selected demographic indicators at national and state levels only. There has been little attempt to extend and expand the system so that it can provide estimates of selected demographic indicators at the district level. It continues to remain a stand-alone system with little linkages with the civil registration system.

In 1992, the Government of India launched the National Family Health Survey Programme to obtain information on selected aspects of health and family welfare situation in the country. The first three rounds of the National Family Health Survey, carried out in 1992-93; 1998-99; and 2005-06, provided only national and state level information about the health and family welfare situation including estimates of some demographic indicators. Since the fourth round (2015-16), the survey has provided information related to health and family welfare situation at the district level also (Government of India, 2017). However, estimation of key demographic indicators at the district level could not be possible because of the small size of the sample of households surveyed at the district level, although there have been attempts to estimate demographic indicators at the district level from the data available through the survey.

The Government of India had also launched the district level rapid household survey under the Reproductive and Child Health Programme (Government of India, 2010). This survey could also not provide district level estimates of demographic indicators because of the very small size of the sample at the district level. This survey has now been discontinued. Another initiative taken by the Government of India to generate estimates of demographic indicators at the district level was the Annual Health Survey which was launched in 2010. This survey, however, was confined to selected states only, known as the Empowered Action Group (EAG) states, and was discontinued in 2013 (Rathi et al, 2018).

Given the weakness of the civil registration system and the limitations of the sample registration system and the National Family Health Survey, the only source for estimating demographic indicators below the state level in India is the decennial population census. The summary birth history data (SBH) collected during the decennial population census have been used to estimate selected indicators of fertility and mortality at the district level using indirect techniques of demographic estimation (Ahuja, no date; Bhat, 1996; Guilmoto and Rajan, 2001; 2002; 2013; Government of India, 1988; Government of India, 1989; Government of India, 1997; Kumar and Sathyanarayana, 2012; Rajan and Mohanchandran, 1998; Sharma and Choudhury, 2014). However, a major limitation in the use of census data in estimating demographic indicators at the district level is that these estimates are available at an interval of 10 years only.

The problem of estimating demographic indicators at the district level in India may be viewed as a problem of small area estimation. Small area estimation is related to estimating parameters of a sub-group of the population – a district is a sub-group of the state or the country. Different approaches have been suggested for small area estimation. These approaches can be divided into three categories: 1) direct survey-based estimation approach; 2) small area estimation using auxiliary information; and 3) small area estimation using regression-based models (Asian Development Bank, 2020). The direct survey-based estimation requires selecting a in each sub-population which is large enough to provide statistically reliable estimate of demographic indicators. The sample size requirement, in this approach, increases parabolically when estimates need to be disaggregated by gender, residence, social class, and other characteristics of the population. The small area estimation using auxiliary information, on the other hand, includes broad area ratio estimation and synthetic estimation. Broad area ratio estimation is one of the simplest and most straightforward method of small area estimation. This approach uses direct estimate of the variable of interest for the population and the proportionate distribution of the population across sub-group which can be obtained from the population census (Australian Bureau of Statistics, 2006). Synthetic estimation procedure uses estimate of the variable of interest at some higher level of aggregation and the variable of interest for different sub-groups of the population and then scales these estimates in proportion to the variation across sub-groups within the sub-population of interest. These estimates are not obtained directly from survey and hence are referred to as synthetic estimates (Purcell and Kish, 1979). Finally, regression-based models, include regression-synthetic, empirical best linear unbiased prediction (EBLUP), empirical Bayes, and the hierarchical Bayes techniques and approach suggested by Elbers et al (2003). This approach includes an error structure component that allows measurement of local variation among small areas. This approach can generate efficient estimates. The regression-based approach has become popular because it can handle complex cases such as cross-sectional and time-series data. Moreover, unlike synthetic and composite methods, estimates obtained through regression-based approach measures variability.

In this paper, we propose a non-parametric approach to estimate district level demographic indicators and apply the approach to estimate the probability of death in the first five-years of life in districts of Madhya Pradesh, India. The approach is based on the district level estimates of the probability of death in the first five years of life estimated from the summary birth history data from the decennial population census and the latest estimate of the probability of death in the first five years of life for Madhya Pradesh obtained from the official sample registration system of India. The approach is based on the assumption that the variation in demographic indicators across different mutually exclusive yet exhaustive population subgroups either at the aggregate level or at the lower level remains largely unchanged in the immediate future so that any change in the demographic indicator at the aggregate (state) level leads to corresponding change in the demographic indicator at the local (district) level. The approach, essentially, establishes the pattern of variation in the demographic indicator across districts within the state and across different population sub-groups within the district and assumes that this pattern remains largely unchanged during the inter-census period.

The paper is organised as follows. The next section of the paper describes the proposed method. The third section of the paper presents estimates of the probability of death in the first five years of life (${}_5q_0$) for 12 mutually exclusive yet exhaustive population sub-groups in each district of Madhya Pradesh, India as derived from the data on children ever born and children surviving available through the 2011 population census using the indirect technique of child mortality estimation. These estimates have been used to establish the pattern of variation in ${}_5q_0$ across districts in the state and across 12 mutually exclusive yet exhaustive population sub-groups within each district. The fourth section of the paper uses the pattern of variation in ${}_5q_0$ so established to estimate ${}_5q_0$ for the districts of the state for the year 2018 corresponding to the estimate of ${}_5q_0$ for Madhya Pradesh available through the sample registration system. The last section of the paper discusses the usefulness of the method proposed for estimating demographic indicators at the local level based on the estimate of the indicator available at the aggregate level.

The Method

Suppose that the population of an administrative area (state in the present case), is divided into r sub-administrative areas (district in the present case) and the population in each district is divided into c mutually exclusive, yet exhaustive population sub-groups so that the entire population of the administrative area is divided into $k=r^*c$ mutually exclusive and exhaustive population sub-groups. Suppose also that the estimate of a given demographic indicator of interest, d, is available for each of the k mutually exclusive and exhaustive population sub-groups which can be organised in a matrix or a two-way table comprising of r rows (districts) and c columns so that d_{ij} represents the estimate of the indicator for the j^{th} population sub-group of district i. This matrix or two-way table reflects the pattern of variation in the demographic indicator of interest across mutually exclusive and exhaustive population sub-groups.

The two-way table so constructed can be decomposed in absolute terms (additive decomposition) or in relative terms (multiplicative decomposition). In absolute terms, the value of the demographic indicator in sub-group j of the district i may be decomposed as

$$d_{ij} = \mu + x_i + y_j + r_{ij} \text{ for all } i \text{ and } j. \tag{1}$$

where x_i denotes the row or district effect, y_j denotes the column or population sub-group effect, r_{ij} is the residual term and μ is the mean of d_{ij} over all i and j.

On the other hand, in relative terms, d_{ij} can be decomposed as

$$d_{ij} = \eta * \alpha_i * \beta_j * \nu_{ij} \text{ for all } i \text{ and } j. \tag{2}$$

where α_i is the row or district multiplier, β_j is the column or population subgroup multiplier, ν_{ij} is the residuals multiplier and η is the geometric mean of d_{ij} over all i and j.

It may be noticed that multiplicative decomposition can be transformed into the additive decomposition through logarithmic transformation

$$\ln(d_{ij}) = \ln(\eta)+\ln(\alpha_i) +\ln(\beta_j) +\ln(\nu_{ij}) \text{ for all } i \text{ and } j. \tag{3}$$

The additive decomposition can be carried out through data mining techniques such as mean polish (Selvin, 2004) or median polish (Tukey, 1977) for examining the contribution of different factors in a multifactor model. The advantage of mean or median polish technique is that these techniques make no assumption about the underlying distribution of the data. The technique remains effective even when the data are rates or counts or any other data classified in a two-way table. Since the interest in the present paper is in finding the sub-administrative area (district) and population sub-group effects of the variation in the demographic indicator, the arithmetic mean is preferred over the median for polishing as arithmetic mean is based on all values in the distribution whereas median is based on the middle values of the distribution only. Moreover, since the population composition is not the same across the sub-administrative areas (districts) and across different population sub-groups within the same sub-administrative area, weighted mean should be used in place of simple mean to establish the underlying patterns of variation in the demographic indicator so that estimates of the demographic indicator for different population sub-groups add up to the estimate of the demographic indicator for the whole population (Chaurasia, 2013).

If it is assumed that the row effect, column effect and the residual effect of the decomposition remain unchanged over time, then a change in the grand mean μ or the aggregate (state) level value of the demographic indicator leads to a new value of d_{ij} for all values of i and j. In other words, if the aggregate level estimate of the demographic indicator changes from μ_1 to μ_2 over time, then the new estimate of the demographic indicator, d_{ij2}, for population sub-group j of district i may be obtained as

$$d_{ij2} = \mu_2 + x_i + y_j + r_{ij} \text{ for all } i \text{ and } j \tag{4}$$

if the decomposition is additive, or

$$\ln(d_{ij2}) = \ln(\eta_2) + \ln(\alpha_i) + \ln(\beta_j) + \ln(\nu_{ij}) \text{ for all } i \text{ and } j \tag{5}$$

if the decomposition is multiplicative. Once estimates of the demographic indicator for different population sub-groups are obtained corresponding to the aggregate (state) level estimate, the estimate of the demographic indicator of interest for the district i at the recent date, d_{i2}, may be obtained as the weighted average of the estimates of the demographic indicator of interest for mutually exclusive population sub-groups within each district. In other words

$$d_{i2} = \sum_{j=1}^{c} w_{ij} * d_{ij2} \tag{6}$$

if the additive decomposition is used or

$$\ln(d_{i2}) = \sum_{j=1}^{c} w_{ij} * \ln(d_{ij2}) \tag{7}$$

if the multiplicative decomposition is used for establishing the pattern of variation in the demographic indicator across mutually exclusive yet exhaustive population sub-groups. Here, w_{ij} is the weight assigned for the population sub-group j in district i. In case of the estimation of demographic indicators, the multiplicative decomposition is preferred over the additive decomposition because the change in demographic indicators is not linear. The pace of decrease in demographic indicators slows down with the improvement in demographic indicators as all demographic indicators have an upper limit.

Under-five Mortality in Madhya Pradesh, India

We have applied the above approach to obtain estimates of the probability of death in the first five years of life (${}_5q_0$) for the districts (local level) of Madhya Pradesh, India for the year 2017 which correspond to the latest estimate of ${}_5q_0$ for Madhya Pradesh (aggregate level) available through India's official sample registration system. According to sample registration system, ${}_5q_0$ in Madhya Pradesh is the highest amongst states and Union Territories of the country (Government of India, 2020). We first estimate ${}_5q_0$ for 12 mutually exclusive and exhaustive population subgroups as classified in table 1 for 50 districts of the state from the summary birth history data available from the 2011 population census and using the indirect technique of child mortality estimation (Moultrie et al, 2014). These estimates are presented in table 2. The table also presents district level estimates of ${}_5q_0$ obtained as the weighted average of ${}_5q_0$ for the 12 mutually exclusive population subgroups in each district. The proportionate distribution of the live births across the 12 mutually exclusive population sub-groups in each district obtained from the 2011 population census has been used as weight for calculating the district estimate of ${}_5q_0$. The weighted average of the district level $5q_0$, then, gives the estimate of ${}_5q_0$ for the whole state. According to this exercise, ${}_5q_0$ for Madhya Pradesh is estimated to be 0.097 around the year 2005. On the other hand, ${}_5q_0$ for Madhya Pradesh in 2005-06 is estimated to be 94 under five deaths for every 1000 live births based on the National Family Health Survey 2005-06 (Government of India, 2017). This shows that estimate of ${}_5q_0$ obtained from the summary birth history data of 2011 population census is a close approximation of the estimate of ${}_5q_0$ obtained from the full birth history data collected during the National Family Health Survey 2005-06.

Table 1
Mutually exclusive population sub-groups in a district

Social class	Rural		Urban	
	Male	Female	Male	Female
Scheduled Castes	*SCRM*	*SCRF*	*SCUM*	*SCUF*
Scheduled Tribes	*STRM*	*STRF*	*STUM*	*STUF*
Other Castes	*OCRM*	*OCRF*	*OCUM*	*OCUF*

Table 3 presents results of the multiplicative decomposition analysis of the variation in ${}_5q_0$ across 600 mutually exclusive and exhaustive population sub-groups in Madhya Pradesh (50 districts x 12 sub-groups). The table provides estimates of overall or grand mean or common multiplier, row or district multiplier, column or population sub-group multiplier and residual multiplier for each of the 600 mutually exclusive population sub-groups. Based on table 3, ${}_5q_0$ in any mutually exclusive population sub-group of the any district can be obtained by multiplying the grand mean or common multiplier by the row or district multiplier, column or population sub-group multiplier and the residual multiplier specific to the mutually exclusive population sub-group and the district. For example, ${}_5q_0$ in male Scheduled Castes children living in the rural areas of district Alirajpur of the state can be estimated as

$0.114 = (\eta = 0.097) * (\alpha_i = 0.969) * (\beta_j = 1.110) * (\nu_{ij} = 1.091)$.

In other words, the difference in $_5q_0$ between district Alirajpur and Madhya Pradesh can be explained in terms of district effect or row multiplier, sub-group effect or column multiplier and the residual effect that is specific to the district and the sub-group of the population. In the same manner, the difference between the district $_5q_0$ and the state $_5q_0$ can be explained.

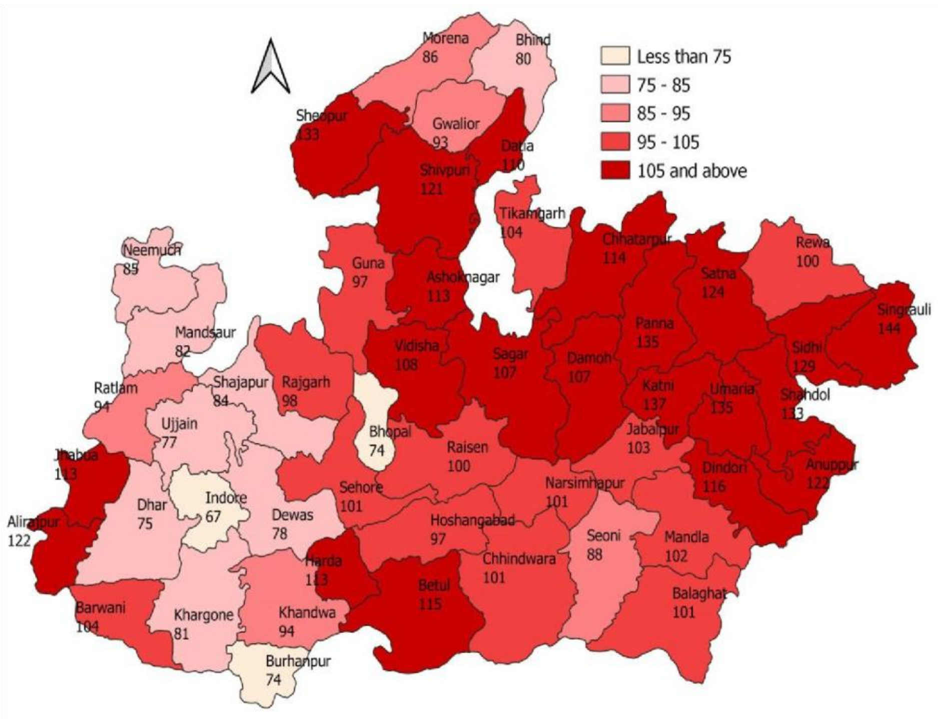

Figure 1: Estimates of 5qo for districts of Madhya Pradesh, based on SBH data from 2011 population census (Circa 2005).
Source: Author

Table 3 can be used for estimating $_5q_0$ for different mutually exclusive and exhaustive population sub-groups in each district at a recent date if the estimate of the grand mean or common multiplier for the recent date is known and if it is assumed that the district or row multiplier, sub-group or column multiplier and the residual multiplier remain unchanged. It may be noticed that the grand mean or the common multiplier is a close approximation of $_5q_0$ for the state as a whole. According to the official sample registration system of the country, $_5q_o$ in Madhya Pradesh was around 0.056 in the year 2017 (Government of India, *no date*). Using the ratio between the grand mean or common multiplier of table 3 and ${}_5q_0$ for Madhya Pradesh obtained from the 2011 population census, a ${}_5q_0$ of 0.056 in the state in the year 2017 is equivalent to a grand mean or common multiplier of 0.054. Replacing the grand mean or common multiplier of table 3 by 0.54 and making necessary calculations yield estimates of ${}_5q_0$ for each of the 600 mutually exclusive yet exhaustive population sub-groups in the state (12 mutually exclusive population sub-groups in each district and 50 districts in the state). These estimates are presented in table 4. These estimates are based on the assumption that the variation in ${}_5q_0$ across the 600 mutually exclusive population sub-groups in the state as revealed through the 2011 population census remains largely the same. Finally, the weighted average of ${}_5q_0$ in different mutually exclusive and exhaustive population sub-groups in a district gives the estimate of ${}_5q_0$ for the district at the recent date which correspond to the estimated of ${}_5q_0$ for the state as a whole as obtained from the sample registration system. The district level estimates of ${}_5q_0$ for the year 2017, so obtained are presented in figure 2. The ${}_5q_0$ in the state varies from 0.038 in district Indore to 0.081 in district Singrauli of the state. In 7 districts of the state, ${}_5q_0$ is estimated to be more than 0.070.

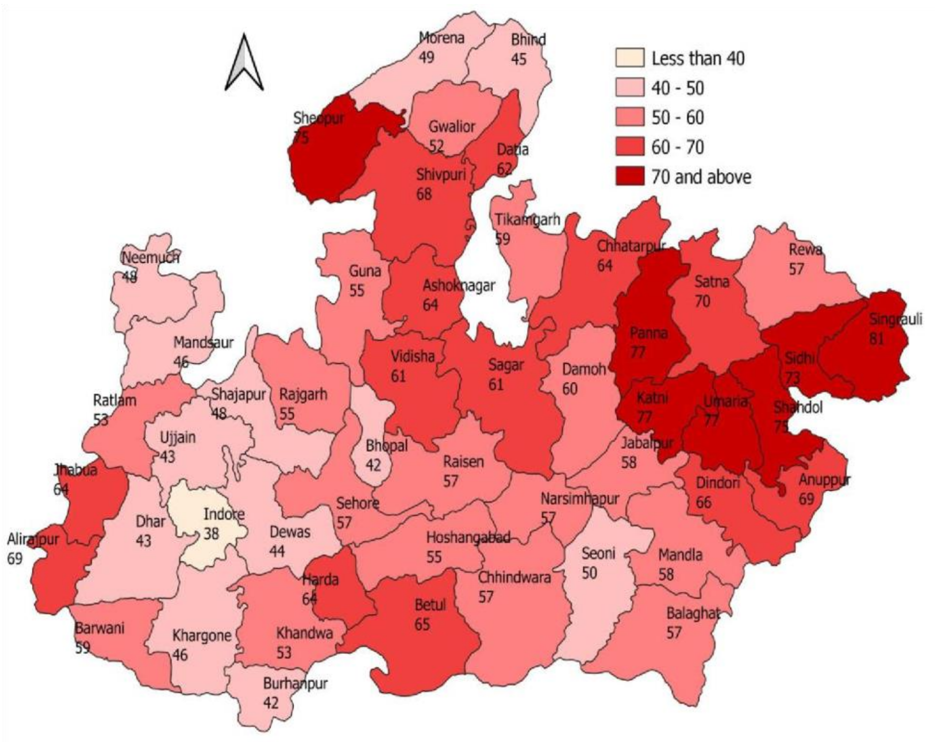

Figure 2: Estimates of 5qo in districts of Madhya Pradesh, circa 2017.
Source: Author

Table 2: Estimates of ${}_5q_0$ in different mutually exclusive and exhaustive population sub-groups in districts of Madhya Pradesh based on 2011 population census.

District	Rural						Urban					
	Scheduled Castes		Scheduled Tribes		Other Castes		Scheduled Castes		Scheduled Tribes		Other Castes	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Madhya Pradesh	0.112	0.119	0.130	0.124	0.093	0.094	0.089	0.087	0.099	0.095	0.075	0.070
Alirajpur	0.114	0.108	0.135	0.122	0.081	0.086	0.046	0.053	0.075	0.058	0.034	0.055
Anuppur	0.136	0.133	0.139	0.125	0.128	0.107	0.116	0.110	0.132	0.104	0.093	0.082
Ashoknagar	0.131	0.133	0.168	0.182	0.095	0.104	0.109	0.097	0.103	0.132	0.079	0.083
Balaghat	0.119	0.101	0.127	0.112	0.107	0.089	0.086	0.078	0.086	0.061	0.086	0.066
Barwani	0.099	0.099	0.118	0.105	0.092	0.083	0.070	0.076	0.083	0.072	0.064	0.053
Betul	0.117	0.105	0.144	0.133	0.101	0.088	0.091	0.077	0.109	0.114	0.087	0.075
Bhind	0.080	0.098	0.115	0.139	0.068	0.087	0.079	0.101	0.043	0.092	0.069	0.086
Bhopal	0.109	0.126	0.119	0.117	0.092	0.085	0.075	0.066	0.066	0.070	0.066	0.067
Burhanpur	0.065	0.054	0.099	0.096	0.059	0.074	0.062	0.055	0.079	0.055	0.054	0.059
Chhatarpur	0.132	0.140	0.158	0.179	0.104	0.113	0.107	0.108	0.120	0.134	0.089	0.090
Chhindwara	0.103	0.097	0.133	0.119	0.097	0.085	0.080	0.065	0.085	0.083	0.065	0.062
Damoh	0.120	0.134	0.130	0.128	0.096	0.108	0.090	0.097	0.092	0.131	0.077	0.072
Datia	0.121	0.128	0.145	0.172	0.101	0.105	0.122	0.129	0.131	0.088	0.108	0.097
Dewas	0.091	0.096	0.099	0.110	0.067	0.070	0.067	0.071	0.077	0.080	0.059	0.056
Dhar	0.078	0.073	0.085	0.086	0.060	0.061	0.064	0.059	0.062	0.066	0.055	0.059
Dindori	0.157	0.144	0.123	0.112	0.109	0.106	0.171	0.049	0.151	0.103	0.092	0.077
Guna	0.098	0.118	0.129	0.140	0.084	0.095	0.071	0.094	0.110	0.131	0.074	0.070
Gwalior	0.102	0.112	0.158	0.168	0.077	0.097	0.099	0.090	0.108	0.146	0.091	0.080
Harda	0.104	0.122	0.142	0.155	0.096	0.099	0.069	0.071	0.122	0.086	0.079	0.065
Hoshangabad	0.119	0.128	0.143	0.126	0.086	0.086	0.090	0.114	0.075	0.072	0.074	0.063

District	Rural						Urban					
	Scheduled Castes		Scheduled Tribes		Other Castes		Scheduled Castes		Scheduled Tribes		Other Castes	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Indore	0.073	0.067	0.080	0.078	0.060	0.058	0.073	0.066	0.078	0.073	0.072	0.063
Jabalpur	0.130	0.120	0.147	0.133	0.107	0.093	0.110	0.099	0.129	0.131	0.094	0.077
Jhabua	0.064	0.072	0.121	0.117	0.079	0.076	0.094	0.050	0.071	0.065	0.077	0.055
Katni	0.141	0.133	0.178	0.170	0.130	0.120	0.116	0.120	0.165	0.129	0.100	0.077
Khandwa	0.088	0.096	0.116	0.120	0.081	0.082	0.072	0.069	0.083	0.069	0.063	0.054
Khargone	0.088	0.085	0.094	0.088	0.075	0.072	0.076	0.049	0.076	0.071	0.057	0.052
Mandla	0.094	0.090	0.114	0.100	0.114	0.096	0.079	0.046	0.101	0.055	0.071	0.056
Mandsaur	0.106	0.102	0.118	0.102	0.084	0.077	0.068	0.075	0.078	0.046	0.056	0.055
Morena	0.082	0.119	0.131	0.142	0.072	0.097	0.084	0.101	0.042	0.099	0.067	0.081
Narsimhapur	0.113	0.110	0.133	0.123	0.105	0.091	0.089	0.085	0.110	0.075	0.075	0.069
Neemuch	0.105	0.094	0.148	0.128	0.082	0.079	0.080	0.071	0.100	0.111	0.068	0.057
Panna	0.147	0.162	0.178	0.174	0.120	0.118	0.118	0.132	0.125	0.169	0.077	0.064
Raisen	0.121	0.119	0.136	0.132	0.090	0.091	0.100	0.093	0.102	0.116	0.077	0.070
Rajgarh	0.115	0.121	0.119	0.103	0.095	0.097	0.090	0.090	0.084	0.077	0.079	0.077
Ratlam	0.114	0.109	0.117	0.117	0.088	0.080	0.071	0.083	0.085	0.103	0.068	0.057
Rewa	0.112	0.124	0.144	0.150	0.084	0.082	0.110	0.101	0.139	0.151	0.072	0.078
Sagar	0.130	0.137	0.149	0.140	0.095	0.096	0.105	0.107	0.136	0.184	0.091	0.088
Satna	0.135	0.142	0.178	0.180	0.109	0.115	0.125	0.106	0.168	0.150	0.074	0.076
Sehore	0.127	0.121	0.131	0.129	0.092	0.086	0.111	0.101	0.093	0.075	0.081	0.080
Seoni	0.095	0.093	0.096	0.088	0.090	0.084	0.092	0.060	0.097	0.063	0.076	0.060
Shahdol	0.137	0.135	0.163	0.146	0.129	0.122	0.097	0.076	0.109	0.116	0.069	0.067
Shajapur	0.099	0.108	0.093	0.098	0.081	0.081	0.093	0.086	0.065	0.056	0.062	0.066
Sheopur	0.111	0.145	0.192	0.194	0.104	0.107	0.117	0.118	0.131	0.165	0.077	0.096

District	Rural						Urban					
	Scheduled Castes		Scheduled Tribes		Other Castes		Scheduled Castes		Scheduled Tribes		Other Castes	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Shivpuri	0.120	0.131	0.189	0.201	0.101	0.111	0.089	0.113	0.136	0.165	0.067	0.078
Sidhi	0.136	0.136	0.168	0.171	0.105	0.109	0.125	0.138	0.139	0.111	0.075	0.076
Singrauli	0.155	0.142	0.170	0.168	0.130	0.130	0.141	0.131	0.161	0.141	0.099	0.080
Tikamgarh	0.102	0.122	0.138	0.160	0.098	0.107	0.072	0.103	0.104	0.065	0.087	0.081
Ujjain	0.095	0.102	0.091	0.087	0.077	0.076	0.073	0.067	0.093	0.050	0.058	0.062
Umaria	0.128	0.130	0.163	0.154	0.115	0.116	0.122	0.101	0.122	0.142	0.081	0.088
Vidisha	0.131	0.138	0.183	0.176	0.098	0.104	0.099	0.108	0.119	0.161	0.076	0.074

Source: Author's calculations

Table 3: Results of the decomposition of inter-district and intra-district variation in ${}_5q_0$

Grand mean (η)	0.097	Population sub-group effect (β_j)											
		SCRM	SCRF	STRM	STRF	OCRM	OCRF	SCUM		SCUSTUM	STUF	OCUM	OCUF
District effect (α_i)		1.110	1.176	1.350	1.291	0.917	0.934	0.916		0.1.010	0.959	0.782	0.737
		Residual (ν_{ij})											
Alirajpur	0.969	*1.091*	*0.973*	*1.058*	*1.005*	*0.932*	*0.982*	*0.533*	*0.631*	*0.791*	*0.641*	*0.467*	*0.786*
Anuppur	1.144	*1.099*	*1.019*	*0.928*	*0.873*	*1.254*	*1.027*	*1.140*	*1.109*	*1.178*	*0.977*	*1.070*	*1.005*
Ashoknagar	1.149	*1.060*	*1.014*	*1.116*	*1.262*	*0.926*	*0.993*	*1.064*	*0.978*	*0.912*	*1.230*	*0.907*	*1.009*
Balaghat	1.029	*1.069*	*0.858*	*0.942*	*0.869*	*1.165*	*0.954*	*0.938*	*0.875*	*0.847*	*0.635*	*1.093*	*0.893*
Barwani	0.874	*1.054*	*0.994*	*1.032*	*0.954*	*1.177*	*1.040*	*0.897*	*1.007*	*0.969*	*0.879*	*0.969*	*0.838*
Betul	1.065	*1.018*	*0.864*	*1.029*	*0.997*	*1.068*	*0.912*	*0.963*	*0.839*	*1.041*	*1.153*	*1.072*	*0.978*
Bhind	0.873	*0.846*	*0.981*	*1.001*	*1.268*	*0.872*	*1.096*	*1.016*	*1.335*	*0.506*	*1.129*	*1.036*	*1.382*
Bhopal	0.906	*1.115*	*1.217*	*1.003*	*1.026*	*1.140*	*1.034*	*0.925*	*0.838*	*0.736*	*0.825*	*0.963*	*1.027*
Burhanpur	0.733	*0.823*	*0.649*	*1.025*	*1.038*	*0.909*	*1.114*	*0.947*	*0.869*	*1.094*	*0.798*	*0.962*	*1.120*
Chhatarpur	1.213	*1.006*	*1.007*	*0.990*	*1.179*	*0.961*	*1.025*	*0.989*	*1.031*	*1.007*	*1.186*	*0.969*	*1.030*
Chhindwara	0.960	*0.992*	*0.884*	*1.058*	*0.986*	*1.128*	*0.974*	*0.935*	*0.786*	*0.905*	*0.932*	*0.891*	*0.904*
Damoh	1.095	*1.018*	*1.069*	*0.902*	*0.934*	*0.987*	*1.083*	*0.919*	*1.025*	*0.860*	*1.282*	*0.924*	*0.919*
Datia	1.187	*0.947*	*0.940*	*0.930*	*1.156*	*0.958*	*0.973*	*1.158*	*1.258*	*1.126*	*0.799*	*1.200*	*1.138*
Dewas	0.790	*1.071*	*1.066*	*0.957*	*1.106*	*0.956*	*0.980*	*0.957*	*1.040*	*0.989*	*1.086*	*0.979*	*0.995*
Dhar	0.680	*1.065*	*0.942*	*0.951*	*1.007*	*0.992*	*0.992*	*1.055*	*1.009*	*0.928*	*1.048*	*1.071*	*1.208*
Dindori	1.016	*1.434*	*1.242*	*0.926*	*0.882*	*1.201*	*1.145*	*1.893*	*0.560*	*1.511*	*1.083*	*1.193*	*1.053*
Guna	0.994	*0.912*	*1.042*	*0.992*	*1.121*	*0.953*	*1.049*	*0.807*	*1.091*	*1.132*	*1.411*	*0.977*	*0.985*
Gwalior	1.070	*0.885*	*0.915*	*1.128*	*1.248*	*0.811*	*0.996*	*1.014*	*0.974*	*1.024*	*1.467*	*1.125*	*1.046*
Harda	1.075	*0.900*	*0.993*	*1.006*	*1.150*	*1.004*	*1.017*	*0.723*	*0.759*	*1.154*	*0.856*	*0.972*	*0.850*
Hoshangabad	0.990	*1.116*	*1.129*	*1.101*	*1.012*	*0.972*	*0.959*	*1.019*	*1.327*	*0.771*	*0.783*	*0.985*	*0.884*
Indore	0.806	*0.844*	*0.724*	*0.759*	*0.769*	*0.839*	*0.793*	*1.013*	*0.938*	*0.979*	*0.966*	*1.170*	*1.091*

Grand mean (η)	0.097	Population sub-group effect (β_j)											
		SCRM	SCRF	STRM	STRF	OCRM	OCRF	SCUM		SCUSTUM	STUF	OCUM	OCUF
District effect (α_i)		1.110	1.176	1.350	1.291	0.917	0.934	0.916		0.1.010	0.959	0.782	0.737
		Residual (ν_{ij})											
Jabalpur	1.142	*1.052*	*0.915*	*0.980*	*0.930*	*1.048*	*0.897*	*1.083*	*0.997*	*1.155*	*1.227*	*1.086*	*0.944*
Jhabua	0.913	*0.653*	*0.688*	*1.014*	*1.018*	*0.974*	*0.923*	*1.155*	*0.630*	*0.796*	*0.758*	*1.107*	*0.844*
Katni	1.344	*0.970*	*0.868*	*1.011*	*1.009*	*1.089*	*0.984*	*0.972*	*1.032*	*1.250*	*1.029*	*0.978*	*0.797*
Khandwa	0.884	*0.922*	*0.945*	*1.002*	*1.082*	*1.029*	*1.018*	*0.911*	*0.903*	*0.956*	*0.840*	*0.944*	*0.849*
Khargone	0.751	*1.081*	*0.984*	*0.950*	*0.933*	*1.124*	*1.051*	*1.133*	*0.752*	*1.030*	*1.011*	*0.990*	*0.963*
Mandla	0.915	*0.957*	*0.864*	*0.948*	*0.872*	*1.401*	*1.152*	*0.969*	*0.574*	*1.124*	*0.645*	*1.014*	*0.856*
Mandsaur	0.879	*1.120*	*1.014*	*1.027*	*0.924*	*1.078*	*0.963*	*0.871*	*0.983*	*0.906*	*0.562*	*0.842*	*0.877*
Morena	0.929	*0.820*	*1.117*	*1.075*	*1.218*	*0.868*	*1.149*	*1.014*	*1.255*	*0.455*	*1.148*	*0.942*	*1.213*
Narsimhapur	1.048	*0.999*	*0.914*	*0.966*	*0.937*	*1.128*	*0.960*	*0.955*	*0.935*	*1.070*	*0.767*	*0.946*	*0.918*
Neemuch	0.902	*1.082*	*0.912*	*1.248*	*1.135*	*1.018*	*0.964*	*0.998*	*0.902*	*1.132*	*1.325*	*0.995*	*0.879*
Panna	1.320	*1.035*	*1.073*	*1.026*	*1.051*	*1.016*	*0.983*	*1.007*	*1.151*	*0.961*	*1.371*	*0.763*	*0.680*
Raisen	1.025	*1.095*	*1.016*	*1.014*	*1.022*	*0.981*	*0.975*	*1.093*	*1.052*	*1.014*	*1.212*	*0.990*	*0.956*
Rajgarh	1.056	*1.009*	*1.004*	*0.858*	*0.781*	*1.013*	*1.011*	*0.961*	*0.982*	*0.814*	*0.786*	*0.990*	*1.017*
Ratlam	0.915	*1.152*	*1.040*	*0.977*	*1.020*	*1.085*	*0.968*	*0.869*	*1.042*	*0.946*	*1.205*	*0.976*	*0.873*
Rewa	1.000	*1.035*	*1.083*	*1.099*	*1.198*	*0.938*	*0.906*	*1.231*	*1.166*	*1.415*	*1.622*	*0.945*	*1.086*
Sagar	1.131	*1.063*	*1.061*	*1.001*	*0.985*	*0.939*	*0.937*	*1.038*	*1.089*	*1.229*	*1.745*	*1.060*	*1.086*
Satna	1.243	*1.009*	*1.002*	*1.094*	*1.154*	*0.981*	*1.017*	*1.126*	*0.986*	*1.373*	*1.296*	*0.786*	*0.855*
Sehore	1.034	*1.136*	*1.027*	*0.964*	*0.995*	*0.995*	*0.912*	*1.207*	*1.129*	*0.916*	*0.775*	*1.028*	*1.086*
Seoni	0.851	*1.039*	*0.959*	*0.860*	*0.828*	*1.189*	*1.087*	*1.218*	*0.814*	*1.165*	*0.794*	*1.175*	*0.982*
Shahdol	1.221	*1.041*	*0.966*	*1.017*	*0.952*	*1.185*	*1.099*	*0.895*	*0.718*	*0.909*	*1.021*	*0.738*	*0.768*
Shajapur	0.902	*1.017*	*1.050*	*0.787*	*0.870*	*1.011*	*0.989*	*1.163*	*1.099*	*0.734*	*0.668*	*0.907*	*1.017*

Grand mean (η)	0.097	Population sub-group effect (β_j)											
		SCRM	SCRF	STRM	STRF	OCRM	OCRF	SCUM	SCUSTUM		STUF	OCUM	OCUF
District effect (α_i)		1.110	1.176	1.350	1.291	0.917	0.934	0.916	0.1.010		0.959	0.782	0.737
		Residual (ν_{ij})											
Sheopur	1.262	*0.816*	*1.007*	*1.158*	*1.226*	*0.928*	*0.937*	*1.037*	*1.083*	*1.057*	*1.405*	*0.807*	*1.066*
Shivpuri	1.198	*0.927*	*0.958*	*1.204*	*1.336*	*0.950*	*1.023*	*0.834*	*1.084*	*1.153*	*1.480*	*0.739*	*0.906*
Sidhi	1.227	*1.026*	*0.967*	*1.044*	*1.109*	*0.964*	*0.976*	*1.149*	*1.301*	*1.158*	*0.971*	*0.807*	*0.860*
Singrauli	1.366	*1.050*	*0.907*	*0.948*	*0.982*	*1.069*	*1.046*	*1.158*	*1.105*	*1.203*	*1.104*	*0.949*	*0.813*
Tikamgarh	1.098	*0.865*	*0.968*	*0.959*	*1.164*	*0.999*	*1.076*	*0.737*	*1.078*	*0.961*	*0.639*	*1.038*	*1.025*
Ujjain	0.839	*1.049*	*1.059*	*0.823*	*0.824*	*1.030*	*0.997*	*0.977*	*0.923*	*1.127*	*0.638*	*0.915*	*1.025*
Umaria	1.243	*0.953*	*0.912*	*1.001*	*0.990*	*1.034*	*1.025*	*1.100*	*0.940*	*1.004*	*1.226*	*0.856*	*0.991*
Vidisha	1.139	*1.068*	*1.060*	*1.222*	*1.230*	*0.963*	*1.009*	*0.973*	*1.093*	*1.064*	*1.513*	*0.881*	*0.902*

Source: Author’s calculations

Table 4: Estimates of ${}_5q_0$ in districts and population sub-group within district in Madhya Pradesh for the year 2017.

State/District	Population sub-groups											
	All	SCRM	SCRF	STRM	STRF	OCRM	OCRF	SCUM	SCUF	STUM	STUF	OCUM	OCUF
Madhya Pradesh	0.056	0.062	0.066	0.073	0.070	0.052	0.052	0.049	0.049	0.055	0.053	0.041	0.039
Alirajpur	0.068	0.063	0.060	0.075	0.068	0.045	0.048	0.026	0.029	0.042	0.032	0.019	0.030
Anuppur	0.068	0.075	0.074	0.077	0.070	0.071	0.059	0.065	0.061	0.074	0.058	0.052	0.046
Ashoknagar	0.063	0.073	0.074	0.093	0.101	0.053	0.058	0.060	0.054	0.057	0.073	0.044	0.046
Balaghat	0.056	0.066	0.056	0.071	0.062	0.059	0.050	0.048	0.043	0.048	0.034	0.048	0.037
Barwani	0.058	0.055	0.055	0.066	0.058	0.051	0.046	0.039	0.042	0.046	0.040	0.036	0.029
Betul	0.064	0.065	0.058	0.080	0.074	0.056	0.049	0.051	0.043	0.060	0.064	0.048	0.041
Bhind	0.044	0.044	0.054	0.064	0.077	0.038	0.048	0.044	0.056	0.024	0.051	0.038	0.048
Bhopal	0.041	0.061	0.070	0.066	0.065	0.051	0.047	0.041	0.037	0.036	0.039	0.037	0.037
Burhanpur	0.041	0.036	0.030	0.055	0.053	0.033	0.041	0.034	0.031	0.044	0.030	0.030	0.033
Chhatarpur	0.063	0.073	0.078	0.088	0.100	0.058	0.063	0.059	0.060	0.067	0.074	0.050	0.050
Chhindwara	0.056	0.057	0.054	0.074	0.066	0.054	0.047	0.044	0.036	0.047	0.046	0.036	0.035
Damoh	0.059	0.067	0.074	0.072	0.071	0.054	0.060	0.050	0.054	0.051	0.073	0.043	0.040
Datia	0.061	0.067	0.071	0.080	0.096	0.056	0.058	0.068	0.072	0.073	0.049	0.060	0.054
Dewas	0.043	0.051	0.054	0.055	0.061	0.037	0.039	0.037	0.040	0.043	0.044	0.033	0.031
Dhar	0.042	0.043	0.041	0.047	0.048	0.033	0.034	0.035	0.033	0.034	0.037	0.031	0.033
Dindori	0.064	0.087	0.080	0.069	0.062	0.060	0.059	0.095	0.027	0.084	0.057	0.051	0.043
Guna	0.054	0.054	0.066	0.072	0.078	0.047	0.053	0.040	0.052	0.061	0.073	0.041	0.039
Gwalior	0.052	0.057	0.062	0.088	0.093	0.043	0.054	0.055	0.050	0.060	0.081	0.051	0.045
Harda	0.063	0.058	0.068	0.079	0.086	0.053	0.055	0.038	0.039	0.068	0.048	0.044	0.036
Hoshangabad	0.054	0.066	0.071	0.079	0.070	0.048	0.048	0.050	0.063	0.042	0.040	0.041	0.035
Indore	0.038	0.041	0.037	0.045	0.043	0.034	0.032	0.040	0.036	0.043	0.040	0.040	0.035

State/District	Population sub-groups											
	All	SCRM	SCRF	STRM	STRF	OCRM	OCRF	SCUM	SCUF	STUM	STUF	OCUM	OCUF
Jabalpur	0.057	0.072	0.066	0.082	0.074	0.059	0.052	0.061	0.055	0.072	0.073	0.052	0.043
Jhabua	0.063	0.036	0.040	0.067	0.065	0.044	0.042	0.052	0.028	0.040	0.036	0.043	0.031
Katni	0.076	0.078	0.074	0.099	0.095	0.072	0.067	0.065	0.067	0.092	0.072	0.056	0.043
Khandwa	0.052	0.049	0.053	0.065	0.067	0.045	0.045	0.040	0.038	0.046	0.038	0.035	0.030
Khargone	0.045	0.049	0.047	0.052	0.049	0.042	0.040	0.042	0.027	0.042	0.039	0.031	0.029
Mandla	0.057	0.052	0.050	0.063	0.056	0.063	0.053	0.044	0.025	0.056	0.031	0.039	0.031
Mandsaur	0.046	0.059	0.057	0.066	0.057	0.047	0.043	0.038	0.042	0.043	0.026	0.031	0.031
Morena	0.048	0.046	0.066	0.073	0.079	0.040	0.054	0.047	0.056	0.023	0.055	0.037	0.045
Narsimhapur	0.056	0.063	0.061	0.074	0.068	0.059	0.051	0.049	0.047	0.061	0.042	0.042	0.038
Neemuch	0.047	0.058	0.052	0.082	0.071	0.045	0.044	0.045	0.039	0.056	0.062	0.038	0.032
Panna	0.075	0.082	0.090	0.099	0.097	0.066	0.065	0.066	0.073	0.069	0.094	0.043	0.036
Raisen	0.056	0.067	0.066	0.076	0.073	0.050	0.050	0.055	0.052	0.057	0.064	0.043	0.039
Rajgarh	0.054	0.064	0.067	0.066	0.057	0.053	0.054	0.050	0.050	0.047	0.043	0.044	0.043
Ratlam	0.052	0.063	0.060	0.065	0.065	0.049	0.045	0.039	0.046	0.047	0.057	0.038	0.032
Rewa	0.056	0.062	0.069	0.080	0.084	0.046	0.046	0.061	0.056	0.077	0.084	0.040	0.043
Sagar	0.059	0.072	0.076	0.083	0.078	0.053	0.053	0.058	0.059	0.076	0.102	0.051	0.049
Satna	0.069	0.075	0.079	0.099	0.100	0.060	0.064	0.069	0.059	0.093	0.083	0.041	0.042
Sehore	0.056	0.070	0.067	0.073	0.072	0.051	0.048	0.062	0.056	0.052	0.041	0.045	0.045
Seoni	0.049	0.053	0.052	0.053	0.049	0.050	0.047	0.051	0.033	0.054	0.035	0.042	0.033
Shahdol	0.074	0.076	0.075	0.091	0.081	0.072	0.068	0.054	0.042	0.061	0.065	0.038	0.037
Shajapur	0.047	0.055	0.060	0.052	0.055	0.045	0.045	0.052	0.048	0.036	0.031	0.035	0.037
Sheopur	0.074	0.062	0.081	0.107	0.108	0.058	0.060	0.065	0.066	0.073	0.092	0.043	0.054
Shivpuri	0.067	0.067	0.073	0.105	0.112	0.056	0.062	0.049	0.063	0.075	0.092	0.037	0.043
Sidhi	0.072	0.075	0.075	0.093	0.095	0.059	0.060	0.070	0.077	0.077	0.062	0.042	0.042

State/District	Population sub-groups												
	All	SCRM	SCRF	STRM	STRF	OCRM	OCRF	SCUM	SCUF	STUM	STUF	OCUM	OCUF
Singrauli	0.080	0.086	0.079	0.094	0.094	0.072	0.072	0.078	0.073	0.090	0.078	0.055	0.044
Tikamgarh	0.058	0.057	0.068	0.077	0.089	0.054	0.060	0.040	0.057	0.058	0.036	0.048	0.045
Ujjain	0.043	0.053	0.056	0.050	0.048	0.043	0.042	0.041	0.037	0.052	0.028	0.032	0.034
Umaria	0.075	0.071	0.072	0.091	0.086	0.064	0.064	0.068	0.056	0.068	0.079	0.045	0.049
Vidisha	0.060	0.073	0.077	0.101	0.098	0.054	0.058	0.055	0.060	0.066	0.089	0.042	0.041

Source: Author’s calculations

State/District	All	Rural						Urban					
		SC		ST		OT		SC		ST		OT	
		M	F	M	F	M	F	M	F	M	F	M	F
MP	0.056	0.061	0.065	0.074	0.071	0.050	0.051	0.050	0.049	0.056	0.053	0.043	0.041
Alirajpur	0.069	0.065	0.061	0.076	0.069	0.046	0.049	0.026	0.030	0.043	0.033	0.019	0.031
Anuppur	0.069	0.077	0.075	0.079	0.071	0.072	0.060	0.066	0.062	0.075	0.059	0.053	0.047
Ashoknagar	0.064	0.074	0.075	0.095	0.103	0.054	0.059	0.062	0.055	0.058	0.074	0.045	0.047
Balaghat	0.057	0.067	0.057	0.072	0.064	0.060	0.050	0.049	0.044	0.048	0.034	0.048	0.037
Barwani	0.059	0.056	0.056	0.067	0.059	0.052	0.047	0.040	0.043	0.047	0.041	0.036	0.030
Betul	0.065	0.066	0.059	0.081	0.075	0.057	0.050	0.052	0.044	0.062	0.065	0.049	0.042
Bhind	0.045	0.045	0.055	0.065	0.079	0.038	0.049	0.045	0.057	0.025	0.052	0.039	0.049
Bhopal	0.042	0.062	0.071	0.067	0.066	0.052	0.048	0.042	0.037	0.037	0.039	0.038	0.038
Burhanpur	0.042	0.037	0.031	0.056	0.054	0.034	0.042	0.035	0.031	0.045	0.031	0.030	0.033
Chhatarpur	0.064	0.074	0.079	0.089	0.101	0.059	0.064	0.060	0.061	0.068	0.076	0.051	0.051
Chhindwara	0.057	0.058	0.055	0.075	0.067	0.055	0.048	0.045	0.037	0.048	0.047	0.037	0.035
Damoh	0.060	0.068	0.076	0.073	0.073	0.055	0.061	0.051	0.055	0.052	0.074	0.044	0.041
Datia	0.062	0.069	0.072	0.082	0.097	0.057	0.059	0.069	0.073	0.074	0.050	0.061	0.055
Dewas	0.044	0.052	0.055	0.056	0.062	0.038	0.040	0.038	0.040	0.043	0.045	0.033	0.032
Dhar	0.043	0.044	0.041	0.048	0.049	0.034	0.035	0.036	0.034	0.035	0.038	0.031	0.033
Dindori	0.066	0.089	0.082	0.070	0.064	0.062	0.060	0.097	0.028	0.085	0.058	0.052	0.043
Guna	0.055	0.055	0.067	0.073	0.079	0.048	0.054	0.040	0.053	0.062	0.074	0.042	0.040
Gwalior	0.052	0.058	0.063	0.090	0.095	0.044	0.055	0.056	0.051	0.061	0.083	0.052	0.045
Harda	0.064	0.059	0.069	0.080	0.088	0.054	0.056	0.039	0.040	0.069	0.049	0.045	0.037
Hoshangabad	0.055	0.067	0.072	0.081	0.071	0.049	0.049	0.051	0.064	0.042	0.041	0.042	0.035
Indore	0.038	0.042	0.038	0.045	0.044	0.034	0.033	0.041	0.037	0.044	0.041	0.041	0.036

State/District	All	Rural						Urban					
		SC		ST		OT		SC		ST		OT	
		M	F	M	F	M	F	M	F	M	F	M	F
Jabalpur	0.058	0.073	0.068	0.083	0.075	0.060	0.053	0.062	0.056	0.073	0.074	0.053	0.044
Jhabua	0.064	0.036	0.041	0.069	0.066	0.045	0.043	0.053	0.028	0.040	0.037	0.043	0.031
Katni	0.077	0.080	0.075	0.101	0.096	0.074	0.068	0.066	0.068	0.093	0.073	0.057	0.043
Khandwa	0.053	0.050	0.054	0.066	0.068	0.046	0.046	0.041	0.039	0.047	0.039	0.036	0.030
Khargone	0.046	0.050	0.048	0.053	0.050	0.043	0.041	0.043	0.028	0.043	0.040	0.032	0.029
Mandla	0.058	0.053	0.051	0.064	0.057	0.065	0.054	0.045	0.026	0.057	0.031	0.040	0.032
Mandsaur	0.046	0.060	0.058	0.067	0.058	0.048	0.043	0.039	0.042	0.044	0.026	0.032	0.031
Morena	0.049	0.047	0.067	0.074	0.080	0.041	0.055	0.047	0.057	0.023	0.056	0.038	0.046
Narsimhapur	0.057	0.064	0.062	0.075	0.070	0.060	0.052	0.050	0.048	0.062	0.042	0.043	0.039
Neemuch	0.048	0.060	0.053	0.084	0.073	0.046	0.045	0.045	0.040	0.057	0.063	0.039	0.032
Panna	0.077	0.083	0.092	0.101	0.099	0.068	0.067	0.067	0.074	0.070	0.095	0.043	0.036
Raisen	0.057	0.069	0.067	0.077	0.074	0.051	0.051	0.056	0.053	0.058	0.066	0.044	0.040
Rajgarh	0.055	0.065	0.069	0.067	0.059	0.054	0.055	0.051	0.051	0.048	0.044	0.045	0.044
Ratlam	0.053	0.064	0.062	0.066	0.066	0.050	0.045	0.040	0.047	0.048	0.058	0.038	0.032
Rewa	0.057	0.063	0.070	0.082	0.085	0.047	0.047	0.062	0.057	0.079	0.086	0.041	0.044
Sagar	0.061	0.073	0.078	0.084	0.079	0.054	0.054	0.059	0.060	0.077	0.104	0.052	0.050
Satna	0.070	0.077	0.081	0.101	0.102	0.061	0.065	0.070	0.060	0.095	0.085	0.042	0.043
Sehore	0.057	0.072	0.069	0.074	0.073	0.052	0.048	0.063	0.057	0.053	0.042	0.046	0.046
Seoni	0.050	0.054	0.053	0.054	0.050	0.051	0.048	0.052	0.034	0.055	0.036	0.043	0.034
Shahdol	0.075	0.078	0.076	0.092	0.083	0.073	0.069	0.055	0.043	0.062	0.066	0.039	0.038
Shajapur	0.048	0.056	0.061	0.053	0.056	0.046	0.046	0.053	0.049	0.037	0.032	0.035	0.037
Sheopur	0.075	0.063	0.082	0.109	0.110	0.059	0.061	0.066	0.067	0.074	0.094	0.044	0.055

State/District	All	Rural						Urban					
		SC		ST		OT		SC		ST		OT	
		M	F	M	F	M	F	M	F	M	F	M	F
Shivpuri	0.068	0.068	0.074	0.107	0.114	0.057	0.063	0.050	0.064	0.077	0.094	0.038	0.044
Sidhi	0.073	0.077	0.077	0.095	0.097	0.060	0.061	0.071	0.078	0.079	0.063	0.043	0.043
Singrauli	0.081	0.088	0.080	0.096	0.095	0.074	0.073	0.080	0.074	0.091	0.080	0.056	0.045
Tikamgarh	0.059	0.058	0.069	0.078	0.091	0.055	0.061	0.041	0.058	0.059	0.037	0.049	0.046
Ujjain	0.043	0.054	0.058	0.051	0.049	0.044	0.043	0.041	0.038	0.053	0.028	0.033	0.035
Umaria	0.077	0.072	0.073	0.092	0.087	0.065	0.065	0.069	0.057	0.069	0.080	0.046	0.050
Vidisha	0.061	0.074	0.078	0.103	0.100	0.055	0.059	0.056	0.061	0.067	0.091	0.043	0.042

Figure 3: Heatmap of ${}_5q_0$ in Madhya Pradesh, 2017
Source: Author

The estimates of $_5q_0$ presented in table 4 reveal very strong variation across the 600 mutually exclusive yet exhaustive population sub-groups of Madhya Pradesh. These variations are depicted more explicitly in the heat-map (Figure 3). These variations suggest that a decentralised district-based approach is required to address the challenge of exceptionally high risk of death in the first five years of life in Madhya Pradesh.

Conclusions

In this paper, we have proposed a simple non-parametric data mining approach for estimating a demographic indicator at the local level on a recent date based on the past estimate of the demographic indicator at the local level usually available through the population census and the recent estimate of the indicator at higher administrative level available from some alternative source such as a survey. The approach has been used to estimate the most recent estimates of $_5q_0$ in districts of Madhya Pradesh based on the district level estimates derived from the 2011 population census and the most recent estimate of $_5q_0$ for Madhya Pradesh available through India's official sample registration system. The underlying assumption of the approach is that the pattern of variation in the $_5q_0$ across districts and across different population sub-groups within the district remain largely unchanged.

The approach proposed here is particularly suited in situations where estimates of the demographic indicator of interest is available on a regular basis at the aggregate level only but estimates of the demographic indicator below the aggregate - local - level are available only at one or two points in time either through a population census using indirect techniques of demographic estimation or from some other source. The usefulness of the approach lies in its simplicity and the fact that most of the data required for the application of the approach can be readily generated from the existing sources which makes the approach time and cost effective. An advantage of the approach is that it is entirely data driven. It makes no assumption about the underlying structure of the data and, therefore, can easily handle skewed data or the data having outliers. This is important as the assumption of the normality in the variation in the demographic indicators is deviated frequently at the local level because of the influence of the local level factors in deciding the level of demographic indicators.

An advantage of the method proposed is that it provides recent estimates of the demographic indicator for different mutually exclusive sub-groups within the sub-population (district). An important limitation of both sample registration system and the National Family Health Survey is that information available from these sources contribute little to within district diversity or inequality in the demographic situation. Assessment of the demographic diversity within the sub-population (district) is important from the perspective of development planning and programming and for monitoring and evaluating the impact of development efforts. The sample registration system and the National Family Health Survey are not designed to provide information that reflects the demographic diversity within the sub-population (district).

The proposed method can constitute the basis for establishing a system of estimating demographic indicators at the sub-administrative area (district) level on a regular basis in India to meet the long-standing demand of annual estimates of district level demographic indicators for the most recent date for the purpose of decentralised population and development planning and programming at the local (district) level. At present, district level planning and programming for population and development activities in India largely remains either anecdotal or analogical because local level estimates of key population and development indicators are either not available or, if available, are outdated.

References

Australian Bureau of Statistics (2006) *A Guide to Small Area Estimation–Version 1.1*. Canberra, Australian Bureau of Statistics.

Ahuja S (*no date*) Indirect estimates of district wise IMR and Under 5 mortality using 2011 census data - draft. New Delhi, National Health Systems Resource Centre.

Asian Development Bank (2020) *Introduction to Small Area Estimation Techniques. A Practical Guide for National Statistics Office*. Manila, Asian Development Bank.

Bhat PNM (1996) Contours of fertility decline in India: a district level study based on 1991 population census. In K Srinivasan (Ed) *Population Policy and Reproductive Health*. New Delhi, Himalaya Publishing Corporation.

Chaurasia AR (2013) Social class and residential disparities in human development in Madhya Pradesh. *Indian Journal of Human Development* 7(2): 275-300.

Elbers C, Lanjouw J, Lanjouw P (2003) Micro-level estimation of poverty and inequality. *Econometrica* 71(1): 355–364.

Government of India (1969) *The Registration of Birth and Death Act 1969*. New Delhi, Ministry of Home Affairs.

Government of India (1988) *Child Mortality Estimates of India*. New Delhi, Controller of Publications.

Government of India (1989) *Fertility in India: An Analysis of 1981 Census Data*. New Delhi, Controller of Publications.

Government of India (1997) District level estimates of fertility and child mortality and their interrelation with other variables. New Delhi, Registrar General and Census Commissioner of India. Occasional Paper 1 of 1997.

Government of India (*no date*) *Sample Registration System Statistical Report 2017*. New Delhi, Registrar General and Census Commissioner of India.

Government of India (2010) *District Level Household and Facility Survey 2007-08, India*. Mumbai, International Institute for Population Sciences.

Government of India (2017) *National Family Health Survey (NFHS-4) 2015-16 India*. Mumbai, International Institute for Population Sciences.

Government of India (2020) *Sample Registration System Statistical Report* 2018. New Delhi, Ministry of Home Affairs, Office of the Registrar General and Census Commissioner of India.

Guilmoto CZ, Rajan SI (2002) District level estimates of fertility from India's 2001 population census. *Economic and Political Weekly* 37(7): 665672.

Guilmoto CZ, Rajan SI (2001) Trends and spatial patterns of fertility in Indian districts. *Population and Development Review* 27(4):713-738.

Guilmoto CZ, Rajan SI (2013) Fertility at district level in India: lessons from 2011 population census. Centre for Population and Development. Working Paper No. 30.

Kumar S, Sathyanarayana KM (2012) District level estimates of fertility and implied sex ratio at birth in India. *Economic and Political Weekly* 47:6672.

Moultrie T, Dorrington R, Hill A, Hill K, Timaeus I, Zaba B (2014) *Tools for Demographic Estimation*. Paris, International Union for the Scientific Study of Population.

Padmanabha P (1982) Sample registration system in India. *Sample Registration Bulletin* 16(2): 45-50.

Purcel NJ, Kish L (1979) Estimation of small area domains. *Biometrics* 35(48): 3-18.

Rajan SI, Mohanchandran P (1998) Infant and child mortality estimates I. *Economic and Political Weekly* 33(19): 1120-40.

Rathi K, Kamboj P, Bansal PG, Toteja GS (2018) A review of selected health and nutrition surveys in India. *Indian Journal of Medical Research* 148(5): 596-611.

Selvin S (2004) *Statistical Analysis of Epidemiological Data*. New York, Oxford University Press.

Sharma R, Choudhury L (2014) Infant and child mortality at district level of India: a modified Brass approach. *Middle East Journal of Age and Ageing* 11(2): 29-34.

Tukey JW (1977) *Exploratory Data Analysis*. Reading, Massachusetts, Addison-Wesley.