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Service Quality beyond Access: A Multilevel Analysis of Neonatal, Infant, and Under-Five Child Mortality Using the Indian Demographic and Health Survey 2015~2016

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Purpose: The purpose of this study was to derive contextual indicators of medical provider quality and assess their relative importance along with the individual utilization of antenatal care (ANC) and institutional births with a skilled birth attendant (SBA) in India using a multilevel framework. **Methods:** The 2015~2016 Demographic and Health Survey (DHS) from India was used to assess the outcomes of neonatal, infant, and under-five child mortality. The final analytic sample included 182,980 children across 28,283 communities, 640 districts, and 36 states and union territories. The contextual indicators of medical provider quality for districts and states were derived from the individual-level number of ANC visits (<4 or ≥ 4) and institutional delivery with SBA. A series of random effects logistic regression models were estimated with a stepwise addition of predictor variables. **Results:** About half of the mothers (47.3%) had attended ≥ 4 ANC visits and 75.8% delivered in institutional settings with SBAs. Based on ANC visits, 276~281 districts (43.1~43.9%) and 13~16 states (36.5~44.4%) were classified as "low" quality areas, whereas 268~285 districts (41.9~44.5%) and 8~9 states (22.2~25.0%) were classified as "low" quality areas based on institutional delivery with SBAs. Conditional on a comprehensive set of covariates, the individual use of both ANC and SBA were significantly associated with all mortality outcomes (OR: 1.17, 95% CI: 1.08, 1.26, and OR: 1.10, 95% CI: 1.02, 1.19, respectively, for under-five child mortality) and remained robust even after adjusting for contextual indicators of medical provider quality. Districts and states with low quality were associated with 57~61% and 27~43% higher odds of under-five child mortality, respectively. **Conclusion:** When simultaneously considered, district- and state-level provider quality mattered more than individual access to care for all mortality outcomes in India. Further investigations are needed to assess the importance of improving the quality of health service delivery at higher levels to prevent unnecessary child deaths in developing countries.

Key Words: Antenatal care, Provider quality, Child mortality, India, Multilevel analysis

INTRODUCTION

The Sustainable Development Goals (SDG) proposed in 2015 made a clear commitment to improve child survival, with an explicit target for all countries to reduce neonatal mortality to as low as 12 deaths per 1,000 live births and under-five mortality to 25 deaths per 1,000 live births.[1)] As of 2015, 20% of the total under-five deaths in the world (or 1,201,000 deaths) was attributed to India,[1)] despite the country's remarkable 4.1 percent rate of reduction from 1990 to 2016 (from 126 to 43 deaths per 1,000 live births).[2)] In recent years, India has strengthened its relevant policies and increased budgetary allocations to improve maternal and child survival, as exemplified by Expanded Programmes on Immunization (Mission Indradhanush)[3)] and pilot programmes to improve the quality of care in

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maternal labour rooms especially in remote areas.[4-6] Given this movement, up-to-date empirical evidence on modifiable factors to reduce postnatal deaths has important and timely relevance for policy discussions in India.

A key component of maternal and child health interventions is promoting coverage of appropriate and timely care both during pregnancy and at delivery.[7-9] The World Health Organization (WHO) specifically recommends at least four antenatal care (ANC) visits, ideally occurring between 8 and 12 weeks of gestation, between 24 and 26 weeks, at 32 weeks, and between 36 and 38 weeks.[10] The WHO guidelines further outline the service package required for each visit, including screening for complications, educational advice on healthy lifestyle, 2 tetanus toxoid injections, and 90 iron/folic acid tablets.[11] Additionally, ensuring birth delivery in institutional settings with the assistance of a skilled birth attendant (SBA) can substantially reduce the risk of stillbirth or maternal deaths due to intrapartum-related complications.[1,12] The latest estimates from India report that just over half of the mothers had at least 4 ANC visits and almost 79% had institutional births.[13]

Contrary to the expected benefits of ANC visits and SBA at delivery, a number of prior studies found that expanding the coverage of individual uptake of these services does not necessarily translate into improvements in neonatal, infant, and child mortality outcomes in the context of low- and middle-income countries (LMICs) where the quality of health service delivery is not optimal.[12,14-17] Weak health systems and poor incentives are identified as critical barriers that create a gap between individual access to care and the actual health outcomes.[14,18] These conflicting findings suggest that the overall quality of care in maternal services and clinical capacity may play an independent role on birth outcomes and subsequent child survivals over and above individual access to ANC and SBA. Also importantly, they may explain the uneven geographical distribution of the burden of child deaths.[19] Within India, substantial inter- and intra-state disparity exists for infant and under-five mortality with higher concentration in central and eastern regions.[20] To our knowledge, whether this geographic variation in neonatal, infant, and under-five mortality is largely due to clustering of 'high-risk' individuals or presence of contextual factors operating at higher levels (such as provider quality) has not yet been systematically examined using multilevel modeling.

Assessing quality in health care is challenging due to lack of universally accepted definition.[21] Moreover, indicators of contextual provider quality are not routinely available in nationally representative surveys in the context of LMICs. For instance, Demographic and Health Surveys (DHS) do not collect information on patient satisfaction and safety or health inputs or system efficiency.[22] To overcome this data constraint, prior studies have often used caesarean and episiotomy rates,[23] neonatal near-miss events (i.e., newborn infants presenting selected markers of severity and surviving the first neonatal week),[24] and maternal mortality as proxy indicators for quality of care. Another recent study used principal components analysis based techniques to quantify variation in quality of care using core DHS indicators for Indonesia and found disparities by wealth and geographical regions.[22] We offer a fairly new approach to derive contextual provider quality indicators and assess their relative importance along with individual utilization of ANC and SBA in India using multilevel framework.

This study uses the latest nationally representative data from India to first create indicators for district and state provider quality based on residuals deviating from the ecological associations between ANC (and SBA) rate and prevalence of neonatal, infant, and under-five mortality at each respective level. Then, we use multilevel statistical techniques to examine: (1) whether individual use of ANC and SBA is independently associated with each mortality outcome, after taking into account of other important sociodemographic covariates and contextual provider quality indicators, and vice versa, and (2) the magnitude and partitioning of variation in mortality outcomes by multiple relevant levels (i.e., communities, districts, and states), both before and after adjusting for individual compositional characteristics and contextual provider quality indicators.

METHODS

1. Data

The latest Demographic and Health Survey (DHS) conducted in 2015~2016 (round VII), also equivalent to the National Family Health Survey (NFHS)(round 4) in India, was used for this study. All seven union territories in addition to the 29 states in India were surveyed for the first time in the NFHS-4. This allowed estimation of many indicators at the district level for all 640 districts in India as per the 2011 census.[25,26] Survey respondents were selected following a probability-based cluster sampling procedure. Sampling frames were first developed on the basis of non-overlapping units of geography (identified as the primary sampling units (PSUs)) by states and urban and rural areas within each state. At the second stage, a fixed proportion of households were selected using systematic

sampling within each PSU.[26] The full dataset is available upon request from https://dhsprogram.com/ and contains no identifiable information on the study participants. DHS is known for standardized and nationally representative sampling of participants, objective measurement of anthropometric measures, collection of a wide range of monitoring and impact evaluation indicators for health and nutrition, and high response rates.[26]

2. Study Population and Sample Size

India DHS 2015~2016 collected data on all children born within 5 years of age from the survey year in each selected household. A total of 255,327 singleton children were eligible to be included in our analysis. Of them, 68,119 children (26.7%) who were missing information on ANC visits or SBA were excluded. For complete case analysis, 4,228 children (1.7%) who were missing information on one or more of the covariates listed below were also excluded, leaving 182,980 children across 28,283 communities, 640 districts, and 36 states and union territories in the final analytic sample (Fig. 1).

3. Outcome Variables

Three mortality outcomes were assessed in this study: neonatal mortality (i.e., deaths within the first month), infant mortality (i.e., deaths within one year since birth), and under-five child mortality (i.e., deaths within the first five years).

4. Individual Access to Care

From mother's self-reported data on utilization of ANC services, we created a binary variable indicating whether the mother had <4 or ≥ 4 ANC visits. Another binary variable was coded indicating whether the mother had birth delivery in an institutional setting with a SBA (doctor, nurse, or midwife).

5. Contextual Provider Quality

Indicators for outcome-specific provider quality (low versus high) were derived for each district and state (hereafter collectively referred to as 'contextual provider quality indicators') from the following ecological models. An ecological model here simply refers to a regression model with both predictor and outcome variables aggregated at higher levels[27] (i.e., districts and states). For instance, based on an ecological model regressing proportion of mothers reporting ≥ 4 ANC visits and proportion of neonatal mortality at the district level, positive residuals (i.e., districts with higher than average mortality rate given the same proportion of ANC ≥ 4) were coded as 'low provider quality' districts and negative residuals (i.e., districts with lower than average mortality rate given the same proportion of ANC ≥ 4) were coded as 'high provider quality' districts (Fig. 2). This procedure was repeated for infant and child mortality outcomes at both the district and state levels. Similarly, another set of con-

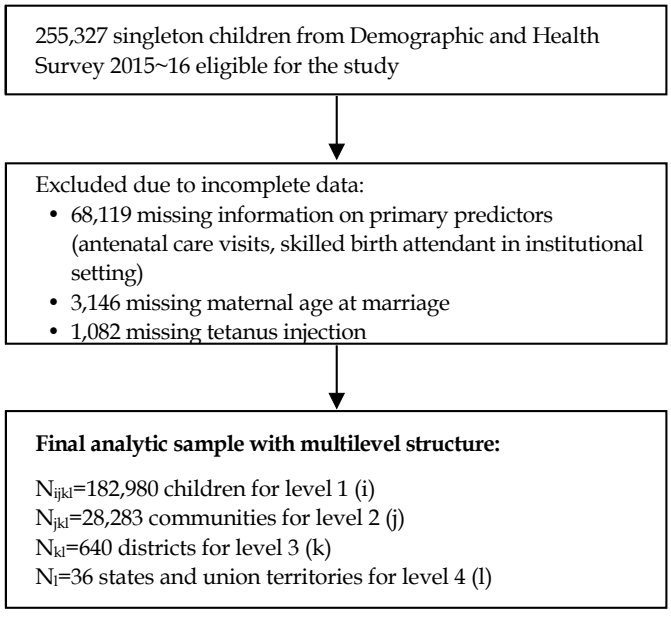

Fig. 1. Four Level Data Structure of the Final Analytic Sample from India Demographic and Health Survey 2015~2016.

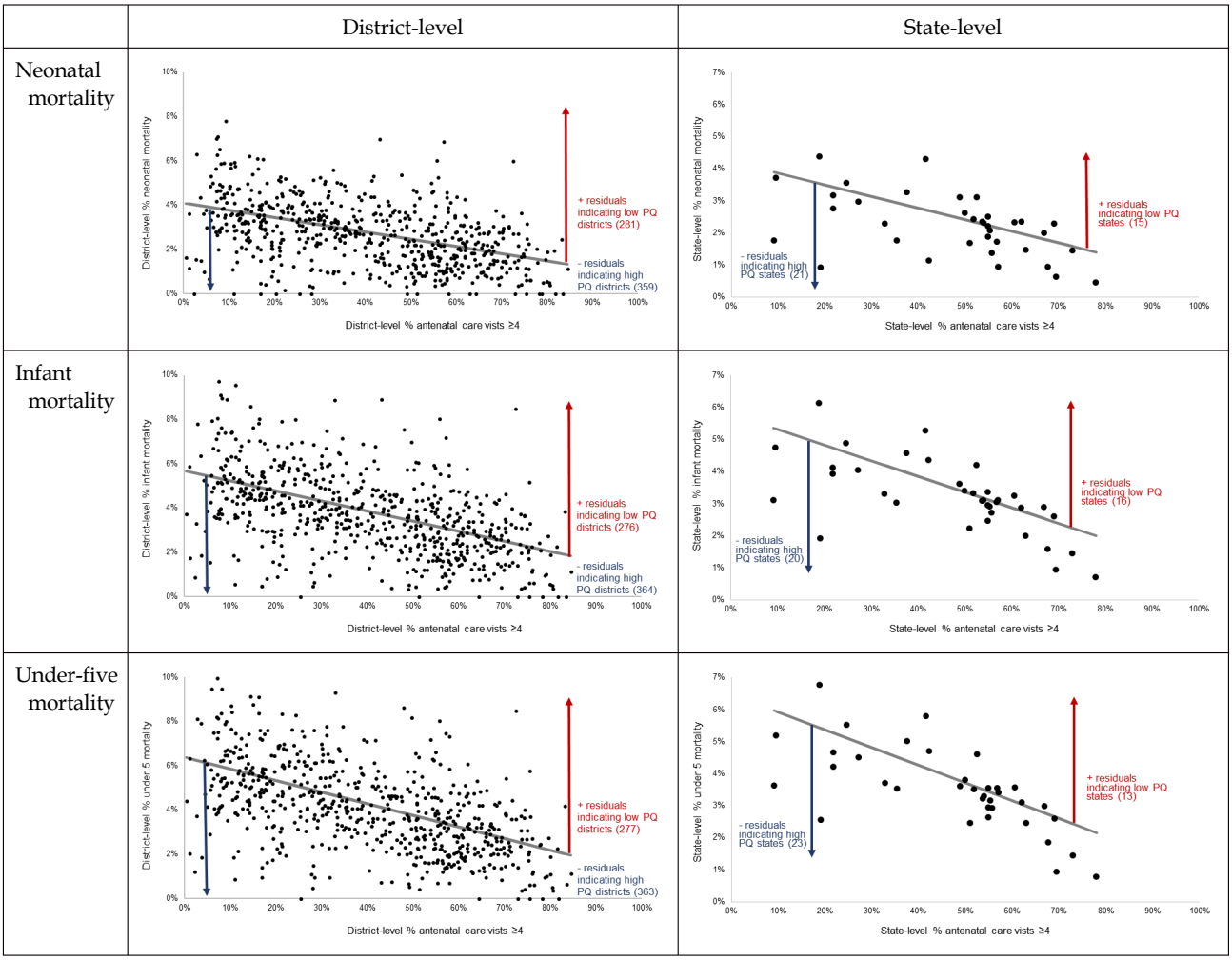

Fig. 2. Constructing District- and State-Level Provider Quality Proxy Measures Based on % Mothers with≥4 Antenatal Care Visits and % Neonatal, Infant, and Under-Five Mortality, India Demographic and Health Survey 2015~2016.

textual provider quality indicators were derived from residuals based on ecological models regressing mortality prevalence by proportion of delivery with SBA (Fig. 3).

6. Other Covariates

Several other important covariates at the child, maternal, and household levels were identified. Child's sex (male, female), birth order (1, 2~3, 4~5, ≥6), birth interval (first birth, <24, 24~47, ≥48 months), and delivery mode (normal, caesarean) were included in our analysis. At maternal level, mother's age (15~19, 20~24, 25~29, 30~34, 35~39, 40~44, 45~49 years), marital status (currently married or living together, never/formerly married), education (none, primary, secondary, higher, college), age at marriage (<18, ≥18 years), and whether tetanus injection was given (yes, no) were assessed. Indicators of household socioeconomic and environmental conditions were coded as following. In DHS, household wealth index, a composite index of relative standard of living, was created using principal component analyses of household characteristics and assets and then categorized into quintiles.[26] The source of drinking water was considered safe for water piped into dwelling or yard/plot, public tap/standpipe, tube well or borehole, protected well or spring, rain water, and bottled water, and unsafe otherwise. The sanitation facility was defined as improved if households had access to flush to piped sewer system, septic tank, or pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet, and unimproved otherwise. A binary variable for whether solid fuels were used for cooking (yes, no) was considered as a crude measure of household air quality. Lastly, household place of residence (urban, rural) was included in our analysis.

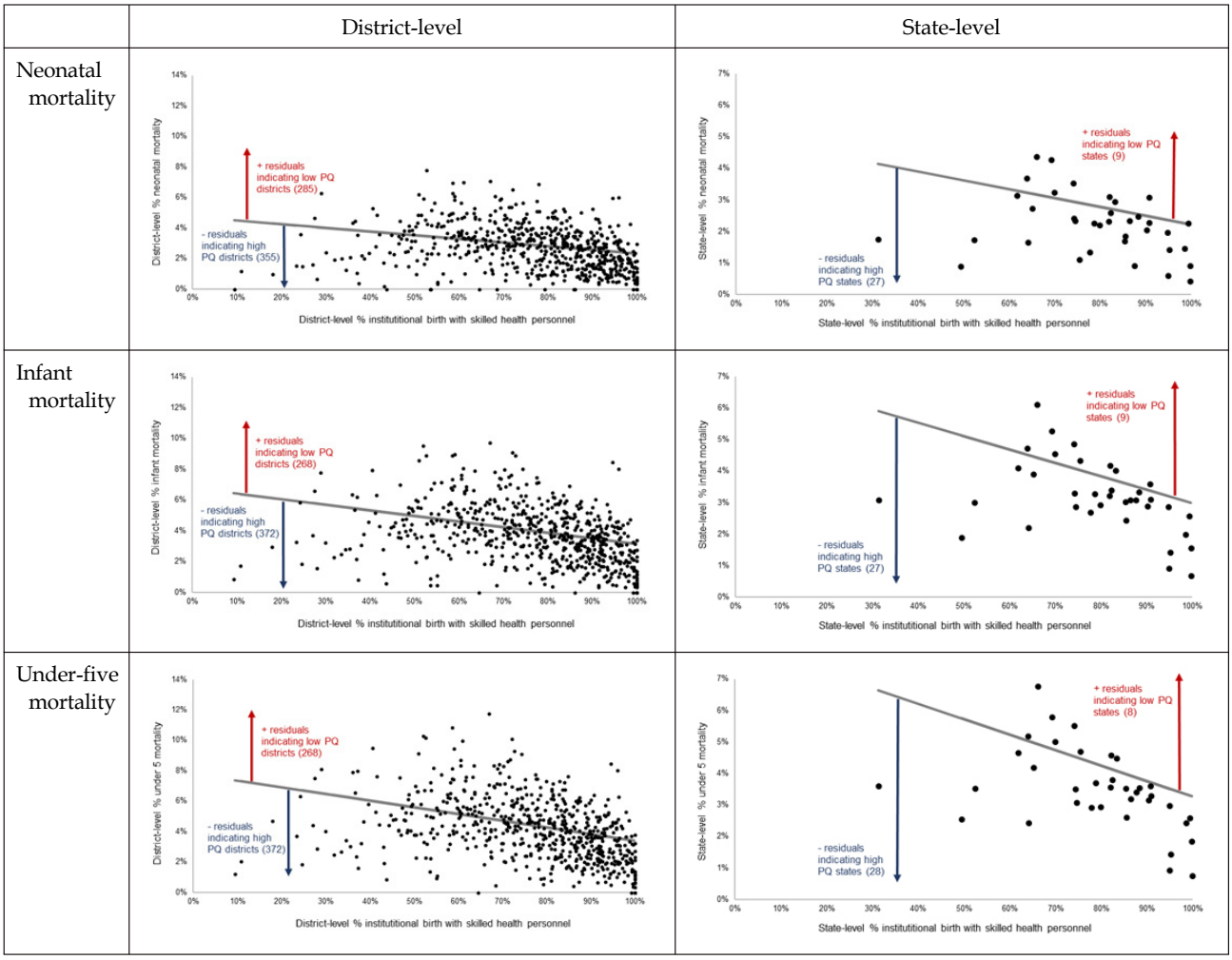

Fig. 3. Constructing District- and State-Level Provider Quality Proxy Measures Based on % Institutional Birth Delivery with Skilled Birth Attendant and % Neonatal, Infant, and Under-Five Mortality, India Demographic and Health Survey 2015~2016.

7. Analysis

In DHS, individual level data followed a four-level hierarchical structure with children at level-1 (i), nested within communities (or PSUs) at level-2 (j), districts at level-3 (k) and states at level-4 (l). In India, states are the political unit at which federal polices operate; districts are the lowest administrative unit at which the elected district councils plan the provision of services and infrastructures; and communities represent villages for rural areas and urban frame survey blocks for urban areas and capture the local environment.[28] Multilevel statistical techniques provide a technically robust and efficient framework to account for the complex survey design and assess variation in outcomes by multiple levels.[29,30] As suggested by its name, multilevel modeling enables simultaneous examination of the circumstances of individuals at one level in the context of multiple higher geographic, administrative, and social levels, and thereby discern the relative contribution of different levels to the scientific question of interest.[29,30]

For each of the three binary outcome variables (neonatal, infant, and under-five mortality), a series of four-level random intercept logistic regression models were estimated based on a logit-link function. We first ran a null model with no predictor variable to serve as a baseline for comparing changes in variance estimates in subsequent models (Model 1).

Model 1: $logit(\pi_{ijkl})=\beta_0+(f_{0l}+v_{0kl}+u_{0jkl})$

For interpretation, β_0 represents the median log odds of mortality across all India and bracketed terms represent random effects associated with states, districts, and communities, respectively. The term f_{0l} is a state-specific residual that represents a departure of each state from the na-

tional median log odds of mortality; v_{0kl} is a district-specific residual conditional on state; and u_{0jkl} is a community-specific residual. Assuming a normal distribution of these residuals, this model partitions the total variation in mortality by between-state (i.e., $f_{0l} \sim N(0, \sigma^2_{f0})$), between-district (i.e., $v_{0kl} \sim N(0, \sigma^2_{v0})$), and between- community (i.e., $u_{0jkl} \sim N(0, \sigma^2_{u0})$) components. For binary outcomes, the variance at the individual level (level-1) cannot be obtained directly from the model, and all remaining variance is assumed to be a function of the binomial distribution (i.e., 3.29).[30]

In subsequent models, all the individual-level covariates(X'_{ijkl}) were included first without ANC and SBA in Model 2 and then with ANC and SBA in Model 3.

Model 2: $logit(\pi_{ijkl}) = \beta_0 + \beta X'_{ijkl} + (f_{0l} + v_{0kl} + u_{0jkl})$
Model 3: $logit(\pi_{ijkl}) = \beta_0 + \beta X'_{ijkl} + \beta ANC_{ijkl} + \beta SBA_{ijkl} + (f_{0l} + v_{0kl} + u_{0jkl})$

Then, the fixed effect of provider quality indicators derived from ANC for districts (Model 4A) and states (Model 4B) were added to evaluate the relative importance of individual access to ANC versus contextual provider quality. Similarly, provider quality indicators derived from SBA were evaluated for districts (Model 5A) and states (Model 5B).

Model 4A/5A: $logit(\pi_{ijkl}) = \beta_0 + \beta X'_{ijkl} + \beta ANC_{ijkl} + \beta SBA_{ijkl} + \beta PQ_{kl} + (f_{0l} + v_{0kl} + u_{0jkl})$
Model 4B/5B: $logit(\pi_{ijkl}) = \beta_0 + \beta X'_{ijkl} + \beta ANC_{ijkl} + \beta SBA_{ijkl} + \beta PQ_{l} + (f_{0l} + v_{0kl} + u_{0jkl})$

For each successive model, the proportion of variance in the log odds of mortality explained by additional factors was computed by subtracting the variance of model with more terms from the variance of simpler model, and converting to percentage. Data were prepared using STATA 13.0 and all multilevel models were estimated using the MLwiN 3.0 with predictive/penalized quasi likelihood approximation with a second-order Taylor linearization procedure. For interpretation, we report odds ratios (ORs) and 95% confidence intervals (CIs).

RESULTS

Of the total 182,980 children, 1.8% died within the first month, 2.6% within the first year, and 2.8% within the first five years (Table 1). A clear patterning in the prevalence of mortality was shown by household wealth and several maternal characteristics. For instance, the proportion of under-five mortality was 4.0% in the poorest quintile whereas only 1.5% in the wealthiest quintile. A J-shaped patterning in mortality was observed for maternal age, with the proportion of under-five mortality being high for the youngest age group (4.8%), lowest for 25~29 year group (2.3%), and highest for the oldest mothers (7.1%). In our final analytic sample, about half of the mothers (47.3% or n=86,626) reported to have attended at least four ANC visits and 75.8% (n=138,789) delivered birth in institutional settings with SBA. The proportion of neonatal mortality was lower for those who had ≥4 ANC visits (1.4% vs 2.2%) and SBA (1.7% vs 2.2%) compared to their counterparts (Table 1). Based on the contextual provider quality indicators derived from ANC visits, 276~281 districts (43.1~43.9%) and 13~16 states (36.5~44.4%) were classified as low quality areas depending on the mortality outcome (Fig. 2). Similarly, when derived from SBA, 268~285 districts (41.9~44.5%) and 8~9 states (22.2~25.0%) were classified as low quality areas (Fig. 3). The full list of states and districts and their classifications are presented in Appendix.

1. Neonatal Mortality

In the base model with no predictors (Model 1), we found most variation in neonatal mortality attributed to the community level (Variance Partitioning Coefficient [VPC]: 40.3%) followed by substantially smaller variation at state (VPC: 2.6%) and district (VPC: 1.2%) levels (Table 2). In Model 2, several individual-level covariates were significantly associated with increased odds of neonatal mortality. Important associations were found in respect to birth order and birth interval. Conditional on all other factors, being the $2^{nd}/3^{rd}$ and $4^{th}/5^{th}$ child was associated with significantly lower odds of neonatal mortality compared to being the first born (OR: 0.68; 95% CI: 0.60, 0.79 and OR: 0.81; 95% CI: 0.67, 0.99, respectively) whereas being the 6th or above was not significant. Birth interval of <24 months was associated with almost 40% increased odds of neonatal mortality (OR: 1.37; 95% CI: 1.19, 1.57) whereas longer interval (24~47months) showed 15% reduced odds (OR: 0.85; 95% CI: 0.75, 0.96). Higher odds of neonatal mortality were found for c-section vs normal delivery (OR: 1.31; 95% CI: 1.17, 1.47) and not having received tetanus injection before birth (OR: 1.53; 95% CI: 1.36, 1.72). Lack of maternal education (OR: 1.43; 95% CI: 1.17, 1.73) and poorest household wealth (OR: 1.72; 95% CI: 1.37, 2.15) were also significant risk factors for neonatal mortality, suggesting the importance of socioeconomic conditions. Inclusion of these covariates explained 56.3% of between-district variation and 34.1% of between-community variation, but less than 20% of between-state variation in neonatal mortality.

Table 1. Distribution of Final Analytic Sample by Selected Individual-Level Predictor Variables and Proportion of Neonatal, Infant, and Under-Five Deaths, India Demographic and Health Survey 2015~2016

Variables	n	Neonatal deaths (%)	Infant deaths (%)	Under-five deaths (%)
Total	182,980	1.8	2.6	2.8
Child sex				
Male	99,320	1.9	2.6	2.8
Female	83,660	1.7	2.5	2.8
Birth order				
1st	59,296	2.0	2.6	2.7
2nd or 3rd	91,770	1.4	2.1	2.3
4th or 5th	23,708	2.1	3.4	3.9
≥6th	8,206	3.6	5.4	6.2
Birth interval				
<24 months	30,119	2.4	3.5	4.0
24~47 months	61,756	1.5	2.2	2.5
≥48 months	31,809	1.6	2.3	2.6
Delivery method				
Normal	154,767	1.9	2.6	2.9
C section	28,213	1.7	2.2	2.3
Maternal age				
15~19	5,649	3.4	4.6	4.8
20~24	54,182	2.0	2.6	2.8
25~29	67,358	1.5	2.1	2.3
30~34	35,683	1.6	2.3	2.7
35~39	14,571	2.2	3.3	3.8
40~44	4,263	2.8	4.3	5.0
45~49	1,274	4.3	5.8	7.1
Marital status				
Currently married	182,923	1.8	2.6	2.8
Never/formerly married	57	3.5	5.3	5.3
Maternal education				
No education	53,245	2.4	3.5	4.0
Primary education	25,322	2.2	3.0	3.3
Secondary education	66,006	1.6	2.3	2.4
Higher education	19,060	1.2	1.6	1.7
≥College	19,347	1.1	1.4	1.4
Maternal age at marriage				
<18 years	67,339	2.1	3.0	3.4
≥18 years	115,641	1.7	2.3	2.5
Tetanus injection				
Received before birth	166,733	1.7	2.4	2.7
Did not receive before birth	16,247	2.7	4.0	4.5
Household wealth				
Poorest	44,923	2.5	3.5	4.0
Poorer	42,031	2.1	3.0	3.3
Middle	36,670	1.7	2.4	2.6
Richer	31,761	1.3	1.8	2.0
Richest	27,595	1.0	1.4	1.5
Source of drinking water				
Unsafe	31,663	1.8	2.6	2.8
Safe	151,317	1.8	2.6	2.8
Type of sanitary facility				
Unimproved	93,067	2.3	3.1	3.5
Improved	89,913	1.4	2.0	2.2
Cooking fuel				
Solid fuel	126,807	2.1	2.9	3.2
Non solid fuel	56,173	1.2	1.8	2.0
Place of residence				
Rural	137,409	2.0	2.8	3.1
Urban	45,571	1.4	2.0	2.1
Antenatal care visits				
<4 visits	96,354	2.2	3.1	3.5
≥4 visits	86,626	1.4	1.9	2.1
Institutional delivery with skilled birth attendant				
No	44,191	2.2	3.3	3.8
Yes	138,789	1.7	2.3	2.5

Table 2. Associations between Individual- and Contextual-Level Predictors and Neonatal Mortality from Four-Level Random Effects Logistic Models, India Demographic and Health Survey 2015~2016

Variables	Model 1	Model 2	Model 3	Model 4A	Model 4B	Model 5A	Model 5B
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Fixed part							
Intercept	0.01 (0.01, 0.02)	0.02 (0.01, 0.02)	0.01 (0.01, 0.02)	0.01 (0.01, 0.02)	0.01 (0.01, 0.02)	0.01 (0.01, 0.02)	0.01 (0.01, 0.02)
Child sex (ref: male)							
Female		0.90 (0.84, 0.98)	0.90 (0.84, 0.98)	0.90 (0.84, 0.97)	0.90 (0.84, 0.97)	0.90 (0.84, 0.97)	0.90 (0.84, 0.97)
Birth order (ref: 1st)							
2nd or 3rd		0.68 (0.60, 0.79)	0.68 (0.59, 0.78)	0.68 (0.60, 0.78)	0.68 (0.59, 0.78)	0.68 (0.60, 0.78)	0.68 (0.60, 0.77)
4th or 5th		0.81 (0.67, 0.99)	0.81 (0.67, 0.98)	0.81 (0.68, 0.98)	0.81 (0.67, 0.97)	0.81 (0.68, 0.97)	0.81 (0.68, 0.96)
≥6th		1.05 (0.82, 1.34)	1.04 (0.81, 1.33)	1.04 (0.82, 1.32)	1.04 (0.82, 1.32)	1.04 (0.83, 1.31)	1.05 (0.84, 1.31)
Birth interval (ref: 1st)							
<24 months		1.37 (1.19, 1.57)	1.36 (1.19, 1.56)	1.36 (1.19, 1.56)	1.37 (1.20, 1.56)	1.36 (1.19, 1.55)	1.37 (1.21, 1.55)
24~47 months		0.85 (0.75, 0.96)	0.84 (0.74, 0.96)	0.84 (0.75, 0.95)	0.85 (0.75, 0.96)	0.84 (0.75, 0.95)	0.85 (0.75, 0.95)
Delivery method (ref: normal)							
Caesarean section		1.31 (1.17, 1.47)	1.34 (1.19, 1.50)	1.33 (1.18, 1.49)	1.33 (1.19, 1.49)	1.34 (1.19, 1.49)	1.34 (1.20, 1.49)
Maternal age (ref: 15~19 years)							
20~24		0.62 (0.52, 0.74)	0.62 (0.52, 0.74)	0.62 (0.52, 0.74)	0.62 (0.52, 0.74)	0.62 (0.52, 0.73)	0.62 (0.53, 0.73)
25~29		0.53 (0.43, 0.64)	0.53 (0.43, 0.64)	0.53 (0.44, 0.64)	0.53 (0.44, 0.64)	0.53 (0.44, 0.63)	0.53 (0.44, 0.63)
30~34		0.55 (0.44, 0.68)	0.55 (0.44, 0.68)	0.55 (0.45, 0.68)	0.55 (0.45, 0.68)	0.55 (0.45, 0.68)	0.55 (0.45, 0.67)
35~39		0.66 (0.52, 0.85)	0.66 (0.52, 0.85)	0.66 (0.52, 0.85)	0.66 (0.52, 0.85)	0.66 (0.52, 0.84)	0.67 (0.53, 0.84)
40~44		0.73 (0.54, 1.00)	0.73 (0.54, 1.00)	0.73 (0.54, 0.99)	0.73 (0.54, 0.99)	0.73 (0.54, 0.98)	0.73 (0.55, 0.98)
45~49		1.02 (0.68, 1.51)	1.01 (0.68, 1.50)	1.02 (0.69, 1.49)	1.02 (0.69, 1.50)	1.02 (0.70, 1.48)	1.02 (0.71, 1.47)
Marital status (ref: currently married)							
Never/formerly married		2.02 (0.43, 9.43)	2.02 (0.44, 9.35)	2.00 (0.45, 8.90)	2.00 (0.45, 8.92)	2.02 (0.47, 8.70)	2.02 (0.49, 8.31)
Maternal education (ref: college)							
No education		1.43 (1.17, 1.73)	1.40 (1.15, 1.70)	1.37 (1.14, 1.66)	1.40 (1.15, 1.70)	1.39 (1.15, 1.68)	1.41 (1.18, 1.70)
Primary education		1.56 (1.28, 1.90)	1.54 (1.26, 1.88)	1.51 (1.24, 1.83)	1.54 (1.26, 1.87)	1.52 (1.26, 1.84)	1.55 (1.29, 1.87)
Secondary education		1.30 (1.09, 1.56)	1.29 (1.08, 1.55)	1.28 (1.07, 1.52)	1.29 (1.08, 1.54)	1.28 (1.08, 1.52)	1.30 (1.10, 1.54)
Higher education		1.02 (0.83, 1.26)	1.02 (0.82, 1.25)	1.01 (0.82, 1.24)	1.02 (0.83, 1.25)	1.02 (0.83, 1.25)	1.02 (0.84, 1.25)
Maternal age at marriage (ref: ≥18 years)							
<18		0.98 (0.90, 1.07)	0.98 (0.89, 1.07)	0.98 (0.90, 1.07)	0.98 (0.90, 1.07)	0.98 (0.90, 1.06)	0.98 (0.90, 1.06)
Tetanus injection (ref: received)							
Not received before birth		1.53 (1.36, 1.72)	1.49 (1.32, 1.67)	1.49 (1.33, 1.68)	1.48 (1.32, 1.66)	1.48 (1.33, 1.66)	1.47 (1.31, 1.64)
Household wealth (ref: richest)							
Poorest		1.72 (1.37, 2.15)	1.67 (1.33, 2.09)	1.65 (1.32, 2.05)	1.66 (1.34, 2.07)	1.64 (1.33, 2.03)	1.62 (1.32, 2.00)
Poorer		1.71 (1.39, 2.11)	1.67 (1.36, 2.06)	1.65 (1.35, 2.02)	1.67 (1.36, 2.05)	1.64 (1.35, 1.99)	1.64 (1.35, 1.99)
Middle		1.53 (1.26, 1.85)	1.51 (1.25, 1.82)	1.49 (1.24, 1.79)	1.51 (1.25, 1.81)	1.48 (1.24, 1.77)	1.49 (1.25, 1.78)
Richer		1.19 (0.99, 1.42)	1.18 (0.99, 1.41)	1.17 (0.98, 1.39)	1.18 (0.99, 1.40)	1.17 (0.98, 1.38)	1.17 (0.99, 1.39)
Source of drinking water (ref: safe)							
Unsafe		1.00 (0.90, 1.11)	1.00 (0.90, 1.11)	0.99 (0.89, 1.10)	1.00 (0.90, 1.11)	0.98 (0.89, 1.09)	1.00 (0.90, 1.10)
Type of sanitary facility (ref: improved)							
Unimproved		1.11 (1.00, 1.24)	1.11 (1.00, 1.24)	1.11 (1.00, 1.23)	1.11 (1.01, 1.23)	1.12 (1.01, 1.23)	1.12 (1.01, 1.23)
Cooking fuel (ref: non solid fuel)							
Solid fuel		0.98 (0.86, 1.11)	0.98 (0.86, 1.11)	0.98 (0.86, 1.11)	0.98 (0.86, 1.11)	0.98 (0.87, 1.10)	0.98 (0.87, 1.11)
Place of residence (ref: urban)							
Rural		0.97 (0.86, 1.09)	0.96 (0.86, 1.09)	0.96 (0.85, 1.07)	0.96 (0.86, 1.08)	0.96 (0.86, 1.07)	0.96 (0.87, 1.07)
ANC visits (ref: ≥4 visits)							
<4 visits			1.12 (1.02, 1.23)	1.15 (1.05, 1.26)	1.13 (1.03, 1.24)	1.12 (1.03, 1.22)	1.12 (1.03, 1.22)
Institutional delivery with SBA (ref: yes)							
No			1.04 (0.94, 1.15)	1.04 (0.95, 1.14)	1.04 (0.95, 1.14)	1.05 (0.96, 1.15)	1.04 (0.95, 1.14)
Contextual PQ (ref: high)							
Low PQ at district level				1.69 (1.54, 1.84)		1.78 (1.62, 1.94)	
Low PQ at state level					1.47 (1.16, 1.87)		1.61 (1.27, 2.05)
Random part							
Level: state							
Variance estimate (95% CI)	0.15 (0.06, 0.24)	0.12 (0.05, 0.20)	0.12 (0.04, 0.19)	0.07 (0.02, 0.11)	0.09 (0.03, 0.15)	0.04 (0.01, 0.07)	0.07 (0.02, 0.11)
VPC (%)*	2.6%	2.4%	2.3%	1.6%	2.0%	1.0%	1.9%
% explained†		18.7%	5.7%	41.7%	22.6%	66.1%	40.9%
Level: district							
Variance estimate (95% CI)	0.07 (0.03, 0.11)	0.03 (0.00, 0.06)	0.03 (0.00, 0.06)	0.00 (0.00, 0.00)	0.03 (0.00, 0.06)	0.00 (0.00, 0.00)	0.02 (0.00, 0.05)
VPC (%)*	1.2%	0.6%	0.6%	0.0%	0.6%	0.0%	0.6%
% explained†		56.3%	3.2%	100.0%	13.3%	100.0%	26.7%
Level: community							
Variance estimate (95% CI)	2.37 (2.15, 2.58)	1.56 (1.37, 1.74)	1.46 (1.28, 1.64)	0.86 (0.71, 1.01)	1.04 (0.88, 1.20)	0.55 (0.41, 0.69)	0.25 (0.13, 0.38)
VPC (%)*	40.3%	31.2%	29.9%	20.4%	23.4%	14.1%	7.0%
% explained†		34.1%	6.1%	41.3%	29.0%	62.6%	82.7%

ANC=antenatal care; CI=confidence interval; OR=odds ratio; PQ=provider quality; ref=reference; SBA=skilled birth attendant; VPC=variance partitioning coefficient.
Model 1: A null four-level random effects model, with individuals at level-1, communities at level-2, districts at level-3, and states at level-4; Model 2: Model 1 + all individual-level covariates (except for ANC and SBA); Model 3: Model 2 + ANC + SBA; Model 4A: Model 3 + district PQ derived from ANC; Model 4B: Model 3 + state PQ derived from ANC; Model 5A: Model 3 + district PQ derived from SBA; Model 5B: Model 3 + state PQ derived from SBA.
*% VPC for level z calculated as: $[\sigma_z^2/(\sigma_{f0}^2+\sigma_{c0}^2+\sigma_{s0}^2+3.29)]$*100; † % explained calculated as: $[(\sigma^2_{model\ N}-\sigma^2_{model\ N+1})/\sigma^2_{model\ N}]$*100; Variance estimates from Model 4A/B and Model 5A/B were compared against variance from Model 3.

Model 3 included individual-level ANC and SBA predictors (Table 2). Failure to meet the WHO recommended 4 ANC visits was associated with 12% increased odds of neonatal mortality (OR: 1.12; 95% CI: 1.02, 1.23). Absence of SBA at delivery and births in non-institutional settings was associated with 4% increased odds of neonatal mortality, albeit not statistically significant (OR: 1.04; 95% CI: 0.94, 1.15). Compared to Model 2, additional consideration of individual-level ANC and SBA explained around 6% of variation each at community and state levels, and 3% at district level. Individual-level ANC remained statistically significant even after additionally adjusting for contextual provider quality indicators, which showed even stronger associations with neonatal mortality. In Model 4A/B, districts and states with low provider quality based on ANC were associated with almost 70% and 50% increased odds of neonatal mortality, respectively. Similarly, districts and states with low provider quality based on SBA were associated with almost 80% and 60% increased odds of neonatal mortality, respectively, in Model 5A/B. Relative to Model 3, district provider quality indicators explained all the remaining variation in neonatal mortality at the district level, and state indicators explained 22.6 ~40.9% of the between-state variation in neonatal mortality.

2. Infant Mortality

Contextual variation in infant mortality was smaller in magnitude compared to neonatal mortality. In Model 1, 29.4%(VPC) of total variation in infant mortality was attributed to communities and only 2.3%(VPC) to states and 1.3%(VPC) to districts (Table 3). The associations between individual-level covariates and infant mortality in Model 2 were comparable to those observed for neonatal mortality, with a larger fraction of variation explained at state (23.4%) and community (41.0%) levels. In Model 3, individual-level ANC was significantly associated with increased odds of infant mortality (OR: 1.15; 95% CI: 1.07, 1.24) conditional on all other covariates. Moreover, children born in non-institutional settings with no SBA had 9% higher odds of dying in the first year compared to their counterparts (OR: 1.09; 95% CI: 1.01, 1.18). These two individual-level primary predictors explained additional 7~8% of variation in infant mortality at all contextual levels. Contextual provider quality indicators showed strong influence on infant mortality, but to a lesser degree than they did for neonatal mortality. In Model 4A/B, districts and states with low provider quality based on ANC were associated with almost 64% and 32% increased odds of infant mortality, respectively. In Model 5A/B, districts and states with low provider quality based on SBA were associated with 61% and 46% increased odds of infant mortality, respectively. The between-district variation in infant mortality was fully explained after adjusting for district provider quality indicators, whereas 20~40% of the between-state variation was explained by state provider quality indicators.

3. Under-Five Mortality

Of total variation in under-five mortality, 28.7% (VPC) was attributed to community level in Model 1 (Table 4). Among individual-level covariates included in Model 2, socioeconomic factors showed stronger associations with under-five mortality than with other mortality outcomes. Lack of maternal education and poorest household wealth were each associated with 1.63 (95% CI: 1.39, 1.91) and 1.80 (95% CI: 1.50, 2.15) higher odds of under-five mortality compared to the best off reference groups. All covariates taken together explained larger proportion of variation at state (30%) and community (43%) levels. In Model 3, individual-level ANC and SBA were both significantly associated with under-five mortality, with OR: 1.17 (95%: 1.08, 1.26) and OR: 1.10 (1.02, 1.19) respectively, and explained additional 9~10% of variation at state and community levels and only 5.4% at district level. Moreover, they remained robust even after accounting for contextual provider quality indicators. Districts and states with low provider quality based on ANC were associated with almost 61% and 27% increased odds of under-five mortality, respectively. Similarly, districts and states with low provider quality based on SBA were associated with 57% and 43% increased odds of under-five mortality, respectively. In the final models (Model 4, 5), contextual variation in under-five mortality substantially reduced especially at the district level.

DISCUSSION

This study provides three salient findings. First, individual-level ANC and SBA were both significantly associated with all mortality outcomes conditional on a comprehensive set of maternal and child covariates. Overall, the magnitude of association was stronger for ANC than for SBA, and both were most strongly associated with under-five mortality. Second, individual use of ANC and SBA and contextual provider quality indicators were all importantly associated with mortality outcomes, independent of one another. Contextual provider quality mattered more than individual use of ANC and SBA for neonatal,

Table 3. Associations between Individual- and Contextual-Level Predictors and Infant Mortality from Four-Level Random Effects Logistic Models, India Demographic and Health Survey 2015~2016

Variables	Model 1	Model 2	Model 3	Model 4A	Model 4B	Model 5A	Model 5B
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Fixed part							
Intercept	0.02 (0.02, 0.02)	0.02 (0.02, 0.03)	0.02 (0.02, 0.02)	0.02 (0.01, 0.02)	0.02 (0.01, 0.02)	0.02 (0.01, 0.02)	0.02 (0.01, 0.02)
Child sex (ref: male)							
Female		0.96 (0.91, 1.03)	0.96 (0.91, 1.03)	0.96 (0.91, 1.02)	0.96 (0.91, 1.03)	0.96 (0.91, 1.02)	0.96 (0.91, 1.02)
Birth order (ref: 1st)							
2nd or 3rd		0.75 (0.67, 0.84)	0.74 (0.66, 0.83)	0.74 (0.66, 0.83)	0.74 (0.66, 0.83)	0.74 (0.66, 0.83)	0.74 (0.66, 0.83)
4th or 5th		0.99 (0.85, 1.15)	0.97 (0.83, 1.14)	0.98 (0.84, 1.14)	0.97 (0.84, 1.13)	0.98 (0.84, 1.13)	0.97 (0.84, 1.13)
≥6th		1.24 (1.02, 1.52)	1.22 (1.00, 1.49)	1.21 (1.00, 1.47)	1.22 (1.00, 1.48)	1.22 (1.01, 1.48)	1.22 (1.01, 1.47)
Birth interval (ref: 1st)							
<24 months		1.42 (1.27, 1.59)	1.40 (1.26, 1.57)	1.40 (1.26, 1.57)	1.41 (1.26, 1.57)	1.40 (1.26, 1.56)	1.41 (1.27, 1.57)
24~47 months		0.89 (0.80, 0.99)	0.89 (0.80, 0.98)	0.88 (0.80, 0.98)	0.89 (0.80, 0.98)	0.89 (0.80, 0.98)	0.89 (0.81, 0.98)
Delivery method (ref: normal)							
Caesarean section		1.23 (1.12, 1.36)	1.27 (1.15, 1.40)	1.26 (1.15, 1.39)	1.27 (1.15, 1.40)	1.26 (1.15, 1.39)	1.28 (1.16, 1.40)
Maternal age (ref: 15~19 years)							
20~24		0.59 (0.51, 0.68)	0.59 (0.51, 0.68)	0.59 (0.51, 0.68)	0.59 (0.51, 0.68)	0.59 (0.51, 0.68)	0.59 (0.51, 0.68)
25~29		0.50 (0.43, 0.59)	0.50 (0.43, 0.59)	0.50 (0.43, 0.59)	0.50 (0.43, 0.59)	0.50 (0.43, 0.59)	0.50 (0.43, 0.59)
30~34		0.51 (0.42, 0.61)	0.51 (0.43, 0.61)	0.51 (0.43, 0.61)	0.51 (0.43, 0.61)	0.51 (0.43, 0.61)	0.51 (0.43, 0.61)
35~39		0.63 (0.51, 0.77)	0.63 (0.51, 0.77)	0.63 (0.51, 0.77)	0.63 (0.51, 0.77)	0.63 (0.51, 0.76)	0.63 (0.52, 0.77)
40~44		0.69 (0.53, 0.89)	0.69 (0.53, 0.89)	0.69 (0.54, 0.88)	0.69 (0.54, 0.88)	0.68 (0.54, 0.87)	0.69 (0.54, 0.88)
45~49		0.83 (0.60, 1.16)	0.83 (0.60, 1.15)	0.83 (0.60, 1.14)	0.83 (0.60, 1.15)	0.82 (0.60, 1.13)	0.83 (0.61, 1.13)
Marital status (ref: currently married)							
Never/formerly married		2.33 (0.69, 7.84)	2.32 (0.69, 7.77)	2.25 (0.68, 7.39)	2.29 (0.70, 7.54)	2.21 (0.68, 7.20)	2.27 (0.71, 7.19)
Maternal education (ref: college)							
No education		1.58 (1.34, 1.87)	1.54 (1.31, 1.82)	1.51 (1.29, 1.78)	1.54 (1.31, 1.82)	1.54 (1.31, 1.80)	1.56 (1.33, 1.82)
Primary education		1.56 (1.32, 1.85)	1.53 (1.29, 1.82)	1.50 (1.27, 1.77)	1.53 (1.30, 1.82)	1.53 (1.29, 1.80)	1.55 (1.31, 1.82)
Secondary education		1.36 (1.17, 1.59)	1.35 (1.16, 1.57)	1.33 (1.14, 1.55)	1.35 (1.16, 1.57)	1.34 (1.16, 1.56)	1.35 (1.17, 1.57)
Higher education		1.07 (0.89, 1.27)	1.06 (0.89, 1.27)	1.06 (0.89, 1.26)	1.06 (0.89, 1.27)	1.06 (0.89, 1.27)	1.07 (0.90, 1.27)
Maternal age at marriage (ref: ≥18 years)							
<18		0.98 (0.91, 1.05)	0.97 (0.90, 1.05)	0.97 (0.90, 1.04)	0.97 (0.90, 1.04)	0.97 (0.90, 1.04)	0.97 (0.91, 1.04)
Tetanus injection (ref: received)							
Not received before birth		1.50 (1.36, 1.65)	1.43 (1.30, 1.58)	1.43 (1.30, 1.58)	1.43 (1.30, 1.57)	1.43 (1.31, 1.58)	1.42 (1.30, 1.56)
Household wealth (ref: richest)							
Poorest		1.76 (1.46, 2.12)	1.69 (1.40, 2.04)	1.67 (1.39, 2.01)	1.68 (1.39, 2.01)	1.64 (1.37, 1.96)	1.65 (1.38, 1.98)
Poorer		1.77 (1.48, 2.10)	1.72 (1.44, 2.05)	1.70 (1.44, 2.02)	1.71 (1.44, 2.02)	1.66 (1.41, 1.96)	1.69 (1.44, 1.99)
Middle		1.57 (1.34, 1.85)	1.55 (1.32, 1.81)	1.54 (1.32, 1.79)	1.54 (1.32, 1.80)	1.51 (1.30, 1.75)	1.53 (1.32, 1.78)
Richer		1.24 (1.07, 1.44)	1.23 (1.06, 1.42)	1.22 (1.06, 1.41)	1.22 (1.05, 1.41)	1.21 (1.05, 1.40)	1.22 (1.06, 1.41)
Source of drinking water (ref: safe)							
Unsafe		1.02 (0.94, 1.12)	1.02 (0.93, 1.11)	1.01 (0.93, 1.11)	1.02 (0.93, 1.11)	1.01 (0.93, 1.10)	1.02 (0.94, 1.11)
Type of sanitary facility (ref: improved)							
Unimproved		1.07 (0.98, 1.17)	1.07 (0.98, 1.17)	1.08 (0.99, 1.17)	1.07 (0.98, 1.16)	1.07 (0.99, 1.17)	1.07 (0.98, 1.16)
Cooking fuel (ref: non solid fuel)							
Solid fuel		0.91 (0.82, 1.01)	0.91 (0.81, 1.01)	0.91 (0.82, 1.00)	0.91 (0.82, 1.01)	0.91 (0.82, 1.01)	0.91 (0.82, 1.00)
Place of residence (ref: urban)							
Rural		1.02 (0.92, 1.12)	1.01 (0.92, 1.12)	1.01 (0.92, 1.11)	1.01 (0.92, 1.12)	1.00 (0.91, 1.10)	1.01 (0.93, 1.11)
ANC visits (ref: ≥4 visits)							
<4 visits			1.15 (1.07, 1.24)	1.18 (1.09, 1.27)	1.16 (1.07, 1.25)	1.15 (1.07, 1.24)	1.15 (1.07, 1.23)
Institutional delivery with SBA (ref: yes)							
No			1.09 (1.01, 1.18)	1.08 (1.00, 1.17)	1.09 (1.01, 1.18)	1.10 (1.02, 1.19)	1.09 (1.01, 1.17)
Contextual PQ (ref: high)							
Low PQ at district level				1.64 (1.52, 1.76)		1.61 (1.49, 1.73)	
Low PQ at state level					1.32 (1.08, 1.61)		1.46 (1.21, 1.77)
Random part							
Level: state							
Variance estimate (95% CI)	0.11 (0.04, 0.18)	0.09 (0.03, 0.14)	0.08 (0.03, 0.13)	0.04 (0.01, 0.07)	0.06 (0.02, 0.10)	0.03 (0.01, 0.05)	0.05 (0.02, 0.08)
VPC (%)*	2.3%	2.0%	1.9%	1.1%	1.6%	0.8%	1.3%
% explained†		23.4%	8.2%	47.4%	20.5%	60.3%	39.7%
Level: district							
Variance estimate (95% CI)	0.07 (0.03, 0.10)	0.03 (0.01, 0.05)	0.03 (0.01, 0.05)	0.00 (0.00, 0.00)	0.03 (0.00, 0.05)	0.00 (0.00, 0.00)	0.02 (0.01, 0.04)
VPC (%)*	1.3%	0.7%	0.7%	0.0%	0.7%	0.0%	0.6%
% explained†		53.0%	6.5%	100.0%	10.3%	100.0%	20.7%
Level: community							
Variance estimate (95% CI)	1.44 (1.30, 1.59)	0.85 (0.73, 0.97)	0.78 (0.66, 0.90)	0.52 (0.42, 0.63)	0.60 (0.49, 0.71)	0.35 (0.25, 0.44)	0.19 (0.10, 0.28)
VPC (%)*	29.4%	20.0%	18.7%	13.6%	15.1%	9.5%	5.3%
% explained†		41.0%	8.2%	33.1%	22.9%	55.6%	76.1%

ANC=antenatal care; CI=confidence interval; OR=odds ratio; PQ=provider quality; ref=reference; SBA=skilled birth attendant; VPC=variance partitioning coefficient.
Model 1: A null four-level random effects model, with individuals at level-1, communities at level-2, districts at level-3, and states at level-4; Model 2: Model 1 + all individual-level covariates (except for ANC and SBA); Model 3: Model 2 + ANC + SBA; Model 4A: Model 3 + district PQ derived from ANC; Model 4B: Model 3 + state PQ derived from ANC; Model 5A: Model 3 + district PQ derived from SBA; Model 5B: Model 3 + state PQ derived from SBA.
*% VPC for level z calculated as: $[\sigma_z^2/(\sigma_{f0}^2+\sigma_{c0}^2+\sigma_{s0}^2+3.29)]$*100; † % explained calculated as: $[(\sigma^2_{\text{model } N}-\sigma^2_{\text{model } N+1})/\sigma^2_{\text{model } N}]$*100; Variance estimates from Model 4A/B and Model 5A/B were compared against variance from Model 3.

Table 4. Associations between Individual- and Contextual-Level Predictors and Under-Five Mortality from Four-Level Random Effects Logistic Models, India Demographic and Health Survey 2015~2016

Variables	Model 1	Model 2	Model 3	Model 4A	Model 4B	Model 5A	Model 5B
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Fixed part							
Intercept	0.02 (0.02, 0.03)	0.02 (0.02, 0.02)	0.02 (0.01, 0.02)	0.02 (0.01, 0.02)	0.02 (0.01, 0.02)	0.02 (0.01, 0.02)	0.02 (0.01, 0.02)
Child sex (ref: male)							
Female		0.98 (0.92, 1.04)	0.98 (0.92, 1.04)	0.98 (0.92, 1.04)	0.98 (0.92, 1.04)	0.98 (0.93, 1.04)	0.98 (0.93, 1.04)
Birth order (ref: 1st)							
2nd or 3rd		0.75 (0.67, 0.83)	0.74 (0.66, 0.83)	0.74 (0.67, 0.83)	0.74 (0.67, 0.83)	0.74 (0.67, 0.82)	0.74 (0.67, 0.82)
4th or 5th		0.98 (0.85, 1.14)	0.97 (0.83, 1.12)	0.97 (0.84, 1.12)	0.97 (0.84, 1.12)	0.97 (0.84, 1.12)	0.97 (0.84, 1.11)
≥6th		1.18 (0.98, 1.43)	1.16 (0.96, 1.40)	1.15 (0.96, 1.39)	1.16 (0.96, 1.39)	1.16 (0.97, 1.38)	1.16 (0.97, 1.39)
Birth interval (ref: 1st)							
<24 months		1.47 (1.32, 1.63)	1.45 (1.31, 1.61)	1.46 (1.32, 1.61)	1.46 (1.32, 1.61)	1.45 (1.32, 1.61)	1.46 (1.32, 1.61)
24~47 months		0.90 (0.82, 0.99)	0.89 (0.81, 0.98)	0.89 (0.81, 0.98)	0.89 (0.81, 0.98)	0.89 (0.81, 0.98)	0.90 (0.82, 0.98)
Delivery method (ref: normal)							
Caesarean section		1.20 (1.09, 1.32)	1.24 (1.13, 1.37)	1.24 (1.13, 1.36)	1.24 (1.13, 1.36)	1.24 (1.13, 1.36)	1.25 (1.14, 1.37)
Maternal age (ref: 15~19 years)							
20~24		0.61 (0.53, 0.71)	0.61 (0.53, 0.71)	0.61 (0.53, 0.71)	0.61 (0.53, 0.71)	0.61 (0.53, 0.71)	0.61 (0.53, 0.71)
25~29		0.55 (0.47, 0.64)	0.55 (0.47, 0.64)	0.55 (0.47, 0.64)	0.55 (0.47, 0.64)	0.55 (0.47, 0.64)	0.55 (0.47, 0.64)
30~34		0.58 (0.49, 0.69)	0.58 (0.49, 0.69)	0.58 (0.49, 0.69)	0.58 (0.49, 0.69)	0.58 (0.49, 0.69)	0.58 (0.49, 0.69)
35~39		0.73 (0.60, 0.89)	0.73 (0.60, 0.89)	0.72 (0.60, 0.88)	0.73 (0.60, 0.89)	0.73 (0.60, 0.88)	0.73 (0.61, 0.88)
40~44		0.82 (0.65, 1.05)	0.82 (0.64, 1.04)	0.82 (0.65, 1.03)	0.82 (0.65, 1.04)	0.82 (0.65, 1.03)	0.82 (0.65, 1.03)
45~49		1.04 (0.76, 1.41)	1.03 (0.76, 1.40)	1.02 (0.76, 1.38)	1.03 (0.76, 1.39)	1.03 (0.77, 1.39)	1.03 (0.77, 1.38)
Marital status (ref: currently married)							
Never/formerly married		2.09 (0.62, 7.04)	2.08 (0.62, 6.97)	2.04 (0.62, 6.68)	2.05 (0.62, 6.74)	2.04 (0.63, 6.65)	2.04 (0.64, 6.49)
Maternal education (ref: college)							
No education		1.63 (1.39, 1.91)	1.58 (1.35, 1.86)	1.56 (1.34, 1.83)	1.58 (1.35, 1.85)	1.58 (1.36, 1.85)	1.60 (1.37, 1.86)
Primary education		1.61 (1.36, 1.90)	1.58 (1.34, 1.86)	1.56 (1.32, 1.83)	1.58 (1.34, 1.85)	1.58 (1.34, 1.85)	1.59 (1.36, 1.86)
Secondary education		1.38 (1.19, 1.60)	1.37 (1.18, 1.59)	1.35 (1.17, 1.56)	1.36 (1.18, 1.58)	1.36 (1.18, 1.57)	1.37 (1.19, 1.58)
Higher education		1.08 (0.91, 1.28)	1.07 (0.90, 1.28)	1.07 (0.90, 1.27)	1.07 (0.90, 1.27)	1.07 (0.91, 1.27)	1.08 (0.91, 1.27)
Maternal age at marriage (ref: ≥18 years)							
<18		1.04 (0.97, 1.11)	1.03 (0.96, 1.11)	1.03 (0.96, 1.11)	1.03 (0.97, 1.11)	1.03 (0.96, 1.10)	1.03 (0.97, 1.11)
Tetanus injection (ref: received)							
Not received before birth		1.50 (1.37, 1.64)	1.43 (1.31, 1.57)	1.43 (1.31, 1.57)	1.43 (1.30, 1.56)	1.43 (1.31, 1.57)	1.42 (1.30, 1.55)
Household wealth (ref: richest)							
Poorest		1.80 (1.50, 2.15)	1.72 (1.44, 2.06)	1.67 (1.41, 1.99)	1.70 (1.43, 2.04)	1.66 (1.40, 1.97)	1.69 (1.42, 2.00)
Poorer		1.74 (1.47, 2.06)	1.69 (1.43, 2.00)	1.66 (1.41, 1.95)	1.68 (1.43, 1.98)	1.63 (1.39, 1.92)	1.67 (1.42, 1.95)
Middle		1.56 (1.34, 1.81)	1.53 (1.31, 1.78)	1.50 (1.30, 1.74)	1.52 (1.31, 1.76)	1.49 (1.29, 1.72)	1.51 (1.31, 1.75)
Richer		1.24 (1.07, 1.43)	1.23 (1.06, 1.41)	1.21 (1.06, 1.40)	1.22 (1.06, 1.41)	1.21 (1.05, 1.39)	1.22 (1.06, 1.40)
Source of drinking water (ref: safe)							
Unsafe		1.02 (0.94, 1.11)	1.02 (0.94, 1.11)	1.00 (0.93, 1.09)	1.02 (0.94, 1.10)	1.01 (0.93, 1.09)	1.02 (0.94, 1.10)
Type of sanitary facility (ref: improved)							
Unimproved		1.05 (0.97, 1.15)	1.05 (0.97, 1.14)	1.05 (0.97, 1.14)	1.05 (0.97, 1.14)	1.06 (0.98, 1.14)	1.05 (0.97, 1.14)
Cooking fuel (ref: non solid fuel)							
Solid fuel		0.92 (0.83, 1.02)	0.91 (0.83, 1.01)	0.92 (0.84, 1.02)	0.92 (0.83, 1.01)	0.92 (0.83, 1.01)	0.91 (0.83, 1.01)
Place of residence (ref: urban)							
Rural		1.02 (0.93, 1.13)	1.02 (0.93, 1.12)	1.02 (0.93, 1.11)	1.02 (0.93, 1.12)	1.01 (0.92, 1.10)	1.02 (0.93, 1.11)
ANC visits (ref: ≥4 visits)							
<4 visits			1.17 (1.08, 1.26)	1.19 (1.11, 1.28)	1.17 (1.09, 1.26)	1.17 (1.09, 1.25)	1.16 (1.08, 1.24)
Institutional delivery with SBA (ref: yes)							
No			1.10 (1.02, 1.19)	1.10 (1.02, 1.18)	1.10 (1.03, 1.19)	1.12 (1.04, 1.20)	1.10 (1.03, 1.18)
Contextual PQ (ref: high)							
Low PQ at district level				1.61 (1.50, 1.73)		1.57 (1.46, 1.69)	
Low PQ at state level					1.27 (1.05, 1.55)		1.43 (1.19, 1.72)
Random part							
Level: state							
Variance estimate (95% CI)	0.12 (0.05, 0.18)	0.08 (0.03, 0.13)	0.07 (0.03, 0.12)	0.04 (0.01, 0.06)	0.06 (0.02, 0.09)	0.03 (0.01, 0.05)	0.04 (0.01, 0.07)
VPC (%)*	2.4%	1.9%	1.8%	1.0%	1.5%	0.8%	1.2%
% explained†		29.6%	9.9%	47.9%	21.9%	60.3%	41.1%
Level: district							
Variance estimate (95% CI)	0.08 (0.05, 0.11)	0.04 (0.01, 0.06)	0.04 (0.01, 0.06)	0.00 (0.00, 0.00)	0.03 (0.01, 0.05)	0.00 (-0.01, 0.02)	0.03 (0.01, 0.05)
VPC (%)*	1.6%	0.9%	0.8%	0.0%	0.8%	0.1%	0.8%
% explained†		53.8%	5.4%	100.0%	8.6%	88.6%	17.1%
Level: community							
Variance estimate (95% CI)	1.40 (1.27, 1.54)	0.80 (0.69, 0.91)	0.73 (0.62, 0.83)	0.44 (0.35, 0.54)	0.54 (0.44, 0.64)	0.31 (0.22, 0.40)	0.20 (0.12, 0.28)
VPC (%)*	28.7%	18.9%	17.6%	11.7%	13.9%	8.5%	5.6%
% explained†		43.3%	8.9%	38.9%	25.0%	57.5%	72.6%

ANC=antenatal care; CI=confidence interval; OR=odds ratio; PQ=provider quality; ref=reference; SBA=skilled birth attendant; VPC=variance partitioning coefficient.
Model 1: A null four-level random effects model, with individuals at level-1, communities at level-2, districts at level-3, and states at level-4; Model 2: Model 1 + all individual-level covariates (except for ANC and SBA); Model 3: Model 2 + ANC + SBA; Model 4A: Model 3 + district PQ derived from ANC; Model 4B: Model 3 + state PQ derived from ANC; Model 5A: Model 3 + district PQ derived from SBA; Model 5B: Model 3 + state PQ derived from SBA.
*% VPC for level z calculated as: $[\sigma_z^2/(\sigma_{f0}^2+\sigma_{v0}^2+\sigma_{u0}^2+3.29)]$*100; † % explained calculated as: $[(\sigma^2_{\text{model } N}-\sigma^2_{\text{model } N+1})/\sigma^2_{\text{model } N}]$*100; Variance estimates from Model 4A/B and Model 5A/B were compared against variance from Model 3.

infant, and under-five mortality. In particular, district provider quality indicators had stronger influence than state indicators, and the magnitude of associations was the greatest for neonatal mortality. Third, for all mortality outcomes the largest contextual variation was observed at the local level (community) rather than for districts or states. Substantial fraction of variation, especially at district level, was explained by individual and contextual variables.

We used the latest nationally representative data of children in India, but there are potential limitations to our study. The use of cross-sectional analysis prohibits us from making any causal claim. Although we adjust for a comprehensive set of demographic, socioeconomic, and birth-related factors, the coefficient estimates from our models should not be interpreted as independent effects on mortality outcomes as they may be biased from over-adjustment for mediators and inadequate adjustment for important confounders. For instance, our estimation of individual-level ANC and mortality outcomes may be conservative given that we simultaneously adjusted for SBA in institutional delivery, which is suggested to be promoted by the quality of ANC service provision.[31-33] Another data constraint relates to the pregnancy and childbirth measures being self-reported by mothers with a recall period of up to five years. Prior validation studies suggest that the sensitivity and specificity of self-reported coverage of maternal and child health indicators can vary substantially when compared to health care records[34] or direct observations.[35]

The validity of our contextual provider quality indicators is another critical concern. Our method relies on a simple assumption that districts (or states) with higher than average mortality rate given the same proportion of women with ≥ 4 ANC visits (or SBA) are due to poor service quality in the area. Similar approaches are taken in multilevel analyses when there are scientific interests in simultaneously assessing the effects of ecological and individual exposure variables yet contextual level data are not available.[36] Despite our approach being methodologically robust, in the absence of indicators related to the types of health messages and education provided by health personnel and surveys on patient satisfaction, it is difficult to validate how well these indicators truly capture care that is timely, sufficient, and appropriate in content. Further applications of our methodology using other available DHS variables, such as timing of ANC visits, health check-ups conducted during the visit (i.e., measures on weight, height, blood pressure, urine sample, blood sample, stomach examination), whether iron supplementary and pregnancy complication advice were given to the mother, and indication of postnatal checks, are needed. Nevertheless, the states identified as "low quality" areas in our study largely aligned with a prior study that found lower than desired quality of ANC (in terms of utilization, clinical quality, and interpersonal quality of care) in both northern and southern states in India.[37]

Our findings provide useful insights to current literature and policy discussions around discrepancy between individual access to care and overall quality of care.[38-40] Lack of, or inadequate, ANC visits to a health facility as well as delivery without SBA or in non-institutional settings have been linked to increased risk of neonatal and infant mortality across LMICs.[8,41-43] Other studies, however, have found non-significant relationships[12,14,41] and questioned the underlying causal mechanisms as large gaps exist between contact and content of care during antenatal, birth and postnatal periods.[39,40] We attempted to further advance this literature by simultaneously assessing the relative importance of individual access to care and contextual provider quality in respect to neonatal, infant, and under-five mortality. In doing so, we found both to be importantly related to mortality outcomes, independent of one another, with the magnitude of associations being stronger for contextual provider quality.

Taken together with existing evidence, our findings suggest that policies should continue to promote individual access to ANC and institutional deliveries; yet, without addressing supply-side constraints that compromise quality of care, such policies will be less effective in reducing newborn deaths.[12] For instance, the Janani Suraksha Yojana program in India invested more than 200 million US dollars annually to incentivize women (in the form of cash transfers) to give birth in a health facility.[41] Despite its success in significantly increasing the rate of institutional deliveries, studies found no effect of the program on either neonatal mortality or early neonatal mortality (deaths within the first 24 hours).[41] Our findings suggest that regardless of institutional deliveries with SBA, poor quality of care at the district level (and to a lesser degree at the state level) can be detrimental for neonatal, infant, and under-five mortality. In order to achieve large improvements in child survival, there must be concomitant improvements on training of service providers to treat complications, ensuring adequate emergency obstetric-care facilities, specialist and staff, essential drugs and necessary equipment, and allocating resources to facilities in proportion to caseloads and actual need.[12]

Another important policy implication of our findings is

in identifying the geographic level that contributes most to the total variation in neonatal, infant, and under-five mortality. While programs on maternal and child health in India tend to focus on districts or states for the purpose of monitoring and intervention, we found the largest contextual variation in mortality outcomes attributed to within-district local area. Therefore, the role of communities merits further investigation to better understand the geographic disparity in child survival in India. Previous multilevel studies on poverty[28] and catastrophic health spending[42] also documented the importance of village level. In our study, a substantial fraction of the contextual variation was explained by the individual and contextual predictors, indicating that their clustering has largely induced geographic variation in neonatal, infant, and under-five mortality.

CONCLUSION

We used the India DHS from 2015~2016 to demonstrate a method to construct contextual provider quality indicators based on individual-level data on access to care during pregnancy and at delivery. Based on a multilevel analysis, we found consistent evidence to support the importance of both individual use of ANC and SBA and contextual provider quality in respect to neonatal, infant, and under-five mortality. When simultaneously considered, contextual provider quality mattered more than individual use of ANC and SBA for all mortality outcomes and they explained substantial geographic variation especially at the district level. Further investigations are needed to assess the importance of improving quality of health service delivery at higher levels to prevent unnecessary child deaths in developing countries.

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Appendix 1. 36 Indian States/Union Territories Classified as High versus Low Provider Quality Areas

Neonatal mortality		Infant mortality		Under-five mortality	
High provider quality states	**Low provider quality states**	**High provider quality states**	**Low provider quality states**	**High provider quality states**	**Low provider quality states**
Andaman and Nicobar Islands	Andhra Pradesh†	Andaman and Nicobar Islands	Andhra Pradesh†	Andaman and Nicobar Islands	Andhra Pradesh†
Arunachal Pradesh	Assam	Arunachal Pradesh	Assam	Arunachal Pradesh	Assam
Bihar*	Chandigarh	Bihar*	Chandigarh	Bihar*	Chhattisgarh
Dadra and Nagar Haveli	Chhattisgarh	Daman and Diu	Chhattisgarh	Chandigarh	Dadra And Nagar Haveli†
Daman and Diu	Gujarat†	Goa	Dadra and Nagar Haveli†	Daman and Diu	Delhi†
Delhi	Himachal Pradesh†	Haryana	Delhi†	Goa	Gujarat†
Goa	Jammu and Kashmir†	Jharkhand	Gujarat†	Haryana	Jammu and Kashmir†
Haryana	Lakshadweep	Karnataka	Himachal Pradesh†	Himachal Pradesh	Madhya Pradesh
Jharkhand	Madhya Pradesh	Kerala	Jammu and Kashmir†	Jharkhand	Mizoram
Karnataka	Odisha	Maharashtra	Lakshadweep†	Karnataka	Odisha
Kerala	Punjab†	Manipur	Madhya Pradesh	Kerala	Sikkim†
Maharashtra	Sikkim†	Meghalaya	Mizoram	Lakshadweep	Uttar Pradesh
Manipur	Telangana†	Nagaland	Odisha	Maharashtra	West Bengal†
Meghalaya	Uttar Pradesh	Puducherry	Sikkim†	Manipur	
Mizoram	West Bengal†	Punjab	Uttar Pradesh	Meghalaya	
Nagaland		Rajasthan*	West Bengal†	Nagaland	
Puducherry		Tamil Nadu		Puducherry	
Rajasthan*		Telangana		Punjab	
Tamil Nadu		Tripura		Rajasthan*	
Tripura		Uttarakhand		Tamil Nadu	
Uttarakhand				Telangana	
				Tripura	
				Uttarakhand	

*Low provider quality based on institutional delivery with skilled birth attendant; †High provider quality based on institutional delivery with skilled birth attendant.

Appendix 2. 640 Indian Districts Classified as High versus Low Provider Quality Areas

Neonatal mortality		Infant mortality		Under-five mortality	
High provider quality districts	Low provider quality districts	High provider quality districts	Low provider quality districts	High provider quality districts	Low provider quality districts
Adilabad	Agra	Adilabad	Agra	Adilabad	Agra
Ahmadnagar	Ahmadabad†	Ahmadnagar	Ahmadabad†	Ahmadnagar	Ahmadabad†
Aizawl	Akola	Ajmer	Aizawl†	Ajmer	Aizawl†
Ajmer	Aligarh	Alappuzha	Akola†	Alappuzha	Akola†
Alappuzha	Ambedkar Nagar	Alirajpur	Aligarh	Alirajpur	Aligarh
Alirajpur	Anand	Allahabad*	Ambedkar Nagar	Almora	Allahabad
Allahabad	Anantnag	Almora	Anand	Alwar	Ambedkar Nagar
Almora	Anugul	Alwar	Anantnag	Ambala	Anand
Alwar	Araria	Ambala	Anugul	Amravati	Anantnag
Ambala	Azamgarh	Amravati	Araria	Amreli	Anugul
Amravati	Badgam†	Amreli	Badgam†	Amritsar	Araria
Amreli	Bagalkot†	Amritsar	Bagalkot†	Anantapur	Badgam†
Amritsar	Baghpat	Anantapur	Baghpat	Anjaw	Bagalkot†
Anantapur	Bahraich	Anjaw	Bahraich	Anuppur	Baghpat
Anjaw	Balaghat	Anuppur	Balaghat	Ariyalur	Bahraich
Anuppur*	Balangir	Ariyalur	Balangir	Arwal	Balaghat
Ariyalur	Balrampur	Arwal	Balrampur	Ashoknagar	Balangir
Arwal	Banaskantha	Ashoknagar	Banaskantha	Auraiya	Balrampur
Ashoknagar	Bandipore	Auraiya	Bandipore	Aurangabad	Banaskantha
Auraiya	Bankura	Aurangabad*	Bankura†	Aurangabad	Banda
Aurangabad	Bareilly†	Aurangabad	Baramula	Azamgarh*	Bandipore
Aurangabad	Barnala	Azamgarh*	Barddhaman†	Bageshwar	Bankura†
Bageshwar	Barwani	Bageshwar	Bareilly	Baksa	Baramula†
Baksa	Bastar	Baksa	Bargarh	Baleshwar	Bareilly
Baleshwar	Baudh	Baleshwar	Barnala	Ballia	Bargarh†
Ballia	Bellary	Ballia	Barpeta†	Bangalore	Barnala
Banda*	Bhandara	Banda*	Bastar	Bangalore Rural	Bastar
Bangalore	Bharuch	Bangalore	Baudh	Banka*	Basti
Bangalore Rural	Bhilwara	Bangalore Rural	Bellary†	Banswara*	Baudh
Banka*	Bhind	Banka*	Bhandara	Bara Banki*	Bellary
Banswara	Bhiwani	Banswara	Bharuch†	Baran	Bhandara
Bara Banki	Bhopal	Bara Banki*	Bhilwara	Barddhaman	Bharuch
Baramula	Bidar	Baran	Bhind	Barmer*	Bhilwara
Baran*	Bijapur	Barmer*	Bhiwani	Barpeta	Bhiwani
Barddhaman	Bijnor	Barwani	Bhopal	Barwani	Bhopal
Bargarh	Bilaspur	Basti*	Bidar	Bathinda	Bijapur
Barmer*	Birbhum†	Bathinda	Bijapur	Begusarai	Bijnor
Barpeta	Budaun	Begusarai	Bijnor	Belgaum	Bilaspur
Basti*	Bulandshahr	Belgaum	Bilaspur	Betul	Birbhum†
Bathinda	Burhanpur	Betul	Birbhum†	Bhadrak	Bishnupur†
Begusarai*	Buxar	Bhadrak	Budaun	Bhagalpur	Budaun
Belgaum	Cachar	Bhagalpur	Bulandshahr	Bharatpur*	Bulandshahr
Betul	Central†	Bharatpur	Burhanpur	Bhavnagar	Burhanpur
Bhadrak	Chamarajanagar†	Bhavnagar	Buxar	Bhind*	Buxar
Bhagalpur	Chamba	Bhojpur	Cachar	Bhojpur	Cachar
Bharatpur*	Champawat	Bid	Central	Bid	Central
Bhavnagar*	Chandigarh	Bijapur	Chamarajanagar	Bidar*	Chamarajanagar
Bhojpur*	Chatra	Bikaner	Chamba	Bijapur	Chamba
Bid	Chhindwara	Bilaspur	Champhai	Bikaner	Chhatarpur
Bijapur	Chitrakoot	Bishnupur	Chandigarh	Bilaspur	Chhindwara
Bikaner	Chittaurgarh	Bokaro	Chhatarpur	Bokaro	Chitradurga
Bilaspur	Dakshin Bastar Dantewada	Bongaigaon	Chhindwara	Bongaigaon	Chitrakoot
Bishnupur	Dakshin Dinajpur	Buldana	Chitradurga	Buldana	Dadra & Nagar Haveli†
Bokaro	Daman	Bundi*	Chitrakoot	Bundi*	Dakshin Bastar Dantewada
Bongaigaon	Darrang	Chamoli	Dadra & Nagar Haveli†	Chamoli	Dakshin Dinajpur
Buldana	Datia	Champawat*	Dakshin Bastar Dantewada	Champawat*	Daman†
Bundi	Davanagere	Chandauli	Dakshin Dinajpur	Champhai	Damoh
Chamoli	Debagarh	Chandel	Daman	Chandauli	Datia
Champhai	Deoghar	Chandrapur	Damoh	Chandel	Davanagere
Chandauli	Dewas	Changlang	Datia	Chandigarh	Debagarh
Chandel	Dhamtari	Chatra*	Davanagere	Chandrapur	Dewas
Chandrapur	Dhanbad	Chennai	Debagarh	Changlang	Dhamtari
Changlang	Dhar	Chikkaballapura	Dewas	Chatra*	Dhar
Chennai	Dharwad	Chikmagalur	Dhamtari	Chennai	Dharwad
Chhatarpur*	Dhemaji	Chirang	Dhar	Chikkaballapura	Dhemaji
Chikkaballapura	Dhenkanal	Chittaurgarh*	Dharwad	Chikmagalur	Dhenkanal
Chikmagalur	Dima Hasao†	Chittoor	Dhemaji	Chirang	Dima Hasao†
Chirang	Dindori	Churachandpur	Dhenkanal	Chittaurgarh*	Dindori
Chitradurga	Dohad	Churu	Dindori	Chittoor	Dohad

Chittoor	Dumka	Coimbatore	Dohad	Churachandpur	Dumka
Churachandpur	Durg	Cuddalore	Dumka	Churu	Durg
Churu	Etah	Cuttack	Durg†	Coimbatore	East Godavari
Coimbatore	Faizabad	Dakshina Kannada	East†	Cuddalore	Etah
Cuddalore	Farrukhabad	Darbhanga	East Godavari	Cuttack	Faizabad
Cuttack	Fatehabad	Darjiling	Etah	Dakshina Kannada	Farrukhabad
Dadra & Nagar Haveli	Firozabad	Darrang	Faizabad	Darbhanga	Fatehgarh Sahib
Dakshina Kannada	Firozpur	Dausa*	Farrukhabad	Darjiling	Firozabad
Damoh*	Gadchiroli	Dehradun	Fatehgarh Sahib	Darrang	Gajapati
Darbhanga	Gajapati	Deoghar	Firozabad	Dausa*	Ganderbal
Darjiling	Ganderbal	Deoria*	Gajapati	Dehradun	Gandhinagar
Dausa	Gandhinagar	Dhalai	Ganderbal	Deoghar	Garhwa
Dehradun	Ganganagar	Dhanbad	Gandhinagar†	Deoria*	Gautam Buddha Nagar
Deoria*	Garhwa	Dharmapuri	Garhwa	Dhalai	Gaya
Dhalai	Gautam Buddha Nagar	Dhaulpur*	Gautam Buddha Nagar	Dhanbad	Ghaziabad
Dharmapuri	Gaya	Dhubri	Gaya	Dharmapuri	Ghazipur
Dhaulpur	Ghazipur	Dhule	Ghaziabad	Dhaulpur*	Giridih
Dhubri	Giridih	Dibang Valley	Ghazipur	Dhubri	Godda
Dhule	Godda	Dibrugarh	Golaghat	Dhule	Golaghat
Dibang Valley	Golaghat	Dima Hasao	Gonda	Dibang Valley	Gonda
Dibrugarh	Gonda	Dimapur	Gorakhpur	Dibrugarh	Gorakhpur
Dimapur	Gorakhpur	Dindigul	Guna	Dimapur	Guna
Dindigul	Guna	Diu	Guntur	Dindigul	Gwalior
Diu	Gwalior	Doda	Gwalior	Diu	Hailakandi
Doda	Hailakandi	Dungarpur	Hailakandi	Doda	Hamirpur†
Dungarpur	Hamirpur†	East District	Hamirpur†	Dungarpur	Haora†
East	Haora†	East Garo Hills	Haora†	East	Hardoi
East District	Hardoi	East Kameng	Hardoi	East District	Hardwar
East Garo Hills	Hazaribagh	East Khasi Hills	Hardwar	East Garo Hills	Hingoli
East Godavari	Hingoli	East Siang	Hingoli	East Kameng	Hisar
East Kameng	Hoshangabad	Ernakulam	Hisar	East Khasi Hills	Jabalpur
East Khasi Hills	Jabalpur	Erode	Jabalpur	East Siang	Jagatsinghapur
East Siang	Jagatsinghapur	Etawah*	Jagatsinghapur	Ernakulam	Jaipur
Ernakulam	Jalaun	Faridabad	Jaisalmer	Erode	Jaisalmer
Erode	Jalgaon	Faridkot	Jalandhar	Etawah*	Jalandhar†
Etawah	Jalor	Fatehabad	Jalaun	Faridabad	Jalaun
Faridabad	Jamnagar	Fatehpur	Jalor	Faridkot	Jalor
Faridkot	Jamtara	Firozpur	Jamnagar†	Fatehabad	Jamnagar†
Fatehgarh Sahib	Jamui	Gadag	Jashpur	Fatehpur	Jashpur
Fatehpur	Janjgir - Champa	Gadchiroli	Jaunpur	Firozpur	Jaunpur
Gadag	Jashpur	Ganganagar*	Jehanabad	Gadag	Jehanabad
Ganjam	Jaunpur	Ganjam	Jhalawar	Gadchiroli	Jhalawar
Garhwal	Jehanabad	Garhwal	Jhansi	Ganganagar*	Jhansi
Ghaziabad*	Jhalawar	Giridih	Jharsuguda	Ganjam	Jharsuguda
Goalpara	Jhansi	Goalpara	Jhunjhunun	Garhwal	Jorhat†
Gondiya	Jharsuguda	Godda	Jorhat†	Goalpara	Jyotiba Phule Nagar
Gopalganj	Jorhat	Gondiya	Jyotiba Phule Nagar	Gondiya	Kabirdham†
Gulbarga	Jyotiba Phule Nagar	Gopalganj	Kachchh	Gopalganj	Kachchh
Gumla	Kabirdham†	Gulbarga	Kaithal	Gulbarga	Kaithal
Guntur	Kachchh	Gumla	Kalahandi	Gumla	Kalahandi
Gurdaspur	Kaithal	Gurdaspur	Kamrup Metropolitan	Guntur*	Kamrup Metropolitan
Gurgaon	Kamrup Metropolitan	Gurgaon	Kandhamal	Gurdaspur	Kandhamal
Hamirpur*	Kandhamal	Hamirpur*	Kangra†	Gurgaon	Kangra†
Hanumangarh*	Kangra	Hanumangarh	Kannauj	Hamirpur*	Kannauj
Harda	Kannauj	Harda	Kanshiram Nagar	Hanumangarh	Kanshiram Nagar
Hardwar*	Kanshiram Nagar	Hassan	Karauli	Harda*	Kapurthala†
Hassan	Kapurthala†	Haveri	Karbi Anglong	Hassan	Karauli
Haveri	Karauli	Hazaribagh*	Kargil†	Haveri	Karbi Anglong
Hisar*	Karbi Anglong	Hoshangabad	Karimganj	Hazaribagh*	Kargil
Hoshiarpur	Kargil†	Hoshiarpur	Karimnagar	Hoshangabad	Karimganj
Hugli	Karimganj	Hugli	Kathua†	Hoshiarpur	Karimnagar
Hyderabad	Karimnagar	Hyderabad	Katihar	Hugli	Kathua†
Idukki	Kathua	Idukki	Katni	Hyderabad	Katni
Imphal East	Katihar	Imphal East	Kaushambi	Idukki	Kaushambi
Imphal West	Katni	Imphal West	Kendujhar	Imphal East	Kendujhar
Indore	Kaushambi	Indore	Kheda	Imphal West	Kheda
Jaintia Hills	Kendujhar	Jaintia Hills	Kheri	Indore	Kheri
Jaipur	Khagaria	Jaipur*	Kinnaur†	Jaintia Hills	Kinnaur†
Jaisalmer*	Khargone (West Nimar)	Jajapur*	Kiphire†	Jajapur	Kiphire†
Jajapur*	Kheda	Jalgaon	Kishtwar†	Jalgaon	Kishtwar†
Jalandhar	Kheri	Jalna	Koch Bihar	Jalna	Koch Bihar
Jalna	Kinnaur†	Jalpaiguri	Kolar	Jalpaiguri	Kokrajhar†
Jalpaiguri	Koch Bihar	Jammu	Kolasib	Jammu	Kolar
Jammu	Kokrajhar	Jamtara	Korba	Jamtara	Kolasib

Jhabua	Kolar	Jamui*	Korea (Koriya)	Jamui*	Korba
Jhajjar*	Koraput †	Janjgir - Champa	Krishnagiri	Janjgir - Champa	Korea (Koriya)
Jhunjhunun*	Korba	Jhabua	Kulgam	Jhabua*	Krishnagiri
Jind	Korea (Koriya)	Jhajjar	Kushinagar	Jhajjar	Kulgam
Jodhpur*	Krishnagiri	Jind	Lakhimpur †	Jhunjhunun*	Kupwara †
Junagadh	Kulgam	Jodhpur*	Lakshadweep †	Jind	Kushinagar
Kaimur (Bhabua)*	Kupwara †	Junagadh	Lalitpur	Jodhpur	Lakhimpur
Kalahandi	Kushinagar	Kabirdham	Lawngtlai †	Junagadh	Lalitpur
Kamrup	Lakshadweep †	Kaimur (Bhabua)*	Lohit †	Kaimur (Bhabua)*	Leh †
Kancheepuram	Lohit †	Kamrup	Lucknow	Kamrup	Lohit †
Kanniyakumari	Lucknow	Kancheepuram	Ludhiana †	Kancheepuram	Lucknow
Kannur	Ludhiana	Kanniyakumari	Lunglei	Kanniyakumari	Ludhiana †
Kanpur Dehat*	Mahamaya Nagar	Kannur	Mahamaya Nagar	Kannur	Lunglei
Kanpur Nagar	Mahasamund	Kanpur Dehat*	Mahasamund	Kanpur Dehat*	Mahamaya Nagar
Karaikal	Mahrajganj	Kanpur Nagar	Mahbubnagar	Kanpur Nagar	Mahasamund
Karnal	Mainpuri	Kapurthala	Mahesana †	Karaikal	Mahesana †
Karur	Malkangiri	Karaikal	Mahrajganj	Karnal	Mahrajganj
Kasaragod	Mandla	Karnal	Mainpuri	Karur	Mainpuri
Kendrapara	Mandsaur	Karur	Malkangiri	Kasaragod	Malkangiri
Khammam	Mandya †	Kasaragod	Mandla †	Katihar*	Mandla
Khandwa (East Nimar)	Mathura	Kendrapara	Mandsaur	Kendrapara	Mandsaur
Khordha	Mau	Khagaria*	Mandya †	Khagaria*	Mandya †
Khunti	Medak	Khammam	Mathura	Khammam	Mathura
Kiphire	Meerut	Khandwa (East Nimar)	Mau	Khandwa (East Nimar)	Mau
Kishanganj	Mewat	Khargone (West Nimar)*	Medak	Khargone (West Nimar)*	Mayurbhanj †
Kishtwar	Mirzapur	Khordha	Meerut	Khordha	Medak
Kodagu	Moga	Khunti	Mewat	Khunti	Meerut
Kodarma	Moradabad	Kishanganj	Mirzapur	Kishanganj	Mewat
Kohima	Morigaon	Kodagu	Moga	Kodagu	Mirzapur
Kolasib	Munger	Kodarma	Moradabad	Kodarma	Moga
Kolhapur	Murshidabad †	Kohima	Morena	Kohima	Moradabad
Kolkata	Muzaffarnagar	Kokrajhar	Morigaon	Kolhapur	Morena
Kollam	Nabarangapur	Kolhapur	Muktsar	Kolkata	Morigaon
Koppal	Nadia †	Kolkata	Mumbai Suburban †	Kollam	Muktsar
Kota	Nagaon	Kollam	Muzaffarnagar	Koppal	Mumbai Suburban †
Kottayam	Nalbari	Koppal	Nabarangapur	Koraput	Muzaffarnagar
Kozhikode	Nanded	Koraput	Nadia †	Kota	Nabarangapur
Krishna	Nandurbar †	Kota	Nagaon	Kottayam	Nadia †
Kullu	Narayanpur	Kottayam	Nalbari	Kozhikode	Nagaon
Kurnool	Narsimhapur	Kozhikode	Nanded †	Krishna	Nalbari
Kurukshetra	Navsari †	Krishna	Narmada †	Kullu	Narmada †
Kurung Kumey	Nayagarh	Kullu	Nayagarh	Kurnool	Navsari †
Lahul And Spiti	Nizamabad	Kupwara	Nizamabad	Kurukshetra	Nayagarh
Lakhimpur	North	Kurnool	North	Kurung Kumey	Nizamabad
Lakhisarai*	North Goa †	Kurukshetra	North East †	Lahul And Spiti	North †
Lalitpur*	Nuapada	Kurung Kumey	North Tripura	Lakhisarai*	North East †
Latehar	Pali	Lahul And Spiti	Nuapada	Lakshadweep	North Tripura
Latur	Panna	Lakhisarai*	Pali	Latehar	Nuapada †
Lawngtlai	Parbhani	Latehar	Panna	Latur	Pali
Leh	Paschim Medinipur †	Latur	Parbhani †	Lawngtlai	Panna
Lohardaga	Pashchim Champaran	Leh	Paschim Medinipur †	Lohardaga	Parbhani †
Longleng	Patan	Lohardaga	Pashchim Champaran	Longleng	Paschim Medinipur †
Lower Dibang Valley	Pilibhit	Longleng	Pashchimi Singhbhum	Lower Dibang Valley	Pashchim Champaran
Lower Subansiri	Pithoragarh	Lower Dibang Valley	Patan	Lower Subansiri	Pashchimi Singhbhum
Lunglei	Prakasam	Lower Subansiri	Pilibhit	Madhepura	Patan
Madhepura*	Pulwama †	Madhepura	Pithoragarh	Madhubani	Perambalur †
Madhubani	Puri	Madhubani	Prakasam	Madurai	Pilibhit
Madurai	Purnia	Madurai	Pulwama	Mahbubnagar	Pithoragarh
Mahbubnagar	Puruliya †	Mahe	Purba Medinipur †	Mahe	Prakasam
Mahe	Rae Bareli	Mahendragarh	Puri	Mahendragarh	Pratapgarh
Mahendragarh	Raichur	Mahoba*	Purnia	Mahoba*	Pulwama
Mahesana	Raigarh †	Malappuram	Rae Bareli	Malappuram	Puri
Mahoba*	Raigarh	Maldah	Raichur	Maldah	Purnia
Malappuram	Raipur	Mamit	Raigarh	Mamit	Rae Bareli
Maldah	Raisen	Mandi	Raigarh	Mandi	Raichur
Mamit	Rajgarh	Mansa	Raipur	Mansa	Raigarh †
Mandi	Rajkot †	Mayurbhanj	Rajgarh	Mokokchung	Raigarh
Mansa	Rajnandgaon	Mokokchung	Rajkot †	Mon	Raipur
Mayurbhanj	Rajsamand	Mon	Rajnandgaon	Mumbai	Rajgarh
Mokokchung	Rampur	Mumbai	Rajsamand	Munger*	Rajkot †
Mon	Rayagada	Munger*	Rampur	Murshidabad	Rajnandgaon
Morena*	Rewa	Murshidabad	Rayagada	Muzaffarpur	Rajsamand
Muktsar	Rohtak	Muzaffarpur	Rewa	Mysore	Rampur
Mumbai	Rohtas	Mysore	Rohtak	Nagapattinam	Rayagada

Mumbai Suburban	Rupnagar†	Nagapattinam	Rohtas	Nagaur	Rewa
Muzaffarpur*	Sagar	Nagaur	Sagar	Nagpur	Rohtak
Mysore	Saharanpur	Nagpur	Saharanpur	Nainital	Rohtas
Nagapattinam	Saharsa	Nainital	Saharsa	Nalanda*	Saharanpur
Nagaur	Sahibganj	Nalanda*	Sahibganj	Nalgonda	Saharsa
Nagpur	Sahibzada Ajit Singh Nagar	Nalgonda	Sahibzada Ajit Singh Nagar†	Namakkal	Sahibganj
Nainital	Sambalpur	Namakkal	Saiha	Nanded	Saiha
Nalanda*	Sangrur	Nandurbar	Sambalpur†	Nandurbar	Sambalpur
Nalgonda	Sant Kabir Nagar	Narayanpur	Sangrur†	Narayanpur	Sangrur†
Namakkal	Sant Ravidas Nagar (Bhadohi)	Narsimhapur*	Sant Kabir Nagar	Narsimhapur	Sant Kabir Nagar
Narmada	Sawai Madhopur	Nashik	Sant Ravidas Nagar (Bhadohi)	Nashik	Sant Ravidas Nagar (Bhadohi)
Nashik	Seoni	Navsari	Sawai Madhopur	Nawada	Saraikela Kharsawan
Nawada	Shahjahanpur	Nawada	Seoni	Neemuch	Sawai Madhopur
Neemuch	Shajapur	Neemuch	Serchhip†	New Delhi	Seoni
New Delhi	Sheohar	New Delhi	Shahdol	Nicobars	Serchhip†
Nicobars	Shimoga	Nicobars	Shahjahanpur	North District	Shahdol
North District	Shivpuri	North District	Shajapur	North & Middle Andaman	Shahjahanpur
North & Middle Andaman	Shrawasti	North & Middle Andaman	Sheohar	North Goa	Shajapur
North East	Shupiyan†	North Goa	Shimoga	North Twenty Four Parganas	Sheohar
North Tripura	Siddharth Nagar	North Twenty Four Parganas	Shivpuri	North West	Shimoga†
North Twenty Four Parganas	Sidhi	North West	Shrawasti	Osmanabad	Shivpuri
North West	Sikar	Osmanabad	Shupiyan†	Pakur	Shrawasti
Osmanabad	Simdega	Pakur	Siddharth Nagar	Palakkad	Shupiyan†
Pakur	Sindhudurg†	Palakkad	Sindhudurg†	Palamu	Siddharth Nagar
Palakkad	Sirmaur	Palamu	Sirmaur	Palwal	Sidhi
Palamu	Sirohi	Palwal	Sirohi	Panchkula	Simdega
Palwal	Sirsa	Panchkula	Sirsa	Panchmahal	Singrauli†
Panchkula	Sitamarhi	Panchmahal	Sitamarhi†	Panipat	Sirmaur
Panchmahal	Sitapur	Panipat	Sitapur	Papumpare	Sirohi
Panipat	Sivasagar	Papumpare	Sivasagar	Pathanamthitta	Sitamarhi
Papumpare	Siwan	Pathanamthitta	Solan†	Patiala	Sitapur
Pashchimi Singhbhum	Solan†	Patiala	Sonitpur	Patna	Sivasagar
Pathanamthitta	Sonbhadra	Patna	South	Peren	South
Patiala	South	Perambalur	Sri Potti Sriramulu Nellore†	Phek	South Garo Hills
Patna*	South Twenty Four Parganas†	Peren	Srikakulam	Porbandar	South Twenty Four Parganas†
Perambalur	Sri Potti Sriramulu Nellore	Phek	Srinagar	Pratapgarh*	Srikakulam
Peren	Srikakulam	Porbandar	Subarnapur	Puducherry	Srinagar
Phek	Srinagar	Pratapgarh*	Sultanpur	Pudukkottai	Subarnapur†
Porbandar	Subarnapur†	Pratapgarh*	Surguja	Punch	Sultanpur
Pratapgarh*	Sultanpur	Puducherry	Thanjavur†	Pune	Sundargarh†
Pratapgarh*	Surguja	Pudukkottai	Thiruvallur†	Purba Champaran	Surguja
Puducherry	Thanjavur†	Punch	Thiruvarur	Purba Medinipur	Thanjavur†
Pudukkottai	Thiruvarur	Pune	Tinsukia	Purbi Singhbhum	Thiruvallur†
Punch	Thoubal†	Purba Champaran	Tiruchirappalli	Puruliya	Thiruvarur†
Pune	Tinsukia	Purbi Singhbhum	Tirunelveli	Raisen*	Tinsukia
Purba Champaran	Tiruchirappalli†	Puruliya	Tiruppur	Rajouri	Tiruchirappalli
Purba Medinipur	Tirunelveli	Raisen*	Tumkur	Ramanagara	Tirunelveli
Purbi Singhbhum	Tiruppur	Rajouri	Udalguri	Ramanathapuram	Tiruppur
Rajouri	Tonk	Ramanagara	Udhampur†	Ramban	Tumkur
Ramanagara	Tumkur	Ramanathapuram	Umaria	Ramgarh	Udaipur
Ramanathapuram	Udhampur	Ramban	Unnao	Ranchi	Udhampur†
Ramban	Udupi†	Ramgarh	Uttar Bastar Kanker	Rangareddy	Umaria
Ramgarh	Umaria	Ranchi*	Uttarkashi	Ratlam	Uttar Bastar Kanker
Ranchi*	Unnao	Rangareddy	Vadodara†	Ratnagiri	Uttarkashi
Rangareddy	Uttar Bastar Kanker	Ratlam	Valsad†	Reasi	Vadodara
Ratlam	Uttar Dinajpur†	Ratnagiri	Vidisha	Rewari*	Valsad†
Ratnagiri	Valsad	Reasi	Visakhapatnam†	Ribhoi	Vidisha
Reasi	Varanasi	Rewari*	West District	Rudraprayag	Visakhapatnam†
Rewari	Virudhunagar	Ribhoi	Y.S.R.	Rupnagar	West District
Ribhoi	Visakhapatnam†	Rudraprayag		Sabarkantha	Y.S.R.
Rudraprayag	Wardha†	Rupnagar		Sagar*	
Sabarkantha	West District	Sabarkantha		Sahibzada Ajit Singh Nagar	
Saiha	West Garo Hills†	Salem		Salem	
Salem	Y.S.R.	Samastipur		Samastipur	
Samastipur		Samba		Samba	
Samba		Sangli		Sangli	
Sangli		Saraikela Kharsawan		Saran	
Saraikela Kharsawan		Saran		Satara	
Saran		Satara		Satna*	
Satara		Satna*		Sehore*	
Satna*		Sehore*		Senapati (Excluding 3 SD)	
Sehore		Senapati (Excluding 3 SD)		Shahid Bhagat Singh Nagar	
Senapati (Excluding 3 SD)		Shahid Bhagat Singh Nagar		Sheikhpura*	
Serchhip		Sheikhpura*		Sheopur*	

Shahdol*		Sheopur*		Shimla	
Shahid Bhagat Singh Nagar		Shimla		Sikar	
Sheikhpura*		Sidhi*		Sindhudurg	
Sheopur		Sikar		Sirsa*	
Shimla		Simdega*		Sivaganga	
Singrauli		Singrauli		Siwan*	
Sivaganga		Sivaganga		Solan	
Solapur		Siwan*		Solapur	
Sonipat		Solapur		Sonbhadra	
Sonitpur*		Sonbhadra		Sonipat	
South Andaman		Sonipat		Sonitpur*	
South District		South Andaman		South Andaman	
South Garo Hills		South District		South District	
South Goa		South Garo Hills		South Goa	
South Tripura		South Goa		South Tripura	
South West		South Tripura		South West	
Sundargarh		South Twenty Four Parganas		Sri Potti Sriramulu Nellore	
Supaul		South West		Supaul	
Surat		Sundargarh		Surat	
Surendranagar		Supaul		Surendranagar	
Tamenglong		Surat		Tamenglong	
Tapi		Surendranagar		Tapi	
Tarn Taran*		Tamenglong		Tarn Taran	
Tawang		Tapi		Tawang	
Tehri Garhwal		Tarn Taran		Tehri Garhwal	
Thane		Tawang		Thane	
The Dangs		Tehri Garhwal		The Dangs	
The Nilgiris		Thane		The Nilgiris	
Theni		The Dangs		Theni	
Thiruvallur		The Nilgiris		Thiruvananthapuram	
Thiruvananthapuram		Theni		Thoothukkudi	
Thoothukkudi		Thiruvananthapuram		Thoubal	
Thrissur		Thoothukkudi		Thrissur	
Tikamgarh*		Thoubal		Tikamgarh*	
Tirap		Thrissur		Tirap	
Tiruvannamalai		Tikamgarh*		Tiruvannamalai	
Tuensang		Tirap		Tonk*	
Udaipur		Tiruvannamalai		Tuensang	
Udalguri*		Tonk*		Udalguri	
Udham Singh Nagar		Tuensang		Udham Singh Nagar	
Ujjain*		Udaipur		Udupi	
Ukhrul		Udham Singh Nagar		Ujjain*	
Una		Udupi		Ukhrul	
Upper Siang		Ujjain*		Una	
Upper Subansiri		Ukhrul		Unnao*	
Uttara Kannada		Una		Upper Siang	
Uttarkashi*		Upper Siang		Upper Subansiri	
Vadodara		Upper Subansiri		Uttar Dinajpur	
Vaishali*		Uttar Dinajpur		Uttara Kannada	
Vellore		Uttara Kannada		Vaishali*	
Vidisha*		Vaishali*		Varanasi*	
Viluppuram		Varanasi*		Vellore	
Vizianagaram		Vellore		Viluppuram	
Warangal		Viluppuram		Virudhunagar	
Washim		Virudhunagar		Vizianagaram	
Wayanad		Vizianagaram		Warangal	
West		Warangal		Wardha	
West Godavari		Wardha		Washim	
West Kameng		Washim		Wayanad	
West Khasi Hills		Wayanad		West	
West Siang		West		West Garo Hills	
West Tripura		West Garo Hills		West Godavari	
Wokha		West Godavari		West Kameng	
Yadgir		West Kameng		West Khasi Hills	
Yamunanagar		West Khasi Hills		West Siang	
Yanam		West Siang		West Tripura	
Yavatmal		West Tripura		Wokha	
Zunheboto		Wokha		Yadgir	
		Yadgir		Yamunanagar	
		Yamunanagar		Yanam	
		Yanam		Yavatmal	
		Yavatmal		Zunheboto	
		Zunheboto			

SD=sub-divisions.
*Low provider quality based on institutional delivery with skilled birth attendant; † High provider quality based on institutional delivery with skilled birth attendant.