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This supplementary material has been provided by the authors to give readers additional information about their work.

eMethods 1. Assessment of the NFHS-4 Figures on Cesarean Births

The preliminary analysis of original NFHS-4 data revealed that very high cesarean birth rates were observed in several states in India. Especially noticeable were the states of Andhra Pradesh and Telangana, where rates reach the unusually high levels of 40% and 58% respectively. The NFHS-4 estimates can be further compared with the state-wise estimates drawn from the previous NFHS round conducted in 2005-06 (eTable 1).

eTable 1. Population-Based Cesarean Rates in India by State and Union Territory According to 3 Demographic Surveys, 2005-2016

Survey	NFHS-4	NFHS-3	Difference between NFHS rounds	DLHS-4*
Year	2015-16	2005-6		2012-13
Andaman and Nicobar Islands	19.3%	NA		12%
Andhra Pradesh	40.1%	22.2%	25.3%**	34%
Arunachal Pradesh	8.9%	3.0%	6.0%	4%
Assam	13.4%	5.3%	8.2%	10%
Bihar	6.2%	3.1%	3.1%	5%
Chandigarh	22.6%	NA		14%
Chhattisgarh	9.9%	4.1%	5.7%	7%
Dadra and Nagar Haveli	16.2%	NA		NA
Daman and Diu	15.7%	NA		NA
Goa	31.4%	25.8%	5.6%	31%
Gujarat	18.4%	8.9%	9.5%	NA
Haryana	11.7%	5.3%	6.4%	8%
Himachal Pradesh	16.7%	12.6%	4.1%	11%
Jammu and Kashmir	33.1%	13.5%	19.6%	NA
Jharkhand	9.9%	3.9%	6.0%	8%
Karnataka	23.6%	15.5%	8.0%	21%
Kerala	35.8%	30.1%	5.7%	37%
Lakshadweep	38.4%	NA		NA
Madhya Pradesh	8.6%	3.5%	5.1%	6%
Maharashtra	20.1%	11.6%	8.5%	14%
Manipur	21.1%	9.0%	12.1%	11%
Meghalaya	7.6%	4.1%	3.5%	4%
Mizoram	12.7%	6.2%	6.5%	5%
Nagaland	5.8%	2.0%	3.8%	3%
Delhi	26.7%	13.7%	13.0%	NA
Odisha	13.8%	5.1%	8.7%	9%
Puducherry	33.6%	NA		38%
Punjab	24.6%	16.6%	8.0%	17%
Rajasthan	8.6%	3.8%	4.8%	7%
Sikkim	20.9%	12.3%	8.5%	15%
Tamil Nadu	34.1%	20.3%	13.8%	31%
Telangana	57.7%	NA		53%
Tripura	20.5%	12.9%	7.6%	13%
Uttar Pradesh	9.4%	4.4%	5.0%	7%
Uttarakhand	13.1%	8.1%	5.0%	11%

West Bengal	23.8%	10.2%	13.6%	23%
India	17.2%	8.5%	8.7%	

NFHS: National Family and Health Surveys; DLHS: District-Level Household Survey; NA: data not available for these states

*: AHS data (2011-12) used for Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Uttarkhand, and Uttar Pradesh where DHLS-4 was not conducted.

**: computed over the old Andhra Pradesh state (including Telangana)

Computed from DLHS and NFHS datasets

This comparison points to the very rapid increase observed in the former Andhra Pradesh state, which included then Telangana: the cesarean rate more than doubled in Andhra Pradesh, rising by 25.3 points in a decade. The national in cesarean rates have been significantly slower in India (+8.7%) and in specific regions, notably among other South Indian states such as Kerala (+5.7%), Tamil Nadu (+13.8%) or Karnataka (+8.0%). Thus, in spite of strong congruence between estimates of cesarean rates from the last two NFHS rounds (r^2=.81), the proportion of cesarean deliveries seems to have recorded an unusual growth in the states of Andhra Pradesh and Telangana.

In order to test the reliability of the NFHS-4 figure for Andhra Pradesh and Telangana, we conducted two consistency tests at state- and district-level. We used for that the results of the DLHS-4 survey conducted in 2011-12. This is the latest survey-based estimates of cesarean deliveries in India. The DLHS-4 was replaced by the Annual Health Survey (AHS) in nine less advanced poorer states (Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Uttarkhand, and Uttar Pradesh). We use therefore data from the AHS (2011-12) for these states. Cesarean rates from AHS were computed from the rates in government and private institutions mentioned in the respective state AHS publications. In addition, no result has been published by the DLHS-4 for several states and territories including Gujarat. A total of 29 state-wise estimates of cesarean rates are therefore available for comparison between the NFHS-4 and the NFHS-4 and AHS conducted about 2 years earlier (eTable 1).

The values plotted in eFigure 1 demonstrate the very strong correlation (r^2=0.94) existing between the two series, in spite of the overall increase in cesarean rates between the two successive surveys. We observe in particular that the NFHS-4 estimates for Telangana and Andhra Pradesh where cesarean rates rose very fast between the last two NFHS rounds are confirmed by the DLHS-4 figures.

eFigure 1. Population-Based Cesarean Rates in India by State and Union Territory According to the DLHS-4 and the NFHS-4 Surveys, 2011-2016
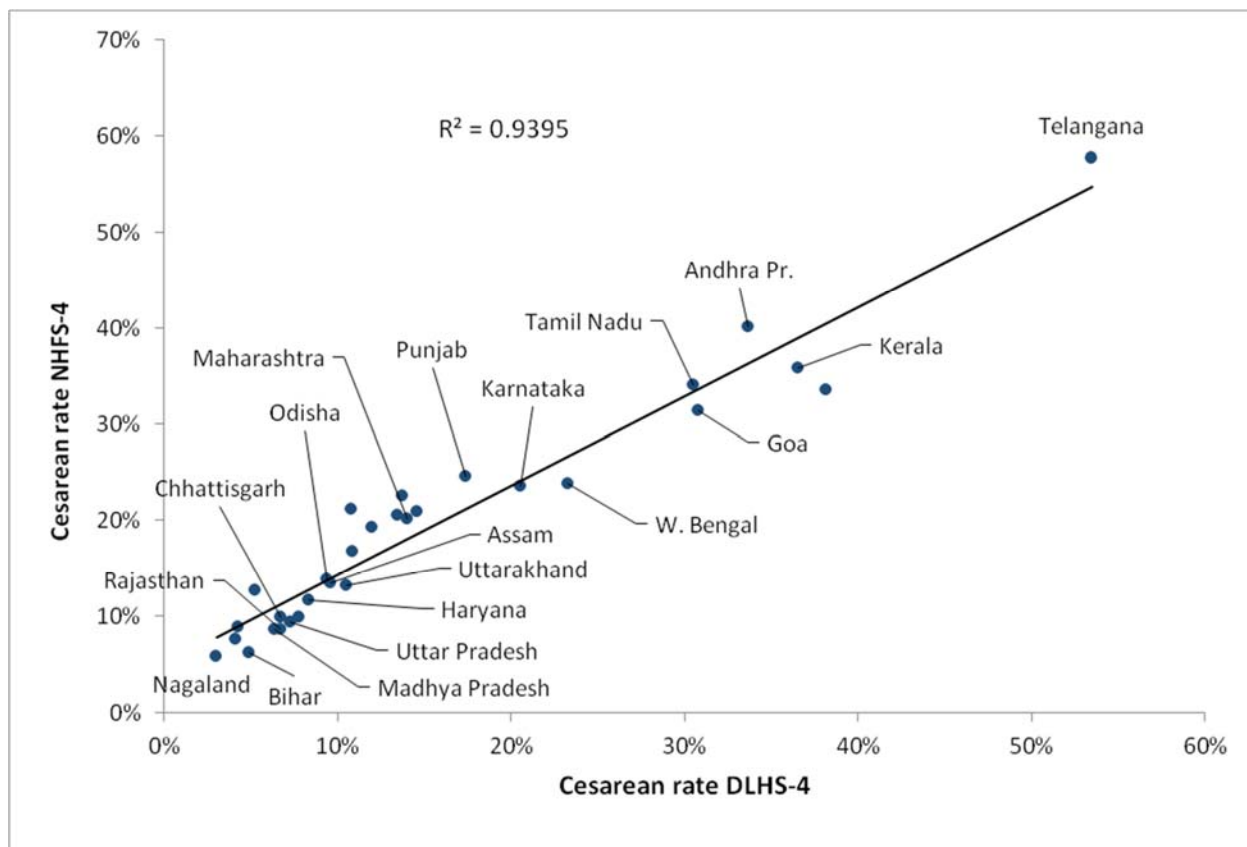
We conducted a further district-level analysis for the former state of Andhra Pradesh (Andhra Pradesh and Telangana). We plotted again the DHLS-4 estimates against the NFHS-4 estimates for the 23 districts that constitute today Andhra Pradesh and Telangana. The correlation coefficient (r^2=0.65) between the two series is high and significant at 1%, while lower than the coefficient measured at state-level because of the higher variability of district-level estimates. This strong correlation confirms the consistency of NFHS-4 figures in the two states where cesarean rates recorded the fastest growth during the last ten years.

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eTable 2. Population-Based Cesarean Section Rates in India and Relative Risk by Socioeconomic Quintile and by State and Rural/Urban, National Family Health Survey (NFHS-4), 2010-2016

State	Poorest		Poor		Middle		Richer		Richest		Total		Relative risk*
Unit	% (95% CI)	Births	% (95% CI)	Births	% (95% CI)	Births	% (95% CI)	Births	% (95% CI)	Births	% (95% CI)	Births	Ratio (95% CI)
Andhra Pradesh	19.6 (13.2-26)	149	26.9 (23.2-30.6)	553	37.5 (34.6-40.3)	1118	46.7 (43.3-50)	865	57.1 (52.5-61.7)	443	40.1 (38.4-41.8)	3128	2.9 (2.1-3.9)
Arunachal Pradesh	1.4 (0.7-2)	1239	3 (2.1-3.9)	1339	8 (6.5-9.5)	1225	20.2 (17.5-22.9)	846	28.6 (23.6-33.6)	317	8.9 (8.1-9.7)	4966	21.1 (13-32.1)
Assam	3.3 (2.7-4)	3256	8.1 (7.2-8.9)	4016	19.7 (17.9-21.6)	1782	39.2 (36.1-42.4)	924	60.1 (54.8-65.3)	331	13.4 (12.7-14.1)	10309	18 (14.9-21.7)
Bihar	3.4 (3.1-3.7)	14223	5.9 (5.3-6.5)	6145	10.2 (9.1-11.3)	2910	19.5 (17.6-21.4)	1668	28.6 (24.6-32.6)	491	6.2 (5.9-6.5)	25437	8.5 (7.7-9.9)
Chhattisgarh	3.3 (2.7-3.9)	3588	6.1 (5.1-7.2)	2151	10.5 (8.9-12.1)	1448	15.7 (13.5-18)	1047	29.8 (27-32.6)	1049	9.9 (9.3-10.5)	9283	9.1 (7.5-10.9)
Gujarat	5.8 (4.4-7.1)	1140	5.9 (4.8-6.9)	1804	11.5 (10.1-13)	1852	25.7 (23.5-27.9)	1574	35.1 (32.6-37.7)	1360	18.4 (17.5-19.3)	7730	6.1 (4.8-7.6)
Haryana	4.6 (2-7.1)	251	5.1 (3.5-6.6)	770	6.5 (5.2-7.8)	1476	9.8 (8.5-11.1)	2115	17.3 (16-18.6)	3270	11.7 (11-12.4)	7882	3.8 (2.1-6)
Himachal Pradesh	2.4 (-1.7-6.5)	54	4.6 (2.4-6.9)	340	10 (7.8-12.3)	703	15.2 (13-17.3)	1052	28.7 (25.5-31.9)	780	16.7 (15.3-18)	2929	11.8 (2.2-32.6)
Jammu and Kashmir	8.6 (6.9-10.3)	1029	17.6 (16-19.1)	2215	33 (31-35)	2115	44.7 (42.2-47.2)	1573	50 (47.3-52.7)	1313	33.1 (32.1-34.1)	8245	5.8 (4.8-7)
Jharkhand	3.8 (3.3-4.3)	6346	8.6 (7.6-9.7)	2649	15.7 (13.9-17.4)	1592	22.1 (19.6-24.7)	988	39.6 (35.7-43.4)	629	9.9 (9.3-10.4)	12204	10.4 (9.1-12)
Karnataka	12.7 (10-15.3)	595	14.6 (13-16.2)	1861	21.6 (20-23.2)	2457	26.3 (24.4-28.3)	2000	37.8 (34.6-41)	876	23.6 (22.6-24.5)	7789	3 (2.4-3.7)
Kerala	41.6 (16.7-66.5)	15	26.5 (15.9-37.2)	66	36.5 (31.5-41.6)	353	36.7 (33.7-39.7)	973	35.1 (32.3-38)	1055	35.8 (33.9-37.7)	2462	0.8 (0.5-1.2)
Madhya Pradesh	2.3 (2-2.6)	8878	4.4 (3.9-4.9)	5896	8.1 (7.2-9)	3762	15.1 (13.9-16.4)	3268	28.9 (27.2-30.5)	2807	8.6 (8.3-9)	24611	12.5 (10.9-14.4)
Maharashtra	5.3 (4-6.6)	1171	9.6 (8.3-11)	1931	16.6 (15.1-18.1)	2400	23.3 (21.6-25.1)	2268	36.6 (34.3-39)	1631	20.1 (19.3-20.9)	9401	6.9 (5.4-8.6)
Manipur	3.9 (2.6-5.3)	788	10.4 (9-11.8)	1917	20.8 (18.8-22.8)	1598	34.5 (31.5-37.6)	928	51.4 (46.5-56.3)	405	21.1 (20.1-22.2)	5636	13.1 (9.2-17.8)
Meghalaya	2.6 (1.5-3.8)	731	3.2 (2.4-4.1)	1768	9.8 (8.3-11.4)	1353	20.8 (16.9-24.6)	425	29.4 (21.7-37.2)	132	7.6 (6.8-8.4)	4409	11.2 (7.1-17.1)
Mizoram	1.5 (0.3-2.7)	389	4.6 (3.2-6.1)	798	6 (4.7-7.2)	1295	13.2 (11.5-15)	1439	24.5 (21.8-27.2)	984	12.7 (11.7-13.6)	4905	16.3 (7.3-29.7)
Nagaland	0.4 (0-0.8)	885	2 (1.4-2.7)	1852	6.3 (4.8-7.8)	1045	13.3 (10.5-16.2)	546	23.5 (18.5-28.4)	279	5.8 (5.1-6.5)	4607	63.3 (21.4-136.6)
Odisha	6.2 (5.5-6.9)	4564	11.4 (10.2-12.5)	2872	16.9 (15.3-18.6)	1992	30.7 (28-33.5)	1110	40.6 (36.5-44.6)	568	13.8 (13.2-14.4)	11106	6.5 (5.8-7.5)
Punjab	11.3 (2.7-19.9)	52	8.4 (4.8-11.9)	232	15.7 (13.1-18.3)	752	17.6 (15.5-19.6)	1278	31 (29.3-32.7)	2902	24.6 (23.4-25.7)	5216	2.7 (1.3-4.7)
Rajasthan	2.3 (1.8-2.8)	3640	4.4 (3.8-5)	4185	7.7 (6.9-8.6)	3539	11 (9.9-12.2)	2869	22.2 (20.6-23.8)	2599	8.6 (8.2-9)	16832	9.8 (7.9-12)
Tamil Nadu	30.7 (25.2-36.1)	275	25.4 (23-27.8)	1271	32.1 (30.3-34)	2524	35.7 (33.9-37.6)	2561	41.5 (38.8-44.2)	1291	34.1 (33-35.1)	7922	1.4 (1.1-1.6)
Uttar Pradesh	3 (2.7-3.3)	12937	5.3 (4.9-5.8)	10151	10 (9.4-10.7)	7534	14.1 (13.2-15)	5970	29.2 (27.9-30.4)	5159	9.4 (9.1-9.7)	41751	9.7 (8.8-10.8)
Uttarakhand	3 (1.2-4.7)	364	3.3 (2.3-4.3)	1275	7.1 (5.9-8.3)	1647	16.2 (14.2-18.2)	1308	27 (24.6-29.5)	1231	13.1 (12.2-14)	5825	9.1 (5-14.6)
West Bengal	8.6 (7.2-10)	1508	14.6 (13-16.2)	1791	28.5 (25.8-31.2)	1063	45.1 (41.4-48.8)	690	74.9 (69.7-80)	276	23.8 (22.7-25)	5328	8.7 (7.3-10.2)
Telangana	37.9 (31.1-44.8)	192	41.3 (37-45.5)	511	54.2 (50.4-58)	668	64.3 (60.7-67.9)	671	71.4 (66.9-75.9)	385	57.7 (55.8-59.7)	2427	1.9 (1.6-2.2)
Rural India	4.3 (4.2-4.5)	65664	9.5 (9.3-9.8)	55036	18.4 (18.1-18.8)	40028	25.2 (24.7-25.7)	24371	29.1 (28.3-29.9)	13149	12.8 (12.7-13)	198248	6.7 (6.4-7)
Urban India	5.8 (5-6.6)	3032	10.7 (10-11.5)	6400	20.7 (20-21.4)	11734	28.5 (27.8-29.1)	18575	38.8 (38.2-39.5)	21638	28.2 (27.9-28.6)	61379	6.7 (5.8-7.7)
India	4.4 (4.3-4.6)	68696	9.7 (9.4-9.9)	61436	19 (18.7-19.4)	51762	26.8 (26.4-27.2)	42946	35.9 (35.4-36.4)	34787	17.2 (17-17.3)	259627	8.1 (7.8-8.4)

Based on cesarean rates computed by socioeconomic quintile for the states with more than 2000 sample births. To calculate relative inequality, we divided the CS rate in the richest quintile by the CS rate in the poorest quintile. The same computations were replicated separately for rural and urban areas.

* Relative risk (inter-quintile ratio) computed as the ratio of rates in the richest and poorest quintiles
- Values are percentages of cesarean births among all births.
- States with fewer than 2000 samples births omitted

eMethods 2. Computation of the Excess, Deficit and Concentration of Cesarean Births

Following WHO latest indications, we use the values of 10 and 15% as lower and upper limits of cesarean births. We consider proportions below or above this range to represent respectively a deficit or an excess of cesarean deliveries.

The easiest way to compute any excess cesarean births would be to use the all-India rate of 17.2% and to estimate the excess above the 15% threshold as 2.1% of deliveries. This, however, ignores the considerable variations observed across regions or social groups that are documented in this paper (Table 2, eTable 2). Bihar for instance recorded a proportion of 6.2%, pointing to the presence of a significant deficit of 3.8 in a major state of India. In contrast, Kerala recorded a cesarean rate of 35.9%, pointing to a potential excess by 20.9 percentage points in this state. Cesarean rates similarly vary along a broad range according to wealth quintile or place of delivery. We also rejected the place of delivery as a criterion since the place of delivery may be as much a cause as a consequence of the delivery methods: in case of pregnancy complications, poor women may for instance be referred to a public hospital instead of delivering at home, while middle-class women in the same situation may opt for private facilities instead.

To estimate the excess or deficit of cesarean deliveries, we therefore decided to divide the NFHS-4 sample into more homogenous subgroups, using states, districts, fertility levels, and socioeconomic quintiles for that purpose. For each subgroup, we counted excess or deficit cesarean births by using the 10-15% threshold. A purely regional division (by states or districts) was abandoned as it proved unable to capture the socioeconomic variations within regional units. It may, for instance, be observed that the richest quintile in Bihar—a state with low cesarean rates—had cesarean rates close to 30%, i.e. distinctly above the 15% threshold. Inversely, the poorest quintile in Gujarat—a state with high cesarean rates—recorded a cesarean rate of 6% below the 10% threshold. The division by fertility levels also proved insufficient. The best disaggregation was obtained by dividing the NFHS-4 sample by states and socioeconomic quintiles. The resulting 180 groups (36 states x 5 quintiles) had an average 1442 births. These subgroups yielded a detailed partition of India into homogenous regional and economic subpopulations. We then computed the deficit or the excess of cesarean births in each of these 180 subgroups by using the 10-15% range.

A majority of these subgroups (97) had cesarean rates above 15%, half of them with rates greater than 30%. When cumulated over these subgroups, the excess cesarean deliveries amount to an overall excess of cesarean deliveries of 7.0% of all deliveries. In contrast, a substantial number (65) of subgroups recorded on the contrary rates below 10% and half of them less than 5%. The overall shortfall in cesarean births among them affects 2.2% of deliveries. When we restricted our computation to cesarean rates significantly different from the 10-15% range in each subgroup, we obtained an identical number of deficit and excess cesarean births. Using the estimated number of annual births in India during this period derived from United Nations

estimates and the proportion of excess and deficit cesarean deliveries, we further computed the total deficit of cesarean births at 0.5 million per year and the total excess at 1.8 million per year in 2010-16.

The division of the Indian sample into 180 subgroups was also used to draw the Lorenz concentration curve in which subgroups are ranked by increasing cesarean rates (eFigure 2). The observed distribution of cesarean deliveries (in red) can be related to the equal distribution (in blue). The curve illustrates the gap between Indian subpopulations: the less privileged 40% of births account only for 10% of all cesarean deliveries while less than 20% of the births among better-off populations account for half of the cesarean deliveries. The Gini coefficient of inequality presented in this paper was computed as the relative difference between the observed and equal distributions derived from the Lorenz curve.

eFigure 2. Lorenz Concentration Curve of Cesarean Deliveries in India, National Family Health Survey (NFHS-4), 2010-2015
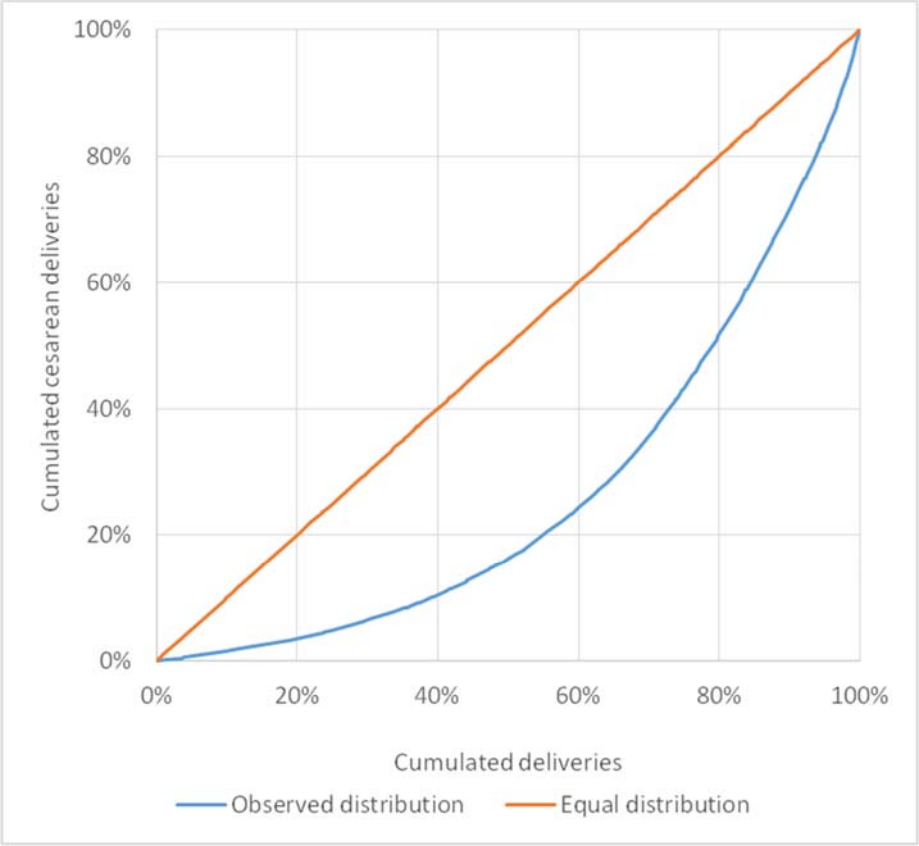
eFigure 3. Cesarean Rates and Neonatal Mortality Rates in India for States With More Than 20 Million Inhabitants, National Family Health Survey (NFHS-4), 2010-2016

Sources: NFHS-4, 2010-2016