

# The impact of institutional delivery on neonatal and maternal health outcomes: evidence from a road upgrade programme in India

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## ABSTRACT

**Introduction** Persistently high rates of neonatal and maternal mortality have been associated with home births in many low-income and middle-income countries (LMICs). However, causal evidence of the effect of institutional deliveries on neonatal and maternal health outcomes is limited in these settings.

**Methods** We investigate the effect of institutional deliveries on neonatal mortality and maternal postpartum complications in rural India using data from the 2015–2016 Indian Demographic and Health Survey and an instrumental variable methodology to overcome selection bias issues inherent in observational studies. Specifically, we exploit plausibly exogenous variation in exposure to a road upgrade programme that quasi-randomly upgraded roads to villages across India.

**Results** We find large effects of the road construction programme on the probability that a woman delivered in a health facility: moving from an unconnected village to a connected village increased the probability of an institutional delivery by 13 percentage points, with the biggest increases in institutional delivery observed in public hospitals and among women with lower levels of education and from poorer households. However, we find no evidence that increased institutional delivery rates improved rates of neonatal mortality or postpartum complications, regardless of whether the delivery occurred in a public or private facility, or if it was with a skilled birth attendant.

**Conclusion** Policies that encourage institutional delivery do not always translate into increased health outcomes and should thus be complemented with efforts to improve the quality of care to improve neonatal and maternal health outcomes in LMICs.

## INTRODUCTION

High rates of neonatal and maternal mortality persist in many low-income and middle-income countries (LMICs), with approximately 2.4 million neonatal and 293 000 maternal deaths in 2019 and 2017, respectively.<sup>1 2</sup> This issue is particularly pronounced in India, which accounts for more than 21% of global neonatal deaths and 12% of global

## WHAT IS ALREADY KNOWN ABOUT THIS SUBJECT?

- ⇒ Previous studies have identified correlations between institutional deliveries and poor maternal and health outcomes in low-income and middle-income countries but most have been unable to control for unobserved characteristics that may bias these estimates.
- ⇒ Previous studies in India have found the programmes aimed at increasing facility deliveries have led to higher rates of institutional deliveries but have failed to find an effect on health outcomes.

## WHAT ARE THE NEW FINDINGS?

- ⇒ The road construction programme greatly increased the proportion of women who gave birth in a clinic, but it did not translate into improved rates of neonatal mortality or postpartum complications.
- ⇒ The poorest women and those with lower levels of education benefited the most from the road construction programme and led to large increases in public facility deliveries.

## HOW MIGHT IT IMPACT CLINICAL PRACTICE IN THE FORESEEABLE FUTURE?

- ⇒ Policies aimed at increasing rates of institutional deliveries should also consider strengthening the quality of care or other barriers to improve neonatal and maternal health outcomes.

maternal deaths.<sup>1 2</sup> Although a number of factors contribute to high rates of neonatal and maternal mortality, the proportion births that take place at home, as opposed to a health facility, is believed to be important contributing factor.<sup>3</sup> While the proportion of institutional births in India nearly doubled from 43% in 2004 to 83% in 2014, a large number of births still take place at home, especially in rural areas and among the poor.<sup>4</sup> Increasing rates of institutional delivery is an important policy priority in India where the government has launched numerous large-scale programmes to address the problem.<sup>5 6</sup>

Past research has demonstrated that roughly 23% of neonatal and 42% of maternal deaths occur on the day of birth<sup>7</sup> and thus it is widely believed that shifting the location of delivery from home to a health facility would reduce mortality due to the availability of equipment, the presence of skilled health attendants, and overall closer proximity to other medical services. Numerous observational studies in various international contexts have shown that delivering in a health facility or in the presence of a skilled birth attendant is correlated with better outcomes.<sup>8–10</sup> However, observational studies may be subject to important selection bias. For example, if wealthier or more educated women, or conversely if sicker women with higher risk pregnancies, are more likely to give birth in a facility, then the selection of women who give birth in a facility will bias the estimated relationship between facility deliveries and health outcomes. Indeed, a pooled analysis of almost 1.5 million births recorded in household surveys from 67 LMICs found no association between institutional deliveries and early neonatal mortality (NMR) after individual and household characteristics had been taken into consideration,<sup>11</sup> suggesting there is likely selection bias based on what types of mothers give birth in health facilities.

In India, observational studies have also generated mixed results. A small prospective cohort study in Gujarat did not find any overall association between institutional deliveries and NMR in the overall sample but found a protective effect among a subsample of women.<sup>12</sup> A national-level study found that institutional deliveries, regardless of if it was in a public or private facility, reduced NMR as compared with giving birth at home.<sup>13</sup> However, using the same dataset, as well as the same dataset used in this study, another study found that women who gave birth at an institution or in the presence of a skilled provider did not have lower NMR.<sup>14</sup> The discrepancy between these studies may be the result of which characteristics were controlled for and which were not.

Therefore, it is important to overcome selection bias to better understand the association between institutional deliveries and maternal and newborn health outcomes. A few studies have attempted to overcome the bias inherent in observational studies by using quasi-experimental methods to estimate the causal effects of institutional deliveries on neonatal health outcomes but have also found mixed results. A study in the Netherlands used the distance from a mother's residence to the closest hospital as an instrument for facility delivery and found that giving birth in a hospital led to a substantial reduction in NMR.<sup>15</sup> However, rates of maternal and NMR are much lower in the Netherlands than in most LMICs. By exploiting the time of day of the birth as an instrument in Nigeria, Okeke and Chari<sup>16</sup> found that institutional deliveries reduced NMR by 10 deaths per 1000 live births, a large effect in the Nigerian context. In contrast, using a difference-in-difference approach in India, Powell-Jackson *et al*<sup>17</sup> evaluated the effects of a conditional cash transfer programme (CCT) and while they observed a 7.5 percentage point increase in institutional delivery rates, they did not observe a reduction in NMR. Godlonton and Okeke<sup>18</sup>

assessed the effect of a ban on informal birth attendants in Malawi and found no statistically significant reduction in the NMR, despite a 12 percentage point increase in institutional delivery rates. Chari and Okeke<sup>19</sup> further showed that increases in the rate of institutional delivery resulting from the randomised rollout of a government performance-based financing programme in Rwanda were also not associated with a reduction in the NMR.

Quasi-experimental studies focusing on the effects of institutional delivery on maternal health outcomes are very limited, likely due to dearth of population-level data. Okeke and Chari<sup>20</sup> found that reductions in institutional delivery rates resulting from unanticipated weather shocks led to a significant increase in the probability that mothers developed preventable postpartum complications. However, to the best of our knowledge, no other published rigorous evidence exists in an LMIC context.

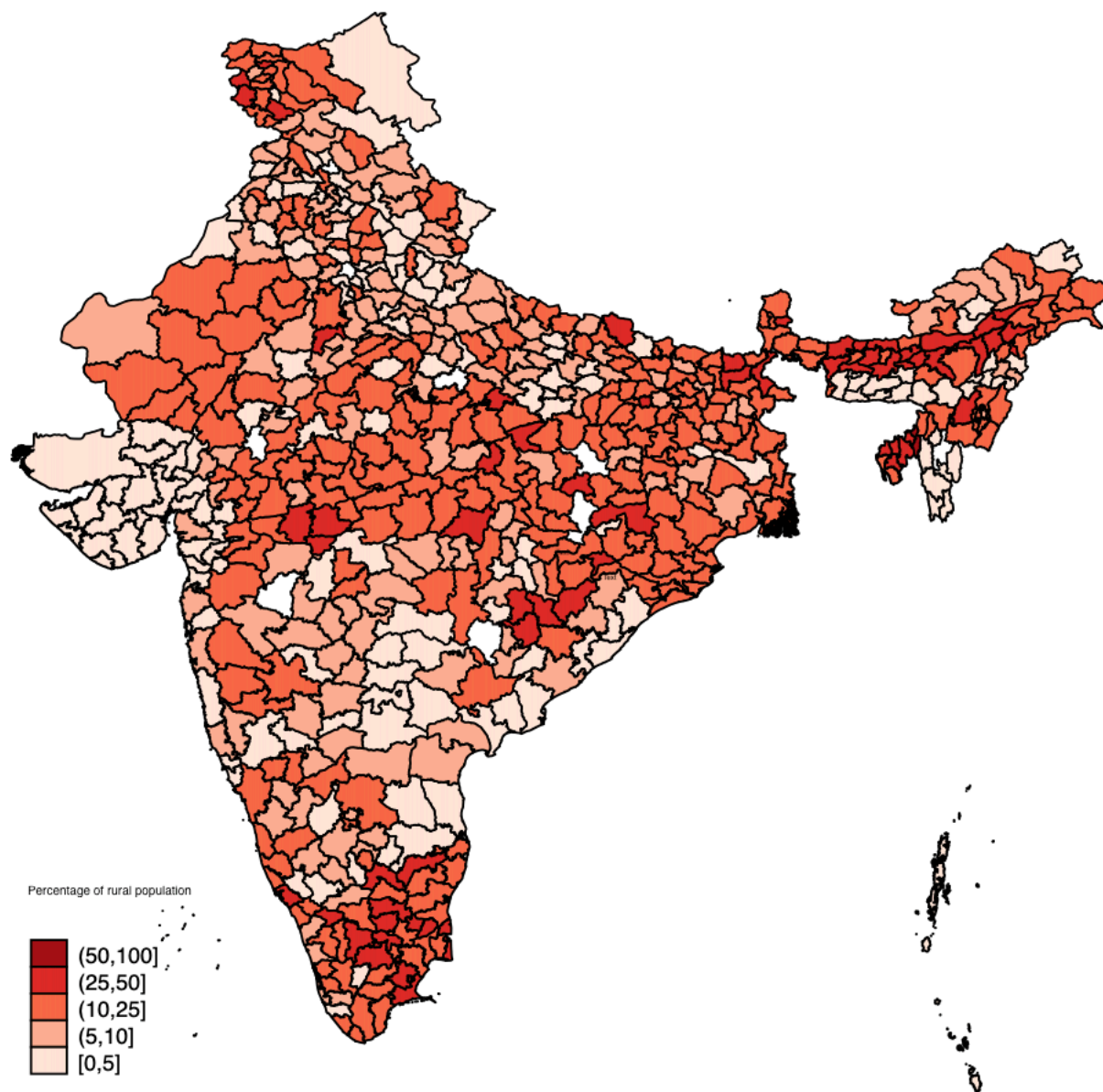
The purpose of this study is to address this research gap by estimating the causal effect of institutional delivery on neonatal and maternal health outcomes in rural India using data from the 2015–2016 Indian Demographic and Health Survey (DHS). To overcome selection bias, we exploit a large-scale road upgrade programme that quasi-randomly improved access to health facilities across rural India over time and we develop an instrumental variable (IV) strategy to estimate the causal impact of institutional deliveries on neonatal and maternal health outcomes. We further describe the programme and our methods in the next section, before presenting and discussing our findings and then providing a conclusion.

## METHODS

### The study context

The Pradhan Mantri Gram Sadak Yojana (PMGSY) programme was launched in 2000 with the goal of constructing all-weather, cross-drained roads in all eligible unconnected rural habitations in India. Habitations were defined as clusters of people that remain in the same location over time and were considered unconnected if they were located 500 m or more from an all-weather road leading to a market centre or a connected habitation. A village may consist of one or more habitations. For convenience, the terms habitation and village are used interchangeably throughout the remainder of this paper.

For an unconnected village to receive a road through the PMGSY programme, it had to meet certain eligibility criteria. Specifically, villages in Plain areas were required to have a population of 500 or more, while villages in Hill States, Desert Areas and Tribal areas were required to have a population of 250 or more. Among the villages that met these criteria, priority was first given to villages with a population of more than 1000, targeted before 2003. This was followed by villages with a population of more than 500, which were targeted to be connected by 2007. Finally, villages with a population of more than 250 were connected last. Additionally, exceptions were made if an unconnected village smaller than 250 people lay on



**Figure 1** Percentage of the rural population that received upgraded roads between 2010 and 2015 across Indian districts.

the straight path of a road that was being built to a larger village. Further, after all the previously unconnected eligible villages had been provided with all-weather roads only then were existing paved roads allowed to be upgraded to all-weather roads. During our study period, which was from 2010 to 2015, nearly 172 000 km of road connecting 58 000 villages were upgraded, and the programme was still in operation as of 2021. **Figure 1** demonstrates the geographical distribution of the population exposed to the PMGSY programme across Indian districts.

#### Data

##### Online management and monitoring system

The government of India recently mandated that all ministries implementing any large programme must make all programme data publicly available. As a result, habitation-level road upgrade data for PMGSY

is available online through <http://omms.nic.in>. The information that can be obtained includes the name of the village that received an upgrade, the name of its block, district and state as well as the road award date and the road completion date from December 2000 to March 2015 (we are grateful to Paul Novosad, Department of Economics, Dartmouth College for sharing these data). Importantly, as previously mentioned, roads were upgraded at the habitation-level, not necessarily the village-level. Consequently, there are more habitations than villages. Therefore, we consider a village to have received a new road if any habitation within that village was given a road upgrade. In the remainder of this paper, we use a road's upgrade completion date as a proxy for the date which a village was connected to the nearest town.



### Indian population census 2001

To determine a village's population, we needed to match villages in the online management and monitoring system (OMMS) with the 2001 census, which was used by PMGSY to determine a village's eligibility for the programme. To do so, we used a two-stage matching strategy. First, we matched villages using their unique village ID, assigned in the 2001 population census,<sup>21</sup> which was available for approximately 80% of villages in the OMMS database. Second, all remaining villages were matched based on the village name using a machine learning algorithm. As village names can be worded differently between OMMS data and census data, we first trained an algorithm using village names with IDs and then used the algorithm to match villages without IDs. This method allowed us to match 52% of villages without IDs, increasing the total number of matched villages to 90%. The directory of village amenities has information on the population of villages, distance to nearest town and the existence of primary schools, high schools, adult literacy schools, primary health centres, maternity centres, commercial banks, post offices, phones and a power supply within the village.

### DHS of India 2015–2016

Data on health outcomes were sourced from the 2015–2016 Indian DHS.<sup>22</sup> The DHS contains information on all births that occurred less than 5 years from the date of the survey (2010–2016) among the sample of reproductive aged women respondents. These dates, therefore, restrict the period of our analysis. The DHS sample was selected using a two-step process, wherein EAs were first randomly sampled from census files and then households were randomly selected from a list of all the households within each EA. We constrained our sample to women residing in rural areas who gave birth between December 2010 and March 2015, reflecting the period in which we have PMGSY programme data. The Indian DHSs uses country-specific criteria to define urban vs rural areas of residence, namely urban areas are defined as those with 'a municipality, corporation, cantonment board or notified town area committee' or a location that has a minimum population of at least 5000 inhabitants, at least 75% of the adult male population engaged in non-agricultural pursuits, and a population density of at least 400 per km<sup>2</sup>.<sup>23</sup> Given these definitions, it is likely that all area targeted by the road construction programme (villages with population of 250 or less) during our study period would be considered rural although it is not possible to exactly map each village.

Our selection of neonatal and maternal health outcomes was limited to the data available in the DHS. To capture neonatal health outcomes, we selected two mortality measures: 7-day (early NMR) and 28-day NMRs. Unfortunately, the DHS collects limited data on maternal health outcomes, but it does collect data on the postpartum complications mothers experienced during their last birth, including vaginal bleeding and a high

fever within the first 2 months post partum. Assuming women with more postpartum complications have worse outcomes, we used these as a proxy for poor maternal health outcomes. It is not possible measure maternal mortality directly using data collected from mothers who survived childbirth, and the 2015–2016 Indian DHS did not collect sibling survival data, so it was not possible for us to measure maternal mortality in this study.

For each birth, women were requested to provide detailed information about the place of birth. They were specifically asked if the birth was in a health facility, and if yes, where the birth took place (eg, public hospital, other public health facilities or private hospitals) and whether the birth was assisted by a skilled birth attendant. They were also asked about the characteristics of their child (eg, if a twin, the sex, the birth order and the size of the neonate at birth), their own characteristics (eg, age at delivery, education level, contraceptive use, insurance status, smoking behaviour, body mass index, history of miscarriage, abortion or stillbirth, religion and if she belongs to a scheduled caste or tribe) along with the characteristics of their household (wealth index and if the household had electricity). We used these characteristics as control variables in our estimation of the effects of institutional delivery on neonatal and maternal health outcomes. In latter specifications, we use some of these variables to test whether institutional delivery has had any differential impact among subgroups.

Our primary variable of interest is institutional delivery, however, using data from the DHS we also tested additional specifications using related variables, which may provide some insights into the mechanism of the relationship between institutional delivery and neonatal and maternal outcomes. We defined an institutional delivery as any birth that was not reported to have taken place at home, which in India may include both public (hospital, dispensary, urban health centre, urban health post, urban family welfare centre, community health centre, primary health centre, subcentre or other public facility) or private facilities (hospital, maternity home, clinic, a Non-Governmental Organisation (NGO) or trust hospital or clinic, or other private facility). We also estimated the impact of hospital deliveries (ie, public hospital, other public health facility or private hospital) on health outcomes. In addition, we estimated the impact of skilled birth attendance, which have also been shown to be important in health outcomes,<sup>24</sup> which was defined in the Indian DHS as giving birth in the presence of a doctor, auxiliary nurse midwife, a nurse, midwife, female health visitor or other health personnel. And lastly, we demonstrated the effect of a road upgrade on delivery via caesarean section and explored if change in delivery via caesarean section affected health outcomes.

### GIS codes

The DHS survey contains Geographic Information System (GIS) codes for each EA included in the survey. To maintain the respondent's confidentiality, the latitude and

longitude positions of all EAs were randomly displaced. In rural areas, this displacement was between 0 and 5 km, and 1% of the rural clusters were displaced between 0 and 10 km. The displacement does not allow us to exactly match EAs in DHS and villages in OMMS dataset. But, we obtained GIS codes of all villages in 2001 population census of India through the Harvard Geospatial Library, which were gathered by ML InfoMap company.<sup>25</sup> The Database of Global Administrative Areas (GADM) provides the polygon of subdivision of India at the town level.<sup>26</sup> A town is a place with a municipality, corporation, cantonment board or notified town area committee. A town usually contains a centre and some villages around it. We used these GIS codes to match clusters and villages that are in a town. Therefore, our data are at the town-level.

### Empirical strategy

The goal of this paper is to estimate the effect of the location of delivery on neonatal and maternal health outcomes. The structural equation of interest is represented by the following equation:

$$y_{ijt} = \beta_0 + \lambda_j + \delta_t + \gamma_\tau + \beta_1 Institutional_{ijt} + X_{ijt}\beta_2 + \xi_{ijt} \quad (1)$$

Where subscript  $i$  denotes an individual (neonate or mother, depending on the outcome of interest),  $j$  denotes town,  $t$  denotes month of birth,  $\tau$  denotes year of birth,  $y$  is an outcome variable capturing the health outcome of the neonate or mother, *Institutional* is a dummy variable indicating if the birth occurred at a health facility,  $\lambda$  is a set of town fixed effects,  $\delta$  is a set of month of birth fixed effects,  $\gamma$  is a set of year of birth fixed effects, and  $X$  is a vector of individual-level control variables.

The coefficient of interest,  $\beta_1$ , captures the average differences in the health outcomes of neonates and mothers for whom delivery occurred in a health facility compared with those whose births took place at home, controlling for observed mother, neonate and household-level characteristics. An ordinary least square (OLS) regression would provide a biased estimate of  $\beta_1$  due to endogeneity in the choice of birth location as high-risk mothers, or conversely wealthier or more educated women, may be more likely to deliver in a health facility. To address this endogeneity problem, we utilised an IV approach, which we have described below.

As the DHS data can only be identified at the town-level (aggregating birth outcomes of all villages within a town), we matched our health data to data on road upgrades at the town-level rather than the village-level. We created an IV that represents the intensity of road upgrades in each town, which we have defined as the cumulative percentage of each town's baseline rural population that had been connected to the nearest town through the PMGSY programme. To generate this variable, we used data from the 2001 Indian census, which provides information on the total population of all connected and unconnected villages. We also used the OMMS database, which has information on the villages

that had road upgrades 2010–2015. We calculated the cumulative percentage of treated population in a town by dividing the total population of the connected village up until the month of birth by the total population of all the villages in that town. As a result, our first stage estimation equation is given by:

$$Institutional_{ijt} = \alpha_0 + \lambda_j + \delta_t + \gamma_y + \alpha_1 SRC_{jt} + X_{ijt}\alpha_2 + \zeta_{ijt} \quad (2)$$

Where  $SRC_{jt}$  is an IV that captures the cumulative percentage of population in each town that had been connected to the nearest town by the month of birth in question, and  $\alpha_1$  captures the marginal effect of a road upgrade after that month. All Standard Errors (SEs) were clustered at the townlevel.

In online supplemental appendix section 1, we explore the validity of our IV strategy by first demonstrating that PMGSY programme in fact lead to significant increases in the probability that a village had been upgraded. We then discussed the validity of the IV strategy by also exploring the validity of our exclusion restriction.

The IV method provides consistent estimates if the instrument satisfies the relevance, the excludability and the monotonicity conditions. In online supplemental appendix section 1, we explored both the relevance and excludability assumptions of our instrument and concluded that our approach provides a valid instrument for institutional deliveries. We used the quasi-randomised assignment of roads as an instrument for delivery in health facilities based on the assumption that these roads may reduce the transportation cost of going to a hospital. Our IV strategy identifies the local average treatment effect (LATE) for mothers who gave birth in a health facility because of their village receiving a road, these same mothers would have given birth at home without the road upgrade.

## RESULTS

### Descriptive statistics

**Table 1** describes the characteristics of our sample. In total, after matching the OMMS, 2001 Indian census and DHS data, we were able to obtain information on 109 303 mothers and 159 570 neonates. In another words, the level of our analysis is at the mother and neonate levels. The descriptive statistics of all variables are provided for the full sample of women included in the study, which are all births in the DHS that occurred in a rural area between 2010 and 2015, and then separately for those who delivered in an institution and those who delivered at home.

Panel A of **table 1** shows the outcome variables: neonatal health outcomes (7-day and 28-day NMRs) and maternal health outcomes: if the mother had heavy vaginal bleeding (bleeding) or a very high fever (fever) in the first 2 months after delivery. The average 7-day and 28-day NMRs in the full sample were 2.6% and 3.1%, respectively, and mortality rates were higher among women who delivered at home compared with women who delivered in an institution. The postpartum

**Table 1** Descriptive statistics for the baseline estimation model

	Full sample		Institutional delivery		Home delivery	
	Mean	SD	Mean	SD	Mean	SD
Panel A. Outcome variables						
7-day death	0.026	0.159	0.024	0.155	0.029	0.168
28-day death	0.031	0.173	0.029	0.168	0.036	0.186
Postpartum complication (bleeding)	0.188	0.391	0.193	0.395	0.174	0.379
Postpartum complication (fever)	0.161	0.368	0.157	0.363	0.173	0.378
Panel B. Place of delivery						
Institutional delivery	0.712	0.453	–	–	–	–
Delivered in public hospitals	0.212	0.409	–	–	–	–
Delivered in other public health facility	0.341	0.474	–	–	–	–
Delivered in private hospitals	0.152	0.359	–	–	–	–
Panel C. Birth attendant						
Delivered with a skilled attendant	0.742	0.438	0.974	0.161	0.168	0.374
Delivered with a doctor attendant	0.634	0.482	0.958	0.201	0.076	0.265
Delivered with a nurse attendant	0.532	0.499	0.933	0.249	0.108	0.310
Panel D. Neonate's characteristics						
Multiple birth	0.016	0.126	0.017	0.130	0.013	0.114
Male	0.519	0.500	0.524	0.499	0.506	0.500
First birth	0.347	0.476	0.403	0.490	0.210	0.408
Delivery order	2.390	1.570	2.140	1.380	3.000	1.820
Born smaller than average	0.124	0.329	0.120	0.326	0.131	0.337
Panel E. Mother's characteristics						
Age at delivery	24.500	5.090	24.100	4.780	25.500	5.670
Younger than 20	0.217	0.412	0.231	0.422	0.183	0.387
21–25	0.431	0.495	0.446	0.497	0.393	0.488
26–30	0.225	0.418	0.219	0.413	0.242	0.428
31–35	0.089	0.284	0.077	0.266	0.117	0.322
36–40	0.029	0.168	0.022	0.146	0.047	0.212
41–45	0.009	0.092	0.005	0.072	0.017	0.129
46–49	0.001	0.026	0.000	0.021	0.001	0.035
Education (years)	5.270	4.870	6.110	4.920	3.200	4.060
Illiterate	0.371	0.483	0.302	0.459	0.542	0.498
Primary	0.156	0.363	0.147	0.355	0.178	0.383
Secondary	0.417	0.493	0.478	0.500	0.266	0.442
Higher	0.056	0.230	0.073	0.260	0.014	0.117
Using modern contraceptive	0.325	0.468	0.351	0.477	0.259	0.438
Is insured	0.140	0.347	0.146	0.353	0.123	0.328
Smoke	0.103	0.303	0.081	0.273	0.155	0.362
BMI	2087	454	2103	456	2046	447
Had previous miscarriage	0.061	0.239	0.065	0.247	0.050	0.218
Had previous abortion	0.025	0.155	0.027	0.163	0.018	0.132
Had previous stillbirth	0.009	0.096	0.009	0.095	0.010	0.097
Religion						
Hindu	0.756	0.430	0.800	0.400	0.647	0.478
Muslim	0.137	0.343	0.117	0.322	0.184	0.388
Christian	0.070	0.255	0.044	0.206	0.134	0.340

Continued

Table 1 Continued

	Full sample		Institutional delivery		Home delivery	
	Mean	SD	Mean	SD	Mean	SD
Sikh	0.015	0.122	0.019	0.138	0.004	0.066
Buddhist/neo-Buddhist	0.009	0.094	0.009	0.095	0.008	0.091
Other	0.014	0.116	0.010	0.100	0.022	0.148
Belong to caste or tribe						
Caste	0.787	0.409	0.828	0.377	0.687	0.464
Tribe	0.170	0.375	0.129	0.335	0.270	0.444
No caste/tribe	0.043	0.203	0.430	0.203	0.403	0.203
Panel F. Household characteristics						
Wealth index	2.290	1.229	2.502	1.259	1.768	0.969
Has electricity	0.804	0.397	0.850	0.357	0.690	0.463
Panel G. Pregnancy health indicators						
Convulsion during pregnancy	0.182	0.386	0.180	0.384	0.186	0.389
Swelling during pregnancy	0.302	0.459	0.311	0.463	0.277	0.448
Received supplementary nutrition	0.807	0.395	0.823	0.382	0.749	0.433
Panel H. Received pregnancy services						
Received antenatal care	0.538	0.499	0.607	0.488	0.368	0.482
No of antenatal cares received	3.224	8.606	3.808	9.003	1.775	7.267
Received postnatal care	0.345	0.476	0.377	0.485	0.257	0.437
Panel I. Delivery health indicators						
Prolonged delivery	0.416	0.493	0.438	0.496	0.352	0.478
Bleeding during delivery	0.333	0.471	0.347	0.476	0.295	0.456
Caesarean delivery	0.103	0.304	0.145	0.352	0	0
Observations: Neonates	159570		113614		45956	
Observations: Mothers	109303		80578		28725	

Note: The DHS only collects data on maternal outcomes for the last birth but contains information on neonatal outcomes for all births from 2010 to 2016. The data in this table contain all DHS data that the delivery occurred in rural area and we were able to match it with OMMS 2001 Indian census.

BMI, body mass index; DHS, Demographic and Health Survey; OMMS, online management and monitoring system.

complications rates were 18.8% for bleeding and 16.1% for fever, and these rates were lower in the home delivery setting for the former and higher for the latter. Panel B summarises the place of delivery. In our sample, 71.2% of deliveries took place in an institution with public health facilities being the most common location. Only a small share of women, 15.2%, delivered in a private hospital.

Panel C of table 1 summarises data on the provider present at the time of delivery. Skilled attendance was defined as a doctor or nurse assisted delivery. We have also presented delivery with doctors and nurses separately. Delivery with a skilled attendant was highly correlated with institutional delivery as more than 90% of institutional deliveries occurred in the presence of a skilled attendant, whereas in a home delivery setting, only 16.8% of births occur in the presence of a skilled attendant.

In panels D, E and F of table 1, we presented data on the neonate, mother and household characteristics, respectively. The institutional deliveries were higher for multiple births, first births and births of lower birth

orders, as well as for male neonates. Younger mothers were more likely to deliver in a hospital setting as well as mothers with higher levels of education. Interestingly, a history of previous stillbirth was not associated with the place of birth. Religion was also found to be an important factor, with Hindu mothers more likely to deliver in an institutional setting than other women. Lastly, women who delivered at home were generally from poorer households and were less likely to have electricity at home.

Panels G, H and I of table 1 illustrate data related to pregnancy and delivery. The rates of experiencing convulsion during pregnancy were similar among women delivered in an institutional setting and those who delivered at home. However, women who delivered in a health institution were more likely to experience swelling during pregnancy. Women who delivered in a health institution were also more likely to receive supplementary nutrition from an Anganwadi/Integrated Child Development Scheme (ICDS) centre, which provides supplementary food to underprivileged groups, including pregnant women. In



**Table 2** Neonatal and maternal health outcomes, institutional delivery and road upgrade

	7-day death	28-day death	Postpartum complication (bleeding)	Postpartum complication (fever)
Panel A. OLS (dependent variable: neonatal and maternal health outcomes)				
Institutional delivery	0.0007	-0.0005	0.0017	0.0064*
	(0.0011)	(0.0012)	(0.0035)	(0.0033)
Panel B. First stage (dependent variable: Institutional Delivery)				
Cum. perc. of treated pop.	0.1261†	0.1261†	0.1084†	0.1084†
	(0.0270)	(0.0270)	(0.0275)	(0.0275)
F-statistic	22.1000	22.1000	15.9234	15.9234
R-squared	0.2522	0.2522	0.2588	0.2588
Panel C. Reduced form (dependent variable: neonatal and maternal health outcomes)				
Cum. perc. of treated pop.	-0.0062	-0.0045	0.0162	-0.0261
	(0.0055)	(0.0061)	(0.0219)	(0.0191)
Panel D. Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Institutional delivery	-0.0494	-0.0356	0.1492	-0.2406
	(0.0456)	(0.0496)	(0.2044)	(0.1896)
Observations	159570	159570	109303	109303
Mean fraction institutional delivery	0.7121	0.7121	0.7378	0.7378
Mean fraction health outcome	0.0262	0.0314	0.1886	0.1612

Note: Each column in each panel lists estimates from separate regressions. All regressions control for month of birth, year of birth, town fixed effects, neonate characteristics (if the birth is a multiple birth, the sex of the neonate, if the birth is the birth and birth order), mother characteristics (age at delivery (categorical variable), education level (categorical variable), using modern contraceptives, being insured, smoking behaviour, BMI, having a previous miscarriage, abortion or stillbirth, religion, if the mother belongs to a caste and tribe), and household characteristics (wealth index, if the household has electricity). The F-statistic corresponds to a test of significance of the instrumental variable. The instrumental variable is the cumulative percentage of treated population (population that gained access to a paved road) in a town. Robust SEs clustered at the town level are shown in parentheses.

\*Significant at the 10 percentage level.

†Significant at the 1 percentage level.

BMI, body mass index; OLS, ordinary least square.

addition, receiving pregnancy care was correlated with the place of delivery: women who delivered in a health institution were more likely to receive antenatal and postnatal care. But prolonged delivery and bleeding during delivery were more common among women who delivered in an institutional setting. The last row in panel I of [table 1](#) shows that the probability of receiving a caesarean section is 15% among women who delivered in a health centre.

### Baseline estimations

[Table 2](#) shows the results of the baseline estimations after controlling for the month and year of birth and town-level fixed effects, as well as the neonate, maternal and household characteristics. Panel A reports the OLS estimation results, which suggest that institutional delivery was not associated with the NMR or postpartum bleeding but was associated with higher postpartum fever after delivery by 0.6 percentage points.

Panel B of [table 2](#) provides results from the first stage of the IV estimation, demonstrating that exposure to the road upgrade programme increases the probability of a mother delivering at a healthcare institution. Specifically,

moving from an unconnected village to a connected village increases the probability of institutional delivery by 12.6 percentage points for our neonate health outcomes sample and by 10.8 percentage points for the maternal health outcomes sample. The F-statistics for a test of significance of the cumulative share of the treated population is equal to 22 and 16 for the neonate and mother samples respectively, indicating a strong instrument. Panel C of [table 2](#) presents the reduced form relationship between the outcome variables and the instrument. The results show no significant relationship between the cumulative share of treated population and the outcome variables. Panel D of [table 2](#) presents the IV estimations. The IV estimation results do not show a significant effect of institutional delivery on NMR or maternal postpartum complications. The coefficients for 7-day and 28-day mortality in the IV estimation are negative and larger than the OLS coefficients, but they are not statistically significant. In online supplemental appendix section 2, we conducted a power calculation to ensure that we had sufficient sample to calculate the impact of the programme on neonate and maternal outcomes and concluded that we do.



We also conducted a set of robustness checks on our baseline estimates, presented in online supplemental appendix. First, we tested whether our IV approach is associated with increases in birth outcomes in urban areas that were not targeted by the PMGSY programme, and we find zero impact of the programme on institutional delivery rates (for the urban population). This further strengthens our finding that the PMGSY was responsible for the observed increases in institutional deliveries in our sample (for the rural population). Second, we conducted robustness checks about our identifying assumption of distance to closest town as the mechanism of action for the PMGSY programme. We found that the effect of the programme increases as distance to the nearest town increases but there are less programme effects after 20 km. This finding would be consistent with distance and travel costs being important barriers to facility delivery, barriers that were minimised by PMGSY programme.

### Birth attendance and health outcomes

Greater road connectivity may also increase the probability of skilled birth attendants to be present at non-institutional deliveries, and there is evidence that greater skilled delivery rates may also be an important independent predictor of neonate and maternal outcomes as well.<sup>27</sup> For these reasons, we also explored the impact of the PMGSY programme on skilled attendance rates and estimate its impact using the same IV strategy.

The results of the IV estimations, presented in panel A of [table 3](#), demonstrate that the road upgrade also increases the probability of a mother delivering with a skilled birth attendant (eg, a midwife, nurse or doctor). Specifically, moving from an unconnected village to a connected village increases the probability of having a skilled birth attendant by 11.7 percentage points for the sample of neonates and by 9.8 percentage points for the sample of mothers, with F-statistics of 21 and 15, respectively. Importantly, the IV estimation results do not show a significant effect of the presence of a formal birth assistant on NMR or maternal postpartum complications. This result is not surprising as the presence of a skilled birth attendant and institutional delivery are highly correlated (see [table 1](#), over 97% of women in our sample who gave birth in a facility also gave birth in the presence of a skilled attendant).

Panels B and C investigate the effect of the presence of doctors and nurses individually on neonate and maternal health. For both, it was found that road upgrade was associated with an increase in the presence of a skilled birth attendant; by 11.5 and 9.6 percentage points for the neonate and mother samples, respectively, for doctors, and by 14.1 and 11.7 percentage points for nurses. However, neither the increased presence of doctors nor nurses at births were associated with reduced NMR or maternal postpartum complications.

In online supplemental appendix section 3, we also explored the effect of the specific location of delivery,

particularly whether giving birth in public hospitals, other public facilities or private facilities had different effects. Our results showed that moving from an unconnected to a connected village increases the probability of delivering in a public hospital by 16 percentage points, in other public health facilities by 12 percentage points, and in a private hospital by 6 percentage points. But, the F-tests for the latter two types of location was low and suggesting that the IV was not a strong instrument for facilities, which were not public hospitals. Similar to before, we found that the location of institutional delivery was not associated with neonatal or maternal health outcomes.

### Impact on caesarean sections

Caesarean sections are usually only provided in health facilities, therefore an increase in facility deliveries could also be associated with an increase in caesarean sections. We tested this in [table 4](#), which demonstrates the effect of road upgrade on delivery via caesarean section. In panel A, it was found that moving from an unconnected to a connected village increased the probability that a woman received a caesarean section by approximately 4 percentage points. This is a relatively large increase given that the mean caesarean section rate in the sample was only 10%, and that this effect was statistically significant. In the second stage, presented in panel B, we tested the impact of increase caesarean section rates on NMR and maternal health outcomes, but found no statistically significant association with any of the outcomes.

### Subgroup analysis

We further investigated which subgroups benefited the most from the road upgrade programme using two socio-economic variables: the wealth index and the education level of the mother. The results of the IV estimation of institutional delivery on neonatal and maternal outcomes within these subgroups are reported in [table 5](#).

Panel A demonstrates that women belonging to the poorest wealth quintile experienced the greatest increases in institutional deliveries because of the road upgrade programme. There was a 26 percentage point increase in the probability of delivering in an institution for this group, compared with an approximately 22, 15 and 6 percentage points increase for women in the poor, middle and rich wealth quintiles. No significant differences in delivery behaviour were observed for mothers in the richest wealth quintile (the baseline group).

With regard to the education level, moving from an unconnected to a connected village appeared to benefit illiterate women the most, increasing the likelihood of institutional delivery by approximately 29 percentage points. This was followed by women who attained primary and secondary education, for whom the increase was around 24 and 15 percentage points, respectively. Interestingly, women who had a higher level of education experienced an 8 percentage point decrease in the probability of institutional delivery from the road upgrade programme (the baseline group).

**Table 3** Neonatal and maternal health outcomes and delivery by skilled health workers

	7-day death	28-day death	Postpartum complication (bleeding)	Postpartum complication (fever)
Panel A. Delivery with skilled assistance				
First stage (dependent variable: delivery with skilled assistance)				
Cum. perc. of treated pop.	0.1171*	0.1171*	0.0975*	0.0975*
	(0.0255)	(0.0255)	(0.0254)	(0.0254)
F-statistic	21.1000	21.1000	14.7776	14.7776
R-squared	0.2262	0.2262	0.2309	0.2309
Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Delivery with skilled assistance	-0.0504	-0.0341	0.1537	-0.2625
	(0.0489)	(0.0534)	(0.2263)	(0.2102)
Mean fraction skilled assistance	0.7414	0.7414	0.7657	0.7657
Mean fraction health outcome	0.0262	0.0314	0.1886	0.1612
Panel B. Delivery with doctor assistance				
First stage (dependent variable: Delivery with doctor assistance)				
Cum. perc. of treated pop.	0.1147*	0.1147*	0.0963*	0.0963*
	(0.0292)	(0.0292)	(0.0286)	(0.0286)
F-statistic	15.4854	15.4854	11.3185	11.3185
R-squared	0.3387	0.3387	0.3459	0.3459
Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Delivery with doctor assistance	-0.0316	-0.0102	0.2620	-0.2515
	(0.0588)	(0.0625)	(0.2614)	(0.2363)
Mean fraction doctor assistance	0.6332	0.6332	0.6699	0.6699
Mean fraction health outcome	0.0262	0.0314	0.1909	0.1563
Panel C. Delivery with nurse assistance				
First stage (dependent variable: delivery with nurse assistance)				
Cum. perc. of treated pop.	0.1413*	0.1413*	0.1171*	0.1171*
	(0.0364)	(0.0364)	(0.0397)	(0.0397)
F-statistic	15.0774	15.0774	8.7123	8.7123
R-squared	0.2263	0.2263	0.2337	0.2337
Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Delivery with nurse assistance	-0.0546	-0.0129	-0.1073	-0.3008
	(0.0611)	(0.0651)	(0.2331)	(0.2414)
Mean fraction nurse assistance	0.5318	0.5318	0.5515	0.5515
Mean fraction health outcome	0.0288	0.0347	0.1813	0.1759

Note: Each column in each panel lists estimates from separate regressions. All regressions control for month of birth, year of birth, town fixed effects, neonate characteristics (if the birth is a multiple birth, the sex of the neonate, if the birth is the birth and birth order), mother characteristics (age at delivery (categorical variable), education level (categorical variables), using modern contraceptives, being insured, smoking behaviour, BMI, having a previous miscarriage, abortion, or stillbirth, religion, if the mother belongs to a caste and tribe) and household characteristics (wealth index, if the household has electricity). The F-statistic corresponds to a test of significance of the instrumental variable. The instrumental variable is the cumulative percentage of treated population (population that gained access to a paved road) in a town. Robust SEs clustered at the town level are shown in parentheses.

\*Significant at the 1 percentage level.

BMI, body mass index.

The IV estimations considering only the wealth index and education groups did not show different results compared with reported results for the whole population. Test results for the differences in institutional delivery as a result of the road upgrade across wealth index and educational groups are reported in online supplemental appendix section 1.

## DISCUSSION

Despite recent efforts to address high rates of neonatal and maternal mortality, including large scale programmes aimed at incentivising institutional deliveries in India, progress has remained suboptimal in many LMICs. Although many factors contribute to these mortality rates, the persistence of home births are believed to

**Table 4** Neonatal and maternal health outcomes and caesarean delivery

	7-day death	28-day death	Postpartum complication (bleeding)	Postpartum complication (fever)
Panel A. First stage (dependent variable: caesarean delivery)				
Cum. perc. of treated pop.	0.0397*	0.0397*	0.0319†	0.0319†
	(0.0129)	(0.0129)	(0.0152)	(0.0152)
F-statistic	9.5664	9.5664	4.3543	4.3543
R-squared	0.1615	0.1615	0.1626	0.1626
Panel B. Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Caesarean delivery	-0.1589	-0.1088	0.4731	-0.8079
	(0.1473)	(0.1606)	(0.7428)	(0.7068)
Mean fraction caesarean delivery	0.1038	0.1038	0.1200	0.1200
Mean fraction health outcome	0.0262	0.0314	0.1886	0.1612

Note: Each column in each panel lists estimates from separate regressions. All regressions control for month of birth, year of birth, town fixed effects, neonate characteristics (if the birth is a multiple birth, the sex of the neonate, if the birth is the birth and birth order), mother characteristics (age at delivery (categorical variable), education level (categorical variable), using modern contraceptives, being insured, smoking behaviour, BMI, having a previous miscarriage, abortion and stillbirth, religion, if the mother belongs to a caste and tribe), and household characteristics (wealth index, if the household has electricity). The F-statistic corresponds to a test of significance of the instrumental variable. The instrumental variable is the cumulative percentage of treated population (population that gained access to a paved road) in a town. Robust SEs clustered at the town level are shown in parentheses.

\*Significant at the 1 percentage level.

†Significant at the 5 percentage level.

BMI, body mass index.

be an important contributor to the burden of disease. Using data from the 2015–2016 Indian DHS and an IV approach, we observed large and statistically significant increases in institutional deliveries in rural India attributable to a government road upgrade programme. Women living in areas more exposed to the programme were more likely to travel to and deliver their babies at a clinic, likely due to a reduction in transportation costs and barriers. Notably, it was poor, illiterate women who benefited the most from this programme. Deliveries in public hospitals increased more than in other types of health facilities. The programme also led to important increases in the proportion of women who gave birth in the presence of a skilled birth attendant and it also increased the probability that they delivered their babies via a caesarean section. Yet, despite all these improvements, we do not observe any improvement in the neonatal or maternal health outcomes we investigated.

Our results are consistent with previous studies that used quasi-experimental studies to investigate the impact of institutional deliveries on outcomes in India and other international contexts.<sup>6 15 16 18–20 28</sup> Unlike our study, many of these other studies evaluated programmes that were specifically aimed at increasing the demand for institutional delivery services through targeted financial incentives.<sup>29</sup> In India, the large scale JSY programme has been previously evaluated and while it was found that the programme was associated with increased rates of institutional delivery, the programme was not consistently associated with health improvements, possibly due to poor quality of care,<sup>17 30</sup> a finding which has been supported

by complimentary qualitative studies.<sup>31 32</sup> Similarly, evaluations of the impact of CCT programmes on the use of maternal health services in other contexts<sup>29 33 34</sup> as well as evaluations of other approaches to increase institutional deliveries, such as vouchers and other financial incentives<sup>6 17 28 34–37</sup> have similarly found that while these programmes can lead to important improvements in rates of institutional deliveries, it is difficult to demonstrate improvements in neonatal or maternal mortality, due to small samples, methodological challenges or poor quality of care. As the PMGSY programme was unlikely to have led to improvements in facility quality, it may be the case that it was an important factor that limited increases in institutional deliveries from translating into improved health outcomes. A recent study using the same dataset also found no association between rates of institutional delivery and NMR in Indian districts with lower quality of care.<sup>38</sup>

Our identification strategy, which employs an IV strategy only identifies the LATE, may also potentially explain the lack of an observed effect. If women who are high risk for poor neonatal or maternal outcomes are already delivering in a clinic, then we might not expect there to be much of an effect in our sample. There is, however, a need to better understand why increased institutional deliveries and increased use of other maternal health services did not appear to translate into improvements in health outcomes.

Our study also points to the importance of overcoming transportation barriers to increase rates of institutional deliveries. Transportation has been shown to be an

**Table 5** Institutional delivery across wealth index and educational groups

	Institutional delivery
Panel A. Institutional delivery based on wealth index quintile	
Cum. perc. of treated pop.	-0.0568 (0.0350)
Cum. perc. of treated pop. ×dummy for poorest	0.2578* (0.0382)
Cum. perc. of treated pop. ×dummy for poor	0.2186* (0.0275)
Cum. perc. of treated pop. ×dummy for middle	0.1499* (0.0184)
Cum. perc. of treated pop. ×dummy for rich	0.0636* (0.0099)
Panel B. Institutional delivery based on education level of the mother	
Cum. perc. of treated pop.	-0.0784† (0.0346)
Cum. perc. of treated pop. ×dummy for illiterate	0.2940* (0.0295)
Cum. perc. of treated pop. ×dummy for primary	0.2442* (0.0303)
Cum. perc. of treated pop. ×dummy for secondary	0.1490* (0.0221)
Mean fraction institutional delivery	0.712
Note: Each panel lists estimates from separate regressions. All regressions control for month of birth, year of birth, town fixed effects, neonate characteristics (if the birth is a multiple birth, the sex of the neonate, if the birth is the first birth, and birth order), mother characteristics (age at delivery (categorical variable), education level (categorical variable), using modern contraceptives, being insured, smoking behaviour, BMI, having a previous miscarriage, abortion or stillbirth, religion, if the mother belongs to a caste and tribe), and household characteristics (wealth index, if the household has electricity). Robust SEs clustered at the town level are shown in parentheses. *Significant at the 1 percentage level. †Significant at the 5 percentage level. BMI, body mass index.	

important barrier to accessing health services in many LMIC contexts.<sup>39</sup> Kesterton *et al*<sup>40</sup> categorise the distance to a facility and the lack of transportation key inhibitors of health utilisation of pregnant women in rural India. Kumar *et al*<sup>41</sup> found that each additional kilometre from the nearest health facility was associated with a 4.4% decline in the probability of institutional delivery. Women in rural areas in India have been shown to pay twice as much as those in urban areas to travel to clinics to give birth.<sup>42</sup> Beyond our study, there is limited evidence of the effectiveness reducing transportation barriers on the use of health services and the improvements in

health outcomes in any international context, although one randomised study in Kenya found that small CCT, labelled as transportation subsidies, were effective at increasing institutional deliveries.<sup>34</sup>

While this study represents one of the more rigorous studies to investigate the impact of institutional deliveries on neonatal and maternal health outcomes in any international context, including India, it is not without limitations. First, due to data limitations, our instrument was defined as the proportion of villages in a town that had roads upgraded and not whether a specific woman had received an upgraded road. This limitation is likely to introduce some measurement error into our estimates; however, it is unlikely to bias our estimates. Second, as we were limited by data, we only investigated a small number of potential health outcomes that could be influenced by institutional deliveries. Third, our data were sourced from a household survey which might be subject to recall bias and other common forms of measurement error, such as social desirability bias. Finally, our dataset covers a period of 10 years after the initiation of the PMGSY programme. As such, in our sample most of the villages with 1000 or more inhabitants had already received an upgraded road and our results are driven from villages with 500 or more inhabitants. It is entirely possible that our results would have been different had we been able to also estimate the impact of the population size rule of the programme for all women exposed to the programme.

## CONCLUSION

We found that the PMGSY programme was associated with an increase in the probability of giving birth in a health facility by approximately 11–13 percentage points, and that the programme led to a larger increase in deliveries in public hospitals relative to other types of facilities. But we found no evidence to suggest that increased institutional delivery rates resulted in reduced NMR or postpartum complications, either in the full sample or among women who delivered in a public hospital.

Our findings have several policy implications for ongoing discussions about the importance of increasing institutional delivery rates in India and elsewhere. First, we found that to reduce NMR or to improve maternal health outcomes, it is not sufficient to simply increase the proportion of women delivering in health facilities or in the presence of skilled health provider. We speculate that it may be because these facilities are not adequately staffed, trained, or equipped to deliver high-quality health services. In fact, several recent studies have found that even among the cadres of health workers that are defined as skilled, many do not provide insufficient clinical care and likely represents an important barrier to increasing clinical outcomes.<sup>43–44</sup> As such, we recommend that programmes designed to improve institutional delivery rates should consider commensurate investments to improve the quality of care delivered, including improved mentorship and training of providers. Second,



most of the studies completed over the past decade have focused on the best ways to increase institutional deliveries and not enough research has been done to better understand whether and how such policies may improve health outcomes. Therefore, more research is needed on this front. Finally, the fact that a road upgrade programme, whose primary goal was not to improve institutional deliveries, had such a large effect on institutional deliveries in a short period of time, suggests that if countries wish to continue to increase institutional deliveries in their country, it is necessary to understand which factors, including transportation or rural development,<sup>45</sup> are limiting access to facilities and target them.

Improving coverage of essential health services to improve neonatal and maternal health remains an important challenge in many countries around the world.<sup>46</sup> However, the findings of our study indicate that simply increasing the proportion of births that take place in a health facility will not necessarily translate into meaningful improvements in neonatal and maternal mortality.

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