The Impact of Institutional Delivery on Neonatal and Maternal Health Outcomes: Evidence from a Road Upgrade Program in India

Supplementary Appendix

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1. Validity of the instrumental variable approach

The IV method provides consistent estimates if the instrument satisfies the relevance, the excludability, and the monotonicity conditions. The first-stage results described in Table 1 in the main manuscript confirm that the relevance condition is satisfied, as there is a strong relationship between the instrument and the endogenous variable. Below, we further explore the relevance of our instrument by demonstrating the relationship between exposure to the program and the likelihood of a road upgrade and then also exploring the excludability of our instrument.

We first need to first confirm that the population-size rule used to allocate road upgrades was followed without any significant deviation, which could invalidate our identification strategy if program exposure was instead determined by potentially endogenous economic, political, or social factors. Previous studies on PMGSY, including Aggarwal (2018) over the period of 2001-2011, Asher and Novosad (2018) over the period of 2001-2015, and Shamdasani (2016) over the period of 2001-2006 have all demonstrated that the population-size rule of road upgrade allocations was followed by the government of India. Using data from our sample, Appendix Figure 1 depicts the likelihood of road upgrade for villages based on their population in the 2001 census. As most villages with 1000 or more inhabitants had already been upgraded by 2010, we see no discontinuity in larger cities, but a jump is apparent for villages with a population 500 or more inhabitants, confirming that the population-size rule of the program was still being adhered to during our study period.

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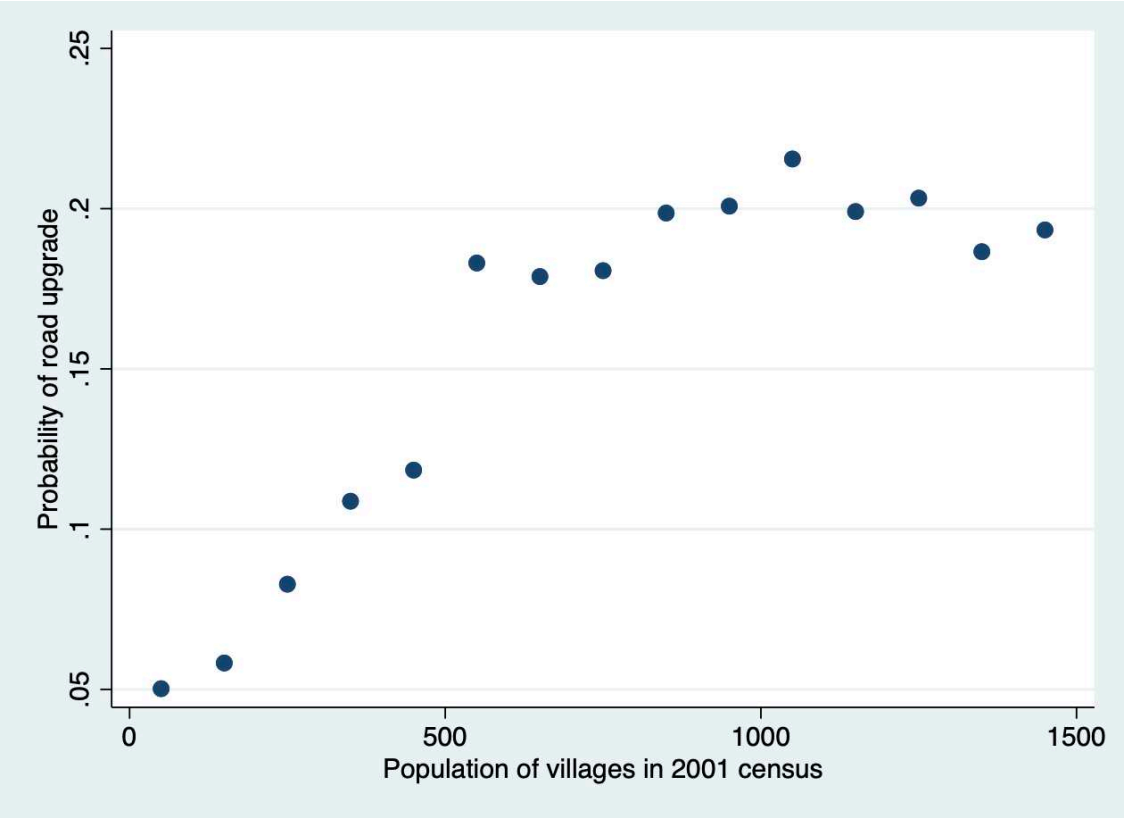

Appendix Figure 1 – Probability of road upgrade across villages between 2010-201

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The excludability condition requires that the instrumental variable affects the outcome variables only through its impact on the endogenous variable, and not directly in any other way. In our setting, this means that neonatal and maternal health outcomes are not directly affected by the instrumental variable. In other words, the instrument would be invalid if neonatal mortality and postpartum complications are affected by road upgrade through channels other than institutional delivery.

Previous research has shown mixed results of the effect of PMGSY on the economic outcomes of households. Asher and Novosad (2018) found that the road upgrade program did not change consumption, assets, or agricultural outcomes of affected households. Aggarwal (2018), on the other hand, concluded that the program lowered prices, increased the availability of non-local goods, increased the use of agricultural technologies, and pulled teenaged members out of school to join the labor force among treated households. Shamdasani (2016) also showed that treated households diversified their crop portfolio, increased their uptake of complementary productive inputs, intensified labor hiring, and entered into the sales of farm outputs. As these changes may have long-term effects on the economic wellbeing of households, and therefore pregnant women, which may also affect other variables related to neonatal and maternal health outcomes.

Therefore, to check the excludability of our instrument, we check if the road upgrade had any effect on neonatal and maternal health outcomes through other potential channels. For this purpose, we report coefficients from regressions where the dependant variables are other health indicators that are known to affect neonatal and maternal health outcomes and the main explanatory variable is our road upgrade variable.

Panel A of Appendix Table 1 explores the effect of the PMGSY program on other health indicators related to pregnancy. Specifically, the first and second columns report the coefficient of the estimate of the effect of road upgrade on the occurrence of convulsion and swelling during pregnancy, finding negative but not significant results. The last column of Appendix Table 1 shows the effect of road upgrade on receiving supplementary nutrition from an Anganwadi/ICDS Centre, which provides supplementary food to underprivileged groups, including pregnant women. If road upgrading increased this service to pregnant women, it may act as another channel that road upgrade affects neonatal and maternal health outcomes. However, the estimates show that the coefficient was not significant. We therefore conclude that there is no meaningful relationship between these health indicators during pregnancy and road upgrade.

Panel B reports the results of the estimation of the effect of road upgrade on the probability of receiving healthcare services before and after delivery. The first and second columns report the results on attending any antenatal care visits, and if yes, the number of antenatal care visits attended, yielding positive, but non-significant coefficients. The last column represents the effect on attending a postnatal care visit and was also non-significant. Road upgrade thus did not change the care-seeking behavior of mothers either before or after delivery.

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The last panel reports the effect of the PMGSY program on health indicators during delivery. The two columns of Panel C report the coefficients for having a prolonged delivery and the occurrence of bleeding during delivery, both of which are not significant. Based on these results, we conclude that the primary pathway through which the road upgrade program affected neonatal and maternal health outcomes was through the increase in institutional deliveries that we observe.

Appendix Table 1- The effect of road upgrade on different health indicators

Panel A. Health indicators related to pregnancy	Convulsion during pregnancy	Swelling during pregnancy	Received supplementary nutrition during pregnancy
Cum. perc. of treated pop.	-0.0047	-0.0059	0.0054
	(0.0206)	(0.0276)	(0.0212)
Mean fraction dependant variable	0.182	0.302	0.807

Panel B. Receiving services related to pregnancy	Receiving antenatal care	Number of antenatal cares received	Receiving postnatal care
Cum. perc. of treated pop.	0.0345	0.6057	0.0222
	(0.0228)	(0.4734)	(0.0287)
Mean fraction dependant variable	0.538	3.22	0 .345

Panel C. Health indicators during delivery	Prolonged delivery	Bleeding during delivery
Cum. perc. of treated pop.	-0.0156	0.0140
	(0.0297)	(0.0293)
Mean fraction dependant variable	0.416	0.333

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 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 (categorical variable), using modern contraceptives, being insured, smoking behavior, BMI, having previous miscarriage, abortion, or stillbirth, religion, if mother belongs to a caste and tribe), and household characteristics (wealth index, if the household has electricity). Robust standard errors clustered at the town level are shown in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

2. Power calculations

To test whether we would expect to detect changes in our outcomes given our sample, we did some ex-post power calculations. With a 0.0001 squared partial correlation of institutional delivery on outcome variables, the power was calculated at 0.98 and 0.91 for the neonatal health outcome sample and maternal health outcome sample, respectively, suggesting that we were powered to detect an effect of institutional delivery on our primary neonatal and maternal health outcomes.

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There are many valid criticisms, however, about reporting ex-post power calculations (Oenig & Eisey, 2001). One solution to these criticisms is to report minimum detectable squared partial correlation, which was zero for the neonatal health outcome sample and 0.0001 for maternal health outcome sample, which again suggests that even a small partial correlation between institutional delivery and our neonatal and maternal health outcomes should be detectable in our analysis.

3. Additional health outcomes

Th effect of location of delivery on additional neonatal and maternal health outcomes is presented in Appendix Table 2, with Panel A showing public hospitals, Panel B showing other public health facilities, and Panel C showing private hospitals. The results of first stage of IV estimation indicate 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. Considering the first stage's F tests, the results show that the instrument is not strong for other public health facilities for the neonate sample and nor for private hospitals. As such, the second stage results for other public health facilities and private hospitals are not reliable. The results of IV estimation for public hospital and other public health facilities for the neonate sample is not significant, indicating that, like the whole sample results, the location of institutional delivery was not associated with neonatal and maternal health outcomes.

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Appendix Table 2- Neonatal and Maternal Health Outcomes and Delivery by type of Health Facility

	7-day death	28-day death	Postpartum complication (bleeding)	Postpartum complication (fever)
Panel A. Delivery in Public Hospitals				
First stage (dependent variable: Institutional Delivery in public hospitals)				
Cum. Perc. Of treated pop.	0.1617***	0.1617***	0.1546***	0.1546***
	(0.0397)	(0.0397)	(0.0428)	(0.0428)
F-statistic	16.55	16.55	13.04	13.04
R-squared	0.3851	0.3851	0.3996	0.3996
Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Institutional delivery in public hospitals	0.0035	0.0384	0.2282	-0.2267
	(0.0479)	(0.0529)	(0.1730)	(0.1782)
Mean fraction institutional delivery	0.424	0.424	0.459	0.459
Mean fraction health outcome	0.026	0.031	0.189	0.168
Panel B. Delivery in Other Public Health Facilities				
First stage (dependent variable: Institutional Delivery in other public health facilities)				
Cum. Perc. Of treated pop.	0.1216***	0.1216***	0.0912**	0.0912**
	(0.0350)	(0.0350)	(0.0383)	(0.0383)
F-statistic	12.04	12.04	5.66	5.66
R-squared	0.2526	0.2526	0.2614	0.2614
Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Institutional delivery in other public health facilities	-0.0768	-0.0742	-0.1343	-0.3361
	(0.0658)	(0.0725)	(0.2919)	(0.2924)
Mean fraction institutional delivery	0.542	0.542	0.567	0.567
Mean fraction health outcome	0.026	0.032	0.177	0.164
Panel C. Delivery in Private Hospitals				
First stage (dependent variable: Institutional Delivery in private hospitals)				
Cum. Perc. Of treated pop.	0.0627**	0.0627**	0.0474*	0.0474*
	(0.0268)	(0.0268)	(0.0288)	(0.0288)
F-statistic	5.46	5.46	2.71	2.71
R-squared	0.4788	0.4788	0.4988	0.4988
Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Institutional delivery in private hospitals	0.0093	0.0514	0.4580	-0.7307
	(0.1396)	(0.1508)	(0.6315)	(0.6817)
Mean fraction institutional delivery	0.344	0.344	0.381	0.381
Mean fraction health outcome	0.029	0.035	0.185	0.164

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 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 (categorical variable), using modern contraceptives, being insured, smoking behavior, BMI, having previous miscarriage, abortion, and stillbirth, religion, if 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 gain access to a paved road) in a town. Robust standard errors clustered at the town-level are shown in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

4. Robustness checks

To ensure that the instrument captures only the effect of the road upgrade program, rather than the effect of other programs or trends in India, a series of robustness checks were also performed. First, we assessed whether our road upgrade instrument had any effect on institutional delivery rates in urban areas, which should not have benefited from the PGSMY program, as demonstrated in Appendix Table 3. The resulting coefficient, which has a magnitude of zero and is not significant, suggests that the program did not change the behaviour of urban women in choosing their place of delivery. This increases our confidence in our IV strategy.

Appendix Table 3 - The effect of road upgrade on Institutional Delivery in Urban Regions

	Institutional Delivery
Cum. perc. of treated pop.	0.0000
	(0.0307)
R-squared	0.2442
No. of observations	47,275
Mean fraction institutional delivery	0.859

Note: The regression controls for month of birth, year of birth, town fixed effects, neonate characteristics (if the birth is 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 (categorical variable), using modern contraceptives, being insured, smoking behavior, BMI, having previous miscarriage, abortion, and stillbirth, religion, if mother belongs to a caste and tribe), and household characteristics (wealth index, if the household has electricity). Robust standard errors clustered at the town level are shown in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

In our second robustness check, we sought to investigate the effect of using distance to the nearest town as the instrument on the observed results. Because the data is at the town-level, however, it is not possible to use the distance of each village to the nearest town directly as an instrument. Instead, we generated a variable that captures the population weighted average distance of villages to the nearest town. To allow for the consideration of the non-linear effect of distance on place of birth decision, we converted the continuous distance variable to dummy variables based on the population weighted average of distance to the nearest town. The dummy variables indicated if the distance was less than 5 kilometers, between 5 and 10 kilometers, between 10 and 15 kilometers, between 15 and 20 kilometers, between 20 and 30 kilometers, between 30 and 50 kilometers, and more than 50 kilometers. We interacted these variables with the road upgrade variable.

Appendix Table 4 presents the results of an estimation that considers both the cumulative percentage of the population affected by road upgrade in a town and the distance to the nearest town as an instrument, indicating that distance has an inverse U-shaped effect on institutional delivery. Specifically, the effect of road upgrade on institutional delivery increases as population weighted average distance to the nearest town increases until 15 to 20 kilometers is reached, after which it declines. In other words, women who live between 15 and 20 kilometers from the nearest

town benefitted most from the road upgrade program, as the magnitude of their coefficient is the largest.

In Panel B, the second stage of IV estimation demonstrates that institutional delivery does not have any significant effect of infant or maternal health outcomes. The F-statistic representing the joint significance of all instrumental variables is approximately 4, however, suggesting that the results for this second stage are not reliable and that we should be cautious in interpreting them.

Appendix Table 4 – Neonatal and Maternal Health Outcomes and Distance to the Nearest Town

	7-day death	28-day death	Postpartum complication (bleeding)	Postpartum complication (fever)
Panel A. First stage (dependent variable: Institutional Delivery)				
Cum. perc. of treated pop.	0.0846***	0.0846***	0.0631*	0.0631*
	(0.0318)	(0.0318)	(0.0325)	(0.0325)
Cum. perc. of treated pop.×D(dis.≤5)	0.0311*	0.0311*	0.0360**	0.0360**
	(0.0164)	(0.0164)	(0.0168)	(0.0168)
Cum. perc. of treated pop.×D(5<dis.≤10)	0.0423**	0.0423**	0.0455***	0.0455***
	(0.0169)	(0.0169)	(0.0171)	(0.0171)
Cum. perc. of treated pop.×D(10<dis.≤15)	0.0439***	0.0439***	0.0468***	0.0468***
	(0.0164)	(0.0164)	(0.0166)	(0.0166)
Cum. perc. of treated pop.×D(15<dis.≤20)	0.0486***	0.0486***	0.0552***	0.0552***
	(0.0168)	(0.0168)	(0.0169)	(0.0169)
Cum. perc. of treated pop.×D(20<dis.≤30)	0.0317*	0.0317*	0.0330**	0.0330**
	(0.0164)	(0.0164)	(0.0167)	(0.0167)
Cum. perc. of treated pop.×D(30<dis.≤50)	0.0317*	0.0317*	0.0340**	0.0340**
	(0.0165)	(0.0165)	(0.0168)	(0.0168)
F-statistic	4.82	4.82	4.45	4.45
R-squared	0.2524	0.2524	0.2589	0.2589
Panel B. Second stage IV (dependent variable: neonatal and maternal health outcomes)				
Institutional delivery	-0.0119	-0.0029	0.0767	-0.2242
	(0.0381)	(0.0419)	(0.1620)	(0.1409)
Mean fraction institutional delivery	0.712	0.712	0.737	0.737
Mean fraction health outcome	0.026	0.031	0.188	0.161

Note: each column in each panel lists estimates from separate regressions. D(<dis.<) is a dummy variable for various population weighted average of distances of villages to nearest town. The omitted category contains towns with population weighted average of distances of more than 50km. All regressions control for month of birth, year of birth, town fixed effects, neonate's characteristics (if the birth is multiple birth, the sex of the neonate, if the birth is the first birth, and birth order), mother's characteristics (age at delivery (categorical variables), Education (categorical variables), using modern contraceptive, being insured, smoking behavior, BMI, having previous miscarriage, abortion, and stillbirth, religion, if 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 joint significance of all instrumental variables. Instrumental variables are the cumulative percentage of treated population (population that get access to a paved road) in a town and the interaction of this variable with distance dummies. Robust standard errors clustered at the town-level are shown in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level