Neonatal mortality in rural India: Does access to health infrastructure play a role?

by

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Abstract: Although child mortality rates have dropped in India over the last two decades, neonatal mortality rates continue to be high. In this paper we use data from the unique nationally representative survey of India 2008 *District Level Household Survey* (DLHS-3) to analyse the links between neonatal mortality at the household level and household's access to health facilities. Our empirical analysis underscores the importance of having well-functioning obstetric and neonatal services of District Hospital closer to the rural households. The regression results show that if the services of District Hospitals are brought 10 km closer to the village, it can save one more child out of 1000 births in India. Having emergency obstetric care at the District Hospital is also found to significantly reduce neonatal deaths.

Key words: Neonatal mortality, health infrastructure, India

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1. INTRODUCTION

Neonatal deaths account for a major proportion of child deaths globally[4]. Major causes of neonatal deaths are pre-term birth, asphyxia, sepsis, pneumonia, congenital anomalies, diarrheal diseases and tetanus (UNDP, 2010). Estimates from the World Health Organization (2012) show that although under-five mortality has fallen globally from 12.2 million deaths in 1990 to 7.6 million deaths in 2010, the fall in neonatal mortality is considerably less than that in the post-neonatal period. Consequently, the proportion of deaths in the neonatal period rose from 38% (4 million) of total deaths in 2000 to about 41% (3.3 million) in 2009 (Lawn *et al*, 2011; Lawn *et al*, 2005). This may be attributable to the high emphasis of child survival programs such nutrition, vaccination and health promotion interventions relative to hospital-related investments necessary for neonatal mortality reduction, particularly in rural areas (Wagstaff et al, 2009). It is argued that for reducing neonatal mortality the availability and adequacy of specialised maternal and child health staff as well as easy access of obstetric and neonatal facilities to pregnant women and newborns are essential. The 2006 World Health Report stresses that the probability of infant, child and maternal survival is positively correlated with increasing density of competent health workers (WHO, 2006). However, there is no rigorous study which systematically examines the role of health professionals and health infrastructure on neonatal death.

In this paper we use data from the 2008 nationally representative *District level Household survey* (DLHS-3) to analyse the links between neonatal mortality and access to health infrastructure and medical professionals. The District Level Household and Facility Survey - one of the largest ever demographic and health surveys carried out in India - is the only survey providing information related specifically to programmes of the National Rural Health Mission (NRHM), especially indicators relevant to delivery of services.

India presents a unique context to study neonatal mortality for several reasons. First, despite the rapid economic growth that has occurred in India over the last two decades, the neonatal mortality rate continues to remain high (900,000 in 2007), and India accounts for nearly 28% of the global deaths among newborn children (Oestergaard *et al*., 2011).

[4] The World Health Organization defines neonatal mortality rate as the number of resident newborns in a specified geographic area dying at less than 28 days of age divided by the number of resident live births for the same geographic area for a specified time period, usually a calendar year, and multiplied by 1,000 (WHO, 2012).

Second, figures from India's three nationally representative National Family Health Survey datasets show that neonatal deaths have increased as a proportion of under-five deaths from 45% in NFHS-1 (1992) to 52% in NFHS-3 (2005-06), higher than the increase in the global proportion from 37% in 1990 to 41% in 2008. This is despite the fall in under-five mortality from 109/1000 live births in NFHS-1 (1992) to 74/1000 live births in NFHS-3 (2005/06) (Awofeso and Rammohan, 2012). This indicates that while India has made remarkable progress in reducing deaths outside of the neonatal period, neonatal death rates have remained static, and are thus rising in proportion to total under-five deaths.

The literature on child mortality has branched out into three different but interrelated directions in social science. The most studied branch is the role of socio-economic factors. There is a large literature that has examined the role of socio-economic factors in influencing child mortality in general (see Pitt, 1997) and particularly in India (Makepeace and Pal S., 2008; Bhalotra S and Van Soest A, 2008; Maitra P and Pal S, 2008, Chakrabarti and Chaudhuri, 2007, Maitra, 2004; Bhargava A, 2003). These studies examine the role of parents' education, sex of the child, sex ratio of the family members, sibling effect and birth spacing along with income, asset, religion and caste. Some of the studies take into account the problem of fertility selection. The common finding is that higher mother's education, household income and asset, and greater birth spacing significantly lowers child mortality The recent paper by Klaauw and Wang (2011) argued that the impacts of socioeconomic and environmental factors on child mortality varies with child's age and found that impacts are more prominent immediately after birth. It shows that the probability of dying in the first month is higher if the child is a boy but the sex reverses if the child dies in later months.

Another branch, which is done mostly in collaboration with medical researchers, is on the causes of child mortality. A recent study on neonatal mortality by the Million-death study collaborators (2010) used data on child death registration and found that the main causes of newborn deaths in India are prematurity and low-birth-weight, infections, asphyxia and birth trauma. These causes accounted for nearly 78% of neonatal deaths in India in 2005.

There is also a large body of Randomized Control Trials (RCT) with particular interventions, especially on behavioural change of health seeking behaviour. For example, Kumar et al.'s (2008) study is based on Shivgarh block in Uttar Pradesh, India's largest state which accounts for a quarter of all newborn deaths in India. They report the results of a community-based strategy that was designed to change unhealthy birth and early newborn care behaviors. The researchers designed and implemented a community-based project called *Saksham* (Empowered), supported by a well-functioning emergency obstetric care system that included dedicated obstetricians, neonatologists, culturally and technically competent community health workers and nurses who organized the referral system from communities to respective district hospitals. Their analysis found that within 18 months of the program's commencement, neonatal deaths dropped by 58%. This finding is supported by Mclure *et al*. (2007) and Pattinson *et al*. (2011) who argue that lack of access to obstetric care services in low-income countries is a serious constraint in improving pregnancy outcomes. This is consistent with Lim et al (2010), who founnd that although the government of India has implemented programs such the *Janani Surakhsha Yojana* (JSY) to improve maternal and child birth outcomes, its impact on reducing neonatal deaths has been limited.

These above studies differ from our contribution in that their focus has been on factors such as the cause of deaths in the neonatal period, or the role of health services using case studies or RCTs. However, they have not used a nationally representative dataset linking access to health infrastructure and workforce adequacy to neonatal survival outcomes. An important contribution of this paper is that we are able to use a unique dataset that has for the first time linked the households to the facilities survey. The links between neonatal-specific care such as access to emergency obstetric care and health infrastructure on neonatal survival probability remains understudied, and a key contribution of this paper is to address this gap in the literature using a large nationally representative dataset.

Our study includes a number of variables on availability and access to different types of health infrastructure facilities and services to explore which of these influences neonatal survival outcomes to address several policy-related questions. Specifically, which type of hospital is most effective in improving neonatal outcomes: District Hospital or lower referral hospitals such as Primary Health Centres and Community Health Centres? does access to emergency obstetric care (including 24-hour Obstetrician and neonatologist availability) at the District Hospital influence neonatal mortality rates, (iii) whether distance to District hospital, or lower referral hospital such as Community Health Centres (CHCs) and Primary Health Centres (PHC) can influence neonatal mortality. To our knowledge, ours is the first nationally representative study that quantifies the influence of access to these three levels of health facilities on neonatal mortality outcomes, in a model that also controls for household's socio-economic characteristics.

The main results of our analysis can be summarised as follows: (i) the probability of neonatal mortality is significantly lower when the child's village is closer to the district hospital, (ii neonatal death is lower in the region where emergency obstetric care is available 24 hours at the DHs, iii) availability of services at lower level referral hospitals such as CHC and PHC are insignificant in influencing neonatal mortality, and finally, (iv) variables relating to parental schooling and household wealth improve neonatal survival outcomes. Boys are significantly more likely to die than girls in the neonatal period and being born later in the birth-order improves neonatal survival outcomes.

The remainder of the paper proceeds as follows. Section 2 provides a brief description of the health infrastructure in rural India; Section 3 descries the data and descriptive statistics of relevant variables; section 4 outlines model and econometric framework for understanding the role of health infrastructure on neonatal outcomes and in Section 5 we present the main results of our analysis. Finally, Section 6 presents our conclusions.

2. HEALTH INFRASTRUCTURE IN RURAL INDIA

India's Public Health System has been developed over the years as a 3-tier system, at the primary, secondary and tertiary level of health care. A typical Indian state is divided into a number of districts and the districts in turn are divided into Blocks. The district Health System is the fundamental basis for implementing various health policies and delivery of healthcare, management of health services for defined geographic area. Every district is expected to have a district hospital linked with the public hospitals/health centres down below the district such as Sub-district/Sub-divisional hospitals, Community Health Centres (CHCs), Primary Health Centres (PHC) and Sub-centres (SC). According to the Ministry of Health and Child Welfare (2011), the role of the DH (should we write district Hospital in full? is to provide effective, affordable health care services (curative including specialist services, preventive and promotive) for a defined population. The DH also acts as a secondary level referral centre for the public health institutions below the district level such as Sub-divisional Hospitals, Community Health Centres, Primary Health Centres and Sub-centres.

The CHCs are the highest tier of health infrastructure operating in rural areas. They were established and maintained by the State Government under the Minimum Needs Programme (MNP)/Basic Minimum Services Programme (BMS). They serve as a referral centre for 4 PHCs and also provide facilities for obstetric care and specialist consultations. A CHC is required to be manned by four medical specialists i.e. Surgeon, Physician, Gynaecologist and Paediatrician supported by 21 paramedical and other staff. According to Datar et al (2010), across the country there was shortfall in CHCs of approximately 50 per cent. Table 1 provides a snapshot of the health infrastructure available at the district level.

The Primary Health Centre (PHC) is the first contact point between the village community and the Medical Officer and are maintained and managed by state governments, under the Minimum Needs Programme (MNP)/Basic Minimum Services Programme (BMS). A medical officer is in charge of the PHC supported by fourteen paramedical and other staff.

The lowest level of the health infrastructure is the Sub-Centre. The sub-centre is the first point of contact between the community and the primary healthcare system. Each sub-centre is manned by one Auxiliary Nurse Midwife (ANM) and one male Multi-purpose Worker. A Lady Health Worker (LHV) is in charge of six sub-centres each of which are provided with basic drugs for minor ailments and are expected to provide services in relation to maternal and child health, family welfare, nutrition, immunization, diarrhoea control, and control of communicable diseases.

Table 1: Health infrastructure at the district level

	Population norm	Human resource available
District hospital	2-3 million	Obstetrician, Anaesthetist, Pathologist, Pediatrician, General doctors, nurses
Community Health Centre (CHC)	100,000 - 300,000	Any specialist, General doctors, nurses
Primary Health Centre (PHC) at the Block level	100,000	General doctors (2), nurses, LHVs, ANMs

Source: Ministry of Health and Child Welfare, 2010

Health Infrastructure in our context refers to the basic support for the delivery of public health activities. In the area of neonatal mortality prevention, skilled workforce entails adequate quality, quantity and distribution of neonatologists, obstetricians, anaesthetists and midwives. Good emergency obstetric care requires improving the availability, accessibility, quality and use of services for the treatment of complications that arise during pregnancy and childbirth (WHO, 2009). The weakest link in India's Emergency Obstetric care Services is the provision of well-functioning and appropriately staffed district and referral hospitals to provide care for complications that arise during late pregnancy and at birth. Even in Indian states where such facilities are provided delays in obtaining care may occur at three levels; (1) delay in deciding to seek care; (2) delay in reaching a first referral level facility; and (3) delay in actually receiving care after arriving at the facility (Post, 1997).

Despite Emergency Obstetric Care improvement being one of the key priorities of the National Rural Health Mission's 2005-2012 Strategic Plan (NRHM, 2005), the rural health workforce for emergency obstetric care remains chronically inadequate and poorly funded. India has a chronic shortage of the core staff, with less than 23 doctors, nurses and midwives per 10,000 populations. This is the minimum health workers-population ratio required for achieving 80% coverage of essential health interventions (WHO, 2006). Critical shortage of neonatal specialists is also more severe than that of the general health services, and health worker shortage in rural areas is more severe than in urban areas. For example, a study of 44 public hospital facilities to determine adequacy of neonatal and maternal care infrastructure in the relatively rich state of Maharashtra, found that only 45% had a qualified obstetrician/s, 30% had a qualified anaesthetist/s while 77% do not have either/ both of these specialists (Chartuvedi and Bandime, 2010).

3. MODEL AND ESTIMATION STRATEGY

Our main aim is to understand to what extent, if at all, access to health infrastructure and services influences neonatal mortality outcomes.

We estimate Probit models for the probability of a child dying in the first month of life:

$$Neonatal_i = \alpha_o + \alpha_1 DH_i + \alpha_2 CHC_i + \alpha_3 PHC_i + \alpha_4\, Private\ Faclitities + \alpha_5 Socioeconomic_i + \alpha_6\, Birth_i + State\ dummies + \varepsilon_i$$

where $Neonatal_i$ is an indicator variable which takes on a value of 1 if a child is born alive and died within a month of birth, 0 otherwise.

Our key explanatory variables include an array of health infrastructure variables. Our choice of variables is driven by structure of public health service in India as well as the medical literature on services critical to neonatal care. The term DH_i is a vector of variables on the characteristics of the District Hospitals (DH), and includes variables such as the distance to the district hospital from household *i*'s village, whether there is a delivery room at the DH, the availability of trained health personnel at the DH, in particular the availability of emergency obstetric care (24-hour gynaecologist), and the availability of a paediatrician at the DH. We assume that household *i* can only access health facilities in their district.

Our next set of health facilities variables are the vectors CHC and PHC, which include variables at the lower referral hospital levels. As with DH, we wish to capture information on availability of health personnel, so we include two variables to indicate the average number of gynaecologists and paediatricians available at the Block-level CHCs. We also include a dummy variable indicating the availability of an operation theatre at the CHC. Since PHC acts as the first point of referral, we create a variable PHC_ref_del which shows the average number of referrals done to the DH as a ratio of number of deliveries performed in PHCs in a Block. In the PHC vector, we also include variables for the availability of an operation theatre. Note that there is no information in the household dataset on the specific CHC or PHC that the household may visit. We assume that the household has access to all the CHCs and PHCs in the Block, and we take the average number of the health personnel and infrastructure of all CHCs and PHCs[5] in the Block.

Households also have access to private health facilities such as private clinic and private hospital. However, the DLHS does not survey private facilities. However, we include average distance of private health facilities from village from village level questionnaire.

The variable Socioeconomic refers to the household characteristics such as the wealth quintile, whether the child's mother and father have attended school, and the household head's religion and caste. The variable Birth includes birth-specific characteristics such as the child's gender, their birth-order, whether it is multiple birth, whether there were any complications during birth such as whether it was a breech delivery, whether the labour was prolonged, etc., and mother specific variables such as her age at birth. We also include

[5] The description of all the health infrastructure variables included in the analysis is given in Appendix A1.

state dummies to control for time in-varying state-specific unobserved heterogeneity and ε is the error term.

Note that the source of identification in our sample is the cross-sectional variation across Block and also across districts. The data on PHCs and CHCs are available at the Block level. In most of the cases, each Block has multiple PHCs and CHCs. We, thus, use the average measure of the health facilities of PHC and CHC at the Block level. District Hospital data are available at the district level, and thus vary only across districts. Note that there are a few districts where there is more than one district hospital.

The health facilities (supply side variables) are fairly exogenous to the health seeking behaviour of the households. All the household specific socioeconomic and birth related characteristics are also exogenous to the household decision. However, one can argue that some unobserved health attributes may lead to both higher income and as well as healthy baby. Note that we have wealth instead of income in the regression which is less likely to be endogenous.

Note that there are variables in the questionnaire on whether the mother has received antenatal and post-natal care, if skilled personnel were present at the time of delivery, whether the child's birth was in an institution, whether the mother received any assistance from government's health related program (such as JSY). These variables are likely to have a direct bearing on neonatal death. However, these decision variables are the outcome of interplays between supply-side variables, child-specific birth characteristics, and also the household's socioeconomic characteristics of the households which we have included in the regression model. In the presence of both supply and demand side variables, the variables on care, skilled personnel, program participation become redundant as the formers determine the latter[6]. Regional unobservable characteristics have the potential to confound the impact of supply side variables. Therefore, we include state dummies to control for state-specific unobserved heterogeneity.

4. DATA AND DESCRIPTIVE STATISTICS

[6] However, we have included these variables in the regression and found that none of these variables are significant. These results are not presented here due to space constraints but are available on request.

The analysis in this paper is based on the 2008 District level household survey (DLHS-3), collected by the International Institute for Population Sciences (IIPS), Mumbai on behalf of the Ministry of Health and Family Welfare (MoHFW), Government of India. It is a household survey at the district level and in DLHS-3, the survey covered 611 districts in India. The DLHS-3 is designed to provide information on family planning, maternal and child health, reproductive health of ever married women and adolescent girls, utilization of maternal and child healthcare services at the district level for India. In addition, DLHS-3 also provides information on new-born care, post-natal care within 48 hours, role of ASHA (health workers) in enhancing the reproductive and child health care and coverage of Government's safe motherhood program such as Janani Suraksha Yojana (JSY). An important component of DLHS-3 is the integration of Facility Survey of health institutions (Sub centre, Primary Health Centre, Community Health Centre and District Hospital) accessible to the sampled villages. The focus of DLHS-3 is to provide health care and utilization indicators at the district level for the enhancement of the activities under National Rural Health Mission (NRHM). The DLHS-3 provides a large sized 5-year retrospective collection of statistical records on maternal and child health practice and outcomes, along with demographic and economic information on both individual mothers and their respective household. For each of the districts in India, all Community Health Centres (CHCs) and District Hospital (DH) were surveyed. Further, all Sub-centres (SC) and Primary Health Centres (PHC) which were expected to serve the population of the selected PSU were covered. There were separate questionnaires for SC, PHC, CHC and DH. They broadly include questions on infrastructure and human resources. This allows us to explore the links between neonatal mortality and access and availability of health infrastructure and services.

The survey used two-stage stratified random sampling in rural and three-stage stratified sampling in urban areas of each district. The information from 2001 Census was used as sampling frame for selecting primary sampling units (PSUs). For the first time, population-linked facility survey has been conducted in DLHS-3. In a district, all Community Health Centres (CHCs) and District Hospital (DH) were covered. Further, all Sub-centres (SC) and Primary Health Centres (PHC) which were expected to serve the population of the selected PSU were also covered. There were separate questionnaires for SC, PHC, CHC and DH. They broadly include questions on infrastructure, human resources, supply of drugs & instruments, and performance.

The data on neonatal deaths comes from the ever- married women's questionnaire, with detailed information on the pregnancy history of women, if any child was born alive but died subsequently, information on the age and sex of the child at the time of death, and information on maternal access to prenatal and postnatal care, delivery. This questionnaire also contains detailed information on the socio-economic, demographic and labour market characteristics of the respondent's household. We link this detailed mother-level data to information on availability, access and services to health infrastructure, using the Village questionnaire, the District Hospital questionnaire, the Primary Health Centre questionnaire and the Community Health Centre questionnaire.

Our analysis is based on 99,735 rural women who gave birth in the last 5 years, and for whom data is available on all our variables of interest. We focus on the last pregnancy since information on birth related characteristics is available only for the last birth. Moreover, the supply side variables correspond to the year of survey. We focus on rural areas for several reasons- data on village-specific characteristics is only available for the rural sample, 75% of the Indian population lives in rural areas, neonatal mortality rates are higher in rural than in urban areas of India and finally, access to health infrastructure is likely to be a bigger constraint in rural areas.

According to the descriptive statistics presented in Table 2, approximately 2% of the children died in the neonatal period. There are statistically significant differences between the sample of neonatal and non-neonatal deaths with regards to the health infrastructure and service variables. While 84% of the full sample had access to a delivery room in the district hospital, the figure is slightly lower at 82% in the neonatal death sample. Similarly, a significantly higher proportion of the households (83%) had access to emergency obstetric care in the full sample, compared to the sample of neonatal deaths (80%).

We control for household characteristics such as religion, respondent's age, and whether the last born child was the first, second or third and higher parity birth. The dataset does not have any information on the household's income, wages or expenditure. Hence, we use the wealth index that is available in the dataset. The wealth index was constructed using household asset data, and is divided into five population quintiles, with the lowest quintile representing the poorest 27 percent and the highest quintile representing the wealthiest 8 percent households for the full sample. A significantly higher proportion of neonatal deaths occur in households that are in the poorest and poor wealth quintile and a significantly lower proportion of children die in the two higher wealth quintiles (Table 2).

While only 45% of the respondents (mothers) have ever attended school, the figure is 71% for husbands in our study. From Table 2 we note that both paternal and maternal schooling is significantly lower among children who have died in the neonatal period compared to the whole sample. Among children who died, only 39% of the mothers have ever attended school, while this figure is 45% for the full sample. Moreover these differences are statistically significant. Also note that the differences in terms of religion and caste are not statistically significant

5. REGRESSION RESULTS

The main results of our analysis are presented in Tables 3-4. Table 3 presents Probit estimation results for the full sample and in Table 4 we present the results separately for the sample of backward states[7] (states with GDP per capita below the national average) respectively. Columns [1] to [4] present specifications with additional controls. The dependent variable neonatal mortality is an indicator variable (0,1) for the probability of a child being born alive, but dying in the first month. For both Tables we report marginal effects and robust standard errors.

Given that the focus of our paper is on the role of health infrastructure, column [1] includes variables on accessibility and availability of services in the district hospital. Columns [2] and [3] add variables relating to the access and availability of lower level referral hospitals such as the Community Health Centre (CHC) and the Primary Health Centre (PHC). In Column [4] we include variables relating to the socio-economic and birth related characteristics of the child's household such as parental education level, household wealth quintile, religion and caste; child-specific characteristics such as the child's sex, birth order, whether or not any problems were experienced during delivery. In column [5] we add dummy variables for states to control for time in-varying state-specific unobserved heterogeneity.

[7] We define as backward state if a state has a GDP per capita below the national average of $1450. These are the states of West Bengal, Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Rajasthan, Orissa, Uttar Pradesh, and Jammu and Kashmir.

Our analysis indicates a statistically significant and negative association between variables relating to district hospitals and neonatal survival outcomes. For the full sample (Table 3), the coefficient of distance to DH is significant and positive at 10% level of significance when we control for state dummies (specification 5). This result is more significant and robust when we restrict our sample to only backward states (Table 4). Specifically, if the respondent's village is closer to the District Hospital, the likelihood of child dying in the first month reduces significantly. Table 4 and 5 show that if a household is one kilometre closer to the district hospital probability of neonatal death decreases by 0.01 percent. That is, if the services of DHs are brought 10 km closer to the village, it can save one more child out of 1000 births. Note that the average distance of a village from DH is about 39 km for the full sample.

However, distance to PHC is found to be negative and statistically significant for full sample result (Table 3). Note that the mean distance of PHC from a village is about 10 km. Although this result may appear counter intuitive, the negative association may simply imply that if the PHC is closer, the household may choose to take the child to the PHC and this in turn may increase the likelihood of neonatal death. This result is line with the evidence that these PHCs are not well equipped to deal with complications in neonatal care. The same argument can be applied for significant positive association between neonatal death and operation theatre at CHC in the first three specifications.

The obstetrician/paediatrician available for 24 hours is found significant and negative for the first four specifications (Table 4). This underscores the importance of having emergency obstetric care, which is captured by the variable -24-hour gynaecologist/obstetrician. Though this result is robust to the inclusion of household and birth characteristics, it becomes insignificant at the standard levels (p-value is 0.13) when we control for state dummies. The reason is that state dummies capture the state specific observed and unobserved characteristics that affect neonatal death and it includes the quality of health service of the states. While other measures of health facilities only capture the number of health professionals in the facilities, the gynaecologist variable captures whether they are really available for 24 hours. This impact is picked up by the state dummies. The impacts are very robust and significant for the backward states too when state dummies are not included (Table 4).

The above results highlight the fact that the access to and the service at the DH, especially the emergency obstetric care matter in reducing neonatal deaths, particularly in the backward states. Though the lower level hospitals such as the CHC and PHC might have role in referring cases to DH, they do not appear to have any direct influence.

In terms of the role of child's characteristics in influencing neonatal survival probability, the results broadly accord with those found in the literature. In particular, relative to a female child, a male child has a significantly higher probability of dying in the first month. The child's birth order is also statistically significant. Relative to a first-born child, higher birth order children have a significantly lower probability of neonatal death. This may be because more experienced mothers may be in a better position to pick the danger signs during pregnancy. These results hold for both full sample and backward states. Similarly, a child who is a twin has a significantly lower probability of survival compared to a singleton birth.

Not surprisingly, mother's schooling attainment has a statistically significant and negative influence on the likelihood of neonatal death. However father's schooling is insignificant for full sample while not controlled for state dummies. Our results from both Tables also show that relative to a child from the lowest wealth quintile, children from the highest three wealth quintiles have a significantly lower probability of dying in the neonatal period. Mother's age has a non-linear relationship with neonatal mortality. Children with younger mothers have a lower probability of dying in the neonatal period, however the probability of neonatal morality increases with mothers age (Table 3 and 4).

We also include variables relating to whether the birth was complicated. The probability of neonatal mortality is significantly increased when there was excessive bleeding and breech presentation during labour. Surprisingly the variables religion and schedule caste/tribe are not statistically significant. This may be because the wealth quintile captures much of these differences and also the Government of India has already introduced a number of programs such as JSY that improve access to health services for disadvantaged people.

Finally, we have included controls for states to account for state-specific differentials for neonatal mortality. The results in Table 4 indicate that relative to children in the state of Tamil Nadu, children in the states of Jammu and Kashmir, Rajasthan, Uttar Pradesh, Bihar, Assam and Madhya Pradesh, have a significantly higher probability of neonatal mortality, after controlling for both demand and supply side characteristics that might influence neonatal death.

Robustness Check

Literature suggests that most of the death occurs in the first week of the birth (Bang et al, 1999; Jahan et al, 2009). In our sample, 80 percent of neonatal death occurs in the first week (Figure 1)[8]. To address this issue, we create a dummy variable indicating who dies in first week and who do not. We use this as our new dependent variable and regress it on other variables as in Tables 3 and 4. The results are reported in Table 5.

The first two columns of Table 5 correspond to the full sample while the last two correspond to the sample of children dying in one month. Within the same sample, state dummies are included in only one specification. The results show that distant to District Hospital is highly significant and positive, indicating its importance in lowering neonatal death. The result of neonatal sample is very interesting: if the distance to DH is reduced by 10 km, probability of death in first week compared to later in the same month decreases by 12 percent. The variable of obstetrician/gynaecologists available 24 hours at DH is significant only in first specification of full sample. The reason for not having significant impact in neonatal sample is that the variations of this variable within the neonatal sample are very low.

We also check if our results hold for the households who had institutional delivery. The results show that among the households who had institutional delivery their distance to DH influences the neonatal outcome. Similar results also hold for the households who had prenatal care[9].

It is likely that if a household is far away from the nearest health facility, health personnel and infrastructure might not have any impact. To assess this, we include two interaction dummy variables between distance and health facilities (e.g., operation theatre) and distance and health personnel (e.g., gynaecologists). The interaction terms are not significant in any specifications. We also interact distance to health facilities with mother's education and sex of the child. The idea is that the impact of distance on neonatal death might be lower if

[8] The global average of 75% of total neonatal deaths occurs in the first week (WHO, 2005).
[9] The results on institutional delivery and prenatal care are not reported in the paper. The results are available upon request.

mother is educated and the child is a boy. But we did not find any support for these hypotheses[10].

6. CONCLUSIONS

India accounts for the largest number of global neonatal deaths – 900,000 annually, or about 27% - in the neonatal period. Despite a dramatic decline in child mortality over the last decade or so, neonatal mortality rates remain high. Though medical literature underscores the importance of emergency obstetric in reducing neonatal mortality, there has been no study examining the links between neonatal death and health infrastructure.

We have combined nationally representative household level data with survey data on health facilities to examine the links between neonatal mortality and access and service of health infrastructure. In this paper we point out that health inputs, especially from the supply sides, required to reduce neonatal mortality is significantly different from child's mortality above one month. Our results show that households closer to the DHs are the households with lesser neonatal death, controlling for socioeconomic and birth related characteristics as well as state dummies. We have created variables for health infrastructure at different hierarchical levels and show that it is only the district level facilities (e.g., emergency obstetric care) that matters. Other lower level health facilities such CHCs and PHCs are insignificant in influencing neonatal mortality.

The above results have significant implications for policies aiming at reducing neonatal deaths in India. It points out what should be the priority areas and what not. There is a growing interest in community-based delivery platforms for maternal and newborn care. Our results indicate that most of these interventions will be ineffective for reducing neonatal mortality without well-equipped emergency obstetric care in district hospitals.

[10] We did not report these results of interaction terms in the paper. These results can be available upon request.

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Appendix

Table 2- Descriptive statistics

Variable	Full sample (99,735)	Neonatal death (2003)	P value
Neonatal = 1 if child is born alive but died within a month of birth	0.02	1	
Distance from Village to DH (kms)	38.72	39.13	0.43
Delivery room at DH - dummy variable = 1 if yes, 0 otherwise	0.84	0.82	0.03
Emergency obstetric care at DH = 1 if gynaecologist is available 24 hrs at DH	0.83	0.80	0.00
Average number of Paediatrician in a district	1.98	2.01	0.46
Distance from Village to CHC (km)	18.27	17.94	0.31
Average number of gynaecologist at CHCs in a Block	0.26	0.28	0.08
Average number of paediatrician at CHCs in a Block	0.18	0.21	0.00
Operation theatre at CHC - dummy variable = 1 if yes,	0.57	0.63	0.00
Operation theatre PHC - dummy variable = 1 if yes,	0.45	0.46	0.62
No of referral as a share of delivery performed in last year	0.27	0.23	0.57
Distance from Village to PHC (kms)	9.64	9.25	0.03
Respondent’s religion: Hindu- dummy variable= 1 if yes	0.81	0.82	0.25
Respondent’s religion: Muslim- dummy variable= 1 if yes	0.13	0.13	0.81
Respondent’s caste: Scheduled caste/tribe - dummy variable= 1 if yes	0.36	0.35	0.76
Wealth poorest - reference group	27	31	0.00
Wealth poor - dummy variable= 1 if yes	0.26	0.29	0.00
Wealth middle- dummy variable= 1 if yes	0.22	0.21	0.17
Wealth rich- dummy variable= 1 if yes	0.17	0.14	0.00
Wealth richest- dummy variable= 1 if yes	0.08	0.05	0.00
Father ever attended school- dummy variable= 1 if yes	0.71	0.66	0.00
Mother ever attended school	0.45	0.39	0.00
Mother’s age at birth	24.97	24.51	0.00
Multiple birth - dummy variable= 1 if yes	0.009	0.05	0.00
Male	0.53	0.58	0.00
Birth order second	0.25	0.19	0.00
Birth order third	0.17	0.13	0.00
Birth order fourth	0.10	0.09	0.16
Birth order fifth and above	0.17	0.19	0.00
Problems during birth: premature labour- dummy variable= 1 if yes	0.31	0.34	0.02
Problems during birth: excessive bleeding- dummy variable= 1 if yes	0.08	0.11	0.00
Problems during birth: prolonged labour- dummy variable= 1 if yes	0.21	0.25	0.00
Problems during birth: obstructed labour- dummy variable= 1 if yes	0.45	0.48	0.00
Problems during birth: breech presentation- dummy variable= 1 if yes	0.04	0.07	0.00
Problems during birth: convulsion/high b.p- dummy variable= 1 if yes	0.04	0.05	0.06

Table 3: Regression results (full sample)

VARIABLES	(1) model 1	(2) model 2	(3) model 3	(4) model 4	(5) model 5
Distance of village from DH	0.0001*	0.0001	0.0001	0.0001	0.0001*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Delivery room at DH	-0.0014	-0.0022*	-0.0013	-0.0007	-0.0009
	(0.0012)	(0.0012)	(0.0013)	(0.0013)	(0.0013)
Gynaecologists available 24 hours at DH	-0.0045***	-0.0039***	-0.0049***	-0.0043***	-0.0019
	(0.0011)	(0.0012)	(0.0013)	(0.0013)	(0.0013)
Paediatrician at DH	0.0004*	0.0003	0.0003	0.0002	-0.0004
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)
Distance of village from CHC		-0.0000	0.0000	-0.0000	-0.0000
		(0.0000)	(0.0000)	(0.0000)	(0.0000)
Gynaecologists at CHC		0.0002	-0.0005	-0.0003	-0.0002
		(0.0008)	(0.0010)	(0.0009)	(0.0009)
Paediatrician at CHC		0.0013	0.0020*	0.0018	0.0019*
		(0.0010)	(0.0012)	(0.0011)	(0.0011)
Operation theatre at CHC		0.0039***	0.0036***	0.0042***	0.0010
		(0.0009)	(0.0010)	(0.0009)	(0.0011)
Referral as a share of delivery (PHC)			-0.0001	-0.0001	-0.0000
			(0.0002)	(0.0002)	(0.0001)
Operation theatre at PHC			0.0014*	0.0012	0.0001
			(0.0009)	(0.0009)	(0.0009)
Distance of village from PHC			-0.0001	-0.0001**	-0.0001**
			(0.0001)	(0.0001)	(0.0001)
Distance to private clinic/hospital			-0.0000	-0.0000	-0.0000
			(0.0000)	(0.0000)	(0.0000)
Hindu				0.0011	0.0027
				(0.0021)	(0.0024)
Muslim				0.0001	0.0033
				(0.0025)	(0.0033)
Scheduled caste/tribe				-0.0010	0.0005
				(0.0009)	(0.0009)
Wealth poor				-0.0005	-0.0002
				(0.0011)	(0.0011)
Wealth middle				-0.0029**	-0.0021*
				(0.0012)	(0.0012)
Wealth rich				-0.0051***	-0.0040***
				(0.0013)	(0.0013)
Wealth richest				-0.0074***	-0.0074***
				(0.0015)	(0.0014)
Husband ever attended school				-0.0018*	-0.0015
				(0.0010)	(0.0010)
Mother ever attended school				-0.0030***	-0.0013
				(0.0010)	(0.0010)
Mother's age at birth				-0.0026***	-0.0018***
				(0.0006)	(0.0006)
Mother's age at birth_square				0.0000***	0.0000***
				(0.0000)	(0.0000)
Multiple birth				0.0865***	0.0842***

	(0.0103)	(0.0101)
Sex of child (male)	0.0039***	0.0038***
	(0.0008)	(0.0008)
Birth order second	-0.0076***	-0.0079***
	(0.0010)	(0.0009)
Birth order third	-0.0076***	-0.0086***
	(0.0011)	(0.0010)
Birth order fourth	-0.0054***	-0.0071***
	(0.0013)	(0.0012)
Birth order fifth and above	-0.0032**	-0.0061***
	(0.0015)	(0.0013)
Problems: premature labour	-0.0001	0.0000
	(0.0010)	(0.0009)
Problems: excessive bleeding	0.0043***	0.0057***
	(0.0017)	(0.0017)
Problems: prolonged labour	0.0016	0.0017
	(0.0011)	(0.0011)
Problems: obstructed labour	0.0006	-0.0003
	(0.0009)	(0.0009)
Problems: breech presentation	0.0104***	0.0114***
	(0.0025)	(0.0025)
Problems: convulsion/high b.p	0.0004	0.0011
	(0.0020)	(0.0020)
Jammu and Kashmir	0.0168**	0.0174***
	(0.0066)	(0.0066)
Himachal		-0.0053
		(0.0034)
Punjab		-0.0124***
		(0.0026)
Uttarakhand		0.0198**
		(0.0081)
Haryana		-0.0100***
		(0.0028)
Rajasthan		0.0139**
		(0.0064)
Uttar Pradesh		0.0108**
		(0.0050)
Bihar		0.0175***
		(0.0048)
Assam		0.0090**
		(0.0045)
West Bengal		0.0056
		(0.0044)
Jharkhand		0.0044
		(0.0046)
Orissa		0.0003
		(0.0046)
Chhattisgarh		0.0019
		(0.0045)
Madhya Pradesh		0.0132**
		(0.0057)
Gujarat		0.0051
		(0.0041)
Maharastra		-0.0063**

					(0.0030)
Andhra					-0.0034
					(0.0035)
Karnataka					0.0095
					(0.0062)
Kerala					0.0075
					(0.0053)
Observations	130,641	125,992	102,604	99,805	99,735

Standard errors in parentheses. We present marginal effects in all our models

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Regression results: backward states

VARIABLES	(1) model 1	(2) model 2	(3) model 3	(4) model 4	(5) model 5
Distance of village from DH	0.0001***	0.0001**	0.0001***	0.0001*	0.0001**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Delivery room at DH	-0.0007	-0.0014	-0.0001	-0.0004	-0.0008
	(0.0014)	(0.0015)	(0.0015)	(0.0015)	(0.0016)
Gynaecologists available 24 hours at DH	-0.0049***	-0.0036**	-0.0043***	-0.0045***	-0.0016
	(0.0014)	(0.0014)	(0.0015)	(0.0015)	(0.0015)
Paediatrician at DH	0.0004	0.0002	-0.0001	-0.0000	-0.0007*
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
Distance of village from CHC		-0.0001*	-0.0000	-0.0000	-0.0000
		(0.0000)	(0.0000)	(0.0000)	(0.0000)
Gynaecologists at CHC		-0.0002	-0.0012	-0.0009	0.0001
		(0.0010)	(0.0011)	(0.0011)	(0.0011)
Paediatrician at CHC		0.0013	0.0017	0.0016	0.0019
		(0.0012)	(0.0014)	(0.0013)	(0.0013)
Operation theatre at CHC		0.0046***	0.0044***	0.0044***	0.0002
		(0.0011)	(0.0012)	(0.0011)	(0.0014)
Referral as a share of delivery (PHC)			0.0000	0.0000	0.0002
			(0.0004)	(0.0004)	(0.0004)
Operation theatre at PHC			0.0016	0.0016	-0.0004
			(0.0011)	(0.0010)	(0.0011)
Distance of village from PHC			-0.0001**	-0.0002**	-0.0002**
			(0.0001)	(0.0001)	(0.0001)
Distance to private clinic/hospital			-0.0001**	-0.0001*	-0.0000
			(0.0000)	(0.0000)	(0.0000)
Hindu				0.0048	0.0014
				(0.0035)	(0.0041)
Muslim				0.0026	0.0014
				(0.0046)	(0.0046)
Scheduled caste/tribe				-0.0006	0.0009
				(0.0011)	(0.0012)
Wealth poor				-0.0005	-0.0006
				(0.0013)	(0.0013)
Wealth middle				-0.0028**	-0.0030**
				(0.0014)	(0.0014)
Wealth rich				-0.0041**	-0.0043***
				(0.0016)	(0.0016)
Wealth richest				-0.0062***	-0.0071***
				(0.0021)	(0.0020)
Husband ever attended school				-0.0019	-0.0018
				(0.0012)	(0.0012)
Mother ever attended school				-0.0022*	-0.0012
				(0.0012)	(0.0012)
Mother's age at birth				-0.0027***	-0.0019***
				(0.0007)	(0.0007)
Mother's age at birth_square				0.0000***	0.0000***

				(0.0000)	(0.0000)
Multiple birth				0.1021***	0.1015***
				(0.0126)	(0.0126)
Sex of child (male)				0.0048***	0.0048***
				(0.0010)	(0.0010)
Birth order second				-0.0083***	-0.0091***
				(0.0012)	(0.0011)
Birth order third				-0.0086***	-0.0101***
				(0.0013)	(0.0012)
Birth order fourth				-0.0067***	-0.0088***
				(0.0016)	(0.0014)
Birth order fifth and above				-0.0049***	-0.0083***
				(0.0017)	(0.0016)
Problems: premature labour				-0.0009	-0.0007
				(0.0011)	(0.0011)
Problems: excessive bleeding				0.0068***	0.0078***
				(0.0021)	(0.0021)
Problems: prolonged labour				0.0019	0.0021
				(0.0013)	(0.0013)
Problems: obstructed labour				0.0002	-0.0004
				(0.0011)	(0.0011)
Problems: breech presentation				0.0129***	0.0134***
				(0.0031)	(0.0031)
Problems: convulsion/high b.p				-0.0007	0.0001
				(0.0023)	(0.0023)
State dummies	No	No	No	No	Yes
Observations	93,919	91,336	78,288	76,072	76,072

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Robustness Check: break down of neonatal death

Dependent variable: child dying in first week

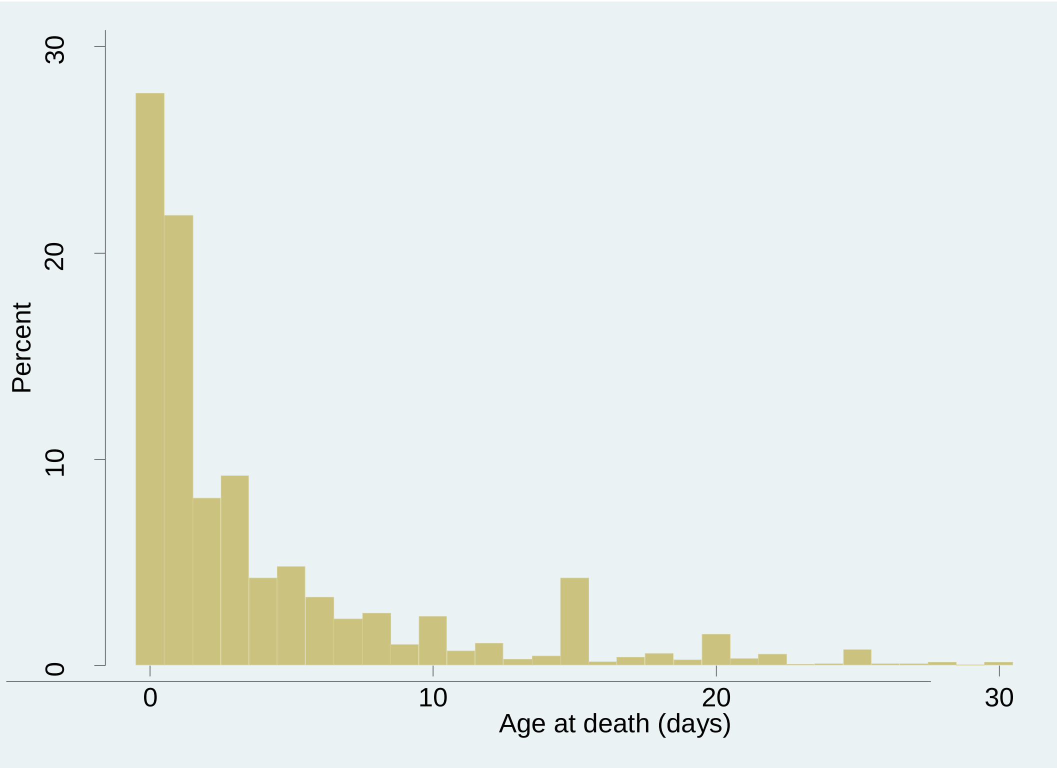
	Full sample		Neonatal death	
VARIABLES	model 1	model 2	model 3	model 4
Distance of village from DH	0.0000	0.0001***	0.0012***	0.0012***
	(0.0000)	(0.0000)	(0.0004)	(0.0004)
Delivery room at DH	-0.0011	-0.0010	-0.0166	-0.0121
	(0.0012)	(0.0012)	(0.0253)	(0.0279)
Gynaecologists available 24 hours at DH	-0.0033***	-0.0011	0.0107	0.0060
	(0.0011)	(0.0012)	(0.0262)	(0.0284)
Paediatrician at DH	0.0002	-0.0003	-0.0012	0.0007
	(0.0002)	(0.0002)	(0.0058)	(0.0067)
Distance of village from CHC	-0.0000	-0.0000	-0.0006	-0.0006
	(0.0000)	(0.0000)	(0.0006)	(0.0006)
Gynaecologists at CHC	-0.0001	-0.0000	0.0059	0.0075
	(0.0008)	(0.0008)	(0.0200)	(0.0208)
Paediatrician at CHC	0.0008	0.0009	-0.0330	-0.0304
	(0.0010)	(0.0010)	(0.0202)	(0.0206)
Operation theatre at CHC	0.0033***	0.0011	0.0001	0.0184
	(0.0008)	(0.0010)	(0.0201)	(0.0246)
Referral as a share of delivery (PHC)	-0.0000	-0.0000	0.0024	0.0012
	(0.0002)	(0.0001)	(0.0074)	(0.0081)
Operation theatre at PHC	0.0007	-0.0002	-0.0181	-0.0212
	(0.0008)	(0.0008)	(0.0177)	(0.0195)
Distance of village from PHC	-0.0001**	-0.0001*	-0.0001	0.0001
	(0.0001)	(0.0001)	(0.0013)	(0.0013)
Distance to private clinic/hospital	-0.0000	-0.0000	-0.0003	-0.0003
	(0.0000)	(0.0000)	(0.0007)	(0.0007)
Hindu	0.0018	0.0031	0.0468	0.0333
	(0.0019)	(0.0021)	(0.0506)	(0.0638)
Muslim	0.0012	0.0040	0.0380	0.0365
	(0.0024)	(0.0032)	(0.0467)	(0.0585)
Scheduled caste/tribe	-0.0009	0.0005	-0.0082	-0.0002
	(0.0008)	(0.0008)	(0.0197)	(0.0203)
Wealth poor	-0.0007	-0.0005	-0.0158	-0.0198
	(0.0010)	(0.0010)	(0.0234)	(0.0240)
Wealth middle	-0.0027***	-0.0021**	-0.0123	-0.0174
	(0.0010)	(0.0010)	(0.0266)	(0.0280)
Wealth rich	-0.0043***	-0.0035***	-0.0012	-0.0107
	(0.0011)	(0.0011)	(0.0308)	(0.0332)
Wealth richest	-0.0053***	-0.0054***	0.0673*	0.0630
	(0.0013)	(0.0013)	(0.0366)	(0.0397)
Husband ever attended school	-0.0014	-0.0011	-0.0000	0.0065
	(0.0009)	(0.0009)	(0.0204)	(0.0210)
Mother ever attended school	-0.0019**	-0.0006	0.0238	0.0237
	(0.0009)	(0.0009)	(0.0201)	(0.0209)
Mother's age at birth	-0.0020***	-0.0015***	0.0022	0.0037

	(0.0005)	(0.0005)	(0.0113)	(0.0117)
Mother's age at birth_square	0.0000***	0.0000***	0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0002)	(0.0002)
Multiple birth	0.0728***	0.0706***	0.0261	0.0297
	(0.0095)	(0.0093)	(0.0382)	(0.0380)
Sex of child (male)	0.0039***	0.0037***	0.0357**	0.0356**
	(0.0007)	(0.0007)	(0.0177)	(0.0181)
Birth order second	-0.0066***	-0.0068***	-0.0325	-0.0336
	(0.0009)	(0.0008)	(0.0267)	(0.0274)
Birth order third	-0.0067***	-0.0075***	-0.0407	-0.0376
	(0.0009)	(0.0009)	(0.0331)	(0.0336)
Birth order fourth	-0.0047***	-0.0061***	-0.0212	-0.0211
	(0.0012)	(0.0010)	(0.0382)	(0.0391)
Birth order fifth and above	-0.0039***	-0.0061***	-0.0827**	-0.0827**
	(0.0013)	(0.0011)	(0.0401)	(0.0415)
Problems: premature labour	0.0004	0.0005	0.0222	0.0257
	(0.0009)	(0.0008)	(0.0196)	(0.0200)
Problems: excessive bleeding	0.0040***	0.0051***	0.0287	0.0288
	(0.0015)	(0.0015)	(0.0272)	(0.0278)
Problems: prolonged labour	0.0012	0.0012	-0.0175	-0.0219
	(0.0010)	(0.0010)	(0.0225)	(0.0232)
Problems: obstructed labour	0.0009	0.0002	0.0209	0.0230
	(0.0008)	(0.0008)	(0.0182)	(0.0188)
Problems: breech presentation	0.0097***	0.0106***	0.0552*	0.0582*
	(0.0023)	(0.0023)	(0.0303)	(0.0306)
Problems: convulsion/high b.p	-0.0001	0.0004	-0.0239	-0.0270
	(0.0017)	(0.0017)	(0.0426)	(0.0439)
State dummies	No	Yes	No	Yes
Observations	99,805	99,735	2,003	1,969

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Break-down of neonatal sample



A1: Description of supply side variables

District Hospital delivery room: It is a measure of the average number of district hospitals having functioning delivery room in a district. This variable is taken from the district hospital survey, where 1 is yes a delivery room is available and 0 is no. For example is a person has access to 2 district hospitals and one has a delivery room available and the other doesn't then the value of this variable will be 0.5.

District Hospital gynaecologists available 24 hours: It is a measure of the number of district hospitals in a district where gynaecologists are available 24 hours. This is a mean of the dummy variables which takes the value of 1 when yes and 0 when no.

District Hospital paediatrician: It is a measure of the average number of paediatricians available in district hospitals. This includes both the number paediatrician both in position and on contract.

CHC gynaecologists: It is a measure of the average number of gynaecologists available in in CHC in a Block. This includes both in position and on contract.

CHC paediatrician: It is a measure of the average number of paediatrician available in in CHC in a Block. This includes both the number paediatrician both in position and on contract.

CHC operation theatre: It is a measure of the average number of CHCs with functional operation theatres that in a Block. This is the mean of dummy variables which takes on values 1 and 0. If a person has access to 2 CHCs where one has functional operation theatres while the other doesn't then the value of this variable will be 0.5.

PHC operation theatre: It is a measure of the average number of PHCs with functional operation theatres that in a Block. This is the mean of dummy variables which takes on values 1 and 0. If a person has access to 3 CHCs where one has functional operation theatres while the other two don't then the value of this variable will be 0.33.

PHC referral delivery: It is the number of delivery cases referred to higher facilities (CHC, DH) as a ratio of delivery performed at the PHC.