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Abstract

Using nationally representative data from India, we document the first survey-based evidence of the unintended consequences of lockdown on neonatal mortality in a developing country. Event-study shows neonatal mortality significantly increased during the first nationwide lockdown and became insignificant one-month later. The difference-in-difference estimates show neonatal mortality increased to 47 from 30 per 1,000 births during the lockdown. Negative *in-utero* exposure, forgone healthcare (through service interruption and avoidance), and delaying vaccinations are crucial impact mechanisms. Our findings stimulate the debate on the efficacy of strict lockdown, its duration, and missing policy directives in resource-poor countries, particularly for the care-dependent population. [100 words]

Keywords: COVID-19, India, Neonatal and infant mortality, Lockdown, *In-utero* exposure, Child vaccinations, Antenatal care visits.

JEL Classifications: I18, J13

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1 Introduction

This paper studies the unintended and indirect impact of the COVID-19 lockdown on neonatal and infant mortality — in a developing country setting with inadequate health infrastructure. India was among the world's worst-affected countries where the pandemic took a high toll.[1] More than half a million deaths in the country were attributed to the pandemic.[2] About 45 million people were reported to be infected by the coronavirus, while uncounted millions suffered from virus symptoms. In late March 2020, the Indian government implemented mobility restrictions to curb the spread of the virus, upon the advice of international agencies, scientists, and public health experts (Walker et al., 2020; Hsiang et al., 2020; COVID, 2020). Termed as the "Great Indian Lockdown" (Roychowdhury et al., 2022), this stringent mobility stipulation helped reduce the number of COVID-19-related deaths, hospitalizations, and new infections in the country (see Thayer et al. (2021)). However, the pandemic-led lockdown came with grim unintended consequences, in the form of rising neonatal and infant mortality for babies born during the lockdown, which we document in this study.

The Indian government ordered one of the strictest COVID-19 lockdowns (Hale et al., 2020),[3] which continued until the end of May 2020 and then was partially relaxed from June to September in districts with low number of COVID-19 cases (IMF, 2023). Typical access to hospitals and healthcare facilities was disrupted during the first lockdown since a curfew was imposed, and transportation came to a standstill in the early stages of the lockdown. Despite allowing for partial population movement, numerous non-COVID patients were refused admission to hospitals due to the overwhelming number of COVID-19 patients, and doctors and nurses were busy attending to rising cases of infections.[4] Lacking sufficient per-

[1] Johns Hopkins coronavirus resource center: https://coronavirus.jhu.edu/.

[2] WHO Coronavirus Dashboard: https://covid19.who.int/.

[3] Government of India Ministry of Home Affairs order number 40-3/2020-DM-I(A): http://ihmeuw.org/5t0r.

[4] Indian Express, 2020. Private Hospitals Can't Refuse Critical Patients or Insist on Testing All for COVID-19:Centre https://www.newindianexpress.com/nation/2020/apr/28/private-hospitals-cant-refuse-critical-patients-or-insist-on-testing-all-for-covid-19-centre-2136540.html

sonal protective gear; these supply-side bottlenecks got amplified due to healthcare workers getting exposed and infected with COVID-19 (Homer et al., 2021). Moreover, early reports document substantial hospital and healthcare facility avoidance by the general population, owing to the fear of contracting the virus (Bisht et al., 2021). All these factors largely affected patients with chronic health conditions (Modesti et al., 2020) and those with time-sensitive care needs, such as pregnant women, newborns, and infants.[5]

Given the length of the lockdown and the fact that mobility restrictions were partially relaxed at different points in time, we identified the lockdown period based on the Oxford Stringency Index.[6] We consider the lockdown period from April to September 2020, when the value of the stringency index was more than the global median value of 81.02 (Santini et al., 2022). Our sample consists of 43,786 children from the latest round of the National Family Health Survey of India 2019-2021 (NFHS-5, known as DHS of India). We estimate the impact of the COVID-19 lockdown on neonatal and infant mortality using event-study design and the difference-in-difference method.[7] The latest NFHS-5 round is unique in the sense that it collected nationally representative household survey data between June 2019 and May 2021, that is, before and during the COVID-19 pandemic. We primarily use data from states where the survey was conducted during 2020 and 2021, representing about 55% of the sample (see Table A9).[8]

[5]New York Times, 2020."8 Hospitals in 15 Hours: A Pregnant Woman's Crisis in the Pandemic" highlights a woman's struggle to find healthcare during childbirth. Mehta et al. (2020) report that due to the nationwide lockdown, maternal and child health care providers, such as Anganwadi workers, faced many challenges, including long travel distances, threats from villagers, and in some cases even beatings for leaving their homes in violation of the lockdown. Similarly, Unicef et al. (2021) predicted 67 million children will partially or fully miss routine vaccination globally, and the highest share of these missing vaccination will be in India (about 3 million).

[6]`https://ourworldindata.org/covid-stringency-index` The Oxford Stringency Index is calculated based on nine metrics, including school closures; workplace closures; cancellation of public events; restrictions on public meetings; closure of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls. The index varies from 0 to 100. See Hale et al. (2020) for detailed information.

[7]Leslie and Wilson (2020) and Abrams (2021) use similar identification strategies to examine the impact of COVID-19 social distancing orders on domestic violence and crime in the U.S. context, respectively.

[8]The NFHS-5 survey was administered by states; hence once data was collected in one state, the survey moved to a different state. We use data from 17 states where the survey was conducted after the lockdown. In our primary analysis, we do not use data from 19 states which had completed the survey before the pandemic and hence did not have any information about neonatal and infant mortality during the lockdown.

We compare mortality rates between two birth cohorts; infants born between October 2018 to September 2019 and infants born between October 2019 to September 2020, where the latter cohort faced strict lockdown between April-September 2020. We also control for individual and household observables as well as seasonality and district-by-month-of-birth and district-by-year-of-birth fixed effects in all our regressions.

Our event-study estimates show that the lockdown took a significant toll on neonatal mortality in April 2020, the first month of the nationwide strict lockdown, and this effect continued during the lockdown period. Our difference-in-difference model quantifies the magnitude of this impact. We find neonatal mortality rates inflate by 1.7 percentage points during the lockdown. This translates to an increase in neonatal mortality rate from 30 per 1,000 live births in 2019 to 47 per 1,000 live births between April and September 2020. A simple back-of-the-envelope calculation suggests that this rise generates an additional 1,165 neonatal deaths per day during the lockdown — equivalent to 40% of all COVID-19 deaths in India.[9] The economic cost of this loss was more than 100 billion US dollars based on the value of statistical life measures.[10]

For infant mortality, we estimate a similar effect, an increase of 53.5% (moving to 43 from 28 per 1,000 live births), which is a conservative estimate since we do not observe the full survival history of all newborns up to 12 months after birth. In the sub-group analysis, we find statistically significant and large negative effects of the COVID-19 lockdown on neonatal and infant mortality among boys, in rural areas, and economically marginalized households — almost all the impact significance is concentrated on male children, families with low

However, for robustness check, we estimated the models with unrestricted samples, which show consistent findings.

[9]This is estimated assuming i) fertility rates during the pandemic remained constant at the pre-pandemic levels and were constant across all states, ii) the estimated mortality rates based on our sample were mortality rates in the entire country. Based on a UNICEF report https://www.unicef.org/india/key-data, about 68,500 babies are born in India daily. In 2019, daily neonatal mortality was 30 deaths per 1000 live births, that is, 68.5*30=2,055 deaths of neonatal infants every day. During the lockdown, we estimate the neonatal mortality rate rose to 47 deaths per 1000 live births, which means 68.5*47=3,220 deaths per day. A total of 182 days are between 1st April to 30th September.

[10]According to Sweis, Nadia (2022), the value of statistical life (VSL) for India ranges from 1.2 to 0.1 with an average VSL of around $0.5 million.

income, and those residing in rural areas.

We perform an array of tests to examine the validity and robustness of our findings. First, we estimate our outcomes by narrowing the strict lockdown period from six months to five, four, and three months respectively. Our estimates for all outcomes are similar, despite the change in the length of the lockdown periods. Second, we use alternative cohort definitions by shifting the cohort window by one and two months forward.[11] Our main findings remain consistent even with changing cohort windows. Third, given that some part of the control cohort was still below the age of 1 year at the start of the lockdown, hence was partially exposed to the lockdown, we alternatively utilized one year prior to the control cohort as the comparison cohort and find similar impact on infant mortality. Fourth, we conduct a falsification test where we move the actual lockdown date back by one and two years and re-estimate our difference-in-difference model using this placebo lockdown date. The falsification test estimates are statistically insignificant and small in magnitude. Fifth, we check the consistency of our findings by using unrestricted data (using the entire NFHS-5 eligible sample regardless of the survey year) for our main outcome variables of interest and find similar impact of statistical significance.

Given these findings, one obvious question is whether we are measuring the direct effect of COVID-19 on neonatal and infants. Existing studies document that COVID-19 had a much smaller direct impact on infants compared with the older population (Goldstein and Lee, 2020). In a recent report, (UNICEF, 2022) concludes that *"... a very modest direct mortality impact from the COVID-19 pandemic for children..."* [pg. 25]. In our event study estimation, we also find a decreasing and insignificant impact on neonatal mortality one month after the lockdown period. Although pregnancy elevated the likelihood of experiencing severe COVID-19, the impact of COVID-19 on the fetus was relatively restricted both clinically and immunologically (Foo et al., 2021). Since COVID-19 primarily affects the respiratory system, it seldom passes through the placenta to infect the fetus. There exists no concerning

[11] Comparing cohorts born between November 2018 to October 2019 with November 2019 to October 2020 and December 2018 to November 2019 with December 2019 to November 2020, respectively.

impact of intrauterine, vertical, or breast-milk transmission of COVID-19 infection (Kotlar et al., 2021), making its effects secondary in nature (Wei et al., 2021).

Hence, we examine possible factors which may explain the rise in neonatal mortality during the lockdown. The indirect impact of COVID-19 in infancy can work through multiple pathways and could be complementary. Several studies (based on data from diverse sources) report adverse outcomes such as preterm labor for pregnant mothers during COVID-19,[12] requiring hospitalization and Cesarean procedures, which were difficult to conduct during the lockdown (Kotlar et al., 2021). Moreover, lack of access to healthcare facilities, deferred healthcare services, and avoidance of visits to doctors happened during the critical stage of antenatal and post-natal care —further deteriorated the situation (Homer et al., 2021). Moreover, the lockdown had a substantial negative *in-utero* impact on pregnant women, triggering depression and anxiety (Shayganfard et al., 2020). This negative *in-utero* exposure was complemented by social (for example, domestic violence (Ravindran and Shah, 2023)) and economic hardships (such as losing a job) along with a reduction in nutritional intake, missing taking essential drugs, and supplements (Bisht et al., 2021; Osendarp et al., 2021).

Although the dataset we use does not have all the information to test these various mechanisms empirically, we broadly checked three groups of variables to understand the mechanism;[13] forgone maternal health care, missing (and delay) in vaccination, and negative *in-utero* exposure. We find a marked reduction in antenatal visits undertaken by pregnant women during the lockdown, along with foregoing important medicines and supplements (iron and intestinal parasite tablets). Moreover, a greater proportion of infants born during the lockdown period did not receive essential vaccines at birth (or received vaccines with a delay of several days), such as the BCG vaccine, which has an established link with infant mortality (Biering-Sørensen et al., 2017).[14] We also find substantial evidence of negative

[12] Although evidence is mixed between high income and LMICs, see (Chmielewska et al., 2021).

[13] We also check whether some mechanism variables systematically had more missing values.

[14] Bisht et al. (2021) reported that many states in India resumed immunization activities in May 2020, following national and state guidelines. However, factors such as lack of awareness, fear of virus exposure, transportation issues, long queues, limited staff, and reassignment of workers discouraged families from vaccinating. Rising temperatures and the rainy season between June and September also added to the

in-utero exposure of lockdown – contributing to neonatal and infant mortality. We subject these impact channels for multiple hypothesis testing and false discovery rate (FDR). All the evidence points to the critical debate on the efficacy of lockdown, its duration and level of stringency, and missing policy directives in Low and Middle-Income countries (LMICs), particularly for the medical care-dependent population. Our analysis calls for more discussion on policies which would include optimizing the lockdown duration to minimize unintended harms while controlling the spread of the virus contamination (Shonchoy et al., 2021), adhering to more non-stringency measures such as a universal mask mandate (Abaluck et al., 2022), more public health messaging to uptake health services for critical care patients (Ho et al., 2023), more support under safety net (Miguel and Mobarak, 2022) and data-driven "smart" contagion risk management (Shonchoy et al., 2023).

Our estimated mortality rates are higher than those reported in the government's Civil Registration System (CRS),[15] the UN Inter-agency Group for Infant and Neonatal Mortality Estimation,[16] and the World Bank.[17] Nevertheless, our findings are consistent with UNICEF (2021) report that predicted a significant increase in neonatal and child mortality in India between April and June 2020 by 39.3% and 36.5%, respectively [pg. 21, Table 9], which partially overlaps with the period of lockdown in our study. One possible explanation for the discrepancy is the large under-reporting of newborns in the system of vital registration during the lockdown, which led to significant under-counting of neonatal mortality. Local news articles report a notable decline in the number of registered pregnant women and childbirth during the lockdown in several states in India.[18] In fact, the CRS (2020) report admits this issue where it states *"..... the share of rural area is only 23.4% while that of urban area is 76.6% in total registered infant deaths during the year. Non-registration of*

challenges. The private sector, which is an important provider of immunization services, also was affected due to shortages of personal protective equipment (PPE), vaccine unavailability, and travel limitations.

[15]The CRS is officially under the Office of the Registrar General, India; Ministry of Home Affairs, Vital Statistics Division

[16]https://childmortality.org/data/India

[17]https://data.worldbank.org/indicator/SP.DYN.IMRT.IN?locations=IN.

[18]For example see https://thefederal.com/health/missing-in-lockdown-lakhs-of-pregnant-women-and-newborns/

infant deaths in rural area is a cause of concern which may be due to non-reporting of infant deaths to the Registrars, especially in case of domiciliary events." [pg. 36]. Such a concern was also echoed by the academics reporting systematic under-counting problems in national statistics (Jha et al., 2022; Dandona et al., 2023). These concerns call for better state capacity for accurate surveillance and reporting procedures as well as more policy response at the time of crisis by local and international agencies.

Our paper adds to the growing literature studying the negative impact of the COVID-19 lockdown, including economic (Deb et al., 2022; Mottaleb et al., 2020), social (Micelli et al., 2020; Abrams, 2021; Leslie and Wilson, 2020) and physiological impact (Aksunger et al., 2023; Engzell et al., 2021), along with school closure effect on learning loss (Azevedo et al., 2021; Engzell et al., 2021), child marriage (Yukich et al., 2021), abortions (Marquez-Padilla and Saavedra, 2022) and parenthood (Micelli et al., 2020). Studies on the impact of the lockdown on physical health have considered among other factors hospital avoidance (Zhang, 2021; Jain and Dupas, 2022), delaying healthcare access (Imlach et al., 2022; Nshimyiryo et al., 2021; Wu et al., 2020; Berthelot et al., 2020) and vaccinations (Saxena et al., 2020; Baghdadi et al., 2021; Causey et al., 2021).

To our knowledge, our paper is the first household survey-based study to examine the causal relationship between the COVID-19 lockdown on neonatal and infant mortality in an LMIC setting. Most of the studies in resource-poor countries, such as the Nepal (Ashish et al., 2020) and Uganda (Hedstrom et al., 2021), utilized hospital administrative records and did not have information on non-institutional pregnancy and birth outcomes, which are important missing components to measure neonatal and infant mortality.[19] Other studies that report concerns on the possible rise in infant mortality are based on prediction analysis utilizing modeling exercise (see Roberton et al. (2020); Ahmed et al. (2022)).

Our paper also speaks to the pandemic and endemic (direct and indirect) impact on infants, such as the Rubella pandemic (Rodriguez, 2003), Zika Virus outbreak (Coelho and

[19]Both these and other relevant studies report a drastic drop in institutional birth during the lockdown, see (Chmielewska et al., 2021; Vaccaro et al., 2021; Calvert et al., 2023) for a review.

Crovella, 2017), Ebola outbreak (Garske et al., 2017), Malaria (Bardají et al., 2011) and HIV/AIDS (Kurewa et al., 2010). We also contribute to the literature on negative *in-utero* exposure of virus outbreak on infant mortality (Dorélien, 2019; Almond, 2006).

The paper proceeds as follows. Section 2 describes the data we used in our analysis. Section 3 explains our empirical framework to examine the causal impact of COVID-19 lockdown on main outcome of interests. We interpret our main findings in Section 4, including robustness checks, falsification tests, and heterogeneity analysis, 5 explains mechanisms, and conclude in Section 6.

2 Data

Survey: The data used in this study come from the most recent National Family Health Survey's (NFHS-5) children recode file, which was conducted in India between June 2019 and May 2021. NFHS-5 covered 636,699 households in 707 districts in all 36 states and union territories and 232,920 children under the age of five.[20]

The latest NFHS-5 survey was conducted in two phases. Phase 1 extended from June 2019 to January 2020 and covered 19 states and union territories, while Phase 2 ran from January 2020 to April 2021 and covered the remaining 17 states and union territories; the survey was paused during the COVID-19 lockdown period from April to October 2020. Through this process, 19 states and union territories had completed the survey before the pandemic and hence did not have any information about neo-natal and infant mortality during the lockdown. For this reason, we excluded these 19 states and union territories from our main estimation sample. The 17 states and union territories interviewed between 2020 and 2021 that make up our main sample represent more than half of the Indian population shown in Table A8. A full list of states and union territories with survey years and observation shares

[20]NFHS-5 is a stratified two-stage sample survey using the 2011 census as the sampling frame for primary survey units (PSUs). In rural areas, PSUs were villages, and in urban areas, they were Census Blocks. The NFHS is a cross-sectional worldwide program conducting nationally representative surveys in developing countries. NFHS data is publicly available and can be downloaded freely after registration from https://dhsprogram.com.

is listed in Appendix Table A9.

Primary Variables: The survey collected information on children and their parents, including family socioeconomic and demographic characteristics, maternal fertility history, infant survival status, maternal healthcare use during pregnancy, and immunization records. We examine three types of infant mortality as our main outcome variables: (i) infant mortality <24 hours shows if the baby died on the first day of birth, (ii) neonatal mortality shows whether the baby died in the first month since birth, and (iii) infant mortality shows whether the baby died in the first year since birth.

Variables measuring mechanism: In addition to the main outcomes, we also examine the mechanism outcomes to find out what drives our main results. We examine seven variables that are related to maternal healthcare during pregnancy: (i) whether the birth was given at a health facility, (ii), whether the mother took an iron tablet, (iii) intestinal parasite tablet, and (iv) whether mother's blood pressure, as well as (v) blood and (vi) urine sample, were taken during the pregnancy, (vii) whether the mother had at least four (recommended) or more antenatal visits.[21] We exploit the cross-sectional nature of the NFHS-5 survey to construct consistent measures of all the outcomes; the Appendix lists all the variables and the definitions used in our study.

In addition to information on maternal healthcare, we consider three vaccines recommended at birth: Bacillus Calmette–Guérin (BCG), Polio (Polio 0), and Hepatitis B birth dose (hepB0). We measure two sets of outcome variables for vaccines. The first set is a binary indicator equal to 1 if the vaccine is received on time, that is, at birth, and 0 if it is delayed. The second set is where we measure the number of days by which the vaccines were delayed.

Index Construction: We created a maternal health usage index that covers six variables: taken iron tablets, and intestinal parasite tablets during pregnancy, blood pressure,

[21] According to guidelines set by the National Health Mission, pregnant women are advised to attend at least four antenatal care appointments. The first visit is recommended as soon as pregnancy is suspected, followed by a second visit between 4 and 6 months of pregnancy. The third appointment should be made at eight months, and the fourth and last appointment at nine months.

urine sample, and blood sample taken during pregnancy, and four or more antenatal care visits. Similarly, we created a vaccine index that covers three variables: BCG at birth on time, Polio at birth on time, and Hepatitis B at birth on time.

We follow Kling et al. (2007) for index construction. That is, we first define each outcome so that higher values correspond to positive outcomes. Then we standardize each outcome into a Z-score by subtracting the mean and dividing it by the standard deviation. These moments come from the control group: babies born in Cohort I. After that, we average all the Z-scores and estimate the effect of the lockdown on these standardized outcome indices. Multiple hypothesis testing is also used to correct for simultaneous inference, using the false discovery rate (FDR) process suggested by Benjamini and Hochberg (1995). As a result of FDR, we are able to tolerate a certain number of tests being incorrectly detected.[22] For each family of outcomes, we show standard errors based on unadjusted p-values and FDR adjusted q-values to address multiple hypotheses.

Cohort Construction: The primary sample includes children born between October 2018 and September 2020. We divide the sample into two main categories: Cohort I (2018-19) includes children born between October 2018 and September 2019; children in this cohort were more than six months old when the lockdown began in April 2020; Cohort II (2019-20) includes children born between October 2019 and September 2020; children in this cohort were either born during the lockdown (April-September 2020) or were less than six months old when the lockdown began in April 2020. Detailed information on sample structure is shown in Appendix Table A7. Our sample consists of 43,786 children and their mothers. Table A3 reports the summary statistics of the main sample (post-COVID) in the second column. The average age of mothers in our sample is 26.16, with about eight years of education. 48% of households are categorized as poor. A large share of the sample is Hindu (81%) and resides in rural areas (80%). In Table A3, we also checked the summary statistics of the Pre-COVID sample (third column) and assessed the difference between the samples. We

[22]FDR-adjusted q-value of 0.01 means that 1% of significant tests will result in false positives.

notice that there are imbalances in demographic characteristics such as religion or income. However, in all our regressions, we control for all these observables.

Lockdown Measures: We use the Oxford Stringency Index (OSI) to identify months of severe lockdown during the COVID-19 pandemic in 2020. The OSI score was initially made at the month-level for each country, which eventually got modified to have data at the geographically disaggregate level (such as the state level for India) from the beginning of 2021. As our study focused on the first lockdown period between April and September 2020, we could not use the state-level variation of the OSI.

The OSI is based on nine metrics, including school closures, workplace closures, cancellation of public events, restrictions on public meetings, closure of public transport, stay-at-home requirements, public information campaigns, restrictions on internal movements, and international travel controls. The index is calculated as the mean score of the nine metrics, each taking a value between 0 and 100. A higher score indicates stricter government policies against COVID-19, while a lower score indicates the government has eased some restrictions.

Appendix Table A6 shows that the stringency index was 0, 10.19, and 52.36 between January and March 2020 and abruptly jumped to 98.64 in April 2020; this is defined as the lockdown starting month in our analysis based on the global median stringency index of 81.02 for lockdown, as mentioned in Santini et al. (2022). The index remained high, above 81.02, between May and September 2020; however, the index dropped to about 62.08 in October and continued to decline in November and December 2020, when many restrictions were eased.

Harmonizing the Government of India's announcements and the OSI, we identify the COVID-19 strict lockdown period as the six months between April and September 2020.[23] However, we also shorten the duration of the lockdown period from six months to five, four, and three months respectively, to test the consistency of our results. Table A1 indicates

[23](Beyer et al., 2021) use daily electricity consumption and monthly night light intensity data as a proxy for economic activity in India. Energy consumption fell sharply after a national lockdown was imposed on March 25, 2020, and remained a quarter below normal levels throughout April. It recovered later, but electricity consumption stayed low even in September.

simple difference-in-difference in means for our three main outcomes. These descriptive findings strongly indicate that there is a rise in neonatal and infant mortality, as well as infant mortality within 24 hours, during the presence of the COVID-19-led lockdown in April-September 2020. While these observations do not establish a causal relationship, they provide plausible evidence assuring further investigation.

Balance test: Appendix Table A2 presents balancing test results between the two cohorts. The balancing test was designed to examine whether observable characteristics of children and their parents are similar among respondents who gave birth in Cohort I and II during the lockdown. The results show that almost all observable characteristics are in balance; only two out of fifteen observable are significantly different, which we controlled in all our estimations.

3 Empirical Framework

3.1 Event Analysis Method

In order to provide evidence that the COVID-19 lockdown led to an increase in neonatal mortality and to examine parallel trends in neonatal mortality before and during the lockdown, we estimate a monthly event study model where the omitted month (March) is the month before most lockdown orders were enforced nationally. The event study model we estimated is given below (following Abrams (2021)):

$$Y_{idmt} = \sum_{m=-6}^{5} \gamma_m (BirthMonth)_m * Cohort - II(2019-20)_{mt} + \beta_1 * Cohort - II(2019-20)_{mt} + \beta_2 * Post(April - Sept)_{mt} + \beta_3 * X_{idmt} + \phi_{dm} + \delta_{dt} + \epsilon_{idmt} \quad (1)$$

where Y_{idmt} is an outcome of interest for individual i residing in district d, born in month m of the year t, $Cohort - II(2019-20)_{mt}$ is an indicator equal to unity if the infant

was born between October 2019 and September 2020, 0 if the infant was born between October 2018 and September 2019; $Post(April - Sept)_{mt}$ is an indicator equal to unity if the infant born between April and September, and 0 otherwise; ϕ_{dm} is district by month of birth and δ_{dt} district by year of birth fixed effects; X_{idmt} is a vector of individual-level characteristic. In all our specifications, we cluster the standard errors at the district by month of birth level. The interaction term $(BirthMonth)_m * Cohort(2019-20)_{mt}$ represents a series of lead and lag indicator variables relative to when the government ordered a lockdown. We include indicator variables from 5 months prior to COVID-19 lockdown announcement $[(BirthMonth)_{-6} * Cohort - II.....(BirthMonth)_{-2} * Cohort - II]$ and 6 months after $[(BirthMonth)_0 * Cohort - II...(BirthMonth)_5 * Cohort - II]$.[24]

The coefficients of interest in equation 1 are the γ_m, which represent the impact of lockdown on neonatal mortality and other outcomes in each birth month from $BirthMonth_{-6}$ to $BirthMonth_{+6}$. The estimated coefficients on the pre-lockdown months $(\gamma_{-6}, .., \gamma_{-2})$ provide evidence on whether neonatal mortality rate and other outcome variables were trending before the lockdown order. If only lockdown affected our outcome variables of interest, these pre-lockdown coefficients should generally be small in magnitude and statistically insignificant. The estimated coefficients of six months of COVID-19 lockdown period $(\gamma_{+1}, ..., \gamma_{+6})$ represent the effect of lockdown on outcome variables.

3.2 Difference-in-Difference Method

To examine the effect of the lockdown on neonatal mortality and other outcomes, we estimate a difference-in-difference model (as done in Leslie and Wilson (2020)). Because the COVID-19 lockdown was implemented across all of India simultaneously, there are no areas that were not subject to the lockdown in 2020 to use as a comparison. Therefore, our analysis focuses on differences in neonatal mortality trends within our study cohort over the six months before

[24]Note $(BirthMonth)_m * Cohort - II$ equals 1 for the child born between October 2019 and September 2020. The omitted month is March, $(BirthMonth)_{-1} * Cohort - II$, the month just prior to the government-ordered lockdown.

and after the lockdown was imposed. However, comparing the neonatal mortality rate before and after the lockdown within Cohort (2019-20) will not take into account seasonal changes in neonatal mortality.[25] To account for such seasonal trends, we compare neonatal mortality rates before and after the COVID-19 lockdown with neonatal mortality rates in the prior cohort without the lockdown. To examine the effect of the COVID-19 lockdown on our outcomes of interest, we estimate the following difference-in-difference equation:

$$\begin{aligned} Y_{idmt} = \beta_1 * (April - Sept) * (Cohort - II)_{mt} + \beta_2 * Cohort - II(2019 - 20)_{mt} \\ + \beta_3 * Post(April - Sept)_{mt} + \beta_4 * X_{idmt} + \phi_{dm} + \delta_{dt} + \epsilon_{idmt} \end{aligned} \tag{2}$$

where Y_{idmt} is an outcome of interest for individual i residing in district d, born in month m of year t, $Cohort - II(2019 - 20)_{mt}$ is an indicator equal to unity if the infant was born between October 2019 and September 2020, 0 if the infant was born between October 2018 and September 2019. $Post(April - Sept)_{mt}$ is an indicator equal to one if the infant was born between April and September and zero otherwise, ϕ_{dm} is district by month of birth and δ_{dt} district by year of birth fixed effects; X_{idmt} is a vector of individual-level characteristics, including mother's age, education, age at first marriage and birth, child's birth order, religion, cast, and economic condition; and ϵ_{idmt} is random disturbance term. In all our specifications, we cluster the standard errors at the district by month of birth level.

The coefficient of primary interest in equation 2 is β_1, which captures the causal effect of the lockdown on our outcome of interest. We include district-by-month of birth and district-by-year-of-birth fixed effects to allow district-specific trends in neonatal mortality across years, by seasons, and by months. These enable us to make within-district comparisons of the monthly neonatal mortality rate in 2020 relative to 2019.

To assess the negative *in-utero* exposure during the COVID-19 lockdown on neonatal

[25] (Gupta, 2022) finds that the infant mortality rate exhibits seasonal variation; in India, infant mortality rates are higher in summer, monsoon, and winter compared to spring.

mortality rate, we employ the following equation:

$$Y_{idmt} = \beta_1 * (InUtero)_{mt} + \beta_2 * Cohort - II(2019-20)_{mt} + \phi_{dm} + \delta_{dt} + \epsilon_{idmt} \quad (3)$$

where $(InUtero)_{mt}$ has two definitions, first it is an indicator equal to unity if the baby was born between May and September 2020 (having at least one month of lockdown exposure), second it is a discrete variable that takes a value between one and five where one indicates that the baby was *in-utero* during the lockdown for one month, five indicates that the baby was *in-utero* during the entire lockdown period. $Cohort - II(2019-20)_{mt}$ is an indicator equal to unity if the infant was born between October 2019 and September 2020, 0 if the infant was born between October 2018 and September 2019; ϕ_{dm} is district by month of birth and δ_{dt} district by year of birth fixed effects; X_{idmt} is a vector of individual-level characteristic. In all our specifications, we cluster the standard errors at the district by month of birth level.

4 Main Results

4.1 Effect of COVID-19 Lockdown on the Main Outcomes

4.1.1 Event Analysis Estimates

We first conduct event analysis to illustrate the impact of the COVID-19 lockdown on neonatal, infant, and infant mortality within 24 hours. We plot the lag γ_m (γ_1, γ_2...γ_6) estimates and their 90% and 95% confidence intervals based on our event study specification, as given by equation 1. Figure 1 (and also reported in Table A4) illustrates the impact of the COVID-19 lockdown on the mentioned outcomes. A similar trend can be observed in the neonatal mortality rate and in the infant mortality rate within 24 hours for babies born before and after the lockdown. Neonatal mortality rate was clearly flat before the initial lockdown order (February coefficient is 0.007), as shown in plot A. The rate shows high magnitude in April

2020 (coefficient rising to 0.023, more than three times larger than in February). The trend declines slightly in May 2020 and reaches its peak in August 2020, and these estimates are statistically significant, except for July. Similarly, plots B and C demonstrate that infant mortality and mortality-within-24-hours abruptly increased among babies born during the lockdown. This could be attributed to the lack of resources and access issues to medical care during the lockdown, which may have led to a decrease in the quality of care newborns receive. It could also be due to the increased stress that families experienced during the lockdown, which may have had an adverse effect on the health of pregnant women and newborns. To test this formally, we evaluate the post-lockdown impact on infant and neonatal mortality in Figure A1, which shows that impact becomes statistically insignificant one month after the lockdown period.

The second step in our analysis is to test whether neonatal, infant, and infant mortality within 24 hours were trending upward prior to the COVID-19 lockdown. The standard approach to testing for pre-trends is to estimate event study specifications as given by equation 1 for the outcomes of interest. The estimated coefficients on the lead treatment indicators γ_m (γ_{-1}, $\gamma_{-2}...\gamma_{-5}$) provide evidence on whether our outcomes of interest were trending upward prior to the lockdown. Figure 1, plots A, B, and C illustrate that for all our outcomes, we find no evidence of any pre-trend because the estimated coefficients between October and March are small in magnitude and jointly statistically insignificant. This implies that the observed effects on our outcomes are due to the lockdown rather than any pre-existing trends.

4.1.2 Difference-in-difference Estimates

We now quantify the effect of the lockdown using the difference-in-difference estimation, as outlined in equation 2. Table 1 presents the effects of the COVID-19 lockdown on neonatal, infant, and infant mortality within 24 hours. The top panel displays estimates with control variables consisting of baseline parental attributes, while the bottom panel shows estimates

without control variables. We begin by discussing the results in column 1, which demonstrate the impact of the COVID-19 lockdown on neonatal mortality for babies born during the lockdown, as measured by whether a child died in the first month after birth. As shown in column 1, the COVID-19 lockdown is associated with a significant increase in neonatal mortality. Specifically, the result indicates that the lockdown led to an approximately 1.7 percentage point increase in the neonatal mortality rate, corresponding to a 56 percent increase relative to the control mean or Cohort I (2018-19). This estimate is statistically significant at the 1 percent level. To contextualize this estimate, according to the Sample Registration System (SRS) Bulletin of the Registrar General of India (RGI), the national-level neonatal mortality rate was 30 per 1,000 live births in 2019 (also that is the mean of Cohort-I in our estimate). Thus, the COVID-19 lockdown increased the neonatal mortality rate to 47 from 30 per 1,000 live births between April and September 2020.

The second and third columns of Table 2 present the impact of the COVID-19 lockdown on infant mortality, as measured by whether a child died in the first year after birth (within the first year of birthday) and infant mortality within 24 hours. As shown in column 2, the COVID-19 lockdown increased the infant mortality rate by around 1.5 percentage points for babies born during the lockdown. This corresponds to a 54 percent increase relative to the control mean of Cohort I (2018-19). In column 3, it is evident that the lockdown increased infant mortality within 24 hours rates by around 2.1 percentage points. This corresponds to a 54 percent increase relative to the control mean of Cohort I (2018-19). These estimates are statistically significant at 1 percent level.

Shapira et al. (2021) estimated model-based forecasting on the relationship between aggregate income shocks and infant mortality in 128 low-income and middle-income countries. They found that income shocks due to COVID-19 led to 267,208 additional infant deaths in 2020 in these countries; a third of the excess infant mortality (99,642 children) was projected to be in India. However, our estimates show a much higher number of infant deaths since we take into account the overall impact of the COVID-19 lockdown and not just its impact

as an income shock.[26]

One concern with our infant mortality estimates is the partial exposure of the control infant cohort born between October 2018 and September 2019. Some of these infants may be affected within one year of their first birthday due to an overlap with the COVID-19 lockdown, making the comparison group contaminated. First, it is highly unlikely that this scenario would be of serious concern since approximately 85 percent of infant deaths occur within the first month after birth in our data.[27] Secondly, if babies born between April and September 2019 died during the lockdown period before their first birthday, it would result in an underestimation of the effect of the COVID-19 lockdown on infant mortality. It is important to note that this issue only pertains to the outcome of infant mortality, as neonatal mortality and mortality within 24 hours will not be affected by our cohort construction. To address this concern empirically, we shifted our control cohort back by one year, replacing cohort-I with babies born between October 2017 and September 2018 and thus having no contamination issue, and re-estimated our primary estimation. Table 2 illustrates that the main estimates obtained before (in Table 1) remain similar, showing similar impact magnitude and statistical significance.

4.2 Robustness and Falsification Tests

In this sub-section, we conduct a series of robustness and falsification tests to assess the internal validity of the main results presented in Table 1. The primary analysis covers a period of 6 months of lockdown period for the main cohort and (a similar time period for the control cohort), starting from April 1st to September 30, 2020.[28] Our first robustness check investigates whether the results are sensitive to narrower time windows before and after

[26] Raman et al. (2021) use cross-sectional data in their non-causal analysis to examine the impact of the COVID-19 lockdown on health and provision of healthcare services in India and find that dimensions of healthcare provision, including non-affordability, non-accessibility, inadequacy, and inappropriateness negatively affected during the COVID-19 lockdown.

[27] Not reported but available upon request.

[28] Please note that although the first COVID-19 lockdown order was enforced on March 24, 2020, we define our lockdown period based on the Oxford Stringency Index, which begins on April 1, 2020.

the COVID-19 lockdown. Specifically, we examine whether changing the duration of the lockdown leads to a different conclusion. Table 3 presents estimates for our primary outcomes of interest based on shorter lockdown windows ranging from 3 to 5 months (April-June, April-July, and April-August, respectively). We find that the magnitude and significance of our primary outcomes remain fairly robust across different lockdown windows, as shown in Panel A-C and columns 1-3 of Table 3. In all cases, the estimated impact of the COVID-19 lockdown on neonatal mortality, infant mortality, and infant mortality rates within 24 hours are similar to the main estimates in Table 1, and the effect sizes are higher in the first three months of the lockdown period when the lockdown was much stricter.

Second, to further explore the sensitivity of our results to different cohort windows, we conduct additional analyses by shifting the starting and ending months of our cohorts while maintaining the same lockdown period (April to September 2020). In Table 4, Panel A, we examine the impact of the COVID-19 lockdown on the main outcomes with a one-month forward shift. In this analysis, we shift the starting month to November (from October) and the ending month to October (from September). Similarly, Panel B presents the results with a two-month forward shift. Here, we shift the starting month to December (from October) and the ending month to November (from September). The results of both panels indicate that our main findings are not sensitive to different cohort windows, as we observe similar effect sizes and significance levels as presented in Table 1.

We then perform a falsification test by shifting the actual date of the COVID-19 lockdown (April 1st, 2020) back one year (to April 1st, 2019) and two years (to April 1st, 2018). We re-estimate our primary difference-in-difference model (Equation 2) using the placebo lockdown years. Table 5 presents the estimates based on the falsification test. Comparing the results to our main findings in Table 1, none of the estimates in the falsification test are statistically significant, and all of them are substantially smaller in magnitude (very close to zero) than those in Table 1. These results indicate that our main findings are not mechanical and can be interpreted as causal.

Finally, we assess the robustness of our main estimates by examining their consistency when using the full sample (without excluding the pre-COVID sample). One might argue that there could be differences between women interviewed in 2019 and those interviewed in 2020 and 2021 (post-COVID). To address this concern, we first compare the baseline characteristics of these two groups in Table A3. The results indicate that nine out of 14 characteristics are statistically significantly different between the pre- and post-COVID groups. The groups exhibit some deviations in their baseline characteristics due to surveys conducted in different states before and after the onset of COVID-19. For example, the pre-COVID survey showed around 20 percent Muslim representation, while the post-COVID survey showed a lower rate of around 10 percent. The main concern is whether these discrepancies affected our primary estimates. Hence, we re-estimated our main difference-in-difference model (Equation 2) using the full sample, which includes women interviewed both before and after the COVID-19 pandemic. The results for our main outcomes are presented in Table 6. As we can see, our main estimates are not affected by the inclusion of the pre-COVID sample, and there appears to be no concern related to sample selection.[29]

Our main findings and their causal interpretation are supported by robustness and falsification test results. Given these findings, one obvious question is whether we are measuring the direct effect of COVID-19 on neonates and infants or the lockdown effect. If we are specifically measuring the impact of COVID-19 on neonates and infants, we should observe a sustained increase in their mortality rates even after the lockdown period. In other words, we would expect a rise in neonatal and infant mortality rates in October, November, and December 2020. To investigate this, we conducted an event study analysis by extending the lag estimators from September to December. Figure A1 demonstrates that while neonatal mortality rates were high in October 2020, they decreased and became statistically insignificant in November and December 2020. This suggests that the high rates of neonatal and infant mortality were primarily influenced by the lockdown rather than COVID-19 itself.

[29]The estimates for the mechanism outcomes with the full sample are shown in Table A5.

4.3 Subgroup Analysis

We conducted subgroup analysis by dividing the main sample based on newborns' gender, household income level, place of residence, and religion. We then estimated our main specification (Equation 2) for each subgroup separately. In Table 7, Panel A presents gender subgroup estimates. The results indicate that neonatal mortality, infant mortality, and mortality within 24 hours are higher among boys. While the estimates for girls are positive, they are statistically insignificant, except for the infant mortality rate. In Table 7, Panel B presents estimates based on income subgroups. The results indicate that the effect of the COVID-19 lockdown is higher and statistically significant among the low-income group (households belonging to the bottom two income quintiles). In contrast, the effect sizes are small in magnitude and statistically insignificant among high-income groups (households belonging to the top two income quintiles). This suggests that the lockdown had a more severe impact on low-income households. In Table 7, Panel C shows that the COVID-19 lockdown impact on neonatal mortality and other main outcomes was more pronounced in rural areas, with statistically significant estimates at the 1 percent level. However, the impact on main outcomes is small and statistically insignificant in urban areas. Finally, in Table 7, Panel D reveals that the COVID-19 lockdown increases neonatal mortality, infant mortality, and mortality within 24 hours for both Hindu and Muslim populations. However, the effect sizes are nearly three times higher for babies born in Muslim families compared to Hindu households.

5 Mechanisms

Several mechanisms likely contributed to the increase in the neonatal mortality rate during the COVID-19 lockdown period. These mechanisms include negative *in-utero* exposure, delay in immunization services and reduced utilization of antenatal care services or maternal health care during pregnancy.

***In-utero* exposure**: We begin our mechanism analysis exploring the impact of *in-utero* exposure to lockdown on neonatal mortality, infant mortality, and infant mortality within 24 hours employing Equation 3. Table 8 presents the impact of being *in-utero* and the duration of *in-utero* exposure to lockdown on neonatal and infant mortality. In Panel A of Table 8 shows that having any *in-utero* exposure during the lockdown increases the neonatal mortality rate by around 1.2 percentage points, which is significant at the 5 percent level and corresponds to about a 39 percent increase. Panel A also demonstrates that *in-utero* exposure to lockdown increases infant mortality and infant mortality within 24 hours by around 1.1 and 1.5 percentage points, respectively, which are also statistically significant at the 5 and 1 percent level. Table 8, Panel B, shows that an additional month of *in-utero* exposure to lockdown increases the probability of neonatal mortality within the first month of birth by around 0.3 percentage points. Similarly, an additional month of lockdown exposure while the baby is in the womb, increases the probability of infant death and infant death within 24 hours by approximately 0.2 and 0.4 percentage points, respectively.

Vaccination: The second mechanism we tested is the compliance with childhood vaccination rate during birth. On-time immunization is highly important in the prevention of infant deaths, resulting in an annual saving of 2-3 million global lives and contributing to a substantial reduction in infant mortality rates (WHO, 2019).[30]

Table 9 presents estimates of the effect of the COVID-19 lockdown on the timing of BCG, Polio, and Hepatitis B vaccines. The first dose of these vaccines should be taken at birth to strengthen the newborn's immune system in preparation for illness. We create an indicator variable equal to one if the child had the vaccine on the first day of birth and zero if the child had it later. As shown in columns 1-3 of Table 9, the lockdown caused a reduction in the on-time BCG vaccine by five percentage points, the polio vaccine on time by three percentage points, and the Hepatitis B vaccine by two percentage points, with various

[30]For instance, the Polio vaccine has been linked to reduced infant mortality rates (Aaby et al., 2005), and the BCG vaccine has been shown to decrease infant mortality in low-income countries, with a particular impact on girls (Roth et al., 2006).

degrees of statistical significance. In addition, we create a vaccination index in column (4), combining variables used in columns (1)-(3) and find that lockdown decreases the on-time vaccination index by 0.6 standard deviation, which is statically significant at the conventional level and marginally satisfies the multiple hypothesis testing.

In column (5), we report the total number of vaccines taken at birth, which shows consistent results and statistical significance as found in column (4). Furthermore, Table 9 columns (6)-(8) show estimates of the effect of COVID-19 lockdown on the total number of days delayed in receiving the BCG, Polio, and Hepatitis B vaccines. We find that the COVID-19 lockdown resulted in an average of 2 to 3 days delay in receiving these vaccines which may have happened due to service interruption and health facility avoidance by parents.[31] These findings are consistent with the estimates of Summan et al. (2022), who reported that the rate of timely receipt of polio and DPT vaccines was lower among children born during the COVID-19 period while Singh et al. (2021) show that immunization services decreased dramatically during the COVID-19 lockdown.

Maternal health care use: Table 10 presents estimates of the effect of the COVID-19 lockdown on various maternal health indicators. These indicators include "Iron Tablet," "Intestinal Parasite Tablet," "Blood pressure," "Urine sample," and "Blood sample," denote whether the mother took iron tablets, intestinal parasite tablets, and whether her blood pressure, urine samples, and blood sample were taken during the pregnancy, "4+ ANC during pregnancy," indicating whether the mother visited health facilities at least four or more times during the pregnancy, "institutional delivery," which refers to whether the mother delivered her baby in a health facility. As presented in Table 10, COVID-19 lockdown had a negative impact on the usage of iron tablets and intestinal parasite tablets during pregnancy, with the latter effect being statistically significant at the 5 percent level. Moreover, the lockdown has a negative impact on overall healthcare utilization (column 7) by the pregnant mother. We further test the COVID-19 lockdown impact on the index measuring maternal health-

[31] https://www.unicef.org/rosa/reports/direct-and-indirect-effects-covid-19-pandemic-and-response-south-asia

care usage (in column 8) which reduce by almost 0.3 standard deviations. Both the results reported in columns (6) and (7) are weekly significant and do not survive the multiple hypothesis testing. Finally, we tested the impact through lacking institutional delivery channel and document no direct negative effect of lockdown.

One issue we faced with the mechanism analysis for vaccination and Maternal health care use is the systematic underreporting of some of the crucial variables, which caused our sample size to decline in Table 9 and 10. In Table 11, we test this formally and find that many mechanism variables are more likely to be reported as "missing" during the lockdown. Other than the institutional delivery variable, all variables in Table 11 show about 3 to 5% more likely to be reported as "missing" for the babies born during the lockdown. We checked the survey manual and unfortunately found no clear instructions on how to interpret this missing data. However, as an exploratory exercise, we re-code "missing" data as zero in Table 12 for all mechanism variables and find a highly statistical significant impact of COVID-19 lockdown on most mechanism variables (except for ANC visit and institutional delivery) as well as Vaccination and Maternal health indexes. All these statistical significance also pass multiple hypothesis testing as reported in square brackets in Table 12.

6 Conclusion

India enforced one of the strictest COVID-19 lockdown in April 2020. The lockdown helped prevent the rapid spread of the virus and slow down the rate of new infections. However, the lockdown also led to a significant disruption in critical non-COVID-19 related healthcare services affecting among others pregnant women and newborns.

In this paper, we studied the indirect effect of the COVID-19 lockdown on neonatal and infant mortality. Our event study analysis and difference-in-difference estimates documented a significant rise in neonatal and infant mortality among babies born during the time of the first COVID-19 lockdown in India. We tested our models against multiple robustness

checks and confirmed our findings to be consistent. We found that the negative impact of the lockdown on mortality was more pronounced for boys, economically marginalized households, and rural populations. Further investigation on possible mechanisms contributing to these findings revealed missing critical and timely antenatal care, negative *in-utero* exposure, and missing or delayed life-saving vaccinations at birth.

This paper contributes to the critical debate on lockdown policies for resource-poor countries to balance the enforcement of stringent restrictions while maintaining access to basic healthcare and transportation services so that the unintended consequences of the lockdown are mitigated. We believe our paper's findings will motivate global organizations and policymakers, especially in countries with inadequate health infrastructure, to design lockdown as a contagion-mitigating instrument more carefully and pragmatically in the future.

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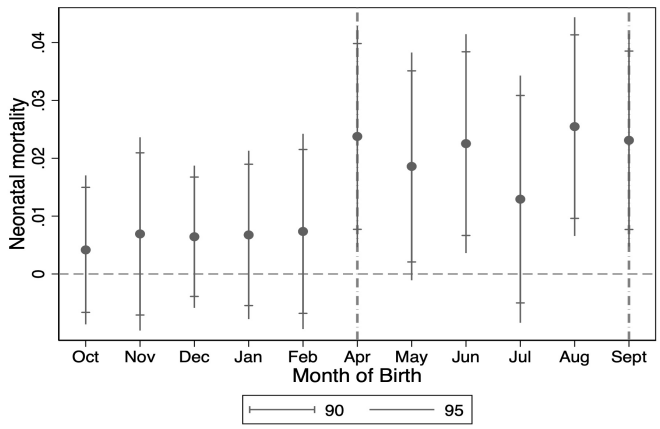
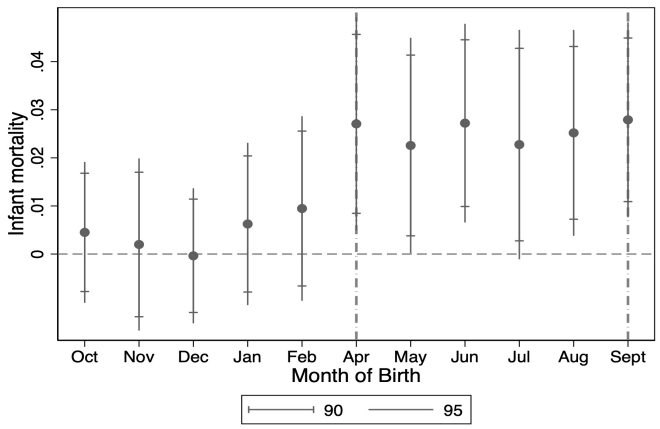
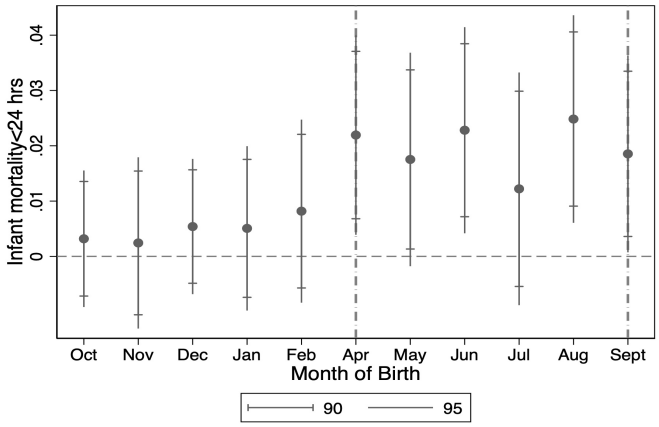


(a) Neonatal mortality



(b) Infant mortality



(c) Infant mortality<24 hours

Figure 1: Event Study: Neonatal mortality, Infant mortality, and Infant mortality<24 hrs in Cohort II (2019-20) relative to Cohort I (2018-19)

Notes: The event study examines the impact of COVID-19 lockdown on neonatal mortality, infant mortality, and infant mortality within 24 hours in Cohort-II (2019-20) relative to Cohort-I (2018-19). The figures present the event study estimates showing the effect of COVID-19 lockdown on the mentioned mortality rates. Coefficients obtained from the event study specification (Equation 1) are reported for the period of 6 months before to 6 months after the initial lockdown order. The month omitted from the analysis is March, which is just prior to the first lockdown order. Each point represents the point estimate derived from the event study model, and solid lines indicate the 90% and 95% confidence intervals. The specification includes a comprehensive set of controls, district-by-month-of-birth, and district-by-year-of-birth fixed effects. Robust standard errors are clustered at the district-by-month-of-birth.

Table 1: COVID-19 and infant mortality

	(1)	(2)	(3)
	Neonatal mortality	**Infant mortality**	**Infant mortality <24 hrs**
Panel A: with Controls			
(April-Sept)*(Cohort-II)	0.0167***	0.0149***	0.0212***
	(0.0054)	(0.0053)	(0.0058)
Cohort-II (2019-20)	0.0068	0.0098	-0.0023
	(0.0102)	(0.0097)	(0.0108)
Post(April-Sept)	0.0017	0.0053	-0.0023
	(0.0068)	(0.0064)	(0.0073)
Observations	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Panel B: without Controls			
(April-Sept)*(Cohort-II)	0.0160***	0.0142***	0.0203***
	(0.0053)	(0.0053)	(0.0058)
Cohort-II (2019-20)	0.0089	0.0116	0.0004
	(0.0102)	(0.0096)	(0.0108)
Post(April-Sept)	0.0027	0.0060	-0.0011
	(0.0068)	(0.0063)	(0.0073)
Observations	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	No	No	No
Mean of Cohort-I (2018-19)	0.030	0.028	0.039

Notes: The sample comprises children born between October 2018 and September 2019, referred to as Cohort-I (2018-19), and between October 2019 and September 2020, referred to as Cohort-II (2019-20). Table presents the impact of the initial COVID-19 lockdown on neonatal mortality, infant mortality, and infant mortality within 24 hours. The estimates are derived from the main difference-in-difference specification (Equation 2). Detailed information about the outcomes can be found in the Appendix. Panel A shows the results with controls, including, the mother's age, education, age at first marriage and birth, child's birth order, gender, religion, caste, economic condition, and place of residence. While Panel B shows the results without controls. All specifications include district-by-month-of-birth and district-by-year-of-birth fixed effects. The standard errors, reported in parentheses, are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 2: COVID-19 and infant mortality with October 2017 and September 2018 control

	(1)	(2)	(3)
	Neonatal mortality	**Infant mortality**	**Infant mortality <24 hrs**
Post(April-Sept)*Cohort(2018-20)	0.0115**	0.0108**	0.0154**
	(0.0057)	(0.0053)	(0.0062)
Mean of Cohort-I (2017-18)	0.031	0.028	0.042
Observations	43224	43224	43224

Notes: The sample comprises children born between October 2017 and September 2018 (one year earlier than our main control cohort), referred to as Cohort-I (2017-18), and between October 2019 and September 2020, referred to as Cohort-II (2019-20). Table presents the impact of the initial COVID-19 lockdown on neonatal mortality, infant mortality, and infant mortality within 24 hours. The estimates are derived from the main difference-in-difference specification (Equation 2). Detailed information about the outcomes can be found in the Appendix. All specifications include controls for various family baseline characteristics, including the mother's age, education, age at first marriage and birth, child's birth order, gender, religion, caste, economic condition, and place of residence. Additionally, district-by-month-of-birth and district-by-year-of-birth fixed effects are included. The standard errors, reported in parentheses, are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 3: COVID-19 and infant health with different lockdown duration

	(1)	(2)	(3)
	Neonatal mortality	**Infant mortality**	**Infant mortality <24 hrs**
Panel A: Keeping Lockdown for 5 Months			
(April-August)*(Cohort-II)	0.0164***	0.0158***	0.0200***
	(0.0056)	(0.0055)	(0.0061)
Observations	35382	35382	35382
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Mean of Cohort-I (April-August)	0.030	0.028	0.038
Panel B: Keeping Lockdown for 4 Months			
(April-July)*(Cohort-II)	0.0138**	0.0138**	0.0186***
	(0.0061)	(0.0060)	(0.0066)
Observations	27070	27070	27070
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Mean of Cohort-I (April-July)	0.028	0.026	0.036
Panel C: Keeping Lockdown for 3 Months			
(April-June)*(Cohort-II)	0.0188***	0.0187***	0.0222***
	(0.0066)	(0.0065)	(0.0072)
Observations	19187	19187	19187
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Mean of Cohort-I (April-June)	0.030	0.028	0.039

Notes: The sample includes children born between October 2018 and September 2019, termed Cohort-I (2018-19), and between October 2019 and September 2020, termed Cohort-II (2019-20). Table reports the impact of COVID-19 lockdown on the main outcomes shown in the first row of each panel based on narrower bandwidths. Panel A includes children born 5 months before and after April, while Panel B and C include children born 4 and 3 months before and after April, respectively. Detailed information about the outcomes is listed in the Appendix. All specifications include the full set of controls listed in Table 1, as well as district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in parentheses are clustered at the district-by-month-of-birth level. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 4: Different cohort windows

	(1)	(2)	(3)
	Neonatal mortality	**Infant mortality**	**Infant mortality <24 hrs**
Panel A: Alternative Cohort Window 1 (Nov 2018-Oct 2019 vs. Nov 2019-Oct 2020)			
Post*Cohort-II(Nov 2019-Oct 2020)	0.0168***	0.0208***	0.0151***
	(0.0053)	(0.0058)	(0.0053)
Cohort-II(Nov 2019-Oct 2020)	0.0048	-0.0018	0.0054
	(0.0073)	(0.0088)	(0.0070)
Post(April-Sept)	-0.0007	-0.0020	0.0012
	(0.0042)	(0.0050)	(0.0040)
Observations	41479	41479	41479
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Mean of Cohort-I (Nov 2018-Oct 2019)	0.031	0.039	0.028
Panel A: Alternative Cohort Window 2 (Dec 2018-Nov 2019 vs. Dec 2019-Nov 2020)			
Post*Cohort-II(Dec 2019-Nov 2020)	0.0168 ***	0.0207 ***	0.0153 ***
	(0.0053)	(0.0058)	(0.0053)
Cohort-II(Dec 2019-Nov 2020)	0.0063	-0.0020	0.0081
	(0.0080)	(0.0096)	(0.0078)
Post(April-Sept)	-0.0004	-0.0015	0.0015
	(0.0043)	(0.0050)	(0.0041)
Observations	39253	39253	39253
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Mean of Cohort-I (Dec 2018-Nov 2019)	0.031	0.040	0.028

Notes: The original sample includes children born between October 2018 and September 2019, termed Cohort-I (2018-19), and between October 2019 and September 2020, termed Cohort-II (2019-20). Panel A examines the main results with a one-month forward shift, where the starting month is shifted from October to November and the ending month is shifted from September to October. Panel B presents main results with a two-month forward shift, where the starting month is shifted from October to December and the ending month is shifted from September to November. All specifications include the full set of controls listed in Table 1, and district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in the parenthesis are clustered at the district by month of birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 5: Falsification test

	(1)	(2)	(3)
	Neonatal mortality	**Infant mortality**	**Infant mortality <24 hrs**
Panel A. Placebo Lockdown (April 1st 2019)			
(April-Sept)*Placebo Cohort (2018-19)	-0.0012	-0.0003	-0.0027
	(0.0046)	(0.0043)	(0.0053)
Observations	49294	49294	49294
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Panel B. Placebo Lockdown (April 1st 2018)			
(April-Sept)*Placebo Cohort (2017-18)	0.0010	0.0016	0.0004
	(0.0050)	(0.0046)	(0.0055)
Observations	49114	49114	49114
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes

Notes: Table reports the impact of COVID-19 lockdown on the main outcomes indicated in the first row of each panel using a placebo lockdown date. Panel A presents estimates for the lockdown period moving from April 2020 to April 2019 (placebo lockdown), while Panel B presents estimates for the lockdown period from April 2020 to April 2018 (Placebo Lockdown). The estimates are obtained from the main difference-in-difference specification (Equation 2). Detailed information about the outcomes is listed in the Appendix. All specifications include the full set of controls listed in Table 1, as well as district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in parentheses are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 6: Main outcomes with full sample

	(1)	(2)	(3)
	Neonatal mortality	**Infant mortality**	**Infant mortality <24 hrs**
(April-Sept)*(Cohort-II)	0.0149***	0.0134***	0.0186***
	(0.0050)	(0.0050)	(0.0054)
Cohort-II (2019-20)	0.0141*	0.0143*	0.0157*
	(0.0078)	(0.0074)	(0.0085)
Post(April-Sept)	0.0088*	0.0095**	0.0112**
	(0.0050)	(0.0048)	(0.0055)
Observations	63641	63641	63641
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.026	0.024	0.033

Notes: The survey was conducted between 2019 and 2021. The primary sample does not include women interviewed in 2019 because the survey was conducted before COVID-19. Table reports the results with the full sample, including the year 2019. The estimates are obtained from the main difference-in-difference specification (Equation 2). All specifications include the full set of controls listed in Table 1, as well as district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in parentheses are clustered at the district-by-month-of-birth level. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 7: COVID-19 and infant mortality, subgroup analysis by gender, income level, place of of residence, and religion

	(1)	(2)	(3)	(4)	(5)	(6)
	Neonatal mortality	Infant mortality	Infant mortality <24 hrs	Neonatal mortality	Infant mortality	Infant mortality <24 hrs
Panel A: Gender		**Male**			**Female**	
(April-Sept)*(Cohort-II)	0.0157**	0.0226***	0.0163**	0.0127	0.0157*	0.0076
	(0.0078)	(0.0086)	(0.0077)	(0.0080)	(0.0089)	(0.0077)
Mean of Cohort-I	0.032	0.040	0.029	0.029	0.039	0.026
Observations	22641	22641	22641	20805	20805	20805
Panel B: Income Level		**Low-Income**			**High-Income**	
(April-Sept)*(Cohort-II)	0.0224**	0.0271 ***	0.0174*	0.0034	0.0102	0.0051
	(0.0092)	(0.0101)	(0.0091)	(0.0086)	(0.0091)	(0.0087)
Mean of Cohort-I	0.039	0.051	0.036	0.023	0.030	0.021
Observations	20618	20618	20618	14283	14283	14283
Panel C: Residence		**Rural**			**Urban**	
(April-Sept)*(Cohort-II)	0.0213 ***	0.0221 ***	0.0180 ***	0.0084	0.0217	0.0078
	(0.0063)	(0.0069)	(0.0062)	(0.0123)	(0.0134)	(0.0122)
Mean of Cohort-I	0.034	0.043	0.031	0.019	0.028	0.017
Observations	34845	34845	34845	8154	8154	8154
Panel D: Religion		**Hindu**			**Muslim**	
(April-Sept)*(Cohort-II)	0.0165 ***	0.0202 ***	0.0134**	0.0542**	0.0580**	0.0578**
	(0.0059)	(0.0064)	(0.0057)	(0.0273)	(0.0282)	(0.0281)
Mean of Cohort-I	0.030	0.039	0.027	0.032	0.041	0.029
Observations	35580	35580	35580	3854	3854	3854

Notes: Table shows the subgroup analyzes performed by dividing the main sample into different subgroups. Each panel of the table shows the impact of the COVID-19 lockdown on key outcomes for various subgroups, including gender, income level, place of residence, and religion. Based on these characteristics, the table provides insights into how lockdown impacts the main outcomes for different segments of the population.

Table 8: COVID-19 and *in-utero* exposure

	(1)	(2)	(3)
	Neonatal mortality	**Infant mortality**	**Infant mortality <24 hrs**
Panel A: Binary measure (Any *in-utero* exposure during the lockdown)			
Birth between May-Sept 2020	0.0122**	0.0114**	0.0153***
	(0.0052)	(0.0051)	(0.0057)
Cohort-II(2019-20)	0.0032	0.0017	-0.0007
	(0.0051)	(0.0049)	(0.0057)
Observations	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Control Mean	0.031	0.028	0.039
Panel B: Continuous measure (Months of *in-utero* exposure during lockdown)			
Birth between May-Sept 2020	0.0030**	0.0026*	0.0036**
	(0.0014)	(0.0014)	(0.0015)
Cohort-II(2019-20)	0.0022	0.0006	-0.0020
	(0.0051)	(0.0049)	(0.0056)
Observations	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes
Control Mean	0.031	0.028	0.039

Notes: The sample includes children born between October 2018 and September 2019, termed Cohort-I (2018-19), and between October 2019 and September 2020, termed Cohort-II (2019-20). Table reports the impact of being inutero during the COVID-19 lockdown on the main outcomes. Panel A presents the impact of being inutero at any time during the COVID-19 lockdown, while Panel B presents the gradual impact of being inutero during the lockdown. The estimates are obtained from Equation 3. Detailed information about the outcomes is listed in the Appendix. All specifications include the full set of controls listed in Table 1, as well as district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in parentheses are clustered at the district-by-month-of-birth level. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 9: COVID-19 and vaccinations at birth

	(1)	(2)	(3)	(4)
	BCG at birth	**Polio at birth**	**Hepatits B at birth**	**Vaccination Index**
(April-Sept)*(Cohort-II)	-0.0485***	-0.0321*	-0.0256	-0.0601**
	(0.0180)	(0.0184)	(0.0203)	(0.0256)
	[0.028]	[0.108]	[0.236]	[0.051]
Cohort-II(2019-20)	0.0928***	0.0744**	0.0373	0.1526***
	(0.0340)	(0.0351)	(0.0384)	(0.0476)
Post(April-Sept)	0.0308	0.0379	0.0226	0.0449
	(0.0221)	(0.0233)	(0.0248)	(0.0306)
Observations	35303	31591	24864	42558
District-by-Month-of-birth	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.614	0.682	0.743	-0.042
	(5)	(6)	(7)	(8)
	Number of vaccines	**BCG Gap**	**Polio Gap**	**Hepatits B Gap**
(April-Sept)*(Cohort-II)	-0.1372***	3.1155**	2.2459**	0.7708
	(0.0486)	(1.4389)	(1.0909)	(2.2045)
	[0.028]	[0.061]	[0.063]	[0.727]
Cohort-II(2019-20)	0.2872***	-5.1788**	-4.0888**	7.4419*
	(0.0939)	(2.4041)	(1.9315)	(4.2237)
Post(April-Sept)	0.1402**	-2.3349	-2.0842	-0.8231
	(0.0610)	(1.5850)	(1.3344)	(2.6236)
Mean of Cohort-I (2018-19)	1.707	14.689	9.568	15.242
District-by-Month-of-birth	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes
Observations	35521	35303	31591	24864

Notes: The sample consists of children born between October 2018 and September 2019, referred to as Cohort-I (2018-19), and between October 2019 and September 2020, referred to as Cohort-II (2019-20). Table presents the impact of the COVID-19 lockdown on child vaccinations being administered on time, as indicated in the first row. The estimates are derived from the main difference-in-difference specification (Equation 2). Detailed information about the outcomes can be found in the Appendix. All specifications include the full set of controls listed in Table 1, as well as district-by-month-of-birth and district-by-year-of-birth fixed effects. FDR-q represents p values adjusted for multiple-hypothesis testing in brackets. The standard errors, reported in parentheses, are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 10: COVID-19 and maternal healthcare usage during pregnancy

	(1)	(2)	(3)	(4)	(5)
	Iron Tablet	**Intestinal Parasite**	**Blood pressure**	**Urine sample**	**Blood sample**
(April-Sept)*(Cohort-II)	-0.0030	-0.0364**	-0.0077	-0.0035	-0.0096
	(0.0108)	(0.0152)	(0.0067)	(0.0080)	(0.0071)
	[0.880]	[0.150]	[0.461]	[0.854]	[0.400]
Cohort-II(2019-20)	-0.0055	0.0121	-0.0071	0.0273*	0.0052
	(0.0210)	(0.0283)	(0.0121)	(0.0161)	(0.0146)
Post(April-Sept)	-0.0010	0.0100	-0.0138*	0.0067	-0.0038
	(0.0142)	(0.0183)	(0.0084)	(0.0114)	(0.0101)
Observations	41240	41303	39395	39395	39395
District-by-Month-of-birth	Yes	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.894	0.371	0.963	0.934	0.948

	(6)	(7)	(8)	(9)
	ANC visit	**Number of Maternal Healthcare**	**Maternal Health Index**	**Institutional Delivery**
(April-Sept)*(Cohort-II)	0.0009	-0.0642*	-0.0286*	-0.0068
	(0.0155)	(0.0385)	(0.0167)	(0.0081)
	[0.955]	[0.287]	[0.287]	[0.599]
Cohort-II(2019-20)	0.0158	0.0553	0.0212	-0.0042
	(0.0291)	(0.0792)	(0.0334)	(0.0175)
Post(April-Sept)	-0.0122	-0.0264	-0.0117	0.0031
	(0.0202)	(0.0523)	(0.0224)	(0.0119)
Observations	40962	41303	43447	43709
District-by-Month-of-birth	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.571	4.536	0.011	0.910

Notes: The sample includes children born between October 2018-September 2019, termed as Cohort-I (2018-19), and October 2019-September 2020, as Cohort-II (2019-20). Table reports the impact of the COVID-19 lockdown on maternal healthcare usage during pregnancy outcomes indicated in the first row of each panel. The estimates are obtained from the main difference-in-difference specification (Equation 2). Detailed information about the outcomes are listed in Appendix. All specifications include the full set of controls listed in Table 1, and district-by-month-of-birth and district-by-year-of-birth fixed effects. FDR-q represents p values adjusted for multiple-hypothesis testing in brackets. Standard errors reported in the parenthesis are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 11: Analysis on missing observations

	(1)	(2)	(3)	(4)	(5)
	BCG info missing	**Polio info missing**	**Hep-B info missing**	**ANC info missing**	**Iron info missing**
(April-Sept)*(Cohort-II)	0.0304**	0.0376***	0.0490***	0.0438***	0.0435***
	(0.0122)	(0.0138)	(0.0140)	(0.0085)	(0.0084)
Cohort-II (2019-20)	0.0180	-0.0417	-0.0740***	-0.0448***	-0.0419***
	(0.0270)	(0.0291)	(0.0287)	(0.0136)	(0.0129)
Post(April-Sept)	-0.0180	-0.0464**	-0.0566***	-0.0249***	-0.0232**
	(0.0179)	(0.0193)	(0.0194)	(0.0094)	(0.0091)
Observations	43786	43786	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.208	0.302	0.466	0.094	0.089
	(6)	(7)	(8)	(9)	
	Int Parasite missing	**Blood pressure missing**	**Urine sample missing**	**Blood sample missing**	**Inst. delivery missing**
(April-Sept)*(Cohort-II)	0.0449***	0.0470***	0.0470***	0.0470***	0.0006
	(0.0083)	(0.0094)	(0.0094)	(0.0094)	(0.0015)
Cohort-II (2019-20)	-0.0415***	-0.0431***	-0.0431***	-0.0431***	0.0045
	(0.0128)	(0.0164)	(0.0164)	(0.0164)	(0.0028)
Post(April-Sept)	-0.0222**	-0.0167	-0.0167	-0.0167	0.0033
	(0.0091)	(0.0116)	(0.0116)	(0.0116)	(0.0021)
Observations	43786	43786	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.088	0.133	0.133	0.133	0.002

Notes: The sample includes children born between October 2018-September 2019, termed as Cohort-I (2018-19), and October 2019-September 2020, as Cohort-II (2019-20). Table reports the impact of the COVID-19 lockdown on missing maternal healthcare usage observation, variables are coded as 1 if the observation is missing, 0 otherwise. The estimates are obtained from the main difference-in-difference specification (Equation 2). All specifications include the full set of controls listed in Table 1, and district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in the parenthesis are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table 12: Missing observations coded as zero

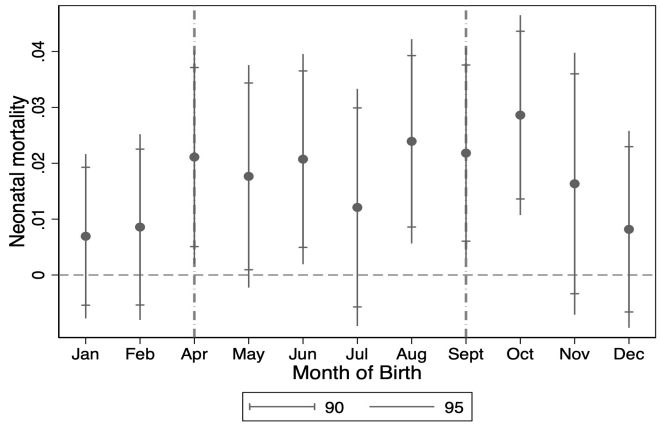
	(1)	(2)	(3)	(4)	(5)	(6)
	BCG at birth	Polio at birth	Hepatits B at birth	Vaccination Index	Iron Tablet during preg.	Int. Parasite during preg.
(April-Sept)*(Cohort-II)	-0.0609***	-0.0486***	-0.0526***	-0.1087***	-0.0425***	-0.0515***
	(0.0162)	(0.0160)	(0.0152)	(0.0295)	(0.0122)	(0.0144)
	[0.000]	[0.003]	[0.001]	[0.000]	[0.001]	[0.001]
Observations	43786	43786	43786	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.486	0.476	0.397		0.814	0.339
	(7)	(8)	(9)	(10)	(11)	(12)
	Blood pressure	Urine sample	Blood sample	ANC visit	Institutional delivery	Maternal Health Index
(April-Sept)*(Cohort-II)	-0.0515***	-0.0476***	-0.0525***	-0.0250*	-0.0069	-0.1167***
	(0.0110)	(0.0113)	(0.0105)	(0.0150)	(0.0081)	(0.0216)
	[0.000]	[0.000]	[0.000]	[0.096]	[0.390]	[0.000]
Observations	43786	43786	43786	43786	43786	43786
District-by-Month-of-birth	Yes	Yes	Yes	Yes	Yes	Yes
District-by-Year-of-birth	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Cohort-I (2018-19)	0.835	0.810	0.822	0.517	0.911	

Notes: The sample includes children born between October 2018-September 2019, termed as Cohort-I (2018-19), and October 2019-September 2020, as Cohort-II (2019-20). Table reports the impact of the COVID-19 lockdown on maternal healthcare usage during pregnancy outcomes indicated in the first row of each panel. The missing observations are coded as 0. The estimates are obtained from the main difference-in-difference specification (Equation 2). All specifications include the full set of controls listed in Table 1, and district-by-month-of-birth and district-by-year-of-birth fixed effects. FDR-q represents p values adjusted for multiple-hypothesis testing in brackets. Standard errors reported in the parenthesis are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

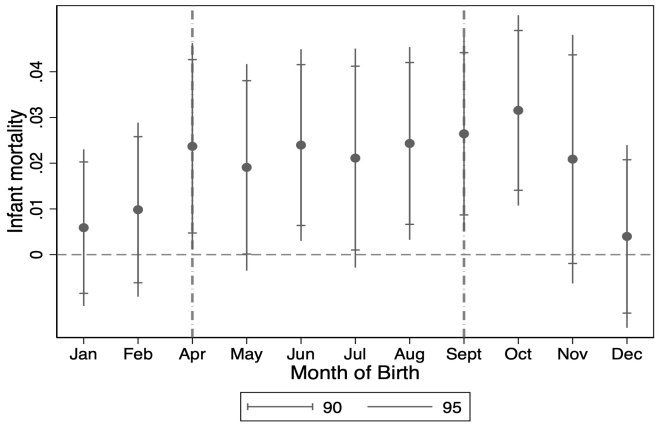
Online Appendix: Not for publication

List of Variables and definitions

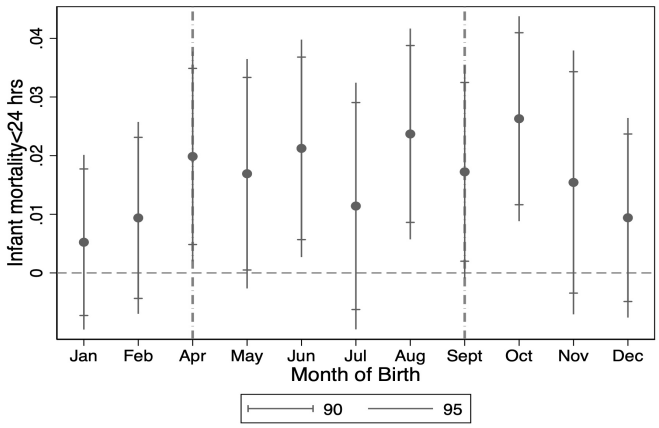
- Neonatal mortality: A dummy variable equals 1 if the child died in the 1st month after birth and 0 otherwise.
- Infant mortality<24 hrs: A dummy variable equals 1 if the child died 24 hours after birth and 0 otherwise.
- Infant mortality: A dummy variable equals 1 if the child died 12 months after birth and 0 otherwise.
- BCG on-time: A dummy variable equals 1 if the child took the BCG vaccine on-time and 0 otherwise.
- Polio on-time: A dummy variable equals 1 if the child took the Polio vaccine on-time and 0 otherwise.
- Hepatitis B on-time: A dummy variable equals 1 if the child took the Hepatitis B vaccine on-time and 0 otherwise.
- Number of vaccines: Number of on-time vaccines (BCG on-time, Polio on-time, and Hepatitis B on-time). This is a discrete variable that takes values between 0 (No on-time vaccines) and 3 (all vaccines are on-time).
- Vaccination Index: The index is constructed by averaging the z-scores from the three vaccines on-time indicators, including, (1) BCG on-time, (2) Polio on-time, and (3) Hepatitis B on-time.
- Iron tablet: A dummy variable equals 1 if the mother took an iron tablet during pregnancy and 0 otherwise.
- Intestinal parasite tablet: A dummy variable equals 1 if the mother took an intestinal parasite tablet during pregnancy and 0 otherwise.
- Blood pressure: Intestinal parasite tablet: A dummy variable equals 1 if the mother's blood pressure has been taken during pregnancy and 0 otherwise.
- Urine sample: A dummy variable equals 1 if the mother's urine sample has been taken during pregnancy and 0 otherwise.
- Blood sample: A dummy variable equals 1 if the mother's blood sample has been taken during pregnancy and 0 otherwise.
- 4+ ANC during pregnancy: A dummy variable is equal to 1 if the mother has been to the health facility 4 or more times during her last pregnancy, and 0 otherwise.
- Number of Maternal Healthcare: Number of healthcare services utilization (Iron tablet, Intestinal parasite tablet, Blood pressure, Urine sample, Blood sample, and 4+ ANC during pregnancy). This is a discrete variable that takes values between 0 (none) and 6 (all).
- Maternal Health Index: The index is constructed by averaging the z-scores from the six maternal healthcare indicators, including, (1) Iron tablet, (2) Intestinal parasite tablet, (3) Blood pressure, (4) Urine sample, (5) Blood sample, and (6) 4+ ANC during pregnancy.
- Institutional delivery: A dummy variable equals 1 if the mother gave birth a health facility and 0 if she gave birth at home.
- Control variables: Mother's age, education, age at first marriage and birth, child's birth order and gender, religion, cast, economic condition, and place of residence, district-by-month-of-birth and district-by-year-of-birth fixed effects.



(a) Neonatal mortality



(b) Infant mortality



(c) Infant mortality<24 hours

Figure A1: Event Study: Neonatal mortality, Infant mortality, and Infant mortality<24 hrs rate in Cohort II (2019-20) relative to Cohort I (2018-19)

Notes: The event study examines the impact of COVID-19 lockdown on neonatal mortality, infant mortality, and infant mortality within 24 hours in Cohort-II (2019-20) relative to Cohort-I (2018-19). The figures present the event study estimates showing the effect of COVID-19 lockdown on the mentioned mortality rates. The coefficients from the event study specification (Equation 1) are reported for a period ranging from 3 months before to 9 months after the initial lockdown order. This allows us to analyze the post-lockdown effect on the main outcomes. The omitted month, in this case, is March, which is just prior to the first lockdown order. Each point represents the point estimate derived from the event study model, and solid lines indicate the 90% and 95% confidence intervals. The specification includes a comprehensive set of controls, district-by-month of-birth, and district-by-year-of-birth fixed effects. Robust standard errors are clustered at the district-by-month-of-birth.

Table A1: Simple difference-in-difference

	Neonatal Mortality (per 1000 live births)		
	Oct-March (A)	**Apr-Sept (B)**	**Δ A-B**
Cohort-I (2018-19)	29.926	30.6987	0.7727
Cohort-II (2019-20)	29.8795	33.8105	3.931
		Diff-in-Diff (II-I)	3.1583

	Infant Mortality (per 1000 live births)		
	Oct-March (A)	**Apr-Sept (B)**	**Δ A-B**
Cohort-I (2018-19)	39.8176	38.4834	-1.3342
Cohort-II (2019-20)	35.8337	40.0521	4.2184
		Diff-in-Diff (II-I)	5.5526

	Infant Mortality<24 hrs (per 1000 live births)		
	Oct-March (A)	**Apr-Sept (B)**	**Δ A-B**
Cohort-I (2018-19)	26.4665	28.8131	2.3466
Cohort-II (2019-20)	26.9213	31.5784	4.6571
		Diff-in-Diff (II-I)	2.3105

Notes: The table presents a simple difference-in-difference calculation of the main outcomes. The sample includes children born between October 2018 and September 2019, referred to as Cohort (2018-19), and between October 2019 and September 2020, referred to as Cohort (2019-20). Oct-March (A) represents the period before the lockdown, while Apr-Sept (B) represents the period during the lockdown.

Table A2: Balancing tests

	(1)	(2)	(3)	(4)	(5)
	Mother's age	Rural	Mother's education	Age at first birth	Age at first cohabitation
Cohort (2019-20)	-0.1010	-0.0006	0.1760	0.2774***	0.1542
	(0.1331)	(0.0113)	(0.1419)	(0.0997)	(0.1020)
Observations	43786	43786	43786	43786	43786
	(6)	(7)	(8)	(9)	(10)
	Low income	Middle income	High income	Schedule caste	Backward class
Cohort (2019-20)	-0.0112	-0.0048	0.0160	-0.0187	0.0125
	(0.0125)	(0.0122)	(0.0124)	(0.0130)	(0.0145)
Observations	43786	43786	43786	43786	43786
	(11)	(12)	(13)	(14)	(15)
	No cast	Hindu	Muslim	Other Religion	Birth order
Cohort (2019-20)	0.0015	-0.0002	-0.0086	0.0088*	-0.0313
	(0.0107)	(0.0103)	(0.0088)	(0.0053)	(0.0361)
Observations	43786	43786	43786	43786	43786

Notes: Table presents balancing tests for children's baseline characteristics. The estimates are obtained from the main difference-in-difference specification (Equation 2 without post and post interacted with cohort II). All specifications include district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in the parenthesis are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table A3: Summary statistics for baseline characteristics

	Post-Covid	Pre-Covid	Difference	P-values	FDR-q	Observations
Mother's Education	7.975	7.990	0.015	0.734	0.734	63770
Birth Order	2.107	2.120	0.013	0.243	0.303	63770
Cohabitation age	19.700	19.724	0.023	0.464	0.535	63770
Schedule caste/tribe	0.411	0.412	0.002	0.686	0.734	63770
Backward class	0.416	0.349	-0.067	0.000	0.000	63770
First birth age	21.762	21.567	-0.196	0.000	0.000	63770
Hindu	0.814	0.639	-0.175	0.000	0.000	63770
Middle	0.184	0.209	0.025	0.000	0.000	63770
Mother's Age	26.159	25.547	-0.612	0.000	0.000	63770
Muslim	0.104	0.196	0.092	0.000	0.000	63770
No cast	0.156	0.147	-0.008	0.008	0.011	63770
Other Religion	0.082	0.165	0.083	0.000	0.000	63770
Poor	0.479	0.521	0.042	0.000	0.000	63770
Rich	0.337	0.270	-0.067	0.000	0.000	63770
Rural	0.798	0.811	0.013	0.000	0.000	63770
Observation	43835	19935				

Notes: Table provides summary statistics for family baseline characteristics. Column 1 (Post-COVID-19) represents the baseline characteristics of families interviewed before COVID-19 in 2019, while Column 2 (Pre-COVID-19) presents the family baseline characteristics of families interviewed post-COVID-19 in 2020 or 2021. Columns 3-6 represent the mean p-values, FDR-q, and number of observations, respectively.

Table A4: Event study for main outcomes

	Neonatal mortality	Infant mortality	Infant mortality <24 hrs
Cohort-II (2019-20)*October	0.0038	0.0028	0.0040
	(0.0066)	(0.0063)	(0.0075)
Cohort-II (2019-20)*November	0.0056	0.0013	0.0004
	(0.0085)	(0.0079)	(0.0092)
Cohort-II (2019-20)*December	0.0055	0.0045	-0.0015
	(0.0062)	(0.0062)	(0.0071)
Cohort-II (2019-20)*January	0.0052	0.0038	0.0044
	(0.0074)	(0.0076)	(0.0086)
Cohort-II (2019-20)*February	0.0063	0.0073	0.0083
	(0.0086)	(0.0084)	(0.0098)
Cohort-II (2019-20)*April	0.0227**	0.0210**	0.0258**
	(0.0098)	(0.0092)	(0.0113)
Cohort-II (2019-20)*May	0.0184*	0.0172*	0.0224**
	(0.0100)	(0.0098)	(0.0114)
Cohort-II (2019-20)*June	0.0222**	0.0226**	0.0268**
	(0.0097)	(0.0095)	(0.0106)
Cohort-II (2019-20)*July	0.0123	0.0117	0.0220*
	(0.0109)	(0.0107)	(0.0122)
Cohort-II (2019-20)*August	0.0254***	0.0248***	0.0251**
	(0.0096)	(0.0096)	(0.0109)
Cohort-II (2019-20)*September	0.0228**	0.0183**	0.0275***
	(0.0094)	(0.0091)	(0.0104)
Observations	43786	43786	43786

Notes: The event study examines the impact of COVID-19 lockdown on neonatal mortality, infant mortality, and infant mortality within 24 hours in Cohort-II (2019-20) relative to Cohort-I (2018-19). Coefficients obtained from the event study specification (Equation 1) are reported for the period of 6 months before to 6 months after the initial lockdown order. The month omitted from the analysis is March, which is just prior to the first lockdown order. The specification includes a comprehensive set of controls, district-by-month-of-birth, and district-by-year-of-birth fixed effects. Standard errors reported in the parenthesis are clustered at the district-by-month-of-birth. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table A5: Mechanism outcomes with full sample

	(1)	(2)	(3)	(4)
	BCG at birth	**Polio at birth**	**Hepatits B at birth**	**Number of Vaccines**
(April-Sept)*Cohort-II	-0.0488***	-0.0308*	-0.0308	-0.1400***
	(0.0168)	(0.0175)	(0.0189)	(0.0457)
Observations	51127	45069	35187	51472
	(5)	(6)	(7)	(8)
	Iron Tablet during preg.	**Intestinal Parasite Tablet**	**Blood pressure**	**Urine sample**
(April-Sept)*Cohort-II	-0.0037	-0.0347**	-0.0080	-0.0051
	(0.0100)	(0.0141)	(0.0061)	(0.0076)
Observations	60852	60964	57641	57641
	(9)	(10)	(11)	(12)
	Blood sample	**ANC visit**	**Number of Maternal Healthcare**	**Institutional Delivery**
(April-Sept)*Cohort-II	-0.0090	-0.0064	-0.0802**	-0.0081
	(0.0067)	(0.0144)	(0.0355)	(0.0075)
Observations	57641	60312	60964	63510

Notes: The survey was conducted between 2019 and 2021. The primary sample does not include women interviewed in 2019 because the survey was conducted before COVID-19. However, the table shows the results with the full sample, including the year 2019. The estimates are obtained from the main difference-in-difference specification (Equation 2). All specifications include the full set of controls listed in Table 1, as well as district-by-month-of-birth and district-by-year-of-birth fixed effects. Standard errors reported in parentheses are clustered at the district-by-month-of-birth level. $*p < 0.01, **p < 0.05, ***p < 0.01$.

Table A6: Stringency index in India by month

Year	Month	Stringency Index	Lockdown
2020	1	0	0
2020	2	10.19	0
2020	3	52.36	0
2020	4	98.64	1
2020	5	83.33	1
2020	6	87.55	1
2020	7	87.55	1
2020	8	85.65	1
2020	9	85.03	1
2020	10	68.08	0
2020	11	64.04	0
2020	12	68.98	0

Notes: Oxford Stringency Index is calculated based on nine metrics, including school closures; workplace closures; cancellation of public events; restrictions on public meetings; closure of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls.

Table A7: Sample structure

Cohort I (2018-19)	Cohort II (2019-20)	Lockdown (April-Sept 2020)
2018 – 10	2019 – 10	0
2018 – 11	2019 – 11	0
2018 – 12	2019 – 12	0
2019 – 1	2020 – 1	0
2019 – 2	2020 – 2	0
2019 – 3	2020 – 3	0
2019 – 4	2020 – 4	1
2019 – 5	2020 – 5	1
2019 – 6	2020 – 6	1
2019 – 7	2020 – 7	1
2019 – 8	2020 – 8	1
2019 – 9	2020 – 9	1

Notes: Table shows that Cohort I (2018-19) includes children born between October 2018 and September 2019; children in this cohort were more than 6 months old when the lockdown began in April 2020; Cohort II (2019-20) includes children born between October 2019 and September 2020; children in this cohort were either born during the lockdown (April-September 2020) or were less than 6 months old when the lockdown began in April 2020.

Table A8: List of state and union territories in the main sample

State and Union Territories	Population	Population share (%)
Uttar Pradesh	230,907,000	16.94%
Madhya Pradesh	84,516,000	6.20%
Rajasthan	79,281,000	5.82%
Tamil Nadu	76,402,000	5.61%
Odisha	45,696,000	3.35%
Jharkhand	38,471,000	2.82%
Punjab	30,339,000	2.23%
Haryana	29,483,000	2.16%
Chhattisgarh	29,493,000	2.16%
Nct of Delhi	20,571,000	1.51%
Jammu and Kashmir	13,408,000	0.98%
Uttarakhand	11,399,000	0.84%
Himachal Pradesh	7,394,000	0.54%
Puducherry	1,571,000	0.12%
Arunachal Pradesh	1,533,000	0.11%
Chandigarh	1,208,000	0.09%
Andaman and Nicobar Island	400000	0.03%
Lakshadweep	68000	0.01%
Total	702,140,000	51.51%

Notes: Table presents the states and union territories included in the main sample, along with their respective population and population share in India.

Table A9: List of states and union territories and survey years in the data

	Survey Year			
State and Union Territories	2019	2020	2021	Total Observations
Bihar	100%	0%	0%	21,040
Assam	100%	0%	0%	10,645
Gujarat	100%	0%	0%	9,868
Maharashtra	100%	0%	0%	9,520
Karnataka	100%	0%	0%	8,383
Telangana	100%	0%	0%	7,318
Meghalaya	100%	0%	0%	6,628
West Bengal	100%	0%	0%	5,618
Manipur	100%	0%	0%	3,225
Nagaland	100%	0%	0%	3,052
Andhra Pradesh	100%	0%	0%	2,833
Kerala	100%	0%	0%	2,734
Himachal Pradesh	100%	0%	0%	2,635
Mizoram	100%	0%	0%	2,454
Tripura	100%	0%	0%	2,074
Dadra and Nagar Haveli	100%	0%	0%	795
Sikkim	100%	0%	0%	620
Goa	100%	0%	0%	369
Ladakh	100%	0%	0%	529
Jammu and Kashmir	90%	10%	0%	5,857
Lakshadweep	56%	44%	0%	276
Uttar Pradesh	0%	55%	45%	35,766
Madhya Pradesh	0%	45%	55%	16,280
Rajasthan	0%	82%	18%	14,643
Jharkhand	0%	41%	59%	10,047
Odisha	0%	52%	48%	8,522
Chhattisgarh	0%	45%	55%	8,514
Haryana	0%	33%	67%	6,915
Tamil nadu	0%	47%	53%	6,498
Punjab	0%	59%	41%	5,616
Arunachal Pradesh	0%	47%	53%	5,524
Uttarakhand	0%	49%	511%	3,784
Nct of Delhi	0%	89%	11%	2,937
Puducherry	0%	68%	32%	766
Andaman and Nicobar Island	82%	18%	0%	461
Chandigarh	0%	0%	100%	174
Survey completion ratio	45.59%	29.37%	25.04%	100%

Notes: Table provides information about the National Family Health Survey (NFHS) conducted in India. The survey was conducted in a total of 28 states and 8 union territories (UT). The NFHS was conducted in two phases. Phase one took place from 17 June 2019 to 30 January 2020 and covered 17 states and 5 UTs. Phase two was conducted from 2 January 2020 to 30 April 2021 and covered 11 states and 3 UTs. This information highlights the time frame and geographical coverage of the NFHS, indicating the states and UTs included in each phase of the survey.