Mission Indradhanush: Revolutionizing Child Health Through Vaccination

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Abstract

In this paper, we study the impact of the Mission Indradhanush (MI) vaccination campaign program on the child's health outcomes. By utilizing an intent-to-treat approach and exploiting exogenous variation in childbirth month and year, we find evidence of higher weight-for-age and height-for-age z-scores for children exposed both in-utero and between the age of 0-24 months. Further, analyzing it, we find that children exposed in their first year of life derived greater benefits from the program than those exposed in their second year. Our findings emphasize the importance of prolonged exposure to the program. Even more, we highlight the program's efficacy in targeting rural areas, Scheduled Castes, and Scheduled Tribes, as well as the mitigating effect of immunization on stunted growth and underweight in females. The results suggest that the program has improved full immunization coverage and strengthened healthcare delivery systems in India.

Keywords: Vaccination, Child Health, Height-for-Age, Weight-for-Age

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1. Introduction

Vaccination is a crucial investment for any country, saving lives, preventing disabilities, and promoting health. Despite well-documented benefits (Zhou et al., 2014; Aaby et al., 2014; Piot et al., 2019), millions of children in developing countries are still denied access to this life-saving intervention, resulting in the preventable deaths of five million children under five globally in 2020 (WHO, 2022). India has one of the highest under-5 mortality rates globally, with one million children dying before their fifth birthday[3] due to birth complications and infectious diseases like pneumonia, diarrhea, and malaria. Despite clear evidence on how wide vaccination coverages have been successful in eradicating certain diseases like measles, diarrhea, whooping cough, pneumonia (Bustreo et al., 2015), smallpox,[4] and are on the verge to eradicating polio (WHO, 2022), only 76.4% of children are fully immunized in India (PIB, 2021).

In 1978, the Indian government launched the Expanded Programme of Immunization, later renamed the Universal Immunization Programme (UIP) in 1985, and expanded its reach beyond urban areas. In 1992, it was integrated into the Child Survival and Safe Motherhood Programme, and in 1997, and became part of the National Reproductive and Child Health Programme (MoHFW, GoI, 2019). The UIP is integral to the National Rural Health Mission, launched in 2005. Despite extensive efforts to increase awareness of vaccines and their benefits and to enhance the health infrastructure, full immunization coverage has been slow to rise. As of 2021, many children failed to receive all essential vaccines in the first year of life, putting themselves and their communities at risk of vaccine-preventable diseases and deadly outbreaks. This paper evaluates Mission Indradhanush (MI), an initiative launched by the Government of India on December 24, 2014, under the UIP. It targets the mobile and vulnerable population to increase immunization rates and reduce the burden of preventable diseases.

The program strives towards achieving full immunization for all children below two years and pregnant women with available vaccines. With a specific focus on medium to high-risk populations and low-full immunization-level districts, the program endeavours to enhance coverage and address equity issues in accessing immunization services. To promote vaccine uptake, the program is implemented in four phases, targeting different districts in each phase. Each phase consists of four rounds, with each round lasting for seven days. Our study aims to evaluate the program's effects on two exposures: in-utero tetanus injections and age-specific

[3] Immunization | UNICEF India
[4] Smallpox (who.int)

vaccinations for children under 24 months. We estimate the impact of these exposures on children's weight-for-age z-score (ZWFA) and height-for-age z-score (ZHFA). The program targets children who are either unimmunized or partially missed vaccinations for various reasons. MI contributes to strengthening the country's healthcare system by improving the delivery of immunization services and increasing awareness of the vital role of vaccines. According to the Integrated Child Health and Immunization Survey (INCHIS) report, the first two phases of the program led to a 6.7% boost in full immunization coverage within a year, surpassing the previous annual rate of 1 percent (PIB, 2018).

We use the NFHS-4 dataset from 2015-16, which includes data on children born within the past five years, to calculate the program's intent-to-treat effect on child health indicators. Our focus is on evaluating the effectiveness of the supply-side enhancements in the vaccine provision, as well as increasing health staff training and availability, with regard to their potential benefits for the children and their ability to reach the targeted population. The program aims to reduce the incidence and deaths caused by vaccine-preventable diseases among children under five while not explicitly targeting post-natal deaths (PIB, 2018). Existing literature suggests that vaccination impacts children's height and weight. Therefore, we examine the impact of vaccination coverage on the child's height and weight in the districts where MI was launched. In this paper, we use the exogeneity of the month and year of childbirth and the access to vaccination coverage to estimate the impact of the MI on the ZWFA and ZHFA.

Maternal immunization with tetanus toxoid-containing vaccines is crucial to reduce the incidence of maternal and neonatal tetanus infections, protecting both the mother and her newborn. Ensuring safe deliveries and clean cord practices further enhance the effectiveness of the delivery. Previous studies find that complete prenatal immunization with tetanus toxoid during pregnancy, comprising two doses administered at an interval of one month, significantly decreases the occurrence of neonatal tetanus among newborn children (Gupta and Keyl, 1998; Demicheli et al., 2015; and Singh et al., 2014). The positive impact of the maternal tetanus injections extends beyond the mother to her child by facilitating the transfer of antibodies in-utero and through breastfeeding. This transfer of protective antibodies reduces the mortality rate and enhances their overall health status (Canning et al., 2011).

Resources expended on postnatal care, such as vaccinating children against BCG, DPT, and measles, enhance their immune systems and reduce morbidity. Brown (2003) finds that

diarrhea can decrease dietary intake and increase nutrient loss due to vomiting and malabsorption, potentially necessitating greater nutrient intake. This implies that there is a vicious cycle of diarrhea and malnourishment. Studies show a negative relationship between infectious diseases and the Height-for-age and Weight-for-age Z-scores for children, immediately and in later childhood (Weisz. et al., 2011; Moore et al., 2001). Health interventions help reduce the incidence and duration of infectious diseases and promote physical growth (Bhargava et al., 2001). Children's growth trajectory is determined by the nutritional and medical health inputs that the child experiences after birth. Weight-for-age and height-for-age z-scores serve as reasonable measures of child health (Waterlow et al., 1977). Interventions between 9-24 months are crucial, as any intervention outside this period is ineffective in reducing stunting (Prentice et al., 2013). Underweight and stunted children have lower ZWFA and ZHFA, respectively, with stunting indicating long-term growth retardation due to chronic undernutrition. Prevention of infectious diseases can improve children's health outcomes, potentially leading to better educational outcomes, wages, and employment opportunities (Bloom et al., 2012; Anekwe et al., 2015; Summan et al., 2022).

Our findings suggest that the implementation of MI significantly improves child health outcomes. In particular, we observe an increase in the ZWFA and ZHFA for children exposed to the program either in-utero or between 0-24 months of age. Children exposed to the program during both periods experienced the most significant increase in ZWFA and ZHFA, with a ZWFA increase of 0.31 standard deviations and a ZHFA increase of 0.87 standard deviations. We further examine the effect of program exposure during the two subgroups of the 0–24 months age group period: the first 12 months and the 13-24 months. We find that children exposed to the program in utero and during the first 12 months of life reap the maximum benefits of the program, with a ZWFA increase of 0.418 standard deviations and a ZHFA increase of 1.09 standard deviations. We obtain positive and significant results for ZWFA in all the categories but estimates on ZHFA turn insignificant for children exposed during the 13-24 months of age only, and those exposed during both 0-12 months and 13-24 months of age. This is due to non-compliance with the recommended vaccine schedule of 13-24 months age children. We show the robustness of our findings by relaxing the duration of exposure in each phase and increasing the time between the interview and the end of a phase. We also correct our in-utero exposure definition and, check for robustness of our estimates with respect to additional covariates. The study suggests that program benefits are more pronounced with prolonged exposure duration.

The positive program effects are more significant for females than for males. It is consistent with the existing literature on the higher efficacy of vaccination on females (Fischinger et al., 2019). Immunization helps mitigate the negative impact of stunted growth and underweight in females. The results also show that children in urban households benefit less than rural households. Kunlarni et al. (2023) show that the full immunization rate is increasing in rural areas more than in urban areas. Furthermore, we also find that Scheduled Caste (SC) and Scheduled Tribe (ST) populations benefit more than the non-SC ST groups, indicating that the program's design effectively targets those typically in the most vulnerable positions. Overall, the immunization program has been beneficial for females and marginalized communities.

Our paper is the first to assess the effectiveness of MI on the anthropometric outcomes of children under five. Previous studies by Jain et al. (2018) in the Tikamgarh district of Madhya Pradesh and Francis et al. (2017) in Rural Vellore provide evidence of the program's positive impact on increasing the full immunization rate in these regions. However, they had data on the weight and height of the children. Thus, it fills an essential gap in the literature by examining the program's effect on anthropometric outcomes. Furthermore, we extend the existing literature by exploring whether the timing of immunization matters by leveraging information on the in-utero exposure of children to maternal tetanus and age-specific vaccinations after birth. Our findings suggest that the program's efforts to increase full immunization among children aged 12-23 months result in improving the ZWFA and ZHFA of the children.

The rest of the paper is organized as follows. Section 2 provides the details on the MI program. In Section 3, we describe our data and introduce our empirical strategy to estimate the effects of MI on child health outcomes. The main results are discussed in Section 4, along with robustness checks and heterogeneity in the obtained estimates. Section 5 discusses the potential mechanism. In Section 6, we present the conclusions of the study.

2. Contextual Framework

MI is a flagship program launched on 24 December 2014 by the Ministry of Health and Family Welfare, Government of India, to achieve more than 90% full immunization coverage by 2020. The program initially targets unvaccinated or partially immunized children under two years of

age against seven preventable life-threatening diseases, including Diphtheria, Whooping Cough, Tetanus, Polio, Tuberculosis, Measles**,** and Hepatitis-B. In some districts/states, additional vaccines against Haemophilus influenzae type b (Hib) and Japanese Encephalitis (JE) are also provided. Pregnant women receive tetanus toxoid injections/vaccines. Children above the age of 2 years are also eligible for due vaccines during the session. Subsequently, Rubella and Rotavirus vaccines are added to the UIP, and Vitamin A, Zinc tablets, and ORS packets are supplied. The mission focuses on areas with low vaccination coverage due to geographic, demographic, ethnic, and operational challenges. Priority is given to populations residing in high-risk areas such as urban slums, construction sites, nomadic sites, brick kilns, and hard-to-reach areas where the proportion of unvaccinated and partially vaccinated children is the highest.

MI is launched in four phases, each being conducted for a week every month for four consecutive months, starting from the 7th of every month. Phase 1 commenced from 7th April 2015 to July 2015, targeting 201 high-priority districts. These districts cover 50% of the country's unvaccinated or partially vaccinated children (PIB, 2015). These include nomads and migrant laborers working on roads, construction sites, riverbed mining areas, brick kilns, remote and inaccessible geographical regions and urban slums, and the underserved and hard-to-reach population dwelling in forested and tribal areas. MI implementation focuses on areas lacking an auxiliary nurse midwife (ANM) for more than three months, villages with three or more consecutive missed routine immunization sessions, and areas with low Routine Immunization coverage identified by measles outbreaks, diphtheria cases, and neonatal tetanus occurrences in last two years. Mobile sessions are organized to reach areas with weak immunization coverage and fewer beneficiaries, including peri-urban areas, scattered slums, brick kilns, and construction sites.

Phase 2 has been implemented in 352 districts, consisting of 279 medium-focus and 73 high-focus districts from Phase 1, from October 2015 to January 2016 (PIB, 2015). During Phase 2, 11.6 lakh sessions of MI are conducted, immunizing 71.6 lakh children and 17 lakh pregnant women, with 18.5 lakh children and 9 lakh women fully vaccinated (PIB, 2016). Phase 3 takes place from April 2016 to July 2016 in 216 districts with immunization coverage below 60% and high dropout rates, including 199 districts covered in either Phase 1 or 2 (PIB, 2016). Phase 4 is launched in two parts: for Northeastern states from February 2017 to May 2017, targeting sixty-eight districts (60 chosen from the earlier phases), and from April 2017 to July 2017 in the rest of the country, selecting 186 districts for implementation (163 selected in earlier rounds as well).

MI is funded by government and donor agencies, including WHO and UNICEF, to cover the costs of vaccines, healthcare worker training, logistics, and other related expenses. The program receives most of its funding from the government and additional support from the donor agencies such as the WHO and UNICEF, NGOs, private sector organizations, and philanthropic foundations. Technical support is sought from multiple agencies like WHO, UNICEF, NPSP, RMNCH+A lead partners, Rotary International, and other state and district-level organizations. The Ministry of Health and Family Welfare collaborates with other Ministries, ongoing programs, and international partners to boost the country's routine immunization.

MI provides a comprehensive solution for achieving high-quality routine immunization coverage. Efforts are made to increase the capacity of health officials and workers through training in routine immunization activities. Vaccination storage facilities are also improved. Awareness about immunization is raised through interpersonal communication, mass media, schools, youth networks, and corporate initiatives. Accountability is ensured at each administration level, with district administration and health machinery responsible for strengthening district task forces and using concurrent session monitoring data to address implementation gaps. ASHA/Anganwadi workers conduct a headcount survey to list eligible beneficiaries and cover every eligible child.

3. Data and Methods

3.1 Data

We use the National Family Health Survey fourth round (NFHS-4) data. It is a nationally representative cross-sectional health survey for India providing rich information on the sampled population's anthropometric, socioeconomic, and demographic characteristics. Conducted between January 2015 and December 2016, the International Institute of Population Sciences (IIPS) survey is administered under the Ministry of Health and Family Welfare (MoHFW), Government of India. It plays a crucial role as a component of the Demographic Health Survey (DHS) program.

The NFHS-4 survey uses a separate questionnaire for interviewing ever-married women and gathering information on prenatal care, fertility history, delivery history, antenatal care, maternal health, child health, and vaccination status. Socioeconomic characteristics, such

as education level, husbands' education level, employment status, and ethnicity, are also recorded, as are demographic characteristics of the child, such as age, gender, and place of residence (rural/urban). However, this information is available only for children born within the five years prior to the survey. This dataset covers 2,59,627 children aged 0 to 59 months from 640 districts, all born in 2010 or later. This dataset is nationally representative, with sampling weights used to ensure accuracy.

We have integrated the MI rollout data with the NFHS-4 data to enhance our analysis, focusing only on phases 1 to 3.[5] The MI rollout data from the Press Information Bureau (PIB, 2015; PIB, 2016) for these phases is integrated with the current residence district information in the NFHS-4 dataset. Implementing the scheme in different districts in each phase, combined with an exogenous variation in the child's birth month and year, is the basis for our identification strategy.

3.1.1 Eligibility for Program Participation and Exposure to MI

The MI program targets children between 0-24 months and pregnant mothers. Our paper studies the impact of exposure to the program in-utero and the first 24 months after birth. We define exposure to the program of a child through two components: district eligibility and child eligibility. The MI rollout data provides the exact month and year when MI reached each district, allowing us to identify the targeted districts for each phase. We calculate the program exposure by combining the MI rollout data with the NFHS-4 dataset.

The child's eligibility for the program is determined at two levels: first, whether the child is eligible for the program during the mother's pregnancy or in utero. For this, we use the birth history of every child ever born to a woman. Specifically, we use the month and year of childbirth and the duration of the mother's pregnancy. Using this information, we calculate whether the woman was eligible for program participation during any MI phase when pregnant. We assume that the mother’s place of residence when the child was in utero is the same as the child’s current residence

Our sample is defined by strict criteria to ensure that only children whose mothers were fully exposed to the program during pregnancy are included. Specifically, we include only

[5] Our analysis is limited to Phase 1-3 of the program since Phase 4 was rolled out in February 2017 after the completion of NFHS-4 interviews in December 2016.

those children whose mothers were pregnant for the entire duration of the program phase and resided in a district where the program was implemented. For a child to be considered exposed to the program in utero, two conditions must be met: First, the mother must have conceived the child before the program phase started, ensuring the child was in utero during all four rounds of a phase. Second, the mother must have been interviewed after the phase was completed. This ensures that the mother and child are fully exposed to all rounds of the phase of the program during pregnancy. Children whose mothers were pregnant for only part of the program phase—such as those who delivered during the phase—are not included in our sample. We focus only on those children whose mothers were pregnant throughout the entire phase, ensuring full exposure to the program. Mothers interviewed before the end of the phase are also not considered, as their exposure to the complete program cannot be verified.

The second eligibility criterion ensures that we include only children who were fully exposed to the program within the first 24 months of life. Using child's birth month and year, we check if the child was less than 24 months old during the last round of any phase of the program. A child is considered exposed if they were under 24 months at the time of the last round, lived in a district where the program was implemented, and their mother was interviewed after the completion of the program phase. Children who do not meet these conditions, such as those who were older than 24 months during the last round or whose mothers were interviewed before the program phase ended, are classified as unexposed. Additionally, children who experienced only partial exposure—those exposed for only part of the program phase—are not included in our sample to ensure consistency. Only children who were fully exposed to the program throughout the entire phase are part of our analysis. We further divide the exposed children into two groups: those exposed during their first 12 months of life and those exposed during the 13-24 month period. This bifurcation allows us to examine the program's impact at different stages of a child's early development.

3.1.2 Outcomes

Our primary outcome variables are the child's height-for-age (HFA) and weight-for-age (WFA), measured through z-score values based on the standardized growth charts developed by the World Health Organization (WHO). These growth chart measures are widely implemented across developed and developing countries, using a reference population of relatively well-nourished children (De Onis, 2013). WHO provides WFA and HFA indices to assess the growth and nutritional status of children under five, which are generally used by

policymakers and researchers to monitor the growth and development of children, thus, identifying malnutrition and stuntedness.

The ZHFA is defined as a child's height in terms of the number of standard deviations above or below the median height in relation to healthy children of the same age and sex. Similarly, ZWFA measures the child's weight in the same context. The values for both ZHFA and ZWFA range from -6 to 6. Children with the ZHFA <-2 SD from the median of the reference group as stunted (WHO, 2006). However, children with the ZWFA <-2 SD from the median of the reference group as underweight. As mentioned earlier, weight is a short-term phenomenon in comparison to height. Stunting is the result of chronic undernutrition. It takes time to reflect on the nutritional status of the height. The NFHS-4 dataset calculates ZWFA and ZHFA for each child, which can be directly used for the analysis after dividing it by 100.

Table 1 provides the descriptive statistics[6] of all the districts, then distinguishes between those exposed to MI program and those not exposed (non-MI). The mean ZWFA and ZHFA are -1.57 and -1.48, respectively. The MI districts have a lower mean of fully vaccinated children (57%) and higher means of unvaccinated children (9%) compared to non-MI districts, with a mean of fully vaccinated children at 64 percentage and a lower mean of unvaccinated children at six percentage. Furthermore, Non-MI districts reveal more tetanus injections given to mothers. These findings suggest that the MI program targeted districts with lower full vaccination rates and lower maternal tetanus-received districts. The average age of children is comparable between MI and non-MI districts at 24.30 and 24.36, respectively. To identify the causal impact of the MI program on ZWFA and ZHFA, we outline our methodology in the following section.

<Insert Table 1>

3.2 Threats to Identification

Our analysis does not follow the traditional Two-Way Fixed Effects (TWFE) model because the Mission Indradhanush (MI) program was implemented in different phases, leading to changes in treatment status for children. The timing of a child's exposure to the program is not fixed; it varies depending on the phase of the program and the child's age at the time. This timing is crucial, as the age at which a child is exposed significantly affects the program's

[6] Descriptive statistics table is created using the sampling weights.

impact. Additionally, the number of times and the specific ages at which children are exposed to the program are important factors that influence the outcomes.

A key advantage of our identification strategy is that the timing of exposure is largely random, as it depends on the child's birth month, which cannot be manipulated. Although the selection of districts for the program was not random, this does not undermine our strategy because a child's eligibility is determined by their birth month—a factor that cannot be influenced by parents or policymakers. While it might be possible to manipulate the year of a child's birth, the specific birth month is not easily altered, ensuring that the exposure to the program remains random.

To address the concern that we cannot directly test for parallel trends, we present placebo results by restricting our sample to children interviewed before the program's launch (January to March 2015). We find no effect of the program on children in MI districts who were 0-24 months old during this period. This supports the validity of our identification strategy, as it indicates that the effects observed in our main analysis are not due to pre-existing differences between treated and untreated groups.

3.3 Estimation Framework

Using the survey data, we use the Intent to Treat (ITT) strategy to assess the program's impact on the targeted population, assuming they are the program's beneficiaries. Given the non-random selection of districts, we use a quasi-experimental approach to establish the causal influence of the MI program on child health indices. Our primary objective is to determine how the program has helped to improve child health outcomes. To achieve this, we examine its impact during different stages of childhood. We employ an identification technique that leverages the variations in the program's exposure that children receive.

With observations for child *i*, who belongs to household *h* living in district *d* and state *s*, we estimate linear regression:

$$\begin{aligned} \boldsymbol{Y_{ihds}} = \ & \boldsymbol{\alpha_0} + \boldsymbol{\alpha_1}(\boldsymbol{Utero_{ihds}}) + \ \boldsymbol{\alpha_2}\ (\boldsymbol{Age\ 0-24\ months_{ihds}}) \\ & + \ \boldsymbol{\alpha_3}(\boldsymbol{Utero_{ihds}} * \ \boldsymbol{Age\ 0-24\ months_{ihds}}) \ + \boldsymbol{\gamma X_{ihds}} \\ & + \ \boldsymbol{\tau_{db}} + \ \boldsymbol{\varepsilon_{ihds}} \end{aligned} \qquad (\mathbf{1})$$

where Y_{ihds} are the ZWFA and ZHFA. $Utero_{ihds}$ is a binary variable that takes the value 1 for the children eligible for the program when in-utero, 0 otherwise. The $Age\ 0-24\ months_{ihds}$ is the dummy variable that takes value 0 or 1, indicating whether the child was exposed to the program within 24 months of birth. The interaction between these two variables is denoted as $Utero_{ihds} * Age\ 0-24\ months_{ihds}$, which takes value 1 for the children eligible both in-utero and within the 24 months of the birth, and 0 otherwise. To address the problem of potential confounding factors in our regression, we include a set of child, woman, and household-level covariates given by X_{ihds}. Child characteristics include the sex of the child, birth order of the child, religion of the child, and ethnicity (General, Other Backward Class (OBC), Schedule Caste (SC), Schedule Tribe (ST)). Mother-level covariates included are the mother's education level (no education, primary education, and secondary education), the mother's age at the time of childbirth, and the mother's height. Mother's age and Mother's height are continuous variables. Household covariates include the area of residence (rural or urban) and wealth index. The NFHS-4 data set provides information on the wealth index measured through consumer goods such as car, air conditioner, refrigerator, and TV. This wealth index is categorized into five categories: poorest, poorer, middle, richer, and richest. We have modified these categories and then categorized them into three groups: poor, middle, and rich. Grouping the poorest and poorest into the poor category and the richer and richest into the rich category. The middle category was kept unchanged. τ_{db} is the district birth year fixed effect. It serves to account for the changes that take place within the district in a particular year. The source of variation in the model originates from the different birth months and years of the children across cohorts. ε_{ihds} is an error term.[7]

We are interested in estimating α_3, the coefficient associated with the interaction term between children exposed in-utero and within 24 months of birth. We expect this coefficient's sign to be positive and have the highest magnitude compared to other coefficients, indicating that the longer duration of program exposure will have a higher positive impact on the child's health.

[7] We cluster standard errors at the district level to address potential correlations that may exist within each district. Specifically, our analysis is conducted with 640 clusters corresponding to the districts.

The recommended vaccination schedule, as outlined by the ACVIP, suggests that children should receive most vaccinations by nine months.[8] However, there is a range in which children can still receive missed vaccinations. Through our empirical strategy, we further intend to examine if there are any differences in the program's impact on children who were exposed during 0-12 months of age and 13-24 months of age. We also aim to investigate how this difference affects the ZWFA and ZHFA of the exposed child during the different stages of their childhood. To achieve this, our estimation equation is:

$$\begin{aligned} \boldsymbol{Y_{ihds}} = \ & \boldsymbol{\alpha} + \boldsymbol{\beta_1}(\boldsymbol{Utero_{ihds}}) + \boldsymbol{\beta_2}\,(\boldsymbol{Age\ 0-12\ months_{ihds}}) \\ & + \boldsymbol{\beta_3}\,(\boldsymbol{Age\ 13-24\ months_{ihds}}) \\ & + \boldsymbol{\beta_4}(\boldsymbol{Utero_{ihds}} * \boldsymbol{Age\ 0-12\ months_{ihds}}) \\ & + \boldsymbol{\beta_5}(\boldsymbol{Utero_{ihds}} * \boldsymbol{Age\ 13-24\ months_{ihds}}) \\ & + \boldsymbol{\beta_6}(\boldsymbol{Age\ 0-12\ months_{ihds}} * \boldsymbol{Age\ 13-24\ months_{ihds}}) \\ & + \boldsymbol{\beta_7}(\boldsymbol{Utero_{ihds}} * \boldsymbol{Age\ 0-12\ months_{ihds}} * \boldsymbol{Age\ 13-24\ months_{ihds}}) \\ & + \boldsymbol{\gamma X_{ihds}} + \boldsymbol{\tau_{db}} + \boldsymbol{\varepsilon_{ihds}} \qquad (2) \end{aligned}$$

where, $Age\ 13-24\ months_{ihds}$ is a dummy variable taking value 1, capturing whether the child was exposed to the program between the age range of 13-24 months. $Utero_{ihds} * Age\ 13-24\ months_{ihds}$ takes value 1 for children eligible for the program in utero and when in age range 13-24 months, and 0 otherwise. $Age\ 0-12\ months_{ihds} * Age\ 13-24\ months_{ihds}$ takes value 1 if the child is eligible for the programme in both the first 12 months after the birth and 13-24 months age, 0 otherwise. $Utero_{ihds} * Age\ 0-12\ months_{ihds} * Age\ 13-24\ months_{ihds}$ takes value 1 if the child is exposed to the programme when in in-utero as well as within 12 months of birth and 13-24 months age. All the remaining variables follow the exact definition as in Equation (1).

4. Results

4.1 ZWFA and ZHFA

Table 2 presents the main results of our analysis using estimating equation (1) and sampling weights. The first and second columns present results for ZWFA, and third and fourth columns

[8] See Appendix Table A1 for the ACVIP-recommended vaccination schedule for children aged 0-24 months.

present results for ZHFA. The second and fourth column are our main results with all the controls and district-birth year fixed effects for ZWFA and ZHFA, respectively.

<INSERT TABLE 2>

Our results indicate that exposure to the program, during both utero and age 0-24 months, helps increase the ZWFA by 0.31 standard deviation and ZHFA by 0.87 standard deviations, compared to the totally unexposed children. For the average Indian child, who was 1.57 z-scores below the normal for WFA, this translates to a 20% reduction in the WFA deficit. Similarly, for the average Indian child, who was 1.48 z-scores below the normal for HFA, this translates to a 59% reduction in the HFA deficit. The program helps reduce the ZWFA deficit by 7-20%. The effect is strongest for children exposed in utero, less for those exposed only in-utero, and smallest for those aged 0-24 months. This is because children exposed in utero have sufficient time to show the program's effect. In contrast, we try to estimate the program's immediate impact on other children, giving them a comparatively shorter time to show the impact and, therefore, potentially underestimating the effect size. We see positive and significant results for ZWFA for *Age 0-24 months* but not for ZHFA because it takes a shorter time for nutritional diets to reflect on the weight than on the height.

Table 3 presents the result of the estimating equation (2), with all columns being the same as in Table 2. We bifurcate our category of age 0-24 months into two other categories and find that children exposed to the program only in age 0-12 months tend to have a higher impact than those exposed only in 13-24 months. In comparison to totally unexposed, exposure to the program at age 0-12 months helps to reduce the ZWFA deficit by 17%, while it reduces the ZWFA deficit for 13-24 months by only 7%. We have no observation in the category of the interaction term between utero exposed and age 13-24 exposed and also for the interaction term of utero exposed, age 0-12 months exposed, and age 13-24 months exposed. As in Table 2, children with exposure in both utero and age 0-12 months have the strongest effect of the program.

<INSERT TABLE 3>

Our results are consistent with the previous empirical findings on the impact of vaccination on child anthropometric outcomes. Ankew and Kumar (2012), evaluating the impact of the UIP, finds that the height-for-age deficit decreased by 22-25%, and the weight-for-age deficit decreased by 15% of the average child. Bogler et al. (2019) find that measles

vaccination reduces the odds of stunting and being underweight. Similarly, Upadhyay and Srivastava (2017) find that Haemophilus influenza type B (Hib) vaccination also reduces the chances of stunting and being underweight.

Our results indicate that the timing of the intervention is crucial. While vaccination coverage is important, it is not synonymous with the timely provision of vaccines according to the recommended schedule (Masters et al., 2019). Achieving higher vaccination coverage without adhering to the age-specific vaccination schedule may not effectively reduce mortality and morbidity. As mentioned earlier, it is recommended to administer most of the vaccines within 12 months of birth, as this is when the body is most susceptible to vaccine-preventable diseases and requires immunization (Wahl et al., 2018). Therefore, timely administration of vaccines according to the schedule, particularly during the early stages of life, is crucial for effectively preventing diseases.

4.2 Robustness checks

We conduct several robustness checks to ensure that the effects are not spurious. Firstly, we expand the definition of the treated cohorts by including children exposed to the program even for only one round of any phase, thus including partially exposed children. This is being done to test if our previous definition influences our results. As we present in A2-A3, the results are consistent with our earlier findings. Additionally, we now have a coefficient for children exposed in all three stages, which was previously a missing category. The effect is positive and significant. However, we observe an underestimation of the program effect when considering children exposed in at least two stages of their life, as they had shorter exposure in each stage.

Secondly, we increase the time gap between exposure and interview from a minimum of 15 days to a minimum of 45 days. However, this results in a loss of some observations. Nonetheless, our results in tables A4-A5 were consistent with our earlier assumptions. Thirdly, we redefine our in-utero exposure after considering the case of migration and pregnancy duration. To account for migration, during pregnancy or after delivery, we levy an additional condition that the mother should have lived in the current place for at least the last two years. Also, the mother's pregnancy duration is a self-reported variable between 4-10 months. Thus, to minimize the measurement error, we only include children for whom the pregnancy period was reported to be seven or more months. After considering these conditions, we recreate our

in-utero exposure variable and find that our results, as presented in Table A6 and A7, are similar to our main findings.

Furthermore, we assessed whether the rich quintile sample drives our findings and whether including control variables like father education and distance from the health facility influence our results. Results presented in Tables A8-A13 are similar to the ones reported earlier. Our robustness checks show that our findings are reliable and suggest that the program positively impacts child health.

4.3 Heterogeneous effects

The implementation of MI may have a differential impact based on gender, area of residence, and ethnicity. The societal preference for male children over females in India has resulted in a neglect of the health and nutritional status of female children (Borooah, 2004), leading to higher under-5 mortality rates (Guilmoto et al., 2018), lower vaccination coverage (Rajan & Morgan, 2018), sub-optimal health outcomes for females (Singh, 2012). According to research by Corsi et al. (2009), females die at higher rates of diseases like BCG, polio, tetanus, and whooping cough due to lower vaccination coverage. However, if vaccinated, females have higher antibodies against the diseases (Fischinger et al., 2019). Table A14-A15 presents the gender-based heterogeneous effects on the ZWFA and ZHFA of the program. The estimates suggest that the program benefits females, increasing their ZWFA and ZHFA. Moreover, the maximum effect on both measures is observed in females exposed to the program in utero and within the first 24 months of age.

Appendix Table A16-A17 shows the differential estimates based on the area of residence. The program's strategy of conducting mobile sessions in low-population and hard-to-reach areas, increasing awareness about the benefits of immunization, and addressing the storage issues for vaccination have led to notable improvements in ZWFA and ZHFA estimated for rural children. However, we find that the program's effects on these outcomes for urban children were insignificant. These results underscore the importance of tailored interventions to address specific challenges in rural areas, which can effectively mitigate disparities in child health outcomes between urban and rural populations.

Disaggregating the program’s effects across different population groups, we find the program benefits Scheduled Caste (SC) and Scheduled Tribe (ST) populations the most.

Ethnicity is strongly associated with poverty, education, use of health services, the subjective well-being of people, and accessibility to sanitation facilities (Borooah et al., 2014; Rani, 2014; Mukherjee et al., 2011; Spears, 2016; Kant et al., 2020). SCs often face discrimination, and STs live in secluded or hard-to-reach areas (Coffey et al., 2019). All these factors contribute to increasing under-five mortality (Bora et al., 2019), malnourishment (Van de Poel & Speybroeck, 2010), and stuntedness among the SC/ST population. Immunization remains a critical measure in reducing the vulnerability of children to vaccine-preventable diseases. This measure continues to facilitate healthy growth and development while promoting disease-free living. As we present in Tables A18-A19, the findings indicate that child health outcomes have improved for both SC-ST and non-SC-ST households. However, the extent of improvement is relatively greater for children born in SC-ST households than those born in non-SC-ST households.

4.4 Mechanisms

As highlighted in the earlier sections, MI helps overcome barriers to immunization for children under 24 months and provides tetanus to pregnant women by targeting underserved areas and leveraging community engagement. In this section, we underpin the mechanisms that make this program successful by analyzing its impact on increasing full immunization, vaccination status for different vaccines, and maternal tetanus toxoid coverage. The NFHS-4 survey includes information on tetanus injections received during the last pregnancy and on the vaccination status of children with different vaccines, enabling us to determine the impact of MI exposure on the likelihood of receiving these crucial health interventions. To determine the causal impact of exposure to MI during pregnancy on receiving tetanus injections, we estimate the following equation:

$$\boldsymbol{MT_{ihds} = \alpha + \beta_1(Utero_{ihds}) + \gamma I_{ihds} + \theta H_{hds} + \tau_{db} + \varepsilon_{ihds}} \qquad (3)$$

where, MT_{ihds} is an indicator variable taking value one if the mother had received one or more tetanus injections during the pregnancy of child *i*, and 0 otherwise. $Utero_{ihds}$ is a dummy variable taking value one if the child was exposed to the program when in-utero. All the remaining variables follow the same definition as in equation (1). We then estimate equation (4) to see the impact of exposure to MI on full immunization and no immunization.

$$\boldsymbol{C_{ihds} = \alpha + \beta_1(Age\ 0-24\ months_{ihds}) + \gamma I_{ihds} + \theta H_{hds} + \tau_{db} + \varepsilon_{ihds}} \qquad \textbf{(4)}$$

where, C_{ihds} are fully vaccinated and not vaccinated. Fully vaccinated is a dummy variable taking value one if child *i* has received one dose of Bacillus Calmette–Guérin (BCG), three doses of Diphtheria, Tetanus, and Pertussis (DPT), three doses of polio (excluding birth dose), and one dose of measles if the child is of at least 12 months of age.[9] Not Vaccinated is also a dummy variable taking value one if the child does not receive any of the above vaccines and is 12 months or older. $Age\ 0-24\ months_{ihds}$ is an indicator variable taking value one if the child is exposed to the program between 0-24 months, and 0 otherwise.

Table 4 presents our results, and it shows that exposure to MI positively impacts the probability of receiving tetanus injections during pregnancy, with an increase of 2.7 percentage points or roughly 2.9%. Moreover, compared to children who were unexposed to the program, children exposed during the first two years of life have a 2.7 percentage points or 3.11% higher likelihood of being fully vaccinated. However, we do not find a statistically significant effect on the probability of not receiving any vaccine.

<INSERT TABLE 4>

We close our empirical analysis by assessing whether there have been any changes in the probability of vaccination status of different vaccines. Specifically, we investigate whether increased vaccination against each vaccine results from exposure to the MI program. To accomplish this, we estimate equation (4) after replacing C_{ihds} with $Vaccine^{v}_{ihds}$. It is a dummy variable, taking value one, if the child *i* had received the vaccine *v* when crossed the vaccine-specific age, and 0 if the vaccine was not given.[10] Several other vaccines are also included in the program, but we could not see their impact due to the unavailability of information on their uptake. Table 5 presents the results of the vaccination status of each vaccine. Our findings show that exposure to the program during the child's first 24 months increase the probability of getting all vaccines except for the hepatitis-b birth dose vaccine. Among all the vaccines, the DPT vaccine demonstrates the highest impact, with an increase of 9.9 percentage points (12.3%). These results indicate that the program has played a crucial role in increasing the immunization rate among children and enhancing maternal health by providing them with tetanus injections during pregnancy for safe delivery.

[9] For children under 12 months of age, the full vaccination and no vaccination variables are coded as missing.
[10] Vaccination status of each vaccine has been coded as one if the vaccination date is recorded on the health card for the vaccine or if explicitly mentioned and if the vaccine was given as reported by the mother. Also, if the child has not attained the age to receive that vaccine, then it is taken as a missing value.

<INSERT TABLE 5>

5. Conclusion

This paper examines the child health impact of MI, a campaign-style vaccination delivery program focused on increasing full immunization in India. The results show that the program successfully improved full immunization rates and had unintended yet beneficial effects of increasing ZWFA and ZHFA of children in the targeted population. We find higher benefits of the program on the children exposed in-utero and during their first year of life. Additionally, the heterogeneity results suggest that females gain from male children, likely due to their ability to generate higher levels of antibodies. Targeting high-risk populations and populations with lower access to essential health services improved outcomes for rural and Scheduled Castes and Scheduled Tribes populations. These results emphasize the importance of investing in targeted public health initiatives prioritizing equity and access for all populations, regardless of location.

A caveat of our study is that, in our sample, we include some children just after the exposure to a phase is over, potentially underestimating the program's overall impact. Overall, the study highlights the importance of addressing supply-side constraints to improving immunization coverage and suggests that vaccine hesitancy and lack of awareness may not always be the primary barriers to vaccination uptake.

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Table 1: Summary Statistics

	Total	MI District	Non-MI District	Diff.
Outcomes				
ZWFA	-1.57	-1.56	-1.59	-0.02***
ZHFA	-1.48	-1.48	-1.48	0.03***
Fully Vaccinated	0.59	0.57	0.64	0.10***
Not Vaccinated	0.08	0.09	0.06	-0.04***
No. of Tetanus Mother Received	1.93	1.92	1.96	0.08***
Individual Characteristics				
Female	0.48	0.48	0.48	0.00
Child Age (in months)	29.84	29.88	29.68	-0.10
Birth Order	2.19	2.21	2.11	-0.18***
Mother Characteristics				
Height (in cm)	151.60	151.62	151.56	0.29***
Age at Child Birth (in years)	24.31	24.30	24.36	-0.06***
Education				
Uneducated	0.30	0.30	0.29	-0.04***
Primary Completed	0.45	0.44	0.46	0.02***
Secondary Completed	0.19	0.19	0.20	0.03***
Household Characteristics				
Rural	0.72	0.72	0.73	-0.00
Ethnicity				
General	0.20	0.21	0.19	0.00
Other Backward Class (OBC)	0.46	0.46	0.45	0.00
Scheduled Caste	0.23	0.22	0.23	0.02***
Scheduled Tribe	0.11	0.11	0.12	-0.03***
Religion				
Hindu	0.79	0.78	0.82	0.07***
Muslim	0.17	0.17	0.13	-0.04***
Christian	0.02	0.02	0.01	-0.05***
Sikh	0.01	0.01	0.02	0.01***
None or Other Religion	0.02	0.01	0.02	0.01***
Wealth Quintile				
Poor	0.47	0.47	0.47	-0.04***
Middle	0.20	0.20	0.20	0.00**
Rich	0.33	0.33	0.32	0.04***

Notes: Fully Vaccinated: the child has taken one BCG, measles, three DPT, and three polio doses if the child is older than 1 year old. Not Vaccinated: the child has not taken any vaccine in the first year of birth. Summary statistics were constructed using state mother/child sampling weights provided by NFHS-4. Child Age: The age of the child at the time of the survey in months. Age at Child Birth: Age of the mother when the child was born. Rural: The area of residence is rural. Wealth Quintile: Merged poorer and poorest households under the poor category, richer and richest households under the rich, and the middle category is kept unchanged. Summary statistics constructed using state mother/child sampling weights provided by NFHS-4.

Table 2: Impact on children exposed in utero & age 0-24 months

	(1) ZWFA	(2) ZWFA	(3) ZHFA	(4) ZHFA
Only Utero	0.143**	0.158**	0.686***	0.676***
	(0.073)	(0.077)	(0.130)	(0.127)
Only Age 0-24 months	0.126***	0.108***	0.115**	0.067
	(0.035)	(0.037)	(0.045)	(0.053)
Utero & Age 0-24 months	0.319***	0.314***	0.898***	0.869***
	(0.073)	(0.073)	(0.095)	(0.113)
Observations	191820	183000	191820	183000
Controls	No	Yes	No	Yes
District Fixed Effects	Yes	Yes	Yes	Yes
Birth Year Fixed Effects	Yes	Yes	Yes	Yes
District Birth Year F.E.	Yes	Yes	Yes	Yes

Notes: *ZWFA* refers to child's weight for age score. *ZHFA* refers to a child's height for age score. *ZWFA* and *ZHFA* lying in[-6,6]. *Only Utero* takes the value 1 for the children exposed to the program when in-utero, 0 otherwise. *Only Age 0-24 months* takes value one if a child is exposed to the program within 24 months of birth, and 0 otherwise. *Utero & Age 0-24 months* will take the value one if the child is exposed in both utero and within 24 months of birth, 0 otherwise. For a child to be exposed to the program, it is necessary that they were eligible during all four rounds of at least one phase. Controls included are child sex, birth order of the child, mother's height, mother's education, mother's age at childbirth, ethnicity, religion, household wealth index, and area of residence. Standard errors are in parentheses and are clustered at the district level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Impact on children exposed in different stages of childhood

	(1) ZWFA	(2) ZWFA	(3) ZHFA	(4) ZHFA
Only Utero	0.283***	0.314***	0.918***	0.911***
	(0.090)	(0.090)	(0.159)	(0.161)
Only Age 0-12 months	0.267***	0.265***	0.349***	0.304***
	(0.055)	(0.057)	(0.090)	(0.099)
Only Age 13-24 months	0.125***	0.108***	0.114**	0.067
	(0.035)	(0.037)	(0.045)	(0.053)
Utero & Age 0-12 months	0.421***	0.418***	1.052***	1.018***
	(0.085)	(0.081)	(0.115)	(0.125)
Age 0-12 & Age 13-24 months	0.180**	0.156**	0.171*	0.121
	(0.077)	(0.076)	(0.103)	(0.099)
Observations	191820	183000	191820	183000
Controls	No	Yes	No	Yes
District Fixed Effects	Yes	Yes	Yes	Yes
Birth Year Fixed Effects	Yes	Yes	Yes	Yes
District Birth Year F.E.	Yes	Yes	Yes	Yes

Notes: *ZWFA* refers to child's weight for age score. *ZHFA* refers to a child's height for age score. *ZWFA* and *ZHFA* lying in[-6,6]. *Only Utero* takes the value 1 for the children eligible for the program when in-utero, 0 otherwise. *Only Age 0-12 months* takes value one if a child is exposed to the program within 12 months of birth, and 0 otherwise. *Only Age 13-24 months* takes value one if a child is exposed to the program between the age of 13-24 months, and 0 otherwise. *Utero & Age 0-12 months* will take the value one if the child is exposed in both utero and within 12 months of birth, 0 otherwise. *Age 0-12 & Age 13-24 months* will take the value one if the child is exposed in both age 0-12 months and age 13-24 months, 0 otherwise. For a child to be exposed to the program, it is necessary that they were eligible during all four rounds of at least one phase. Controls included are child sex, birth order of the child, mother's height, mother's education, mother's age at childbirth, ethnicity, religion, household wealth index, and area of residence. There were missing observations in *Utero & Age 13-24 months* and *Utero, Age 0-12 months, & Age 13-24 months* Standard errors are in parentheses and are clustered at the district level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Mission Indradhanush Targets

	(1) Mother Received Tetanus	(2) Fully Vaccinated	(3) Not Vaccinated
In-Utero Exposed	0.027***		
	(0.010)		
Age 0-24 months		0.027*	-0.019
		(0.016)	(0.012)
Observations	162173	113068	167108
Controls	Yes	Yes	Yes
District Fixed Effects	Yes	Yes	Yes
Birth Year Fixed Effects	Yes	Yes	Yes
District Birth Year F.E.	Yes	Yes	Yes

Notes: *ZWFA* refers to child's weight for age score. *ZHFA* refers to a child's height for age score. *ZWFA* and *ZHFA* lying in[-6,6]. *Only Utero* takes the value 1 for the children eligible for the program when in-utero, 0 otherwise. *Only Age 0-24 months* takes value one if a child is exposed to the program within 24 months of birth, and 0 otherwise. *Utero & Age 0-24 months* will take the value one if the child is exposed in both utero and within 24 months of birth, 0 otherwise. Controls included are child sex, birth order of the child, mother's height, mother's education, mother's age at childbirth, ethnicity, religion, household wealth index, and area of residence. Standard errors are in parentheses and are clustered at the district level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Impact of exposure to children in age 0-12 months on children's vaccination status of different vaccines

	(1) BCG	(2) DPT 1	(3) DPT 2	(4) DPT 3	(5) All DPT	(6) Hep-B 0	(7) Hep-B 1	(8) Hep-B 2	(9) Hep-B 3	(10) All Hep-B	(11) Polio 0	(12) Polio 1	(13) Polio 2	(14) Polio 3	(15) All Polio	(16) Measles
Age 0-24 months	0.029***	0.060***	0.079***	0.098***	0.099***	0.010	0.085***	0.085***	0.084***	0.080***	0.023*	0.034***	0.079***	0.081***	0.079***	0.034**
	(0.010)	(0.014)	(0.016)	(0.016)	(0.016)	(0.018)	(0.015)	(0.015)	(0.014)	(0.014)	(0.012)	(0.010)	(0.012)	(0.013)	(0.013)	(0.013)
Observations	201114	196659	193357	190628	190628	198018	193891	191048	188341	188341	201140	196992	194132	191400	191400	175980
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Birth Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: *ZWFA* refers to child's weight for age score. *ZHFA* refers to a child's height for age score. *ZWFA* and *ZHFA* lying in [-6,6]. *BCG*: child completed the Bacillus Calmette-Guèrin (BCG) vaccination given at birth. *DPT 1*, *DPT 2*, and *DPT 3*: The child was given the first, second, and third dose of diphtheria, pertussis, and tetanus (DPT) vaccination after completing 6, 10, and 14 weeks respectively. *All DPT Doses*: the child was given all three DPT vaccines. *Polio 0*: The child was given a polio birth dose vaccine. *Polio 1*, *Polio 2*, and *Polio*: The child was given the first, second, and third dose of polio vaccination after completing 6, 10, and 14 weeks respectively. *Polio-All Doses*: the child has taken all three doses of the polio vaccine (excluding the birth dose). *Hep-B 0*: The child has taken the hepatitis-B vaccine at birth. *Hep-B 1*, *Hep-B 2*, and *Hep-B 3*: The child was given the first, second, and third dose of the Hepatitis-B vaccine after completing 6, 10, and 14 weeks respectively. *All Hep-B Doses*: The child has taken all three Hepatitis-B vaccine doses (excluding birth dose). *Measles*: The child has completed vaccination against measles. *Fully Vaccinated*: the child has taken one BCG, one Measles, three DPT, and three polio doses (excluding the birth dose) if the child is 12 months or older. *Partially Vaccinated*: the child has missed any vaccination doses if the child is 12 months or older. *Not Vaccinated*: the child has not taken any vaccine in the first year of birth. For the first dose of DPT, Polio, and Hepatitis B, children older than 2 months are included. Similarly, children older than 3 months are included in the second dose. Only children older than four months at the interview are included for *DPT 3*, *All DPT Doses*,*Polio 3*, *All Polio Doses*, *Hep-B 3* and *All Hep-B Doses* vaccines. Similarly, for measles, children older than nine months are considered. And for fully vaccinated, partially vaccinated, and not vaccinated children older than 12 months are included. Controls included are child sex, birth order of the child, mother's height, mother's education, mother's age at childbirth, ethnicity, religion, household wealth index, and area of residence. Standard errors are in parentheses and are clustered at the district level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.