Does Paternal Exposure to an Industrial Disaster affect Early Life Health Investments of Children?

Sarthak Agarwal* Somdeep Chatterjee† Shreyasee Das‡

First Draft: November 30, 2023

Abstract

Health-related investments during infancy and childhood, such as breastfeeding, can play a major role in human capital development. Medical literature suggests parents' health is a crucial determinant of successful breastfeeding and infants' ability to latch on and accept breastfeeding. While direct exposure to environmental hazards (industrial disasters) has affected individuals' respiratory, reproductive, and neurological health, little is known about the intergenerational effects of these health hazards. In this paper, we exploit how men's exposure to a catastrophic industrial disaster in India, the Bhopal Gas Disaster, affected their children's health. Using the NFHS-4 data, our results indicate a significant decrease in breastfeeding, including a reduced likelihood of being breastfed within an hour of birth and for three months after birth. We postulate the underlying mechanism to be the compromised health of the fathers and supplement these results with the health of the mothers. Our paper is one of the very few that contribute to the scant literature on the long-lasting intergenerational effects of exposure to industrial disasters.

JEL: D62, I15, I18, O15

Keywords: Breastfeeding, industrial accident, Bhopal Gas Disaster, Intergenerational Health

*Department of Economics, Indian Institute of Management Lucknow; IIM Road, Prabandh Nagar, Lucknow 226013, Uttar Pradesh, India. Email: phd22003@iiml.ac.in

†Economics Group, Indian Institute of Management Calcutta, M-105, New Academic Block, IIM Calcutta Campus, Diamond Harbor Road, Joka, Kolkata 700104, India. Email: somdeep@iimcal.ac.in

‡Department of Economics, Temple University, Philadelphia, PA, USA 19147, Email: shreyasee.das@temple.edu

1 Introduction

Investments in infancy and childhood are vital for an individual's long-term human capital development and resulting economic conditions. These are often also impacted through intergenerational transmission of parents' human capital (Almond, Currie, & Duque, 2018; Almond & Currie, 2011a, 2011b; Black & Devereux, 2011; Cunha, Heckman, & Schennach, 2010; Cunha & Heckman, 2007; Case, Lubotsky, & Paxson, 2002). Among many, breastfeeding, including the duration of breastfeeding, plays a crucial role in early childhood development. The World Health Organization (WHO) recommends initiating breastfeeding within the first hour of birth and that a child be exclusively breastfed for the first 6 months, after which it should be supplemented with other sources of nutrition.[1,2] Optimal breastfeeding is associated with lower infant and child mortality (Arthi & Schneider, 2021; Keskin, Shastry, & Willis, 2017), lower probability of gastro-intestinal and dermatological infections (Kramer et al., 2001), as well as better cognitive ability in early and later life (Fitzsimons & Vera-Hernández, 2022; Krol & Grossmann, 2018; Rothstein, 2013; Kramer et al., 2008).

Additionally, the *duration of breastfeeding* before weaning the child is an important marker for optimal breastfeeding. Jayachandran and Kuziemko (2011) find future desired fertility a reason for early weaning, an effect larger for girls in families with unrealized son-preference. Other factors include women's education levels (Barrera, 1990; Demir, Ghosh, & Liu, 2020); parental leave policies in the labour market (Jia, Dong, & Song, 2018; Kottwitz, Oppermann, & Spiess, 2016); social perceptions regarding breastfeeding practices (Bicchieri, Das, Gant, & Sander, 2022) and availability of breast-milk substitutes such as baby-formula (Demir et al., 2020; Yue et al., 2023).

[1] More details on WHO guidance on breastfeeding can be found on the following link: `www.who.int/news-room/fact-sheets/detail/infant-and-young-child-feeding`

[2] In May 2012, many countries endorsed the *"Comprehensive implementation plan on maternal, infant and young child nutrition"*, implemented and monitored by WHO, targeting achievement of 50 percent exclusive breastfeeding among 0-6 months old infants by 2025. In 2021, this number was estimated at around 44 percent, leaving significant ground to be covered for universal coverage. Moreover, globally, among children under 5 years, over 820,000 deaths could be prevented annually by optimal breastfeeding in the first two years of life (Victora et al., 2016). Thus, while breastfeeding has been extensively studied as a mechanism leading to better socio-economic and health outcomes, the dismal progress in achieving optimal rates in breastfeeding warrants further investigation.

Another potential determinant of breastfeeding duration is the health of the parents as well as the infants. While literature has heavily focused on the breastfeeding outcomes through the channel of mothers, some studies have highlighted the importance of accounting for paternal health as a factor in children's health outcomes(Kotelchuck, 2022; Azuine & Singh, 2019). In this study, we explore how breastfeeding outcomes are affected when parents are exposed to an exogenous shock, such as an industrial disaster, during their childhood (0-13 years of age). In 1984, a gas leak at the chemical pesticide plant operated by Union Carbide India Limited (UCIL) in the district of Bhopal in Madhya Pradesh, India, exposed around half a million residents to toxic levels of Methyl Isocyanate gas (Lal, 1996). The *Bhopal Gas Disaster (BGD)*, India's deadliest industrial accident to date, had immediate and long-term health consequences among the residents of Bhopal. Studies have documented that women suffered from spontaneous abortions, stillbirths, and other reproductive irregularities (Ganguly, Mandal, & Kadam, 2018; P. Mishra et al., 2009; Cullinan, Acquilla, & Dhara, 1996; Sathyamala, 1996). Men also suffered from lower education levels, and a higher probability of being disabled, and unemployed due to exposure to the BGD(McCord, Bharadwaj, Kaushik, McDougal, & Raj, 2021; Das & Dasgupta, 2022). Our study explores parents', specifically fathers', exposure to the BGD on the duration of breastfeeding on their children. We would like to note that this study does not diminish the importance of maternal health on infants' health. We rather attempt to establish the complementarity of the role of paternal health on infants' health through the lens of exposure to an industrial disaster.

Using a nationally representative dataset, National Family Health Survey (NFHS) 2015-16, we devise an empirical strategy exploiting the interaction of two variations. Our first source of variation is based on fathers' exposure to the BGD: we compare children of fathers born before BGD i.e. up to 1984 (directly exposed to the gas), to those born after BGD i.e. 1985 onwards (refer to Figure 1). Second, we exploit spatial variation by comparing the district of Bhopal (where BGD occurred) to the rest of the districts in the state of Madhya Pradesh. Our empirical strategy is similar to that of Caruso (2017), who estimated the effects of natural disasters on human capital development in Latin America.

Our main findings suggest that children of fathers exposed to the BGD were breastfed for approximately 2.4 fewer months than those not exposed. Additionally, children are 5 percentage points less likely to be breastfed within one hour of birth, and 2 percentage points less likely to be breastfed for the first three months. We postulate that the main driver of these results is the lower health status of fathers as a result of the gas leak and confirm that this cohort was more likely to suffer from respiratory issues and have lower anthropometric health measures. Our results are robust to a battery of tests addressing issues such as age and gender-related heterogeneity in breastfeeding, in-utero effects, placebo effects, controlling for parents' health and education, and others. We supplement our main estimation by examining the intergenerational transmission through the mothers' channel, and our results are robust to this alternate strategy.[3]

Our study makes some important contributions to the literature on the socioeconomic effects of industrial disasters. First, we contribute to a growing conversation on intergenerational transmission of health burdens, focusing on the impact of parents' health status on that of their children's (Bevis & Villa, 2022; BjÖrkegren, Lindahl, Palme, & Simeonova, 2019; Lundborg, Nordin, & Rooth, 2018; Bharadwaj, Johnsen, & Løken, 2014; Bhalotra & Rawlings, 2013). Second, we add to the relatively scant literature on intergenerational consequences in the context of natural, industrial, and human-made disasters. While studies have found that exposure to wars, nuclear testing, nuclear accidents, pollution, and other similar events can have long-term negative impacts on the mental health, cognitive abilities, and education of children of those affected by these disasters (Kiliç, Özgüven, and Sayil (2003), Elsner and Wozny(2023), Colmer and Voorheis(2020), Black, Bütikofer, Devereux, and Salvanes,(2019), Caruso (2017)), the intergenerational impact of these disasters, espe-

[3]We note that since we focus on the intergenerational transmission of health effects through the channel of the father, we do not focus on the nutritional content and quality of breast milk, which depends on the mother's health and care during pregnancy, among other factors.

cially industrial disasters, are understudied. Our paper provides evidence that the negative health shock on parents affected by spills over to their children as well.

Lastly, our study presents insights into the long-run consequences of the BGD and complements recent literature that examines marriage market outcomes, other health-related outcomes, and economic outcomes due to exposure to the gas leak (Das & Dasgupta, 2022; McCord et al., 2021; De et al., 2020; Ganguly et al., 2018; Ganguly, Mandal, & Kadam, 2017). The findings have important implications for public policy design, particularly in the domain of human capital development and industrial disasters. Our findings provide insight for policy decisions regarding feeding practices and supplemental nutrition for children taking into account their parents' health as a result of their exposure to dangerous industrial disasters. While coping strategies for natural disasters are in place, these may not be well-defined for industrial disasters especially in places with weak legal enforcement mechanisms. Additionally, the severe adverse effects of industrial disasters are likely to last longer than those of natural disasters. Accounting for the environmental and long-run spillover effects on future generations is important for appropriate compensation for individuals who continue to suffer.

The rest of this study is organized as follows - Section 2 lays out details of the Bhopal Gas Disaster and related antecedent literature on its consequences for health and socio-economic outcomes. Section 3 outlines the data and empirical strategy. Results, mechanisms, and heterogeneous effects are presented in Sections 4 and 5, respectively. Section 6 presents robustness analysis and Section 7 concludes.

2 The Bhopal Gas Disaster (BGD)

On December 3, 1984, at approximately 1:00 AM Indian Standard Time, a malfunction at a chemical pesticide plant in Bhopal, Madhya Pradesh, operated by Union Carbide India Limited (UCIL), lead to toxic gas leaks into the atmosphere. Over 500000 people were exposed to the chemical, Methyl Isocyanate (MIC), an intermediate product used in the production of carbamate pesticides. A few months preceding the leak, the plant was operating only at one-fourth capacity and was planned to be shut down due to a slowdown in pesticide demand following farmer distress resulting from crop failures and famine in India (Shrivastava, 1987). Until arrangements to dismantle the plant were completed, it continued to operate with sub-standard safety equipment and procedures (Eckerman, 2005). The leak is said to have been triggered by the non-functioning of the safety device responsible for neutralizing toxic discharge from the MIC system (Shrivastava, 1987).

Within hours of the leak, 3800 fatalities were reported in the vicinity of the UCIL plant (MacKenzie, 2002; Fortun, 2001). The death toll within the first few days climbed to 10,000, and an additional 15,000 to 20,000 deaths over the next two decades were attributed to direct and indirect exposure to the gas leak (Sharma, 2005). Individuals reported ocular anomalies such as eye irritation and cataracts (Cullinan et al., 1996; Andersson et al., 1990), long-term chronic respiratory morbidity (De et al., 2020; Ganguly et al., 2018) and other respiratory symptoms (Dhara & Dhara, 2002; Cullinan et al., 1996) and were more likely to be afflicted with cancer (Ganguly et al., 2017; P. Mishra, Raghuram, Bunkar, Bhargava, & Khare, 2015; Malla, Senthilkumar, Sharma, & Ganesh, 2011). Women suffered from adverse reproductive health and fertility outcomes, including higher incidence of miscarriages, stillbirths and neonatal mortality, menstrual abnormalities and premature menopause (Ganguly et al., 2018; P. Mishra et al., 2009; Cullinan et al., 1996; P. Mishra et al., 2009; Sathyamala, 1996). Bhopal's surviving population also experienced neurological symptoms and mental health issues such as exhaustion and anxiety (Cullinan et al., 1996). Post-traumatic stress from witnessing deaths and disease led to depression and dejection among children (Irani & Mahashur, 1986). No systematic effort was made to alleviate the psychological stress caused due to the gas leak (Basu & Murthy, 2003).

Additionally, these negative health effects were exacerbated among those in-utero at the time of the leak. Male children who were in-utero at the time of BGD had lower anthropometric measures (Ranjan et al., 2003) and higher stunting (Sarangi et al., 2010). In-utero cohorts experienced higher infant mortality in the five years following the gas leak (Sarangi et al., 2010) and have a higher likelihood of being vulnerable to cancer as adults (McCord et al., 2021). Additionally, residents in the region today continue to be subjected to groundwater contaminated with toxins from the gas leak (B. Mishra & Banerjee, 2014) which has led to gastrointestinal issues (Sourav, 2019).

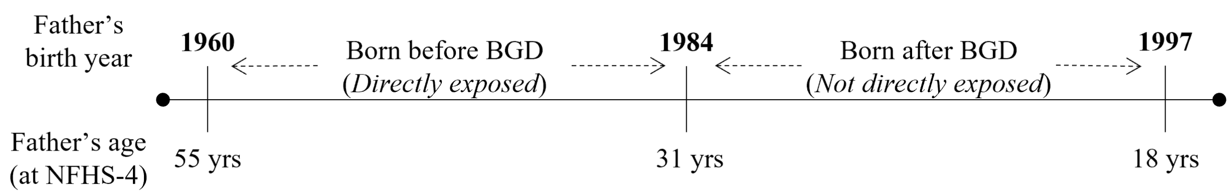
Forty years since the disaster, hitherto unknown adverse consequences on human health continue to be uncovered. In fact, there is a very thin strand of literature covering the intergenerational consequences of BGD. Our study attempts to substantiate the literature by presenting evidence of how ill-effects of direct exposure to BGD were transmitted to the next generation.

3 Methodology

3.1 Empirical Strategy

To empirically estimate the effects of BGD, we exploit two plausibly exogenous variations - the location of the event and the birth cohort of the father of a child. Our empirical framework follows the approach similar to Caruso (2017) who exploits spatial and cohort variation to estimate the long-term intergenerational effects of natural disasters in Latin American countries over a hundred year time span. In our study, we first exploit the geographic variation in exposure to the gas leak - the district of Bhopal, the site of the gas leak, is our treated district, whereas the rest of the state of Madhya Pradesh serves as our control group. Second, we compare children of fathers prior to the BGD, up to 1984 (treated group), with those whose fathers were born after BGD, 1985 onwards. Figure 1 provides a visual representation of our cohort variation. We argue that fathers born before the gas leak were directly exposed to the disaster and may be the vessel of transmission of negative health effects to their children compared to those fathers who were born after the disaster.

Figure 1: ***Father cohorts based on year of birth***



This empirical strategy can be expressed as the following reduced-form regression specification for child i of father f belonging to district d and birth-year t :

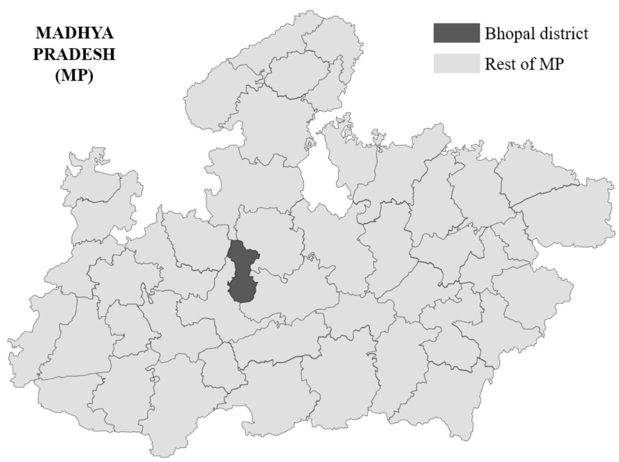
$$Y_{ifdt} = \alpha_0 + \beta_1 \cdot (Bhopal_d * BornBeforeBGD_{ft}) + \beta_2 \cdot X_{ifdt} + \delta_d + \gamma_{ft} + \pi_{it} + \epsilon_{ifdt} \quad (1)$$

where Y_{ifdt} is the outcome variable of interest, breastfeeding duration (months) for the child. $Bhopal_d$ is a dummy variable (=1) indicating whether district of residence is the BGD affected Bhopal district. $BornBeforeBGD_{ft}$ is a dummy variable (=1) for whether the father f of child i was born before BGD (1960-84), and thus directly exposed to the gas leak. The coefficient of interest is β_1, which gives us the differential impact of fathers' exposure to the Bhopal Gas Disaster on their children's breastfeeding outcomes. X_{ifdt} is a vector of control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste (=1 for scheduled), and quintiles of wealth index of the household. District of residence fixed effects (δ_d) capture time-invariant district characteristics such as regional traditions and socio-economic conditions. δ_d also absorbs the $Bhopal_d$ dummy. γ_{ft} and π_{it} are fixed effects for birth-year of the father and the child, respectively, and control for any age-related effects that are similar across districts. γ_{ft} absorbs $BornBeforeBGD_{ft}$ dummy. Standard errors are clustered at the district level.

3.2 Data

We use the 2015-16 round of the National Family Health Survey (NFHS-4), a nationally representative survey that captures detailed information on the demographics and health status of surveyed individuals and covers over 600000 households across the country. We restrict our sample to the state of Madhya Pradesh (MP), where BGD occurred. Figure 2 shows a graphical representation of MP and its districts, with the shaded region highlighting the district of Bhopal where BGD took place in 1984.

Figure 2: ***Districts of Madhya Pradesh***



Our primary outcome variable of interest is breastfeeding outcomes of the child. Since the unit of analysis in our study is the child, we use data from the children's survey in NFHS-4 that collects information on the child's birth year, gender and breastfeeding outcomes, such as the duration of breastfeeding and the time elapsed between birth and first breastfeeding. Specifically, we check whether a child born to a parent who was likely to be in Bhopal at the time of BGD (1984) is breastfeed less than their counterparts. To distinguish whether a parent was exposed to the gas leak or not, we ideally need two sources of identification. First, we need the parents' district of birth, thereby allowing us to place a person in or out of Bhopal district at the time of BGD. However, since the NFHS only captures the place of residence and does not record the place of birth, we rely on the former to identify the father's district of exposure.[4] Evidence suggests that migration after BGD was relatively low at less than 10 percent (Dhara & Dhara, 2002), thus lending confidence in this identification.[5] Second, we need the father's year of birth to identify the cohort that was directly exposed vs. indirectly exposed to the BGD. While the survey does not capture the father's year of birth, we are able to extract information on the age of the father from the household survey data and calculate the father's year of birth. Lastly, we limit our analysis to the father cohort aged 18-55 years (born 1960-97) at the time of the survey.

4 Results

In this section, we present the results from the empirical analysis described above. Our primary outcome of interest is breastfeeding duration (in months). Table 1 presents the estimates of the coefficient β_1 from equation 1. Our preferred specification is in Column 6 which includes the full set of controls, and fixed effects for the district, and the year of birth of the father and the child. We find that children of fathers who were directly exposed to the gas leak are 2.5 months less likely to be breastfed than the reference group. The effect size translates to around 14 % when compared to the mean breastfeeding duration in Madhya Pradesh of 16.6 months. The coefficients are statistically significant at the 1% level.

One concern with our sample is that the cohort of fathers directly exposed to the BGD is much older than the reference cohort that was born after the disaster. Given that fertility and parents' age are correlated, one might argue that our results are driven by some heterogeneity in the fertility characteristics of younger and older fathers. Although we control for any such differences with fixed effects for father's birth year, we also re-run regression equation 1 for a sub-sample of father birth cohorts trimmed at both ends of BGD. Results

[4] Moreover, since there are high chances of post-marriage migration among women in India (Khalil & Mookerjee, 2019), we cannot accurately identify the affected cohort of children through their mothers. Thus, we rely on the father cohort for our empirical analysis since men are less likely to have migrated out of the district. Nevertheless, we run robustness checks through the channel of the mother and present these results in Section 6.3

[5] Additionally, it is highly unlikely that there will be inward migration to the district of Bhopal after the disaster, something we test for in Section 6.2.

Table 1: ***Estimates of the impact of Bhopal Gas Disaster on children's breastfeeding outcomes***

	(1)	(2)	(3)	(4)	(5)	(6)
$Bhopal_d * BornBeforeBGD_{ft}$	-3.997***	-3.885***	-2.893***	-2.573***	-2.386***	-2.382***
	(0.261)	(0.268)	(0.275)	(0.203)	(0.224)	(0.218)
Observations	14,783	14,419	14,419	14,419	14,419	14,419
Dependent mean			— 16.561 —			
Controls	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Father birth year fixed effects	No	No	**Yes**	No	**Yes**	**Yes**
Child birth year fixed effects	No	No	No	**Yes**	**Yes**	**Yes**
District fixed effects	No	No	No	No	No	**Yes**

Notes: All columns report results from regressions using NFHS-4 child data. The outcome variable, *Breastfeeding duration (months)*, in columns (1) through (6), measures the total number of months a child was breastfed by their mother. Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. Each column reports results from regressions using different combinations of fixed effects for the father's and child's birth years and for the district of residence, and control variables indicated by 'Yes' or 'No' at the end of the table. Control variables include - the child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at the district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

are presented in Table 2. In Column (1), the sub-sample includes the 1975-94 birth cohort representing a 20 year period while, in Column (2), we further trim the birth cohort to 1980-89 representing a 10 year period. This ensures that the cohorts are spread out evenly on either side of the disaster in 1984. Our estimates are similar to our main results. Thus, we are reasonably confident that father's age is not confounding the results.

In Table 3, we present two additional results on breastfeeding outcomes using regression equation 1. First, in Column (1), we show the point estimates for whether the child received breastfeeding within 1 hour of birth. Second, in Column (2), we present estimates for whether the child was breastfed consistently for at least 3 months. The results show that children of directly affected fathers cohort are 5 percentage points less likely to be breastfed within the first hour after birth and 2 percentage points less likely to be breastfed consistently for at least 3 months after birth.

Table 2: *Results based on trimmed father birth cohort*

	Father's birth cohort	
	1975-94	1980-89
	(1)	(2)
$Bhopal_d * BornBeforeBGD_{ft}$	-2.292***	-2.364***
	(0.215)	(0.236)
Observations	13,547	9,023
Dependent mean	16.490	17.225

Notes: All columns report results from regressions using NFHS-4 child data. The outcome variable, *Breastfeeding duration (months)*, in columns (1) and (2), measures the total number of months for which a child was breastfed by her mother. Results, the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$, in columns (1) and (2) are based on the sub-samples of father's birth cohorts of 1975-94 and 1980-89, respectively. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

5 Mechanisms and Heterogeneous effects

In the previous section, we presented evidence of a decrease in breastfeeding and the duration of the breastfeeding among children of fathers who were directly exposed to the BGD. We posit that the main underlying channel for these results is compromised paternal health which then negatively impacts children's health. Below, we explore underlying mechanisms, such as paternal health, to evaluate the pathways of the intergenerational transmission of the effects of the toxic leak.

To conduct this exercise, we use the men's survey from NFHS-4 which includes information on the respondent's anthropometric measures, and whether they were afflicted with any respiratory issues, such as *asthma*. [6] Using these health indicators as outcome variables, we run regressions with the same empirical strategy and independent variables as in equation 1, except for the child's gender and birth year fixed effects. Standard errors are clustered at district level.

[6] According to WHO, "asthma is a chronic lung disease affecting people of all ages. It is caused by inflammation and muscle tightening around the airways, which makes it harder to breathe."

Table 3: ***Estimates of the impact of Bhopal Gas Disaster on additional breastfeeding outcomes***

	Breastfed within 1 hour of birth (1)	Breastfed for at least 3 months (2)
$Bhopal_d * BornBeforeBGD_{ft}$	-0.050***	-0.020***
	(0.009)	(0.004)
Observations	14,435	13,351
Dependent mean	0.689	0.965
Controls	Yes	Yes
Father birth year fixed effects	Yes	Yes
Child birth year fixed effects	Yes	Yes
District fixed effects	Yes	Yes

Notes: All columns report results from regressions using NFHS-4 child data. *Breastfed within 1 hour of birth*, in column (1), is a dummy variable for whether a child was breastfed by her mother within 1 hour of birth. *Breastfed for at least 3 months*, in column (2), is a dummy variable which measures whether a child was breastfed by her mother for at least 3 months. Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

Table 4 presents the results from this analysis. Fathers directly affected the toxic gas leak are 1 percentage point more likely to exhibit *asthma* compared to the reference cohort. We use *arm circumference* (MUAC) to examine the physical health and nutritional status of the father.[7] The coefficient is -0.28 centimeters which indicates poorer nutrition health among the affected father cohort. These results suggest that fathers' compromised health could be the main explanation for the intergenerational transmission of adverse health outcomes.

In Table 1, we present results by splitting our sample based on the gender of children to examine if there exists any heterogeneity in outcomes. We find large differences in effect sizes between male and female children with most of the effect being on females (4.5 months) with a smaller point estimate for males (0.5 months). This is not surprising as literature has documented evidence suggesting that girls are weaned earlier than boys due to parents' son preference which increases the likelihood of the mother becoming pregnant again while

[7] Mramba et al. (2017) and Roy and Sekher (2022) find that Mid Upper Arm Circumference (MUAC) is a reasonably accurate indicator of nutritional status

Table 4: ***Father's health outcomes***

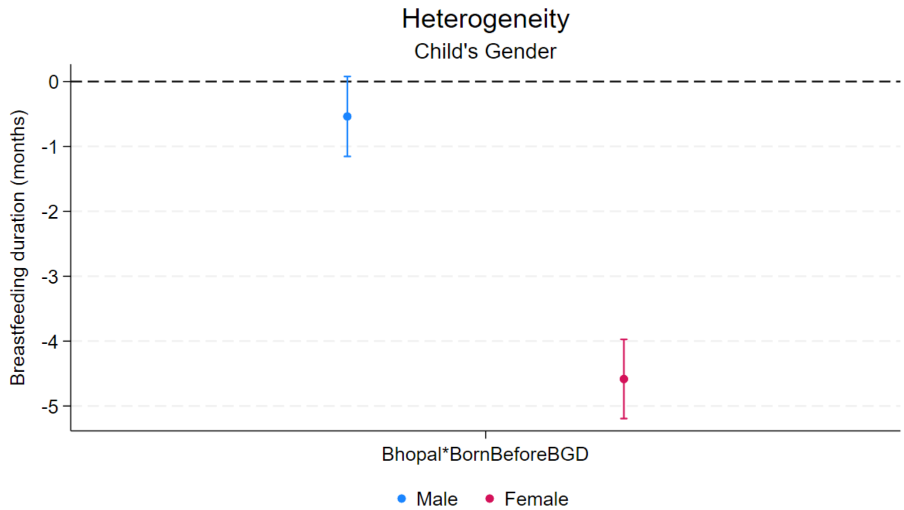
	Asthma (1)	Arm circumference (2)
$Bhopal_d * BornBeforeBGD_t$	0.009*** (0.003)	-0.279*** (0.067)
Observations	8990	8806
Dependent mean	0.012	26.055
Controls	Yes	Yes
Birth year fixed effects	Yes	Yes
District fixed effects	Yes	Yes

Notes: All columns report results from regressions using NFHS-4 men data. *Asthma*, in column (1), is a dummy variable for whether the child's father reported suffering from asthma. *Arm circumference*, in column (2), is an anthropometric health indicator which measures the mid-upper arm circumference in centimeters (cm). Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for birth year and for district of residence and also the following control variables - age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

the girl child is still very young and of breastfeeding age (Jayachandran & Kuziemko, 2011; Barcellos, Carvalho, & Lleras-Muney, 2014; Aurino, 2017).

Additionally, we present variation in our results based on the father's age at exposure at the time of the disaster. De et al.(2020) investigate trends in long-term respiratory morbidity across various age-cohorts exposed to the BGD and found that older cohorts exhibited more extreme respiratory symptoms for a longer duration than their younger counterparts. Following De et al.(2020), we divide our sample into three age-cohorts- 0-6, 7-12, and 13-18. Our results suggest a greater negative impact on children born to fathers who were older at the time of the exposure, i.e., they were breastfed less than those whose fathers were relatively younger at the time of the disaster. These results children born to fathers who were older at the time of exposure exhibit more severe impacts (were breastfed lesser) as compared to those born to fathers who were exposed at a relatively younger age.

Figure 3: ***Heterogeneity in effects by gender of the child***



Note: In figure 3, we plot heterogeneity in effect size by the child's gender. Coefficients β_1 of $Bhopal_d * BornBeforeBGD_{ft}$ along with respective 95% confidence intervals for *Breastfeeding duration (months)* are on the vertical axis. The horizontal dotted line indicates zero effect i.e. $\beta_1 = 0$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors are clustered at the district level.

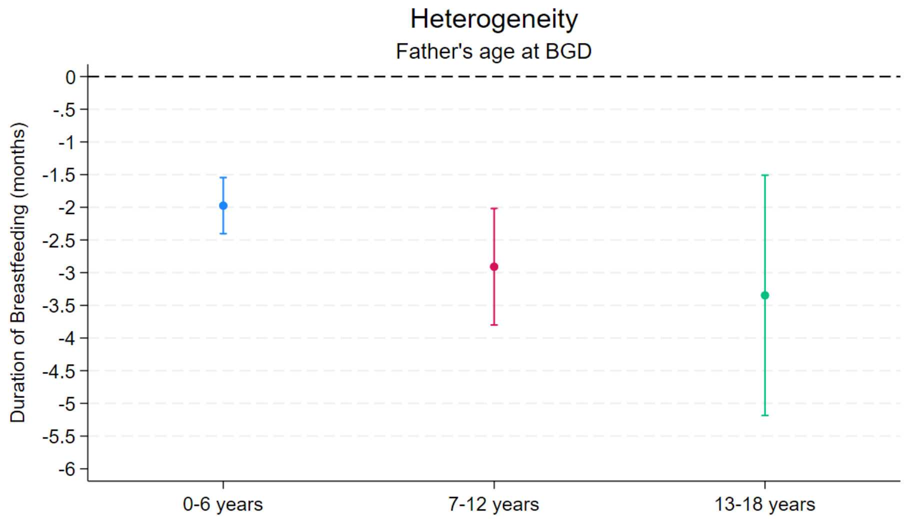
6 Robustness

In this section, we present results from robustness exercises to verify the reliability of our estimates which show that children of fathers directly exposed to the Bhopal Gas Disaster, by virtue of being alive and in Bhopal at the time of the gas leak, have adverse breastfeeding outcomes.

6.1 Falsification

In out empirical strategy, we exploit the timing of the father's birth to identify the intergenerational effects of the *Bhopal Gas Disaster*. We compare the outcomes of children born to the cohort of men born prior to 1984 to those whose fathers were born after 1984. Our assumption is that the post BGD born father-cohort was not present at the time of the leak and, hence, could not have been directly exposed. Thus, children born to this cohort should not exhibit the same adverse breastfeeding outcomes than those born to the pre-BGD cohort do. To test the validity of this assumption, we conduct the following falsification test. Using

Figure 4: ***Heterogeneity in effects (by father's age at exposure)***



Note: In figure 4, we plot heterogeneity in effect size by the father's age at time of BGD. Coefficients β_1 of $Bhopal_d * BornBeforeBGD_{ft}$ along with respective 95% confidence intervals for *Breastfeeding duration (months)* are on the vertical axis. The horizontal dotted line indicates zero effect i.e. $\beta_1 = 0$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors are clustered at the district level.

the cohort born in 1991-92 as the reference group, we create dummies for birth-cohorts in 2-year blocks such that the dummy takes value 1 for the fathers born in that 2-year block, and 0 for fathers born in the 1991-92 block. For instance, for the 1977-78 cohort, the dummy takes a value 1 for fathers born in 1977 or 1978, and 0 for those born in 1991 or 1992. We run regressions using these dummies in place of $BornBeforeBGD_{ft}$ in regression equation 1. The outcome variable is *Breastfeeding duration (months)*. Coefficients β_1 from these regressions along with 90% confidence intervals are plotted in Figure 5. Visually, we can see that the estimates for father-cohorts born before the cut-off (BGD) are negative and statistically significant, in line with our main results reported in Table 1, whereas, the coefficients for father-cohorts born after the cut-off are statistically indistinguishable from zero. Therefore, we have reasonable confidence that our empirical strategy is not picking the effect of some other temporal variation other than BGD.

Figure 5: ***Falsification : Breastfeeding duration (months)***

Note: In this figure, the results from our event study are presented. The reference cohort is that of children whose fathers were born in 1991-92. For instance, the plot for 1983-84 is from a regression with $BornBeforeBGD_{ft}$ taking value 0 if the father belongs to the reference cohort i.e. was born in 1991-92, and 1 if born in 1983-84. Father's birth years are plotted on the horizontal axis. Coefficients β_1 from the regressions for *Breastfeeding duration (months)* are on the vertical axis represented by the colored dots and the respective colored vertical line emerging upwards and downwards from the dots are the upper and lower bounds, respectively, of the 95% confidence interval. The red colored horizontal line indicates zero effect i.e. $\beta_1 = 0$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors are clustered at the district level.

6.2 Excluding Bhopal's bordering districts

One concern is that a shock like BGD could have nudged the then residents of Bhopal to migrate out of the district. Even though empirical evidence to the contrary exists (Dhara & Dhara, 2002), the concern regarding migration is still non-trivial. Additionally, the direction of the migration is likely to be out of Bhopal to its neighboring areas, rather than inward migration into Bhopal (Das & Dasgupta, 2022). To test this, we run regression equation 1 by excluding districts that share their administrative borders with Bhopal.[8] Estimates from this exercise (Table 5) are similar to our main results (Tables 1 & 3) indicating that migration is, potentially, not a big concern in our study.

[8]There are five such districts - Rajgarh, Vidisha, Sehore, Raisen, and Harda.

Table 5: ***Estimates after excluding Bhopal's bordering districts***

	Breastfeeding duration (months) (1)	Breastfed within 1 hr of birth (2)	Breastfed for at least 3 months (3)
$Bhopal_d * BornBeforeBGD_{ft}$	-2.411***	-0.051***	-0.018***
	(0.235)	(0.010)	(0.004)
Observations	13,130	13,145	12,165
Dependent mean	16.594	0.687	0.965

Notes: All columns report results from regressions using NFHS-4 child data. *Breastfeeding duration (months)*, in column (1), measures the total number of months for which a child was breastfed by her mother. *Breastfed within 1 hr of birth*, in column (2), is a dummy variable for whether a child was breastfed by her mother within 1 hour of birth. *Breastfed for at least 3 months*, in column (3), is a dummy variable which measures whether a child was breastfed by her mother for at least 3 months. Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

6.3 Alternative empirical strategy - Mother birth cohorts

Another potential issue with our empirical strategy could be the use of father-cohorts for estimating inter-generational effects. By and large, the effects on the next generation have been studied through the maternal channel. However, as discussed earlier, due to high post-marriage migration of women to their husband's place of residence, and lack of data on place of birth, an identification strategy based on mother's cohort may not be ideal. However, as a robustness test, we present estimates from an alternative empirical strategy using mother's birth-cohorts to identify affected child-cohorts. We follow the same pattern to identify mothers' cohorts as that of the fathers. In equation 1, the dummy $BornBeforeBGD_{ft}$ takes value 1 for children of mothers born up to 1984 (BGD year), and 0 for post-BGD birth cohorts. All controls and fixed effects remain the same as in equation 1, and we replace fathers' birth year fixed effects with that of mother's birth year. Results (Table 6) suggest adverse breastfeeding outcomes among children of potentially exposed mothers, similar to the estimates from our original empirical strategy using father-cohorts.

Table 6: *Estimates based on Mother birth cohort*

	Breastfeeding duration (months) (1)	Breastfed within 1 hr of birth (2)	Breastfed for at least 3 months (3)
$Bhopal_d * BornBeforeBGD_{ft}$	-3.888***	-0.044***	-0.033***
	(0.305)	(0.012)	(0.005)
Observations	14,419	14,435	13,351
Dependent mean	16.561	0.689	0.965

Notes: All columns report results from regressions using NFHS-4 child data. *Breastfeeding duration (months)*, in column (1), measures the total number of months for which a child was breastfed by her mother. *Breastfed within 1 hr of birth*, in column (2), is a dummy variable for whether a child was breastfed by her mother within 1 hour of birth. *Breastfed for at least 3 months*, in column (3), is a dummy variable which measures whether a child was breastfed by her mother for at least 3 months. Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for mother's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

6.4 Additional controls

We include additional controls to the ones specified in equation 1 to verify that our estimates are robust to these new control variables. First, we control for the mother's health indicated by Body Mass Index (BMI).[9] Since our empirical strategy is based on transmission of health effects through the father, controlling for mother's health lends more credibility to our proposed channel - father's health. Second, we control for the educational level of both mother as well as father of a child since parents' education, especially mother's education, is positively correlated with breastfeeding duration (CDC, 2020). Finally, we include fixed effects for birth order of the child. Jayachandran and Kuziemko (2011) find that birth order of a child also impacts the duration of breastfeeding. Higher order children are likely to be breastfed for a longer duration as parents' fertility preferences are closer to being met and there is no hurry for the mother to wean the child to try for another child. We present these results in Table 7 and find results similar to those presented in Table 1.

[9]For information on Body Mass Index (BMI), please refer the following website - US Centers for Disease Control and Prevention (CDC)

Table 7: *Estimates after including additional controls*

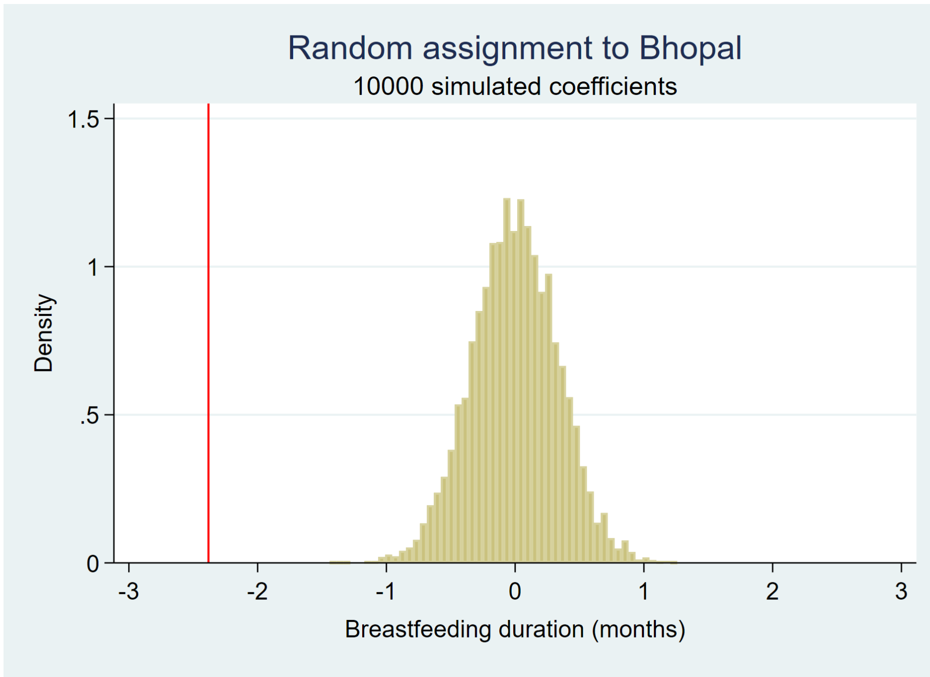
	(1)	(2)	(3)	(4)	(5)
$Bhopal_d * $ Born Before BGD_{ft}	-2.268***	-2.300***	-2.275***	-2.447***	-2.165***
	(0.214)	(0.212)	(0.218)	(0.213)	(0.202)
Observations	14,285	1,4419	14,317	14,419	14,185
Dependent mean			— 16.560 —		
Additional controls:					
Mother's Body Mass Index (BMI)	Yes	No	No	No	Yes
Mother's education	No	Yes	No	No	Yes
Father's education	No	No	Yes	No	Yes
Birth order fixed effects	No	No	No	Yes	Yes

Notes: All columns report results from regressions using NFHS-4 child data. The outcome variable, *Breastfeeding duration (months)*, in columns (1) through (5), measures the total number of months for which a child was breastfed by her mother. Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Additionally, controls are included as follows - mother's Body Mass Index (BMI) in column (1), mother's education in column (2), father's education in column (3), fixed effects for child's birth order in column (4), and all of these in column (5). Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

6.5 Simulations with random assignment

To show that our results are not driven by some random variation between the district of Bhopal and the reference districts in Madhya Pradesh, we conduct a test of randomization following Bharadwaj et al.(2014). First, we randomly assign each child in our sample to either Bhopal or reference districts with equal probability. With this random assignment, we run regression equation 1 with breastfeeding duration as the outcome variable and record the coefficient, β_1, on the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. This process is repeated 10000 times. The density of the 10000 recorded coefficients is then presented in a histogram (Figure 6). In the graph, the breastfeeding duration (months) is on the horizontal axis, while density is on the vertical axis. The vertical red line indicates the coefficient, β_1, of $Bhopal_d * BornBeforeBGD_{ft}$ reported in Table 1. In Figure 6, the random estimates are distributed around zero while our point estimate lies much farther to the left indicating that our empirical strategy is picking true variation that exists between Bhopal and other districts due to BGD, and not some random variation.

Figure 6: ***Simulated coefficients with random assignment to Bhopal***



Note: The figure depicts the results from our test of random assignment. The outcome variable, *Breastfeeding duration (months)*, measures the total number of months for which a child was breastfed by her mother. Coefficients of $Bhopal_d * BornBeforeBGD_{ft}$ estimated through 10000 simulations are on the the horizontal axis and the density of the estimated coefficients is on the vertical axis. The vertical line represents our actual estimate of the coefficient of $Bhopal_d * BornBeforeBGD_{ft}$ reported in Table 1. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors are clustered at the district level.

6.6 Concerns regarding in-utero effects

The aftermath of the Bhopal Gas Disaster has had adverse effects on educational attainment, employment outcomes, anthropometric measures, incidence of cancer, and infant mortality for the cohort that was in-utero at the time of gas leak, as well as for the offspring of such in-utero cohort (McCord et al., 2021; Sarangi et al., 2010; Ranjan et al., 2003). In this study, we do not dissect the father cohorts based on their in-utero status as our objective is to examine the consequences of direct exposure to gas leak for the children of the exposed. Nonetheless, we address this issue by dropping the father cohort that was, potentially, in-utero at the time of BGD, which is the birth cohort of 1985. Births between January 1985 and September 1985 are likely to qualify as being in-utero at the time of BGD in December

1984. However, since we do not have data on the month of birth of the father, we drop the entire birth cohort of 1985 from our sample and re-run regression equation 1 with this new sub-sample. Results (Table 8) do not change significantly as compared to our primary estimates.

Table 8: ***Estimates after excluding father cohort in-utero at BGD***

	Breastfeeding duration (months) (1)	Breastfed within 1 hr of birth (2)	Breastfed for at least 3 months (3)
$\text{Bhopal}_d * \text{Born Before BGD}_{ft}$	-2.432***	-0.015	-0.028***
	(0.220)	(0.009)	(0.004)
Observations	12,774	12,786	11,815
Dependent mean	16.418	0.685	0.966

Notes: All columns report results from regressions using NFHS-4 child data. *Breastfeeding duration (months)*, in column (1), measures the total number of months for which a child was breastfed by her mother. *Breastfed within 1 hr of birth*, in column (2), is a dummy variable for whether a child was breastfed by her mother within 1 hour of birth. *Breastfed for at least 3 months*, in column (3), is a dummy variable which measures whether a child was breastfed by her mother for at least 3 months. Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

6.7 Adjusting for heterogeneity in breastfeeding duration

Breastfeeding patterns may vary by the age of the parent as well as the child. Differences over age may arise due to variation in labor-force participation, fertility levels and preferences. Similarly, research finds differential breastfeeding preferences for boys and girls (Jayachandran & Kuziemko, 2011). We have attempted to control for these sources of heterogeneity by using fixed effects for birth year of father and child as well as the child's gender, another method of addressing the problem at the source could be adjusting the outcome variable - breastfeeding duration - for age and gender. This also addresses the issue of continuing breastfeeding for children who were very young at the time of the survey by measuring relative breastfeeding duration within age-cohorts. To facilitate interpretation of the results, breastfeeding duration was standardized to mean 0 and standard deviation 1. In Table 9, we present results from various alternative ways of standardization of values - across age cohorts of father (column 2), mother (column 3), and child (column 4). For comparison, we also report results on the basis of standardized values of breastfeeding duration without grouping by age and gender (column 1). We find similar results with some variation in magnitude across specifications. For instance, when adjusted for gender and mother's age, the breastfeeding duration was 0.19 standard deviations smaller for the *affected* cohort.

Table 9: ***Estimates based on standardized breastfeeding duration***

	(1)	(2)	(3)	(4)
$\text{Bhopal}_d * \text{Born Before BGD}_{ft}$	-0.202***	-0.170***	-0.193***	-0.128***
	(0.018)	(0.017)	(0.017)	(0.019)
Observations	14,419	14,418	14,417	14,419
Controls	Yes	Yes	Yes	Yes
Father birth year fixed effects	Yes	Yes	Yes	Yes
Child birth year fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes

Notes: All columns report results from regressions using NFHS-4 child data. The outcome variable is the standardized values of breastfeeding duration. Various combinations of standardization are reported - ungrouped (column 1), grouped by child's gender and father's age (column 2), grouped by child's gender and mother's age (column 3), and grouped by child's gender and child's age (column 4). Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for father's and child's birth years and for district of residence and also the following control variables - child's gender, age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.

7 Conclusion

We study the intergenerational effects of an industrial disaster, the 1984 Bhopal Gas Disaster, on health outcomes, specifically on breastfeeding duration of children of exposed parents. Using potentially exogenous spatial and temporal variations, we find evidence of reduced duration of breastfeeding in children whose parents were exposed to the toxic gas leak. We also find a smaller probability of being breastfed within an hour after birth as well as that of being breastfed for 3 months after birth.

In light of the the long-lasting effects of a one-time industrial disaster, our study provides suggestive evidence highlighting the significance of examining the intergenerational spillover effects, especially while determining monetary compensation. In the context of the Bhopal Gas Disaster, the accused, UCIL, agreed to a compensation of USD 470 million. The Indian government, on behalf of the survivors of BGD, countered the offer with a demand of USD 3.3 billion, seven times the original offer. However, UCIL refused to pay any more money. In 2010, the government followed up on the matter with a demand of an additional USD 1.1 billion, arguing that "the initial compensation was based on incorrect figures and failed to capture the enormity of damage caused to human lives and the environment." However, in March 2023, the Supreme Court of India rejected this demand for additional compensation, saying that the issue could not be "raked up three decades after the settlement[10]." Our findings clearly indicate adverse consequences of the incident on subsequent generations. Poor breastfeeding in infancy can significantly impact human capital formation among the affected groups. Thus, while assessing losses and deciding legal compensation, it is important to account for the intergenerational effects by either imputing the present value of losses to future generations or by including a legal provision for additional compensation to be determined in the future.

References

Almond, D., & Currie, J. (2011a). *Human Capital Development before Age Five* (Handbook of Labor Economics). Elsevier. Retrieved 2023-06-21, from https://econpapers.repec.org/bookchap/eeelabchp/5-15.htm

Almond, D., & Currie, J. (2011b, September). Killing Me Softly: The Fetal Origins Hypothesis. *Journal of Economic Perspectives*, *25*(3), 153–172. Retrieved 2023-06-21, from https://www.aeaweb.org/articles?id=10.1257/jep.25.3.153 doi: 10.1257/jep.25.3.153

[10]This information was sourced from a news article by BBC. More details on the news article can be found here.

Almond, D., Currie, J., & Duque, V. (2018, December). Childhood Circumstances and Adult Outcomes: Act II. *Journal of Economic Literature*, *56*(4), 1360–1446. Retrieved 2023-06-21, from https://www.aeaweb.org/articles?id=10.1257/jel.20171164 doi: 10.1257/jel.20171164

Andersson, N., Ajwani, M., Mahashabde, S., Tiwari, M., Muir, M. K., Mehra, V., ... Mackenzie, C. (1990). Delayed eye and other consequences from exposure to methyl isocyanate: 93% follow up of exposed and unexposed cohorts in bhopal. *Occupational and Environmental Medicine*, *47*(8), 553–558.

Arthi, V., & Schneider, E. (2021). Infant feeding and post-weaning health: Evidence from turn-of-the-century London. *Economics and Human Biology*, *43*. doi: 10.1016/j.ehb.2021.101065

Aurino, E. (2017). Do boys eat better than girls in india? longitudinal evidence on dietary diversity and food consumption disparities among children and adolescents. *Economics & Human Biology*, *25*, 99-111. Retrieved from https://www.sciencedirect.com/science/article/pii/S1570677X16301666 (In Honor of Nobel Laureate Angus Deaton: Health Economics in Developed and Developing Countries) doi: https://doi.org/10.1016/j.ehb.2016.10.007

Azuine, R. E., & Singh, G. K. (2019). Father's Health Status and Inequalities in Physical and Mental Health of U.S. Children: A Population-Based Study. *Health Equity*, *3*(1), 495. Retrieved 2023-11-28, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6786338/ doi: 10.1089/heq.2019.0051

Barcellos, S. H., Carvalho, L. S., & Lleras-Muney, A. (2014, January). Child gender and parental investments in india: Are boys and girls treated differently? *American Economic Journal: Applied Economics*, *6*(1), 157-89. Retrieved from https://www.aeaweb.org/articles?id=10.1257/app.6.1.157 doi: 10.1257/app.6.1.157

Barrera, A. (1990). The interactive effects of mother's scholling and unsupplemented breastfeeding on child health. *Journal of Development Economics*, *34*(1-2), 81–98. doi: 10.1016/0304-3878(90)90077-O

Basu, A. R., & Murthy, R. S. (2003). Disaster and mental health: Revisiting bhopal. *Economic and Political Weekly*, 1074–1082.

Bevis, L., & Villa, K. (2022). Intergenerational Transmission of Maternal Health. *Journal of Human Resources*, *57*(5), 1425–1465. doi: 10.3368/jhr.58.1.0819-10372R2

Bhalotra, S., & Rawlings, S. (2013). Gradients of the intergenerational transmission of health in developing countries. *Review of Economics and Statistics*, *95*(2), 660–672. doi: 10.1162/REST_a_00263

Bharadwaj, P., Johnsen, J. V., & Løken, K. V. (2014). Smoking bans, maternal smoking and birth outcomes. *Journal of Public economics*, *115*, 72–93.

Bicchieri, C., Das, U., Gant, S., & Sander, R. (2022). Examining norms and social expectations surrounding exclusive breastfeeding: Evidence from Mali. *World Development*, *153*. doi: 10.1016/j.worlddev.2022.105824

BjÖrkegren, E., Lindahl, M., Palme, M., & Simeonova, E. (2019). Pre- and Post-Birth Components of Intergenerational Persistence in Health and Longevity Lessons from a Large Sample of Adoptees. *Journal of Human Resources*, *57*(1), 1–41. doi: 10.3368/jhr.57.1.0318-9421R1

Black, S. E., Bütikofer, A., Devereux, P. J., & Salvanes, K. G. (2019). This is only a test? long-run and intergenerational impacts of prenatal exposure to radioactive fallout. *Review of Economics and Statistics*, *101*(3), 531–546.

Black, S. E., & Devereux, P. (2011). Recent Developments in Intergenerational Mobility [Handbook of Labor Economics]. , 1487–1541. Retrieved 2023-06-21, from https://econpapers.repec.org/bookchap/eeelabchp/5-16.htm

Caruso, G. D. (2017, July). The legacy of natural disasters: The intergenerational impact of 100 years of disasters in Latin America. *Journal of Development Economics*, *127*, 209–233. Retrieved 2023-06-21, from https://www.sciencedirect.com/science/article/pii/S0304387817300317 doi: 10.1016/j.jdeveco.2017.03.007

Case, A., Lubotsky, D., & Paxson, C. (2002, December). Economic status and health in childhood: The origins of the gradient. *American Economic Review*, *92*(5), 1308-1334. Retrieved from https://www.aeaweb.org/articles?id=10.1257/000282802762024520 doi: 10.1257/000282802762024520

CDC. (2020). 2018 national immunization survey - child. Retrieved from https://www.cdc.gov/breastfeeding/data/nis_data/rates-any-exclusive-bf-socio-dem-2018.html

Colmer, J., & Voorheis, J. (2020). The grandkids aren't alright: the intergenerational effects of prenatal pollution exposure.

Cullinan, P., Acquilla, S., & Dhara, V. (1996). Long term morbidity in survivors of the 1984 bhopal gas leak. *National Medical Journal of India*, *9*, 5–9.

Cunha, F., & Heckman, J. (2007, May). The Technology of Skill Formation. *American Economic Review*, *97*(2), 31–47. Retrieved 2023-06-21, from https://www.aeaweb.org/articles?id=10.1257/aer.97.2.31 doi: 10.1257/aer.97.2.31

Cunha, F., Heckman, J. J., & Schennach, S. M. (2010). Estimating the Technology of Cognitive and Noncognitive Skill Formation. *Econometrica*, *78*(3), 883–931. Retrieved 2023-06-21, from https://onlinelibrary.wiley.com/doi/abs/10.3982/ECTA6551 doi: 10.3982/ECTA6551

Das, S., & Dasgupta, S. (2022). Hidden costs of industrial disasters: Marriage market consequences of the bhopal gas disaster. *Available at SSRN 4227143*.

De, S., Shanmugasundaram, D., Singh, S., Banerjee, N., Soni, K., & Galgalekar, R. (2020). Chronic respiratory morbidity in the bhopal gas disaster cohorts: a time-trend analysis of cross-sectional data (1986–2016). *Public health*, *186*, 20–27.

Demir, F., Ghosh, P., & Liu, Z. (2020). Effects of motherhood timing, breastmilk substitutes and education on the duration of breastfeeding: Evidence from Egypt. *World Development*, *133*. doi: 10.1016/j.worlddev.2020.105014

Dhara, V. R., & Dhara, R. (2002). The union carbide disaster in bhopal: a review of health effects. *Archives of Environmental Health: An International Journal*, *57*(5), 391–404.

Eckerman, I. (2005). *The bhopal saga: causes and consequences of the world's largest industrial disaster.* Universities press, Hyderabad, India.

Elsner, B., & Wozny, F. (2023). Long-run exposure to low-dose radiation reduces cognitive performance. *Journal of Environmental Economics and Management*, *118*, 102785.

Fitzsimons, E., & Vera-Hernández, M. (2022). Breastfeeding and Child Development. *American Economic Journal: Applied Economics*, *14*(3), 329–366. doi: 10.1257/app.20180385

Fortun, K. (2001). *Advocacy after bhopal: Environmentalism, disaster, new global orders.* University of Chicago Press.

Ganguly, B. B., Mandal, S., & Kadam, N. N. (2017). Genotoxic and carcinogenic effects of methyl isocyanate (mic) reviewed on exposed bhopal population and future perspectives for assessment of long-term mic-effect. *J Environ Anal Toxicol*, *7*(3), 2161–0525.

Ganguly, B. B., Mandal, S., & Kadam, N. N. (2018). Spectrum of health condition in methyl isocyanate (mic)-exposed survivors measured after 30 years of disaster. *Environmental Science and Pollution Research*, *25*, 4963–4973.

Irani, S., & Mahashur, A. (1986). A survey of bhopal children affected by methyl isocyanate gas. *Journal of postgraduate medicine*, *32*(4), 195.

Jayachandran, S., & Kuziemko, I. (2011). Why do mothers breastfeed girls less than boys? evidence and implications for child health in india. *The Quarterly journal of economics*, *126*(3), 1485–1538.

Jia, N., Dong, X.-Y., & Song, Y.-P. (2018). Paid Maternity Leave and Breastfeeding in Urban China. *Feminist Economics*, *24*(2), 31–53. doi: 10.1080/13545701.2017.1380309

Keskin, P., Shastry, G., & Willis, H. (2017). Water quality awareness and breastfeeding: Evidence of health behavior change in Bangladesh. *Review of Economics and Statistics*, *99*(2), 265–280. doi: 10.1162/REST_a_00626

Khalil, U., & Mookerjee, S. (2019). Patrilocal residence and women's social status: evidence from south asia. *Economic Development and Cultural Change*, *67*(2), 401–438.

Kiliç, E. Z., Özgüven, H. D., & Sayil, I. (2003). The psychological effects of parental mental health on children experiencing disaster: The experience of bolu earthquake in turkey. *Family process*, *42*(4), 485–495.

Kotelchuck, M. (2022). The Impact of Father's Health on Reproductive and Infant Health and Development. In M. Grau Grau, M. las Heras Maestro, & H. Riley Bowles (Eds.), *Engaged Fatherhood for Men, Families and Gender Equality: Healthcare, Social Policy, and Work Perspectives* (pp. 31–61). Cham: Springer International Publishing. Retrieved 2023-11-28, from https://doi.org/10.1007/978-3-030-75645-1_3 doi: 10.1007/978-3-030-75645-1_3

Kottwitz, A., Oppermann, A., & Spiess, C. (2016). Parental leave benefits and breastfeeding in Germany: Effects of the 2007 reform. *Review of Economics of the Household*, *14*(4), 859–890. doi: 10.1007/s11150-015-9299-4

Kramer, M. S., Aboud, F., Mironova, E., Vanilovich, I., Platt, R. W., Matush, L., ... Promotion of Breastfeeding Intervention Trial (PROBIT) Study Group (2008, May). Breastfeeding and child cognitive development: New evidence from a large randomized trial. *Archives of General Psychiatry*, *65*(5), 578–584. doi: 10.1001/archpsyc.65.5.578

Kramer, M. S., Chalmers, B., Hodnett, E. D., Sevkovskaya, Z., Dzikovich, I., Shapiro, S., ... for the PROBIT Study Group (2001, January). Promotion of Breastfeeding Intervention Trial (PROBIT)A Randomized Trial in the Republic of Belarus. *JAMA*, *285*(4), 413–420. Retrieved 2023-06-20, from https://doi.org/10.1001/jama.285.4.413 doi: 10.1001/jama.285.4.413

Krol, K. M., & Grossmann, T. (2018). Psychological effects of breastfeeding on children and mothers. *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz*, *61*(8), 977–985. Retrieved 2023-06-20, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6096620/ doi: 10.1007/s00103-018-2769-0

Lal, V. (1996). Review essay: Sovereign immunity: Law in an unequal world. *Social & Legal Studies*, *5*(3), 429–434.

Lundborg, P., Nordin, M., & Rooth, D. (2018). The intergenerational transmission of human capital: The role of skills and health. *Journal of Population Economics*, *31*(4), 1035–1065. doi: 10.1007/s00148-018-0702-3

MacKenzie, D. (2002). Fresh evidence on bhopal disaster. *New Scientist*, *176*(2372), 6–6.

Malla, T., Senthilkumar, C., Sharma, N., & Ganesh, N. (2011). Chromosome instability among bhopal gas tragedy survivors. *Am Eur J Toxicol Sci*, *3*, 245–9.

McCord, G. C., Bharadwaj, P., Kaushik, A., McDougal, L., & Raj, A. (2021). In utero exposure to industrial disasters: A case study of the bhopal gas tragedy. *Available at SSRN 3889363*.

Mishra, B., & Banerjee, N. (2014). Mic leak disaster and environmental contamination: Time to act now. *National Journal of Community Medicine*, *5*(01), 13–20.

Mishra, P., Raghuram, G. V., Bunkar, N., Bhargava, A., & Khare, N. K. (2015). Molecular bio-dosimetry for carcinogenic risk assessment in survivors of bhopal gas tragedy. *International Journal of Occupational Medicine and Environmental Health*, *28*(6), 921–939.

Mishra, P., Samarth, R. M., Pathak, N., Jain, S. K., Banerjee, S., & Maudar, K. K. (2009). Bhopal gas tragedy: review of clinical and experimental findings after 25 years. *International journal of occupational medicine and environmental health*, *22*(3), 193-202.

Mramba, L., Ngari, M., Mwangome, M., Muchai, L., Bauni, E., Walker, A. S., ... Berkley, J. A. (2017). A growth reference for mid upper arm circumference for age among school age children and adolescents, and validation for mortality: growth curve construction and longitudinal cohort study. *bmj*, *358*.

Ranjan, N., Sarangi, S., Padmanabhan, V., Holleran, S., Ramakrishnan, R., & Varma, D. R. (2003). Methyl isocyanate exposure and growth patterns of adolescents in bhopal. *Journal of the American Medical Association*, *290*(14), 1856–1857.

Rothstein, D. (2013). Breastfeeding and children's early cognitive outcomes. *Review of Economics and Statistics*, *95*(3), 919–931. doi: 10.1162/REST_a_00282

Roy, A., & Sekher, T. (2022). Mid upper arm circumference as an alternative measure to assess the nutritional status of adolescents: a study in india based on nfhs-4 data. *Journal of Biosocial Science*, *54*(4), 617–628.

Sarangi, S., Zaidi, T., Pal, R., Katgara, D., Gadag, V., Mulay, S., & Varma, D. (2010). Effects of exposure of parents to toxic gases in bhopal on the offspring. *American Journal of Industrial Medicine*, *53*(8), 836–841.

Sathyamala, C. (1996). Reproductive health consequences of bhopal gas leak: fertility and gynaecological disorders. *Economic and political Weekly*, 43–57.

Sharma, D. C. (2005). Bhopal: 20 years on. *The Lancet*, *365*(9454), 111–112.

Shrivastava, P. (1987). *Bhopal: Anatomy of a crisis.* Cambridge, MA , Ballinger Publishing.

Sourav, S. (2019). Children and disaster. *Indian Anthropologist*, *49*(1), 51–65.

Victora, C. G., Bahl, R., Barros, A. J. D., França, G. V. A., Horton, S., Krasevec, J., ... Rollins, N. C. (2016, January). Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. *The Lancet*, *387*(10017), 475–490. Retrieved 2023-06-21, from https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)01024-7/fulltext doi: 10.1016/S0140-6736(15)01024-7

Yue, A., Cui, M., Yang, Z., Shi, Y., Guo, C., & Song, Q. (2023). Formula feeding: Evidence for health, nutrition and early childhood development during the critical first 1000 days from rural China. *Journal of Asian Economics*, *85*. doi: 10.1016/j.asieco.2022.101580

A Appendix

A1 Descriptive statistics

Table A1: ***Sample means - Control variables***

	(1)
Controls (in equation 1):	
Child's gender (=1 if female)	0.476 (0.003)
Rural residence (=1 if rural)	0.759 (0.003)
Caste (=1 if SC/ST)	0.445 (0.003)
Sex of household head (=1 if female)	0.045 (0.001)
Age of household head	41.892 (0.099)
Household size	6.657 (0.019)
Wealth quintile (1 - poorest; 2 - poorer; 3 - middle; 4 - richer; 5 - richest)	2.698 (0.010)
Additional controls:	
Mother's Body Mass Index (BMI)	20.305 (0.023)
Mother's education (0 - no education; 1 - primary; 2 - secondary; 3 - higher)	1.131 (0.007)
Father's education (0 - no education; 1 - primary; 2 - secondary; 3 - higher)	1.517 (0.006)

Notes: This table reports the summary statistics of control variables used in various regressions throughout this study. Column (1) reports the sample means for respective variables. Standard errors are reported in parentheses.

Table A1: ***Sample means***

District →	Full sample	Bhopal		Rest of MP	
Father's birth cohort →		Pre-BGD	Post-BGD	Pre-BGD	Post-BGD
	(1)	(2)	(3)	(4)	(5)
Outcome variables:					
Breastfeeding duration (months)	16.561 (11.83)	15.528 (10.751)	15.617 (10.203)	18.948 (12.731)	15.043 (10.977)
Breastfed within 1 hr of birth	0.689 (0.463)	0.677 (0.469)	0.748 (0.436)	0.677 (0.468)	0.696 (0.46)
Breastfed for atleast 3 months after birth	0.906 (0.291)	0.898 (0.304)	0.922 (0.27)	0.924 (0.265)	0.895 (0.307)
Covariates:					
Child's gender (=1 if female)	1.443 (0.497)	1.449 (0.499)	1.435 (0.498)	1.423 (0.494)	1.456 (0.498)
Rural residence (=1 if rural)	1.741 (0.438)	1.134 (0.342)	1.261 (0.441)	1.679 (0.467)	1.797 (0.403)
Caste (=1 if SC/ST)	0.426 (0.494)	0.189 (0.393)	0.261 (0.441)	0.395 (0.489)	0.451 (0.498)
Sex of household head (=1 if female)	1.047 (0.211)	1.039 (0.195)	1.104 (0.307)	1.045 (0.206)	1.048 (0.213)
Age of household head	42.438 (14.552)	43.346 (13.052)	39.278 (15.768)	44.202 (13.192)	41.325 (15.264)
Household size	6.584 (2.86)	5.756 (2.308)	5.443 (2.586)	6.647 (2.78)	6.57 (2.916)
Wealth quintile (1 to 5) (1-poorest; 5-richest)	2.812 (1.463)	4.346 (0.979)	4.000 (1.084)	2.948 (1.54)	2.685 (1.393)
Mother's Body Mass Index (BMI)	20.394 (3.416)	22.829 (4.043)	21.258 (3.843)	21.052 (3.791)	19.921 (3.036)
Mother's education (0 - none; 1 - pri.; 2 - sec.; 3 - higher)	1.199 (0.989)	1.78 (0.959)	1.496 (0.921)	1.144 (1.058)	1.221 (0.939)
Father's education (0 - none; 1 - pri.; 2 - sec.; 3 - higher)	1.577 (0.908)	1.944 (0.826)	1.757 (0.812)	1.551 (0.992)	1.586 (0.851)
Father's age	30.177 (5.732)	35.74 (4.183)	27.652 (2.152)	35.849 (4.326)	26.455 (2.719)

Notes: This table reports the sample means of outcome variables and other covariates used in various regressions. Column 1 presents information for the full sample, Columns 2 and 3 for the district of Bhopal and Columns 4 and 5 present information for the rest of the state of Madhya Pradesh. Pre-BGD represents the cohort of fathers born prior to the 1984 disaster and are the (*directly exposed group*), whereas Post-BGD is the cohort of fathers born after the disaster (*indrectly exposed group*). Standard deviations are reported in parentheses.

Table A2: *Father's health outcomes*

	Cancer (1)	Heart disease (2)
$\text{Bhopal}_d * \text{Born Before BGD}_{ft}$	0.012***	0.024***
	(0.001)	(0.002)
Observations	8976	8989
Dependent mean	0.002	0.012
Controls	Yes	Yes
Birth year fixed effects	Yes	Yes
District fixed effects	Yes	Yes

Notes: All columns report results from regressions using NFHS-4 men data. *Cancer* and *Heart disease*, in columns (1) and (2), respectively, are dummy variables for whether the child's father reported suffering from these ailments. Results are the coefficients of the interaction term $Bhopal_d * BornBeforeBGD_{ft}$. All regressions include fixed effects for birth year and for district of residence and also the following control variables - age and sex of household head, household size, rural/urban residence, caste, and quintiles of wealth index of the household. Standard errors clustered at district level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1.