WATER QUALITY AWARENESS AND BREASTFEEDING: EVIDENCE OF HEALTH BEHAVIOR CHANGE IN BANGLADESH

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Abstract—Decades of campaigns have cautioned households in Bangladesh about waterborne contaminants such as arsenic. In addition to switching water sources, mothers can protect young children from contaminated water by breastfeeding longer. We exploit time series variation in whether children were born before or after a nationwide information campaign and geographic variation in exposure to arsenic. We find that mothers breast-feed children longer in response to the campaign, especially when they have less access to uncontaminated wells, and that infants are more likely to be exclusively breast-fed. We find consistent evidence of lower mortality rates and diarrheal incidence for infants.

I. Introduction

WATER-RELATED diseases pose a major global health problem, particularly in the developing world. According to the World Health Organization, water- and hygiene-related causes account for more than 3.5 million deaths each year, almost all in developing countries (Prüss-Üstün et al., 2008). Despite extensive research on how to encourage better water practices, eliciting behavior change remains a challenge, in part due to low willingness to pay for clean water.[1] In this paper, we provide evidence of behavior change in response to water quality concerns in Bangladesh: increased breastfeeding duration and longer periods of exclusive breastfeeding. Breastfeeding can protect infants from contaminants in drinking water, such as arsenic or those causing potentially fatal diarrheal illnesses (Fängström et al., 2008; Habicht, DaVanzo, & Butz, 1988).

The first water safety efforts in Bangladesh began in the 1970s when millions of shallow tubewells were built to combat the spread of waterborne diseases through surface water. In the 1990s, high levels of arsenic were discovered in water from many tubewells, and about 35 million people were thought to be drinking contaminated water (British Geological Survey and Department of Public Health Engineering [BGS & DPHE], 2001). In 1999, the Bangladesh government began testing wells, painting contaminated wells red, disseminating information on arsenic, and encouraging households to switch to clean wells. In 2004, 84% of households had heard of arsenic and 8% were drinking arsenic-contaminated water (Bangladesh Demographic and Health Survey [BDHS] data, authors' tabulations).[2]

To study the response to the campaign, we take advantage of variation in when a child was born and geographic variation in arsenic contamination using a differences-in-differences (DID) strategy. Using a sample of children born each year from 1995 to 2007, we find that children born after the information campaign are breast-fed longer and more likely to be exclusively breast-fed (not fed anything besides breast milk, even plain water) in arsenic-contaminated areas relative to other areas. Our identifying assumption is that conditional on village and birth year fixed effects and district-specific linear trends, breastfeeding patterns were not changing differentially in more contaminated and less contaminated villages other than for reasons related to the campaign. An event study confirms this result and provides support for the assumption: prior to the campaign, breastfeeding patterns in contaminated areas are indistinguishable from those in uncontaminated areas.

Of course, the behavior change recommended to avoid arsenic, switching to a clean well, can protect the whole household from both arsenic and microbial pathogens. In fact, if a household switches to a clean well, there is arguably no need to adjust breastfeeding behavior. We look for differential responses to the information campaign with respect to the cost of switching to an arsenic-safe well by exploiting variation in the geographic distribution of uncontaminated wells and estimating a triple difference. We verify that households that live farther from an uncontaminated well are less likely to drink from a clean well; they drink either arsenic-contaminated well water or surface water. Regardless of which water source they choose, these mothers can protect their youngest children from both arsenic and waterborne diseases by breastfeeding. It is unlikely that mothers knew that breastfeeding protects children from arsenic specifically,[3] but previous nationwide promotions have emphasized that breastfeeding provides protection from other contaminants. We first show that the DID effect described is driven by households that are not using clean wells. Next, acknowledging the endogeneity of water source, we find that the DID effect is driven by mothers who live far from uncontaminated wells.

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[1] See Ahuja, Kremer, and Zwane (2010) for a review of recent randomized evaluations.

[2] More recent estimates are unavailable since many (untested) wells have been built since 2004.

[3] Based on the campaign documentation, we do not believe breastfeeding was mentioned. However, it is possible that workers spoke about other public health efforts and mentioned breastfeeding. This would affect our interpretation regarding whether women made the mental leap from contaminated water to breastfeeding on their own.

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Finally, we look for heterogeneous effects by age and find that the exclusive breastfeeding result is driven by infants. We find consistent evidence of lower mortality rates, lower incidence of diarrhea, and greater weight for infants but not older children.

Our paper contributes to the literature on health behavior change by demonstrating that in response to new information about water quality, mothers in Bangladesh were more likely to exclusively breast-feed their children and to breast-fed their children longer. In section VI, we discuss various motivations for this behavior change, including concern for child well-being. However, these results evoke a puzzle: Why would mothers protect their infants through breastfeeding when they could protect the entire family by switching to an arsenic-free tubewell? Protection for the entire family seems worth the cost of walking to a slightly farther well. One explanation is that households do switch to an arsenic-safe water source, but mothers choose to breast-feed more in addition (either because water quality concerns are more salient or because the new water source is farther and it is easiest to reduce breast-fed children's water consumption).

However, not all households switch to a water source that is safe from both arsenic and other pathogens.[4] For these mothers, breastfeeding longer implies a concern for child health belied by the decision not to switch to a clean water source. This is especially true when we consider that women in Bangladesh do most of the water collection. We turn to the "separate spheres" model of intrahousehold bargaining (Lundberg & Pollak, 1993) and ethnographic research on access to arsenic-free water in Bangladesh (Sultana, 2009, 2011) to provide some insight: men and women exercise control over different parts of the process of collecting water. Sultana (2009, 2011) describes a hierarchical household structure that gives the male household head authority over most decisions, including the time allocation of household members. The youngest women usually collect water, but the patriarch determines the source. Traveling far to collect water involves a reputation cost as well as a time cost, because exposing women to public spaces violates traditional social norms and suggests that the men are not able to provide for their family by digging a safe tubewell. When women do collect water from a neighbor's well, they are required to negotiate complex socioeconomic hierarchies, generating additional social and emotional stress. Thus, one possible explanation is that women respond by breastfeeding longer because switching to an arsenic-free well is outside their sphere of influence.[5] In section VI, we discuss suggestive evidence of heterogeneity among women in the two responses to the campaign that is consistent with this theory.

More generally, our results are in line with a growing literature on the success of the arsenic mitigation campaign in Bangladesh in increasing knowledge of arsenic and reducing use of contaminated wells (Opar et al., 2007; Jakariya, 2007; Madajewicz et al., 2007; Bennear et al., 2013). Why was the Bangladesh program able to elicit behavior change when other campaigns have been less successful? Dupas (2011b) reviews the literature on health behavior change and concludes that providing information can have an impact on behavior, but it depends on the recipient's characteristics (such as gender) and the content. For example, comprehensive information on relative risks may be more effective than limited information focusing on risk avoidance (Dupas, 2011a; Duflo, Dupas, Kremer, 2015). We discuss features of the campaign that might have contributed to its success in section VII and the online appendix.

The paper is organized as follows. The following section provides background on water quality, arsenic mitigation efforts, and the benefits of breastfeeding in Bangladesh. Section III describes the empirical strategy, including the data and the specifications. Section IV documents the impact of the information campaign on breastfeeding patterns. Section V presents the effect of the information campaign on child health. Section VI provides a discussion of the results and alternative motivations. Section VII concludes.

II. Background

Arsenic is naturally present in groundwater in many regions. Chronic arsenic exposure through drinking water is associated with many health conditions. In the short run, the symptoms can be relatively mild, including skin rashes and irritation, weakness, diabetes, edema, and respiratory problems. After extended exposure, however, arsenic is linked to increased risk of skin and internal organ cancers, many of them fatal. There is little evidence that arsenic exposure is related to ill physical health among very young children, although there is some evidence of diminished motor function, lung capacity, and intellectual function among 6- to 12-year-old children (Parvez et al., 2011; Wasserman et al., 2007). Pitt, Rosenzweig, & Hassan (2015) examine the economic consequences of arsenic poisoning and find long-term negative effects on cognition, schooling, and earnings for men and on domestic productivity for women.

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[4] In fact, Field, Glennerster, and Hussam (2011) document an unintended consequence of the campaign that provides further justification for mothers to breast-feed longer: an increase in under-5 mortality from diarrheal diseases among households whose closest well is contaminated. Some possible explanations are that households switched back to surface water sources despite the risks, storage time increased and water was contaminated during storage, or shallow wells with low arsenic levels have higher rates of diarrhea-causing pathogens than those with high arsenic levels (van Geen et al., 2011; Wu et al., 2011). Our findings complement their results: their mortality effects are robustly estimated for older children, while our mortality results are evident only for the youngest children—those most likely to be exclusively breast-fed.

[5] The empirical rejection of the unitary model of the household (see, e.g., Thomas, 1990; Duflo, 2003) suggests that information may have different impacts depending on who receives it and what options are available to each parent. In our context, it could also be that breastfeeding their children is a response women can conceal from their spouses (see Ashraf, Field, & Lee, 2014).

A. *Water Safety Efforts in Bangladesh*

In the 1970s and 1980s, water safety campaigns in Bangladesh focused on waterborne infections and the dangers of surface water. Millions of shallow tubewells were built to access clean drinking water and prevent gastrointestinal diseases: 95% of rural households began drinking protected groundwater (Caldwell et al., 2003).

In the late 1980s, however, groundwater samples tested positive for naturally occurring arsenic. Soon, the skin lesions characteristic of arsenic poisoning were identified and diagnosed. However, the extent of the problem was not clear until 1998 when the British Geological Survey (BGS) began systematically testing samples from tubewells across the country. The BGS found that water from 27% of shallow tubewells (i.e., depths of less than 150 meters) exceeded the Bangladesh standard for arsenic in drinking water (more than 50 μg/L).[6] The BGS estimated that 35 million people were exposed to dangerous levels of arsenic (BGS & DPHE, 2001).

In 1999, the Department of Public Health Engineering of Bangladesh (DPHE) initiated the Bangladesh Arsenic Mitigation Water Supply Program (BAMWSP), a comprehensive screening of shallow wells in contaminated regions, with the assistance of UNICEF and the World Bank. Through the project, 55% of nearly 8.5 million wells around the country were tested for arsenic. Tubewells were labeled to clearly indicate the amount of arsenic in the water: if the arsenic content fell below the government threshold of 50 μg/L, the spout of the tubewell was painted green. If not, the spout was painted red (UNICEF, 2008). The program also dug new wells, increasing access to arsenic-safe water for 2 to 2.5 million people (World Bank, 2007).

UNICEF also launched a campaign in 1999 to disseminate information on the dangers of arsenic exposure through DPHE engineers conducting the arsenic tests, teachers, religious leaders, NGO staff, and health care workers. The campaign also presented physical evidence of contamination and explained the color-coding of the wells (UNICEF, 2008). This information campaign, along with similar efforts, raised awareness of the need to stop drinking arsenic-contaminated water (Jakariya, 2007). In the late 1990s, less than 10% of the population knew about arsenic contamination. According to a UNICEF report in 2008, this number had risen to 80%. Seventy percent of informed households claimed to avoid contaminated water. The most common response was collecting water from a safe well, often owned by a neighbor or relative (van Geen et al., 2002; UNICEF, 2008). The local nature of arsenic variation indicates that this option was, at least in principle, available to most Bangladeshis. Van Geen et al. (2002) show that 88% of contaminated wells in their study area were within 100 meters of a clean well. A data set with 4.5 million wells across contaminated regions shows that only 4.4% of 48,000 villages have no wells with arsenic levels below 50 μg/L, while in 87% of villages, more than 10% of wells have arsenic levels below the threshold (the average percent of wells contaminated is 34%) (BAMWSP data, authors' tabulations). Villages are very small (likely smaller than 1 square kilometer), thus confirming that most Bangladeshis, even in contaminated regions, live within walking distance of a clean well.

It is also possible that the information campaign affected other water-related behaviors. Field et al. (2011) document that some households were encouraged to switch to surface water. In addition, a longer walk to the water source may increase water storage time, which can lead to water becoming contaminated (Wright, Gundry, & Conroy 2004), or decrease the amount of water people drink. All of these mechanisms are likely to have health effects.

B. *Breastfeeding and Arsenic Exposure*

The health benefits of breastfeeding are well documented and especially relevant in poor countries. Breast milk protects infants against infections in two ways. First, it inactivates pathogens, such as those causing diarrhea, or prevents them from attaching to the gastrointestinal tract (Isaacs 2005), and, second, mechanically, breast-fed children are less likely to consume contaminated food and water. This feature helps protect them in areas with poor sanitation (Habicht et al., 1988), particularly if they are exclusively breast-fed. Exclusively breast-fed children are also protected from arsenic (Concha et al., 1998; Fängström et al., 2008). Fängström et al. (2008) found a positive relationship between arsenic concentrations in a mother's blood and her breast milk, but the concentration in breast milk was relatively low despite high maternal exposure.

Breastfeeding is nearly universal in Bangladesh: in 1999, 97% of children under the age of 5 had been breast-fed (NIPORT, 2001). Haider, Kabir, and Ashworth (1999) report that Bangladeshi women know about the benefits of breastfeeding and commonly mention protection from illness. However, exclusive breastfeeding rates remain low. The WHO recommends that infants be exclusively breastfed for the first six months, but supplementary feeding starts at a very early age in Bangladesh. The median duration of any breastfeeding was 30 months in 1999, but the median duration of exclusive breastfeeding was only 1.8 months (NIPORT, 2001). Instead, many infants under 6 months of age are fed honey, sugar water, mustard oil, rice, wheat or barley gruels and other kinds of milk (Greiner, 1997).

III. Empirical Strategy

A. *Identification Strategy*

Our identification strategy relies on geographic variation in arsenic levels and variation over time in villagers'

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[6] Forty-six percent of the wells exceeded the WHO guideline value of 10 μg/L. Arsenic contamination levels in groundwater vary widely in Bangladesh. The highest levels of arsenic are concentrated within medium-depth soil (10–150 m below the surface; Kaufmann et al., 2001), and where the sediment was derived from the Bengal Delta Plain during the Holocene Age (Mukherjee & Bhattacharya, 2001).

knowledge about these levels. The campaign was nationwide, but households near contaminated wells would have been most affected. Households whose well tested positive for arsenic would have to decide whether to continue using their contaminated well, find a new, clean well, or switch to surface water. Regardless of whether they chose a clean water source, water safety would have been more salient to them. Even households whose well tested negative may be concerned about water safety if, for example, they do not trust the test or have updated their prior beliefs on the possibility of water dangers yet to be discovered.

We interact this geographic variation with temporal variation in whether a child was born before or after the information campaign in a DID strategy. To infer a causal relationship, we assume that confounding variables, such as land quality or wealth, were not changing differentially over time in places with high and low levels of arsenic. The local variation created by the biogeochemical sources of arsenic has been found to be uncorrelated with common observable characteristics within villages (Yu, Harvey, & Harvey 2003). However, local variation in arsenic has been found to be correlated with some village-level characteristics. We include village fixed effects and district-specific trends over time to deal with possible omitted variables.[7] Relying on local variation may still be a problem if moving is an option, but 90% of men and 75% of women have lived in the same residence for more than five years and this did not change from 1999 to 2007 (BDHS, authors' tabulations).

Village-specific trends correlated with arsenic contamination could still be a problem for our strategy. While the fixed effects and trends absorb any variation in breastfeeding preferences that is time invariant or linearly time varying by district, our strategy would be vulnerable to a concurrent breastfeeding promotion campaign correlated with arsenic exposure, for example. We have found no evidence of any such campaign targeting contaminated areas. In fact, UNICEF (2009) reports that breastfeeding was not a substantial part of their nutrition profile in Bangladesh over this period. In addition, the variation we use in arsenic contamination is sufficiently local that it would be unusual for such campaigns to operate in one village but not in a nearby village. We discuss various robustness checks, including specifications with richer controls for village-specific trends, effectively eliminating many of these concerns.

We also respond to these concerns by implementing a triple difference strategy using distance to an uncontaminated well as a proxy for the cost of switching to a clean water source, further exploiting the nonlinear geographic variation in where contaminated and uncontaminated wells are located within a village. While all households may be more concerned about water quality, mothers who use a clean water source would not need to modify their breastfeeding behavior in order to protect their children from waterborne diseases. Certainly they should modify their breastfeeding behavior less than in households using contaminated water sources. We first estimate a triple difference with whether the household is currently sourcing water from a clean well; if not, these households are using either a contaminated well or surface water. Recall that breastfeeding protects children from both arsenic and waterborne pathogens. Next, since a household's water source is endogenous, we estimate a triple difference with distance from an uncontaminated well as the third difference. Opar et al. (2007) confirms that distance to the nearest arsenic-safe well affected whether a household changed its source of drinking water.

Finally, another threat to our strategy would be a change in the composition of mothers due to the campaign. While there is no consensus on arsenic's effect on reproductive health, some studies suggest that prolonged maternal exposure may cause elevated rates of spontaneous abortion, stillbirth, preterm birth, and infant death (see, e.g., Rahman et al., 2010). However, we find no evidence that the campaign and subsequent reduction in arsenic exposure affected the probability of getting pregnant or of a pregnancy terminating in a miscarriage, abortion, or stillbirth (results available on request).

B. Data

The household data are from the Bangladesh Demographic and Health Surveys (BDHS), conducted in 1999 to 2000, 2004, and 2007. These nationwide surveys were conducted by the National Institute of Population Research and Training. In each year, a sample of approximately 10,000 households is chosen from about 360 villages (clusters). The survey is administered to all ever-married women, aged 10 to 49, and a subset of men in each household. In addition to standard demographic data, the women's questionnaire contains questions on all children born in the past five years, including the child's current health, how long the child was breast-fed, and foods consumed in the past 24 hours. The data include approximately 20,000 children born each year from 1995 to 2007.

The BDHS also includes a section on the source of the household's drinking water and water used for other purposes such as dishwashing. In 2004, the survey contained questions on arsenic: the respondent was asked about her knowledge of arsenic, drinking water was tested for arsenic, source wells were inspected, and any markings (red or green) were noted.

The BDHS also collected GPS data for the 360 clusters in each round but not for each household. GPS coordinates are displaced up to 2 km in urban areas and 5 km in rural areas, with 1% of rural locations displaced up to 10 km. One data challenge is that the clusters are not the same

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[7] Madajewicz et al. (2007) show that across 54 villages in Araihazar District, villages with richer households have lower contamination levels prior to the campaign. The authors suggest a geological relationship between arsenic levels and soil types. However, Field et al. (2011) find the opposite correlation in Barisal District: arsenic contamination is higher in richer villages. We believe our fixed effects and time trends should account for most omitted variable bias, but we also run many robustness checks described in section IV.

across survey rounds. We either include cluster fixed effects (where clusters are survey-year specific) or, if not possible, we match clusters from 1999 and 2007 to the closest 2004 cluster using the GPS coordinates.

Measures of arsenic contamination. Our measures of arsenic contamination are from the BGS. In 1998 and 1999, the BGS tested the arsenic levels of 3,534 wells across the country and recorded the GPS location of each tested well.[8] Using the locations of the wells and the BDHS clusters, we calculate various measures of arsenic contamination for each cluster. Recall that the cluster's GPS coordinates only approximate a household's location (in part because they are displaced, but also because they mark the closest enumeration area and not the residence). Thus, our preferred measure is the probability that a household living within 5 miles (8 km) of the GPS coordinates of the BDHS cluster would be within 1 mile (a 15–20 minute walk) of a BGS-tested contaminated well, weighted by the inverse of the distance from the cluster's GPS coordinates.[9] We choose an 8 km radius to allow the true location of the cluster to be displaced up to 5 km from the GPS coordinates and the household to be located even farther.[10] We weight this measure because the actual location of the cluster and the household are more likely to be closer to the center of the circle because of the amount of displacement (up to 5 km) and assuming that population density is higher at the actual location of the enumeration area. For expositional ease, we refer to a value of 0.07 as a cluster with 7% contamination. More straightforward measures, such as the number and percent of contaminated wells within 5 miles of a cluster's GPS location or the average contamination level of these wells, are not as accurate because they do not take into account the geographic distribution of contaminated wells around the cluster. For example, if all the contaminated wells are clustered in a small part of the cluster's catchment area, the fraction of households exposed to contaminated wells would be different than if the contaminated wells were spread out. Appendix figure A1 depicts two clusters with the same number of BGS-tested wells but different levels of exposure due to the location of the contaminated wells. Nevertheless, the various measures are highly correlated with each other.

There are advantages and disadvantages to using this village-level variable. A household-level variable would be more precise but might be endogenous. Using the arsenic content of a household's water (measured in 2004) is problematic since it is based on the water source the household chose after the campaign, which may be correlated with many omitted variables. Ideally, we would want the contamination level of the well the household used before the campaign or the well closest to the household's exact location, but neither is available in the data. Our village-level measure is as close as we can get to the latter. One strength of our measure is that the BGS ended the same year the BAMWSP began, which avoids reverse-causality concerns about new wells being built in contaminated areas.

Recall that the BGS tested only a small fraction of the wells in the country. Figure 1 indicates that the geographic coverage of this sample is respectable. More than 90% of the children in our sample have at least three tested wells within 5 miles of their cluster, and 74% have five or more tested wells. Our results are robust to dropping those clusters with very few nearby wells. Nevertheless, it is possible that these measures introduce measurement error. Classical measurement error would simply suggest that our results are biased toward 0, but it is important to verify that our preferred measures of contamination are picking up something real. Table 1 presents estimates from regressions of the household-level variables (from the 2004 survey) on the village-level measures. Our preferred measure is shown in the top row. For each combination of measures, the correlation is positive and strongly significant (at 1%). The first column shows that households in more contaminated areas are more likely to have heard of arsenic, supporting our assumption that these are the villages where the campaign was most salient. Columns 2 to 5 use variables that depend on the household's choice of water source, which is likely to introduce bias, but it is reassuring that the village-level measures of contamination predict whether households are still using contaminated water sources in 2004.

We can provide similar support for our measures of access to clean wells. Our first measure parallels our measure of contamination: the probability that a household living within 5 miles of a BDHS cluster's GPS coordinates lives within 1 mile of a BGS-tested uncontaminated well. Our second measure is the average distance to the closest uncontaminated well.[11] We also weight these measures by the inverse of the distance from the cluster. Table 2 demonstrates that this local geographic variation does predict household behavior: we regress whether a household drinks arsenic-contaminated water or surface water (i.e., is not using an arsenic-free well, from the 2004 BDHS) on contamination, access to clean wells, the interaction of the two

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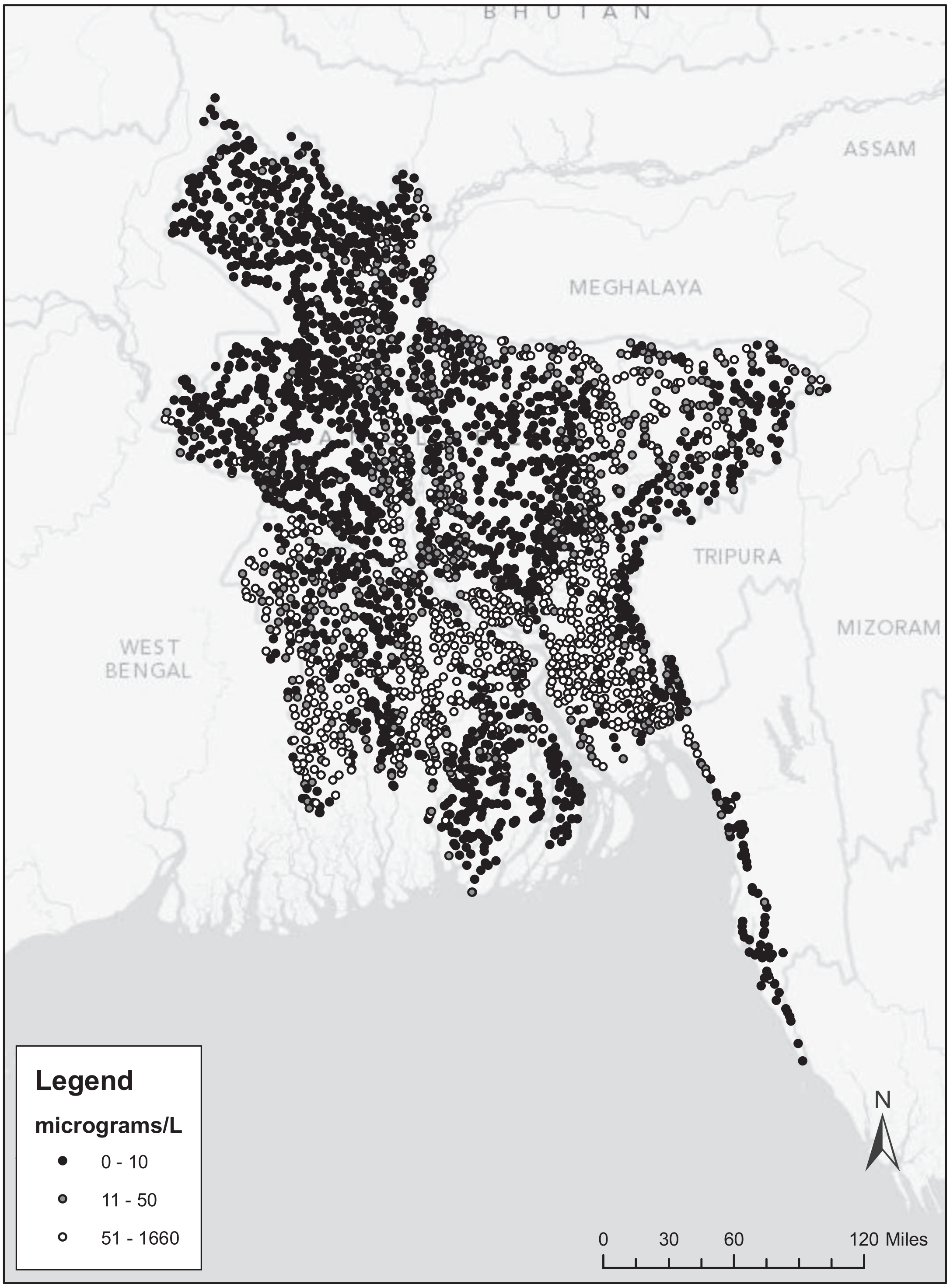
[8] The BGS tested a geographically representative sample of wells, but did not visit 3 districts out of 64. We drop the 300 children from those three districts in the BDHS.

[9] While Bangladeshis do not generally walk this far for water, we are constrained by the number of wells tested. We provide evidence that our measures pick up local variation in arsenic below. In practice, we calculate this probability by generating a grid of 10,000 points within 5 miles of the cluster's GPS location and calculating a weighted average over all the points.

[10] Our results are robust to dropping clusters that we suspect are displaced a great distance, based on the household's district of residence and the district of the cluster's GPS location.

[11] One might ask whether access to clean wells is simply the negative of exposure to arsenic. This is not the case. The two measures are negatively correlated, but variation in contamination explains a small fraction of the variation in access to clean water. We exploit the nonlinear geographic variation in the location of clean and contaminated wells within a cluster, as can be seen in appendix figure A2, which depicts two clusters with the same level of contamination but different levels of access to clean wells.

Figure 1.—Arsenic Contamination Levels of Wells Tested in the BGS Survey



Each point represents one well. Wells containing over 50 μg/L arsenic (the Bangladeshi standard) are shaded white, and wells containing over 10 μg/L arsenic (the W.H.O standard) are shaded gray.

(all regressors are from the BGS data), and district fixed effects. The interaction term is statistically significant and of the expected sign. For example, in columns 1 and 2, people who live in more arsenic-contaminated areas are less likely to be using contaminated water if the probability that they have a clean well within 1 mile is higher (the interaction term is negative and significant). The main effect of contamination is positive and statistically significant: people living in more contaminated areas with no access to a clean well are likely to still use contaminated sources. In

TABLE 1.—VARIOUS MEASURES OF EXPOSURE TO ARSENIC CONTAMINATION

Dependent Variable	(1) Heard of Arsenic	(2) Level of Arsenic in Household Water (μg/L)	(3) Level of Arsenic > 50 μg/L	(4) Household Well Painted Red	(5) Household Well Painted
Probability of living within 1 mile of a contaminated well (weighted)	0.718***	176.1***	0.880***	0.931***	1.279***
	(0.0685)	(39.66)	(0.137)	(0.189)	(0.159)
Probability of living within 1 mile of a contaminated well (unweighted)	0.929***	238.9***	1.117***	1.185***	1.664***
	(0.0840)	(55.03)	(0.177)	(0.250)	(0.177)
Fraction of contaminated wells within 5 miles	0.246***	80.46***	0.366***	0.417***	0.529***
	(0.0274)	(17.41)	(0.0494)	(0.0723)	(0.0521)
Mean dependent variable	0.845	15.26	0.0818	0.170	0.317

This table shows the relationship between cluster-level measures of arsenic contamination (calculated from BGS-tested wells) and household-level measures of arsenic contamination and awareness in the 2004 BDHS. Each cell is from a separate regression of the household-level variable on the cluster-level measure. Standard errors, clustered by BDHS cluster, are in parentheses. Significant at *10%, **5%, ***1%.

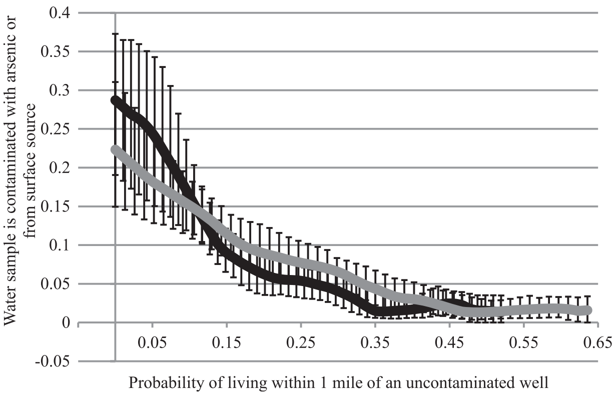
TABLE 2.—PREDICTING WHICH HOUSEHOLDS CONTINUE TO DRINK ARSENIC-CONTAMINATED WATER OR SURFACE WATER

Measure of Access to Clean Well	(1) Probability of Living within 1 Mile of a Clean Well	(2) Probability of Living within 1 Mile of a Clean Well (Weighted)	(3) Average Distance to Closest Clean Well	(4) Average Distance to Closest Clean Well (Weighted)
Contamination	0.996***	0.836***	−0.534*	−0.234
	(0.298)	(0.294)	(0.297)	(0.270)
Contamination × access to clean well	−3.148***	−1.546*	0.408***	0.312***
	(1.159)	(0.867)	(0.114)	(0.107)
Number of observations	10,373	10,373	10,373	10,373
R^2	0.259	0.253	0.269	0.262

This table shows the relationship between whether a household drinks arsenic-contaminated water or surface water from the 2004 BDHS (the dependent variable) and cluster-level measures of arsenic contamination, access to clean wells, and an interaction term. The measure of contamination used is the weighted probability of living within 1 mile of a contaminated well. All regressions include district fixed effects and the measure of access to a clean well. Standard errors, clustered by BDHS cluster, are in parentheses. Significant at *10%, **5%, ***1%.

columns 3 and 4, people who live in more contaminated areas are more likely to be using contaminated water, the farther they have to travel in order to reach an uncontaminated well (the interaction term is positive and significant). Here the main effect of contamination is negative but not statistically significant at the 5% level: people with easy access to a clean well are not more likely to still be using contaminated water even if they live in contaminated areas.[12]

FIGURE 2.—ACCESS TO A CLEAN WELL



This figure plots a kernel-weighted local polynomial of the relationship between a household's access to a clean well (weighted in gray and unweighted in black) and whether a household gets water from a contaminated well or a surface source, with cluster-bootstrapped 95% confidence intervals. The plots use an Epanechnikov kernel.

Figure 2 predicts use of contaminated water nonparametrically: we plot a kernel-weighted local polynomial of the relationship between access to clean wells from the BGS data and whether a household drinks contaminated or surface water from the 2004 BDHS survey, with cluster-bootstrapped 95% confidence intervals. As expected, the more access to clean wells people living within 5 miles of a cluster's GPS location have, the fewer households in that cluster choose to drink contaminated water. Appendix figure A3 plots this relationship separately for clusters with 0% contamination and greater than 0% contamination and for households that have heard of arsenic and those that have not. While having heard of arsenic is not exogenous, the negative relationship between access to clean wells and drinking contaminated water is driven by households that have heard of arsenic in more contaminated regions, suggesting that this relationship is related to the campaign.

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[12] We also have data from the Bangladeshi government, collected as part of BAMWSP, with arsenic levels for 4.5 million wells across contaminated regions. We do not use these data primarily because they do not include GPS coordinates, so we are unable to generate local measures of arsenic exposure and access to clean wells. Using the *mouza* of the well (an administrative unit just above village), however, allows us to generate reasonable arsenic measures that strongly support our BGS measures. In the online appendix, we reproduce our results with these data. Our DID results are robust—in fact, the magnitudes are remarkably similar—but there is limited variation in access to clean wells conditional on contamination due to the lack of GPS coordinates. Thus, we are able to replicate our triple difference results only using a combination of BGS and BAMWSP measures.

TABLE 3.—DESCRIPTIVE STATISTICS IN 1999 (BEFORE THE CAMPAIGN) AND IN 2007 (AFTER THE CAMPAIGN)

	(1)	(2) Survey Year 1999	(3)	(4)	(5) Survey Year 2007	(6)
Contamination Level	Low	High	Conditional Difference	Low	High	Conditional Difference
Control variables						
Child's age (in months)	27.2	26.4	−0.750	28.2	28.3	0.222
Muslim	0.89	0.89	−0.009	0.91	0.92	0.031
Mother's age (in years)	25.7	25.9	0.199	25.8	25.7	−0.049
Mother's years of education	3.0	3.3	−0.078	4.8	4.9	−0.016
Father's years of education	3.9	4.2	−0.037	4.8	4.8	−0.194
Mother works outside home	0.20	0.14	0.008	0.26	0.22	−0.009
Household has electricity	0.33	0.33	−0.021	0.48	0.47	0.013
Drinking water source						
Tubewell	0.87	0.92	0.030	0.86	0.93	0.006
Surface water	0.022	0.041	0.014	0.022	0.039	0.012
Mother's weight-for-height z-score	−1.56	−1.56	−0.015	−1.23	−1.22	0.025
Outcomes						
Months breast-fed	19.31	18.62	−0.573	19.95	19.83	0.067
Breast-fed for longer than:						
12 months	0.93	0.93	0.001	0.93	0.94	−0.003
24 months	0.77	0.76	−0.001	0.77	0.77	0.019
Exclusively breast-fed	0.13	0.14	−0.005	0.09	0.10	−0.010
Exclusively breast-fed for children:						
Less than 6 months old	0.53	0.55	−0.008	0.43	0.47	−0.027
6–14 months old	0.09	0.05	−0.043	0.03	0.04	−0.013
Older than 12 months	0.01	0.01	0.011	0.02	0.004	−0.0295***
Child died	0.08	0.07	0.013	0.06	0.06	−0.008
Height for age z-score	−1.81	−1.81	−0.062	−1.55	−1.53	−0.0004
Weight-for-height z-score	−0.98	−0.90	0.0755**	−1.15	−1.05	0.144***
Arsenic measures						
Probability of living within 1 mile of a contaminated well (weighted)	0.001	0.136	0.101***	0.002	0.141	0.112***
Probability of living within 1 mile of a contaminated well	0.002	0.120	0.0860***	0.003	0.125	0.0955***
Fraction contaminated in 5 miles	0.008	0.484	0.372***	0.013	0.471	0.381***
Number of observations	3,147	3,478		3,124	2,952	

This table shows summary statistics separately for clusters with lower- and higher-than-median exposure to arsenic. Columns 3 and 6 show the difference between areas, conditional on district fixed effects. The standard errors used to indicate significant differences are clustered by BDHS cluster. Significant at *10%, **5%, ***1%.

Summary statistics. Table 3 presents the means of demographic, outcome, and contamination variables separately for areas with lower- and higher-than-median arsenic exposure. Data from 1999, prior to the information campaign, are in columns 1 and 2. Column 3 presents the differences between contaminated and uncontaminated areas, conditional on district fixed effects, and indicates significant differences. Reassuringly, there is only one statistical difference among the control variables and the outcomes (weight-for-height z-score); multiple-comparisons logic suggests this is not surprising. As expected, arsenic exposure is significantly different in the two areas.[13]

Columns 4 to 6 repeat this exercise for 2007. All of these children were born after the information campaign. The main result of our paper can be observed by computing the simple DID estimate for the months-breast-fed outcome. From 1999 to 2007, the average number of months a child was breast-fed increased by 0.64 months in uncontaminated areas and by 1.21 months in contaminated areas, about half a month more. We bolster this result by exploiting more variation in time and arsenic exposure and including various control variables.

Empirical model. To see how mothers respond to the information campaign, we estimate the following:

$$B_{ijkst} = \alpha_{js} + \alpha_t + \alpha_k t + \beta A_{js} \times post_t + \gamma X_{ijkst} + \varepsilon_{ijkst}, \quad (1)$$

where B_{ijkst} is a measure of how long child i living in cluster j and district k, born in year t and surveyed in year s, was breast-fed, A_{js} is a measure of arsenic exposure for (survey s-specific) cluster j and $post_t$ is a dummy variable for being born in 2002 or later. Although the program was in place from 1999 to 2006, its completion report indicates that progress was very slow for the first two and a half years (World Bank, 2007). We include fixed effects for BDHS cluster (α_{js}) and birth year (α_t), as well as district-specific trends ($\alpha_k t$). The set of control variables, X_{ijkst}, includes the current age of the child (age at death for children who died) and a dummy variable for whether the child died. Our preferred measure of breastfeeding, the number of months a child is breast-fed, imposes a functional form assumption about the effect of the campaign and is right-censored for children

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[13] Arsenic measures in all years are from the BGS, but since clusters differ for each survey round, the measures of arsenic contamination differ as well.

Table 4.—Information Campaign's Effect on Breastfeeding Patterns

	(1)	(2)	(3)	(4)	(5)	(6)
				With District Trends		
Areas Included	All	Urban	Rural	All	Urban	Rural
A. Dependent variable: Months breast-fed						
Post × contamination	5.95***	3.57	7.02***	5.66***	1.42	6.16***
	(2.14)	(4.20)	(2.48)	(1.97)	(3.93)	(2.20)
Number of observations	19,420	5,811	13,609	19,420	5,811	13,609
R^2	0.61	0.56	0.63	0.62	0.57	0.64
B. Dependent variable: Exclusive breastfeeding						
Post × contamination	0.24**	0.12	0.28**	0.17*	−0.05	0.28***
	(0.10)	(0.18)	(0.11)	(0.10)	(0.19)	(0.11)
Number of observations	9,929	2,873	7,056	9,929	2,873	7,056
R^2	0.35	0.34	0.36	0.37	0.36	0.38

This table shows the relationship between breastfeeding patterns and exposure to arsenic-contaminated wells after the information campaign. The dependent variable is the number of months the child was breast-fed (panel A) and an indicator variable for whether the child is currently exclusively breast-fed (panel B). The independent variable of interest is the interaction between arsenic contamination and an indicator for being born in 2002 or later. We include fixed effects for BDHS cluster and the child's year of birth, as well as the child's current age (or age at death) in months and a dummy for whether the child had died in panel A. Columns 4–6 also include district-specific linear trends. Standard errors, clustered by BDHS cluster, are shown in parentheses. Significant at *10%, **5%, ***1%.

who died and those still being breast-fed. We address these issues in a number of ways, discussed in section IVA.

The identifying assumption is that breastfeeding trends were not correlated with arsenic exposure, conditional on BDHS cluster, other than because of the information campaign. The district-specific trends strengthen the validity of this assumption: our estimates are identified off deviations from district trends. In addition, we provide support for our parallel trend assumption with an event study specification where we interact arsenic exposure with dummy variables for each birth year. Specifically, we estimate:

$$B_{ijkst} = \alpha_{js} + \alpha_t + \alpha_k t + \sum_{l=1996}^{2007} \beta_l A_{js} \times d_l + \gamma X_{ijkst} + \varepsilon_{ijkst}, \tag{2}$$

where d_l for $l \in [1996,2007]$ are indicator variables for birth year and everything else is as defined above. With this specification, we can test whether areas with more or less arsenic exposure were experiencing differential trends in breastfeeding duration by examining the coefficients for children born before the campaign.

We also strengthen the validity of the identifying assumption by focusing on those who should be most responsive: households that use arsenic-contaminated wells or drink surface water. These mothers should choose to breastfeed longer to protect their children from arsenic and waterborne diseases, while those who have already switched to a clean water source (a well not contaminated with arsenic) do not need to. We estimate this with the following specification:

$$\begin{aligned} B_{ijkst} = {} & \alpha_{js} + \alpha_t + \alpha_k t + \delta_1 A_{js} \times post_t \\ & + \delta_2 A_{js} \times post_t \times D_{ijkst} + \gamma X_{ijkst} + \varepsilon_{ijkst}, \end{aligned} \tag{3}$$

where D_{ijkst} is an indicator for whether the water tested contained arsenic or was surface water. According to our hypothesis, δ_1 should be 0 because women who drink clean water should not change their behavior and δ_2 should be positive. Since a household's choice of water source may be correlated with other household characteristics, potentially biasing our results, we reestimate specification (3) using predictors of whether the household uses clean well water: measures of access to an uncontaminated well.

IV. Response to Information Regarding Arsenic Exposure

A. *Breastfeeding Practices*

Table 4 presents results from specification 1, estimating how breastfeeding practices responded to the campaign. The dependent variable in panel A is the number of months the child is breast-fed. The coefficient on the interaction term is positive and strongly significant for all children (column 1); a 1 standard deviation increase in contamination (a 10% point increase, from the 25th to the 75th percentile) would lead a mother to breast-feed an additional 0.6 months.[14] Recall from table 3 that the average number of months breast-fed increased by only 0.6 months in less contaminated areas and 1.2 months in more contaminated areas from 1997 to 2007. Including district-specific trends (column 4) hardly changes the estimate.

We next divide the sample into urban households (columns 2 and 5) and rural households (columns 3 and 6). The result is driven by rural areas (although the coefficients are usually not statistically distinguishable). We focus on rural areas for the remainder of the paper.

Recall that the dependent variable is right-censored for children who are still being breast-fed and children who died while still being breast-fed. In appendix tables A2 and A3, we confirm that the results are robust to different assumptions, such as assuming children who died would have been breast-fed until the survey, and using a different outcome variable: whether a child was breast-fed for a specific number of months conditional on having survived.

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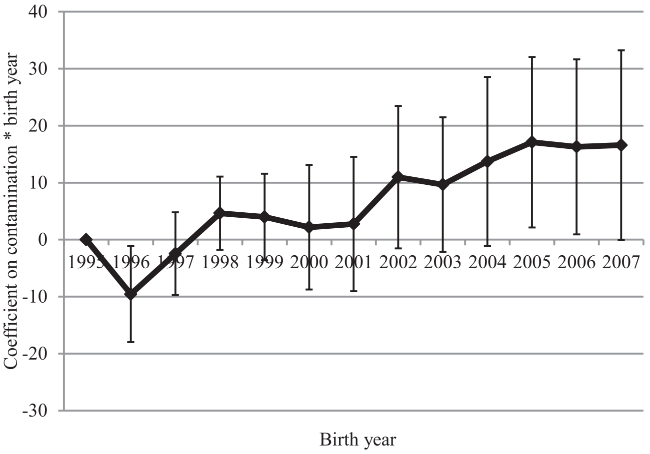
[14] In appendix table A1, we confirm robustness to different measures of arsenic exposure.

TABLE 5.—HETEROGENEOUS EFFECTS ON EXCLUSIVE BREASTFEEDING BY AGE

Ages Included	Less Than 6 Months	6–14 Months	More Than 12 Months
A. Dependent variable: Exclusive breastfeeding			
Post × contamination	0.85*	0.36**	0.03
	(0.48)	(0.16)	(0.06)
Number of observations	1,351	1,839	4,332
R^2	0.38	0.26	0.11
B. Dependent variable: Had plain water in past 24 hours			
Post × contamination	−1.22***	−0.73***	0.10
	(0.42)	(0.22)	(0.07)
Number of observations	1,469	1,894	7,848
R^2	0.43	0.27	0.08

This table shows the relationship between feeding patterns at different ages and exposure to arsenic-contaminated wells after the information campaign. The dependent variable is an indicator for whether the child is currently exclusively breast-fed (panel A) or was given plain water in the past 24 hours (panel B). The independent variable of interest is the interaction between arsenic contamination and an indicator for being born in 2002 or later. We include fixed effects for the nearest 2004 BDHS cluster, the child's year of birth, and the survey year, as well as the child's current age in months, the arsenic exposure main effect, a dummy for whether the child had died, and district-specific linear trends. Only childen living in rural areas are included. Standard errors, clustered by BDHS cluster, are shown in parentheses. Significant at *10%, **5%, ***1%.

FIGURE 3.—MONTHS BREAST-FED AND ARSENIC EXPOSURE



This figure plots the coefficients on the interactions between birth year dummies and arsenic exposure in a regression similar to those in table 4. Only rural areas are included in this figure. The error bars are 95% confidence intervals, after clustering on BDHS cluster.

In table 4, panel B, we consider another dependent variable: whether the child is exclusively breast-fed. The BDHS does not ask explicitly whether children are exclusively breast-fed, but it does ask for the types of foods and liquids given to the child. We define a child as exclusively breast-fed if he or she has not received any liquids, even plain water, in the past 24 hours, conditional on currently being breast-fed. Out of the 10,000 children still being breast-fed in our sample, less than 12% are exclusively breastfed. Fifty percent of children younger than 6 months are exclusively breast-fed, but only 5% of children aged 6 to 14 months are. We see the same behavior change: children born in contaminated areas after the information campaign are more likely to be consuming only breast milk. A 1 standard deviation increase in contamination would increase the probability of being exclusively breast-fed by an additional 2.8 percentage points, a 24% increase when evaluated at the mean (column 6).

Given the variation in exclusive breastfeeding by child age, we look for heterogeneous effects in table 5.[15] The dependent variable in panel A is whether the child is being exclusively breastfed and the sample is divided by age: younger than 6 months, 6 to 14 months, and older than 12 months.[16] The effect on exclusive breastfeeding is stronger for younger children, exactly where we expect the most variation in this variable. A 1 standard deviation increase in exposure increases the probability a child is exclusively breast-fed by an additional 8.5 percentage points for children younger than 6 months and 3.6 percentage points for children between 6 and 14 months. The effect is substantially smaller and not significant for older children.

Even if a mother is not exclusively breastfeeding, she may choose to give her children non-water-based liquids, such as milk, in response to the campaign. In panel B of table 5, we use whether a child drank plain water in the past 24 hours as the dependent variable. A 1 standard deviation increase leads to a 12 percentage point decline in whether a child under 6 months is given water, a 30% decline, and a 7.3 percentage point decline for children between 6 and 14 months old. The effect is not statistically significant for older children, which is as expected since these children are not likely to be getting enough hydration through breast milk.

We next provide support for the identifying assumptions with an event study. Figure 3 plots the coefficients on the interaction between birth year and arsenic exposure for each cohort, β_l where $l \in [1996,2007]$, after estimating specification 2 with months breast-fed as the dependent variable. The coefficients for the cohorts born before the information campaign are small and not statistically significant. Starting in 2002, however, the coefficients are positive, and by 2005, they are statistically significant. We test and reject the hypothesis that the average of the coefficients from 1996 to 2001 is equal to the average from 2002 to 2007 (p-value 0.003).

We present two further checks to address the possibility of village-level trends in appendix table A4. First, we reproduce the results from table 4 with village trends instead of district trends. Cluster trends eliminate a lot of power when our specifications involve age-specific samples (since clusters differ by survey), but the increase in breastfeeding duration is robust to this specification. Second, in the 2004 data, we use whether the household has heard of arsenic as the measure of contamination. This measure provides household-level variation in contamination and is arguably less endogenous than measures based on the household's choice of water source. Even in villages with 0 contami-

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[15] The results in table 4 are estimated primarily off 2004 data because we include survey-year-specific cluster fixed effects, arsenic exposure is survey year specific, and only 2004 clusters have children born before and after 2002. When focusing on a cohort, there is no variation in 2004 and we include fixed effects for the nearest 2004 cluster instead of survey-specific cluster.

[16] We are unable to use 12 or 13 months because the variance matrix is highly singular. The coefficients are of similar magnitudes, but we could not calculate standard errors.

Table 6.—Differential Responses with Respect to Water Source or Access to Uncontaminated Wells

	(1)	(2)	(3)	(4)	(5)
		Measure of Access to Uncontaminated Well			
		Probability of Living within 1 Mile of an Uncontaminated Well		Average Distance to Closest Uncontaminated Well	
Triple Difference Measure	Water Sample Is Contaminated with Arsenic or from Surface Source	Unweighted	Weighted	Unweighted	Weighted
Post × Contamination	2.571	11.50***	8.205**	−1.347	1.352
	(2.850)	(3.435)	(3.393)	(4.350)	(3.967)
Post × Contamination × triple difference measure	12.98***	−41.28**	−13.43	2.485**	1.660
	(4.959)	(19.02)	(15.55)	(1.202)	(1.088)
Number of observations	4,769	13,609	13,609	13,609	13,609
R^2	0.680	0.641	0.641	0.641	0.641

The specification is identical to the one in table 4, panel A, column 6, except for the triple difference measure, the two-way interactions, and the triple interaction. The dependent variable is the number of months the child was breast-fed. The independent variables of interest are the interaction between arsenic contamination and an indicator for being born in 2002 or later, and the triple interaction between this variable and an indicator for households that did not source water from a clean well (column 1) or a measure of the distance to an uncontaminated well (columns 2–5). Column 1 includes data only from 2004. Standard errors, clustered by BDHS cluster, are shown in parentheses. Significant at *10%, **5%, ***1%.

nated wells, however, more than half the respondents had heard of arsenic; therefore, we split the sample into villages with below- and above-average contamination. We run these regressions with our usual set of controls and also with cluster × birth year fixed effects, effectively eliminating any cluster × birth year idiosyncrasies.[17] Our results are robust to these specifications in more contaminated villages: mothers who have heard of arsenic breast-feed their children longer. In addition, the point estimate does not change much when cluster × birth year fixed effects are included, suggesting that village-level trends are not biasing these results.

B. *Heterogeneity in the Response with Respect to Access to a Clean Well*

To further strengthen the validity of the identifying assumptions, we estimate a triple difference (specification 3) using variation in the ease of switching to a clean well. Households that live very close to an uncontaminated well should find it easy to switch water sources, and therefore mothers would not need to modify their breastfeeding choices. Table 6 presents the two coefficients of interest. In column 1, we estimate the differential effect of the information campaign for those who are using clean well water and those who are using either arsenic-contaminated wells or surface water. We find no evidence that those who are drinking clean well water breast-feed longer after the campaign (top row), but the triple difference indicates that the response differs significantly and is positive for those who do not use clean wells.

In columns 2 to 5, we address the endogeneity of water source by replacing the triple-difference measure with proxies for the cost of switching to a clean well. Given the difficulty in predicting which households switch water sources, we use four measures of access to an arsenic-safe well. In column 2, we use the probability of living within 1 mile of an uncontaminated well. The coefficient on the two-way interaction is the effect for households with no nearby clean wells. As expected, women in these households breast-feed longer. The triple interaction is significant and negative, as predicted: as more households are within 1 mile of a clean well, the breastfeeding response falls. At the mean value of clean well access, 0.15, the effect is still positive and significant, but the effect is not significantly different from 0 for clusters where the probability of being within 1 mile of a clean well is 20% or more. Column 3 uses the weighted measure. The main effect for those with no nearby clean wells is positive and significant and the triple interaction is not significant, but it is negative and nontrivial in magnitude: the effect of the campaign is no longer significant in clusters where the probability of being within 1 mile of a clean well is more than 25%.

Column 4 uses the average distance to the closest clean well. Again, the signs of the coefficients are as expected. Clusters where the average household is 0 miles from an uncontaminated well do not alter their breastfeeding behavior (the two-way interaction is not significant), but as the average household gets farther from an uncontaminated well (the triple interaction), mothers breast-feed significantly longer. When we use the weighted measure (column 5), the triple-interaction term is not statistically significant (although it is close; p-value 0.128), but the effect of the campaign when the average household is 2 or more miles away from an uncontaminated well (the median) is positive and significant. When we jointly test all four triple-interaction terms across columns 2 to 5, the p-value is 0.0146. Thus, while not every triple-interaction term is statistically significant at conventional levels, taken together, these results suggest that there is heterogeneity in the response to the information campaign and that our DID results are driven by mothers still drinking contaminated water.

These results strengthen our causal argument. In table 4, the identifying assumption was that no omitted determinants of breastfeeding trends are correlated with arsenic, conditional on the controls. While district trends take out

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[17] Concern about potential bias from concurrent NGO activity or a breastfeeding promotion is also mitigated by the fact that NGO activity from the BDHS community survey is not correlated with arsenic contamination in 2004.

TABLE 7.—HEALTH EFFECTS BY AGE

A. Child Mortality	Age in Months			
Dependent Variable	6	12	24	36
Child died before the age of . . .	−0.108**	−0.120*	−0.0413	−0.126
	(0.0502)	(0.0628)	(0.0877)	(0.106)
B. Health Status of Children	**Age in Months**			
Ages included	0–12	12–24	24–36	36–48
Incidence of diarrhea in past 2 weeks	−0.426***	0.0807	−0.0690	0.121
	(0.157)	(0.224)	(0.186)	(0.167)
Weight for height Z-score	1.225**	1.488*	0.0781	−0.481
	(0.620)	(0.826)	(0.617)	(0.591)
Height for age Z-score	0.292	1.098	0.275	−0.386
	(0.808)	(0.963)	(0.721)	(1.098)

The specification is identical to the one in table 5 except for the dependent variable and age sample restrictions. Each number reported is the coefficient on the interaction between arsenic contamination and an indicator for being born in 2002 or later. The dependent variable in panel A is a dummy variable for whether the child died before a certain age; we include in the sample only children who attained the respective age. The dependent variables in panel B are the incidence of diarrhea in the previous two weeks, weight for height, or height for age. Other differences from table 5 are that we control for the child's current age or potential age, had the child died (panel A), and for the child's current age or age at death in months and a dummy for whether the child had died (panel B). Only children living in rural areas are included. Standard errors, clustered by BDHS cluster, are shown in parentheses. Significant at *10%, **5%, ***1%.

some secular trends, one could still argue that places with more exposure are trending differently, and these differential trends may be changing over time. Including birth year dummies interacted with maternal education, paternal education, or a wealth index does not alter our results. Table 6 provides additional evidence: to bias our results, these omitted variables would have to affect just households with little access to clean wells.

V. Health Effects

We next turn to the health consequences of the information campaign. Table 7 presents estimates of specification 1 with health outcomes as dependent variables. In panel A, the dependent variable is a dummy variable for whether the child died before the age of 6, 12, 24, or 36 months in columns 1 to 4, respectively. The information campaign has a negative and strongly significant effect on child deaths before the age of 6 months and a marginally significant effect on deaths before the age of 12 months. The magnitude is not trivial: a 1 standard deviation increase in contamination would lead to a 1.1 percentage point greater decline in infant mortality. The point estimates for older ages are also negative but not statistically significant.

We find corroborating evidence from other health outcomes (panel B). We divide the sample by age and study the effect of the information campaign on diarrhea incidence. There is a significant fall in diarrhea incidence among children in their first year of life. We also find that weight for height is greater for children younger than 12 months (and marginally for children aged 12–24 months), but we find no evidence of an effect on height for any age group.

Note that we cannot identify the mechanism behind these health effects. They could be due to increased rates of exclusive breastfeeding, which the health literature suggests can have a large impact on diarrheal diseases and infant survival in areas with poor sanitation (Habicht et al., 1988). Our point estimates on the increase in exclusive breastfeeding of infants were sizable. If infants are more likely to be exclusively breast-fed, they are less likely to suffer from waterborne diseases that can be especially fatal at that age. At the same time, we saw no increase in exclusive breastfeeding for older children and little evidence of health impacts either. For this reason, we believe our results complement, not contradict, the findings in Field, Glennerster, and Hussam (2011, henceforth FGH). Their results are estimated robustly for older children, while our results are only for the youngest children, the ones most likely to be exclusively breast-fed. The statistically significant evidence of an increase in infant mortality that FGH find is primarily from the data they collected from 155 villages in Barisal district. When they use nationwide BDHS data, they find statistically significant evidence for older children but not for infants. We believe this is due to district-specific differences in the response to the campaign (the water source households switch to and the breastfeeding response) and find empirical evidence to support this explanation that confirms both our findings and their results.[18]

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[18] The impact on diarrheal incidence depends on both the household's new water source and whether mothers breast-feed more. Mothers who switch to an arsenic-safe shallow well (for clarity, call these type A households) do not breast-feed longer, thinking their water is safe from arsenic and pathogens. However, van Geen et al. (2011) and Wu et al. (2011) suggest that their children (of all ages) may suffer higher rates of diarrhea because low-arsenic shallow wells have higher rates of diarrhea-causing pathogens than high-arsenic shallow wells. An increase in diarrheal incidence is also possible for children of all ages in households that switched to surface water (type B), but here mothers are more likely to protect their infants through exclusive breastfeeding. Children in households that continue to use arsenic-contaminated wells (type C) should experience no change in diarrhea incidence unless their mothers are more likely to breast-feed exclusively. Thus, without data on a household's initial and new water source, the estimated effects are a weighted average that depends on the relative proportions of children in each category. In fact, FGH write that Barisal district had a particularly high rate of switching away from contaminated water sources by 2004 relative to other districts. In this case (many type A households), we might expect infant and child mortality to rise. In results available on request, we divide districts by the rate of using arsenic-safe wells and find that the increase in months breast-fed is driven by districts with low rates of using clean wells (many type B and C households). We find a reduction in diarrheal incidence and mortality for infants and an increase in both outcomes for older children in districts with fewer clean well users.

However, the campaign could also have improved child survival by reducing arsenic exposure. We argue that reducing arsenic exposure should have affected older children as well, but we concede that these health effects could be the combined effects of all changes in health behaviors. We also note that one reason these health effects are concentrated among the youngest children could be that parents have less control over what older children drink than what infants drink, regardless of whether the infant is breast-fed.

VI. Discussion

Our principal finding is that mothers improve their breastfeeding practices in arsenic-contaminated areas after a water-safety campaign and that this change is greater when households have less access to clean wells. We interpret this as a conscious choice to protect children from contaminated water, but there are at least three alternate explanations. Even if the true motivation is concern for child health, we still need to explain why mothers would breastfeed longer instead of switching to an arsenic-safe well and protecting the entire family. We summarize ethnographic evidence on intrahousehold decisions and describe heterogeneous responses among our sample of women to address this puzzle.

A. *Spheres of Influence*

We argue that mothers choose to breast-feed longer because breastfeeding is within their sphere of influence, while the choice of water source is not. Ethnographic research conducted by Farhana Sultana (2009, 2011) in Bangladesh describes a household structure where men and women play different roles in the provision of drinking water. Although women collect most of the water, male household heads own the tubewells and are responsible for providing alternate water sources. When unable to provide safe water within the household, men decide from where women may collect water. Social norms frown on women traveling in public and can outweigh the need for safe water. Sultana also notes that preexisting social networks play an important role in well sharing. Women also reported social and emotional stress when they had to navigate these social hierarchies and power relations.

Thus, it seems likely that women will resort to other means to avoid contaminated water when available, such as breastfeeding. A large literature suggests that women, relative to men, allocate more resources to child health (see, e.g., Duflo, 2003). In the online appendix, we present heterogeneous effects among women in whether they switch to a clean water source and whether they breast-feed longer that are consistent with the idea that women breast-feed more because switching to an arsenic-free well is outside their control (appendix table A5). We find that women with greater club participation are more likely to use arsenic-free wells, perhaps due to better social skills or a permissive household culture that allows well sharing. Second, educated women are more likely to respond on both dimensions. They may have a greater ability to understand the information provided and make the connection with breastfeeding and more control over whether the household switches wells (due to either decision-making power or different preferences on the part of the patriarch). Women who participate in more household decisions are more likely to breast-feed their children longer, a behavioral response more likely to be within their sphere of influence. This last finding suggests that women have decision-making power about breastfeeding; otherwise, our results would also be consistent with a patriarch dictating all household decisions (a unitary household) in an environment where women are essentially barred from public spaces. While these heterogeneous effects are consistent with our interpretation, we cannot claim definitely that they are not picking up differences in responses due to unobservable variables correlated with these characteristics.

B. *Productivity Shock due to Reduced Arsenic Exposure*

In the next three sections, we address alternate explanations for the breastfeeding response. It is possible that the campaign improved mothers' health due to reduced arsenic exposure. This productivity shock could improve their ability to breast-feed and their efficiency in other work. It could also affect the relative prices of these activities, but the direction is unclear. It is not obvious where women will expend this increased productivity. If the two effects have an impact on breastfeeding in the same way, women closer to clean wells, whose health is more likely to improve, should exhibit a bigger breastfeeding response. Our results prove otherwise.[19]

It could be, however, that the change in the relative prices favors other activities, such as household tasks or market work. If the productivity shock and the change in relative prices have opposite effects on breastfeeding, one could argue that something else, such as a secular trend in breastfeeding, could explain our findings. We cannot test this explanation due to the lack of time use data in the BDHS, but this alternative explanation is unlikely. First, the more serious effects of arsenic poisoning are long term, and to the best of our knowledge, there is no evidence of a biological link to improved milk supply. It is possible that short-run symptoms such as weakness and respiratory problems may affect breastfeeding or other tasks, but these effects are likely to be similar across activities. Second, while we know individuals substitute from home production

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[19] Only the health of women who switched from contaminated wells to clean wells would improve. Women who continued to use contaminated wells or were not initially using contaminated wells would not experience any change in arsenic exposure. Given the local variation in arsenic, we assume that the share of women in the first group is higher closer to clean wells. If not true, our triple difference result would not rule out the health channel.

toward market work, few women in Bangladesh work outside the house. It seems unlikely that women would forgo breastfeeding to spend more time on other household production, such as cooking and cleaning, especially given the lack of good substitutes for breast milk.

C. *Time to Fetch Water*

A second alternative explanation is related to households using water from a more distant source. Since most water gatherers in Bangladesh are female, this could affect a woman's breastfeeding choices. The increase in the time spent getting water reduces the time available to breastfeed, but also increases the mother's comparative advantage in breastfeeding. One explanation for our results is that women substitute away from getting water and toward breastfeeding not because of arsenic but because water is more expensive in terms of time. It is unlikely that this explanation drives all of our results because the increased time cost was fairly small: multiple studies documented an increase of about 4 to 18 minutes per day for those who switched wells (Madajewicz et al., 2007; Ahmad et al., 2003), suggesting a smaller increase (potentially due to crowding) for those who continued to use their previous well.

A simpler version of this explanation is that infants are given less water and therefore are breast-fed more: this differs from our interpretation because infants are breast-fed more because water is more expensive, not because mothers are concerned about the health effects of contaminated water. This explanation seems unlikely to drive our results because an infant's water intake is small relative to a household's water needs. A non-breast-fed infant needs only 800 to 1200 mL of water per day in addition to liquid intake from other food (World Health Organization, 2004).

D. *Motives for Breastfeeding*

Another explanation is that women breast-feed longer to take advantage of breastfeeding's contraceptive effects. This could be because of more salient concerns about child health or because of lower desired fertility if the cost of raising children rises. Jayachandran and Kuziemko (2011) show that breastfeeding patterns in India respond to this contraceptive effect and reflect fertility preferences. We find no evidence that the campaign affected the desired number of children, actual birth spacing, or desired birth spacing (measured by whether women respond they want another child, but only after two years).

A related explanation is that the composition and preferences of mothers changed after the campaign, perhaps due to changes in home values (Field et al., 2011; Hornbeck & Keskin, 2014) or marriage markets. Qualitative work by Hassan, Atkins, and Dunn, (2005) suggests that women with skin lesions may have difficulty in arranging a marriage, but Pitt et al. (2015) do not find evidence of marital sorting by arsenic absorption. We believe this is unlikely to explain the changes in breastfeeding because breastfeeding preferences in Bangladesh are not correlated with demographic characteristics and this did not change over time. In addition, we find no evidence of differential changes in mother's age at marriage or at first birth, father's age, or mother's or father's education (results available on request).

In sum, our results suggest that the breastfeeding response we document is evidence of behavior change. We posit that women breast-feed more to protect their children from arsenic and pathogens. Mothers are not likely to be fully informed about how breastfeeding affects infants' arsenic exposure, but they may naturally assume that their own breast milk is safe due to past breastfeeding promotions. The fact that they are less likely to give infants water and that infant health improved supports this hypothesis, but we cannot fully rule out other explanations.

VII. Conclusion

With a few exceptions, the literature on whether information campaigns elicit health behavior change has found disappointing results. Water safety is one area where relatively easy precautions can dramatically reduce the burden of disease in the developing world, and yet persuading households to treat their drinking water remains a challenge. In this context, the arsenic awareness campaign in Bangladesh poses a puzzle. Many papers, including this one, have found that this campaign had success in generating awareness and motivating behavior change, even including some changes with adverse consequences. Mobarak et al. (2012) document a relatively high willingness to pay for arsenic-free water compared to other important goods such as clean cook stoves. One explanation is that arsenic poisoning is more frightening than other health risks, for an unknown reason. Another explanation is that a feature of this campaign made it particularly effective. For example, the campaign gave villagers comprehensive information on multiple mitigation methods (Inauen et al. 2013) instead of focusing on one type of preventive behavior; providing comprehensive information has proven to be more effective in other contexts as well (Duflo et al., 2015; Dupas, 2011a). In addition, the blanket testing and the color-coding of the wells provided a visual and continuous reminder of arsenic contamination, which might have aided in the campaign's effectiveness. Finally, the campaign primarily used public forums rather than individual household visits, which have been found to be more effective in other settings (Kremer et al., 2009). We leave this important puzzle to future work.

In this paper, we have provided evidence of a simple change that mothers in Bangladesh made in response to new information about the dangers in drinking water: they breast-fed their children longer and were more likely to exclusively breast-feed infants. This response may have had beneficial health effects: infants had lower mortality rates and lower diarrhea incidence. Our results are strongest for mothers who have less access to uncontaminated wells, supporting our view that this behavior change is a conscious response to concerns about water quality and its effect on child health. To address the puzzle of why mothers breastfeed longer, protecting just their youngest children, instead of switching to an arsenic-safe well and protecting the entire household, we point to ethnographic evidence that mothers may not have decision-making authority in the household to switch water sources, even if they are the primary water gatherers (Sultana, 2009, 2011). Collecting water from a distant well comes with both a time cost and a social reputation cost for the household. Our results imply that public health campaigns may be more successful if they address the reality of households made up of multiple decision makers, each with his or her own set of preferences, as well as his or her own set of socially acceptable behavioral responses.

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