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ABSTRACT

Information Campaign on Arsenic Poisoning: Unintended Consequences in Marriage Market

Unintended consequences of public policies, while common, are under-studied and often unaccounted for in economic analysis. In this paper we study the unintended consequences of a public information campaign on water quality on the marriage market in rural Bangladesh. Despite being heavily contaminated with arsenic, groundwater was the main source of drinking water for rural dwellers in Bangladesh since the 1970s. This created a major health emergency in the country as arsenic exposure causes multiple health problems, ranging from skin lessons to various types of cancer. However, until the mid 1990s, the contamination remained largely unknown and became public knowledge only later through a nationwide information campaign. We study the impact of the campaign on marriage patterns in rural Bangladesh. Using a difference-in-difference model, we analyse the age at marriage, bride price agreed at the time of marriage and find that both of them decreased in arsenic affected areas compared to areas unaffected by arsenic contamination. The effect on age at marriage is primarily driven by younger cohorts who got married earlier. Additionally, we find an increase in the likelihood of females having their first child at an early age (between 16 to 20 years). These are important social consequences, however, often ignored in most analyses.

JEL Classification: I12, J12, R11

Keywords: arsenic contamination, health shock, information campaign, age at first marriage, bride price, age at first birth, Bangladesh

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1 Introduction

Unintended consequences of public policies, while common, are understudied and often unaccounted for in economic analysis. For example, one common unintended consequence of conditional cash transfer programs which aim to boost immunization or school enrolments of children is a reduction in the labour force participation of mothers (De Brauw et al., 2015). Similarly, adults' participation in public works programs which reduces seasonal poverty may increase the amount of domestic work children have to do in order to compensate for their parents' absence at home. This in turn can reduce their school enrollment rates as found in India (Shah and Steinberg, 2021). Unintended consequences can be positive too. For example, an education CCT in Malawi which aimed to enhance school enrollment also improved the psychological well-being of adolescent female beneficiaries (Baird et al., 2013). In this paper we study the unintended consequence of a public information campaign on water quality on the marriage market in rural Bangladesh.

Arsenic contamination of drinking water is a major and fairly widespread public health problem in many parts of the world, having been detected in at least 70 countries (Ravenscroft et al., 2009). However, it is especially severe in South Asia (Mukherjee et al., 2006), particularly in Bangladesh, where more than 30 percent of its population has been affected by arsenic contamination (Ahmad et al., 2018). While various solutions have been suggested to address this problem,[1] educating the population through information campaigns still remains one of the most important public policy tools available (Weiss and Tschirhart, 1994). Given the gravity of the problem, Bangladesh was one of the first countries to inform its exposed population through a nationwide campaign about water quality and the various harmful effects of arsenic consumption on human health. We estimate the effect of the information campaign on the marriage market in rural Bangladesh, focusing primarily on two outcomes: age at first marriage (for males and females), and the value of marriage payments (bride price[2] and dowry). We also extend our analysis to assess the spillover effects of the campaign on early childbearing in females.

Our study is motivated by the fact that while the various health effects of arsenic poisoning (also known as arsenicosis) – such as the development of skin lesions (see Appendix Figure A1, panel

[1] For example, see Ravenscroft et al. (2009) for a discussion of different strategies to counter arsenic contamination, such as the development of alternative water sources and methods for arsenic testing and removal.

[2] Specifically, when we look at the bride price known as *mehr*, a monetary payment from the husband to the wife. According to Islamic law, Muslim marriage contracts require specifying a mehr (Bianquis (1996), Carroll (1986)).

A), various types of cancers, higher mortality rates and lowered fertility – have been extensively studied, the literature on the socio-demographic (and mental) effects of such poisoning is relatively sparser (Brinkel et al., 2009). Skin lesions can affect the beauty of an individual, which has been documented to have negative effects in labor market and marriage market (Hamermesh and Biddle (1994); Hamermesh (2011)). If such effects are indeed important, then information campaigns that aim to increase awareness may have important demographic consequences, some unintended. Since arsenic exposure increases health risks, it can also increase the chance of not finding a match in a marriage market where information about arsenic contamination has been made public. This may then cause changes in the marriage market equilibrium, some of which may be uninteded and welfare reducing.

Since the work of Becker and Lewis (1973), the notion that brides and grooms have preferences for certain attributes in their spouses has been widely established in the literature on marrriage markets. For example, Kalmijn (1998) in his survey discusses how marriages exhibit sorting of prospective matches along many attributes including physical traits indicative of health status. In a study spanning 37 culutures, Buss (1989) finds that females value *resource acquisition* in males, while males place a high value on *reproductive capacity* in females. Other research on marriage markets (e.g., Chiappori et al. (2012); Bjerk (2009)) has also established that physical attractiveness and BMI (a rough measure of health) are valued in the spousal matching process. Buchmann et al. (2021) report similar findings in their study of the Bangladeshi marriage market, with husbands ranking "nature, reputation, character and looks" among the top desirable attributes in a bride, and 60 percent of brides reporting earning capacity as the most important attribute in a prospective husband. Significantly, most of these "valued" attributes can be adversely affected by arsenic exposure.[3]

Suppose that spousal matching in a marriage market is based on attributes, which can be subsumed in a single index value over which the sorting for partners takes place. For an individual belonging to an arsenic-contaminated area, the expected value of this index will be lower than that of an individual who hails from an uncontaminated area. Given a higher index value is more desirable in the market, stable matching means the highest ranked female gets matched to the highest ranked male, the second highest ranked female gets matched to the second highest

[3]For example, the effects of arsenic contamination on life expectancy and female beauty and fertility have been documented in various studies (Hassan et al. (2005); Milton et al. (2005); Rahman et al. (2007); Sohel et al. (2009); Argos et al. (2010)).

ranked male and so on. The Gale-Shapley algorithm (Gale and Shapley, 1962) will thus give an equilibrium outcome in which high ranked females from non-arsenic areas get matched to high ranked males from non-arsenic areas, and low ranked females from arsenic-contaminated areas get matched to low ranked males from arsenic-contaminated areas. We call this arsenic-arsenic matching for the purpose of our discussion.

Our hypothesis is the following: Attributes of prospective partners may not be fully observable in the marriage market and agents tend to hide adverse information related to health and financial well-being (Becker, 1973; Gary et al., 1981). Information asymmetry in this market has consequences on marriage timing (see, e.g., Angelucci and Bennett (2021) in the case of Malawi). However, by making contamination information widely available, the public information campaign complemented the index value in the marriage market. This is because the labelling of all TWs as either safe (green) or unsafe (red), discussed in detail in Section 2.3 enabled individuals living in arsenic-contaminated areas to know their likelihood of being affected by arsenic poisoning. Similarly, the campaign gave individuals from non-arsenic areas, who were looking for a match, visual information regarding arsenic contamination in the form of red and green painted tube-wells allowing them ascertain probabilistically the chance of a prospective match being affected by arsenicosis and other negative outcomes associated with arsenic poisoning. Thus, given arsenic-arsenic matching, an individual from an arsenic-contaminated area, facing the possibility of lower life-expectancy and a higher probability of developing skin lesions which diminish their prospects of finding a good match in marriage market, would strive to get married before their symptoms first appear.

In addition to age at first marriage, we also consider two marriage market payments – bride price and dowry – as outcome variables since such payments are pegged to the inferred quality of prospective brides and grooms, and may get affected in equilibrium. Bride price is a common Islamic practice prevalent in many countries, including Bangladesh. It is the amount which is agreed upon at the time of the marriage and is considered a payment owed by the groom's family for the use of the bride's labor and reproductive capabilities and puts a value on the number of children they expect the bride to bear (Anderson, 2007). Dowry, the payment from a bride's family to the groom's faimly, which is exchanged at the time of marriage, is also commonly practiced in Bangladesh and values the groom in the marriage market. It characterizes endogamous marriages where the payments are pegged to the social status of the groom's family and the groom's future prospects and earning potential (Anderson, 2007). Both these payments can be large enough to impact household finances.[4] However, unlike age at first marriage, the direction of the effect of the campaign on marriage market payments is not obvious and thus remains an open empirical question.[5]

The information campaign that we evaluate and discuss in Section 2.3 was effectively implemented from 2002 and designed to create awareness about the harmful effects of arsenic in drinking water. The campaign was visually complemented by painting tubewells (TWs)[6] either red (dangerous) and green (safe) and aimed to pursude users to switch to safe sources of drinking water. The campaign also suggested mitigation strategies such as shifting to a safer well in the neighborhood or well-sharing and informed people about the harmful health effects of arsenic exposure via public forums. The information campaign was successful in generating awareness and various studies (Chen et al. (2007); Opar et al. (2007); Bennear et al. (2013); Keskin et al. (2017); Jakariya (2007)) have found evidence of a reduction in the usage of contaminated wells in response to the campaign.

To evaluate the impact of the information campaign, we use a Difference in Difference (DID) strategy using the period 1990-2001 as the pre-intervention period and the years 2002-2010 as the post-intervention period.[7] Using a sample of individuals who got married between 1990 and 2010, we find that males and females got married earlier and the bride price reduced after the information about arsenic in drinking water was made public. In particular, we find that the informaiton campaign casued age at first marriage to reduce by 3.3 months (a reduction of 1%) for males and

[4]Dowry payments have been documented to form 62 percent of the average annual household income in Bangladesh (Esteve-Volart, 2004).

[5]Given arsenic-arsenic matching, the marriage pool available for grooms from arsenic areas became smaller as brides from non-arsenic areas were no longer available for matching, which could have driven up the bride price. However, at the same time, the social structure of Bangladesh is such that the stigma attached to a female with skin lesions and potentially low fertility are far greater than that attached to a male with the same attributes, meaning females suffer disproportionately more than males in the marriage market. Conseuqently, concerns about a prospective bride's beauty and possible low fertility coupled with asymmetrical costs associated with females developing skin lesions can drive down bride prices. A similar argument applies to dowry as well.

[6]A tubewell (TW) is a type of water well in which water is collected from an underground aquifer through a tube or pipe. Until the discovery of arsenic in ground water in the mid 1990s, it was considered a safe and affordable source of drinking water and was widely promoted by the Government of Bangladesh supported by the UNICEF and World Bank. The widespread adoption of TWs was considered a public health success: it became the main source of drinking water for over the 95% of rural population, with the number of TW increasing form virtually zero in 1970 to 2.5 millions by 1990 (Caldwell et al., 2003).

[7]We use the same cut-off as Keskin et al. (2017). Also see (World Bank (2007) - project completion report).

by 1.8 months (a reduction of 0.67%) for females in arsenic-contaminated areas. In addition, the bride price in arsenic-contaminated areas reduced substantially due to the information campaign, whereas dowry payments remained unaffected. We also find that the information campaign had a greater impact on younger cohorts, with a greater proportion of individuals from these cohorts getting married earlier. The campaign also had a spillover effect on childbearing, with females exhibiting a greater likelihood of early childbearing (for ages between 16 to 20 years old).

Our paper contributes to the literature on the effects of information campaigns, a topic extensively evaluated in economics and other disciplines (de Walque (2007); Dupas (2011); Briscoe and Aboud (2012); Gallagher and Updegraff (2011); Huffman et al. (2009)). Studies have documented how information campaigns nudge people to change their behaviors.[8] The impacts of the provision of health information on people's health seeking behavior and other socio-economic dimensions have also been studied in other contexts. Oster et al. (2013) find that in the case of Huntington disease, a hereditary disease with significant ramifications on life expectancy, individuals who have not been tested for the disease are optimistic about their health and make decisions similar to those without Huntington's. However, individuals with confirmed diagnoses (to whom an accurate picture of their health status has been revealed) behave differently. Moreover, Goldstein et al. (2008) find that HIV-positive mothers who learn their status are more likely to receive medication to prevent transmission to their children. However, in contrast to these studies which focused on the impacts of information campaigns on their intended consequences, we explore the unintended consequences of information campaigns.

In the case of Bangladesh, the literature on the impacts of the specific information campaign we are focusing on is limited to Keskin et al. (2017) and Buchmann et al. (2019), who study mothers' behavioral change in terms of increased breastfeeding duration for infants, and the unintended consequences of the information campaign on child mortality, respectively.[9] However neither of these studies look at how such information campaigns affect the marriage market. Thus, our paper is the first to examine the causal effects of information about health outcomes associated

[8]For example, using a randomised control trial Kirby et al. (2004) find that providing information about the human immunodeficiency virus (HIV) and sexually transmitted diseases (STDs) reduces risky sexual behavior in males who previously indulged in unprotected sex. Moreover, Duflo et al. (2015) demonstrate that girls switch to committed relationships and are significantly more likely to report faithfulness as a way to protect themselves from HIV following the implementation of a HIV-related curriculum in schools in Kenya.

[9]Other papers have explored the direct effect of the information campaign on tubewell switching behaviour and are listed in Section 2.3.

with poor water quality on marriage market. In the process, our paper links information about the local disease environment to marriage market outcomes.

Empirical evidence at a macro level shows that exogenous variations in adult mortality lead to a higher level of risky behavior, higher fertility and lower investment in physical capital (Lorentzen et al., 2008). The extant micro-economic evidence on age at marriage focuses primarily on women and argues that an increase in age at marriage affects educational attainment, fertility decisions (Currie and Moretti, 2003; Breierova and Duflo, 2004; Field and Ambrus, 2008), labor market outcomes (Loughran et al., 2004) and well-being of offspring (Chari et al., 2017). All these socially and individually desirable outcomes can thus be adversely affected by a reduction in age at marriage. However, despite the importance of age at marriage in relation to individual well-being and social benefits, little research is devoted to understanding how shocks such as the one we examine influence individuals' decisions to marry early or later.

The paper is organized as follows. The next section provides background on matching in marriage markets, water quality and related policies undertaken in Bangladesh. Section 3 describes the various data sources we use in our analysis. Section 4 describes our empirical strategy, and Section 5 presents the corresponding results. Finally, Section 6 provides the conclusions of our study.

2 Arsenic in Water, Health Effects and Information Campaign

2.1 Arsenic in Water: Bangladesh

During the 1960s Bangladesh struggled with a high disease burden due to various water borne diseases transmitted through surface water usage.[10] Soon, millions of tubewells were dug all across the country. In rural areas, the switch to groundwater was almost universal, and by the 1990s, almost 95% of households were using tubewells as their primary source of drinking water (Caldwell et al., 2003). By 1998, the infant mortality rate and under-5 mortality rate (per 1,000 live births)

[10] Aggregate statistics available from the World Bank's World Development Indicators suggest that in 1961, the infant mortality rate and under-5 mortality rate (per 1,000 live births) in Bangladesh were 257.5 and 171.7 respectively, and thus among the highest rates in the world at that time.

had reduced to 97.9 and 70.6, respectively.[11]

However, the installation of tubewells, hailed as one of the best public health success stories in Bangladesh, turned into one of the major arsenic-related public health crises in human history in 1987 when it was discovered that tubewell water in Bangladesh is contaminated with naturally-occurring arsenic in ground water (Smedley and Kinniburgh, 2001). Subsequently, a nationwide survey conducted by the British Geological Survey (BGS) in 1999 found that most of the tubewells being used were of shallow depth and many contained dangerous levels of arsenic.[12] The BGS and Department of Public Health Engineering of Bangladesh (DPHE) report (2001) estimated that around 35 million people were inadvertently exposed to harmful levels of arsenic by sourcing water from tubewells. Smith et al. (2000) also document that between 35-77 million people were exposed to arsenic through their use of contaminated tubewells.

2.2 Effects of Exposure to Arsenic

Arsenic is a known carcinogen and exposure to it causes many health problems, many of which have been explored in the bio-medical literature.[13] In terms of attributes highly valued in the marriage market, exposure to arsenic-contaminated water can affect "beauty", fertility, mortality and income. Skin lesions are among the first few symptoms of arsenic poisoning (see Appendix Figure A1), with both higher doses of arsenic and longer exposure to arsenic are positively associated with a higher probability of developing skin lesions.[14] In addition, adverse pregnancy outcomes such as still birth and spontaneous abortion have also been linked to arsenic exposure (Milton et al. (2005); Rahman et al. (2007); Ahmad et al. (2001)). Studies have also found that the risk of all-cause and chronic-disease mortality is higher for people exposed to dangerous levels of arsenic (Argos et al. (2010); Sohel et al. (2009)). Importantly, the various health effects observed after chronic exposure to arsenic could be irreversible (Dauphiné et al., 2011; Mazumder et al., 2008; Parvez et al., 2013).

The physical manifestation of early symptoms of arsenicosis such as skin lesions (Ahsan et al.,

[11] The fall in infant and child mortality cannot be attributed solely to switching to TW water. Other public health interventions such as oral rehydration treatments, immunizations etc., were also in place concurrently.

[12] Though arsenic was first detected in tubewell water in 1987, no comprehensive study ensued after this discovery until the late 1990s, when the BGS conducted a nationwide survey of tubewells.

[13] Such health problems include various types of cancers – lung, skin, kidney, bladder (Smith et al., 1992) – as well as adverse effects on mental health (Brinkel et al., 2009; Chowdhury et al., 2016).

[14] Ahsan et al. (2006) document such effects in their longitudinal study.

2000) is more than just a health issue. Given its visibility on the body, such skin lesions are linked to the "beauty" of a person and thus have broader repercussions on the marriage market (Elder Jr, 1969). Due to a lack of information and generally low education levels, skin lesions are often confused with leprosy, a disease considered as a contagious killer by the rural population of Bangladesh. The early symptoms of arsenicosis such as the formation of black spots and warts thus lead to ostracism and social isolation (Alam et al., 2002; Brinkel et al., 2009). Additionally, beyond this social problem, arsenic exposure has also been found to have implications in the labor market, primarily in the form of reduced labor supply and income (Carson et al., 2010; Pitt et al., 2021).

2.3 Intervention: Information Campaign on Arsenic

Between 1999 and 2005, the Bangladesh government (Department of Public Health Engineering (DPHE)) along with UNICEF and other non-profit organisations implemented the Bangladesh Arsenic Mitigation and Water Supply Programme (BAMWSP), a nationwide water quality information campaign. However, the campaign didn't pick up any steam during the initial 2.5 years (World Bank (2007) - project completion report) with the major roll-out happening only later, especially after 2002.[15] The campaign had a few distinct features: it tested almost five million tubewells for arsenic and categorized each tubewell as either safe (containing arsenic level of 50μg/litre or less) or unsafe (containing arsenic contamination level of more than 50μg/litre); it disseminated information about the contamination of tubewells visually by painting tubewells either red (unsafe) or green (safe); it suggested mitigation strategies such as shifting to a safer well in the neighbourhood or well-sharing; and finally, it informed people about the harmful health effects of arsenic exposure via public forums.

The constant visual reminders along with the dissemination of information about the adverse health effects of arsenic exposure had an impact on the intended population. The information campaign was quite effective in terms of generating awareness of arsenic and the symptoms of arsenicosis with over 80 percent of people reporting that they had heard of arsenic following the information campaign (Keskin et al. (2017)). Moreover, existing empirical evidence (Chen et al. (2007); Opar et al. (2007); Bennear et al. (2013); Balasubramanya et al. (2014); Madajewicz et al.

[15] Keskin et al. (2017) looks at the impact of the same intervention on a different outcome and also uses 2002 as the cut-off for the treatment period.

(2007)) suggests that people did switch to safer sources of water after the information campaign.

3 Data

In order to analyse the causal impact of the information campaign on marriage market outcomes, our analysis combines information on arsenic contamination with the demographic data. We describe our various sources of data below.

3.1 Contamination data

We source data on arsenic contamination from tests carried out by the British Geological Survey (BGS) in 1998 and 1999. The BGS tested a geographically representative sample of 3,534 wells across the entire country and also recorded the GPS coordinates of each tubewell along with other details such as the depth of the tubewell and the year in which it was installed. However, as the BGS only took samples from 61 of the 64 districts in Bangladesh, our study is necessarily limited to these 61 districts. The BGS found that more than a quarter of total sampled tubewells contained levels of arsenic higher than what was deemed safe according to guidelines from the Government of Bangladesh.[16]

Based on the BGS survey data, we categorize each subdistrict an arsenic-contaminated or uncontaminated. This is calculated by averaging the arsenic contamination levels for all tubewells located in a sub-district.[17] To decide the threshold level of contamination that may be deemed dangerous, we use the Bangladeshi government's threshold value of 50μg/litre. If the mean arsenic concentration for a sub-district was above 50μg/litre, we code it as an arsenic-contaminated sub-district, whereas a sub-district with contamination 50μg/litre or less is coded as an uncontaminated sub-district. Figure 1 shows the geographical variation in arsenic contamination at the sub-district level. The light shaded (green) sub-districts represent uncontaminated sub-districts (i.e., arsenic contamination was 50μg/litre or lower) while the dark shaded (red) show arsenic contaminated sub-districts. As is evident from the figure, contaminated tubewells are more likely to be found in the south of Bangladesh. However, many of them are also located in the east and west of the country.

[16]Although the Bangladeshi Government deems >50μg/litre a dangerous level of arsenic contamination, the WHO recommends a lowercut-off of >10μg/litre.

[17]On average this survey tested eight tubewells in each sub-district.

3.2 Demographic data

3.2.1 Census Survey Data - 2011

The individual and household data are obtained from Census Survey Data collected by the Bangladesh Bureau of Statistics (BBS) in March 2011. This dataset contains information on place of residence (sub-district); duration of residence in current place; type of construction of house; education of household members; and our main variable of interest: the age at which an individual first got married. While the 2011 census surveyed both urban and rural households, we focus only on the rural sample as the use of tubewell was almost universal in rural areas before the implementation of the information campaign (Caldwell et al., 2003). We combine the census data with arsenic contamination data (BGS data) at the sub-district level to generate the arsenic contamination status of the sub-district. Our final estimation sample comprised of individuals who got married between 1990 and 2010 (73,114 males and 84,544 females) from over 400 sub-districts in Bangladesh. 32 percent of the sub-districts had arsenic levels above 50μg/litre. It should be noted that we don't observe the original household of females, i.e., the household they were born in. We only observe females in the households they got married into, and for this reason, we primarily focus on males and suggest interpreting results from the female sample with caution.[18]

We provide summary statistics for the male and female estimation sample in Table 1 (panels A and B). The average highest grade completed by both males and females is the seventh grade.[19] In arsenic-contaminated areas, a greater proportion of individuals (both males and females) belong to households which own assets (land and a house). However, this does not mean that they are necessarily richer, as only a small proportion have houses with cement walls. Most of the individuals in both arsenic-contaminated and uncontaminated regions are Muslim. The differences in characteristics of individuals mean that we cannot compare outcomes across arsenic-contaminated and uncontaminated regions. Hence, as we describe in detail later, we resort to looking at changes over time instead.

Appendix Figure A2 plots the age at which males and females got married. We observe that

[18] In Section 1, we describe how males from arsenic-contaminated areas get matched to females from arsenic-contaminated areas in the marriage market; this mitigates some of the concerns that may arise when interpreting our results for females.

[19] Table 1 doesn't show statistical difference between the two groups (arsenic-contaminated and uncontaminated groups); however, differences are significant for variables in both male and female samples. We address how these differences in characteristics might affect marriage market outcomes in Section 5.5.4.

males (panel A) in Bangladesh tend to get married earlier than the world average. The mean age at first marriage is 24 years, with 60 percent of males married by this age, and 70 percent of females married by the age of 18 (panel B). In Figure 2, we explore the trends in mean age at marriage during the pre-treatment period in arsenic-contaminated and uncontaminated areas. Panels A and B show the actual age at marriage for males and females respectively. We observe that the mean age of marriage is higher for both males and females in arsenic-contaminated areas and seem to follow parallel trends.

In Figure 3 the difference in age at marriage between arsenic-contaminated and uncontaminated areas is shown via scattered points and fitted lines (panels A and B for males and females, respectively). The graphs indicate that the information campaign shifted marriage patterns. The apparent shift in marriage patterns is observed more explicitly in the downward shift in the fitted trend lines for the pre-intervention period versus the trend line for the post-intervention period. Our empirical analysis tests the robustness of this result by controlling for changes in other covariates.

3.2.2 Primary Survey

For our bride price analysis we rely on data collected in the Palli Karma-Sahayak Foundation (PKSF) survey. This survey contained modules on marriage market outcomes, including payments. It was conducted by researchers from the University of Sydney in December 2010-January 2011 (described in Chowdhury et al. (2020)). We combine data from this survey with contamination data from the BGS to arrive at our final estimation sample for the period of study (1990-2010). The final sample contains information on 875 marriages from 20 sub-districts. Nine out of these 20 sub-districts were arsenic-contaminated. This dataset contains detailed information about marriage unions, including the year of first marriage; the amount of dowry paid; the bride price agreed upon;[20] the ages of the bride and groom; the highest education level attained by the bride and groom; and the income status of the families of the bride and groom at the time of marriage.

We summarize our data from this survey in panel C in Table 1. Both the bride and groom in couples from the arsenic-contaminated group are more educated than couples from the uncontaminated group (a statistically significant difference). The mean bride price is close to 53,300 Taka, and there is no statistically significant difference in mean bride price between the two groups.

[20]The figures for both bride price and dowry have been expressed in real terms.

Though the overall mean dowry is 22,700 Taka, the mean dowry in uncontaminated areas is around 20,000 Taka. Conversely, the mean dowry in arsenic-contaminated areas is 22 percent higher than the dowry paid in uncontaminated areas (a statistically significant difference). In Table 2, which contains summary statistics about the mean bride price before and after the campaign, we observe that the mean bride price in uncontaminated sub-districts increased from 42,611 Taka in pre-treatment period to 66,619 Taka in post-treatment period (an increase of 56 percent). However, the arsenic-contaminated areas experienced only a 30 percent increase in bride price.[21] The average dowry payments over time reveal an opposite pattern: while it increased by 16 percent between the pre-treatment and post-treatment period in uncontaminated areas, the corresponding increase in arsenic-contaminated areas was over 40 percent.

4 Estimation Methodology

To estimate the effect of the information campaign about arsenic contamination on age at marriage and bride price, we follow a difference-in-difference (DID) approach using the following specification:

$$Y_{ijdt} = \alpha + \theta \mathsf{Arsenic}_j * \mathsf{post2002}_t + \beta X_{ijdt} + \gamma_j + \delta_t + \rho_d t + \varepsilon_{ijdt} \quad (1)$$

where Y_{ijdt} is the marriage market outcome – age at first marriage (for males or females) or log of bride price or dowry for an individual i who resides in sub-district j, belonging to district d and who belongs to marriage cohort t (i.e. who got married in year t). $\mathsf{Arsenic}_j$ is the dummy variable which takes a value of 1 if the mean arsenic contamination level is greater than 50μg/litre for a sub-district and 0 otherwise, and $\mathsf{post2002}_t$ is the dummy variable which takes a value of 1 for the post-treatment period (2002-2010) and 0 for the pre-treatment period (1990-2001). X_{ijdt} includes controls for individual characteristics which matter in the marriage market. Since they differ for the outcomes being assessed, we describe them in detail below. To control for time-invariant differences between sub-districts and location-invariant differences between marriage cohorts, we include sub-district fixed effects, γ_j and marriage cohort fixed effects, δ_t. We also control for district level trends, $\rho_d t$ to account for any underlying trends present at the district level. These fixed effects and trends account for any omitted variables at the sub-district and year level and any

[21] We don't provide detailed year by year figures for this dataset as they are imprecisely estimated due to small sample size available for each year.

linearly time varying factors at the district level. The errors have been clustered at the sub-district level for our analysis.

Our coefficient of interest is θ, which captures the effect of the information campaign. Essentially, we compare the difference in outcomes between marriage cohorts from arsenic-contaminated sub-districts before and after the information campaign to the difference in outcomes in the same marriage cohort from uncontaminated sub-districts. The individual-level controls (X_{ijdt}) for age at marriage regressions based on the Census data include religion being Islam; ownership of land; ownership of a house; highest level of education attained; and whether the individual resides in a dwelling with cement walls (an indicator of the quality of the dwelling).

For bride price (and dowry) regressions, we rely on PKSF survey data. Individual level controls here include the highest education level attained by the bride and groom; the ages of the bride and groom at time of marriage; a dummy for when an individual has chosen their marital partner by themselves (as opposed to the partner being chosen by their family); a dummy for when the bride's family is richer than the groom's family; and a dummy for when the groom's family is richer than the bride's family (the omitted category is when two families belonging to same income class).[22]

Our identifying assumption is that trends in age at marriage (and bride price or dowry) were not different across arsenic-contaminated and uncontaminated sub-districts, other than because of the information campaign. The district specific trends also help in establishing the validity of our results as our estimates are identified off deviations from district trends. The possible threats to our identification thus come from sub-district-level trends which might be correlated with arsenic contamination.

For each of our DID specifications we test whether the parallel trend assumption is satisfied by conducting the following estimation exercise:

$$Y_{ijdt} = \alpha + \Sigma_{2001}^{1990} \lambda_t (Arsenic_j * I_t) + \beta X_{ijdt} + \gamma_j + \delta_t + \rho_d t + \varepsilon_{ijdt} \quad (2)$$

where Y_{ijdt} is our outcome of interest – age at first marriage, bride price or dowry – and j is the sub-district of residence. I_t is an indicator variable for each of the pre-treatment years. In presence of sub-district and year of marriage fixed effect, the interaction terms between year dummies and arsenic dummy reveal whether the control and treatment groups followed different trends over time. We look for individual significance of all these interaction terms. If these terms are individually insignificant, the parallel trend assumption is satisfied, meaning the two groups

[22]The controls are similar to the ones used in Ambrus et al. (2010).

followed similar trends in the pre-treatment period.

We estimate specification 2 for all our outcome variables for the pre-treatment period and present our results in Appendix Figure A3 (panels A, B, C and D for age at marriage for males, age at marriage for females, bride price and dowry respectively). We notice that all our models satisfy the parallel trend assumption as all the interaction terms are insignificant.[23]

5 Results

5.1 Age at Marriage

In Table 3 we present results from specification 1. All columns include sub-district and marriage cohort (year of marriage) fixed effects. Columns 1 and 2 refer to results for the male sample while columns 3 and 4 present results for the female sample. Our main results in columns 2 and 4 control for district-level trends. The coefficient of $\mathsf{Arsenic*Post2002}$ (in Table 3) shows that both males and females from arsenic-contaminated areas got married earlier after the implementation of the information campaign. For the male sample, the reduction in age at marriage is 0.28 years (around 3.3 months), while the magnitude is slightly lower for the female sample – around 0.15 years (1.8 months).[24] These results translate into a reduction in age at marriage after the information campaign of around 1 percent for males and 0.67 percent for females. The magnitude of our results is similar to the effects found in Gershoni and Low (2021) (albeit in the opposite direction), who establish that women increased their age at marriage by a quarter of a year in response to a free IVF policy in Israel. Results on other controls reveal that a higher level of education,[25] ownership of assets, and residence in a relatively better dwelling - an indicator of wealth are all associated with a higher age of marriage. In constrast, being of Islamic faith is associated with getting married earlier.

[23]The only exception is the parallel trend assumption for Dowry where the coefficient for the year 1993 is significant.

[24]The results on age at marriage of females should be interpreted with some caution as we don't observe them in their original place of residence. We assume that marriage matches happen between similar areas, i.e. males from arsenic-contaminated areas get matched to females from arsenic-contaminated areas and vice versa - a point discussed in Section 1.

[25]Educational attainment can be endogenous as it might be simultaneously determined with marriage-timing decisions. Our results remain unchanged even when we don't include any demographic controls like education in our estimation.

Next, we provide a graphical summary of an event study (Figure 4) which provides support for our results. The outcome variable in this analysis is age at first marriage and the plotted coefficients in Figure 4 are interaction terms between the arsenic dummy and an indicator variable for each year. In the estimation we control for district level time trends, sub-district fixed effects, year of marriage fixed effects and demographic controls. The event analysis shows that the information campaign shifted age at first marriage for both males and females. However, the effect is observed much more clearly for males (panel A) than for females (panel B), who show a smaller downward shift in the age at first marriage. This is perhaps becuase the mean age at first marriage for females was already near the minimum legal age (18 years), and getting married even younger could have had legal consequences.

5.2 Proportion of marriages

We now focus on cohorts which might be driving this decrease in age at first marriage. We use information on individuals who were at or above a certain age at the time of intervention to create our main dependent variable: the proportion of individuals married by a certain age for each subdistrict and year (subdistrict-year panel data).

We then use a simple difference-in-difference model to evaluate the impact of the information campaign on the proportion of individuals getting married by a certain age.[26] Figure 5 plots the coefficient for the interaction term (Arsenic*Post2002).[27] We observe that a higher proportion aged 18 to 30 got married earlier, with the point estimates tending to be larger for those aged 24 and 26. For females, the effect is observed for a younger age group: 14 to 18 years. This is concerning as it suggests the occurance of marriages where the bride is below the legal age of marriage. Significantly, these early marriages for females can have important consequences for early child bearing which we describe in the next section.

5.3 Age at First Birth

To explore the effect of the information campaign on child bearing for females, we use data from the Demographic Health Surveys for Bangladesh (BDHS) (rounds for 1999, 2004, 2007, 2011). These surveys were conducted by the National Institute of Population Research and Training

[26] Gershoni and Low (2021) adopt a similar methodology to identify cohorts which drive the main results.

[27] Each coefficient is from a separate regression.

(NIPORT) and used the same questionnaire in each round. Each year around 10,000 households were sampled from 350 clusters. The only exception was in 2011, when 17,000 households were sampled from 600 clusters. For our rural sample, we focus on the women's questionnaire, which contains questions regarding a woman's reproductive history and demographic characteristics. Our estimation sample contains 1,089 primary sampling units or clusters.

The BDHS data contains GPS information for all sampled clusters, enabling us to construct arsenic contamination figures for each individual sampled cluster in the BDHS data by matching them with the arsenic contamination data collected by the BGS and described in Section 3.1. We calculate the "local" level of arsenic contamination for a cluster by averaging the contamination levels for all tubewells located within a five mile radius of the cluster location. Clusters with a mean contamination level greater than 50μg/litre are classified as arsenic-contaminated and those with 50μg/litre or less are classified as uncontaminated.

We use a difference-in-difference model to assess the impact of the information campaign on early childbearing. The sample for analysis is restricted to the rural sample, and we consider the mother's age the birth of her first child for all births which took place between 1990 and 2010. The dependent variable for this analysis is a dichotomous variable for giving birth to the first child by a certain age (age cut-offs which are chosen for analysis include 14, 16, 18, 20, 22, 24, 26, 28 and 30). Other controls include the educational level of the mother and whether she is Muslim. We additionally introduce year of birth fixed effects, district-trends, dummy for arsenic contamination status and an interaction variable (arsenic contamination X post-intervention period)

The results are presented in Figure 6. Each coefficient represents a separate regression for different age cut-offs. We plot the coefficient for the interaction term which captures the effect of the information campaign on the probability of having the first child by a certain age. We observe that the information campaign increased the probability of having a child at an early age (i.e., 16 to 20 years) for the rural sample (Panel A), while it had no such effect on the urban sample (Panel B). This is expected as the urban population were not reliant on tubewells and thus had no exposure to the information campaign. Thus, the information campaign not only changed marriage market outcomes, it also led to early childbearing in the rural population.

5.4 Bride Price and Dowry

Table 4 presents our results for bride price and dowry. Our dependent variable here is log of bride price (dowry amount), and the coefficients of interaction variables can be interpreted in terms of the percentage changes in bride price (dowry) for arsenic-contaminated areas in the treatment period. Column 1 presents results with no district-level trends, and we find a 40 percent decrease [28] in bride price, however this effect is not found to be statistically significant. Column 2 accounts for district-level trends, and we find that arsenic-contaminated areas witnessed a significant decrease ($\approx$ 90 percent) in bride price following the information campaign.[29] We also observe that bride price is positively associated with a bride's education level. Dowry payments (results presented in columns 3 and 4) were unaffected by the information campaign (dowry unlike bride price is exchanged at the time of marriage when a groom may not have developed any symptoms related to arsenic poisoning; also see footnote 5), and also positively associated with the groom's education level (a similar finding to Anderson (2007)) and his age.

5.5 Robustness Checks

5.5.1 Two-way Fixed Effect Diagnostics

We use a two-way fixed effects (TWFE) model for estimation which controls for location-specific (sub-district) and period-specific shocks (year of marriage). Recent literature (Goodman-Bacon, 2021; De Chaisemartin and d'Haultfoeuille, 2020) in this domain has established that when treatment effect changes within treated units (i.e. homogeneity assumption is not satisfied) then estimates from TWFE can be severely biased. Specifically, the problem arises due to negative weights in presence of heterogenous effects. We adopt the diagnostic methodology laid out in Jakiela (2021) and begin by checking for negative weights by using a stripped down version of our main model which uses just $\mathsf{ArsenicXPost}_{2002}$ interaction variable, sub-district and year of marriage fixed effects.[30] Appendix Figure A4 plots a histogram of weights received by observations

[28] We are using a log-linear model, the calculation of magnitude of coefficients follows the standard methodology, i.e. magnitude is $(e^{\beta} - 1) * 100$, so 0.34 coefficient gives you $(e^{0.34} - 1) * 100 = 40$ percent change. Similarly for column 2, 0.64 coefficient gives a 90 percent change.

[29] As our bride price (and dowry) results rely on a small sample, many estimated coefficients have large standard errors, leading to statistically insignificant results.

[30] This model is in line with the model used by Jakiela (2021); $Y_{it} = \lambda_i + \gamma_t + \beta D_{it} + \epsilon_{it}$, where i denotes location, t denotes time period, β is the TWFE estimate and D_{it} is the treatment variable which varies at location-time-period

in our analysis sample. We observe that all treated observations in the treated years (post-2002) receive a positive weight. Although negative weights do not pose a threat to our estimation, we nonetheless explicitly test for homogeneity assumption which implies that the relationship between the residualized outcome $\widetilde{\mathsf{Y}_{it}}$ and residualized treatment*post variable $\widetilde{\mathsf{ArsenicXPost}_{it}}$ is linear.[31] In other words, the slope between $\widetilde{\mathsf{Y}_{it}}$ and $\widetilde{\mathsf{ArsenicXPost}_{it}}$ shouldn't be different between the control and treatment groups. In appendix Table A1 we present our results from this analysis and we find support for the fact that the slope between residualized outcome and treatment is linear and the coefficient on $\mathsf{ArsenicXPost2002}$ (i.e. treatment variable for treated years) interacted with $\widetilde{\mathsf{ArsenicXPost}_{it}}$ is statistically insignificant for both the male and female analysis sample.

5.5.2 Marriage pool before and after information campaign

The results which we observe can potentially arise if the information campaign affected the marriage pool, i.e., the mix of males and females in the marriageable age group could have changed, potentially due to out migration. We explicitly test for this by looking at the sex ratio at the sub-district level before and after the implementation of the information campaign. We use data from the IPUMS Census 2001 data and the Census Survey 2011 to calculate the sub-district level mean sex ratio between males and females in the 15 to 35 years age group for the years 2001 (before intervention) and 2011 (after intervention).[32] Table A2 presents our results for this analysis. It can be observed in columns 1 to 3 (which correspond to different specifications) that the sex ratio did not change due to the information campaign. This essentially cements our original hypothesis that the information campaign's effects on marriage market are driven by behavioural factors rather than changes in the marriage pool.

5.5.3 Placebo tests

Next, we conduct two placebo tests to establish the validity of our results. First, we replicate our analysis on the urban sample. We don't expects to see any effect of the information campaign as those living in urban areas didn't rely on tubewells as a source of water. In Table 5 (column 1 and 2), we observe that the information campaign had no effect on age at marriage for either

level similar to our interaction variable $\mathsf{ArsenicXPost}_{2002}$.

[31] Residualized variables are obtained by regressing the variable on location (sub-district in our case) and time (year of marriage) fixed effects.

[32] 410 sub-districts are matched between the IPUMS Census 2001 data and the Census Survey 2011 data.

males or females, which is in line with our expectation. This is similar to the findings of Keskin et al. (2017), who find that the information campaign did not change the breastfeeding practices of mothers in urban areas.

We also perform a second placebo test by randomly shuffling the arsenic contamination status of sub-districts. This basically randomly assigns sub-districts into new treatment and control groups. We then estimate the coefficient of (Arsenic * Post2002) variable by following our original specification (specification 1). The randomization breaks the true relationship between arsenic exposure and outcome variable (age at first marriage), thus giving us an estimate by chance. We repeat this exercise 1,000 times, each time randomly assigning treatment and control status to sub-districts. This gives rise to a distribution of θ based on 1,000 simulations. In appendix figure A5, we plot the cumulative probability density for the simulated betas. We observe that the true estimate (shown by dotted line) is an extreme value in this distribution for both males and females samples and thus unlikely to arise purely by chance.

5.5.4 Addressing differences in characteristics

We complement our findings from the 2011 Census Survey data regarding age at first marriage by using additional demographic surveys. The arsenic-contaminated sub-districts can be systematically different from uncontaminated sub-districts. Therefore, we additionally analyze whether arsenic-contaminated areas which are *similar* to uncontaminated areas exhibit different marriage patterns after the information campaign. We conduct this analysis by using sub-district characteristics prior to the information campaign to match arsenic-contaminated sub-districts with uncontaminated sub-districts. The data for pre-treatment characteristics (at the sub-district level) are sourced from the IPUMS Census Data for 2001. The IPUMS Census was originally compiled by the Bangladesh Bureau of Statistics (BBS) and is a very large data set, containing both individual and household information at the sub-district level. For matching purposes, we use characteristics which covered over 12 million individuals (2.6 million households) residing in all 64 districts of Bangladesh, focusing on 19 specific variables collapsed at the subdistrict level.[33] These include details about employment, education, household characteristics, and the sex-ratios for the unmarried population and children below one year old, respectively. It should be noted that we don't use the IPUMS dataset for our main analysis as it doesn't contain information about our main

[33] IPUMS data are available here: https://international.ipums.org/international-action/sample_details/country/bd

dependent variable i.e. the age at which individuals first got married.

Table A3 compares the mean characteristics of arsenic-contaminated (treated) and uncontaminated (control) sub-districts in 2001. Columns 1 and 2 reveal that these two groups are considerably different from each other. To address this concern, we implement a matching procedure by using sub-district level characteristics from the IPUMS data. Our matching exercise results in 79 arsenic-contaminated sub-districts getting matched to 79 unique uncontaminated sub-districts. Columns 4 and 5 show the mean characteristics of the matched control and treated sub-districts, while column 6 shows that the matched sub-districts are statistically similar in terms of various demographic and non-demographic characteristics.[34]

We use the sub-sample from the 2011 Census data comprised of observations from the matched sub-districts (158 sub-districts) and repeat our main empirical analysis (specification 1). In Table A5 (columns 1 and 2), we observe the mean age at marriage of both female and male subsamples decreased following the information campaign. The magnitude is similar to our original results, where the age at marriage decreased for both males and females by $\approx$ 1 percent.

Additionally, to assuage any concerns about differences in the growth patterns of characteristics between the two sets of sub-districts, we use pre-treatment sub-district-level characteristics (identical to the ones used in the matching analysis and presented in the variable list in Table A3) from 2001 and introduce linear time trends for them in our empirical estimation.[35] Adding these trends (which capture the growth of these characteristics overtime) doesn't change our original results. The effect sizes are -0.28 and -0.13 for males and females respectively, and the estimates retain their significance as well.[36]

5.5.5 Alternate contamination cut-offs and additional data on bride price

In our analysis we have categorized sub-districts into arsenic-contaminated and uncontaminated sub-districts using 50μg/litre (or less) of arsenic as the cut-off for drinking water to be considered safe. We now provide additional results where alternate contamination cut-offs are used for

[34]The probit regression for generating propensity scores for matching is presented in Appendix Table A4. Figure A6 plots the number of treated and control sub-districts matched over p-score. 410 sub-districts from the IPUMs dataset are used for analysis. Caliper used for matching is 0.05.

[35]This approach is similar to the one followed in Hoynes et al. (2016) and Hjort et al. (2017), who evaluate the long-run impact of the US food stamp program and the long-run impact of the infant home visit program in Denmark respectively.

[36]Results available on request.

analysis. Table A6 (age at marriage results) and Table A7 (bride price results in columns 1 to 4) present results based on four alternate measures of contamination. $\mathsf{MeanArsenic}$ is a continuous measure of arsenic contamination while $\mathsf{Arsenic10}$ is a dummy variable which takes a value of 1 if the mean arsenic contamination in a sub-district is above 10μg/litre (the WHO's cut-off for the maximum concentration of arsenic allowed in drinking water). We also use the proportion of wells in a sub-district above two other threshold values: 50μg/litre and 75μg/litre. We present results for the male and female samples in columns 1 to 4, and columns 5 to 8 of Table A6, respectively. Table A7 (columns 1 to 4) provides results for bride price analyses. The effect of the information campaign on both age at marriage and bride price is negative when using these alternate measures of arsenic contamination. The effect of the information campaign evaluated using a continuous measure of arsenic contamination is significant for both age at marriage (males and females) and bride price. When we use 10μg/litre as the cut-off for arsenic contamination, we observe that the point estimate (of $\text{Arsenic}_{>10\mu g/\text{litre}}$ X Post2002) is negative for all outcome variables. The estimate for age at marriage for males is -0.17 (which is smaller than our original estimate), while the estimate for females is -0.10 (not statistically significant). The corresponding bride price estimate using a 10μg/litre cut-off is negative and smaller in magnitude (in comparison to results based on a 50μg/litre cut-off) but not significant.

The results corresponding to two other proportion-related contamination measures reveal that as more wells (higher proportion) in a sub-district are contaminated with arsenic, the corresponding negative effect on behavioral responses in the marriage market is stronger. This is perhaps because stronger visual cues (in the form of a greater number of wells painted red and thus marked as unsafe) are available to residents in arsenic affected sub-districts.

Our bride price analysis has thus far only used PKSF survey data. Since the PKSF survey was conducted on a very small sample, we expand our dataset by incorporating additional data from the Bangladesh Rural Urban Linkage (BRUL) Survey. This survey was conducted by the International Food Policy Research Institution between December 2004 and January 2005 and used identical modules on marriage, divorce, bride price and dowry.[37] The combined marriage data from the PKSF and BRULS for marriages between 1990 and 2010 contains 1,699 marriages from 80 sub-districts. In column of Table A7, we replicate our original bride price analysis using this expanded dataset. We find that the (log of) bride price reduced by 0.60 in arsenic-contaminated areas after the information campaign, which is similar to our original estimate of a 0.64 reduction

[37] See Ambrus et al. (2010) for the survey details.

in bride price following the intervention.

5.6 Heterogeneity

Information campaigns can have differential impacts based on various demographic characteristics. We explore how the information campaign affected the marriage market outcomes of individuals with differing educational backgrounds. The results for this analysis with outcome variable as age at first marriage are presented in Table 6 (columns 1 to 4). Slicing the sample based on literacy status reveals interesting patterns. We find that for both males and females, it is only the literate group (defined as the ability to read or write or to both read and write) which exhibited a behavioral change in the marriage market following the information campaign; no such change is seen for the not-literate group. This finding is similar in spirit to other studies such as de Walque (2007), who finds that educated women reacted strongly to a HIV/AIDS information campaign in Uganda. Thus, the hypothesis that education mediates reaction to knowledge-enhancing campaigns is supported by our findings.

6 Conclusion

The discovery of arsenic in drinking water in Bangladesh and the subsequent nationwide information campaign informing the public about the harmful health effects of arsenic poisoning and providing constant visual cues by painting tubewells either red or green (depending on their arsenic level) was successful in increasing public awareness of the adverse health effects of arsenic poisoning. The extant literature has explored the behavioral change induced by the campaign primarily in the health domain. We have gone a step further and shown that the campaign had consequences for the marriage market by increasing the rate of early marriages. In a country where child marriage is already a common practice, we find evidence of a further decrease in age at first marriage. This is clearly quite concerning given the long-term negative impacts of child marriage on females. Another related unintended effect of the information campaign was the greater likelihood of early childbearing. The bride price agreed at the time of marriage also suffered a dampening effect.

Our findings are consistent with the hypothesis that the information campaign enabled those live in arsenic-contaminated areas to learn about their greater likelihood of developing skin lesions and other health problems due to arsenic exposure. As the onset and discovery of such symptoms that could hamper their chances of finding a good match in the marriage market, inviduals from these areas strive to get married earlier. Similarly, the decrease in bride price can be attributed to the fact that public knowledge about arsenic contamination in an area generates concerns about the beauty and fertility of a prospective female match. While our results are consistent with these explanations, a more detailed investigation of these mechanisms is outside the scope of this paper due to limitations of data.

Well-intended public policies can nevertheless have undesirable social and economic consequences. How to avoid such unintended consequences is an important but difficult question. Clearly, more careful policy design is warranted. However, it is not always possible to assess or predict the future consequences of public policies prior to their implementation, and some negative consequences are simply unavoidable. However, learning about their unintended consequences are important, and our work provides a key contribution to this area. The information campaign on arsenic contamination in drinking water owes its success in generating awareness to its unique design. Constant visual reminders, multiple strategies to avoid contaminated water and public forums for information disbursal seem to have worked in Bangladesh. However, we find evidence that campaigns, which inform people about adverse outcomes may also lead to undesirable social outcomes, and we demonstrate the impacts of such a campaign on the marriage market and childbearing domains.

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Tables and Figures

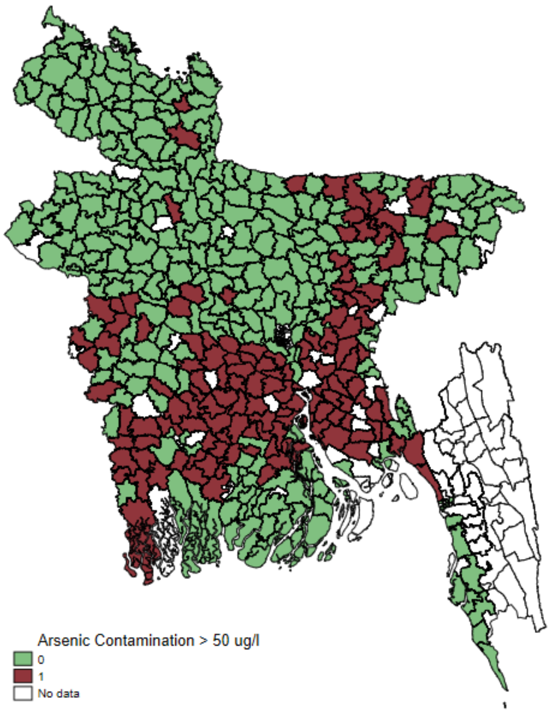
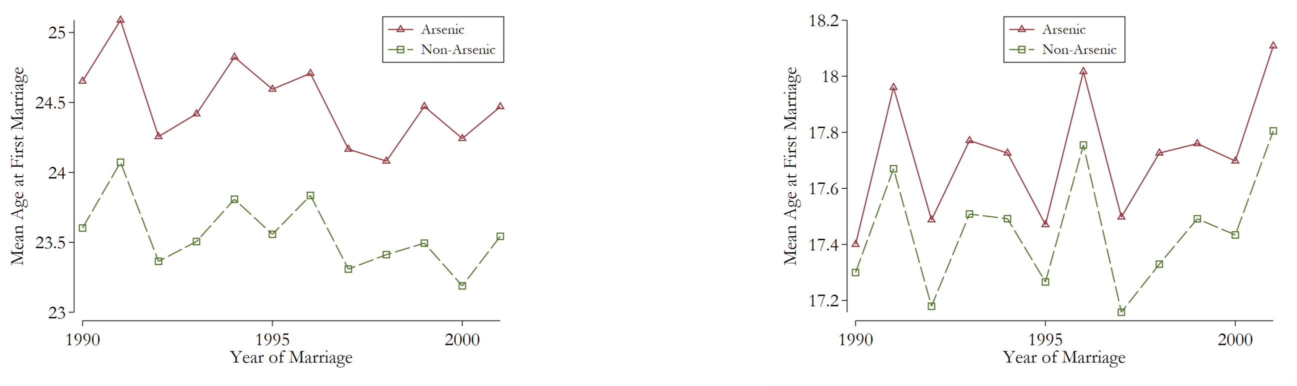


Figure 1: Arsenic Contamination Map for Bangladesh.

Source: British Geological Survey 1999.

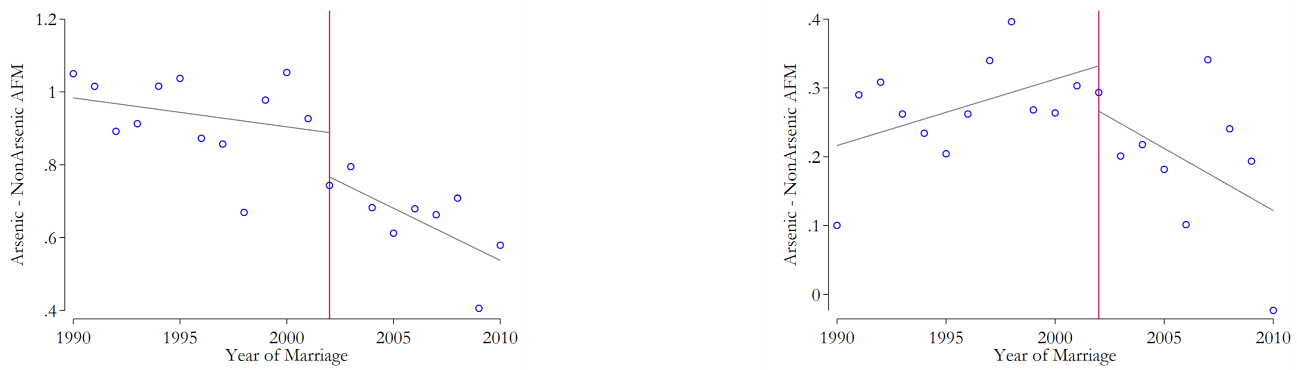


(A) AFM for Males (B) AFM for Females

Figure 2: Age at First Marriage (AFM) during the Pre-treatment period for Males and Females in Arsenic and Non-arsenic Areas.

Notes: Panels A & B - Average age at first marriage for arsenic vs non-arsenic areas by year of marriage, shown for males and females separately.

Source: Census 2011, Bangladesh Bureau of Statistics. Sample restricted to rural areas.

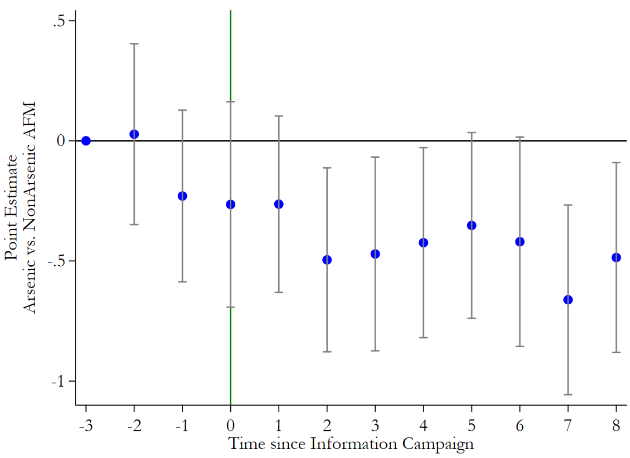


(A) AFM difference for Males (B) AFM difference for Females

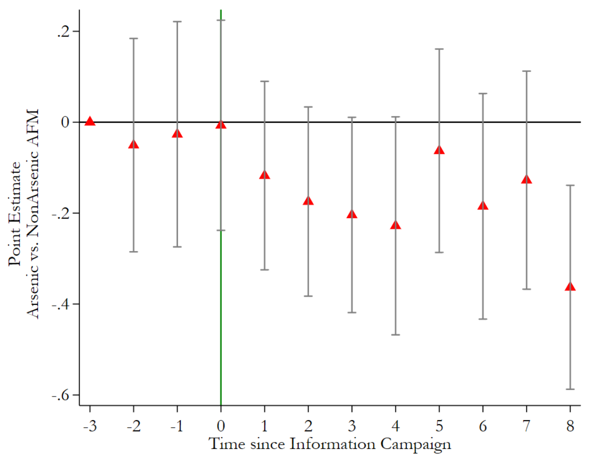
Figure 3: Arsenic vs Non-Arsenic Age at First Marriage (AFM) for Males and Females (Sample period 1990 to 2010)

Notes: Scattered points represent the difference in levels of mean age at first marriage between arsenic and non-arsenic areas. Fitted lines correspond to the pre-treatment period (1990-2001) and post-treatment period (2002 to 2010).

Source: Census 2011, Bangladesh Bureau of Statistics. Sample restricted to rural areas.



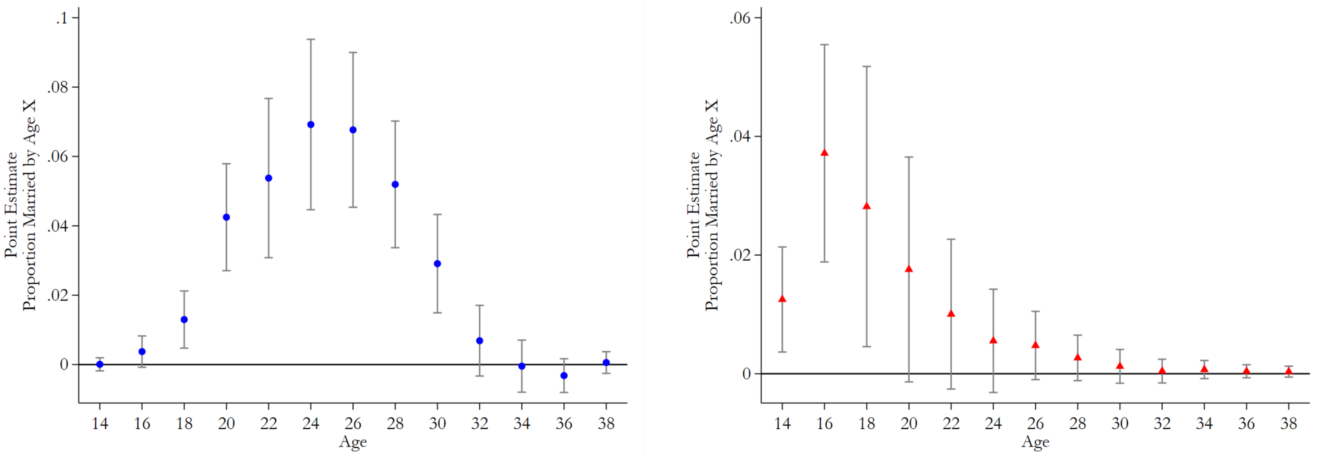
(A) Males



(B) Females

Figure 4: Event Study Analyses

Notes: The figure presents dynamic lag event study analysis for the impact of the information campaign on age at first marriage for arsenic relative to non-arsenic regions. Point estimates and confidence intervals (90% CI) are for the coefficients on yearly dummy variables interacted with an indicator for arsenic contamination (treatment group). Time is year of marriage, with 2002 as time "zero." The regression equation includes year-group interactions for the entire sample period (1990-2010), as well as a district level linear time trends, sub-district fixed effects, year of marriage fixed effects and demographic controls (same as the ones mentioned in notes of Table 3) with clustering at sub-district level. Sample weights have been used in analysis. All regressions restricted to individuals in rural areas.

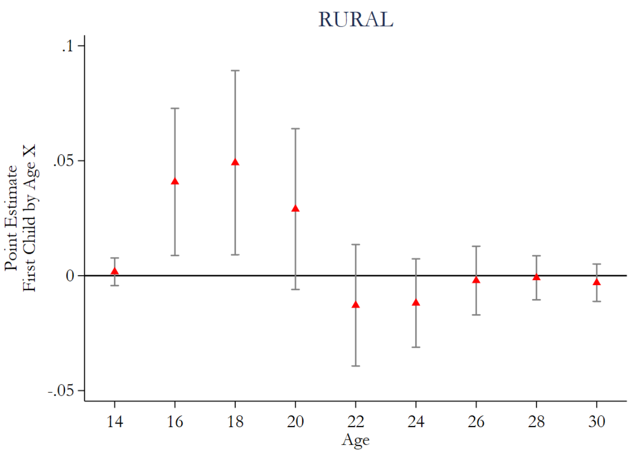


(A) Males

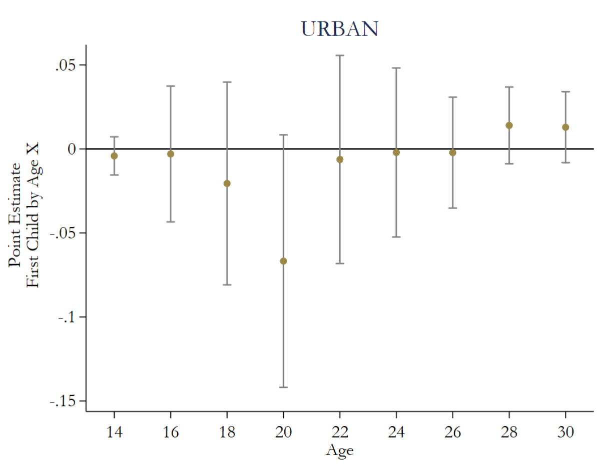
(B) Females

Figure 5: Effect of Information Campaign on Proportion Married by a Given Age

Notes: Each coefficient represents results from individual regressions for the interaction variable (arsenic contamination dummy X post-treatment dummy) from a subdistrict-year level dataset. The dependent variable in these regressions is the proportion of individuals married by a certain age and the controls include an interaction variable, arsenic contamination dummy, year of marriage fixed effects and district level trends. The error bars are 95% confidence intervals with robust standard errors. Estimation sample in each regression is limited to rural areas for all marriages which took place between 1990 and 2010.



(A)



(B)

Figure 6: Effect of Information Campaign on having First Child by a Given Age

Notes: Each coefficient represents results from individual regressions for the interaction variable (arsenic contamination dummy X post-treatment dummy). The dependent variable in these regressions is dummy variable for giving birth by a certain age and other controls apart from the interaction variable include demographic controls (educational level of the mother and her religion being Islam, district level time trends, arsenic contamination dummy and year of child's birth fixed effects. The error bars are 95% confidence intervals, clustering at PSU level. Sample weights have been used in analysis. Estimation sample in each regression is limited to all first births which took place between 1990 and 2010.

Table 1: Summary Table

PANEL A. CENSUS DATA MALES

variablename	*All*		*Non-Arsenic*		*Arsenic*	
	Mean	SE	Mean	SE	Mean	SE
Education (highest class passed)	7.34	0.014	7.38	0.017	7.25	0.023
Religion is Islam (%)	0.89	0.001	0.90	0.001	0.87	0.002
Owns Land (%)	0.92	0.001	0.91	0.001	0.94	0.001
Owns House (%)	0.89	0.001	0.88	0.001	0.91	0.002
House has Cemeneted Walls (%)	0.16	0.001	0.16	0.002	0.16	0.002
Age at First Marriage (years)	23.65	0.015	23.38	0.018	24.19	0.027
Observations	73114		48889		24225	

PANEL B. CENSUS DATA FEMALES

	All		*Non-Arsenic*		*Arsenic*	
	Mean	SE	Mean	SE	Mean	SE
Education (highest class passed)	6.85	0.011	6.81	0.013	6.93	0.017
Religion is Islam (%)	0.89	0.001	0.90	0.001	0.88	0.002
Owns Land (%)	0.92	0.001	0.91	0.001	0.95	0.001
Owns House (%)	0.89	0.001	0.88	0.001	0.91	0.002
House has Cemeneted Walls (%)	0.17	0.001	0.17	0.002	0.16	0.002
Age at First Marriage (years)	17.87	0.010	17.79	0.012	18.03	0.017
Observations	84544		55640		28904	

PANEL C. PKSF DATA

	All		*Non-Arsenic*		*Arsenic*	
	Mean	SE	Mean	SE	Mean	SE
Education bride (in years)	5.31	0.13	4.98	0.19	5.56	0.17
Education groom (in years)	5	0.14	4.74	0.21	5.19	0.18
Bride's age at the time of marriage	16.75	0.1	16.88	0.16	16.64	0.12
Groom's age at the time of marriage	23.59	0.15	23.59	0.22	23.6	0.2
Partner chosen by bride	0.08	0.01	0.08	0.01	0.08	0.01
Brides family richer	0.32	0.02	0.33	0.02	0.32	0.02
Groom's family richer	0.25	0.01	0.21	0.02	0.28	0.02
Bride Price (in Taka)	53366	2230	53980	3236	52900	3060
Dowry (in Taka)	22709	1034	20168	1291	24642	1528
Observations	875		378		497	

Table 2: Mean Bride Price and Dowry (in local currency - Taka): PKSF Data

	Bride Price		**Dowry**		**Observations**
	Pre-2002	*Post-2002*	*Pre-2002*	*Post-2002*	
Arsenic	45952 (4013)	59600 (4569)	20268 (1581)	28862 (2388)	497
Non-Arsenic	42611 (4226)	66619 (4801)	18774 (1756)	21718 (1902)	378

Notes: US Dollar - Bangladesh Taka exchange rate in year 2002 was 1 USD = 58 Taka. In the pre-intervention period the mean bride price was $792 in Arsenic areas while it was $735 in Non-Arsenic areas. For the same period the mean dowry was $350 in Arsenic areas while it was $323 in Non-Arsenic areas.

Table 3: Effect of Information Campaign on Age at First Marriage (AFM)

	Males		Females	
	(1)	(2)	(3)	(4)
Arsenic X Post2002	-0.22**	-0.28***	-0.097	-0.15**
	(0.091)	(0.098)	(0.061)	(0.069)
Education	0.096***	0.096***	0.050***	0.050***
	(0.0063)	(0.0063)	(0.0060)	(0.0060)
Religion is Islam	-0.91***	-0.91***	-0.55***	-0.55***
	(0.095)	(0.095)	(0.063)	(0.063)
Owns Land	0.41***	0.42***	0.25***	0.26***
	(0.10)	(0.10)	(0.067)	(0.067)
Owns House	0.18**	0.18**	0.16**	0.16**
	(0.079)	(0.079)	(0.066)	(0.066)
House has Cemented Walls	0.85***	0.85***	0.32***	0.31***
	(0.062)	(0.062)	(0.037)	(0.037)
Observations	73114	73114	84544	84544
Control Group Mean AFM (in years)	23.38		17.79	
Subdistrict Fixed Effects	✓	✓	✓	✓
Year of Marriage Fixed Effects	✓	✓	✓	✓
District Trends		✓		✓

Note: Standard errors in parentheses are clustered by sub-district. Sample weights used in analysis. Notation for p-values *** is $p < 0.01$, ** is $p < 0.05$ & * is $p < 0.1$. Regression includes a constant term and other controls as mentioned in the table.

Table 4: Effect of Information Campaign on Bride Price & Dowry

	Bride Price		**Dowry**	
	(1)	(2)	(3)	(4)
Arsenic X Post2002	-0.34	-0.64*	-0.09	0.08
	(0.45)	(0.37)	(0.19)	(0.22)
Education Bride (in years)	0.06*	0.07**	0.03	0.03
	(0.03)	(0.03)	(0.02)	(0.02)
Education Groom (in years)	0.05*	0.04	0.05***	0.05***
	(0.02)	(0.02)	(0.02)	(0.02)
Age of Bride	-0.06	-0.07*	-0.01	-0.00
	(0.04)	(0.04)	(0.01)	(0.01)
Age of Groom	0.01	0.01	0.02**	0.02**
	(0.03)	(0.03)	(0.01)	(0.01)
Partner Chosen by Bride	0.16	0.11	-0.43	-0.39
	(0.31)	(0.31)	(0.26)	(0.26)
Bride's Family Richer	0.12	0.14	-0.05	-0.04
	(0.16)	(0.16)	(0.09)	(0.09)
Groom's Family Richer	0.24	0.27	0.16	0.16
	(0.17)	(0.16)	(0.10)	(0.10)
Observations	875	875	875	875
Control Group Mean Bride Price (in Taka)	53980		20168	
Subdistrict Fixed Effects	✓	✓	✓	✓
Year of Marriage Fixed Effects	✓	✓	✓	✓
District Trends		✓		✓

Note: Dependent variables are log variables. Standard errors in parentheses are clustered by sub-district. Notation for p-values *** is $p < 0.01$, ** is $p < 0.05$ & * is $p < 0.1$. Regression includes a constant term and other controls as mentioned in the table.

Table 5: Placebo Analysis using Urban Sample

	Urban Sample	
	Males	*Females*
	(1)	(2)
Arsenic X Post2002	-0.13	-0.045
	(0.33)	(0.20)
Education	0.22***	0.22***
	(0.015)	(0.015)
Religion is Islam	-1.16***	-0.69***
	(0.17)	(0.16)
Owns Land	0.64***	0.21**
	(0.17)	(0.10)
Owns House	0.027	0.17*
	(0.15)	(0.094)
House has Cemented Walls	0.96***	0.60***
	(0.12)	(0.081)
Observations	14382	16174
Control Group Mean AFM (in years)	24.89	18.47
Subdistrict Fixed Effects	✓	✓
Year of Marriage Fixed Effects	✓	✓
District Trends	✓	✓

Note: Standard errors in parentheses are clustered by sub-district. Sample weights have been used in the analysis. Notation for p-values *** is p < 0.01, ** is p < 0.05 & * is p < 0.1. Regression includes a constant term and other controls as mentioned in the table.

Table 6: Heterogeneity

	Education			
	Males		*Females*	
	(1)	(2)	(3)	(4)
	Not Literate	*Literate*	*Not Literate*	*Literate*
Arsenic X Post2002	-0.21	-0.34***	-0.15	-0.21***
	(0.15)	(0.12)	(0.11)	(0.071)
Observations	31956	41158	32231	52313
Subdistrict Fixed Effects	✓	✓	✓	✓
Year of Marriage Fixed Effects	✓	✓	✓	✓
District Trends	✓	✓	✓	✓

Note: Standard errors in parentheses are clustered by sub-district. Sample weights have been used in the analysis. Notation for p-values *** is p < 0.01, ** is p < 0.05 & * is p < 0.1. Regression includes a constant term and other controls as mentioned in Table 3.

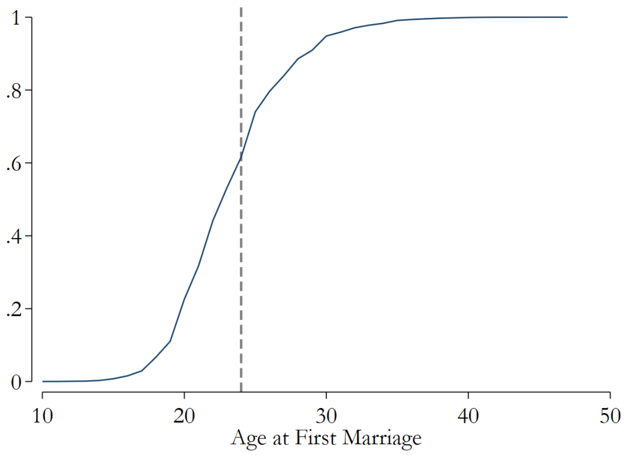
Appendix

(A) Skin lesions due to Arsenicosis

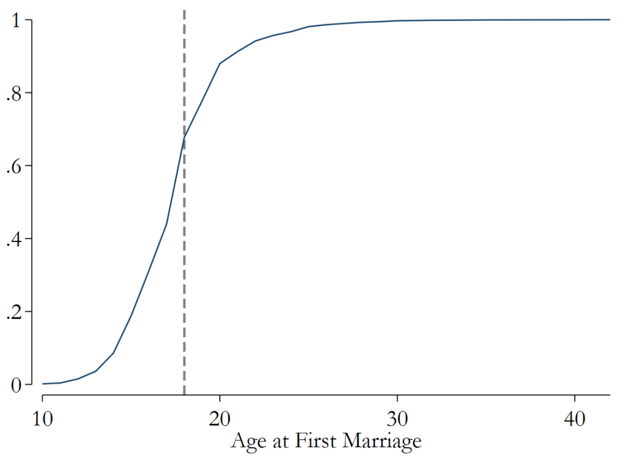
(B) BAMWSP campaign

Figure A1: Arsenicosis and Information Campaign.

Notes: Panel A shows skin lesions due to arsenicosis. Panel B shows Bangladesh Arsenic Mitigation and Water Supply Programme (BAMWSP) implementation with arsenic affected (unsafe) tubewells painted as red and non-arsenic (safe) tubwells painted in green color.



(A) Males

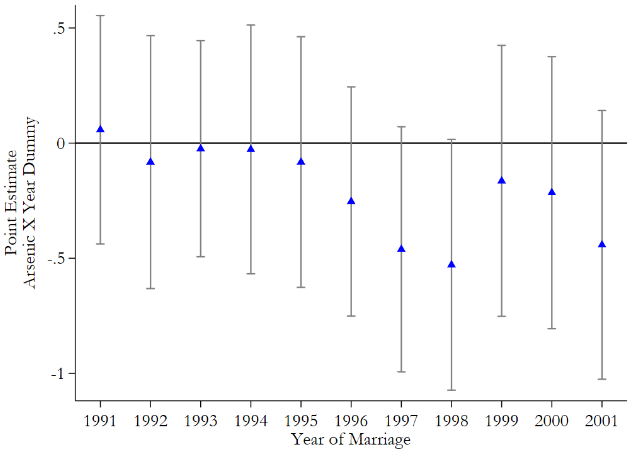


(B) Females

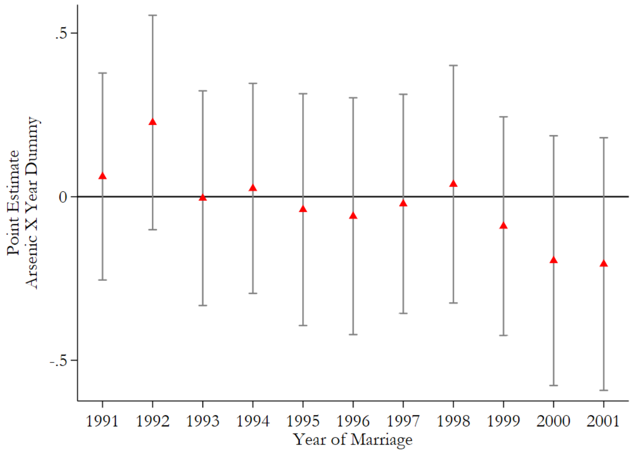
Figure A2: Cumulative Density Function for Age at First Marriage

Notes: Figures correspond to data for all marriages which took place between 1990 and 2010. The mean age at first marriage for males in our sample is 24 years while for females it is 18 years.

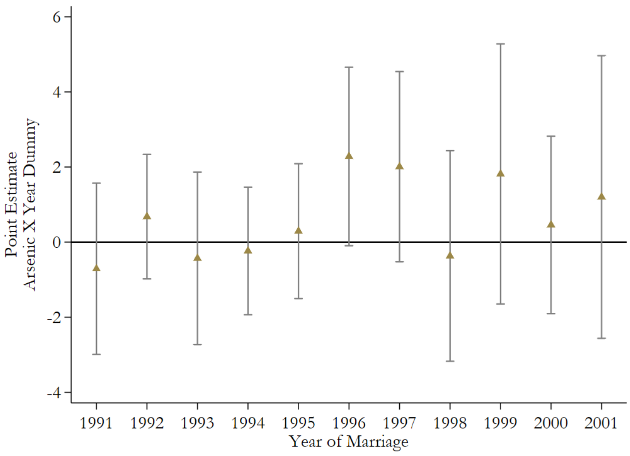
Source: Census 2011, Bangladesh Bureau of Statistics. Sample restricted to rural areas.



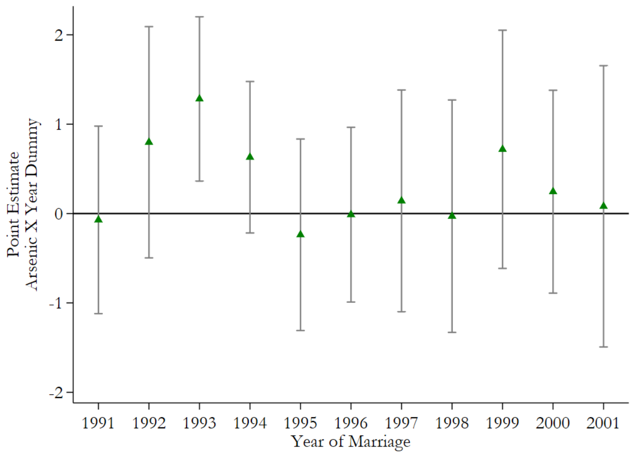
(A) AFM for Males



(B) AFM for Females



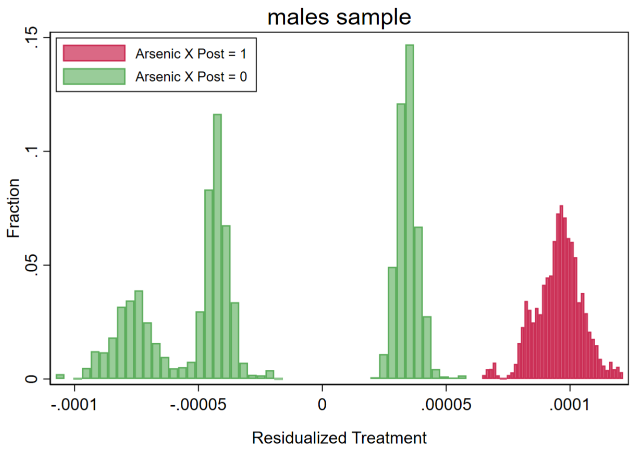
(C) Bride Price



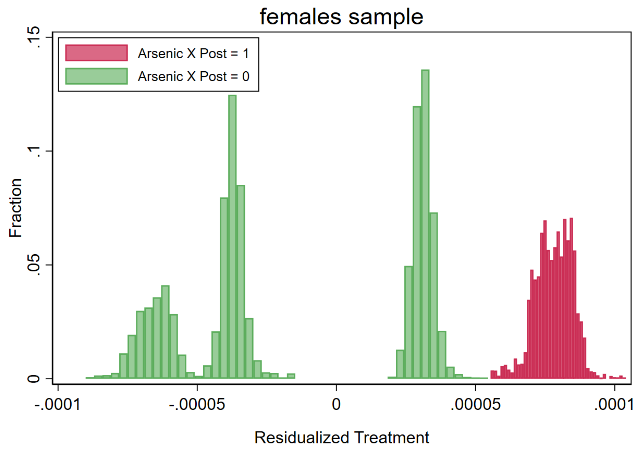
(D) Dowry

Figure A3: Testing for Parallel Trend Assumption.

Notes: Each coefficient represents the interaction variable (arsenic contamination dummy X year dummy) for each year during the pre-treatment period. The dependent variable in these regressions are: (A) age at first marriage for males, (B) age at first marriage for females, (C) logarithm of bride price and (D) logarithm of dowry. Other controls apart from the interaction variable include demographic controls (see full list of controls mentioned in Table 3 for panels A & B and Table 4 for panels C & D), subdistrict fixed effects, year of marriage fixed effects and district level time trends. The error bars are 95% confidence intervals, clustering at subdistrict level, sample weights have been used for analysis. All analyses restricted to individuals in rural areas.



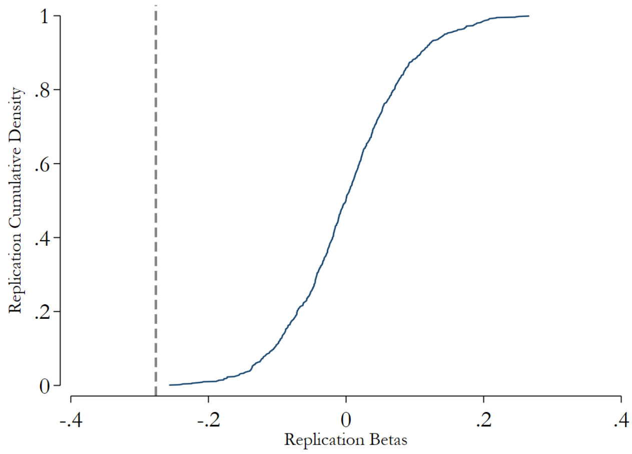
(A) Males



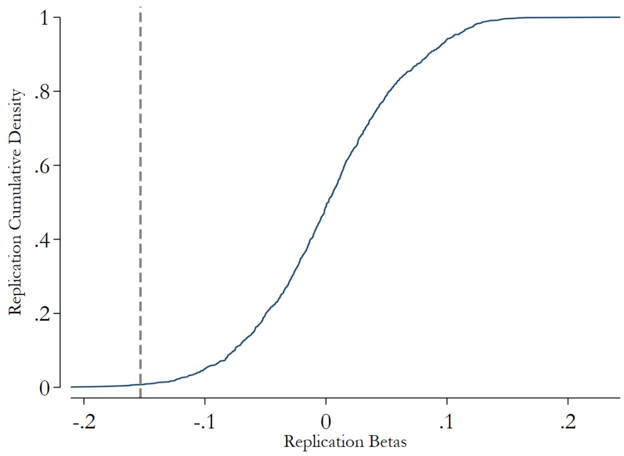
(B) Females

Figure A4: Weights in Two-way Fixed Effects Regressions

Notes: Figure represents weights received by observations in the analysis sample. Weights are calculated using a residualized regression of ArsenicXPost2002 variable on location (subdistrict) fixed effects and time (year of marriage) fixed effects. Clustering at subdistrict level, sample weights have been used for analysis. All analyses restricted to individuals in rural areas.



(A) Males



(B) Females

Figure A5: Placebo Test using Randomized Inference

Notes: Monte Carlo empirical CDF for coefficient Arsenic Dummy * Post 2002 (from Eq. (1)). The CDF plots estimates based on randomized inference obtained after conducting 1000 simulations which randomly assign exposure to arsenic, 1 (arsenic levels higher than 50µg/l = 1) or 0 (arsenic levels lower than 50 µg/l = 0) to observations. Our results are extreme values in these set of “coefficients” indicating that they were unlikely to arise due to chance.

Matching Analysis

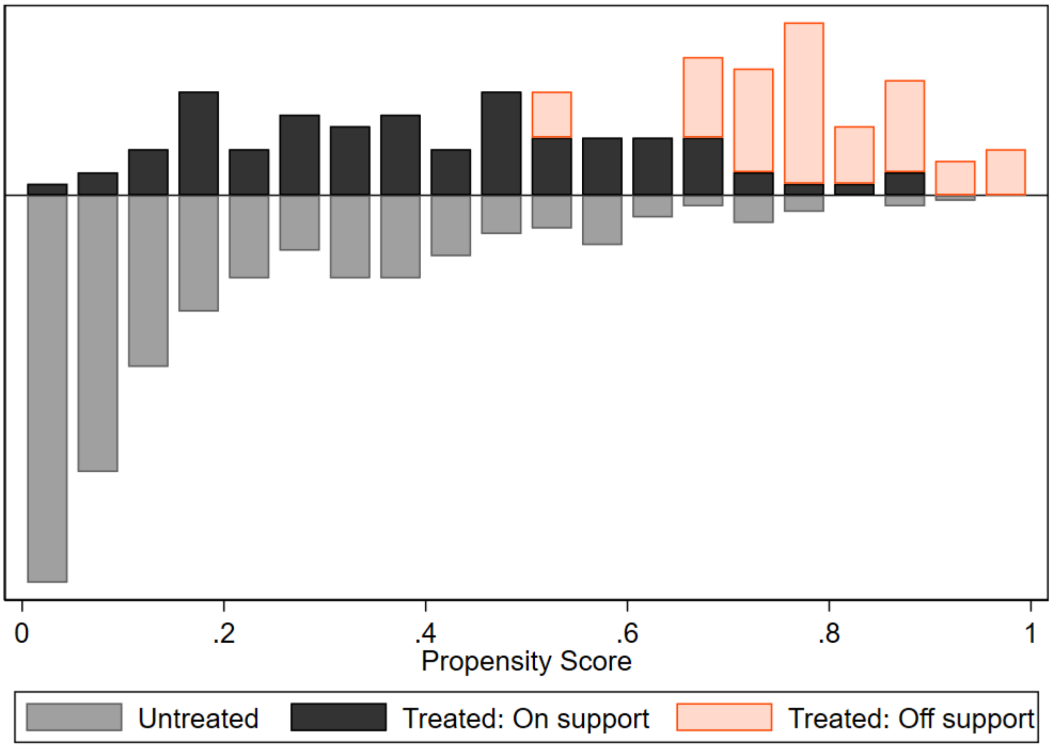


Figure A6: Density of sub-districts over propensity score. The matching is done using psmatch2 command in stata, with caliper value 0.05 and unique matching strategy with no replacement

Table A1: Testing for Homogeneity Assumption

	Males (1)	Females (2)
$\widetilde{\text{ArsenicXPost}}_{it}$	-0.239**	-0.096**
	(0.096)	(0.072)
$\widetilde{\text{ArsenicXPost}}_{it}$ * ArsenicXPost2002	0.0483	0.004
	(0.116)	(0.092)
Observations	73114	84544

Note: Dependent variable is residualized age at marriage. Standard errors in parentheses are clustered by sub-district. Sample weights used in analysis. Notation for p-values *** is p < 0.01, ** is p < 0.05 & * is p < 0.1. Regression includes a constant term and other controls as mentioned in the table.

Table A2: Effect of Information Campaign on Marriage Pool (as captured by Adult Sex Ratios)

	(1)	(2)	(3)
Arsenic X Post	-0.008	-0.008	0.008
	(0.013)	(0.013)	(0.018)
Post	0.12***	0.12***	
	(0.007)	(0.007)	
Arsenic		-0.008	-0.016
		(0.011)	(0.013)
Observations	820	820	820
Subdistrict	✓		
District		✓	
District*Year			✓

Note: Analysis uses a subdistrict-year panel for two census years 2001 (IPUMS data) and 2011 (Census). Post dummy takes value 1 for observations for year 2011 and 0 otherwise. Adult Sex Ratio is calculated by using individuals aged between 15 and 35 years. Notation for p-values *** is p < 0.01, ** is p < 0.05 & * is p < 0.1. Regression includes a constant term and other controls as mentioned in the table.

Table A3: Sub-district characteristics, full sample and matched sample of sub-districts; means and t-stat for differences

	1	2	3	4	5	6
SUBDISTRICT LEVEL MEANS	**Control**	**Treated**	**t-stat ((1) vs (2))**	**Matched Control**	**Matched Treated**	**t-stat ((4) vs (5))**
Employment Category						
Employed in Agriculture (%)	0.56	0.63	-5.13	0.58	0.58	-0.01
Employed in Formal Sector (%)	0.16	0.14	2.99	0.16	0.16	0.17
Employed in Business (%)	0.13	0.11	5.93	0.13	0.12	0.28
Employed in Others (%)	0.15	0.12	4.22	0.14	0.14	-0.30
Education Details						
Literacy Level (%)	0.44	0.40	4.02	0.43	0.43	-0.07
Number of Years of Education	3.30	2.96	4.29	3.19	3.20	-0.08
Completed Primary Education (%)	0.91	0.91	-1.41	0.91	0.91	-0.12
Employment Status details						
Employed (%)	0.42	0.43	-4.50	0.43	0.43	0.84
Unemployed (%)	0.02	0.02	3.18	0.02	0.02	-0.65
Inactive (%)	0.15	0.14	3.15	0.15	0.15	0.39
Involved in Housework (%)	0.40	0.40	0.24	0.40	0.41	-1.42
Household Characteristics						
Number of Children	1.67	1.61	2.98	1.63	1.63	0.06
Number of Families	1.45	1.39	5.21	1.44	1.45	-0.36
Electricity Connection (%)	0.24	0.18	4.55	0.22	0.22	-0.10
Ownership of House (%)	0.95	0.94	2.44	0.95	0.95	-0.71
Religion is Islam (%)	0.87	0.89	-2.39	0.87	0.89	-1.18
Other Demographic Characteristics						
Ratio of Males to Females for Adults	0.49	0.50	-5.44	0.50	0.49	1.65
Ratio of Males to Females in Children with age <1 year	0.52	0.52	-0.84	0.52	0.52	1.12
Number of Sub-districts	277	133		79	79	

*Source - IPUMS data for 2001

Table A4: Probit Estimation for Propensity Score Matching

Sub-district level means	**Arsenic Contamination = 1 or 0**
Employment Category	
Employed in Agriculture	0.11
	(0.44)
Employed in Formal Sector	0.11
	(0.64)
Employed in Business	2.05**
	(0.88)
Employed in Others	-
Education details	
Literate	-1.88**
	(0.80)
Number of Years of Education	0.39***
	(0.14)
Completed Primary Education	6.55***
	(1.57)
Employment Status Details	
Employed	1.40
	(1.45)
Unemployed	-2.83
	(5.85)
Inactive	0.16
	(0.86)
Involved in housework	-
Household Characteristics	
Number of Children	0.23**
	(0.11)
Number of Families	-0.080
	(0.27)
Have Electricity Connection	0.77***
	(0.19)
Ownership of House	2.12***
	(0.64)
Religion is Islam	-0.93***
	(0.23)
No Toilet Facility	-0.59***
	(0.16)
Other Demographic Characteristics	
Ratio of Males to Females in Adults	-7.58***
	(1.81)
Ratio of Males to Females in with age <1 year	-0.92
	(0.94)
Psuedo R-square	0.3089
Observations (number of subdistricts)	410

Notation for p-values *** is p < 0.01, ** is p < 0.05 & * is p < 0.1. Regression includes a constant term and other controls as mentioned in the table.

Table A5: Matched Sample Analysis for Age at First Marriage

	Males (1)	*Females* (2)
Arsenic X Post2002	-0.26*	-0.20**
	(0.15)	(0.096)
Education	0.096***	0.056***
	(0.011)	(0.0097)
Religion is Islam	-1.21***	-0.59***
	(0.16)	(0.10)
Owns Land	0.17	0.30***
	(0.16)	(0.10)
Owns House	0.26**	0.14
	(0.13)	(0.11)
House has Cemented Walls	0.74***	0.31***
	(0.090)	(0.050)
Observations	28189	33053
Control Group Mean AFM (in years)	23.58	17.92
No. of Subdistricts used in analysis	158	158
Subdistrict Fixed Effects	✓	✓
Year of Marriage Fixed Effects	✓	✓
District Trends	✓	✓

Note: Standard errors in parentheses are clustered by subdistrict. Sample weights have been used in analysis. Notation for p-values *** is p < 0.01, ** is p < 0.05 & * is p < 0.1. Regression includes a constant term and other controls as mentioned in the table.

Other Robustness Checks

Table A6: Age at First Marriage - Alternate Contamination Cut-offs

	Males				Females			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean Arsenic X Post2002	-0.002***				-0.001**			
	(0.001)				(0.000)			
$\text{Arsenic}_{>10\mu g/litre}$ X Post2002		-0.171*				-0.108		
		(0.089)				(0.069)		
$\text{Proportion Affected}_{>50\mu g/litre}$ X Post2002			-0.005***				-0.002	
			(0.002)				(0.001)	
$\text{Proportion Affected}_{>75\mu g/litre}$ X Post2002				-0.006***				-0.004***
				(0.002)				(0.001)
Observations	73114	73114	73114	73114	84544	84544	84544	84544
Subdistrict Fixed Effects	✓	✓	✓	✓	✓	✓	✓	✓
Year of Marriage Fixed Effects	✓	✓	✓	✓	✓	✓	✓	✓
District Trends	✓	✓	✓	✓	✓	✓	✓	✓

Note: Standard errors in parentheses are clustered by sub-district. Sample weights have been used in analysis. Notation for p-values *** is $p < 0.01$, ** is $p < 0.05$ & * is $p < 0.1$. Regression includes a constant term and other controls as mentioned in the Table 3.

Table A7: Bride Price - Alternate Contamination Cut-offs

	PKSF Data				PKSF+BRULS Data
	(1)	(2)	(3)	(4)	(5)
Mean Arsenic X Post2002	-0.01**				
	(0.00)				
$\text{Arsenic}_{>10\mu g/litre}$ X Post2002		-0.10			
		(0.27)			
$\text{Proportion Affected}_{>50\mu g/litre}$ X Post2002			-0.01		
			(0.01)		
$\text{Proportion Affected}_{>75\mu g/litre}$ X Post2002				-0.02**	
				(0.01)	
Arsenic X Post2002					-0.60*
					(0.31)
Observations	875	875	875	875	1699
Subdistrict Fixed Effects	✓	✓	✓	✓	✓
Year of Marriage Fixed Effects	✓	✓	✓	✓	✓
District Trends	✓	✓	✓	✓	✓

Note: Dependent variables are log variables. Standard errors in parentheses are clustered by sub-district. Notation for p-values *** is $p < 0.01$, ** is $p < 0.05$ & * is $p < 0.1$. Regression includes a constant term and other controls as mentioned in the Table 4.