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# Arsenic Exposure and School Participation in Cambodia

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## Abstract

We exploit the exogenous variations of arsenic contamination across regions in Cambodia and apply two-period difference-in-differences (DID) to examine the impact of arsenic-contaminated groundwater on school participation among children aged 5-17. We find that conditional on the DID assumption, a standard deviation increase in the arsenic reduced the probability of having ever been enrolled for children aged 5-17 by approximately 0.017. The effects for girls are slightly larger than those for boys. Our results are robust to adding parental education, province fixed effects and zone trends. We also show that children of all specific age groups experienced the reduction in their probabilities of having ever been enrolled, while the children, who were between 12 and 17 years old, currently enrolled and active in the labor market, experienced more reduction in school enrollment relative to their peers, who were not active in the labor market.

**JEL:** O15, I28

**Key words:** Arsenic, Cambodia, Difference-in-Differences, School participation

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## 1. Introduction

Arsenic contamination of groundwater is a serious public health issue for more than 140 million people living in over one-third of the world's countries (UNICEF 2013). With wide-ranging levels of concentration of arsenic contamination, few of the affected countries have been spared the plague-like proportions. Some of the regions include the Bengal delta in India, Mekong delta in Cambodia and Vietnam, Bangladesh, Thailand (Berg et al., 2007; Sthiannopkao et al., 2008) as well as parts of the United States (Singh et al. 2015). Ingesting arsenic above a certain threshold level can lead to arsenicosis or arsenic poisoning, with severe health consequences including cancer, heart and lung diseases and miscarriages<sup>1</sup>. Left unchecked, the long term effects of arsenic for which there is no known cure, can be fatal. Crucially, children are particularly at risk to the harmful effects of arsenic poisoning which is known to hinder cognitive development. Arsenic poisoning has a disproportionate effect on children health due to their developing bodies which make them far less immune to ingesting the contaminant. Poor child health due to drinking arsenic-contaminated water can reduce school attendance. Time spent in school may also be reduced if adolescents are forced to seek employment to care for family members who themselves become ill. The physical symptoms of arsenicosis expressed in the form of skin lesions may lead to social exclusion arising from the stigma associated with the illness. If children are ostracized at school then the psychological impact may have far-reaching implication for school participation (Asadullah and Chaudhury, 2011).

This paper aims to shed some light on this issue by investigating whether there is a causal impact of exposure to arsenic on school participation of children in Cambodia. School participation among children is an important issue because while the enrollment rate in primary education is considered to be relatively high in Cambodia, there is still the problem of dropout rates which in 2014 ranged from 9.4 percent at the primary level to 29.5 percent at the upper secondary level (MOEYS, 2015). High dropout rates may be determined by illness and economic factors such as the opportunity costs of schooling and employment opportunities. Therefore, analyzing the effects of arsenic

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<sup>1</sup> The World Health Organization (WHO) recommends a guideline value of 10 micrograms per liter (g/L) or parts per billion (ppb) as the threshold level since it is difficult to remove arsenic below this amount.

concentrations on school participation is relevant to policy aimed at devising strategies and implementing programs to curb and eliminate these effects.

We exploit regional variation in the levels of arsenic that are detected in groundwater and the timing of exposure to identify the impact of arsenic contamination on school participation for children in Cambodia. According to census data, more than 2 million Cambodian residents live in areas affected by arsenic in groundwater exceeding levels based on the WHO guidelines of 10µg/L. Most of the arsenic is heavily concentrated in areas near the major rivers running through the lower middle central parts of the country (Figure 1). To measure exposure to arsenic, we employ detailed data on the arsenic level of groundwater from the UNICEF-sponsored Arsenic Center established in 2008 to provide information on the location and levels of arsenic. To measure children participation in school we use sample data from the census of children aged 5 to 17 of the general population of Cambodia: a cohort of 428,947 children of the 1998 sample and a cohort of 411,387 children of the 2008 sample. Children from the 1998 sample were born before the discovery of arsenic in Cambodia while the cohort of children from the 2008 sample born after the discovery were exposed to differential levels of arsenicosis. Our identification strategy exploits differences in the arsenic intensity between regions and the differences in the exposure to arsenic between the same age cohorts over the different periods.

[Figure 1: Here]

This study is part of a large literature exploring the relationship between health and education (Grossman, 2008). Emanating from these studies is a branch of research looking at the implications for schooling arising from adverse health conditions among children. For example, Fowler et al. (1992) using U.S. data for children around the ages of 6 to 17, noted that children with asthmatic conditions compared to children without the condition were absent from school three times as much while a higher proportion of unwell children had repeated a grade. Currie et al. (2009) also found that pollution via elevated levels of carbon monoxide increases absences of children in elementary and middle schools in Texas. Within developing countries, some of the earlier studies on children's health and school participation include Moock & Leslie (1986), Glewwe & Jacoby (1995), and Behrman (1996). A preponderance of the evidence in the literature shows that school attendance increases when children are healthier, whether it be through de-worming in Kenya (Miguel and Kremer 2004),

providing a mid-day meal in India (Drèze and Kingdon, 2001) or other forms of nutrition as in the case of Pakistan (Alderman et al., 2001).

Despite the growing literature on the health impacts on school participation, most of these studies focus on nutritional effects. To the best of our knowledge, there are no studies that investigate the impact of an environmental pollutant (arsenic contamination of groundwater) on school enrollment. This is particularly surprising because the significant impact of education on earnings and the greater role it plays in developing countries are well documented (Psacharopoulos, 1994). Moreover, the largest returns to education are attributable to primary schooling (Schultz, 2002). Given the economic significance of education, the physiological and psychological impact of exposure to arsenic-contaminated water on school participation is an important empirical issue.

This paper is closely related to studies examining the adverse impacts of arsenic exposure on various aspects of child development related to intelligence (Wasserman et al., 2009), lesions (Carpenter et al., 2000) and ostracization (Hassan, Atkins & Dunn, 2005). The study that comes closest to ours is that of Asadullah and Chaudhury (2011), who uses administrative data for Bangladesh to investigate the effect of arsenic contamination in groundwater on the level of cognitive development as well as the psychological state of affected children in secondary schools. In their results, the authors observed declines in math test scores (as well as subjective well-being) of children residing in a home with a contaminated water well. The decrease in test scores ranged from 0.05 to 0.17 standard deviations. Our study contributes to the literature by using a rich and nationally representative dataset to investigate the causal effect of exposure to differential levels of arsenic contamination on school participation in Cambodia.

We investigate the impact of arsenic-contaminated groundwater exposure on a child's propensity to enroll in school. The issue of enrollment is important in Cambodia because despite the recent progress made with education, average years of schooling are still less than five<sup>2</sup>, suggesting the average school-age child is unlikely to obtain a full primary education. A recent report of the United Nations (UNICEF, 2012) documents how factors such as late enrollment, poverty, and the lack of drinking water cripple a child's ability to stay in school.

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<sup>2</sup> <http://www.kh.undp.org/content/cambodia/en/home/countryinfo.html>

We employ a difference-in-differences (DID) estimation strategy by exploiting exogenous variations in exposure to arsenic contamination first identified in 2000. Intensity in the degree of exposure varied across districts of the country. We use census data for the periods 1998 and 2008, to investigate the extent to which exposure to the water-borne contaminant had an impact on school participation among children age 5 to 17. The school-going children from the 2008 sample were exposed to arsenic-contaminated water, while those from the 1998 census data were not. The “treatment” effect is measured by the interaction between the district-level intensity of the exposure to arsenic and the indicator variable of post-arsenic discovery. The validity of the estimates in our difference-in-differences analysis relies on the assumption that in the absence of arsenic, there should be no differences in the two groups of children.

We find that an exogenous increase in exposure to arsenic-contamination in water triggered a change in school participation among children. Conditional on the DID assumption, a one standard deviation increase in arsenic exposure reduced the probability of a child enrolling in school by 0.017. The effects are greater for girls compared to boys. Across age groups, we find that exposure had the greatest impact on children in the 7 to 11 years range. We also compared the effect on 12-17 year-olds before and after the discovery and find that the exposed children in this specific age category were more likely to not attend school. One potential avenue through which arsenic exposure can influence children's ability to attend school is its impact on child health where the effects may be more acute among working adolescents who might eventually choose work over school after a prolonged illness. We also speculate that the effect might run through parental health and income. While we are unable to determine the exact mechanism through which arsenic exposure alters school participation, we demonstrate there is a robust effect on school attendance.

The remainder of the paper proceeds as follows: Section 2 describes the arsenic situation and water use in Cambodia. Section 3 provides a conceptual framework. Section 4 explains the identification strategy for modeling the causal impact of arsenic exposure. Section 5 describes in detail the data and provides some descriptive statistics of the same. The results of the effect of exposure to arsenic on school enrollment are presented in section 6. Section 7 concludes.

## 2. Arsenic situation and water use in Cambodia

Cambodia is considered a low middle-income country that is located in the continental Southeast Asia region. It is sandwiched between Thailand and Laos on its northern and western borders, Vietnam in the east and south and the Gulf of Thailand on the southwest. As of 2013, per capita gross domestic product was USD 1,036. Over the past two decades, the economy has witnessed average growth rates in excess of 7 percent, an unprecedented level for any post-conflict country (IMF, 2016).

In Cambodia, surface water (river and pond), shallow hand-dug well water and rainwater have traditionally been used for various daily consumption purposes, such as drinking and cooking. Surface water use is more common in rural Cambodia, especially during dry season between November and April. Since 1989 when the country began to experience reforms in moving from a command economy to more market-based, there has been a significant increase in inflow of official development assistance<sup>3</sup> (ODA). This has led to substantial increases in the number of tube wells (Figure 2). The introduction of tube wells was in response to the high child mortality rates owing to the consumption of surface water, which is often contaminated with bacteria that carry diseases, such as typhoid and diarrhea.

[Figure 2: Here]

The first evidence of naturally-occurring arsenic in groundwater was confirmed in 2000 when two government ministries (the Ministry of Rural Development and the Ministry of Industry, Mines and Energy), jointly conducted an assessment of the quality of drinking water in Cambodia (World Bank, 2012). Results of the testing that was carried out in 13 provinces, indicated that more than 10 percent of the water samples was found to be contaminated at levels exceeding the WHO maximum permissible guidelines of 10µg/L; the Cambodian authorities deem a level of 50µg/L to be safe. More than 2 million Cambodians live in arsenic-affected areas (UNICEF, 2009). Although rainfall provides an adequate supply of surface water, the lack of proper hygiene renders much of it unusable. Together with the fact that arsenic is undetectable by humans (i.e. it requires chemical testing), odorless and tasteless, arsenic-rich water has become the de facto source of drinking water. This is crucial because

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<sup>3</sup> Total official development assistance was USD 24.7 million in 1989 and went up to USD 200.5 million in 1992 and USD 742.8 million in 2008 (World Bank, 2016).

most of the affected regions are found in rural communities, which account for more than 80 percent of the country's population, while the main economic driver - agriculture - relies heavily on groundwater.

In response to the discovery of arsenic, a number of initiatives were undertaken by the government as well as key international organizations such as the UNICEF. These measures included the establishment of national drinking water standards, a database of tube wells and their arsenic content via an arsenic center, as well as campaigns increasing awareness and promoting safer drinking water habits. Although there is no known comprehensive study on the arsenic situation in the country, the UNICEF (2009) reports that an estimated 1,607 villages in 49 districts of seven provinces are affected by the contaminant found in tube well water. Approximately one quarter of the population residing in these provinces have at some point used tube well water for cooking and drinking. More than 35 percent of the tube wells were contaminated with arsenic at levels well above the country's safe guidelines of 50µg/L, implying the number might be much closer to 50 percent using the WHO standards of 10µg/L. Overall, over 500,000 households living in the arsenic-affected areas consume contaminated water (UNICEF, 2009).

### **3. Conceptual framework**

This section discusses likely channels through which contamination of naturally occurring arsenic may impact school participation of children at school-going age. It is reasonable to believe that children are likely to be absent from school if they fall ill because of consuming arsenic-contaminated water; parents who fall sick owing to the same health reason are more likely to be absent from work, which results in income loss, possibly inducing them to withdraw their children from school; and children who get arsenicosis after prolonged consumption of arsenic-contaminated water are less likely sent to school for ostracism reason.

It is important to note that the common pathway from arsenic to school outcomes in this setting is individual's health. The contamination depends on both the degree to which households are exposed to tube wells and the degree to which arsenic is ingested and retained in the individual's body (Pitt, Roseinzeig & Hassan, 2012). Ingestion of arsenic is normally through drinking water and



consuming foods grown or cooked in arsenic-contaminated water. Since different foods have distinct reaction to and extent of the carriage of the arsenic, the degree of arsenic retention varies based on the dietary sources of the individual. For instance, Hossain (2006) reports based on his extensive tests of the food products in Bangladesh that leafy vegetables have the highest concentration of arsenic. In addition, some foods contain nutrients that enable detoxification and excretion of arsenic, the process of which is known as methylation (Pitt et al., 2012).

Previous studies show that poor health among children reduces their time in school and performance (see Glewwe and Miguel (2007) for the review and discussion). Hence, the effect of arsenic-contaminated water use on children's school participation may work through reduced quality of child health owing to consumption of the contaminated water. It is important to note that although a range of severe diseases, such as cancers of urinary organs, skin, bladder and lung, arise after 10-15 years of exposure to arsenic poisoning (Kapaj et al., 2006; Tchounwou et al., 2003; Lamm and Kruse, 2005), immediate symptoms, such as diarrhea, abdominal pain and vomit, are also the results of excessive absorption of arsenic via drinking (WHO, 2016). Therefore, the mechanism may work through its immediate effect on child health.

Another potential channel is through the problem of exclusion for children in school and the community (Asadullah and Chaudhury, 2011). If children are exposed to arsenic poisoning at birth or a very early age, they are more likely to develop skin condition, known as arsenicosis, where patients experience changes in skin color and patches of hard skin on the palms and the feet (Shantz et al., 2012), by the time they reach school-enrolling age. In Bangladesh, there is anecdotal evidence, which suggests that children with such symptoms are often not sent to school in order to avoid ostracism at school (Hassan, Atkins & Dunn, 2005). Therefore, the mechanism may work through arsenicosis carried among school-age children.

In addition, severe arsenic poisoning to the head of the households or parents of the children may result in a negative income shock due to absence from work or loss of job due to illness. Such shocks are likely to reduce investment in a child's schooling. Previous studies show a positive relationship between health status and income (Deaton & Paxson, 1998; Paxson, 2008). Other studies also show that households may cut back spending on their children's schooling, withdraw them from

school or even place them in the labor market as a means to smooth their consumption after they experience negative income shocks (Jacoby, 1994; Jacoby & Skoufias, 1997; Fitzsimmons 2003; Beegle et al., 2006). Thus, in an environment where about 80 percent of the population reside in the rural areas, in which credit constraint is quite prevalent, such mechanism is also likely at work.

#### **4. Identification strategy**

We use the exogenous variations of arsenic contamination in groundwater and apply two-period difference-in-differences (DID) method to identify the impact of arsenic poisoning on school participation for children aged 5-17 in Cambodia. The DID estimate is obtained by subtracting average effect in lower-arsenic (control) districts from average effect in higher- or at-risk-arsenic (treatment) districts. This eliminates bias due to permanent differences of the two groups when comparing after the exposure occurs and bias due to trends when comparing treatment group over time (Imbens & Wooldridge, 2009). Interpretation of the estimate is based on the assumption that outcomes in the control and the treatment groups should not have differed systematically in the absence of arsenic poisoning.

The groundwater contamination is due to naturally occurring high concentration of arsenic in deep groundwater. Arsenic poisoning occurs when an individual consumes drinking-water from tube wells that pump the groundwater directly from the aquifers. Figure 1 shows that districts with high or at-risk (50+ ppb) level of arsenic are concentrated in the south-east of Cambodia, which provides us with substantial variations of arsenic levels. The DID method requires that the same individuals are observed in the two periods. Although households observed during the 1998-2008 period are not the same, districts are the same; thus, the DID method is still feasible (Agrist & Pischke, 2009). We assume that our baseline period is 1998, which is two years before the arsenic contamination was detected, while our post-arsenic period is 2008. We believe that selection of the baseline year is reasonable as the installation of tube wells became widespread across Cambodia around the time as indicated in Figure 2. We follow Angrist and Pischke (2009) and estimate the following equation by using Ordinary Least Squares (OLS).

$$Y_{ijt} = \alpha + \gamma Arsenic_j + \lambda Post_t + \beta(Arsenic_j * Post_t) + \delta X_{ijt} + \epsilon_{ijt} \quad (1)$$

where  $Y_{ijt}$  represents school attendance of a child  $i$  in district  $j$  at time  $t$  and takes the value one if she has ever attended school and zero otherwise.  $Arsenic_j$  is the average level of arsenic from the tub wells in district  $j$ , while  $Post_t$  is a time dummy, which equals one if it is year 2008 and zero if it is 1998. Our variable of interest is the interaction term  $(Arsenic_j * Post_t)$  whose coefficient  $\beta$  provides an estimate of the impact of exposure to arsenic.  $X_{ijt}$  is a vector of additional controls, which include sex of a child, education of mother and education of father, while  $\epsilon_{ijt}$  is an error term. As data are grouped at district level, we cluster our standard errors at village level to correct for intra-cluster correlation and heteroskedasticity (Liang & Zeger 1986; Angrist & Pischke, 2009; Cameron & Miller, 2003).

#### 4.1. Potential threat to identification strategy

Our DID estimates are potentially driven by various mitigation programs which were implemented in the at-risk regions after the arsenic contamination was detected in 2000. Various interventions were put in place in those regions. For instance, Kandal province, the most highly at-risk location relative to others, received a mitigation program that provided households in selected villages with ceramic water purifiers in addition to education programs conducted at school, health centers and the community (UNICEF, 2009). This suggests that our DID estimates are likely to exhibit downward bias, that is, in the absence of the mitigation programs, the magnitude of the effect would have been larger. Accordingly, our estimates are likely to constitute a lower bound of the impact of the exposure to arsenic poisoning.

#### 5. Data

We use data from the 1998 and 2008 censuses of Cambodia, obtained from IPUMS-International of the Minnesota Population Center. The census was conducted by the National Institute Statistics of the Royal Government of Cambodia. Two sets of questionnaires, namely housing and household, were used in the census. The former covered housing structures, while the latter included household

demographic information, education, occupation, fertility and mortality in the last 12 months. We also collected data on tube wells in 2009 from the Arsenic Center of Cambodia<sup>4</sup> (ACC). The data consist of information of the year of well installation, well depth, arsenic level and the number of households that each well serves. Information on arsenic level is reliable and less prone to measurement error because the UNICEF and the WHO provide technical support to the Ministry of Rural Development and the ACC in collecting the sampled groundwater from each well and conducting lab test. The total number of tube wells in the dataset is 52,382.

We merge the two data sets by manually identifying common district names. Because not every district has data on tube wells as indicated in Figure 1, we keep only census districts that exactly match with those in the data on tube wells to obtain two-period district panel data for our analysis. It is important to note that our treatment variable is measured at district level and it is the average of the arsenic content across tube wells in each district. Summary statistics of the outcome and explanatory variables are presented in Table 1. Enrollment among children aged 5-17 increased markedly between 1998 and 2008; similar patterns are also evident for each specific age group and for both boys and girls during the period. Enrollment for girls across specific age groups was much lower than that for boys of the same age groups in 1998, but such disparity for boys and girls almost disappeared in 2008.

[Table 1: Here]

## 6. Estimation Results

Results from the DID estimation are shown in Table 2. The results show that conditional on the DID assumption, arsenic contamination has a negative impact on the probability of having ever been enrolled in school for children aged between 5 and 17. Column (1) in Table 2 shows that conditional on the DID assumption, a standard deviation increase in arsenic reduced the probability of having ever been enrolled in school for children by approximately 0.017 ( $33.42 \times 0.00051$ ). The impact on the probability of being enrolled for boys, shown in column (2), is slightly lower than that for girls, shown in column (3). This suggests that the mechanism might work through the reduction in the quality of child health (i.e. diarrhea or skin lesions) or parental health; however, due to the absence of

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<sup>4</sup> <http://www.arseniccentercambodia.com>

health data for children and parents, we are unable to test this mechanism directly. To the extent that our treatment group may have received various arsenic-related mitigation programs after the detection of at-risk levels of arsenic in 2000, it is likely that the impact will produce a lower-bound estimate. Therefore, the impact would have been larger had the various mitigation programs not been implemented in the arsenic-at-risk regions. This implies that the programs reduced the extent of the harmful effect inflicted by the poisoning. On the other hand, more efforts and resources are needed for the programs to eliminate the poisoning completely.

[Table 2: Here]

### **6.1. Impact in rural and urban areas**

As households in the rural areas either are less connected to or have less access to facilities, such as water treatment equipment, piped water and health centers, relative to households in the urban areas, there is a reason to believe that the impact among rural children could be larger. We investigate this by restricting our sample to urban and rural population separately and results of the impact are shown in columns (4)-(9) in Table 2. The coefficients in columns (4)-(6) are negative and statistically significant at the 1 percent level, while those in columns (7)-(9) are negative, but are statistically insignificant. This indicates that such differential effects are likely to be attributed to the fact that urban households probably have better access to arsenic-mitigating facilities and information, and therefore, were able to completely mitigate the impact from the arsenic poisoning. Furthermore, we use information on whether households have access to piped water to restrict the sample to households with access to piped water (both inside and outside dwellings) as such access is more common among households in the urban areas. Using this restricted sample, we obtain negative coefficients of the impact for all children, boys and girls, but the coefficients are not statistically significant at any percent level (results are not shown and available upon request). This ascertains the fact that urban households with arsenic-mitigating facilities are better insulated from arsenic poisoning.

## 6.2. Impact by housing conditions

We are also interested in investigating whether the impact on all children's school participation in the rural Cambodia vary by households' wealth status. We use number of rooms of households' home as a proxy for households' wealth status and estimate the impact for each group separately. The results as presented in Table 3 show that almost every children across housing statuses experienced reduction in the probability of having ever been enrolled, except for the children of households residing in houses with at least four rooms, which is a small population in the sample. Interestingly, the effect on the probability of being enrolled of the children residing in three-room houses is smaller than the effect on the probability of being enrolled for children residing in one-room and two-room houses. Our results suggest that wealthier households, which is a small population in the sample, were able to circumvent the effects. Meanwhile, it is important to note that the effects found here are interpreted as lower bounds. Our results also provide policy-relevant implications in a manner that the extent of the impact could be

better ameliorated if arsenic-mitigating programs target households from the lower wealth status.

[Table 3: Here]

## 6.3. Robustness Check

We also conduct robustness checks by including additional control variables, such as sex, education of mother and father of children, province fixed effects and zone trends. The results are shown in Table 4. Province fixed effects capture the unobserved time-invariant factors that are common for both control and treatment groups in each province. Province is the second lower administrative unit after zone. There are five geographical zones and 24 provinces in Cambodia. The zone trend is the interaction between zone dummies and  $(Post_t)$ . It controls for the fact that the trends of outcome may differ across zones.

[Table 4: Here]

With the inclusion of additional controls, the coefficients of impact for all children, boys and girls, shown in columns (1)-(3) in Table 4, are slightly larger than those in columns (1)-(3) in Table 2,

while their signs do not change. Moreover, the results from adding province fixed effects, shown in columns (4)-(6) and zone trends, shown in columns (7)-(9), do not differ substantially from those in Table 2. This indicates that our results are robust to adding additional controls, province fixed effects and zone trends. Overall, conditional on the DID assumption, a standard deviation increase in the arsenic reduced the probability of having ever been enrolled for all children between 0.018 and 0.019<sup>5</sup>.

#### **6.4. Impact by specific age groups**

Table 5 presents the age-specific impact of arsenic poisoning on the probability of having ever been enrolled for all children aged 5-17. Our results reveal three patterns of impact: children aged 5-6 received the least impact (columns 1 and 2), while children aged 7-11 experienced the most impact (columns 3 and 7), which is approximately twice as large as the impact for children aged 12-17, indicated (columns 8 and 9). The least impacts found among children aged 5-6 are due probably to their low probabilities of having ever been enrolled in school compared with those children aged 7-17 as indicated in Table 1. It should be noted that delayed enrolment is common to primary school-age children in Cambodia. On the differential impacts between children aged 7-11 and 12-17, due to lack of data we can only speculate that it is probably owing to the fact that younger children were more susceptible to symptoms, such as diarrhea, abdominal pain and vomit, that arose after being excessively exposed to arsenic poisoning, compared with their elder peers.

[Table 5: Here]

#### **6.5. Impact by labor status**

We also examine whether children, who are currently enrolled in school and active in the labor market, experience different impact on their probability of having ever been enrolled in school as it is common that children in developing countries such as Cambodia engage in various forms of child labor, be they unpaid labor at home or paid labor outside home. We test this by replicating results in

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<sup>5</sup> Our results rely on the strong DID assumption that in the absence of the arsenic-contamination, there will be no significant difference in the two groups. With only two census-period of data available, we are unable to verify this assumption through, say a *placebo* test.

Table 5 and adding the interaction between  $(Arsenic_j * Post_t)$  and  $(Active_i)$ .  $(Active_i)$  is a dummy variable, which takes the value of one if a child is currently enrolled in school and active (employed or unemployed) in the labor market and zero if he or she is inactive or not working as defined in the census. We restrict our sample to children aged 12-17 as this group is more active in the labor market, relative to those aged 5-11<sup>6</sup>.

[Table 6: Here]

Table 6 presents the results of the age-specific impacts. The coefficients of the interaction term for all ages of children (columns 1 and 6), are negative and statistically significant at the 1 percent level. This confirms that among the children aged 12-17 those who were currently enrolled and active in the labor market, experienced more reduction in probability of having ever been enrolled in school due to arsenic exposure compared with their peers who were not active in the labor market. The negative effect from arsenic poisoning compounded the school and work burden so that children were more likely to give up on schooling in preference to maintain their jobs.

## 7. Conclusion

Arsenic contamination in drinking water is a world health issue which threatens the livelihood of many found in some of the faster growing economies. While the impact on health is well-documented, the health consequences can have serious implications for education and human capital which represent key ingredients to growth and development, especially in developing countries. Despite the first discovery of the poisonous contaminant in the 1970s, little research has been devoted to the adverse impact on children's propensity to attend school. In this paper, we attempt to redress this by investigating whether an increase in exposure to arsenic poisoning affects children's ability to participate in school.

We use census data from Cambodia where arsenic contamination of ground water was first discovered in 2000. Exploiting exogenous variation in exposure to the contaminant across various

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<sup>6</sup> The number of observations for children, who are between 5 and 11 years old and in the labor market, ranges from 137 to 489, and children of this group are less likely to engage in the labor market. The number of observations for children, who are between 12 and 17 and active in the labor market, ranges from 1,000 to 5,000.



districts, we analyze whether an increase in exposure because of the discovery had an impact on the probability of entering school for children age 5-17. We also examine whether there was a differential impact on adolescents who were active in the labor market.

The results point to a negative relationship between arsenic contamination of drinking water and the probability of entering school. Specifically, conditional on the DID assumption, a one standard deviation increase in the exposure to arsenic reduced the probability of having ever been enrolled for children by about 0.017. The greatest impact is observed among girls and as well as for working adolescents. These findings are robust after controlling for gender of children, parental education, province fixed-effects and zone trends. The exact channels through which arsenic poisoning alters the probability for the children to attend school is unclear. This impact can be due to a number of influences including child health, parental health, income and wealth, and labor market involvement. Nevertheless, conditional on the DID assumption, an increase in exposure to arsenic contamination has a causal effect on school participation.

Our work adds to existing studies on arsenic contamination on schooling in Cambodia in that we use a large nationally representative sample of children. To our knowledge, there is no known work on arsenic exposure on the likelihood of school enrollment among children for any country. To the extent that our conservative estimates are causal, they point to the need for overdue policy aimed at, in the very least, ramping up resources to undertake a comprehensive inventory on the status of pollution of tube wells within the country, particularly in schools and homes. Improving our knowledge in these areas will pave the way for mechanisms that effectively target those polluted areas which may predispose children to illness and the inability to attend school.

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Figure 1: Distribution of arsenic across district in Cambodia between 2000 and 2009

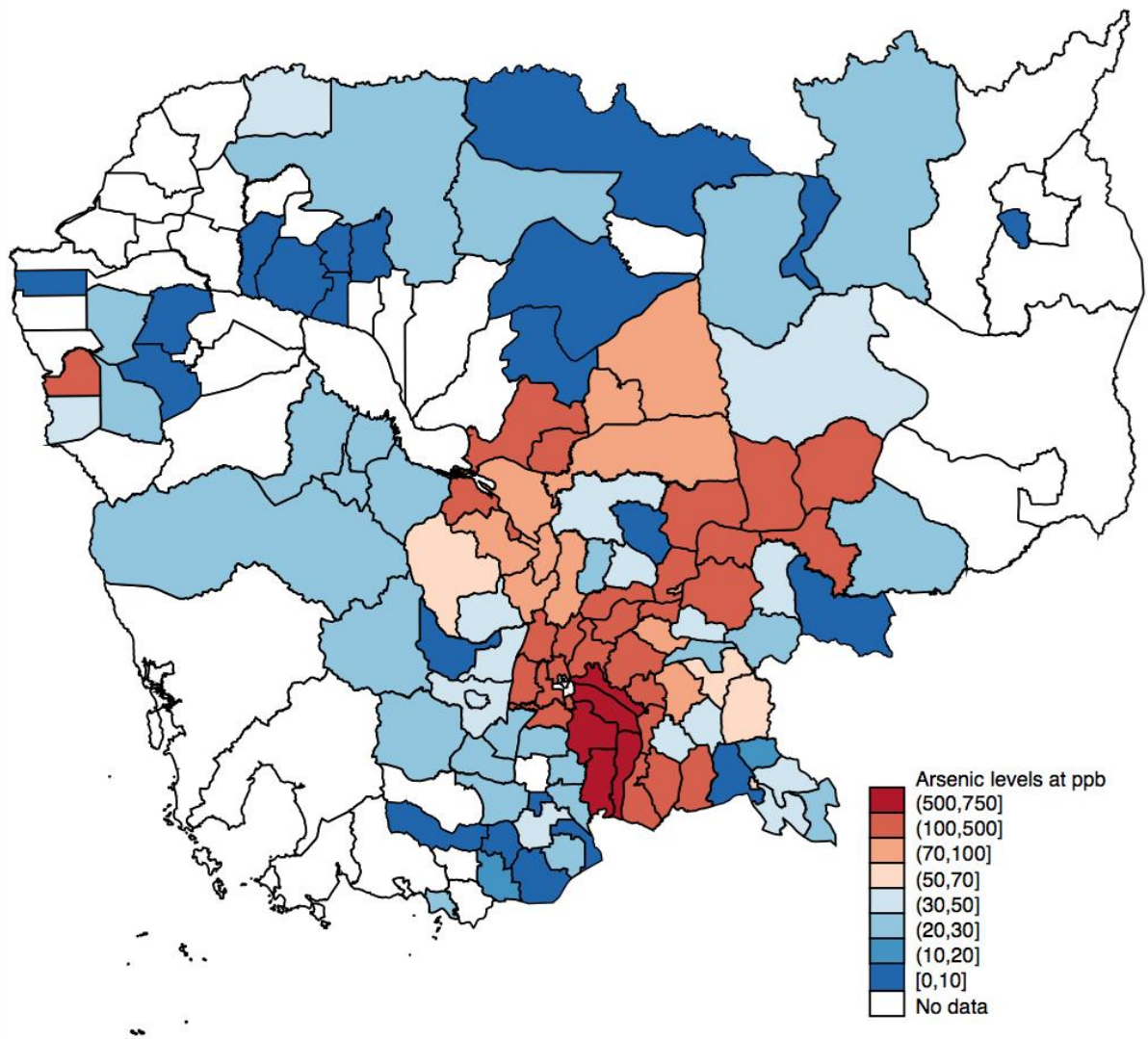
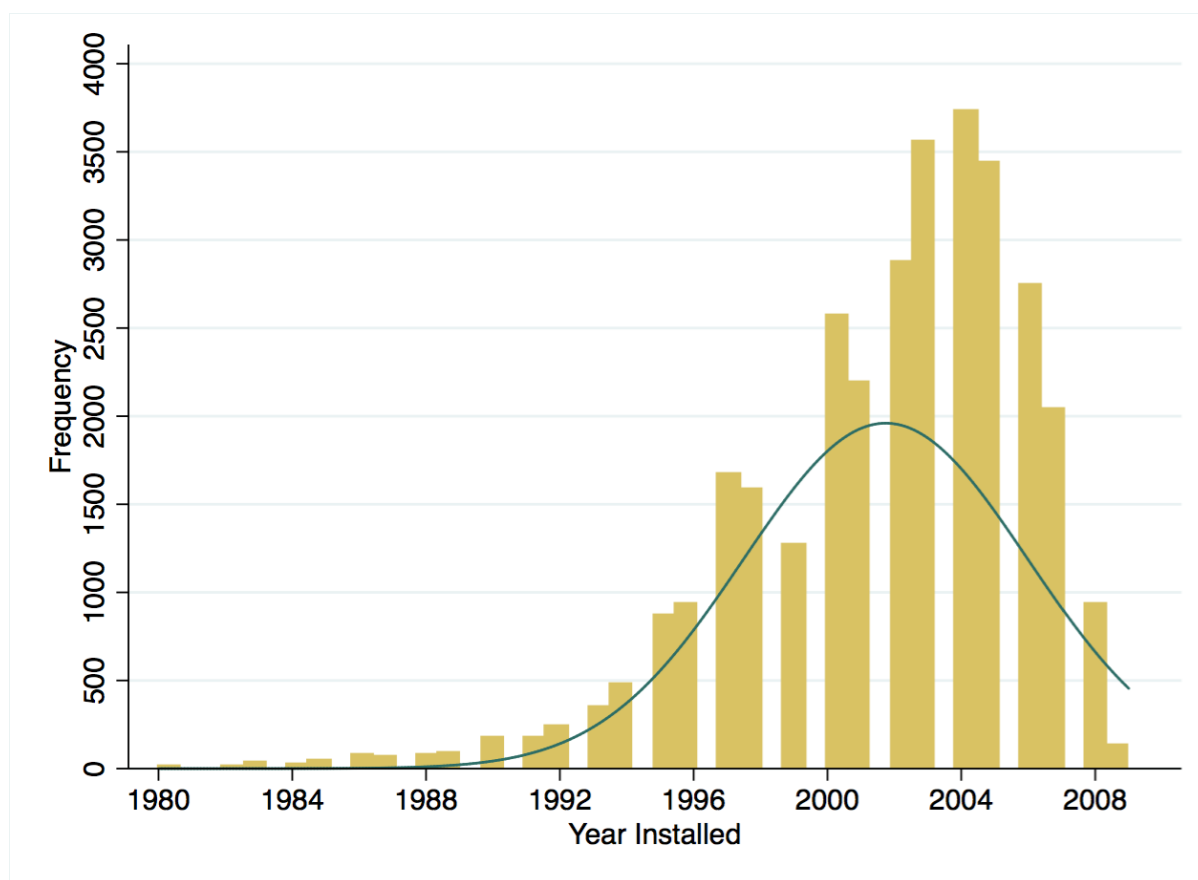


Figure 2: Distribution of tube wells in six at-risk provinces in Cambodia as of 2009



Note: Six provinces at risk from arsenic exposure include Kandal, Prey Veng, Kampong Cham, Kampong Chhnang, Kampong Thom and Kratie.

Table 1: Summary statistics (Samples of children aged 5-17)

Variables	1998			2008		
	Mean	S.D.	N	Mean	S.D.	N
<b>Outcome variables</b>						
Probability of ever enrolled for children aged 5-17	0.60	0.49	317,754	0.80	0.40	292,642
Probability of ever enrolled for boys						
Aged 5-17	0.62	0.49	162,111	0.80	0.40	151,048
Aged 5	0.05	0.23	14,510	0.10	0.30	10,724
Aged 6	0.19	0.39	13,891	0.41	0.49	10,760
Aged 7	0.39	0.49	13,949	0.70	0.46	11,050
Aged 8	0.53	0.50	13,769	0.81	0.39	11,542
Aged 9	0.64	0.48	11,194	0.87	0.34	9,813
Aged 10	0.71	0.45	15,076	0.89	0.31	12,168
Aged 11	0.79	0.41	11,162	0.92	0.27	10,303
Aged 12	0.81	0.39	13,445	0.92	0.26	13,023
Aged 13	0.84	0.37	12,406	0.93	0.26	13,106
Aged 14	0.86	0.35	10,872	0.93	0.25	12,737
Aged 15	0.85	0.36	11,437	0.92	0.27	13,076
Aged 16	0.84	0.37	10,543	0.91	0.28	11,724
Aged 17	0.84	0.37	9,857	0.91	0.28	11,022
Probability of ever enrolled for girls						
Aged 5-17	0.58	0.49	155,643	0.80	0.40	141,594
Aged 5	0.06	0.23	14,272	0.11	0.32	10,404
Aged 6	0.19	0.39	13,425	0.43	0.50	10,267
Aged 7	0.37	0.48	13,370	0.71	0.45	10,600
Aged 8	0.51	0.50	13,320	0.81	0.39	10,832
Aged 9	0.63	0.48	10,752	0.88	0.33	9,347
Aged 10	0.69	0.46	13,954	0.91	0.29	11,456
Aged 11	0.77	0.42	10,275	0.93	0.25	9,701
Aged 12	0.78	0.41	12,509	0.93	0.25	12,414
Aged 13	0.78	0.41	11,426	0.93	0.25	12,332
Aged 14	0.79	0.41	11,022	0.93	0.26	12,503
Aged 15	0.75	0.43	10,238	0.92	0.27	11,199
Aged 16	0.74	0.44	10,803	0.91	0.29	10,618
Aged 17	0.73	0.44	10,277	0.90	0.30	9,921
<b>Explanatory variables</b>						
Sex (female=1)	0.49	0.50	317,754	0.48	0.50	292,642
Number of children per household	0.00	0.07	317,754	0.00	0.05	292,642
Years of schooling of father	4.15	3.23	248,984	4.81	3.48	234,591
Years of schooling of mother	2.44	2.80	289,982	3.33	3.16	264,706
<b>Treatment variable</b>						
Arsenic levels (ppb) at district level in 2009	Mean	S.D.	N	Minimum	Maximum	
	17.26	33.42	115	0	251.72	



Table 2: Impact of arsenic exposure on probability of ever enrolled of children aged 5-17

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Whole sample			Rural sample			Urban sample		
	Both sexes	Boys	Girls	Both sexes	Boys	Girls	Both sexes	Boys	Girls
<i>Arsenic</i>	0.00071*** (0.00015)	0.00066*** (0.00013)	0.00076*** (0.00016)	0.00075*** (0.00015)	0.00070*** (0.00014)	0.00081*** (0.00017)	0.00030 (0.00146)	0.00023 (0.00146)	0.00034 (0.00153)
<i>Post</i>	0.20954*** (0.00646)	0.18873*** (0.00614)	0.23119*** (0.00717)	0.21009*** (0.00743)	0.18952*** (0.00700)	0.23148*** (0.00826)	0.19846*** (0.02636)	0.17733*** (0.02432)	0.22008*** (0.02948)
<i>Arsenic*Post</i>	-0.00051*** (0.00009)	-0.00049*** (0.00008)	-0.00051*** (0.00011)	-0.00052*** (0.00008)	-0.00052*** (0.00008)	-0.00052*** (0.00010)	-0.00024 (0.00146)	-0.00018 (0.00146)	-0.00027 (0.00153)
Constant	0.58427*** (0.01009)	0.60501*** (0.00979)	0.56269*** (0.01065)	0.57689*** (0.01066)	0.59802*** (0.01040)	0.55489*** (0.01123)	0.65477*** (0.02731)	0.67219*** (0.02542)	0.63691*** (0.02985)
Observations	610,396	313,159	297,237	552,784	283,946	268,838	57,612	29,213	28,399
R-squared	0.04871	0.04004	0.05852	0.04832	0.03980	0.05793	0.05281	0.04302	0.06384

Note: Standard errors are in parentheses and clustered at the district levels. \* significant at the 10% level; \*\* significant at the 5% level; \*\*\* significant at the 1% level.

Table 3: Impact on probability of ever enrolled of children aged 5-17 by housing status

	(1) One room	(2) Two rooms	(3) Three rooms	(4) Four rooms & more
<i>Arsenic</i>	0.00085*** (0.00017)	0.00107*** (0.00025)	0.00074*** (0.00019)	0.00032 (0.00024)
<i>Post</i>	0.21924*** (0.00781)	0.20222*** (0.01086)	0.13863*** (0.01515)	0.15624*** (0.03588)
<i>Arsenic*Post</i>	-0.00062*** (0.00012)	-0.00083*** (0.00019)	-0.00041*** (0.00015)	-0.00006 (0.00028)
Constant	0.55075*** (0.01106)	0.63019*** (0.01262)	0.71731*** (0.01646)	0.72481*** (0.03383)
Observations	405,883	118,618	15,758	4,064
R-squared	0.05012	0.05007	0.03092	0.04082

Note: Standard errors are in parentheses and clustered at the district levels. \* significant at the 10% level; \*\* significant at the 5% level; \*\*\* significant at the 1% level.

Table 4: Impact of arsenic exposure on probability of ever enrolled of boys and girls aged 5-17

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Both sexes	Boys	Girls	Both sexes	Boys	Girls	Both sexes	Boys	Girls
<i>Arsenic</i>	0.00062*** (0.00014)	0.00058*** (0.00013)	0.00066*** (0.00015)	0.00037** (0.00014)	0.00034** (0.00013)	0.00039** (0.00016)	0.00036** (0.00014)	0.00034** (0.00013)	0.00039** (0.00015)
<i>Post</i>	0.19003*** (0.00675)	0.17195*** (0.00635)	0.20891*** (0.00756)	0.19660*** (0.00675)	0.17880*** (0.00638)	0.21516*** (0.00752)	0.19479*** (0.00850)	0.17558*** (0.00795)	0.21488*** (0.00950)
<i>Arsenic*Post</i>	-0.00054*** (0.00010)	-0.00053*** (0.00011)	-0.00054*** (0.00011)	-0.00058*** (0.00012)	-0.00058*** (0.00012)	-0.00058*** (0.00012)	-0.00057*** (0.00012)	-0.00056*** (0.00012)	-0.00057*** (0.00012)
Female	-0.01519*** (0.00188)			-0.01490*** (0.00189)			-0.01490*** (0.00188)		
Education of mother	0.01237*** (0.00088)	0.01146*** (0.00091)	0.01333*** (0.00091)	0.01172*** (0.00090)	0.01083*** (0.00093)	0.01267*** (0.00095)	0.01172*** (0.00090)	0.01084*** (0.00092)	0.01266*** (0.00095)
Education of father	0.01668*** (0.00076)	0.01679*** (0.00083)	0.01657*** (0.00078)	0.01573*** (0.00072)	0.01568*** (0.00079)	0.01578*** (0.00074)	0.01571*** (0.00072)	0.01566*** (0.00079)	0.01576*** (0.00074)
Constant	0.48616*** (0.01201)	0.49800*** (0.01219)	0.45873*** (0.01227)	0.49486*** (0.01025)	0.50703*** (0.01028)	0.46732*** (0.01064)	0.49501*** (0.01028)	0.50719*** (0.01027)	0.46744*** (0.01071)
Observations	472,264	241,707	230,557	472,264	241,707	230,557	472,264	241,707	230,557
R-squared	0.07979	0.07050	0.08960	0.08619	0.07722	0.09598	0.08625	0.07729	0.09604
Province fixed effects	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Zone trends	No	No	No	No	No	No	Yes	Yes	Yes

Note: Standard errors are in parentheses and clustered at the district levels. \* significant at the 10% level; \*\* significant at the 5% level; \*\*\* significant at the 1% level.

Table 5: Impact of arsenic exposure on probability of ever enrolled of children at specific age groups

	(1) Age 5	(2) Age 6	(3) Age 7	(4) Age 8	(5) Age 9	(6) Age 10	(7) Age 11	(8) Age 12
<i>Arsenic</i>	0.00025*** (0.00007)	0.00035* (0.00018)	0.00057*** (0.00020)	0.00040** (0.00018)	0.00035 (0.00021)	0.00039** (0.00018)	0.00025 (0.00015)	0.00018 (0.00017)
<i>Post</i>	0.05541*** (0.00647)	0.22272*** (0.01038)	0.31071*** (0.01403)	0.27635*** (0.01373)	0.22367*** (0.01363)	0.17984*** (0.01316)	0.13275*** (0.01215)	0.11080*** (0.01085)
<i>Arsenic*Post</i>	-0.00016*** (0.00006)	-0.00039*** (0.00012)	-0.00081*** (0.00013)	-0.00084*** (0.00017)	-0.00073*** (0.00020)	-0.00083*** (0.00016)	-0.00072*** (0.00017)	-0.00057*** (0.00013)
Female	0.00246 (0.00267)	0.01246** (0.00476)	-0.00463 (0.00498)	-0.00952** (0.00417)	-0.00356 (0.00440)	0.00068 (0.00421)	-0.00301 (0.00371)	-0.00614* (0.00327)
Education of mother	0.00531*** (0.00054)	0.01713*** (0.00100)	0.02309*** (0.00130)	0.02243*** (0.00109)	0.01870*** (0.00122)	0.01815*** (0.00122)	0.01427*** (0.00097)	0.01392*** (0.00096)
Education of father	0.00491*** (0.00061)	0.01582*** (0.00081)	0.01884*** (0.00104)	0.01834*** (0.00094)	0.01812*** (0.00092)	0.01706*** (0.00088)	0.01357*** (0.00088)	0.01439*** (0.00081)
Constant	0.01251*** (0.00318)	0.06007*** (0.00635)	0.23029*** (0.01030)	0.38240*** (0.01221)	0.50657*** (0.01262)	0.58728*** (0.01270)	0.69205*** (0.01236)	0.71263*** (0.01176)
Observations	41,444	39,935	39,887	39,883	33,268	41,360	32,299	39,399
R-squared	0.02671	0.11318	0.17014	0.16156	0.14730	0.12861	0.10396	0.10161
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Zone trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors are in parentheses and clustered at the district levels. \* significant at the 10% level; \*\* significant at the 5% level; \*\*\* significant at the 1% level.

Table 5: Impact of arsenic exposure on probability of ever enrolled of children at specific age groups (Continued)

	(9) Age 13	(10) Age 14	(11) Age 15	(12) Age 16	(13) Age 17
<i>Arsenic</i>	0.00021 (0.00014)	0.00014 (0.00015)	0.00018 (0.00014)	0.00022 (0.00015)	0.00026** (0.00012)
<i>Post</i>	0.09507*** (0.00943)	0.08195*** (0.00825)	0.09448*** (0.01127)	0.09504*** (0.00920)	0.09108*** (0.00890)
<i>Arsenic*Post</i>	-0.00047*** (0.00012)	-0.00041*** (0.00011)	-0.00047*** (0.00013)	-0.00048*** (0.00012)	-0.00054*** (0.00014)
Female	-0.01945*** (0.00345)	-0.02770*** (0.00363)	-0.04074*** (0.00405)	-0.04152*** (0.00474)	-0.04783*** (0.00484)
Education of mother	0.01297*** (0.00096)	0.01287*** (0.00081)	0.01357*** (0.00105)	0.01561*** (0.00111)	0.01538*** (0.00111)
Education of father	0.01344*** (0.00089)	0.01419*** (0.00083)	0.01563*** (0.00094)	0.01606*** (0.00100)	0.01651*** (0.00100)
Constant	0.74073*** (0.01104)	0.75328*** (0.01029)	0.73220*** (0.01210)	0.72007*** (0.01191)	0.71607*** (0.01207)
Observations	37,269	35,289	33,605	30,816	27,810
R-squared	0.09523	0.09628	0.11077	0.11461	0.11405
Province fixed effects	Yes	Yes	Yes	Yes	Yes
Zone trends	Yes	Yes	Yes	Yes	Yes

Note: Standard errors are in parentheses and clustered at the district levels. \* significant at the 10% level; \*\* significant at the 5% level; \*\*\* significant at the 1% level.

Table 6: Impact of arsenic exposure on probability of ever enrolled at specific age and employment status

	(1) Age 12	(2) Age 13	(3) Age 14	(4) Age 15	(5) Age 16	(6) Age 17
<i>Arsenic</i>	0.00017 (0.00016)	0.00020 (0.00013)	0.00018 (0.00015)	0.00014 (0.00013)	0.00018 (0.00017)	0.00037*** (0.00012)
<i>Post</i>	0.11528*** (0.01085)	0.09781*** (0.00955)	0.08681*** (0.00885)	0.08855*** (0.01075)	0.09950*** (0.01028)	0.10353*** (0.01153)
<i>Active</i>	-0.61326*** (0.01917)	-0.64836*** (0.01705)	-0.63989*** (0.01505)	-0.63056*** (0.01358)	-0.60030*** (0.01380)	-0.59782*** (0.01139)
<i>Arsenic*Post</i>	-0.00054*** (0.00012)	-0.00042*** (0.00011)	-0.00036*** (0.00012)	-0.00028** (0.00012)	-0.00033** (0.00016)	-0.00045*** (0.00010)
<i>Arsenic*Post*Active</i>	-0.00152*** (0.00038)	-0.00133*** (0.00042)	-0.00126*** (0.00026)	-0.00117*** (0.00019)	-0.00116*** (0.00018)	-0.00091*** (0.00027)
Female	-0.00654** (0.00320)	-0.01860*** (0.00356)	-0.02831*** (0.00357)	-0.03710*** (0.00393)	-0.05012*** (0.00482)	-0.06622*** (0.00504)
Education of mother	0.01277*** (0.00090)	0.01153*** (0.00093)	0.01073*** (0.00077)	0.00981*** (0.00093)	0.01309*** (0.00106)	0.01324*** (0.00113)
Education of father	0.01336*** (0.00078)	0.01195*** (0.00078)	0.01256*** (0.00077)	0.01234*** (0.00087)	0.01333*** (0.00094)	0.01410*** (0.00087)
Constant	0.72513*** (0.01139)	0.75997*** (0.01040)	0.77591*** (0.01026)	0.78711*** (0.01142)	0.76031*** (0.01209)	0.74554*** (0.01204)
Observations	38,595	35,684	32,129	27,895	22,445	17,423
R-squared	0.15852	0.19978	0.25779	0.38706	0.42306	0.47569
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Zone trends	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors are in parentheses and clustered at the district levels. \* significant at the 10% level; \*\* significant at the 5% level; \*\*\* significant at the 1% level.