DATA 621—Final Project

Critical Thinking Group 2

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Abstract

Nearly a billion people lack access to clean drinking water (World Health Organization 2019). There are many well-known solutions to this problem, but most of them are too expensive to work in the areas hardest-hit. Providing affected areas better information about their water is cheap—but how effective is it?

To answer this question, we examine a dataset collected in rural Bangladesh (Opar, et al., 2007). It marks whether a household switched wells after learning their routine well had unsafe levels of arsenic.

Keywords: Water contamination, arsenic poisoning, Bangladesh, developmental economics

Introduction

Perhaps the greatest public health crisis in the world remains access to clean drinking water and proper sanitation. Billionaire and philanthropist Bill Gates regards it as so serious, he spent millions of dollars holding a 'Reinvent the Toilet' challenge (Bill and Melinda Gates Foundation 2012).

The central hurdle, however, is not scientific, so much as *economic*. The developing nations that suffer the most from lack of clean water often have the least resources to deal with it. In many cases, solutions imported from developed nations—e.g., industrial water treatment plants—are simply too expensive. Even the winning solutions from the Gates Foundation's reinvented toilets remain too expensive to be practically implemented on a large scale.

Transmitting information is far less expensive than other proposed solutions. But can providing affected households information about their unsafe drinking water really help mitigate the water crisis? Are households able to change water supply, even when it comes with costs?

Literature Review

As of 2017, 29 percent of the world lacked accessed to safe and managed drinking water that is clean, located on premises, and available regularly. Contamination is a massive obstacle to raising this number. Through diarrhea, drinking contaminated water kills almost half a million people each year (World Health Organization 2019).

The largest case of ground water contamination was discovered in Bangladesh in the early 1990s. Throughout the second half of the twentieth century, the government, humanitarian NGOs, and the private sector attempted to solve the country's water supply issues by mass installing *tube wells* throughout the country. Typically five centimeters in diameter, these tubes are inserted into the ground to depths less than 200 meters. Water is brought to the surface via a hand pump. In 1997, UNICEF announced it had surpassed its Millennium goal to provide 80 percent of Bangladesh with 'safe' drinking water thanks to these tube wells (van Geen, et al., 2002).

Tragically, research in the 1990s slowly uncovered that up to 77 million were drinking from tube wells contaminated with arsenic—half the population of Bangladesh. Arsenic consumption results in cancer, painful skin lesions, and other awful illnesses. The World Health Organization (WHO) considers water with a concentration higher than 10 micrograms/liter as dangerous. Studies estimate that 10 percent of people that consume water with 500 micrograms/liter of arsenic will likely die from its effects (van Geen, et al., 2002).

Although the World Health Organization considers water with concentration higher than 10 micrograms/liter as dangerous, the arsenic concentration used to define unsafe drinking water in the data set is based on the Bangladesh standard of 50 microgram per liter. All the households in the data set have original wells with arsenic levels above the Bangladesh standard of 50 microgram per liter. So, these are all affected households. The Bangladesh Arsenic Mitigation and water Supply Program (BAMWSP) coordinated a blanket survey of million tubewells. This survey generated nearly five million field-kit results of well-testing, which identified wells as safe or unsafe. Household response surveys in the area of Araihazar upazila (administrative region) indicate roughly half the affected households switched to safe wells. However, the survey also showed that a significant number of households did not stop drinking from unsafe wells after they had learned that it was unsafe (Van Geen, et al., 2006).

Several studies have documented the extent of arsenic poisoning in Bangladesh. A survey conducted in the mid-1990s examined 1630 residents of affected regions. They found that 57.5 percent suffered from skin lesions associated with toxic levels of arsenic (Dhar, et al., 1997). Another study examined 7264 patients, finding that a full one-third suffered from the same kind of skin lesion (Biswas, et al., 1999). Another study investigated chidlren's intellectual function to exposure to arsenic in Bangladesh. The study found that exposure to arsenic in drinking water was associated with reduced scores on measures of intellectual function, before and after adjusting for sociodemographic features known to contribute to intellectual function (Wassermanm et al., 2004).

It is not an overstatement to say this is a crisis that dwarfs the Chernobyl incident, or really any other nuclear accident in history.

There is one bright side, however. A study in the Araihazar upazila district found that the distribution of arsenic in groundwater is 'spatially highly variable.' This means it is not the case that excessive arsenic is concentrated in large regions. Instead, it is often that case that a contaminated well will be very near a safe well. Indeed, van Geen and his coauthors found about 90 percent of residents lived within 100 meters of a safe well (van Geen, et al., 2002).

This fact suggests a quick solution to Bangladesh's water problem: Find the poisoned wells and get residents to switch to a safe water supply that is likely nearby. Poisoned wells can be readily identified with cheap field kits. van Geen, et al., consider the 'real problem' to be convincing residents to switch to the safer wells. In their paper, they conclude 'social barriers to well-switching need to be better understood and, if possible, overcome.'

Researchers set about doing just that. Schoenfeld (2005) likewise confirmed that well switching was influenced by 'less predictable factors,' that interacted with physical variables (distance to nearest safe well, etc.). Social barriers could influence residents to not switch, even after being informed of the health risk of arsenic poisoning. On the other hand, a village 'arsenic activist' could persuade even those far from a safe well to switch.

Most the research just cited is primarily concerned with conducting surveys and 'simple' analysis of their results. The most statistically 'sophisticated' work in this literature is Gelman, et al. (2004), and Opar, et al. (2007).

Opar and his colleagues returned to Araihazar upazila several years after initial education efforts had been conducted; the data in this present paper is the result of their studies. They examined the effects of these efforts, which included public education, directly posting arsenic poisoning test reults onto the wells themselves, and installing community wells. A Probit regression estimated the relationships between well switching and the following independent variables: water arsenic content, distance to nearest safest well, years of education, and 'easily observable proxies for income and wealth.' These variables were found to be significant, except the income and wealth-related variables. The Probit regression had a psuedo-R^2 of 0.29.

Although Gelman, et al. (2004) use an earlier version of this data, their primary concern seems to be using it as a demonstration of Bayesian decision analysis. The authors directly avoid parametric methods, including regression. Instead they rely on k-means clustering and *a priori* probability models to answer: How effective is encouraging villagers to switch to alternative, non-poisoned wells? Where should new (safe) wells be located to maximize their availability? How deep should new wells be drilled? They conclude that recommendding new wells results reduces average arsenic exposure by 38 percent.

Methodology

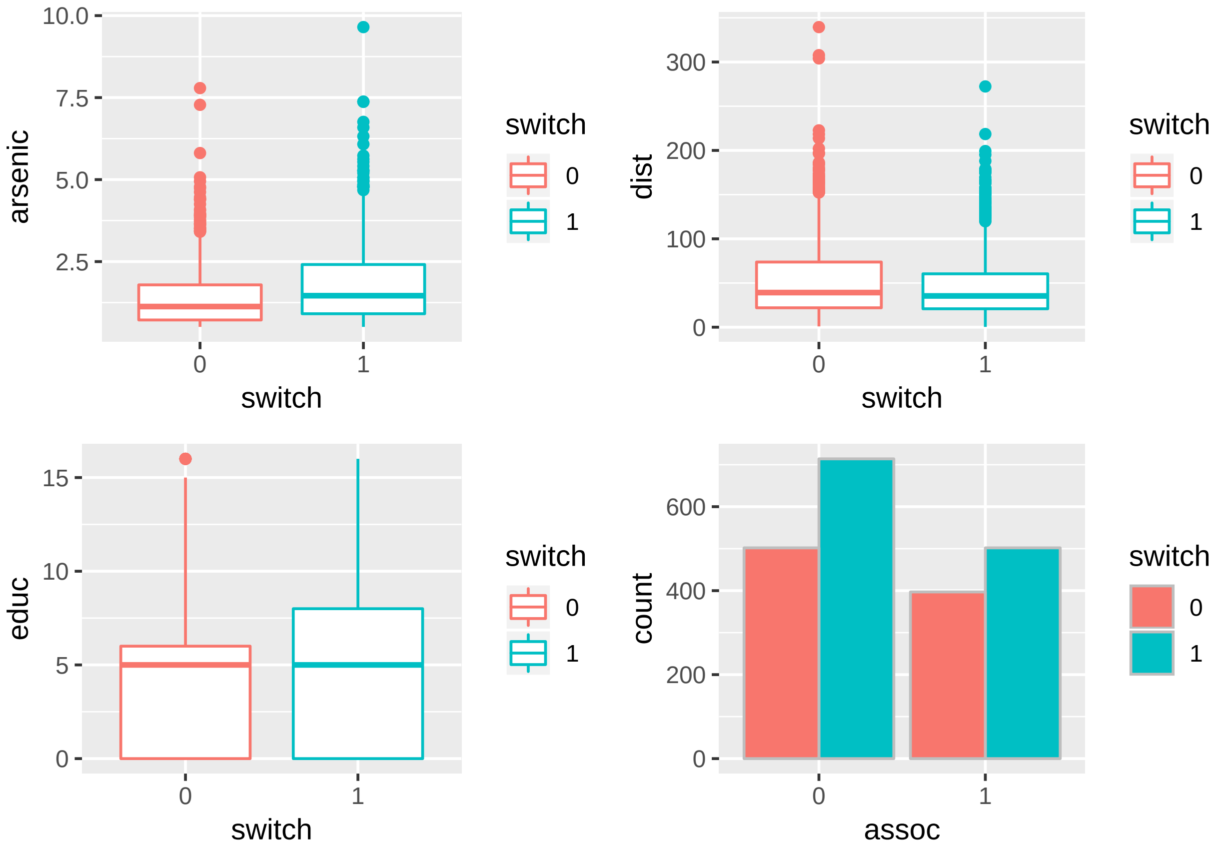
The `Wells` data set is loaded from 'http://www.stat.columbia.edu/~gelman/arm/examples/arsenic/wells.dat'. This data set has 3020 rows, although we split the data set into train and test sets (70 and 30 percent, respectively).

Below is a summary of the well switching data. As you can see, all the observations in the data set are complete cases.

switch	arsenic	dist	assoc	educ
0: 899	Min. :0.510	Min. : 0.387	0:1216	Min. : 0.000
1:1216	1st Qu.:0.820	1st Qu.: 21.318	1: 899	1st Qu.: 0.000
NA	Median :1.290	Median : 36.875	NA	Median : 5.000
NA	Mean :1.636	Mean : 49.112	NA	Mean : 4.822
NA	3rd Qu.:2.185	3rd Qu.: 64.057	NA	3rd Qu.: 8.000
NA	Max. :9.650	Max. :339.531	NA	Max. :16.000

Below is a box plot of the variables grouped by `switch`.

It appears that families that originally used wells with higher arsenic switched more compared to families with lower arsenic levels. It seems that families that are farther from safe wells did not switch. The plot suggests that families with higher education tend to switch more. Families with associations to the community don't necessarily have a higher rate of switching. The relationships that the data suggests support the theoretical relationships discussed above except for families' association with the community.



Of the families with associations to the community (`assoc = 1`), 55% switched. And of the families without associations to the community (`assoc = 0`), 59% switched.

```
## [1] "Percent of families with association to community that switched: 0.56"
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## [1] "Percent of families with association to community that did not switched: 0.44"
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## [1] "Percent of families without association to community that switched: 0.59"
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```
## [1] "Percent of families without association to community that did not switched: 0.41"
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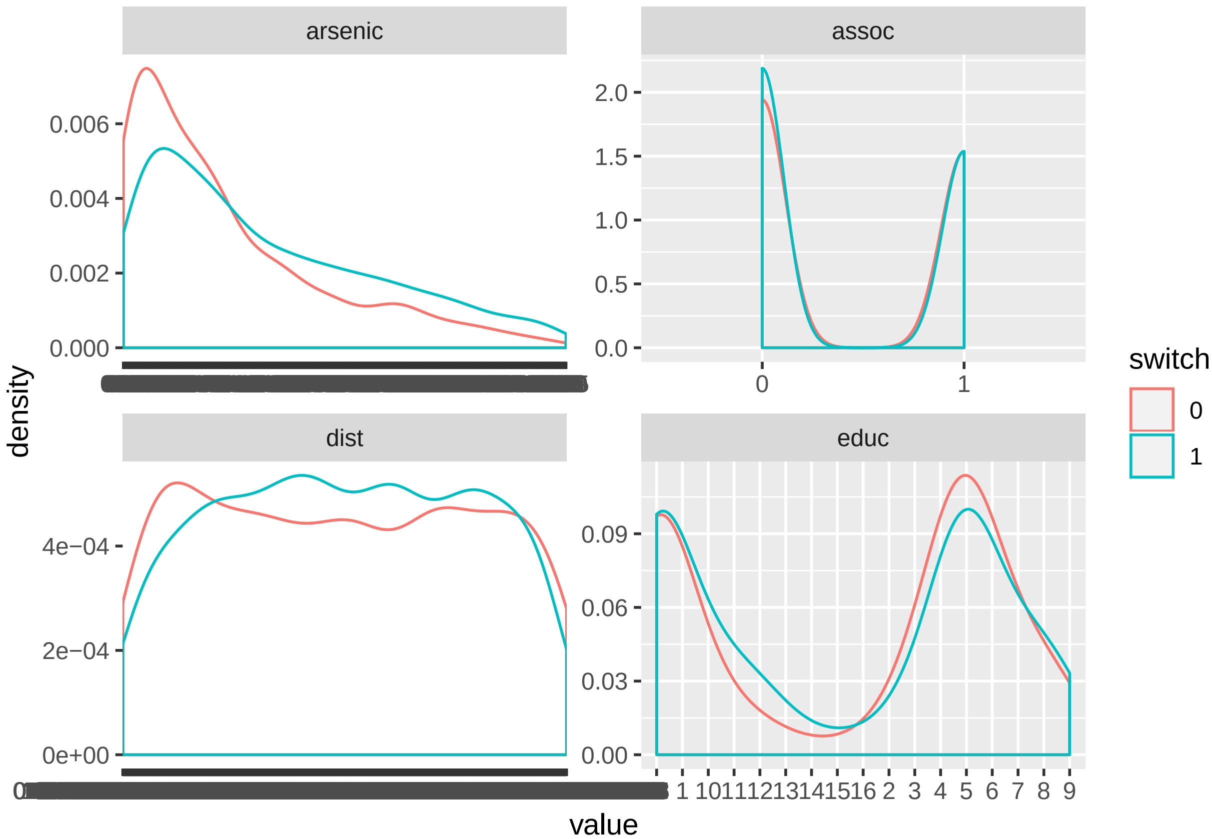
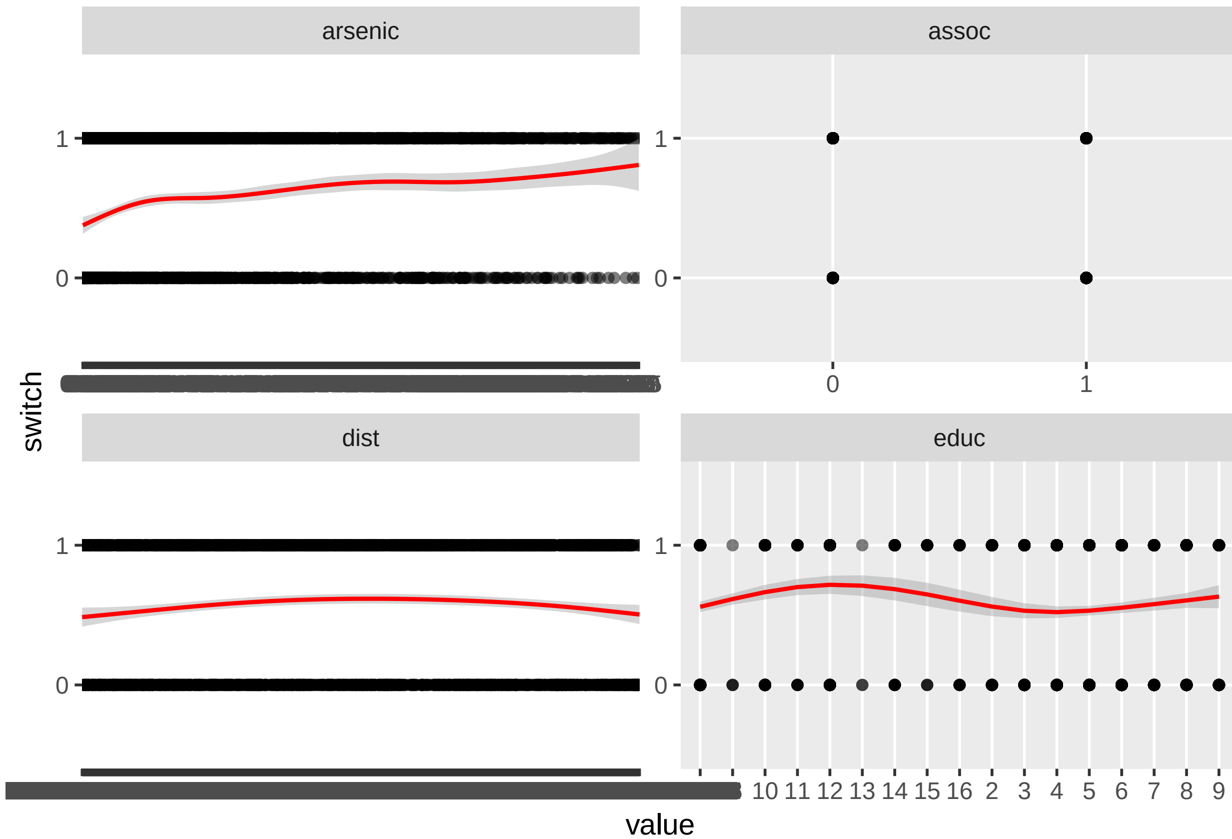
Below is a density plot of each explanatory variable grouped by `switch`.

Families tend to switch the higher the arsenic level is. There are more families without association to the community, but more families switched among those without community associations. This is a very interesting finding. There seems to be a “cut off” point in the number of years of education where there’s a reversal in the trend of switching. Families with less than 16 years of education, more proportion-wise switched compared to families with more than 16 years of education.



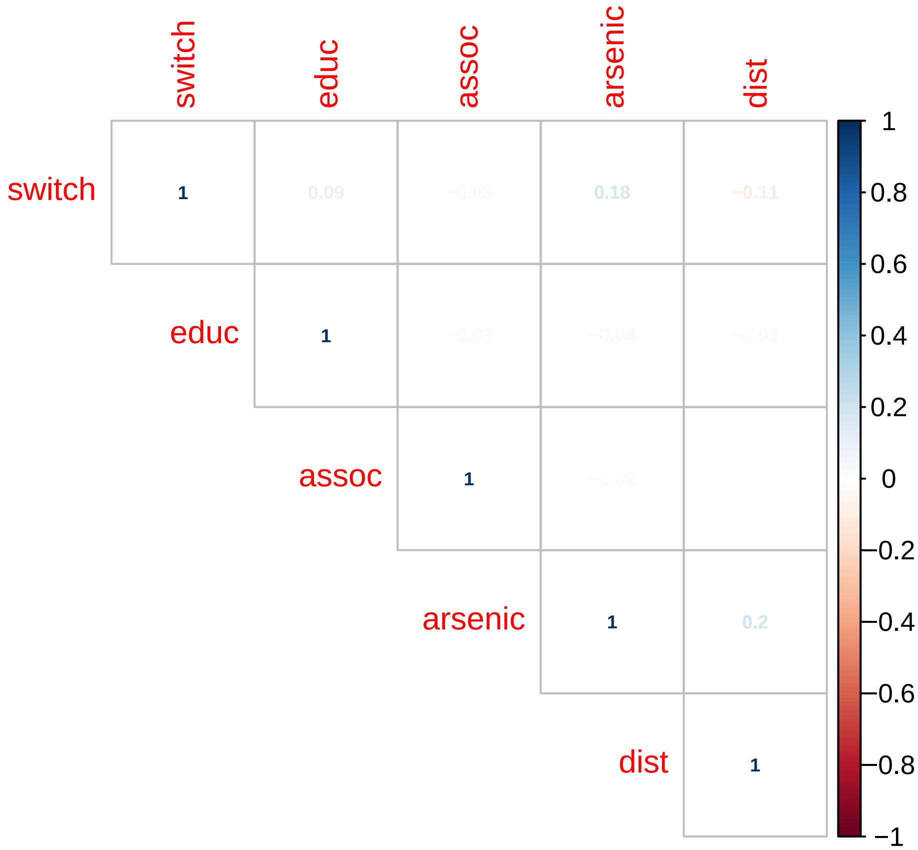
Below are plots that describe the relationship of each explanatory variable with `switch`.

There's a clear relationship that as arsenic levels go higher, a switch happens. Distance seems to have a parabolic relationship with switch. There's an amount of distance where families start to no longer switch. Education appears to have a polynomial relationship with switch.



The correlation plot below shows a weak positive correlation between arsenic and switch (0.1839). None of the explanatory variables appear to be strongly correlated to each other.

	switch	arsenic	dist	assoc	educ
switch	1.0000	0.1763	-0.1058	-0.0288	0.0931
arsenic	0.1763	1.0000	0.1982	-0.0189	-0.0396
dist	-0.1058	0.1982	1.0000	-0.0008	-0.0261
assoc	-0.0288	-0.0189	-0.0008	1.0000	-0.0279
educ	0.0931	-0.0396	-0.0261	-0.0279	1.0000



Experimentation and Results

Discussion and Conclusion

Appendix A: Whatever (as necessary)

Appendix B: Some more stuff (as necessary)

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