Water, Health and Wealth

Nava Ashraf, Edward Glaeser, Abraham Holland and Bryce Millett Steinberg*

July 21, 2017

Abstract

Providing clean water requires maintenance, as well as the initial connections that are typically measured. Frequently, the water supply fails in the developing world, especially when users don't pay the marginal cost of water. This paper uses the timing of frequent, unexpected water service outages in Lusaka, Zambia to identify the short-term impacts of piped water access on contagious disease, economic activity and time use. We use microdata from the primary water utility in the city on the timing and location of supply complaints to identify outages, matched to extensive administrative data across the city. Conditional on fixed effects for time and water service district within Lusaka, we find that increases in outages are associated with increased incidence of diarrheal disease, upper respiratory infections, typhoid fever and measles. We match outages to geolocated microdata on financial transactions from the largest mobile money provider in Zambia, and find that outages cause a reduction in financial transactions. Outages also increase the time that young girls spend at their chores, possibly at the expense of time they spend doing schoolwork. Imperfect infrastructure appears to burden the poor in ways that go far beyond obvious health consequences.

*Nava Ashraf (London School of Economics), Edward Glaeser (Harvard University), Abraham Holland (Harvard Kennedy School) and Bryce Millett Steinberg (Brown University). We thank the International Growth Centre for financial support, and Kelsey Jack, Corinne Low, and Natalie Bau for helpful input. Superb research support was provided by Jitka Hiscox, Shotaro Nakamura, Kim Sarnoff, Dylan Knaggs, Rachel Levenson, and Rachna Chowdhuri. We thank the Lusaka Water and Sewerage Company, Zoona, and the Zambia Ministry of Health for generously sharing their data.

1 Introduction

In 2015, one half of the over 660 million people worldwide who regularly accessed water from unsafe sources, such as unprotected wells and surface water, lived in Sub-Saharan Africa. While the past two decades have seen sizeable improvements in clean water access for rural areas, the percentage of people in urban areas using improved water has changed very little, and has even fallen in Sub-Saharan Africa (WHO, 2015).[1] Moreover the standard measure of water access, the "percentage of population with access to improved water," doesn't typically capture the irregular service provision in many developing world cities. The United Nations predicts that the number of city dwellers will rise by 3.5 billion over the next 40 years, and that 96 percent of that increase will come in poor countries. As urban environments grow, low levels of piped water usage not only threaten the welfare of unconnected households, but pose increasingly large negative externalities on neighbors—one of the many potential downsides of density.

Following the example of developed countries, where large investments in water systems led to significant welfare gains (Troesken, 2002; Cutler and Miller, 2005), development assistance is often targeted at infrastructure, with the goal of increasing the share of people with nominal access to clean water. However, infrastructure alone did not improve welfare in rich countries—only once households connected to new piped water systems could they actually benefit (Ashraf, Glaeser and Ponzetto, 2016).[2] In the developing world, not only do water utility companies struggle to connect households, but systems frequently fail, possibly interfering with the presumed benefits of infrastructure investment. In this paper, we document that breakdowns in water supply have consequences far beyond water-borne illness, including the spread of other infectious diseases, lost economic activity and distortion in the time use of young women.

The literature on water provision typically focuses on the initial connection to piped water, not on the disruptions that can often follow that connection (Gamper-Rabindran, Khan and Timmins, 2010, Devoto et al., 2012).[3] Yet the average water district in Lusaka receives a complaint about water supply disruption approximately every other day. Even in the best of circumstances, Lusaka Water and Sewage Company (LWSC), the main water provider in Lusaka, only provides water during daytime hours, and this service is routinely disrupted because of burst pipes and blockages. Transportation economists often argue that the benefits of maintaining existing roads are higher than the benefits of building new roads (Gramlich, 1994), and that may also hold true for water pipes.

Since drinking water is a necessity and drinking clean water a near necessity, supply disruptions create a dilemma for households. Should they get their water from nearby sources, like shallow wells, that are less clean, or spend time walking and waiting for a cleaner well? If households decide to trade health for time, then this creates a negative externality on their neighbor through the potential spread of infectious disease. The gap between the private willingness to pay for reliable water, and the social value of that reliability, depends on whether individuals respond to breakages by spending time or by risking disease. Infrastructure's impact on cities is often mediated by individual behavior.

We identify the consequences of water disruptions for the lives of the urban poor by using a common feature of piped water in developing country cities: frequent, localized, unexpected outages. The Lusaka Water and Sewerage Company (LWSC), a publicly owned independent company that is the primary water provider in Lusaka, Zambia, provided us with data on the timing and location of customer complaints about interrupted water supply. We then aggregate these complaints over the 70 water service districts in Lusaka, to get a weekly measure of outages in a given area of the city. The key assumption is that while the total frequency of outages (or complaints, conditional on outages) is correlated with area characteristics, the timing of those outages, conditional on district and time fixed effects, is plausibly exogenous.

Before estimating the impact of outages, we briefly examine the geography of these outages. We find that outage complaints are more common, relative to the total number of water subscribers, in areas that are more remote, and therefore poorer. These are also areas where customers are more likely to complain about losing service because of missed payments. We also find more outages where customers pay a flat monthly fee, rather than paying per gallon. In addition, the water company takes longer to resolve complaints when

[1] In Sub-Saharan Africa, access to improved water sources decreased from 43% in 1990 to 33% in 2015.

[2] In New York, the great reduction in mortality did not follow the construction of the Croton Aqueduct but rather the creation of the Metropolitan Health Board and the Tenement Acts, which banned shallow wells and required privies to be connected to sewage pipes (Ashraf, Glaeser and Ponzetto, 2016).

[3] Galiani, Gertler and Schardrogsky (2005) find that privatization of water utilities in Argentina led to increased piped water and decreased child mortality, which might reflect better maintenance.

customers pay a flat fee, suggesting that the company's financial incentives may shape its maintenance behavior. The water company appears to be investing more in maintenance in higher income, higher paying districts, and that poorer areas may particularly suffer from low maintenance.

The direct impact of water disruptions is that families may substitute into less clean water, which should increase the prevalence of water-borne illnesses. Yet water disruption may also have indirect health consequences. Contagious, non-water-borne diseases may spread because families may wash their hands less often, or because water-borne illnesses, like diarrhea, weaken their immune systems. Families may allocate less time to preventive medical care, such as getting vaccines.

To estimate the impact of outages on health, we match the LWSC data with geocoded administrative data on health procedures and outcomes at the monthly level from 21 health clinics throughout Lusaka. We find that, conditional on district and month fixed effects, a one standard deviation increase in outstanding supply complaints (24 days) led to an increase of 24 cases of diarrhea, and .05 cases of typhoid fever, an increase of 12% and 22%, respectively. The increase in diarrhea was particularly concentrated in children under five.

The indirect disease impacts are also significant. A one standard deviation increase in outstanding supply complaints was associated with 57 extra cases of respiratory infections and .83 extra cases of the measles, increases of 13% and 18% respectively. The impact of water disruptions extends beyond water-borne illnesses, into highly contagious diseases which prey on weakened immunity and lack of water for handwashing and consumption. The outages did not significantly impact cases of intestinal worms or malaria, which is not surprising, since these conditions are not related to either hand washing or consuming contaminated water.

We also find a decline in the use of preventative services like well-child visits and vaccines. A one standard deviation increase in the number of water outage complaints is associated with twelve fewer vaccinations for children under one. While this drop might impact a wide range of diseases, our identification strategy cannot estimate indirect effects through decreased vaccination, because those effects are likely to occur weeks and months after the disruption in water service.

We then examine whether water disruptions impact outcomes other than health, by examining financial transactions, using data from Zoona, the most popular over-the-counter electronic money transfer service in Zambia. We match data on outages at the district-week level to individual financial transactions based on at which of 164 geolocated Zoona booths in Lusaka the individual typically transacts. We find that a one standard deviation increase in water supply complaints causes an individual to be about 2 percentage points less likely to complete a transaction, from a mean of .029. This impact occurs despite the fact that the booths themselves are not reliant on water or electricity, and thus are no less likely to be open during outages.

The decrease in economic activity associated with water outages might reflect illness or the loss of time spent getting water from farther away. The clinic data analysis shows evidence for both channels: people are more likely to be sick, and less likely to be at the clinic for routine activities like vaccinations. We cannot distinguish which channel is causing the link between water disruptions and financial transaction, but our finding begins the analysis that water disruptions have costs that go beyond health.

For additional evidence on the importance of water outages for time use, we turn to a survey of adolescent girls in the same water districts we study. In our context, as in many developing countries and much of Sub-Saharan Africa, adolescent girls in the household are most responsible for fetching water, and can thus be those most affected when there are water interruptions (Blackden and Wodon, 2006). We take advantage of extensive time-use data collected for a set of adolescent girls in grade 8 who took part in a separate education intervention (Ashraf et al, 2017). We then map girls' responses to water service districts using school locations, and assess the impact of the water service disruptions on girls' time use in household chores and schoolwork.

We find that a one standard deviation increase in water supply complaints is associated with about 10 minutes more housework per day for these young women. This increase in chore time seems to be offset by an equivalent decrease in time spent doing homework, although this result is not statistically significant. Time spent on school work at home has been shown in other research to be significantly important in determining educational outcomes, even when students are able to catch up on time spent in school (Muralidharan and Sundararaman, 2015). These findings are also complementary to previous work showing that demands on household time induce young women to substitute from educational investments into domestic work, which may have long run consequences (Shah and Steinberg, 2016), and work that shows that female empowerment leads not only to greater clean water investment politically but also less time spent by adolescent girls on household chores (Beaman et al, 2012).

For households living on the edge of subsistence, shocks to the provision of a human necessity can have considerable consequences. If households end up drinking dirtier water, then this will increase the risk of water-borne illness. If households wash their hands less often, then this will increase the risk of other infectious diseases. If households spend time to get water, then this may decrease the time children spend doing schoolwork or getting vaccinations. Direct time loss and illness may also decrease overall economic activity. Alcott, Collard-Wexler, and O'Connell (2016) find that intermittent electricity failures cause significant costs for Indian manufacturers. Our results suggest potentially significant value in institutional and engineering investments that will improve the maintenance of existing urban infrastructure.

If maintenance problems are large enough and unanticipated enough, then they could eliminate any benefits from piped water altogether. Households might not invest in alternative technologies for water purification (such as point-of-use technologies, storage, or even digging their own deep-water borehole) if they anticipate having access to regular piped water. In addition, households with intermittent access to clean water might have less immunity to water-borne diseases than those who consistently drink untreated water. If maintenance issues are worse than anticipated, households could be worse off with intermittent access to piped water than with no access at all. We now turn to describing the context of piped water and supply interruptions in Lusaka, and estimating the effects of imperfect water availability.

2 Maintaining Piped Water

The great debates about urban water systems occurred more than a century ago in most large western cities, and resulted in vast amounts of spending on sewers, aqueducts and water pipes. Cutler and Miller (2005) report that America's cities and towns were dedicating more money to water at the start of the twentieth century than the Federal government was spending on everything except for the post office and the army. These public water investments achieved near miraculous results, drastically improving life expectancy (Troesken, 2002, Ferrie and Troesken, 2008). But the advantages of water infrastructure only materialized in the 19th century when households were induced to pay the costs of connection, and many poorer urbanites today (understandably) prefer cheaper, less safe alternatives to piped water and sewage systems, such as shallow wells and cesspits (Ashraf, Glaeser and Ponzetto, 2016). More generally, the potential benefits of water infrastructure may vary between modern sub-Saharan African and 19th century America due to different medical technology, political institutions and culture. Antibiotics and water therapy have significantly reduced the mortality consequences of many diseases. Many developing world cities lack the resources to protect infrastructure from damage, and without maintenance the benefits of investment may vanish.

This paper focuses on the costs of imperfect maintenance. Most of the large literature on water and health has focused on initial access, not disruptions in water supply, and much of the work on water in the developing world has focused either on point of use solutions or on rural areas (see, e.g. Ashraf, Berry and Shapiro, 2010, Kremer et al, 2011). Fewtrell et al. (2005) and Esray et al. (1991) both provide meta-analyses of the public health literatures on water and health. Typically, the papers that measure the impact of piped water infrastructure find a negative correlation between piped water and disease (Merrick, 1985; Galiani, Gertler and Schardrogsky, 2005; Gamper-Rabindran, Khan and Timmings, 2010), but not in all cases (Fewtrell et al., 2005), perhaps because of maintenance problems, or perhaps because better water reduces the incentives to engage in sanitary behavior (Bennett, 2012). Devoto et al. (2012) find that increased household connections in urban areas lead to no difference in health but an improvement in subjective well-being. Sasaki et al. (2008) also examine Lusaka, and test the impact of rainfall and poor drainage on cholera epidemics in Lusaka.

2.1 Piped Water in Lusaka

According to the World Health Organization, 86 percent of households in urban Zambia have access to improved water sources (WHO, 2015). According to the 2010 Zambian Census, 66.6% of the households used piped water supply (drawn to the housing unit or communal tap), and the other 12% use other protected water sources, such as wells or boreholes. 22.9% used flush toilets (either private or communal), but 73% use pit latrines. Most piped water in Lusaka is provided by the Lusaka Water and Sewerage Company (LWSC), a commercial utility company established in 1988. It operates in urban areas of Lusaka Province, which encompasses the metropolitan area of Lusaka as well as surrounding rural districts.

Formerly managed and operated by local city councils, Lusaka's water and sewerage system was the first in Zambia to be turned into an independent, but publicly owned, company. Local city councils are the owners of LWSC, and the management structure is aimed at cost recovery (including tariff increases). An independent board, the National Water and Sanitation Council (NWASCO), formally regulates LWSC. There are also local consumer groups called water watch groups, or WWGs (Schwartz, 2008). Piped water services in certain communities outside the reach of LWSC are provided by water trusts, neighborhood level water projects financed by NGOs or bilateral organizations. These trusts are managed by local communities but are required by mandate to have oversight from LWSC technical staff.

Cost-recovery for LWSC and other utility companies, however, remains a challenge despite commercialization, with non-revenue water (including water theft, water loss, and delinquent bill payments) accounting for a sizeable fraction of the water supply. LWSC has often received external subsidies to fill in funding gaps. Old infrastructure and inadequate maintenance contribute to water-loss, as many pipes predate commercialization and have not been replaced since the 1970s.

2.2 Water Utility Data

We use data from the company's digital complaints system, which began in 2000. Whenever customers call to complain about their water, the complaints are logged into the system, with the location and type of complaint catalogued. The six categories of complaints are: accounts, connection/meter, property details, sewerage, supply, and water quality. For this paper, we concentrate on supply complaints: namely, people calling to tell the water company that their water is out.

On average, a water district receives a supply complaint every other day. For analysis, we calculate the number of outstanding water supply complaints in each day (a complaint is outstanding if it has been lodged by a consumer and is not yet reported resolved by LWSC).[4] We then group the complaints data to count the number of supply complaints in each of 38 water service districts (WSDs) in Lusaka. We then sum these outstanding complaints to the month level (for the health analysis) or the week level (for the Zoona financial transaction analysis). This will be a proxy for the total number of household-days without piped water. We refer to our measure as "days of supply issues".

Even conditional on district and month or week fixed effects, this will be a noisy measure of outages. Some outages will go unreported, while others might be reported several times. For the purposes of estimation, we assume that the number of complaints and the time to resolution are correlated with the severity of the outages. Based on interviews with both LWSC customers and the teams at LWSC tasked with resolving complaints, we think that this assumption is reasonable.

2.3 Where and When Outages Occur

Our identification strategy will identify off of the within-district variation in the timing of complaints, but before proceeding with our analysis of the impact of supply outages, we focus on where and when outages are more prevalent. We look at three measures of outages at the water district level: (1) our supply days measure which sums the total number of household complaints over a month, (2) our supply days measure divided by the number of households connected in the water district, (3) our supply days measure divided by the total number of complaints, and (4) the share of days in which a supply complaint is reported. In our analysis, we will use (1) as a measure of outages, but because all of the regressions will contain WSD fixed effects, we will identify off of the deviations in complaints from district averages. For this reason, we include the other three normalizations, which attempt to correct for the fact that some districts are larger and some districts might have more complaints conditional on the number of outages.

Table 1 shows summary statistics from the LWSC complaints data. The average number of supply days is 14, which means that on any given day, there is on average 0.5 outstanding supply complaints in each water service district, which have on average, just under a thousand water connections. This may seem relatively low, but we suspect that under-reporting means that this is a vast underestimate of the true extent of supply

[4]It is likely that some large outages will cause several households to complain, and that some households might complain more than once about the same outage.

problems. The fact that there is typically one supply problem every second day seems like an indication of significant maintenance challenges.

Table 2 examines the correlations with water consumption, the share of households that have metered water, whether the area is peri-urban, and population density. The first row shows that there is little connection between total water consumption and our measures of supply days. When we normalize supply days by the number of households in the district, the correlation becomes negative and it remains negative if we normalize by the number of account complaints. There is no correlation with the number of days in which there is a complaint.

The second column shows the share of connections that are metered. All four measures show strong negative correlations between metering and maintenance problems. As the metering of a connection is not random, this is not a clean test of the hypothesis that financial incentives increase the amount of maintenance. Nonetheless, it does suggest that when a firm has no financial stake in maintaining a water connection, it is less likely to maintain that connection.

The third column shows the relationship with whether the area is peri-urban. In this case, there is a strong positive connection. Areas that are not incorporated within the city's core infrastructure are more likely to have maintenance issues, which supports the view that these problems are more likely to impact the poor.

The last column shows the relationship with population density. Denser areas do have more complaint days, but they have fewer complaints per household. They also have slightly fewer days in which any complaint was registered. This suggests that maintenance is probably somewhat better in the more densely settled areas of the city.

In Table 3, we examine the correlates of the number of supply complaints and the time it takes the water company to fix those complaints in regression form. It appears as though the fraction of metered connections in a district is the most reliable predictor of the time it takes to resolve a complaint once it is lodged, while there is no clear pattern in determining the average number of supply complaints. While these estimates should not be taken as causal, the coefficients are consistent with the water company being less responsive to households without metered water connections, and more likely to fix pipes in areas in which they charge for water by volume, rather than a flat fee. Once again, these results are compatible with the view that financial incentives shape the maintenance behavior of the water company.

3 Outcome Variables

3.1 Health Clinic Data

To measure the impact of water on disease, we use internal data from 21 clinics in Lusaka on disease incidence and health care. Clinics report each diagnosis and procedure into their internal information system (the Zambian Health Management Information System, or HMIS), and these are reported to the Ministry of Health. Our data consists of monthly totals for each diagnosis and procedure for each clinic. To match health clinics to the water data, we sent surveyors to geocode each clinic, and matched the clinics to a Water Service District. Fortunately, many of the catchment areas of the clinics line up well with the borders of the WSDs, since they correspond to well-known neighborhoods and "compounds" (slums).

For this analysis, we focus on two potential channels through which water outages might affect health: hygiene, and substitution toward contaminated drinking water. We show results for six (fairly) common contagious diseases: two spread through contaminated water (non-specific diarrhea and typhoid fever), two spread through close contact (measles and upper respiratory infections), one spread through mosquitos (malaria) and one spread through soil contamination (intestinal worms). If water outages cause substitution to dirty drinking water, we should see effects on water-borne diseases. If water outages cause decreased hygiene (particularly hand washing), we should see effects on diseases spread by person-to-person contact.

We do not expect that outages will affect diseases spread through mosquitos or soil. It is however possible that water-borne illnesses will weaken the immune system, and leave people more vulnerable to almost any disease. Consequently, there might even be a positive impact on diseases spread by mosquitos or soil. We cannot be sure that a positive effect on diseases spread by close contact is not in turn the result of water-borne illnesses weakening the immune system.

We will use data on routine well-child visits and vaccinations to see whether the time costs of water disruptions also reduce the amount of preventative care. Reductions in vaccination and preventative care could in turn increase the prevalence of a number of other diseases. Our identification strategy will not be able to pick up such effects, as it relies on relatively high frequency correlations between water outages and disease. The impacts of reduced vaccination will surely occur over much longer time periods.

3.2 Zoona Booth Data

Zoona is a company specializing in domestic over-the-counter electronic money transfers. A customer enters into a kiosk and gives the booth's agent money. An SMS message is then sent to the recipient's mobile phone, informing them of the transfer and providing them with a code. By using the code and an additional sender-created private pin number, the recipient can collect the money at any Zoona location.

In Zambia, Zoona kiosks are more common than branch banks and are a leading financial transfer service for poorer urban residents. By 2015, Zoona's Lusaka-based kiosks process 5807 transactions on an average day. While 51% of transfers out of Lusaka are to rural areas outside of Zambia's main population centers, 16% are used to make payments to people elsewhere in Lusaka.[5] While these transfers are far from a perfect proxy for urban economic activity, we believe Zoona's network is the best available high-frequency measure of economic action available with fine geographic disaggregation.

There are two reasons why Zoona's data is correlated with economic activity. First, the transfers themselves may be part of a sale. Second, even when they are not part of an economic transaction (like sending money to family), there are presumably more transfers when Zambians have more cash to transfer. This view was supported by our fieldwork interviewing Lusaka's residents. Naturally, there are many other reasons why transfers occur, which is why this dependent variable is surely an imperfect proxy for underlying economic activity.

Our data contains information on the universe of Zoona transactions from 2009 to 2015. For each kiosk, we code the total number of weekly transactions and the total sending and receiving activity at that location. To connect Zoona transaction activity with the water supply data, we sent a field team to geocode every Zoona kiosk in Lusaka. We then matched each booth to a water service district, and attributed all complaints in that district to all booths in the district.

At the water district level, there are an average of 623 transactions per week. The majority, 338, or these transactions involve sending money. The greater preponderance of sending money relative to receiving money reflects the fact that Lusaka is wealthier than other parts of Zambia, and consequently Lusakans are more likely to transfer money to their poorer, distant relations than those relations are to send money to the wealthier urbanites.

As the transfer process requires positive identification of both the sender and receiver, we can also track individual users across time. Table 1 shows that the average Zoona user makes .029 transactions per week. They send .016 times and receive .013 times. This is a relatively rare activity for most people in our data. Yet there is a distinct tail of Zoona 'super users' who engage in transactions far more regularly. This tail is captured by the high standard deviation of this variable (.245). While the specific purpose of each transaction is not recorded, anecdotal conversations with Zoona customers and employees indicate this bimodal distribution probably reflects the fact that most people use Zoona to send money to distant relatives, a relatively infrequent event. For a small minority, Zoona is used quite regularly for commercial purposes.

3.3 Time Use Data

Our third set of results focus on the time use of young women. A midline survey for a randomized control trial that assesses the impact of negotiation skills training on educational outcomes (Ashraf et al., 2017), contains time use information for the most recent school day, divided into every half-hour. The survey unfortunately does not isolate water-related housework from other household chores, but provides the respondents with the following list of activities as examples: preparing meals or buying food and charcoal at the market; washing clothes and cleaning house; collecting water or drawing water from other places; and other household chores.

[5] Over the entire sample, the corresponding numbers are 1514, 50.9%, and 5.2%.

The interviews took place between October 2 to December 8, 2013, where a team of surveyors typically spent about a week per school.[6]

The survey data and WSD data are matched using school geo-coordinates and the WSD areas, with the assumption that most girls lived close enough to the school that their homes would be within the same WSD. 38 schools were matched to 30 distinct WSDs. Each girl in a school with a matched WSD is matched with the number of complaints in that WSD on the day for which she provided accounts of her time use.

Panel D of table 1 shows that the average girl in our survey sample spends 4.1 hours on household chores on the most recent school day, and 4.9 hours on school and school work. The water services interruption variable is constructed at the day-level for the time use analysis, which is defined as the number of water service complaints outstanding on that day in the WSD that contains the school. This analysis relies on the variation caused from the day of interview within the school, and complaint cases cannot be aggregated over a week or a month, as is the case for the HMIS and Zoona analysis. Table 1 shows that on the day of the time use sample, the WSD of the average girl is sitting on 6.9 outstanding complaints.

4 Results for Health Outcomes

We first discuss our results linking outages with health outcomes. We see our regressions as testing the compound hypothesis that water impacts health and that people are unable or unwilling to fully substitute into equally healthy water sources if there is a water line break.

4.1 Empirical Strategy

Our objective is to estimate the impact of piped water on diseases, economic activity, and time use. Since access to piped water is not randomly allocated, we cannot simply compare places with and without access to piped water. However, because pipe breaks and other infrastructure issues can cause water supply to temporarily stop, we can use the timing of these outages to compare the same district with and without piped water. The identifying assumption is that the timing of water outages, conditional on month and year fixed effects, is not correlated with disease burden except through its effect on the supply of piped water.

In the case of health, we estimate the following regression

$$H_{imy} = \alpha + \beta C_{imy} + \gamma_i + \delta_m + \theta_y + \epsilon_{imy}$$

where H_{imy} is a health outcome (such as diagnoses of diarrheal disease) in district i in month m and year y, C_{imy}? is the total days of supply issues in district i in month m, γ_i is a vector of district fixed effects, δ_m is a vector of month fixed effects. An observation is a district-month. β is the coefficient of interest, and it measures the impact of water supply outages on each specified health outcome.

4.2 Results

Table 3 shows our results for water-borne diseases: diarrhea and typhoid fever. In the first panel, we find that for all age groups, additional outstanding water supply complaints are associated with higher numbers of diarrhea cases at district clinics. Each additional day of an outstanding complaint is associated with about one additional case of diarrhea, split roughly equally between each age group (under 1 year, 1-5, and over 5). Given that there are far more people over 5 than under one year olds, this even split suggests that it is the very young who suffer the most. It is also possible that older people are more likely to ignore the disease and not seek medical attention.

While these effect estimates might seem large, our qualitative work suggests that many individual complaints actually reflect outages of entire streets or neighborhoods, and not all outages will be reported. Thus, an excess of supply complaints in a given WSD-month is indicative of an outage in that area, but the number of households affected will likely be larger than the number of households that complain. A one standard deviation increase in supply days increases the number of diarrhea cases by 13 percent of the mean.

[6] The girls were asked to attend the sessions assigned to them by the surveyor, but were allowed to attend later dates if they were unable to show up on the assigned dates.

The second panel shows the results for typhoid fever. One extra day of supply issues is associated with .002 extra typhoid fever cases. The effect seems modest, but a one standard deviation increase in days of supply issues increases the number of typhoid fever cases by 22 percent, which is larger than the effect on diarrhea. The bulk of the increase in typhoid fever occurs for older people, but the effect on small children is proportionally larger. A one standard deviation increase in days with supply issues increases typhoid fever among children under one by more than the mean prevalence rate.

These results on water-borne diseases suggest that Lusaka residents are not just responding to water outages by spending time to get clean water sources. They do seem to be consuming worse water, and that has impacts on their health. Since these diseases are contagious, this suggests that the private willingness to pay for better water connections is likely to be less than the social benefit from better water pipe maintenance.

Table 4 shows the effect of water outages on two other contagious diseases—respiratory infections and measles. The first panel shows that an extra day of supply issues is associated with 2.4 more respiratory illnesses. This effect is spread across all age groups. A one standard deviation increase in days with supply issues is associated with an increase of 56.9 respiratory cases, which is 12.3 percent of the mean. The number of illnesses created does seem to be large, but respiratory diseases are particularly common.

Measles is considerably rarer, and the effect of water supply issues is smaller. One extra water supply day is associated with .035 more measles cases. A one standard deviation increase in days with water supply issues seems to generate .83 more measles cases, which is 17.8 percent of mean. In the case of measles, the impact is almost exclusively on older Lusakans.[7]

The effects on respiratory infections and measles might reflect reduced hand-washing, weakened immune systems, less preventative medicine or just more clinic visits. When water goes out, handwashing and other hygienic practices are likely reduced, encouraging the spread of airborne diseases. Infections from water-borne pathogens could weaken immune systems, making secondary infections of any type more likely. As our estimates of prevalence come from clinic visits, it is conceivable, but unlikely, that people are more likely to go to the clinic, conditional on sickness, when the water is out.

To shed light on these mechanisms in Appendix Table 1, we show the effect of supply complaints on two other common contagious diseases in Zambia: intestinal worms and malaria. These provide a possible placebo test, because they are unlikely to be affected, at least in the short run, by water outages (though it is possible that they could be affected by weakened immune systems). Intestinal worms are typically spread through soil and swimming in infested fresh water. Malaria is transmitted through mosquitos. The coefficients on both of these outcomes are small relative to their prevalence, and none are statistically significant.

4.3 Preventative Healthcare

The third channel through which water outages could impact health occurs through preventative care. If water problems reduce time availability, then parents and children may be less likely to go to clinics for routine checkups or vaccinations. The first two columns in Table 5 show the correlation between days of water supply complaints and routine checkups or "well child" visits. In both cases, the number of check-up visits declines. The effects are statistically weak, but meaningful in magnitude. A one standard deviation increase in days with supply issues is associated with 192 fewer "well child" visits for children under the age of one. This reduction is 15 percent of the sample mean. A one standard deviation increase in days with supply issues is associated with a 19 percent decrease in the number of "well child" visits for children between one and five years of age.

The next columns in Table 5 address vaccinations for diphtheria, pertussis and tetanus (DPT). The third column shows the impact on visits for the first vaccination shot. One extra day of supply issues reduces the number of first vaccination shots in the clinic by .52. A one standard deviation increase in the days with supply issues is associated with a 12 percent reduction in such shots. The fourth and fifth columns show the impact on visits for the second and third vaccination shots. In both cases, the number of visits declines with the number of days of supply issues, but the coefficient is statistically insignificant from zero for third vaccination shots.

These results suggest that our findings on visits for measles and diarrhea are not driven by a general tendency to go to health clinics more when there are water supply problems. They instead suggest that

[7] This is possibly driven by the fact that many more young people than older people in Lusaka are vaccinated against the disease.

water supply problems drive up the opportunity cost of time, which holding all else constant, drives down the tendency to visit local health clinics. We cannot estimate the long run consequences of reductions in vaccination, but it does suggest yet another health consequences of maintenance problems with water provision.

5 Results on Financial Transactions

We now turn to the effect of water supply on Zoona transactions, our measure of general economic activity. As with diarrhea reports, our economic activity proxy is imperfect. However, if water outages affect Zoona transactions, this suggests that water outages could affect economic transactions more generally.

5.1 Empirical Approach

We employ two distinct empirical strategies to understand the impact of water supply outages on financial transactions: at the individual level and aggregated to the WSD level. For the individual level estimation, we need to identify the relevant water service outages for each individual. We do not directly observe the home address of the users, only the booth locations at which they transact. Thus, we construct a total composite outage experience for each individual across the WSDs in which they transact, weighted by the number of transactions in each WSD.[8]

We look only at individuals who use Zoona more than once between 2009-2016, conduct at least 75% of their transactions in Lusaka, and we only look at individuals following their first transaction. These restrictions make it more likely that the customer actually lives in Lusaka during a period of water breakage. Moreover, the decision to adopt a new service is fundamentally different than the choice to repeatedly use that same service, and we have chosen to focus on repeat use. Even with these restrictions, the majority of weeks for the majority of individuals have 0 transactions. For this reason, we estimate the individual effects using a negative binomial specification, which is appropriate for over-dispersed distributions of count data.

We estimate:

$$T_{ibt} = \alpha + \beta C_{ibt} + \pi_b + \delta_t + \epsilon_{ibt}$$

where T_{ibt} is the number of Zoona transactions performed by an individual i in district $b$in week t, C_{ibt} is the weighted number of days of supply issues for the individual, our proxy for water outages, π_b is a control for the number of users that share the same composite WSD profile, δ_t is a vector of week fixed effects.[9] The coefficient of interest, β, measures the impact of water supply outages on each specified outcome. Standard errors are clustered at the composite-WSD level.

The analysis at the water service district level is relatively more straightforward. We aggregate the total number of transactions at booths in each WSD, and regress this on the total number of days of supply issues in the water service district, at the week level. For this specification, we estimate:

$$T_{bt} = \alpha + \beta C_{bt} + \gamma_b + \pi_{bt} + \delta_t + \epsilon_{bt}$$

where T_{bt} is the total number of Zoona transactions in district $b$in week t, $C_{bt}$is the weighted average number of days of supply issues for the individual, our proxy for water outages, γ_b is a vector of WSD fixed effects, π_{bt} is the number of kiosks operating in the WSD during each week, and δ_t is a vector of week fixed effects. The coefficient of interest, β, measures the impact of water supply outages on each specified outcome. Standard errors are clustered at the WSD level.

[8] This approach incorporates some degree of future information, as the weights are constructed based on the consumers entire consumption history.

[9] It is technically impossible to include a composite WSD-level fixed effect. The maximum number of variables that can be included in any of STATA's estimation commands is 11,000. There are 39,034 composite WSD profiles and 278,113 unique individuals, averaging 7.12 Zoona clients per composite WSD.

5.2 Results

Table 6 shows our primary estimates of the effect of water supply outages on financial transactions. Panel A shows result from the individual-level regressions. Column 1 shows total transactions, while column 2 shows the effect on total transactions sent (money sent from a Lusaka-based kiosk), and column 3 shows the effect on receiving activity (money sent from another location and picked up at a Lusaka-based kiosk). In each case, water outages lead to a decrease in the probability that an individual performs a Zoona transaction in a given week.

In the first column, we find that one extra day with water supply issues is associated with -.0005 fewer Zoona transactions. This seems like a small effect, but a one standard deviation increase in the number of days with supply issues seems to reduce the number of Zoona transactions by two percentage points, which is 70 percent of the mean. The second and third columns show the effects for sending money, -.0006, and receiving money, -.0004. These effects are not statistically different from one another.

In Panel B, we show results for the district-level analysis. Here, we see a similar pattern—more outages are associated with fewer transactions, but only the effect on transactions received is statistically significant at traditional levels. Most of the effect seems to be coming from the received transactions. This might reflect the fact people tend to receive money closer to home, and send money near work or in the marketplace.

Table 7 investigates the timing of the effects of outages on transactions. Our measure of outages is mechanically serially correlated, so we would expect to see some effects of lagged outages. In addition, since we are aggregating at the week level, some of the complaints that are initiated this week might actually reflect outages that happen after the relevant transactions. Thus, one might expect the lagged effects to be even stronger than the contemporaneous effects. Table 7 shows the effect of lagged and current weekly water supply outages on Zoona transactions in the current week. Column 1 shows the effect of the three weeks combined, which is negative in all three panels and statistically significant, though the coefficient is smaller than in our main specification (including only outstanding complaints in the current week). Column 2 replicates our main findings from Table 6.

In Columns 3 and 4, we add lags for the previous week and two weeks prior separately. In these specifications, complaints outstanding in the week prior actually have the strongest negative effect on transactions, which perhaps reflects the fact that the complaint timing (and reported resolution) are not always perfect. We cannot distinguish whether these negative effects reflect time costs or health shocks, but the lagged timing is suggestive. A time shock would presumably be more likely to be contemporaneous. A health shock seems more likely to work with a lag. Consequently, these timing results suggest that health may be mediating the impact of water maintenance issues. Table 8 scales point estimates by one standard deviation increase in the relevant complaints measure.

5.3 Placebo

While our main specification should account for static differences across places and for city-wide timing effects, a remaining concern might be that complaints themselves are correlated with financial transactions for some other reason. To test this, we run a placebo specification in which we use account complaints (which are typically billing disputes, and not related to supply outages) in place of supply complaints. In Appendix Table 2, we show the results of that regression. Reassuringly, the magnitudes of the effects are close to zero, and none are statistically significant.

5.4 Mechanisms

In the above sections, we have shown that water outages are associated with higher incidence of contagious disease, and fewer economic transactions. While the interpretation of the former is relatively straightforward: during outages, households substitute toward dirtier water sources and away from water-intensive hygiene behaviors such as handwashing, the latter has several possible underlying mechanisms.

Perhaps the most straightforward explanation is that the increase in disease incidence itself is causing the reduction in financial transactions. However, in qualitative interviews, the most common complaint about water outages was not illness, but inconvenience. For many families, water outages in their neighborhood induce them to travel further to gather water, taking up time, and displacing other household activities (such as financial transactions). Indeed, we see evidence for this in Table 5, where we see that though incidence of communicable disease goes up during outages, routine visits and vaccinations actually go down, consistent with routine chores being cancelled or postponed so that household members can gather water. It seems likely that both increased illness and time cost contribute to the effect of outages on Zoona transactions.

Third, there could be a mechanical effect, in which outages cause Zoona booths to close. This is unlikely because Zoona kiosks are not connected to water, sewer, or electricity. Water outages should not have a direct impact on the ability of the booths to conduct business. Moreover, our main specification tests whether customers conduct fewer transactions when there are outages in their typical transaction locations, regardless of where they conduct the transaction. When we test whether booths in areas with outages see fewer overall transactions, the results are actually weaker, suggesting that these are not transactions that are displaced, but rather transactions that do not take place at all. Lastly, in Table A3, we test directly for whether booths are more likely to be closed (zero transactions sent or received) in weeks with more outages. We do not find evidence that fewer booths are open on average when there are more complaints.

6 Time Use and Education

We now turn to our results on the time use of young women. In this case, we assess the effect of water service disruptions on time spent on household chores at the individual respondent level of the time use survey. For this specification, we estimate:

$$U_{ist} = \alpha + \beta C_{st} + \mu_s + \epsilon_{isjt}$$

where U_{ist} is the time spent on a type of activity for an individual i whose responses were recorded for day t, at school s. C_{st} is the weighted average number of days of supply issues for the WSD to which the school s is associated, on day t for which we have the time use information of student i and μ_s is a vector fo school fixed effects. Standard errors are clustered at the composite-WSD level.

6.1 Results

Table 9 shows our results. The first column shows the estimated impact on hours of chores. Each extra day of supply issues is associated with .016 more hours of chore work. A one standard deviation increase in days with supply issues seems to increase hours of chore work by 0.171 hours (10.26 minutes). This effect is not huge, but it does suggest that when water goes out, young women bear some of the burden. The most natural explanation is that they are either getting the water themselves or substituting for their mothers' who are spending time getting water.

The next two columns show results on school work and other uses of time. While the coefficient is not statistically distinct from zero, the bulk of the increase in time spent doing chores seems to come out of school work. A one standard deviation increase in the days with supply issues is associated with 0.012 fewer hours of school work.

These results are limited by our modest sample sizes and the limited variation at the water district level. Yet they do confirm anecdotal evidence from qualitative interviews run in the compounds. When water fails, the household must find other sources and that takes time. Household members, often young women, bear the cost and that cost does not just come today. Conceivably, longer term human capital accumulation is limited by these young women's bearing the costs of dealing with intermittent infrastructure.

7 Conclusion

Connections to water pipes do not eliminate the problems associated with water supply in the developing world. This paper documents the regularity of complaints about water supply disruptions in Zambia. The average water district in Lusaka received at least one complaint about water supply every other day, and complaints were more common in poorer areas where water was paid for by the month rather than by the liter. In this paper, we investigated the costs of water supply disruptions.

We found significant increases in diarrhea and typhoid fever after water disruptions, suggesting that households substitute into inferior water sources. There were also increases in respiratory illnesses and measles, suggesting after effects of a weakened immune system or a decrease in the amount of hand washing. The water supply disruptions were associated with a decrease in preventative care, especially vaccinations.

We also find that Zoona transactions decline significantly in weeks when there are more complaints about breakages that are resolved slowly. We cannot tell if this reduction reflects illness, time spent getting more water, or a bit of both. Our individual level analyses suggest outages may affect transactions through new customer acquisition, as fewer people engage Zoona for sending transactions on days with higher numbers of complaints.

The effects of our estimates are not extraordinarily large. Thirty fewer days of unresolved complaints are associated with 264 dollars of increased kiosk-level transfer activity. Yet the fact that water breakages seem associated with economic disruption provides more impetus to focus on cost-effective means of improving water infrastructure in the developing world.

We also found that water supply disruptions were associated with increases in chore work for young women. This increased chore time seems to reduce the amount of time spent doing school work. Consequently, the price of dealing with water disruptions today may be less education and less economic success in the future.

Given water's crucial role in so many daily needs, supply disruptions can cause significant costs, even in wealthy countries—drinking water still must be bought and stored, and solutions must be found for bathing and sanitation. These same problems occur in the developing world, where families have far fewer resources, and cannot substitute hand sanitizer or gym showers for lack of water at home. Our qualitative surveys suggest that when piped water is out, wealthier Zambians use large storage tanks on their properties, or purchase bottled clean water. Poorer people generally turn to protected wells or boreholes, other tapped sources, or avoid water use if possible. Many of these choices involve time costs and the risks of contagious disease, which means that their decisions also impact the wider community.

This paper extends the growing literature on the lives of urban poor in the developing world. Many of the world's poorer urbanites live on the edge of subsistence, and when something goes wrong costs appear across the spectrum. Water disruptions do not just mean a bit of inconvenience, but more disease, less economic activity, and less time for school work.

But we also highlight the importance of maintenance of infrastructure in developing world cities. New pipes are not going to do much good if poor people do not connect to those pipes or if they routinely break. Greater study on the institutions and incentives that lead to better maintenance of water related infrastructure seems crucial.

We found that water supply complaints were more common in areas where water was less likely to be metered, and consequently where the water company had less of a financial interest in maintaining the flow of water. Our data does not allow us to be sure that this correlation reflects a causal like between financial incentives and pipe maintenance. Yet it does suggest that more study of the institutional incentives facing water providers is surely warranted.

References

Alcott, Hunt, Allan Collard-Wexler, and Stephen D. O'Connell. "How do electricity shortages affect industry? Evidence from India." The American Economic Review 106.3 (2016): 587-624.

Ashraf, Nava, Natalie Bau, Corinne Low, and Kathleen McGinn. Negotiating a better future: how interpersonal skills facilitate inter-generational investment. Working paper. N.p., 2017. Web

Ashraf, Nava, James Berry, and Jesse M. Shapiro. "Can higher prices stimulate product use? Evidence from a field experiment in Zambia." The American Economic Review 100.5 (2010): 2383-2413.

Ashraf, Nava, Edward L. Glaeser, and Giacomo A.M. Ponzetto. "Infrastructure and Development Infrastructure, Incentives, and Institutions." The American Economic Review: Papers & Proceedings 106.5 (2016): 77-82.

Beaman, Lori, Esther Duflo, Rohini Pande, and Petia Topalova. "Female leadership raises aspirations and educational attainment for girls: A policy experiment in India." Science 335.6068 (2012): 582-586.

Bennett, Daniel. "Does clean water make you dirty? Water supply and sanitation in the Philippines." Journal of Human Resources 47.1 (2012): 146-173.

Blackden, C. Mark, and Quentin Wodon, eds. Gender, time use, and poverty in sub-Saharan Africa. Vol. 73. World Bank Publications, 2006.

Cutler, David, and Grant Miller. 2005. "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States." Demography 42 (1). Springer: 1–22.

Devoto, Florencia, Esther Duflo, Pascaline Dupas, William Parienté, and Vincent Pons. 2012. "Happiness on Tap: Piped Water Adoption in Urban Morocco." American Economic Journal: Economic Policy 4 (4). American Economic Association: 68–99.

Ferrie, Joseph, and Werner Troesken. 2008. "Water and Chicago's Mortality Transition, 1850--1925." Explorations in Economic History 45 (1): 1–16.

Fewtrell, Lorna, Rachel B. Kaufmann, David Kay, Wayne Enanoria, Laurence Haller, and John M. Colford. 2005. "Water, Sanitation, and Hygiene Interventions to Reduce Diarrhoea in Less Developed Countries: A Systematic Review and Meta-Analysis." The Lancet Infectious Diseases 5 (1). Elsevier: 42–52.

Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. "Water for Life: The Impact of the Privatization of Water Services on Child Mortality." Journal of Political Economy 113 (1). JSTOR: 83–120.

Gamper-Rabindran, Shanti, Shakeeb Khan, and Christopher Timmins. 2010. "The Impact of Piped Water Provision on Infant Mortality in Brazil: A Quantile Panel Data Approach." Journal of Development Economics 92 (2). Elsevier: 188–200.

Gramlich, Edward M. "Infrastructure investment: A review essay." Journal of economic literature 32.3 (1994): 1176-1196.

Kremer, Michael, Jessica Leino, Edward Miguel, and Alix Zwane. "Spring cleaning: Rural water impacts, valuation, and property rights institutions." The Quarterly Journal of Economics 126.1 (2011): 145-205.

Merrick, Thomas W. 1985. "The Effect of Piped Water on Early Childhood Mortality in Urban Brazil, 1970 to 1976." Demography 22 (1): 1–24. doi:10.2307/2060983.

Muralidharan, Karthik, and Venkatesh Sundararaman. "The Aggregate Effect of School Choice: Evidence from a two-stage experiment in India." The Quarterly Journal of Economics 130.3 (2015): 1011-1066.

Sasaki, Satoshi, Hiroshi Suzuki, Kumiko Igarashi, Bushimbwa Tambatamba, and Philip Mulenga. 2008. "Spatial Analysis of Risk Factor of Cholera Outbreak for 2003--2004 in a Peri-Urban Area of Lusaka, Zambia." The American Journal of Tropical Medicine and Hygiene 79 (3). ASTMH: 414–21.

Schwartz, Klaas. 2008. "The New Public Management: The Future for Reforms in the African Water Supply and Sanitation Sector?" Utilities Policy 16 (1). Elsevier: 49–58.

Shah, Manisha and Bryce Millett Steinberg. 2016. "Workfare, Wages and Human Capital Investment: Evidence from India." NBER Working Paper No. 21543.

Troesken, Werner. 2002. "The Limits of Jim Crow: Race and the Provision of Water and Sewerage Services in American Cities, 1880--1925." The Journal of Economic History 62 (03). Cambridge Univ Press: 734–72.

World Health Organization. Progress on sanitation and drinking water: 2015 update and MDG assessment. World Health Organization, 2015.

Table 1: Summary Statistics

Panel A: WSD-level Variables				
Avg. Consumption	197.3			
	[732.4]			
Fraction Metered	.548			
	[.325]			
Fraction Peri-Urban	.275			
	[.450]			
Population Density	7,015			
	[6,779]			
Panel B: Health Clinic Analysis Variables				
Days of Supply Issues (per month)	14.36			
	[23.70]			
Cases of Disease:				
	All Ages	*Under 1*	*1-5*	*Over 5*
Diarrhea	181.9	44.2	71.1	66.6
	[224.1]	[64.3]	[94.5]	[89.7]
Respiratory Infection	461.9	97.8	147.7	216.4
	[660.0]	[136.4]	[196.0]	[408.4]
Typhoid Fever	.209	.007	.057	.145
	[1.33]	[.110]	[.413]	[1.03]
Measles	4.65	.590	2.02	2.04
	[15.5]	[3.52]	[7.25]	[6.97]
Intestinal Worms	12.2	.281	5.41	6.48
	[35.8]	[1.82]	[15.4]	[6.97]
Malaria	296.2	56.6	96.6	143.0
	[438.2]	[100.7]	[152.8]	[220.8]
Visits:				
	All Ages	*Under 1*	*1-5*	
Well Child	2,542	1,283	1,259	
	[4,716]	[2,045]	[2,845]	
	Dose 1	*Dose 2*	*Dose 3*	
DPT Vaccinations	103.8	96.7	142.5	
	[132.0]	[121.7]	[137.3]	

Notes: The table presents summary statistics of main outcome variables and regressors. Panel A shows averages for each measure over months and water service districts. These data come directly from Lusaka Water and Sewerage Company. Panel B shows the number of cases of each disease or visit/procedure reported in a clinic on average in a WSD. These data come from the administrative clinic data. Standard deviations are reported in brackets.

Table 1: Summary Statistics (continued)

Panel C: Financial Transaction Analysis Variables		
Days (per week) of:	*Supply Issues*	*Account Issues*
	15.9	.359
	[38.3]	[2.24]
Zoona transactions:		
	WSD Level	*Individual Level*
Total	623	.029
	[1,182]	[.245]
Sent	338	.016
	[679]	[.167]
Received	285	.013
	[508]	[.166]
Panel D: Time Use Analysis Variables		
Hours spent on:		
		Individual Level
Housework		4.109
		[2.519]
School and homework		4.947
		[3.465]
All other		14.928
		[2.968]
Number of cases outstanding:		
Supply Issues		6.895
		[10.705]

Notes: The table presents summary statistics of main outcome variables and regressors. In Panel C, we present the summary of LWSC complaint issues, collapsed at the weekly level and merged to the Zoona financial transaction data. Supply issues refer to complaints made about water supply issues, and account issues refer to account and billing related cases. In Panel D, we present the summary of the time use variables and the supply issue complaints data merged to the survey dataset. The supply issues variable is defined as the number of outstanding cases in the water service district associated with the school that the girls in the survey attend and are surveyed at. The respondent was asked the following question: "Think back to yesterday or the last non-holiday school day if yesterday was the weekend. Can you talk me through your day, from when you woke up in the morning to when you went to sleep at night?" They were then asked to categorize every half-hour of the day spent into the following categories: 1. sleeping or resting; 2. bathing, dressing, doing hair, or related self-care activities; 3. in school (including transportation);4. doing housework; 5. doing school work; 6. caring for other household members; 7. helping with household business (unpaid); 8. working/doing piecework, or other income generating activity; 9. religious activities; 10. visiting with family or relatives; 11. visiting/playing with friends; 12. eating/drinking; 13. watching television; 14. funeral or burial; and 15. other. In the table above, housework only contains activity 4, school and schoolwork contain 3 and 5, and all other categories are combined. Standard deviations are reported in brackets.

Table 2: Correlates of Supply Complaints

	(1) Average Consumption	(2) % Metered Connections	(3) Peri-Urban	(4) Population Density
Days of supply issues	-.192	-.416**	.484***	.165
Days of supply issues (normalized by total connections)	-.060	-.365**	.092	-.146
Days of Supply Issues (normalized by account complaints)	-.046	-.505***	.265*	-.041
Fraction days with at least one supply complaint	-.349**	-.397***	.299*	-.096
Mean	197.3	.548	.275	7,015

Notes: ***indicates significance at .1% level, ** at 1% level, * at 5% level.This table shows correlations between four measures of water supply complaints and WSD characteristics. Each number is a separate (unconditional) correlation coefficient. Days of supply issues is the number of outstanding supply complaints outstanding in each WSD on each day, summed to the month level and averaged over all months for 2009-2014. This is the primary independent variable used throughout our analysis. The second row uses this measure divided by the total number of water connections in a WSD. The third row uses this measure divided by the total number of outstanding *account* complaints outstanding in a given day, summed over each month and averaged over the period 2009-2014. The fourth row uses the fraction of days over the total time period on which there was at least one supply complaint in the WSD. Column one correlates these measures with total monthly water consumption per connection in the WSD, column two with the percent of connections that are metered, column 3 with a dummy for whether the district is peri-urban, and column 4 with the population density of the WSD.

Table 3: Effect of Water Supply Complaints on Water-borne Disease

Panel A: Non-Bloody Diarrhea				
Dependent Variable:	Number of Cases			
Age:	All	Under 1	1-5	Over 5
Days of Supply Issues	1.00	.32	.42	.27
	(.42)**	(.15)**	(.16)**	(.17)
Mean of DV	181.9	44.2	71.1	66.6
1 Std. Deviation Increase Effect	23.7	7.58	9.96	6.40
Observations	1,230	1,230	1,230	1,230
Panel B: Typhoid Fever				
Dependent Variable:	Number of Cases			
Age:	All	Under 1	1-5	Over 5
Days of Supply Issues	.0020	.00046	.00058	.00093
	(.0010)*	(.00022)**	(.00026)**	(.00080)
Mean of DV	.209	.007	.057	.145
1 Std. Deviation Increase Effect	.047	.011	.014	.022
Observations	1,230	1,230	1,230	1,230

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows coefficients from an OLS regression of the number of cases of diarrhea (non-bloody) on the number of outstanding water supply complaints. An observation is a supply-month. The dependent variable in the first column is the number of cases for all ages, in the second column it is the total number of cases for infants under one year, in the third column it is the number of cases for children age 1-5, and the third column is the total number of cases of children over 5 and adults. The dependent variable in the first column is the sum of the dependent variables in the other three columns. All regressions contain month and WSD fixed effects. Standard errors, clustered at the WSD level are reported in parentheses.

Table 4: Effect of Water Supply Complaints on Other Contagious Disease

Panel A: Respiratory Infections				
Dependent Variable:	Number of Cases			
Age:	All	Under 1	1-5	Over 5
Days of Supply Issues	2.40	.61	.89	.90
	(.91)***	(.29)**	(.32)***	(.47)*
Observations	1,230	1,230	1,230	1,230
Mean of DV	461.9	97.8	147.7	216.4
1 Std. Deviation Increase Effect	56.9	14.5	21.1	21.3
Observations	1,230	1,230	1,230	1,230
Panel B: Measles				
Dependent Variable:	Number of Cases			
Age:	All	Under 1	1-5	Over 5
Days of Supply Issues	.035	-.00003	.0047	.030
	(.010)***	(.0035)	(.0084)	(.0077)***
Mean of DV	4.65	.590	2.02	2.04
1 Std. Deviation Increase Effect	.83	-.0071	.11	.71
Observations	1,230	1,230	1,230	1,230

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows coefficients from an OLS regression of the number of cases of contagious diseases (respiratory infections in Panel A, and measles in Panel B) on the number of outstanding water supply complaints. An observation is a supply-month. In each panel, the dependent variable in the first column is the number of cases for all ages, in the second column it is the total number of cases for infants under one year, in the third column it is the number of cases for children age 1-5, and the third column is the total number of cases of children over 5 and adults. The dependent variable in the first column is the sum of the dependent variables in the other three columns. All regressions contain month and WSD fixed effects. Standard errors, clustered at the WSD level are reported in parentheses.

Table 5: Effect of Water Supply Complaints on Routine Visits

Dependent Variable:	Number of Visits				
	Well Child		Vaccinations		
	Under 1	1-5	DPT1	DPT2	DPT3
Days of Supply Issues	-8.1	-10.2	-.52	-.41	-.25
	(4.9)*	(6.6)	(.20)***	(.20)**	(.16)
Mean of DV	1,283	1,259	103.8	96.7	142.5
1 Std. Deviation Increase Effect	-192	-242	-12.3	-9.7	-5.9
Observations	1,230	1,230	1,230	1,230	1,230

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows coefficients from an OLS regression of the number of routine visits (well child visits is columns 1 and 2, and diphtheria, pertussis, and tetanus vaccinations in columns 3-5) on the number of outstanding water supply complaints. An observation is a supply-month. The dependent variable in the first column is well child visits for infants (under 1 year), in column 2 it is well child visits for children ages 1-5, in column 3 it is the first of three DPT vaccination shots, column 4 is the second DPT vaccination, and column 5 is the third DPT shot. All regressions contain month and WSD fixed effects. Standard errors, clustered at the WSD level are reported in parentheses.

Table 6: Water Outages and Zoona Activity

Panel A: Individual Level

	Combined (1)	Sending (2)	Receiving (3)
Complaint Days	-.0005	-.0006	-.0004
	(.0002)**	(.0002)**	(.0002)*
DV Mean	.029	.016	.013
1 Std. Deviation Increase Effect	-.02	-.02	-.016
Observations	11,953,363	11,953,363	11,953,363

Panel B: Water Supply District Level

	Combined (1)	Sending (2)	Receiving (3)
Complaint Days	-.21	-.05	-.16
	(.16)	(.12)	(.06)***
DV Mean	622	337	285
1 Std. Deviation Increase Effect	-8	-1.9	-6.1
Observations	3,827	3,827	3,827

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows estimates of the effect of water outages on Zoona transactions. Panel A shows coefficients from a negative binomial regression in which the independent variable is the weighted average of the individual's previous transaction districts' total number of outstanding water supply complaints in each day, summed over the calendar week. Panel B shows the coefficients from an OLS regression in which the independent variable is the total number of outstanding water supply complaints in the booth's WSD in each day, summed over the calendar week. In each panel, the dependent variable in the first column is the total number of transaction, in column 2 it is total transactions in which money was sent, and in column 3 it is total number of transactions in which money was received. The dependent variable in the first column is the sum of the dependent variables in the other two columns. Panel A regressions contain week fixed effects and controls for the total number of users in each composite WSD. Panel B regressions contain week and WSD fixed effects. Standard errors, clustered at the composite-WSD level (Panel A) or WSD level (Panel B) are reported in parentheses.

Table 7: Effect of Lagged Complaints on Zoona Activity

Panel A: All Transactions

	(1)	(2)	(3)	(4)
Total Supply Issues previous 3 weeks	-.00018 (.00007)***			
Days of Supply Issues this week		-.00048 (.00019)**	.00032 (.00024)	.00034 (.00024)
Days of Supply Issues 1 week prior			-.00086 (.00022)***	-.0011 (.0003)***
Days of Supply Issues 2 weeks prior				.00022 (.00024)
Mean of DV	.029	.029	.029	.029
Observations	11,953,363	11,953,363	11,953,363	11,953,363

Panel B : Receiving Activity

	(1)	(2)	(3)	(4)
Total Supply Issues previous 3 weeks	-.00014 (.00008)*			
Days of Supply Issues this week		-.0004 (.00022)*	-.00015 (.00031)	-.00011 (.00031)
Days of Supply Issues 1 week prior			-.00027 (.0003)	-.00065 (.00038)*
Days of Supply Issues 2 weeks prior				.00036 (.0003)
Mean of DV	.013	.013	.013	.013
Observations	11,953,363	11,953,363	11,953,363	11,953,363

Panel C: Sending Activity

	(1)	(2)	(3)	(4)
Total Supply Issues previous 3 weeks	-.00023 (.00008)***			
Days of Supply Issues this week		-.00056 (.00023)**	.00079 (.00031)**	.0008 (.00031)**
Days of Supply Issues 1 week prior			-.00147 (.00032)***	-.00157 (.00049)***
Days of Supply Issues 2 weeks prior				.0001 (.00033)
DV Mean	.016	.016	.016	.016
Observations	11,953,363	11,953,363	11,953,363	11,953,363

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows coefficients from a negative binomial regression in which the independent variable is the weighted average of the individual's previous transaction districts' total number of outstanding water supply complaints in each day, summed over the calendar week. In all panels, column 1 includes only complaints in the current week, column 2 contains complaints on the current week and complaints from the previous week, and column 3 includes complaints from the current week, the previous week, and two weeks prior. Column 4 includes an aggregate of total days of supply issues over the previous 3 weeks. In Panel A, the dependent variable is total transactions, in Panel B it is total transactions in which money was received, and in Panel C it is total transactions in which money was sent. All regressions contain week fixed effects and controls for the total number of users in each composite WSD. Standard errors, clustered at the composite-WSD level are reported in parentheses.

Table 8: Effect of Lagged Complaints on Zoona Activity, Normalized 1 Standard Deviation Increase

Panel A: All Transactions

	(1)	(2)	(3)	(4)
Total Supply Issues previous 3 weeks	-0.022			
	(.00007)***			
Days of Supply Issues this week		-0.019	0.013	0.014
		(.00019)**	(.00024)	(.00024)
Days of Supply Issues 1 week prior			-0.035	-0.045
			(.00022)***	(.0003)***
Days of Supply Issues 2 weeks prior				0.009
				(.00024)
Mean of DV	.029	.029	.029	.029
Observations	11,953,363	11,953,363	11,953,363	11,953,363

Panel B : Receiving Activity

	(1)	(2)	(3)	(4)
Total Supply Issues previous 3 weeks	-0.017			
	(.00008)*			
Days of Supply Issues this week		-0.016	-0.006	-0.004
		(.00022)*	(.00031)	(.00031)
Days of Supply Issues 1 week prior			-0.011	-0.027
			(.0003)	(.00038)*
Days of Supply Issues 2 weeks prior				0.015
				(.0003)
Mean of DV	.013	.013	.013	.013
Observations	11,953,363	11,953,363	11,953,363	11,953,363

Panel C: Sending Activity

	(1)	(2)	(3)	(4)
Total Supply Issues previous 3 weeks	-0.028			
	(.00008)***			
Days of Supply Issues this week		-0.023	0.032	0.032
		(.00023)**	(.00031)**	(.00031)**
Days of Supply Issues 1 week prior			-0.060	-0.064
			(.00032)***	(.00049)***
Days of Supply Issues 2 weeks prior				0.004
				(.00033)
DV Mean	.016	.016	.016	.016
Observations	11,953,363	11,953,363	11,953,363	11,953,363

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows coefficients from a negative binomial regression in which the independent variable is the weighted average of the individual's previous transaction districts' total number of outstanding water supply complaints in each day, summed over the calendar week. In all panels, column 1 includes only complaints in the current week, column 2 contains complaints on the current week and complaints from the previous week, and column 3 includes complaints from the current week, the previous week, and two weeks prior. Column 4 includes an aggregate of total days of supply issues over the previous 3 weeks. In Panel A, the dependent variable is total transactions, in Panel B it is total transactions in which money was received, and in Panel C it is total transactions in which money was sent. All regressions contain week fixed effects and controls for the total number of users in each composite WSD. Standard errors, clustered at the composite-WSD level are reported in parentheses.

Table 9: Effect of Household-days of Outstanding Complaints on Time Use

	(1) Hrs chores	(2) Hrs school/hw	(3) Hrs other
Number of outstanding comp.	0.016*	-0.0116	-0.00466
	(0.00876)	(0.0233)	(0.0159)
DV Mean	4.078	4.926	14.98
1 Std. Deviation Increase Effect	0.171	-0.124	-0.050
Observations	2,103	2,103	2,103

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows coefficients from an OLS regression. In column 1, the dependent variable is the number of hours the girls spent on household chores. In column 2, the dependent variable is the number of hours the girl spent in school or on school work at home. In column 3, the dependent variable is all other hours accounted for in the time use survey. All regressions contain week fixed effects and controls for the total number of users in each composite WSD. Standard errors, clustered at the composite-WSD level are reported in parentheses.

A Appendix Tables and Figures

Table 1: Effect of Water Supply Complaints on Non-Water Contagious Disease

Panel A: Intestinal Worms				
Dependent Variable:	Number of Cases			
Age:	All	Under 1	1-5	Over 5
Days of Supply Issues	.033	.00083	.023	.0088
	(.042)	(.0014)	(.014)*	(.030)
Observations	1,230	1,230	1,230	1,230
Mean of DV	12.2	.28	5.4	6.7
Panel B: Malaria				
Dependent Variable:	Number of Cases			
Age:	All	Under 1	1-5	Over 5
Days of Supply Issues	-1.09	.023	-.39	-.72
	(1.29)	(.23)	(.44)	(.64)
Observations	1,230	1,230	1,230	1,230
Mean of DV	296.2	56.6	96.6	143.0

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows coefficients from an OLS regression of the number of cases of contagious diseases (intestinal worms in Panel A and malaria in Panel B) on the number of outstanding water supply complaints. An observation is a supply-month. In each panel, the dependent variable in the first column is the number of cases for all ages, in the second column it is the total number of cases for infants under one year, in the third column it is the number of cases for children age 1-5, and the third column is the total number of cases of children over 5 and adults. The dependent variable in the first column is the sum of the dependent variables in the other three columns. All regressions contain month and WSD fixed effects. Standard errors, clustered at the WSD level are reported in parentheses.

Table 2: Account Complaints and Zoona Activity

Panel A: Individual Level

	Combined (1)	Sending (2)	Receiving (3)
Account Complaint Days	-.006	-.000019	-.01
	(.006)	(.006)	(.007)*
DV Mean	.029	.016	.013
1 Std. Deviation Increase Effect	-0.00	-0.00	-0.01
Obs.	11,776,279	11,776,279	11,776,279

Panel B: Water Supply District Level

	Combined (1)	Sending (2)	Receiving (3)
Account Complaint Days	-3.08	-1.39	-1.69
	(2.18)	(1.09)	(1.33)
DV Mean	639	348	291
1 Std. Deviation Increase Effect	-6.89	-3.11	-3.78
Obs.	3,639	3,639	3,639

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows estimates of the effect of water outages on Zoona transactions. Panel A shows coefficients from a negative binomial regression in which the independent variable is the weighted average of the individual's previous transaction districts' total number of outstanding account complaints in each day, summed over the calendar week. Panel B shows the coefficients from an OLS regression in which the independent variable is the total number of outstanding water supply complaints in the booth's WSD in each day, summed over the calendar week. In each panel, the dependent variable in the first column is the total number of transaction, in column 2 it is total transactions in which money was sent, and in column 3 it is total number of transactions in which money was received. The dependent variable in the first column is the sum of the dependent variables in the other two columns. Panel A regressions contain week fixed effects and controls for the total number of users in each composite WSD. Panel B regressions contain week and WSD fixed effects. Standard errors, clustered at the composite-WSD level (Panel A) or WSD level (Panel B) are reported in parentheses.

Table 3: Do Complaints Affect Whether Booths are Open?

Dependent Variable:	Total Booths Open
Days of Supply Issues	-.003
	(.02)
DV Mean	70.4
Obs.	3,827

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level. This table shows estimates of the effect of water outages on whether a Zoona booth is open, which is defined as having any transactions in a given week. The regression contains week and WSD fixed effects. Standard errors, clustered at the WSD level, are shown in parentheses.