WATER, HEALTH AND WEALTH

by

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July 19, 2015, Extremely Preliminary Draft

Not for Citation or Distribution, References Incomes

Abstract

This paper estimates the impact of water supply disruptions on disease and economic activity in Lusaka, the capital city of Zambia. We link supply-related complaints to the Lusaka water company, which are common, with data on disease in related clinics. We find that in months when there are more, and more severe, breaks, the number of diarrhea-related cases increases. More surprisingly, we also find a modest increase in respiratory diseases and pneumonia, perhaps because of decreased hygiene, and a small, but statistically significant, increase in infant mortality. We also link water supply complaints to economic transactions that occur through Zoona, the dominant provider of phone-based banking in Lusaka, which is a primary financial tool for the poor. We find that there are fewer Zoona transfers in weeks with more complaints, suggesting that water breaks reduce economic activity. It is unclear whether this reduction in economic activity is driven by illness, or increased time spent finding alternative sources of water.

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[1] We thank the International Growth Centre for financial support. Superb research assistance was provided by Shotaro Nakamura. We thank the Lusaka Water and Sewerage Company, Zoona, and the Zambia Ministry of Health for generously sharing their data.

I. Introduction

The United Nations predicts that the number of city dwellers will increase by 3.5 billion over the next 40 years, and that 96 percent of that growth will come in poor countries.[2] The growth of cities brings tremendous economic potential, facilitating the spread of innovation, industry and education. The promise of economic opportunity and prosperity, however, is blighted by the significant negative externalities that can be associated with big city density, including congestion and contagious disease.

In high-income countries, expensive infrastructure investments made early on, including sewers and clean water provision, are thought to have made cities livable (Troesken, 2005) and to have played an outsize role in increasing American life expectancies during the first half of the twentieth century (Cutler and Miller, 2005). One traditional view is clean water may be the most important task of city government (e.g. Mills and Hamilton, 1994). While this view was based more on epidemiology than economics, the financial costs associated with water-borne diseases, like cholera, may also have been quite large. As the developing world contemplates spending trillions on infrastructure, it is particularly important to understand the economic, as well as the health, costs of underperforming water and sewage infrastructure in the developing world.[3]

In this paper, we examine both the health and economic effects of failures in water-related infrastructure in Lusaka, the capital of Zambia. Zambia is the most urbanized country in Sub-Saharan Africa with 36% of its population living in urban areas (WHO, 2012). Like many developing world cities, Lusaka has an imperfect water system, and has been the recipient of hundreds of millions of dollars in international aid for investment in its water infrastructure.[4] Currently, households rely on a combination of latrines, boreholes, sewers and piped water.

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[2] http://www.huffingtonpost.com/2013/12/10/city-dwellers-double-2050_n_4418386.html

[3] While many papers find strong correlations between improved water quality and health, relatively fewer papers measure a causal effect of piped water on health and, particularly, on socio-economic outcomes. Galiani, Gertler and Schardrogsky (2005) find that privatization of water utilities in Argentina led to increased piped water and decreased child mortality. Gamper-Rabindran,Khan and Timmins (2010) use Brazilian panel census data to estimate the effect of piped water, relying on identification via minimally compatible areas. Finally, Devoto, Duflo, Dupas, Pariente and Pons (2012) find that household connections to piped water infrastructure did not have strong health effects but did have strong and positive effects on subjective well-being.

[4] The Millennium Challenge Account alone has committed over $354Million USD in a compact between the US and Zambian government signed in 2012 for investments in water supply, sanitation, and drainage infrastructure. https://www.mcc.gov/pages/countries/program/zambia-compact

Breaks in sewer lines may lead to local water pollution, which may infect those consumers using near-by boreholes.

Measuring the causal effects of piped water on socio-economic outcomes has been difficult to do in the past because it requires both a credible identification strategy—investments in infrastructure are often undertaken with strategic consideration in mind and are rarely exogenous in their rollout—and high-frequency micro-data on numerous outcome measures. Our attempt to address these challenges uses matched administrative data on water pipe breakages, geographic data on weather and topography, geo-coded public health clinic data on a range of health outcomes, and private sector economic data on money transactions.

Lusaka Water and Sewage have generously provided us with the 14 year history of water-related complaints for the city and their reports on the time it takes to resolve these complaints. Problems with the system are not uncommon: about half of the 72 water service districts have at least one supply complaint in a given week. Moreover, their own data shows that it can sometimes take Lusaka Water and Sewer over six months to fix a broken sewer pipe. Our identification strategy then relies on the assumption that the exact timing of breaks within a neighborhood is essentially random.

All of our estimates include both neighborhood and time fixed effects, as we suspect that seasonal and spatial patterns of breakage are non-random. We rely on the assumption that it is essentially random if place A had a water break in March rather than April in one year while place B had a water break in April rather than March. Our primary measure is a count of the number of unresolved complaints on each day aggregated up to the week or month. While we cannot be confident that two complaints aren't reflecting the same underlying problem, we suspect that a larger number of complaints implies a larger underlying problem.

Our first test examines the connection between water breaks and disease, a natural place to start. Our primary health outcomes come from public health clinics, using government records, which report the number of patients who arrive with specific complaints. We find that when water supply complaints increase by one standard deviation, the number of infant diarrhea cases increases by almost one-quarter of a standard deviation or four ninths of the mean level of such diseases. We also find significant correlations with under-5 diarrhea and infant pneumonia.

We also measure the impact of water supply on economic outcomes. We have the universe of records from Zoona, which is the dominant electronic banking firm in Zambia. The poorer citizens of Zambia are largely unbanked, and rely on Zoona to make payments and transfers. The ubiquitous nature of Zoona provides us with a remarkably detailed picture of the financial lives of many thousand Zambians. Moreover, since there are over 250 Zoona booths in Lusaka, this data also gives us a rich geographic picture of the city.

We find that there are fewer overall transactions in the weeks in which there are complaints about water supply. The results are consistent with less overall economic activity, either because Zoona booth operators are open for fewer hours, or because customers are either ill or occupied with finding and gathering water. We do not find an increase in transactions into districts without water, which one might expect if these transactions were being used as a form of insurance across family networks.

These results collectively document the downsides of weak water infrastructure. When pipes break, water quality deteriorates, disease spread, and economic activity decreases. We have not incorporated our estimates into cost benefit analysis of water investments in Zambia, or elsewhere, but we hope that future work will take that next step.

II. Water, Health and Wealth

Urban density can create both positive and negative externalities. Alfred Marshall emphasized the flow of knowledge in dense clusters, but bacteria can also move more readily when distances are short. For centuries, the cities of the west have invested in ways that are meant to diminish the downsides of density. In the 1980s within the U.S., there was considerably more crime in big cities than in small towns, partially because the ability to catch criminals appears to be lower in crowded urban areas (Glaeser and Sacerdote, 1999). Since then, American governments, including cities, states and the Federal government, increased spending on police and prisons and this spending appears to have reduced urban crime rates (Levitt, 2002).

Traffic congestion remains a pressing problem in wealthy and poor cities alike. While congestion pricing seems to have been effective in Singapore and London, political forces seem to push against such demand management tools and towards new transport infrastructure investment. Yet the track record of those investments are mixed. New mass transit systems appear to have had only modest impacts on commuting patterns within the U.S. (Baum-Snow and Kahn, 2002). Vehicle miles traveled appear to rise roughly one-for-one with highway miles built which implies that new highways are unlikely to reduce traffic congestion (Duranton and Turner, 2010). This last example shows how unforeseen behavioral responses (more highways means more drivers) can undo many of the benefits of urban infrastructure.

But while many economists are skeptical about transportation infrastructure spending, there is much less of a debate about investments in urban water. The great debates about urban water systems occurred more than a century ago in most large western cities. A consensus emerged that favored spending on sewers, aqueducts and water pipes. A vast amount of money was spent. Cutler and Miller (2005) report that America's cities and towns were spending more on water at the start of the twentieth century than the Federal government was spending on everything except for the post office and the army.

But that spending appears to have achieved near miraculous results. In 1900, life expectancy for boys born in New York City was six years less than national average but today life expectancy is more than two years longer in New York. Epidemics, especially those related to water, were once a regular feature of urban life in the west. They are no longer. Moreover, serious academic work (Troesken, 2002, Ferrie and Troesken, 2005) seems to document that public water investments really did save lives in the west.

However, this history does not make the case for every water investment in the developing world. In many cases, these countries are far poorer than the U.S. was at the start of the 20th century. For example, in the 1920s, when the U.S. became a predominantly urban nation, per capita gross domestic product in modern dollars was $7,500. Per capita incomes in the Democratic Republic of the Congo today are less than one-twentieth that amount. Even Zambia, which is far closer to middle income, has per capita incomes that are less than one-fourth U.S. incomes during the 1920s. Spending on water becomes harder and harder to justify when income levels are much lower.

Moreover, the impact of water investment may be different in modern sub-Saharan African than in 19th century Chicago, perhaps because of the different political or cultural institutions. If developing world cities lack the resources to protect infrastructure from damage or abuse, the benefits of investment may vanish. If consumers aren't willing to switch from boreholes to piped water, then the benefits of building water mains is limited. Moreover, the benefits from clean water depend partially on the state of the health system. If the health system is weak then the mortality consequences of poor water may be far more extreme.

One particularly notable problem with water systems in the developing world context is that many poorer urbanites may (understandably) prefer the less safe alternatives to piped water and sewage systems, such as shallow wells and cess-pits, as long as they are cheaper. This was true in 19th century New York City, and it often seems true in 21st century Lusaka as well. If these alternatives create grave health-related externalities, then presumably they should be taxed or banned. 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. This fact should remind us that regulation and infrastructure can often be complements, and that an inability or unwillingness to regulate may sharply reduce the benefits of infrastructure.

The institutional limitations of developing world cities would make any such bans difficult to enforce. In many cases, property ownership may be murky at best. As a result, urban health advocates turn to subsidies, but these carry their own downsides, because taxes are frequently distortionary, subsidized programs can readily become boondoggles and because a subsidy to urban water use creates a spatial distortion.

The implementation challenges inherent in the adoption of expensive, collective water technologies makes it all the more important to understand the true benefits of water-related infrastructure. If the social costs of disrupted water are low, then it makes little sense to obsess over ensuring adoption of the more expensive, more sanitary technology.

There is a large literature on the connection between water and health. Among economists, the work of Werner Troesken and Joseph Ferrie is particularly distinguished. Fewtrell et al. (2004) 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 et. al; Gamper et al. 2010). A relative study finds that increased household connections lead to no difference in health but an improvement in subjective well-being (Devoto et al.). Sasaki et al. (2009) also examine Lusaka, and test the impact of rainfall and poor drainage on cholera epidemics in Lusaka.

Our Approach

We focus on temporal variation in the availability of clean water piped in from the Lusaka Water and Sewage Company, the dominant water utility in Lusaka. Pipes occasionally break, and this means that families need to find alternatives to their regular sources. In some cases, these alternatives may be less safe, for example a neighbor's shallow well. In other cases, the alternatives may just be inconvenient, a long wait at a deep public well that is further away.

We have begun qualitative work in Lusaka that involves interviewing residents who experience water outages. Three facts from this work seem clear. Outages and intermittent water service are part of their lives. People respond to outages in different ways, often by storing buckets of water for days on end. The process of getting new water, if their pipes are out, involves either time or increased health risk, and in many cases, the families prefer to take the risk of a neighbor's bore-hole than the spend the time waiting for a piped communal tap.

The sporadic water pipe breakages have three features that make them appealing as sources of variation. First, the exact timing of any particular break in any particularly is at least plausibly exogenous. Certainly, some neighborhoods may be more prone to have breaks and some time periods may be more break intensive. But the fact that neighborhood A had a break in May while neighborhood B had a break in June has a greater chance of being random. Second, the number of breaks is obviously related to a clear public policy question: how much to invest in the maintenance of the pipe system.

Finally, and perhaps most interesting, random breaks specifically lead us to focus on the behavioral response to a temporary outage in water quality. Typically, Lusaka residents will still get water if their pump fails. They will turn to a neighbor or go to a public pump. There is a clear behavioral response involved and the nature of that response informs us about the benefits of future attempts to make clean water more or less convenient.

It is also possible that infrastructure more generally, and the water breaks that we examine, are not that crucial for either health or economic prosperity. The primary medial risk appears to come from consuming polluted water, yet there are ways for wary individuals to reduce any risk from bad water. The worried can buy bottled water or boil their water. They can adjust their food consumption to avoid products that are likely to be polluted by bad water. There is almost always a behavioral response that can mitigate the downsides of weak infrastructure.

We first focus on the connection between water and health problems, particularly on diarrhea. One hypothesis is that water breaks cause people to turn to more polluted sources. The alternative is that they find equivalently healthy alternatives that are some distance from home. The willingness of people to inconvenience themselves to healthy alternatives is particularly when evaluating the case for expensive infrastructure that brings water directly into people's homes or onto their lots.

We then turn to the connection between water breakages and economic outcomes. As we discuss later, we proxy for these outcomes by using electronic transactions that use a single large company. One hypothesis is that water line breaks will reduce economic outcomes because people get sick. While that is certainly possible, an alternative is that water line breaks cause people to spend more time getting clean water. In both cases, the breaks carry social costs, but the external effects will be much higher if the breaks cause people to get sicker than if the breaks cause people to walk further.

Illness may also reduce economic activity even if the individual himself is not sick. Illness in the home may lead a parent to work a little less. The illness of a co-worker or an employer may also reduce productivity. Finally, if there is a real outbreak of disease, some people might stay home rather than increasing health risks of going to work.

The goal of this paper then is to see whether these behavioral responses mitigate the downsides of infrastructure failures or whether such failures carry significant consequences for health, education and the economy. We do this in the context of Lusaka and we discuss that context next.

III. The Lusaka Context and Data Description

In this section, we discuss the nature of water provision in Lusaka and the sources and nature of our data.

a. Piped Water in Lusaka

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 to be commercialized in Zambia. Although commercially operated, the company shares are retained by local city councils, and the management structure is aimed at cost recovery (including tariff increases). The utility company is regulated by an independent board, the National Water and Sanitation Council (NWASCO) along with local consumer groups called water watch groups, or WWGs (Schwartz, 2008). Additionally, piped water services in certain communities outside the reach of LWSC are provided by water trusts, a 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 the 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. Old infrastructure and inadequate maintenance contribute to water-loss, as many pipes predate the commercialization and have not been replaced since the 1970's. Recovery of non-revenue water through monitoring the pipe leakages and customer complaints has therefore been a priority for LWSC.

Despite these challenges, a vast swath of the population in Lusaka has been served by LWSC or local water trusts in some capacity. According to the 2010 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. Additionally, our qualitative surveys suggest that when piped water is out, people generally turn to protected wells or boreholes, other tapped sources, or avoid water use.

b. 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.

We collapse the complaints data to count the number of supply complaints per month in each of 38 water service districts (WSDs) in Lusaka. For analysis, we primarily use two measures of supply: whether there were any supply complaints at all, and the total number of outstanding complaints on a given day (according to LSWC internal records) aggregated to a weekly or monthly level. This will be a proxy for the total number of household-days without piped water[5]. Obviously outages will be more common in some districts than others, but our identification strategy will identify off of the within-district variation in the timing of complaints in order to identify the effect of water outages on diarrheal disease.

We refer to our measure as "days of supply issues", and we recognize that it is an imperfect measure. Some problems go unreported in Lusaka. In other cases, multiple reports might refer to a single problem. We cannot really determine the degree of overlap of the complaints. Our best hope is that multiple reports will somewhat capture the degree of the problem.

Table 1a shows summary statistics from the LSWC complaints data. The Table is split into monthly data, which corresponds to our measurement of health clinic outcomes, and weekly data, which corresponds to our measurement of economic outcomes based on Zoona booths. Many more water service districts contain a Zoona booth than a health clinic, so the samples differ significantly from the right-hand-side to the left-hand-side panel.

The first part of the panel shows that complaints typically fall into one of three main categories: connection/meter, supply and sewerage. There are often fifty complaints per month per district in these three main categories together. There is less than one complaint per month per district in

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[5] Of course, some people may complain more than once about the same problem, and many issues likely go unreported. For the purposes of this analysis, this should not matter as long as under- and over-reporting are not systematically correlated with our outcome variables, conditional on district, year, and month means.

the other three categories together. In this paper, we focus entirely on complaints about water supply, since our primary concern is on the effect of access to piped water.[6]

The second block of responses delivers the total days to resolve in each category. This effectively multiplies the number of complaints times the average number of days it takes for each complaint to be resolved. We see this as a measure of the length that the problem persisted. For example, it takes about 20 days to resolve the average water supply problem and hence the total number of days to resolve in a district month is 360. Notably, the standard deviation of supply days is enormous since there are many cases in which it can take more than six months to resolve a supply issue.

c. *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. For this analysis, we focus primarily on the disease burdens known to be caused by contaminated water. Our main outcomes of interest will be diarrheal disease (often caused by drinking dirty water), respiratory illnesses and pneumonia (spread more easily when there is no water for handwashing), and infant death.

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 slums.

Table 1b provides summary statistics for the health data, where the unit of analysis is a clinic-month. On average each clinic receives 44 visits for diarrhea per month from an infant under one. This represents about one-thirtieth of the total number of visit from the under-one year olds. There are 71 diarrhea-related visits from one to five year olds, and 66 such visits from people

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[6] While it is possible that the connection/meter complaints also refer to supply, the bulk of these appear to be disputes about billing.

over the ages of five. These represent a slightly higher share of the visits for these older age groups.

For infants, there are 14 visits per month for pneumonia and almost 100 visits per month for respiratory infections. There are 56 visits per month related to malaria, which remains a significant problem in Lusaka. The number of visits for these illnesses are significantly higher among the older children and adults. We should not interpret this as meaning that the older children and adults are more likely to get these diseases, after all there are far more older children then under-one year olds. Instead, there are simply more visits by under one year olds to the clinic for other reasons. They are, after all, practically newborn.

Finally, we show, only for the under-one year olds, the level of child mortality at the clinic. This does not represent the total death rate within the district, but rather the number of children who come to the clinic before dying. The death rate is much lower for older children, which is why we focus only on mortality for the very young.

d. Zoona Booth Data

Finally, we turn to our data on Zoona booths. Zoona is a company that specializes in transferring money by cell phone. A customer enters into a booth and gives the booth money. A message is then sent to the recipient providing them with a code. By using the code, the recipient can collect the money at any convenient booth.

Zoona booths are more common than branch banks in Zambia. They have become the financial transfer mechanism for poorer residents of the city. They are used to transfer money to rural areas, to relatives who need cash. They are also used to make payments to people who are elsewhere in Lusaka. While these transfers are far from a perfect proxy for the economic activity in the city, we believe that they serve as the best available measure of economic action that is available at a high frequency level with fine geographic disaggregation.

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

Our data contains information on the universe of Zoona transactions from 2009 to 2014. For each booth, we code the number of transactions in a week as well as the average amount of these transactions. We will also separately look at the places that the transfers are being sent to, since we also know where the recipient is when they collect the money.

To connect the Zoona booth data with the water supply data, we sent a field team to geocode every Zoona booth in Lusaka. We then matched each booth to a water service district, and attributed all complaints in that district to all of the booths within the district.

The average Zoona booth in our sample sends 35 transfers per week and receive 33 transfers per week. However, this average is not particularly representative of the norm, for the standard deviation of the number of transfers sent is over 500. Consequently there are a number of booth-weeks that handle an extremely large number of transfers, while many other booth-weeks have close to zero. While there is surely a great deal of noise in the amount of transactions, there is also a substantial amount of permanent booth differences, which will be controlled for with our booth-specific fixed effects.

On a weekly basis, the average amount sent or receive is about 10,000 kwacha or $1,250 dollars. Again, the standard deviation is quite large (over 100,000 kwacha) which reflects the enormous heterogeneity of Zoona booths. Those booths that are in particularly crowded market locations do extremely well. Others have very small amounts of business.

IV. Results for Health Outcomes

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

a. Empirical Strategy

Our objective is to estimate the impact of piped water on diseases, mortality and economic activity. 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 be temporarily shut down, 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 an indicator of the supply complaints (either the days of supply issues, or a dummy for any complaints), γ_i is a vector of district fixed effects, δ_m is a vector of month fixed effects, and θ_y is a vector of year 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.

b. Results

Table 2 shows our results for diarrhea. As diarrhea is both a relatively common health problem that is a standard physical response to bad water, it is perhaps the most natural health outcome. We will be focusing on diarrhea outcomes particularly for the young.

However, one major shortcoming of diarrhea research based on clinic data is that many people may choose not to come to a clinic even if they have a relatively serious case. As such, this variable is surely measured with considerable error. This is particularly worrying if families have less time to bring their children to the clinic for more minor health concerns when the water is out.

The first panel shows the results using only our simplest measure: if there is any supply-related complaint in the district at all during the month. As an overwhelming majority of districts have such complaints have such complaints, there is relatively little variation in this variable and while our results point towards positive effects on disease, these effects are not statistically significant.

The first column shows that there are 36 more diarrhea cases overall when there is a complaint than when there is no complaint. The next three columns show the breakup across age categories. There are twenty more cases for babies under one and eighteen more cases among one to five year olds. There are three fewer cases among people who are over five. These results are not significant, but they do at least suggest that any effect that water supply is having is working mainly on the young.

Panel B shows our preferred independent variable: the days of supply issues. Again, this is measured as the number of unresolved complaint during the month times the average days during that month that the complaint remains unresolved. We think of this weighting by time-to-resolution as providing a picture of the seriousness of the problem.

The first column shows the impact of an increase in the number of days with reported water supply problems on the number of diarrhea cases. As the number of days increase by one, the number of diarrhea cases overall increases by .028, which is statistically significant. A one standard deviation increase in water supply problem days (or 631 days) increase the number of diarrhea cases by 17 or .07 standard deviations. Cleary the relationship between the two variables is far from perfect, but the estimated impact is not trivial either.

In the second through fourth columns we split this effect up by age groups. We find that the results are similar in magnitude for the three age groups, but only significant for the 1-5 year olds. As the number of supply problem days increases by one standard deviation, then number of diarrhea cases increases by one-tenth of a standard deviation for this age group. As there are far more people who are over five than under five, the roughly equal coefficients suggest that the impact of water breakages on diarrhea are higher for infants in an absolute sense. Naturally, we cannot rule out the possibility that people are just more prone to take infants with diarrhea to the clinic.

We also cannot rule out the possible interaction between age and behavioral response. For example, it may be that parents of small children have more difficulty in responding to the water line break. It may be that parents are more likely to let infants drink water from polluted sources.

When we surveyed individual households, we observed numerous examples of parents allowing children to drink from water sources (e.g. water used for washing shoes) that seemed less than healthy.

In Table 3, we turn to the connection between water supply days and other infant diseases. The first column shows that there is small but reasonably precisely estimated link between the water supply breaks and pneumonia, which is probably best understood as general class of lung ailments. This is somewhat surprising since we typically think of such lung diseases as being air-borne, rather than water-borne, diseases. However, these diseases are spread much more easily when children and adults do not wash their hands. In qualitative work, when water is in short supply, drinking, cooking, cleaning, and bathing all get higher priority than handwashing. . It is also quite possible that a water-borne disease can weaken the immune system and make it more susceptible to an air-borne disease. Moreover, the effect is quite small. If the estimated slope is correct, then it takes 33 days of supply problems to produce one extra pneumonia case. In the second column, we see a similar effect on respiratory illness, though the estimate is not statistically significant.

The third column shows the effect on malaria. In this case, the estimated coefficient is small and negative, but not statistically significant. As there is no direct reason why water outages would increase the prevalence of this mosquito-borne disease[7], we are not surprised to find no statistically significant relationship. The fourth column looks at the impact of infant mortality, which seems to go up slightly, but the effect is not statistically significant.

In Table 4, we look at the impact of water on the number of children seen at the clinic overall. The first and second columns show a significantly reduced number of children seen at the clinic when the water is out. A one-standard-deviation change in days of supply issues decreases the number of infants seen at the clinic by 170 (13.8%), and 1-5 year olds by 233 (19%).

This result might mean that even though there is more diarrhea and pneumonia, children as a whole get healthier with water breaks. We prefer the alternative interpretation that water breaks make it less likely that parents take their children to the clinic holding the level of illness

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[7] Other than a general weakening of the immune system, or perhaps an increase in diagnoses stemming from an increase in clinic visits due to other ailments.

constant. If the parent is more likely to be slightly unwell or if time is being used up getting water, then it becomes more difficult to get to the clinic and clinic visits drop.

V. Pipe Breakages and Economic Outcomes

We now turn to examining the effect of water supply on Zoona transactions, our measure of general economic activity. As in the case of diarrhea reports, our proxy for economic activity is quite noisy. However, if we find that water outages affect Zoona transactions, we see this as evidence that they are affecting economic transactions more generally.

a. Empirical Approach

We will be able to take two different empirical approaches to the Zoona data: individual data and Zoona booth data. Since each transaction comes with an individual identifier, we are able to test whether any particular person does more or less activity on any particular day. We can then match the person with a particular neighborhood by using the geography of the booths that they use most often. There are a variety of technical problems with this approach, including the need to estimate millions of fixed effects and the highly non-Gaussian nature of the Zoona data. Consequently, we anticipate having individual results in a later draft, but we do not have it as yet.

We will instead use a Zoona Booth based approach in which case, an observation is a Zoona Booth month. We will also perform regressions at the Zoona booth week level, which will enable us to investigate timing more thoroughly

We estimate:

$$T_{bmy} = \alpha + \beta C_{bmy} + \gamma_b + \delta_m + \theta_y + \epsilon_{bmy}$$

where T_{imy} is the number of Zoona transaction in district *b* in month *m* and year y, C_{bmy} is an indicator of the supply complaints (either the weighted number of complaints, or a dummy for any complaints), γ_b is a vector of booth fixed effects, δ_m is a vector of month fixed effects, and θ_y is a vector of year 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.

b. Results

We continue use the day-weighted number of complaints as our indicator of supply outages. The first panel in Table 5 shows the result for transactions paid out. The second panel shows the results for payments received. The results are broadly similar. We find that an additional complaint-day decreases both types of transactions by about .15, and the amount transferred in either direction by about 40 kwacha. In both cases, the results are statistically significant.

The standard deviation of supply complaints is 70, so a one standard deviation increase in day-weighted supply complaints is associated with ten fewer transactions, of each type, over the course of the week. This is a decrease of about a third. A one standard deviation increases the days of supply complaints is associated with a decrease of about ZK 2800, or about 465 dollars, sent in or out of the booth.

Given that the average number of days per complaint is about 15, this implies that there is about 2.25 fewer transactions and one hundred fewer dollars sent through the booth. There is no way to quantify the actual loss in economic welfare associated with this reduction in economic activity. For example, if the lost transaction had been a transfer to a distant relative, the loss may be minor. If the lost transaction was a missed business interaction and the Zoona transaction are a modest share of overall business transactions, which also declined, then this may be a significant underestimate of the overall effect of water on economic activity.

To get a better handle on the nature of the transactions that are displace, Table 6 estimates transactions to and from particular locations: Lusaka City, Lusaka Province (outside the city), Copperbelt, Livingstone, and Other. As a percentage of the mean, the coefficients to each location are remarkably similar—all imply that between .35 and .5 percentage points of total transactions are lost for each day of supply issues in the district. This is consistent with the idea that, whatever the purpose of the Zoona transactions, people are simply conducting fewer of them. This might reflect less economic activity in Lusaka or it might just alternatively mean that if families are spending more for their water, then they feel less wealth and are less able to transfer cash. In Table 7 we show results by amount of transaction. Again, we see reductions in all size transactions, both in and out.

c. Timing

One significant question is whether the economic impacts of a water supply break is long-lived or over quickly. We will test this issue by looking at the impact of lagged breakages. Ideally, we would be able to separate out the two ways in which a break today can impact economic activity next week. The most direct way is that the break today is still not fixed by next week. The second way is that there are health consequences of the break that linger. We will be able to address this in the future by looking only at the impact of past breaks which are resolved.

Table 8 shows results where the economic transactions at the Zoona booth in one week are regressed on the contemporaneous breaks and the breaks in the previous week. The first and fourth regressions in both Panel a and Panel b look at the impact of the current and last week only. Somewhat surprisingly in all four regressions, the coefficients on the one week lag are almost identical to the coefficients on the contemporaneous break.

Regressions two and five in the two panels show the impact of adding in the two week lag in the break measures. The final regressions show the incremental impact of adding in a third week lag. The pattern persists over all of the regressions. The weights go on the most recent week and the last week in the regression. This suggests that recent breaks matter, but also that there is a lasting impact of the oldest breaks.

In a sense this is unsurprising. Breaks often take a long time to fix. But these results do suggest that looking only at the contemporaneous impact of a break will miss its larger impact over the next weeks. This implies that the overall impact of a break could be three or four times as large as the effect estimated in the contemporaneous regression.

VI. Conclusion

Water infrastructure appears to impact both health and economic outcomes in Zambia. When there are breakages, there are more diarrhea cases, more respiratory cases, and even more infant deaths at local clinics. These findings are not shocking. Previous work has often found that water matters for health.

In the Lusaka context, these findings imply that behavior cannot perfectly adapt to and respond for faulty infrastructure. While our field work has found that people are able to find difference sources of water, those alternative sources do not seem to be as healthy.

If we valued the life of a Zambian infant at 100,000 dollars, and if we took our infant mortality data at face value, then it would be worth four dollars to reduce the number of complaint days by one day. We do not know the cost of reducing complaint days, but it could be compared against this type of benefit estimate.

This paper's more novel contribution is documenting a link between water breakages and economic activity. We 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 or time spent getting more water or a bit of both.

The effects of our estimates are not extraordinarily large. Thirty fewer days of unresolved complaints are associated with a 30 dollar reduction in transfers. 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.

References

Baum-Snow, Nathaniel and Matthew E Kahn, “The effects of new public projects to expand urban rail transit,” *Journal of Public Economics*, 2000, *77* (2), 241–263.

Cutler, David and Grant Miller, “The role of public health improvements in health advances: the twentieth-century United States,” *Demography*, 2005, *42* (1), 1–22.

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

Duranton, Gilles and Matthew A Turner, “The fundamental law of road congestion: Evidence from US cities,” *The American Economic Review*, 2011, pp. 2616–2652.

Enger, Kyle S, Kara L Nelson, Thomas Clasen, Joan B Rose, and Joseph NS Eisenberg, “Linking quantitative microbial risk assessment and epidemiological data: informing safe drinking water trials in developing countries,” *Environmental science & technology*, 2012, *46* (9), 5160–5167.

Esrey, Steve A, James B Potash, Leslie Roberts, and Clive Shiff, “Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma.,” *Bulletin of the World Health organization*, 1991, *69* (5), 609.

Ferrie, Joseph and Werner Troesken, “Water and Chicago’s mortality transition, 1850–1925,” *Explorations in Economic History*, 2008, *45* (1), 1–16.

Fewtrell, Lorna, Rachel B Kaufmann, David Kay, Wayne Enanoria, Laurence Haller, and John M Colford, “Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis,” *The Lancet infectious diseases*, 2005, *5* (1), 42–52.

Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky, “Water for life: The impact of the privatization of water services on child mortality,” *Journal of political economy*, 2005, *113* (1), 83–120.

Gamper-Rabindran, Shanti, Shakeeb Khan, and Christopher Timmins, “The impact of piped water provision on infant mortality in Brazil: A quantile panel data approach,” *Journal of Development Economics*, 2010, *92* (2), 188–200.

Glaeser, Edward L and Bruce Sacerdote, “Why is There More Crime in Cities?,” *Journal of Political Economy*, 1999, *107* (S6), S225–S258.

Levitt, Steven D, “Using electoral cycles in police hiring to estimate the effects of police on crime: Reply,” *American Economic Review*, 2002, pp. 1244–1250.

Merrick, Thomas W, “The effect of piped water on early childhood mortality in urban Brazil, 1970 to 1976,” *Demography*, 1985, *22* (1), 1–24.

Sasaki, Satoshi, Hiroshi Suzuki, Kumiko Igarashi, Bushimbwa Tambatamba, and

Philip Mulenga, "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*, 2008, *79* (3), 414–421.

Troesken, Werner, "The limits of Jim Crow: Race and the provision of water and sewerage services in American cities, 1880–1925," *The Journal of Economic History*, 2002, *62* (03), 734–772.

Table 1: Summary Statistics

Panel A: Supply Complaints									
	Per Month			Per Week					
	Mean	SD	Obs.	Mean	SD	Obs.			
Number of Complaints:									
Account	.161	.608	1,230	.110	11.1	16,802			
Connection/Meter	23.1	32.3	1,230	2.90	11.6	16,802			
Property Details	.653	1.74	1,230	.128	1.67	16,802			
Sewerage	10.8	18.9	1,230	.936	8.13	16,802			
Water Supply	17.52	23.9	1,230	2.07	19.9	16,802			
Water Quality	.022	.196	1,230	.003	.070	16,802			
	Mean	SD	Obs.						
Average Days to Resolve:									
Account	29.5	87.1	1,859						
Connection/Meter	23.4	73.4	49,288						
Property Details	36.2	130.6	2,120						
Sewerage	11.0	26.4	16,036						
Water Supply	15.4	42.3	35,494						
Water Quality	43.6	101.2	60						
	Per Month			Per Week					
	Mean	SD	Obs.	Mean	SD	Obs.			
Days of Supply Issues	443	631	16,802	39.0	70.6	16,802			
Panel B: Clinic Data									
Ages:	Under 1 Year			1-5 Years			Over 5 Years		
	Mean	SD	Obs.	Mean	SD	Obs.	Mean	SD	Obs.
Diarrhea	44.2	64.3	1,230	71.1	94.5	1,230	66.6	89.7	1,230
Pneumonia	13.9	23.3	1,230	20.7	42.9	1,230	20.4	70.5	1,230
Respiratory Infection	97.8	136.4	1,230	147.7	196.0	1,230	216.5	408.4	1,230
Clinical Malaria	56.6	100.7	1,230	96.6	152.8	1,230	143.0	220.8	1,230
Total Child Visits	1,282	2,045	1,230	1258.8		2,845	1,230		
Infant Deaths	.084	.58	1,230						
Panel C: Zoona Transactions Data									
	Mean	SD	Obs.						
No. Transactions Sent	34.5	524.3	16,802						
Total Amount Sent (ZK)	9,984	135,326	16,802						
No. Transactions Received	32.3	560.2	16,802						
Total Amount Received (ZK)	10,858	151,556	16,802						

Notes: This tables shows summary statistics for data on water supply complaints, health outcomes, and Zoona transactions.

Panel A shows number of complaints per district on average in our sample for each type of complaints, per week and per month, respectively. Panel B shows summary statistics of cases of clinical diagnoses by age, for each clinic in a given month. Panel C shows summary statistics for the number and amount of Zoona transactions per booth per week in our sample. All data are from 2009-2014.

Table 2: Effect of Water Supply Complaints on Diarrheal Disease

Panel A: Any Water Supply Complaints				
Dependent Variable:	Cases of diarrheal disease			
Age:	All	Under 1	1 to 5	Over 5
Any Complaint	36.25 (33)	20.35 (13.01)	18.68 (15.38)	-2.79 (9.74)
Observations	1,230	1,230	1,230	1,230
Mean of DV	181.9	44.2	71.1	66.6
Panel B: Days of Supply Issues				
Dependent Variable:	Cases of diarrheal disease			
Age:	All	Under 1	1-5	Over 5
Days of Supply Issues	.028 (.014)**	.0086 (.0053)	.012 (.0057)**	.0074 (.0063)
Observations	1,230	1,230	1,230	1,230
Mean of DV	181.9	44.2	71.1	66.6
District FEs	YES	YES	YES	YES
Month FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level.

Table 3: Effect of Water Supply Complaints on Infant Disease and Death

Dependent Variable:	Pneumonia	Respiratory Infection	Malaria	Death
Days of Supply Issues	.0026 (.001569)*	.015 (.011957)	-.0063 (.007122)	.000024 (.000028)
Observations	1,225	1,225	1,225	1,225
Mean of DV	13.9	97.8	56.6	.084
District FEs	YES	YES	YES	YES
Month FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level.

Table 4: Effect of Water Supply Complaints on Number of Child Visits to Clinic

Dependent Variable:	Children Seen at Clinic	
Age:	Under 1	1 to 5
Days of Supply Issues	-.27 (.075)***	-.37 (.13)***
Mean of DV	1,282	1,230
District FEs	YES	YES
Month FEs	YES	YES
Year FEs	YES	YES

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level.

Table 5: Effect of Water Supply Complaints on Zoona Transactions

Panel A: Transactions Paid Out		
Dep. Var:	Number of Transactions	Transaction Amount
Days of Supply Issues	-.15 (.044)***	-40 (13)***
Observations	16800	16800
Mean DV	34.5	9,983
Panel B: Transactions Received		
Dep. Var:	Number of Transactions	Transaction Amount
Days of Supply Issues	-.15 (.037)***	-45 (13)***
Observations	16,800	16,800
Mean DV	32.3	10,858
District FEs	YES	YES
Week FEs	YES	YES

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level.

Table 6: Effect of Water Supply Complaints on Zoona Transaction Locations

Panel A: Transactions Paid Out					
Dep. Var:	Number of Transactions to:				
	Lusaka City	Lusaka Province	Copperbelt	Livingstone	Other
Days of Supply Issues	-.010 (.0029)***	-.0036 (.0012)***	-.045 (.013)***	-.0077 (.0025)***	-.081 (.025)***
Observations	16,800	16,800	16,800	16,800	16,800
Mean DV	2.23	.71	9.93	2.39	19.3
Panel B: Transactions Received					
Dep. Var:	Number of Transactions from:				
	Lusaka City	Lusaka Province	Copperbelt	Livingstone	Other
Days of Supply Issues	-.013 (.0028)***	-.14 (.035)***	-.044 (.011)***	-.0079 (.0021)***	-.082 (.021)***
Observations	16,800	16,800	16,800	16,800	16,800
Mean DV	2.50	29.7	8.39	2.74	18.2
District FEs	YES	YES	YES	YES	YES
Week FEs	YES	YES	YES	YES	YES

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level.

Table 7: Effect of Water Supply Complaints on Zoona Transaction Amounts

Panel A: Transactions Paid Out				
Dep. Var:	Number of Transactions:			
	<ZK50	<ZK100	>ZK300	>ZK1000
Days of Supply Issues	-.017 (.0045)***	-.055 (.015)***	-.040 (.014)***	-.0069 (.0027)***
Observations	16,800	16,800	16,800	16,800
Mean DV	3.82	12.25	9.87	1.89
Panel B: Transactions Received				
Dep. Var:	Number of Transactions:			
	<ZK50	<ZK100	>ZK300	>ZK1000
Days of Supply Issues	-.017 (.0043)***	-.052 (.012)***	-.046 (.013)***	-.0094 (.0032)***
Observations	16,800	16,800	16,800	16,800
Mean DV	3.26	10.24	10.91	2.43
District FEs	YES	YES	YES	YES
Week FEs	YES	YES	YES	YES

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level.

Table 8: Effect of Water Supply Complaints on Zoona Transactions

Panel A: Transactions Paid Out						
Dep. Var:	Number of Transactions			Transaction Amount		
Days of Supply Issues (current week)	-.074 (.023)***	-.077 (.024)***	-.066 (.020)***	-19 (7.3)***	-20 (7.5)***	-17 (6.3)***
Days of Supply Issues (1 week prior)	-.089 (.026)***	-.027 (.013)**	-.039 (.016)**	-25 (7.8)***	-7.8 (4.1)*	-11 (5.0)**
Days of Supply Issues (2 weeks prior)		-.072 (.020)***	-.010 (.0094)		-20 (6.1)***	-2.7 (2.9)
Days of Supply Issues (3 weeks prior)			-.070 (.022)***			-19 (7.1)***
Observations	15,879	15,879	15,879	15,879	15,879	15,879
Mean DV	34.5	34.5	34.5	9,983	9,983	9,983
Panel B: Transactions Received						
Dep. Var:	Number of Transactions			Transaction Amount		
Days of Supply Issues (current week)	-.086 (.021)***	-.089 (.022)***	-.077 (.019)***	-27 (7.4)***	-27 (7.6)***	-24 (6.5)***
Days of Supply Issues (1 week prior)	-.076 (.02)***	-.016 (.0080)*	-.028 (.010)***	-23 (7.0)***	-4.0 (2.7)	-8.0 (3.7)**
Days of Supply Issues (2 weeks prior)		-.070 (.018)***	-.0069 (.0080)		-21 (6.1)***	-.83 (3.1)
Days of Supply Issues (3 weeks prior)			-.071 (.019)***			-23 (7.3)***
Observations	15,879	15,879	15,879	15,879	15,879	15,879
Mean DV	32.3	32.3	32.3	10,858	10,858	10,858
District FEs	YES	YES	YES	YES	YES	YES
Week FEs	YES	YES	YES	YES	YES	YES

Notes: ***indicates significance at 1% level, ** at 5% level, * at 10% level.