Utilities as Creditors: The Effect of Enforcement of Water Bill Payment in Zambia

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Abstract

Policy goals of increasing household access to piped water and cost recovery for utility providers are often at odds. Nonpayment of utility bills is a common constraint to improving the quality of utility service, yet nonpayment is widely tolerated, and households often accumulate significant debt to the utility provider. I study the effect of increases in enforcement of water bill payment through supply disconnections in Livingstone, Zambia. I develop a dynamic model of household monthly payments and accumulation of arrears, which determines the household's probability of disconnection. I show that higher levels of enforcement increase the optimal payments for connected households but reduce a household's willingness to reconnect to the water utility when disconnected. I empirically test this model using an event-study framework of exogenous increases in enforcement capacity that occur during administrative rezoning events, which reduce the number of households that one enforcement agent is responsible for. I find that low-income households are 20 percent more likely to be disconnected from their water supply after rezoning events, while high-income households experience no change in disconnections. Households are more likely to make a payment following rezoning events, but revenue increases are small and short run. The results suggest that high enforcement of water bill payment toward credit-constrained households may be ineffective and leads to reduced piped-water access.

Keywords: piped water access, utilities, payment enforcement, credit constraints

JEL Codes: Q25, O13, L21, D14

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1 Introduction

Providing safe and affordable drinking water to low-income households in developing countries remains a challenge. Policy goals of increasing household access to piped water and cost recovery for utility providers are often at odds. Expansion of utility networks not only requires large infrastructure investments from utility companies but often high connection fees from households, which have been shown to be a significant barrier to the expansion of water and electricity grids (Lee *et al.* (2020); Devoto *et al.* (2012); Golumbeanu and Barnes (2013); Blimpo *et al.* (2018)). Another challenge in expanding utility access to underserved communities is that low-income households may have limited ability to pay monthly bills. Expansion of grid access to households that seldom pay generates an externality on the rest of the network by hindering the ability of utility companies to recover costs. Nonpayment of utility bills is common and has been cited as a cause of service rationing and a primary constraint to improving the quality of electricity and piped-water service delivery (Burgess *et al.* (2020); McRae (2015); Szabó and Ujhelyi (2015)). Furthermore, service rationing and intermittent supply of piped water have been shown to have negative health consequences to customers (Ashraf *et al.*, 2021), and health externalities associated with alternative sources of water, such as shared shallow wells, can be severe during cholera epidemics (Nanzaluka *et al.*, 2020). Despite these consequences, nonpayment of utility bills is generally tolerated due to weak institutions for payment enforcement (Jack and Smith, 2020), the widespread view of utility access as a right instead of a private good (Burgess *et al.*, 2020), the negative political consequences of enforcing payment (Khan *et al.*, 2016), or large external subsidies that reduce the incentive for utilities to enforce payment (McRae, 2015).

In addition to the institutional challenges of enforcing payment of utility bills, the effect of high levels of enforcement is uncertain. Utility companies may attempt to enforce payment through disconnecting nonpaying customers from the network. Enforcement of this type may be ineffective because it may increase feelings of mistrust in governments and utility companies. Trust in governments is thought to be a key determinant of voluntary payment compliance (Slemrod, 2007), but this channel has had little documentation outside of a laboratory setting (Luttmer and Singhal, 2014). Secondly, if customers lack the ability to pay water bills, enforcement through disconnections may result in customers being unable to reconnect for extended periods of time, which undermines the goal of expanding access. Szabó and Ujhelyi (2015) argue that increased enforcement of water bill payment will only be effective in cases of planned default and show that default in Pretoria, South Africa is largely unplanned and a result of negative income shocks. However, enforcement through supply disconnections may be a useful policy tool for encouraging upfront payment of water bills in other cases, for example, when households strategically delay bill payment. Violette (2021) shows that households with volatile monthly income and little access to formal sources of credit may delay bill payments as a way to smooth consumption.

Despite the uncertain effect of enforcement through supply disconnections, little empirical evidence exists on whether enforcement is successful in increasing revenue for utilities or if it further limits access through long-term disconnections. In this study, I test the effect of increases in payment enforcement on revenue collected and disconnections in the context of a piped-water distribution network in Livingstone, Zambia. In Zambia, enforcement of water bill payment is high, and households are frequently disconnected due to nonpayment. Approximately one fifth of customers in Livingstone have disconnected accounts. Disconnected households often draw water from a neighbor's water connection until they save enough to reconnect by clearing their debt to the water utility. Even with high levels of enforcement through supply disconnections, water utilities in Zambia often do not recover operating and management costs. High disconnection rates in Zambia may also suggest that excessive enforcement is detrimental to both goals of expanding access to improved water sources and cost recovery of the utility provider.

I develop a theoretical model of household water consumption, payments, and the accumulation of arrears resulting from partial bill payment. I model the probability of being disconnected as a function of arrears and an exogenous level of enforcement determined by the water utility, which represents the utility's capacity to conduct supply disconnections. I show that higher levels of enforcement increase the optimal monthly payments for connected households. However, when a household becomes disconnected, higher enforcement lowers the value of a household's water connection and reduces the household's willingness to reconnect to the water network. I further show that access to credit plays a key role in the ability of low-income households to reconnect to the water utility. Households in Livingstone with high arrears are often unable to reconnect to their water supply for extended periods of time, which also limits the water utility's ability to recoup these losses. Allowing households to reconnect by following a payment plan may therefore increase a household's willingness to reconnect to the water utility and allows credit-constrained households to repay debt without long-term loss of their water connection.

I test the predictions of this theoretical framework using a quasi-experiment of increases in enforcement capacity that occur during administrative rezoning events. In Livingstone, one enforcement agent is responsible for enforcing bill payment through payment reminders and supply disconnections in each administrative zone, which may contain several geographically separate neighborhoods. As new customers are added to the piped-water network, the water utility creates new administrative zones and rezones existing regions of the piped-water network to balance the number of customers per enforcement agent. During rezoning, entire neighborhoods may be reassigned to a newly formed zone. I define a rezoning event as the largest decrease in zone size that a neighborhood experiences during the sample period. Administrative rezoning events create a discrete increase in enforcement capacity by decreasing the number of households that one enforcement agent is responsible for. I study the effect of rezoning events on household payments and disconnections using a two-way fixed effect event-study framework. Administrative zone size decreases sharply at the time of the rezoning event with minimal pre- or post-trends when conditioning on year-by-month fixed effects, customer fixed effects, and a vector of control variables. This quasi-experimental approach therefore allows me to cleanly identify the effect of enforcement capacity on household payments and disconnections.

I study the impact of increases in enforcement capacity that occur during administrative rezoning events separately for low-income and high-income households in Livingstone. I find that low-income households experience an increase in new disconnections following rezoning events, and they remain nearly 20 percent more likely to be disconnected from their water supply after 10 months. Similar to the predictions of the theoretical framework, low-income households also experience a decrease in reconnections. High-income households, on the other hand, experience no change in disconnections. After rezoning, households are 8 percent more likely to make a payment, but increases in revenue collected per customer are small and short run. Results indicate that households may make more frequent payments but pay a smaller share of their bill at each payment after rezoning events. Furthermore, I find that the monthly labor costs of increases in enforcement are higher than the monthly increases in revenue collected after rezoning.

This paper provides some of the first empirical estimates of the effect of high enforcement of utility bill payment through supply disconnections. Recent research on this topic by Coville *et al.* (2021) find large revenue gains from credible threats of water disconnections in a context of low baseline levels of enforcement. The context of this study, on the other hand, is one of high baseline levels of enforcement and may imply diminishing returns to enforcement. The results of this paper suggest that high enforcement of water bill payment through supply disconnections targeted toward credit-constrained households may be ineffective and leads to reduced piped-water access.

This paper proceeds as follows. Section 2 discusses the contribution of this paper to the literature on utility access and enforcement of bill payments. Section 3 discusses the research setting and a description of the administrative and household survey data used in this research project. Section 4 presents the theoretical framework. Section 5 presents the empirical strategies used and their results, and Section 6 concludes.

2 Related Literature

Much of the previous research on improving access to water and electric utilities has focused on the structure of tariffs and connection charges (Devoto *et al.* (2012); Lee *et al.* (2020); McRae and Meeks (2016); Burgess *et al.* (2019); Blimpo *et al.* (2018); Szabo (2015)). However, there has been a recent focus on the consequences of connecting nonpaying households and the detrimental effect of nonpayment on utility quality (Burgess *et al.* (2020); McRae (2015); Szabó and Ujhelyi (2015); Jack and Smith (2020)). Several studies have documented the benefits of privatization of piped water for reducing infant mortality, particularly for low-income households (Galiani *et al.* (2005); Gamper-Rabindran *et al.* (2010)), but demand for improved sources of water among low-income households is often low (Kremer *et al.* (2011); Null *et al.* (2012)). Several studies have shown that connection subsidies are a useful policy tool for increasing household welfare through access to water and electric utilities (Lee *et al.* (2020); Blimpo *et al.* (2018)), however, (Ashraf *et al.*, 2016) argue that connection subsides may have limited effectiveness if there is widespread access to cheaper substitute sources of water. This study contributes to this growing literature by discussing the challenges of connecting low-income households to the piped-water network and ensuring that these households continue to make payments once connected.

The primary contribution of this paper to the literature is providing empirical evidence of the effect of enforcement of bill payment through supply disconnections. There is little existing evidence of the effect of increased enforcement on utility cost recovery and access, and much of the previous work on this topic studies providing information and engagement with households. To address nonpayment in water utilities, Szabó and Ujhelyi (2015) argue that providing information to households about their water bill consumption may encourage short-run payment increases primarily through the channel of reciprocity. Coville *et al.* (2021), however, find no effect of engagement with households about the importance of water bill payment on utility revenue collection. Coville *et al.* (2021) additionally study the effect of randomly assigned credible threats of disconnection and find large gains in revenue collected by the water utility with no negative effects to households in terms of access to water. Other research has found that pre-paid systems may be effective at improving utility cost recovery because they allow poor households to make smaller and more frequent payments upfront instead of large monthly payments (Jack and Smith, 2020). However, Heymans *et al.* (2014) argue that while pre-paid water meters show much promise in African cities, these technologies are still not consistently reliable and require significant management from providers.

The findings of this study produce contrary findings to recent research on the effect of enforcement of water bill payment. In a field experiment of informal settlements in Nairobi, Coville *et al.* (2021) find that credible threats of disconnection resulted in a 20 percentage point increase in the probability of making a payment and a 11 percentage point increase in debt collected among treated households after one month. The authors also do not find evidence that tenants were negatively affected by the enforcement intervention and show no significant differences between treatment and control compounds in access to a water connection. My results differ from Coville *et al.* (2021) in that low-income households experience a large increase in disconnections that appear to persist following changes in enforcement. Furthermore, I do not find strong evidence of increases in revenue collected by the water utility after administrative rezoning. There are several potential explanations for these differing results. First, Coville *et al.* (2021) focus the intervention toward landlords to encourage the enforcement of contracts between tenants and landlords that stipulate water provided in rental agreements. In my setting, most customers own the property with the water connection, and only 40 percent of customers are renting from landlords. Secondly, my setting is one of high levels of baseline enforcement, while Coville *et al.* (2021) study the introduction of water supply disconnections due to nonpayment. Finally, a key finding of my theoretical model is that households may benefit from reconnection conditional on following a payment plan. Payment plans are possible in Livingstone but uncommon, while Coville *et al.* (2021) discuss this option as widespread in their intervention.

3 Research Setting and Data Description

This research project was conducted in Livingstone, Zambia in cooperation with the Southern Water & Sanitation Company (SWSC). SWSC is one of eleven national commercial utility companies, which are regulated nationally by the National Water Supply and Sanitation Council (NWASCO). SWSC is responsible for providing water and sewerage services to the entire Southern Province of Zambia. Proposed tariff increases or policy changes by SWSC are accepted or rejected by NWASCO conditional on performance indicators such as new customers added, service hours, the share of customers who are metered, and revenue collection efficiency (NWASCO, 2020). One of the key challenges facing SWSC and other commercial utilities in Zambia is insufficient revenue collection to cover operating and management costs. It is estimated that between 2011 and 2017, the national water utility companies in Zambia lost a combined $554 million due to non-payment of utility bills and technical losses from leaks or theft. (The World Bank, 2020). Low cost recovery limits the ability of commercial utilities to upgrade service, which often leads to additional technical losses and lower payments from households that receive poor service. Figure 1 shows the marginal cost, average price, and effective price (the average price that consumers face after accounting for nonpayment) of water in Livingstone. Average price is set above the marginal cost of supply, but the effective price is often insufficient to cover operational costs. Consequently, commercial utilities in Zambia often enforce payment of utility bills through service disconnections.

The Zambian government, as part of its National Long Term Vision 2030 plan, strives to achieve universal access to water supply and sanitation by 2030, however urban and rural water coverage in Zambia remains below 88 percent and 44 percent, respectively (see Figure 2). Large disparities exist between urban and rural populations, and rural access to improved water and sanitation is 51 percent and 19 percent, respectively (The World Bank, 2020). In addition, access to a water connection does not necessarily mean that the connection is currently in use. Approximately one fifth of water customers in Livingstone have disconnected or inactive accounts due to service disconnections from enforcement of water bill payment. High disconnection rates, particularly in areas of high shallow well use such as Lusaka, Zambia, may indicate that the percentage of customers with true access to improved water sources is underestimated.

Administrative data was collected from SWSC from all 24,710 residential and commercial water customers in Livingstone from December 2012 to June 2019. This data includes an itemized list of charges, all payments made, total arrears to the company, an indicator for whether the customer is metered or unmetered, and an indicator for whether the customer's connection is currently active or disconnected. Additional administrative data was collected on the locations of customer accounts, pay stations, and water supply points. To supplement the administrative data, a random sample of 808 households in Livingstone that are customers of SWSC were surveyed in September of 2019.[1]

Table 1 presents summary statistics of the administrative data collected from SWSC of residential customers and the household survey data. Connected households consume an average of 24 cubic meters of water a month and are billed at an average of 120 ZMW per month (approximately 12 USD). Customers in Livingstone pay less than 90 percent of their full water bill and accumulate significant debt to the water utility over time. Residential customers had average arrears of approximately 5 times the average water bill by the end of the survey period (June of 2019). Commercial and residential nonpayment has resulted in a cumulative loss of revenue to the water utility of more than 30 million Zambian Kwacha from 2013 to mid-2019 (see Figure 3).

Household survey results show that customers in Livingstone have an average monthly income of 2,650 ZMW (approximately 265 USD). The share of income used for water was calculated by taking the average (connected) water bill of customers in 2019 and dividing it by monthly income. Households in Livingstone that are connected to the water utility

[1]See Appendix A for a summary of the household survey methodology.

spend an average of 11 percent of households income on piped water.[2] More than half of households surveyed live in houses that the family owns, 40 percent of households live in rental units, and 3 percent live in government housing. More than half of the surveyed households do not have indoor plumbing, flush toilets, bathtubs, or showers in their dwelling, but approximately 90 percent of households have an electricity connection. Forty percent of households are connected to SWSC's sewer system, and these households are located geographically near the center of town.

Water source options for households in Livingstone include piped water, boreholes, public taps, and shallow wells. However, the nearly 98 percent of surveyed households (including both connected and disconnected households) responded that piped water from SWSC was their primary source of water, either through their own connection or a neighbor's connection. Furthermore, only two percent of SWSC customers have a private borehole. When households are disconnected from their individual water connections, survey data indicate that most households choose to share with a neighboring households within 100 meters of their home.[3]

Sixty-five percent of residential customers are classified Domestic Low cost households, which is a taxcode designation for the size of the household's plot.[4] Domestic Low households

[2]Previous research has argued that self-reported measures of income are likely to be underreported, and consumption data in household surveys is often more reliable (Meyer and Sullivan (2003); Carletto *et al.* (2021)). The household survey asked respondents to estimate monthly household income, and therefore the water bill share of income measures are likely to be overstated.

A commonly used affordability threshold for water is 5 percent of income (Banerjee *et al.*, 2011). Banerjee *et al.* (2011) find that urban households in Africa spend an average of 2 to 5 percent of household income on water. Chitonge (2011) estimates that customers of commercial utilities in Zambia pay approximately 5 to 7 percent of household income on water. Dagdeviren (2008) finds that the households in Zambia in the lowest income decile spend nearly 30 percent of income on water, the median household spends approximately 5 percent of income on water, and the highest income decile spends approximately 0.4 percent of income on water.

[3]Households that were disconnected at the time of the survey were asked how far they travel to fetch water, and 100 meters is the 90th percentile of the responses.

[4]Household plots that measure less than 540 square meters are classified as Domestic Low cost and households plots that measure between 540 and 1,350 square meters are classified as Domestic Medium cost. Household plots larger than 1,350 square meters are classified as Domestic High cost plots (UN-Habitat, 2012).

are generally lower income households in densely populated areas. Table 2 presents a comparison of several administrative and household survey variables for Domestic Low and Domestic Medium and High households and shows that the household's taxcode designation is a reasonable proxy for household income. Domestic Low households consume less water, have a lower monthly bill, and make lower payments to the water utility than Domestic Medium and High households. However, Domestic Low households have similar arrears to Domestic Medium and High households. Domestic Low households are also more likely to be unmetered and disconnected.[5] Domestic Low households have a household income that is approximately half of the average income of Domestic Medium and High households. Domestic Low households also spend an average of 12.6 percent of monthly income on water compared to 7.6 percent for Domestic Medium and High households. Domestic Low households are also less likely to have indoor plumbing, bathtubs or showers, septic tanks, and electricity connections. Figure 4 shows an example of a Domestic Low property in Livingstone, and Figure 5 shows the locations of Domestic Low, Medium, and High households. In the primary analysis of this paper, I examine the effect of enforcement capacity separately for Domestic Low households and Domestic Medium and High households.

Figure 6(a) shows a histogram of the number of disconnections that households experience during the sample period for Domestic Low and Domestic Medium and High customers. Less than half of Domestic Medium and High customers experience a disconnection during the sample period, and the average number of disconnections is 0.92. Nearly 75 percent of Domestic Low customers experience a disconnection during the sample period, and the average number of disconnections experienced is 2.2. Conditional on becoming disconnected, Domestic Low households spend an average of 6 months disconnected and Domestic Medium and High households spend an average of 5.5 months disconnected (see Figure 6(b)).[6]

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[5]Spink (2022) shows that SWSC prioritizes metering for high-income households.

[6]The billing data only record disconnections that occur for longer than 10 days. Additional short-term

Sixty-five percent of households in the sample period are metered and are billed according to an increasing block tariff (see Figure 7(a)) in which larger quantities of water consumed are charged a higher marginal price. The remaining thirty-five percent of households are unmetered and are billed a monthly flat rate (see Figure 7(b)). The unmetered tariff is conditional on the taxcode designation of the household: Domestic Low, Medium, or High.

3.1 Enforcement of Bill Payment

A primary challenge for SWSC is addressing customer nonpayment. Payment enforcement is carried out by Customer Service Assistants (CSAs). Each CSA is responsible for meter reading, bill distribution, payment reminders, and conducting disconnections and reconnections in one of 43 administrative billing zones (see Figure 9). Administrative zones often encompass several geographically separate neighborhoods, which I define as "subzones". At the beginning of the workday, CSAs are printed a list of households in their zone that are current debtors. This list is queried by the zone number and includes households with more than 30 ZMW in debt. Since 93 percent of residential customers owe more than 30 ZMW, it would not be possible for the CSA to disconnect every owing customer in a month.[7] During the workday as CSAs are completing their other tasks, they are expected to issue payment reminders to households on the debtors list. Figure 10 shows the timeline of payment reminders and disconnections. Households are typically offered several reminders to pay their water bill before they are disconnected. I do not observe payment reminders or disconnection threats in the data. Furthermore, I do not observe short-term disconnections (disconnections lasting less than 10 days) in the data. For a household to be recorded as disconnected in the billing records, it must remain disconnected through the next meter reading date.

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disconnections may occur in which the customer reconnects faster than is recorded by the enforcement agent at the next meter reading date.

[7]CSAs may only enforce payment in certain areas of the zone in each month and rotate to other areas in the following months.

New administrative zones are created as new connections are added to the water utility. Figure 8 shows the growth of customers and administrative zones during the sample period.[8] When new zones are created, the water utility attempts to balance the number of households that one CSA is responsible for. Neighborhoods (subzones) may be reassigned to a new administrative zone to equalize responsibilities per CSA. I define a subzone as the smallest neighborhood that remains as one geographic unit over time. During rezoning events, entire subzones may be reassigned to newly created zones or existing zones with fewer customers. The addition of new administrative zones creates a discrete reduction in the number of households that a CSA is responsible for in several administrative zones. These rezoning events are the primary source of variation used in this paper to estimate the effect of enforcement on payment behavior and disconnections.

This research setting is one of high levels of enforcement. Nonpaying customers are frequently disconnected from the piped-water network and approximately 18 percent of households are disconnected. Disconnected households can apply to reconnect their water supply by paying a reconnection fee of 50 ZMW (approximately 5 USD) and clearing their total bill (including arrears). Illegal reconnections and vandalism of pipes has been known to occur but are not widespread. Disconnected households generally make smaller monthly payments to neighbors for use of their water supply with the added hassle cost of traveling longer distances. The benefit of delaying payment for households with volatile incomes may therefore outweigh the cost of potentially losing their water connection for a period of time when households have easy access to substitutes. Additionally, commercial water utilities in Zambia may reconnect defaulting customers to the water network during cholera epidemics, the Covid-19 pandemic,[9] and for political reasons during election years. When disconnected surveyed households were asked the primary reason why they did not reconnect

[8] At the beginning of the survey period (January, 2013), there were 30 administrative zones. By the end of the survey period (June, 2019), there were 43 administrative zones

[9] Commercial water utilities in Zambia were instructed by the national regulator not to disconnect defaulting customers during the height of the Covid-19 pandemic (NWASCO, 2020).

to the piped-water network, 84 percent answered that they did not have available funds needed to clear their bill. Only 8 percent of disconnected households responded either that the quality of the piped water was too poor or that they preferred another source of water to their individual connection. Furthermore, only 65 percent of connected households responded that they would have the necessary funds available to reconnect immediately if they became disconnected, and 12 percent answered that it would take more than several weeks to reconnect. Trust in the water utility is generally low, and Jack *et al.* (2018) find that 40 percent of households in Livingstone state that the water utility is at fault for high water bills instead of high water consumption by the household.

CSAs are given bonuses for high collection efficiency, but this does not preclude the potential for bribery relationships between households and CSAs. Figure 11 shows histograms of the quantity of water consumed per month for Domestic Low and Domestic High metered households. The bunching at multiples of 10 provides suggestive evidence that CSAs may not visit each metered household each month and may record water quantities in multiples of 10 instead. This pattern is more pronounced for Domestic High customers than Domestic Low households likely because these households are further apart, making it difficult for the CSAs to reach all households in a zone, or because the CSA is unable to access the property. Domestic High household are more likely to be gated and may not have household members home during business hours.

4 Theoretical Framework

I develop a theoretical model of household monthly water consumption and payment decisions, which govern the extent to which the households accumulate arrears to the water utility. Households face a probability of being disconnected each month, which is a function of their accumulated arrears and exogenous enforcement levels of the water utility. This model outlines the disconnection and payment responses of households as a function of the household's valuation of the water connection and extent of its credit constraints. I empirically test the prediction of this framework in the following section of this paper.

I model household monthly payment decisions as a dynamic optimization problem in which households choose the optimal amount of water to consume, w, and the payments to make to the water utility, p. I assume that households have a constant per-period income of y. Each month, t, households choose the amount of water to consume, $w_t \in [0, W_t]$, where W_t represents a satiation consumption level of water. Water is billed at an average price of a_t. Households additionally choose whether to make a payment to the water utility and how much of their bill to pay, p_t. Water consumption and monthly payments affect a household's level of arrears to the water utility, A_t, which accumulate according to the following formula:

$$A_{t+1} = \phi(A_t, w_t, a_t, p_t) = A_t + a_t w_t - p_t \tag{1}$$

The probability that a household is disconnected is a function of current arrears and the enforcement level chosen by the water utility, e_t. The enforcement level represents both the water utility's willingness to disconnect customers and their capacity to do so. Households affect their probability of being disconnected through their monthly water consumption and payments, which determines their level of arrears in the next period, but enforcement capacity is exogenously determined by the water utility. Households with more than a minimum level of arrears, $\underline{A}$, are at risk of disconnection.[10] The probability that a households will be disconnected is given by 2. In this equation, λ_A and λ_e are positive constants that determine the sensitivity of the probability distribution to the level of arrears of the households and the exogenous level of enforcement, respectively.

$$P_t(d_t = 1) = f(A_t, e) = \begin{cases} 1 - exp(-\lambda_A(A_t - \underline{A}) - \lambda_e e_t) & \text{if } A_t > \underline{A} \\ 0 & \text{if } A_t \leq \underline{A} \end{cases} \tag{2}$$

[10]In this context, households with more than $\underline{A} = 30$ ZMW in debt are listed on the enforcement agent's debtors list. Households included on this daily list are issued payment reminders and may be disconnected if a payment is not made.

I model household utility as quasilinear in water consumption. Numeraire consumption is given by n_t, and the price of numeraire consumption is normalized to one. Household utility as a function of disconnection status is listed below.

$$u_t = \begin{cases} n_t + \gamma(2w_t - \frac{w_t^2}{\alpha}) & \text{if } d_t = 0 \\ n_t + \gamma(2w_t - \frac{w_t^2}{\alpha}) & \text{if } d_t = 1 \text{ and } p_t \geq A_t + f_r \\ n_t & \text{if } d_t = 1 \text{ and } p_t < A_t + f_r \end{cases} \tag{3}$$

(4)

The quadratic form of the utility function implies that households have a satiation level of water consumption, W_t, which is given by the parameter, α.[11] Unmetered households, whose billing does not depend on water consumption, will attempt to consume their satiation quantity in all periods that they are connected to the water utility. The parameter, γ, represents the household's preference for having an active water connection.

Household utility also depends on its disconnected state, d_t, which is the realized value of the probability distribution represented by equation 2. In each period, disconnected households also determine whether it will reconnect to the water utility through their choice of p_t. If payments are greater than current arrears plus a reconnection fee, $p_t \geq A_t + f_r$, then the water utility will reconnect the household, and it can consume water during that period.[12] Disconnected households that make a payment less than current arrears plus a reconnection fee, $p_t < A_t + f_r$, will not be reconnected during that period. Disconnected households are assumed to use water from an outside source such as a neighbor's water

[11]This can be seen by taking the derivative of utility with respect to w_t.

$$\frac{\partial u_t(w_t, p_t, r_t, d_t, \epsilon_t)}{\partial w_t} = \gamma(2 - \frac{2w_t}{\alpha}) = 0 \implies W_t^* = \alpha$$

[12]Households in Livingstone must pay a reconnection fee of $f_r = 50$ ZMW in order to reconnect.

connection or borehole, which is modeled as a component of numeraire consumption.

I model household payment decisions as an infinite-horizon dynamic optimization problem. In this dynamic optimization problem, the household chooses the infinite sequence of water consumption levels, $\{w_1, w_2, ..., w_t, w_{t+1}, ...\}$, payments to the water utility, $\{p_1, p_2, ..., p_t, p_{t+1}, ...\}$, and consumption of the numeraire good, $\{n_1, n_2, ..., n_t, n_{t+1}, ...\}$, to maximize the discounted expected utility stream. I further assume that this infinite-horizon problem is stationary, meaning that the maximization problem is the same at each time period and differs only by the value of the state variables. The household's utility maximization problem is given by:

$$\max_{\{w_t, p_t, n_t\}_{t=0}^{\infty}} \quad \mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t u(w_t, p_t, n_t, d_t) | A_t\right] \tag{5}$$

$$s.t. \quad n_t + p_t \leq y \tag{6}$$

where β is the exogenously determined discount factor. The associated Bellman is:

$$V(A_t, d_t) = \max_{w_t, p_t, n_t} \quad u_t(w_t, p_t, n_t, d_t) + \mathbb{E}_t\left[\beta V(A_{t+1}, d_{t+1}) | A_{t+1}\right] \tag{7}$$

Current arrears, A_t, affects the probability that a household will be disconnected at the beginning of period t, which is the endogenous state variable that households determine through their choice of w_{t-1} and p_{t-1}. The realized value of the probability distribution given by equation 2 is the household's disconnected state, d_t, which is the exogenous state variable.

4.1 Household Payments

The optimal monthly payments, p_t^*, for households that are connected at the beginning of the period can be found by solving equation 7. The first order condition is as follows.

$$0 = \frac{\partial V(A_t,0)}{\partial p_t} = \frac{\partial u_t}{\partial p_t} + \beta \frac{\partial \mathbb{E}_t V(A_{t+1}, d_{t+1})}{\partial A_{t+1}} \frac{\partial \phi}{\partial p_t} \tag{8}$$

Solving the first order condition for p_t gives the following expression.[13]

$$\begin{aligned} p_t^* = {} & A_t + a_t w_t - \underline{A} + \frac{\lambda_e}{\lambda_A} e_{t+1} \\ & + ln\left(\frac{\frac{1}{\beta} + V'(A_{t+1},0) + \lambda_A[V(A_{t+1},0) - V(A_{t+1},1)]}{\lambda_A[V(A_{t+1},1) - V(A_{t+1},0)] + V'(A_{t+1},1) - V'(A_{t+1},0)} + 1 \right) / \lambda_A \end{aligned} \tag{9}$$

From equation 9, the optimal payments for connected households, p_t^*, increase when the exogenous levels of enforcement in the next period, e_{t+1}, increases.

$$\frac{\partial p_t^*}{\partial e_{t+1}} = \frac{\lambda_e}{\lambda_A} > 0$$

The comparative statics above shows that connected households will respond to higher levels of enforcement by the water utility by increasing their monthly payments. The intuition is that when enforcement increases, households will respond by increasing payments to lower the probability of disconnection. In the following sub-section, I analyze the reconnection decision of households that experience a disconnection at the beginning of the period.

4.2 Reconnections

Figure 12 shows the decision tree of household reconnections and water consumption. At the beginning of each period, nature chooses a disconnection status, d_t, of the household given $P_t(d_t = 1|A_t, e_t)$.[14] For simplicity, I assume that households are unable to save or pay down their arrears over several months. Therefore, due to the stationarity of the utility

[13] The derivation is given in Appendix D. I assume that $V'(A_{t+1},1) < V'(A_{t+1},0) < 0$.

[14] Note that households would never voluntarily choose disconnection because $V(A_{t+1},1) < V(A_{t+1},0)$. Intuitively, households can always choose to make no monthly payments and consume a positive water quantity and would never prefer to disconnect.

maximization problem, households that choose not to reconnect in period t will also choose not to reconnect in all future periods. The household observes its disconnection status and chooses whether to reconnect to the water utility at the beginning of the period, $r_t = \{0, 1\}$. If a household chooses not to reconnect, it spends all its income on numeraire consumption, n_t, for all subsequent months: $t+1$, $t+2$, ..., ∞. Households that choose not to reconnect use an alternative source of water such as a neighbor's connection, which is included in numeraire consumption. If the households reconnects, it can continue consuming water as usual. Households will choose to reconnect if:

$$y - p_t + \gamma(2w_t - \frac{w_t^2}{\alpha}) + \mathbb{E}_t\left[\beta V(A_{t+1}, d_{t+1})|A_{t+1}\right] \geq \sum_{\tau=0}^{\infty} \beta^{\tau} y \quad \text{and } p_t \geq A_t + f_r \tag{10}$$

$$\underbrace{\gamma(2w_t - \frac{w_t^2}{\alpha}) + \mathbb{E}_t\left[\beta V(A_{t+1}, d_{t+1})|A_{t+1}\right]}_{\substack{\text{Discounted Value of Water Connection} \\ B_r}} \geq \underbrace{\frac{\beta y}{1-\beta} + p_t}_{\substack{\text{Cost of Reconnection} \\ C_r}} \quad \text{and } p_t \geq A_t + f_r \tag{11}$$

Households will choose to reconnect if the discounted value of maintaining the water connection, B_r, is greater than the cost of reconnection, C_r. The cost of reconnection for a household includes the repayment of arrears, $p_t \geq A_t + f_r$, and the opportunity cost of spending their full income on numeraire consumption, $\beta y/(1-\beta)$. There are three cases to consider:

Case 1: $B_r > C_r$ and $y > A_t + f_r$

In this case, the household's benefit of reconnection is greater than the cost of reconnection. Disconnected households would choose to reconnect to the water utility and have the available funds to do so.

Case 2: $B_r > C_r$ and $y < A_t + f_r$

The benefit of reconnection is greater than the cost of reconnection, but disconnected households are unable to reconnect because their monthly household income is less than the price of reconnection.

Case 3: $B_r < C_r$

In this case, the benefit of reconnection is less than the cost of reconnection, and disconnected households would not choose to reconnect regardless of whether the income constraint binds.

There are several observations from this theoretical model. First, exogenous changes in enforcement reduce the discounted value of the water connection, B_r, for households with optimal arrears $A_t > \underline{A}$.[15] Higher levels of enforcement reduce the ability of households to delay payments to future periods. For households that were on the margin between reconnecting and not (perhaps due to high arrears and/or easy access to substitute sources of water), higher enforcement may mean that the household will fall under Case 3 above. Exogenous increases in enforcement will only result in higher payments from households with a high valuation of their water connection that remain in Case 1. This model suggests that high levels of enforcement will only be successful at improving cost recovery for the water utility when households do not face significant credit constraints and have a sufficiently high valuation of their individual water connection.

A second observation is that higher values of arrears, A_t, increase the cost of reconnection, making it more likely that households will be in Case 2 rather than Case 1. Households with higher access to credit will have a greater ability to reconnect to the water utility when this income constraint is binding.[16] When households are disconnected indefinitely,

[15] Exogenous increases in enforcement, e, which increases a household's probability of being disconnected at each level of A_t, decreases the discounted value of the water connection.

$$\begin{aligned}\frac{\partial B_r}{\partial e_{t+1}} =& \frac{\partial}{\partial e_{t+1}}\left[\gamma(2w_t - \frac{w_t^2}{\alpha}) + \mathbb{E}_t\left[\beta V(A_{t+1}, d_{t+1})|A_{t+1}\right]\right] \\ =& \beta\frac{\partial}{\partial e_{t+1}}\left[(1-P_{t+1})V(A_{t+1},0) + P_{t+1}V(A_{t+1},1)\right] \\ =& -\lambda_e(1-P_{t+1})\beta\underbrace{\left[V(A_{t+1},0) - V(A_{t+1},1)\right]}_{+} < 0\end{aligned}$$

[16] Access to credit does not change the reconnection condition in equation 11 because identical terms enter

arrears are never recovered by the water utility. An extension to this model would be to incorporate saving between periods (or making smaller payments to the water utility while disconnected to reduce arrears). Households in Livingstone often reconnect after a period of several months after saving enough money to clear their arrears. Allowing households to reconnect immediately while agreeing to a payment plan may be beneficial to credit-constrained households that fall under Case 2 above. This may benefit the water utility as well by increasing the willingness of households to reconnect by allowing them to do so in period t instead of a future period. I test the predictions of this theoretical framework in the following section.

5 Empirical Strategy and Results

5.1 Cross-Sectional Evidence

To estimate the impact of administrative enforcement capacity on payment behavior and disconnections, I first study the effect of zone size on these outcomes. Administrative zones are often comprised of multiple subzones and are redrawn over time as new connections are added. Subzones have been defined as the smallest subpart of the administrative zone that remains as one unit over the study period. Zones with more households are expected to have lower administrative enforcement capacity. Enforcement agents in zones with more households may provide fewer payment reminders and conduct fewer disconnections per customer due to the larger number of customers that they must visit for meter reading and bill distribution. The estimating equation is as follows.

$$Y_{it} = \alpha \ln(\text{Zone Size})_{it} + \mathbb{X}'_{it}\beta + \gamma_i + \gamma_t + \varepsilon_{it} \tag{12}$$

The dependent variable in these regressions, Y_{it}, is an indicator for making a payment, the total monthly payments made per customer, and an indicator for being disconnected

both sides of the inequality.

for customer i in billing period t. The independent variable of interest is the natural log of the number of households in the full administrative zone. I control for characteristics of the customer or neighborhood using customer or subzone fixed effects, γ_i. Month of year fixed effects, γ_t, control for changes in payments and disconnections over time resulting from seasonality, price changes, water production, and other city-wide administrative changes. A vector of household controls is contained in $\mathbb{X}_{it}$, including an indicator of whether the household is unmetered[17] and an indicator of whether the customer has a newly formed account of less than four months. This empirical strategy exploits variation in the size of the administrative zone over time. A primary concern with this empirical strategy is that local changes in the number of connections could affect a household's payment and disconnection behavior through channels other than administrative enforcement capacity. For example, water use by nearby neighbors could affect a household's own water usage through changes in pipe pressure. Neighboring households may also engage in water sharing between households. Changes in the number of local connections may affect a household's water demand through (1) the number of nearby houses drawing water from that household's connection and (2) the possible substitution options available to that household if it became disconnected.[18] Therefore, I further control for the number of connections in a households immediate neighborhood of 100 meters.[19] Assignment to administrative zone varies at the subzone level, and therefore, standard errors for all regressions are clustered at the subzone level (Abadie *et al.*, 2017). In the analyses that follows, households that have inactive accounts are removed from the analysis. This includes households with vacant properties, properties still under constructions, households that have had their water connections uprooted, and

[17]Spink (2022) shows large increases in payments and a reduction in disconnections when unmetered customers become metered in this setting.

[18]See Spink (2022) for an analysis of water sharing in Livingstone.

[19]Household survey results suggest that households share primarily with nearby neighbors. The distance of 100m is the 90th percentile of survey responses of the distance that disconnected households travel to access an alternative source of water.

households that have switched to private borehole supply.

Table 3 presents the results of estimating equation 12. Larger administrative zones with lower administrative enforcement capacity are associated with fewer payments made and lower revenue per customer. A 50 percent increase in the size of the administrative zone is associated with a 2.9 to 3.7 percentage point decrease in the probability of making a payment across specifications.[20] However, a 50 percent increase in the size of the administrative zone results in only 2 to 2.7 ZMW less revenue per customer across specifications, and this result is often statistically insignificant. The results show a lower probability of being disconnected across specifications. A 50 percent increase in the size of the administrative zone is associated in a 2.2 to 2.4 percentage point decrease in the probability of being disconnected, which represents approximately a 14 percent decrease in the likelihood of being disconnected.

5.2 Quasi-experimental Evidence

The above analysis provides suggestive evidence of the role of enforcement capacity on customer payments and disconnections. An ideal experiment to test the impact of administrative enforcement capacity would be to randomly assign subzones to administrative zones of different sizes. Administrative rezoning events provide a quasi-experiment of this type. As new customers are added to the water network, the water utility redraws administrative boundaries to balance the number of customers that one CSA is responsible for.[21] Preexisting subzones may be reassigned to newly formed zones. Administrative rezoning creates a discrete change in the number of households that one CSA must enforce. I define an administrative rezoning event as the month in which the largest decrease in

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[20] A 50 percent increase in the natural logged independent variable results in a $\alpha ln(1.5)$ change in the dependent variable.

[21] Households experience a decrease in enforcement capacity at the time of the rezoning event due to changes in the size of the administrative zone, but they may be assigned a new enforcement agent at the same time. If households have developed a relationship with their enforcement agent and offer bribes to avoid disconnection, the rotation of enforcement agents may force households to reestablish this relationship with a new enforcement officer. Previous research has documented the importance of collusive agreements between revenue collectors and agents (Khan *et al.*, 2016).

households per zone occurs, given that the zone experiences at least a 20 percent decrease in the number of households it contains. Figure 8 shows the growth in customers and administrative zones over time. There are 8 rezoning events during the sample period that occur when new zones are formed. Figure 13 shows an example of the experimental variation generated by rezoning events for an administrative zone in the water network.

Estimating average treatment effects of increases in enforcement capacity using this quasi-experimental approach relies on the standard assumptions of the event-study design including no anticipatory behavior prior to rezoning and the parallel trends assumption. Consumers are unlikely to have prior knowledge of administrative changes of this type, but the water utility may engage in training of new CSAs in the months prior to rezoning. To satisfy the parallel trends assumption, the payment and disconnection outcomes of control subzones that were not rezoned should provide an appropriate counterfactual for subzones that were rezoned when conditioning on covariates. Table 4 presents a comparison of observable characteristics of rezoned subzones and those that are not rezoned during that period or in the three months before or after rezoning. Approximately 39 percent of customers experience a rezoning event during the sample period. Subzones that are rezoned have a higher share of unmetered accounts, new accounts, and accounts farther from pay stations. Rezoned subzones also have a smaller share of households connected to the sewer. Because of these observed differences in the characteristics of rezoned subzones, I control for changes in metering status, new accounts, and the number of other connections in a household's 100-meter neighborhood. Household-level fixed effects control for the distance of households from the pay station and whether the household is connected to the sewer. There are no statistically significant differences in the growth rates of the subzones, the share of Domestic Low households, or the share of disconnected households in the subzone.

5.2.1. Event Study

I examine the dynamic treatment effects of administrative rezoning using an event study framework in which the event is the largest administrative rezoning event for each subzone as defined above. Treatment is staggered because the largest rezoning event occurs at different times in different subzones (see Figure 8). I use a two-way fixed effect estimator to estimate average the average treatment effect of rezoning. The estimating equation is as follows.

$$Y_{it} = \sum_{y} \alpha_y D^y_{it} + \mathbb{X}'_{it}\beta + \gamma_i + \gamma_t + \varepsilon_{it} \tag{13}$$

In this specification, D^y_{it} are event-time dummies indicating when the largest event is y periods away. Specifically, $D^y_{it} = I[t - e_r = y]$, where t is the year and month of the observation and e_r is the year and month of the rezoning event. The estimating equation includes dummies for the five months before and the ten months after the rezoning event. I control for time-invariant differences between subzones using subzone or customer fixed effects, γ_i. Year-by-month fixed effects, γ_t, control for city-wide changes that occur over time such as weather, price changes, or other administrative policy changes. $\mathbb{X}_{it}$ includes a vector of controls for changes in metering status, new accounts, and the local number of connections in a household's neighborhood. Y_{it} includes several payment indicators including an indicator for making a payment, revenue per customer, and the share of the bill paid conditional on making a payment. I further examine several disconnection indicators including an indicator for being disconnected, an indicator for the household becoming newly disconnected, and an indicator for the household reconnecting to the water network. To avoid perfect multicollinearity of the event-time dummies, α_{-1}, the coefficient for the month immediately before the rezoning event, is normalized to zero. The α_y coefficients therefore represent the evolution of payments and disconnections relative to the month immediately before the rezoning event. I apply the following endpoint restrictions, which imply that the effect of rezoning should diminish more than five months before and ten months after the event.

$$\alpha_y = \begin{cases} \bar{\alpha} \text{ if } y > 10, \\ \underline{\alpha} \text{ if } y < -5 \end{cases} \tag{14}$$

Figure 14 shows the first-stage results of estimating equation 13 using zone size as the outcome variable. When conditioning on customer fixed effects, year-by-month fixed effects, metering status of the customer, age of the account, and the number of other connections in a household's neighborhood, the treatment effect for rezoned subzones is an average 40 percent decrease in the number of customers in the administrative zone. Figure 14 shows minimal pre-trends and post-trends in this quasi-experiment. Therefore, I am able to cleanly identify the effect of zone size on payments and disconnections.

Figure 15 and 16 present the main results of this paper. Figure 15 presents the results of equation 13 for payment variables for all customers and for Domestic Low and Domestic Medium and High customer separately. The probability that a household makes a payment increases by about 4 percentage points in the months following an administrative rezoning event. This translates to an 8 percent increase in the probability of making a payment. The share of the bill paid (conditional on making a payment) declines following the rezoning events.[22] The observed increase in the frequency of payments and the decrease in the share of the bill paid results in small and short-run increases in revenue per customer of less than 0.5 USD per month. This increase in revenue is largely driven by Domestic Low households. When conditioning on the sample of always connected customers, payment increases are larger but still less than 1.5 USD per month for Domestic Low households. The theoretical framework presented in Section 4 hypothesized that connected households would increase payments in response to increased enforcement, and empirical results show that revenue increases are largely driven by households that never experience a disconnection.[23] In this

[22]CSAs will typically check whether a payment has been made and may not disconnect households that make a payment regardless of whether the payment is larger than current charges.

[23]The sample of always-connected customers may also include households that were disconnected for a

setting, households primarily draw water either from their own connection or a neighbor's connection when disconnected. Water supply costs for SWSC are therefore unlikely to decrease when households become disconnected. Taken together, these results suggest that households may make more frequent payments as a result of increased enforcement but pay a smaller share of their bill at each payment, resulting in only small and short-run increases in revenue for the water utility.

Figure 16 presents the results of equation 13 for the same groups of customers for disconnection variables. The probability that a household is disconnected increases by more than 4 percentage points six months after the rezoning event. This observed pattern is driven by Domestic Low households that experience a nearly 6 percentage point increase in the probability of being disconnected in the same time frame. After more than 10 months, Domestic Low households remain more than 4 percentage points more likely to be disconnected, which represents a 20 percent increase from prior to rezoning. Domestic Medium and High households, on the other hand, experience no change in the probability of being disconnected. The observed increase in the probability of being disconnected results from an increase in new disconnections for Domestic Low households shortly after rezoning. Domestic Medium and High households again experience no change in new disconnections after rezoning. Similar to the predictions of the theoretical framework from Section 4, there is a decrease in new reconnections following rezoning particularly among Domestic Low households.

Recent research has highlighted some potential limitations of conventional two-way fixed effects estimators to produce reasonable estimates of average treatment effects when the treatment is staggered over time and treatment effects are heterogeneous across cohorts (see De Chaisemartin and d'Haultfoeuille (2020); Sun and Abraham (2021); Callaway and Sant'Anna (2021); Goodman-Bacon (2021)). Appendix B presents a discussion of potential

short period of time and paid to reconnect very quickly thereafter. Short-term disconnections of less than two weeks are not observable in the data. For a household to be recorded as disconnected, they must remain disconnected through the next meter reading date.

issues that may arise and robustness results of the above analysis using an interaction-weighted estimator suggested by Sun and Abraham (2021), which is robust to heterogeneous treatment effects. Results presented in Appendix B show that event-study estimates using an interaction-weighted estimator produce similar results to those presented in Figure 15 and Figure 16.

5.2.2. Post Rezoning Event Difference-in-Difference

To study the long-run effects of increases in enforcement capacity following administrative rezoning events, I estimate a generalized difference-in-difference regression as follows.

$$Y_{it} = \alpha Post_{it} + \mathbb{X}'_{it}\beta + \gamma_i + \gamma_t + \varepsilon_{it} \tag{15}$$

In this specification, $Post_{it}$ is an indicator for months after the subzone experiences the largest rezoning event. Similar to the event study above, control subzones include both subzones rezoned in later periods and those that are never rezoned. Rezoning events represent a decrease in the number of customers per zone, and therefore, months following the largest rezoning event indicate those with higher enforcement capacity. These regressions again control for customer or subzone fixed effects, γ_i, month and year fixed effects, γ_t, and a vector of controls for household characteristics, $\mathbb{X}_{it}$, as above.

Figure 17 shows the results of equation 15. Domestic Low households are 4 percentage points more likely to make a payment, but they pay a smaller share of the bill when they do pay. Domestic Medium and High customers are 2 percentage points more likely to make a payment, but this increase is not statistically significant, and pay a higher share of their bill. Domestic Low households are 3 percentage points more likely to be disconnected in the post-rezoning period, but this result is not statistically significant. Unlike the event study results above, these results suggest that there is no change in new disconnections for Domestic Low households, and rather, there is a decrease in reconnections following rezoning events. Domestic Medium and High households experience no significant change in disconnections, new disconnections, or reconnections. While the difference-in-difference results provide suggestive evidence of the long-run effect of increases in enforcement capacity, the growth of new customers over time may result in enforcement capacity declining in treated subzones following rezoning events. The binned endpoints in figure 14 show that the long-run change in zone size is in fact smaller that the short-run change in zone size. This may explain why significant changes in disconnections are observed in the event-study analysis but not the difference-in-difference analysis.

Table 5 presents full regression results and alternative model specifications for all customers. The results again show a significant increase in the probability of making a payment but only a significant increase in revenue when controlling for subzone fixed effects rather than customer fixed effects. The results show only a modest increase in disconnections, but as noted above, Domestic Medium and High experience no change in disconnections, and the observed increase in disconnections is driven by a higher probability of being disconnected among Domestic Low households.

The above results suggest that rezoning events are largely ineffective at increasing revenue for the water utility. The observed increase in the probability that a household makes a payment is countered by the effect of increased disconnections and a reduced share of the total bill paid when making a payment. Furthermore, Domestic Low households experience a sizable increase in disconnections following rezoning. The results suggest that increases in enforcement of bill payment reduces access for low-income households and do not achieve revenue collection objectives. It is important to note that this setting is one in which payment enforcement is high. In other low-income country settings, enforcement is limited or nonexistent (Burgess *et al.* (2020); McRae (2015)).[24] Enforcement of payment in other

[24]Supply disconnections in high-income countries is more widespread. An estimated 15 million people in the United States experienced a water shutoff in 2016 (Food & Water Watch, 2018). Water and electricity shutoffs have been shown to have severe health and environmental justice implications. Jowers *et al.* (2021) estimate that Covid-19 infection rates could have been reduced by 8.7 percent and deaths by 14.8 percent if a nationwide moratorium on utility disconnections had been enacted from March to November of 2020. Cicala (2021) finds that the likelihood of having electricity disconnected for nonpayment are 4 times higher for customers in Black and Hispanic zip codes after controlling for zip code-level income.

settings with limited baseline enforcement levels may produce larger changes in revenue, which was observed in the setting studied by Coville *et al.* (2021).

5.3 Back of Envelope Calculations

The above analysis examines changes in total revenue after rezoning events. I next estimate changes in net revenue of the water utility by estimating the additional cost of hiring new enforcement agents to enforce newly formed administrative zones. I calculate the additional monthly cost to the water utility of employing additional CSAs using the CSA wage in 2016 of 2,974 ZMW (approximately 297 USD).[25] During rezoning events, an average of 1.9 new administrative zones were added, resulting in an estimated 5,651 ZMW of additional employment costs (approximately 565 USD) per month. I estimate the same generalized difference-in-difference as in equation 15 above. I calculate additional total monthly revenue by multiplying the point estimate by the average number of customers treated during rezoning events.

Table 6 presents the results. Additional monthly enforcement costs were found to be approximately 565 USD per month. Regression results including customer fixed effects in columns (1) through (3) have large confidence intervals. Event study results show that changes in revenue were short-run, which may explain the insignificant point estimates in difference-in-difference regressions. Net revenue in these specifications is found to be negative and range from -398 to -259 USD per month. Regressions using subzone fixed effects instead of customer fixed effects in columns (4) and (5) show higher increases in monthly revenue, which are significant at the 1 percent level. Net revenue is found to be approximately 249 to 290 USD per month. Results using customer fixed effects and controls for metering status, age of account, and the density of the customer's neighborhood in column (3) are the preferred results matching equation 15, which find insignificant but

[25] The wage in 2016 was estimated using the 2022 wage of 6,194 ZMW and adjusting for the inflation rates per year in Zambia. CSAs are given bonus depending on performance, and there is no data available on the actual payments made to CSAs above their monthly wage.

negative net revenue changes for the water utility. The results suggest that increases in revenue from higher enforcement do not justify the higher costs of hiring additional CSAs. However, CSAs conduct a variety of tasks including meter reading and bill distribution in addition to enforcing payment and ensuring that these tasks are done efficiently may justify the additional hiring costs.

6 Conclusion

Nonpayment of water bills in many developing countries is widespread and may hinder efforts to improve utility supply quality. Poor supply quality may further reduce demand for public utilities and undermine efforts for universal access. Previous research has pointed to the need to enforce payment of electric and water bills in order to escape the low-payment, low-quality equilibrium that is often observed in developing countries (Burgess *et al.* (2020); McRae (2015); Coville *et al.* (2021)). However, limited research exists on the effectiveness of high levels of enforcement of utility bill payment. This study aims to address the dearth in experimental evidence of the effect of enforcement though supply disconnections on household payment behavior and disconnections. I study discrete increases in enforcement that occur at administrative rezoning events in Livingstone, Zambia. I find that low-income households experience a more than four percentage point increase in the probability of being disconnected following administrative rezoning events, which represents a 20 percent increase from prior to rezoning. High-income households experience no change in disconnections following rezoning. While households are 8 percent more likely to make a payment following rezoning events, this does not translate into large revenue increases for the water utility. This study finds that increases in enforcement are largely ineffective at increasing revenue for the water utility and instead lead to increased supply disconnections of the poorest customers.

While the results of this study suggest that excessive enforcement may undermine both goals of cost recovery for the utility provider and household access to improved water sources, this study does not suggest that enforcement of payment is not effective in general. I study the impact of increased enforcement of bill payment in a context of high baseline enforcement levels. Several previous studies of electric and water utilities document little to no enforcement of payments in many developing countries (McRae (2015); Szabó and Ujhelyi (2015); Coville *et al.* (2021); Burgess *et al.* (2020)). Increases in enforcement of bill payment in a context of low baseline enforcement may provide higher revenue gains, and this study may suggest diminishing returns to enforcement.

Effective water policies in developing countries must consider both the impact of the policy on household access to improved water sources and revenue collection for the utility provider. The optimal course of action for public utility providers may be highly dependent on the local setting. For example, high levels of enforcement may be effective in settings where citizens do not have deep mistrust of local governments, have high access to credit, and do not have feasible water substitutes available that lower a household's valuation of an individual water connection. Future work is needed on this topic in other settings to determine under which conditions enforcement leads to higher revenue gains and in which conditions it leads to reduced access for low-income households.

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Appendices

A Household Survey Methodology

A randomized survey of 808 current or former piped-water customers in Livingstone, Zambia was conducted in September 2019. Households were sampled from SWSC's customer listing database. The randomization was stratified by SWSC's administrative billing zones. If a household declined to respond or could not be reached after two attempts, it was replaced with a random household from the unsampled population of the same stratum. Table 7 presents balance checks of the administrative data from the surveyed and unsurveyed households. The surveyed sample contains more households that are connected to the sewer and older accounts, and this difference is statistically significant. This difference can be attributed to the fact that customers that were connected after SWSC conducted a network mapping were more difficult to sample because they did not have a GPS location listed.

The household survey included demographic information about the household, the sources of water used, the alternate sources of water the household has used when disconnected from the piped water network, the use of storage tanks and coping behaviors, data on household members including history of diarrheal diseases and educational attainment, and several hypothetical question gauging willingness to pay for improvements in piped-water service quality which was used in another research study.

B Robustness to Alternative Models

B.1 Interaction-weighted Estimator

Recent research has discussed potential limitations of conventional two-way fixed effects estimators to produce reasonable estimates of average treatment effects when treatment is staggered (De Chaisemartin and d'Haultfoeuille (2020); Callaway and Sant'Anna (2021); Sun and Abraham (2021); Goodman-Bacon (2021)). Specifically, the event-time dummies represent a weighted average of cohort-specific treatment effects, in which each cohort includes the subzones that were treated during each of the 8 rezoning events. De Chaisemartin and d'Haultfoeuille (2020), and Goodman-Bacon (2021) show that this weighted average from traditional two-way fixed effect estimators can assign negative weights to event-time dummies. Sun and Abraham (2021) similarly show that coefficients on event-time dummies can be contaminated by treatment effects from other cohorts if there are heterogeneous treatment effects across cohorts.

I apply the method described in Sun and Abraham (2021) in Figure 18 Panel (b), which is robust to treatment effect heterogeneity. Results show that event-study estimates using an interaction-weighted estimator produce similar results to those presented in Figure 15 and Figure 16, which are also presented in Figure 18 Panel (a).

B.2 Administrative Zone Area

The primary analysis used is the paper considers administrative zone size to be a function of only the number of customers in that zone. This section considers zone size as defined by its area. Zones in which the customers are more geographically dispersed could also contribute to difficulties in enforcing those areas because the CSA must travel farther distances to each household.[26] I define a rezoning event as one in which the subzone experiences the largest decrease in area of the full administrative zone, given that this decrease is at least 20

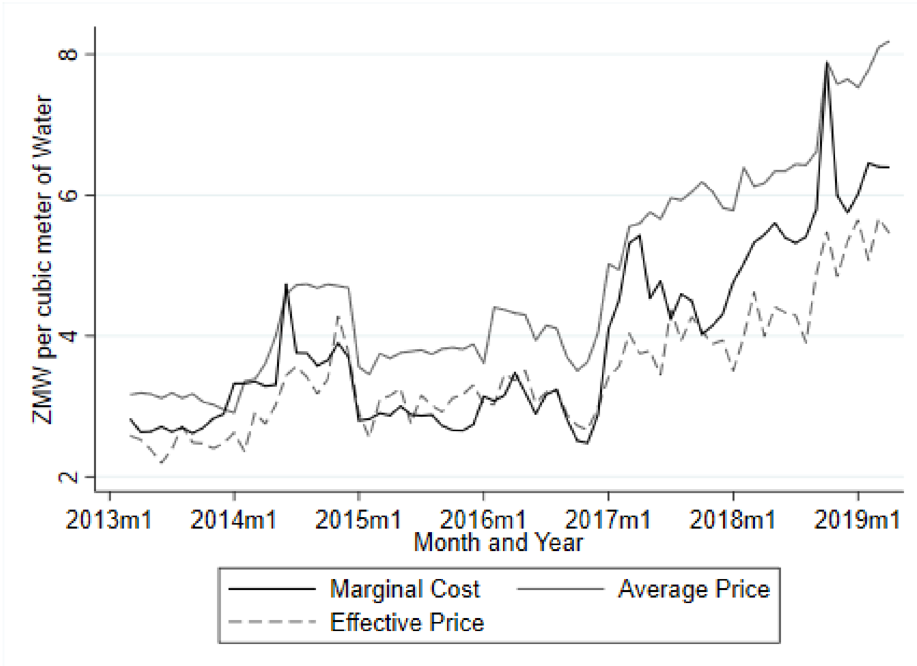
[26] Administrative zones are typically made up of several geographic subzones and the total area of the administrative zone is defined as the sum of these smaller areas.

percent. I conduct the same event study analysis as presented in the main paper using the area definition of rezoning event.

The results are presented in Figure 18 Panel (c). The results show a similar increase in the probability that households make a payment, with modest increases in revenue. There is also a similar sharp increase in disconnections following rezoning which appears to decline after 10 months. These results are similar to those in the main paper with a potentially higher increase in revenue and lower increase in disconnections.

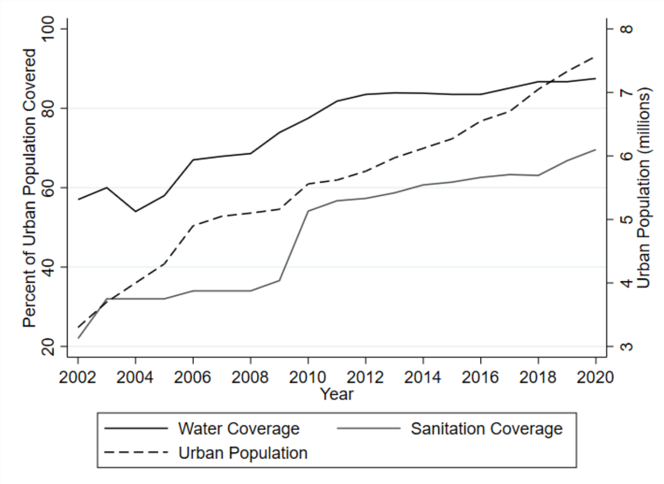
C Figures and Tables

Figure 1: Marginal Cost, Average Price, and Effective Price of Water



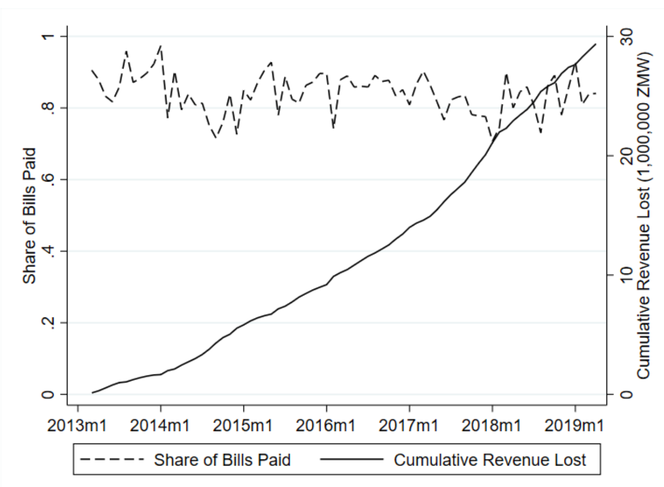
Notes: This figure presents the average price paid per cubic meter of water across all customers (metered and unmetered) and the marginal cost of production from 2013 to mid-2019. The effective price of water is the average price that consumers face after accounting for nonpayment. Marginal cost data are from the NWASCO Urban and Peri-Urban Water Supply and Sanitation Sector Reports from 2001-2020.

Figure 2: Trends in Water and Sanitation Coverage in Zambia



Notes: This figure presents the percent of the urban population with access to piped-water connections and the percent of the urban population with access to sanitation in Zambia from 2002 to 2019. The right axis shows the number of people living in urban areas over the same period. This data is from the NWASCO Urban and Peri-Urban Water Supply and Sanitation Sector Reports from 2001-2020.

Figure 3: Share of Bills Paid and Cumulative Revenue Lost in Livingstone



Notes: This figure shows the share of total bills paid among all residential, commercial, and institutional customers in Livingstone from 2013 to mid-2019. The right-hand axis shows the cumulative revenue lost from unpaid bills over the same period. From 2013 to mid-2019, the water utility lost nearly 30 million ZMW in revenue from nonpayment. 10ZMW $\approx$ 1 USD

Figure 4: Domestic Low Household and Water Connection

(a) Domestic Low Property (b) Domestic Low Water Connection

Figure 5: Locations of Domestic Low, Medium, and High Households in Livingstone

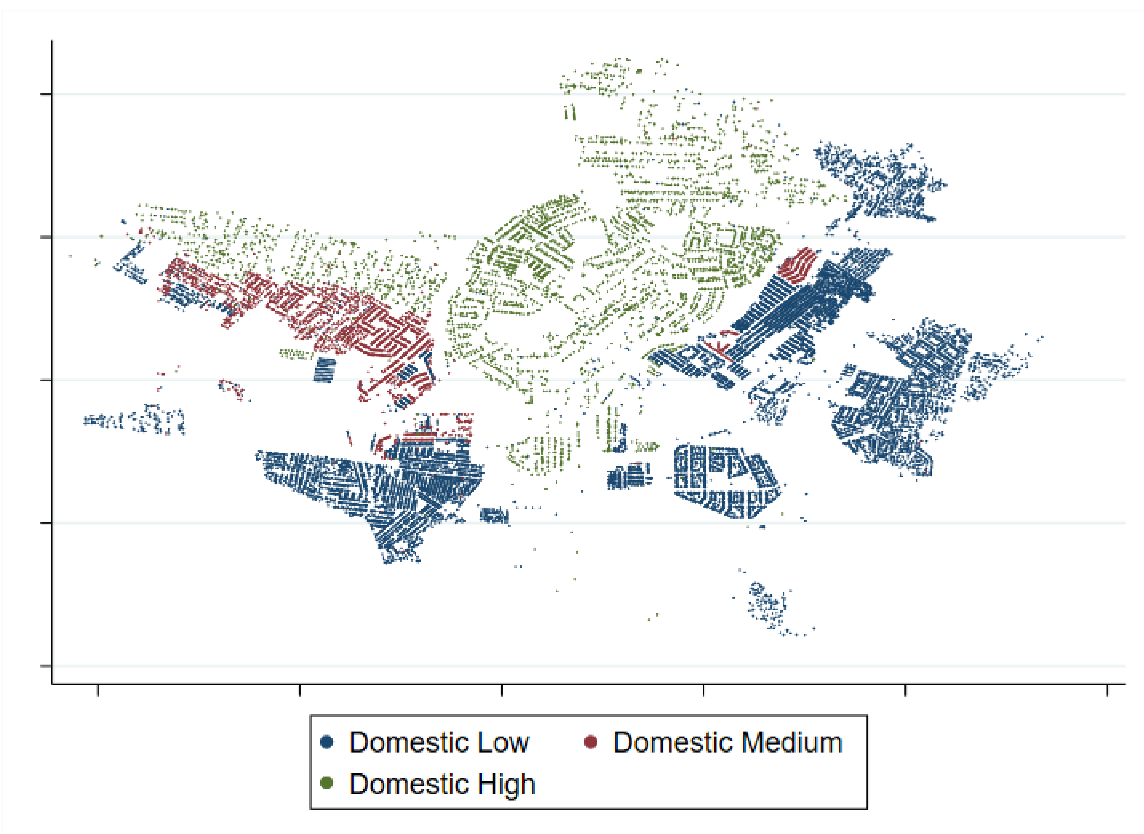
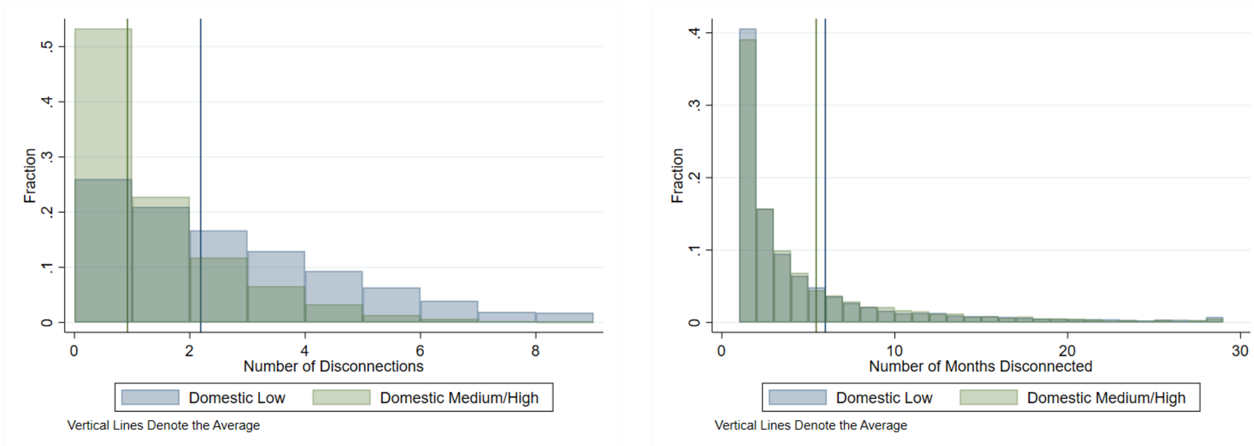


Figure 6: Disconnection Histograms

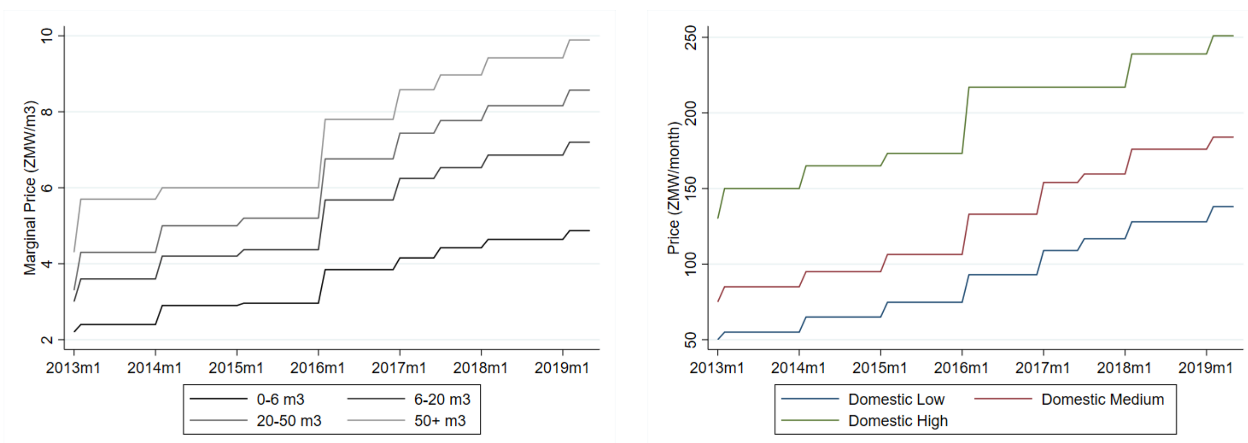
(a) Number of Disconnections (b) Months Spent Disconnected



Notes: This figure presents histograms for the number of disconnections that households experience during the sample period in sub-figure (a), and the number of months spent disconnected (conditional on being disconnected) in sub-figure (b). Histograms are drawn separately by Domestic Low and Domestic Medium and High households, and vertical lines denote the average for each group. A household that experiences a short-term disconnection (a disconnection lasting less than 10 days that is not recorded in the billing data) will be reported as not being disconnected.

Figure 7: Water Tariffs for Metered and Unmetered Households

(a) Metered Price Schedule (b) Unmetered Price Schedule



Notes: This figure presents the increasing block tariff price structure for metered households in sub-figure (a), and the monthly fixed charge for unmetered households in sub-figure (b) from 2013 to mid-2019. Metered households are charged by the cubic meter at different marginal rates for each consumption tier: 0-6 cubic meters, 6-20 cubic meters, 20-50 cubic meters, and more than 50 cubic meters. Unmetered households are charged a fixed monthly price depending on the tax code designation of the household: Domestic Low, Domestic Medium, or Domestic High.

Figure 8: Administrative Zone and Customer Growth

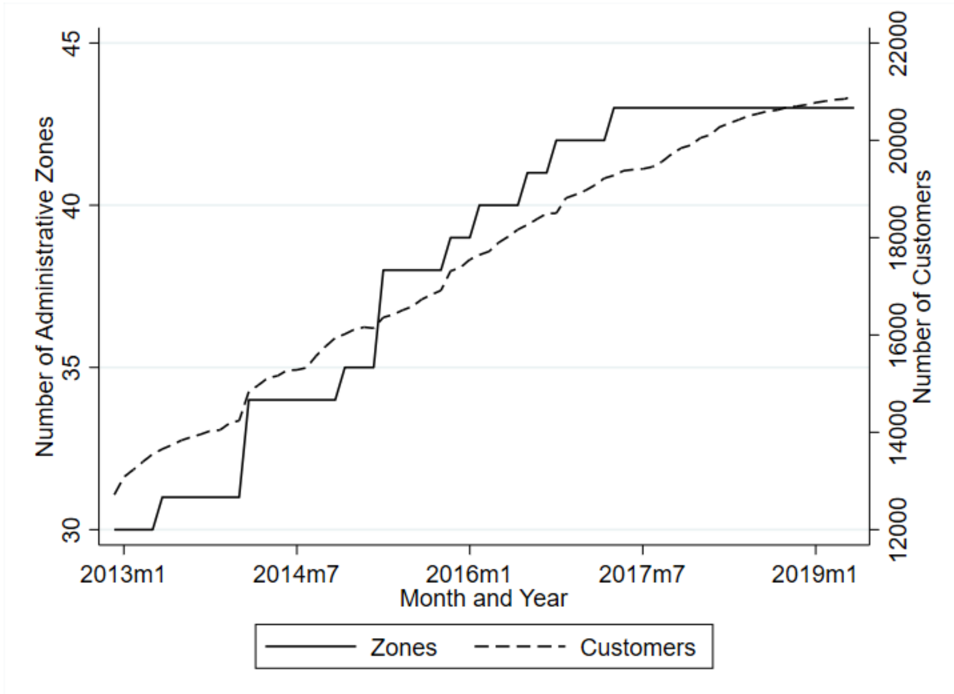


Figure 9: Water Utility Administrative Zones Boundaries in May 2019

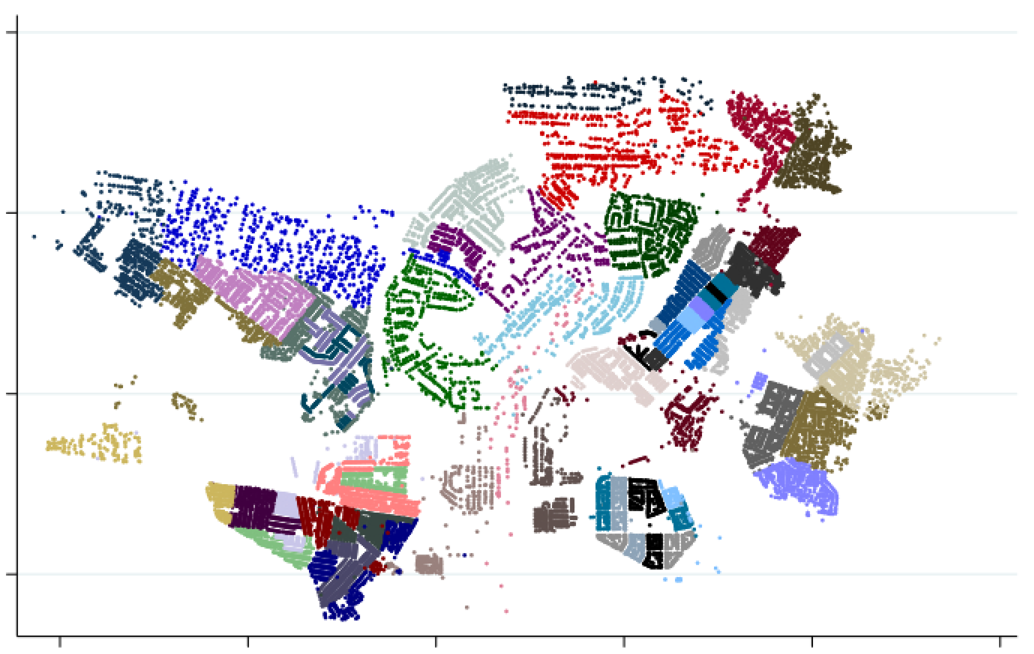


Figure 10: Timeline of Billing, Payments, and Disconnections

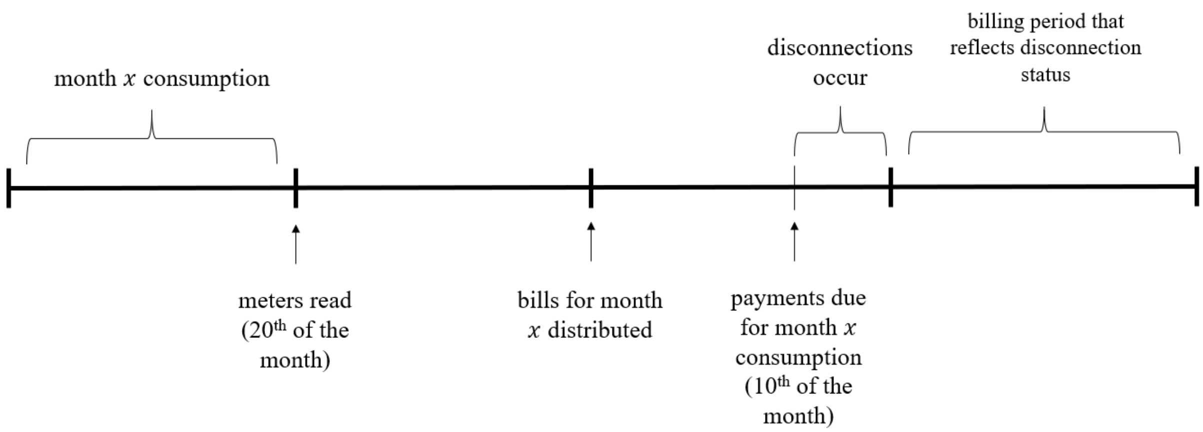
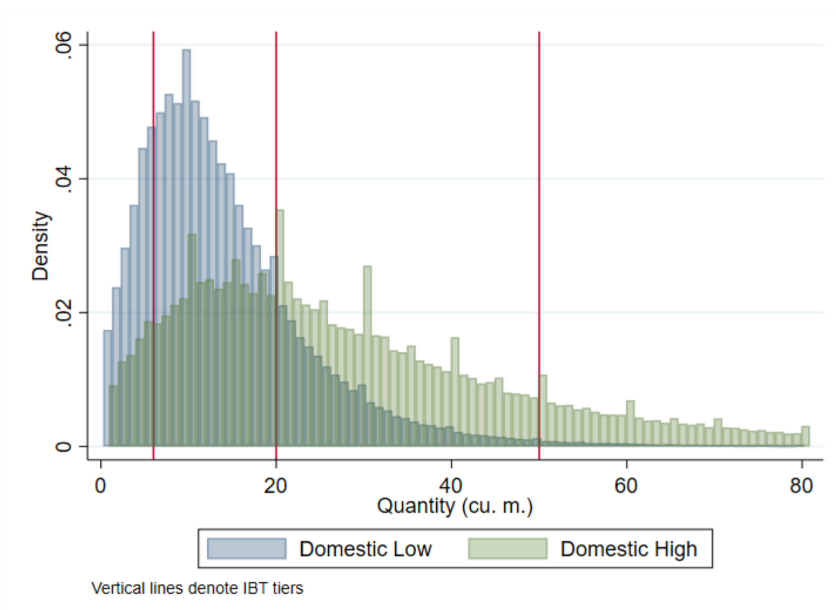


Figure 11: Histogram of the Quantity of Water Consumed per Month for Domestic Low and Domestic High Households



Notes: This figure presents histograms of the quantity of water consumed in cubic meters for metered households for Domestic Low and Domestic High customers separately. The vertical lines denote the cutoffs of the increasing block tariff structure (6, 20, and 50 cubic meters). Bunching at multiples of 10 may indicate intentional or unintentional CSA reporting errors.

Figure 12: Decision Tree of Household Reconnections and Water Consumption

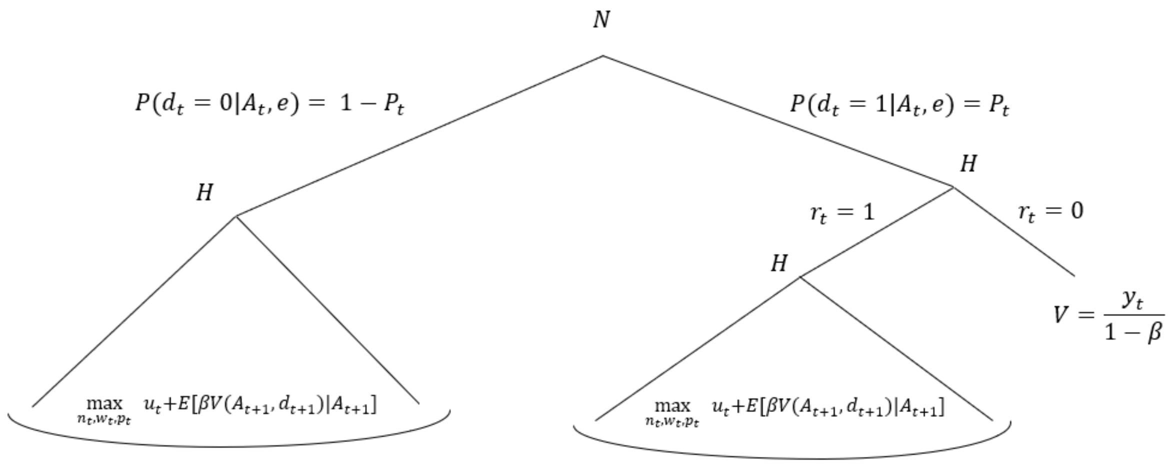
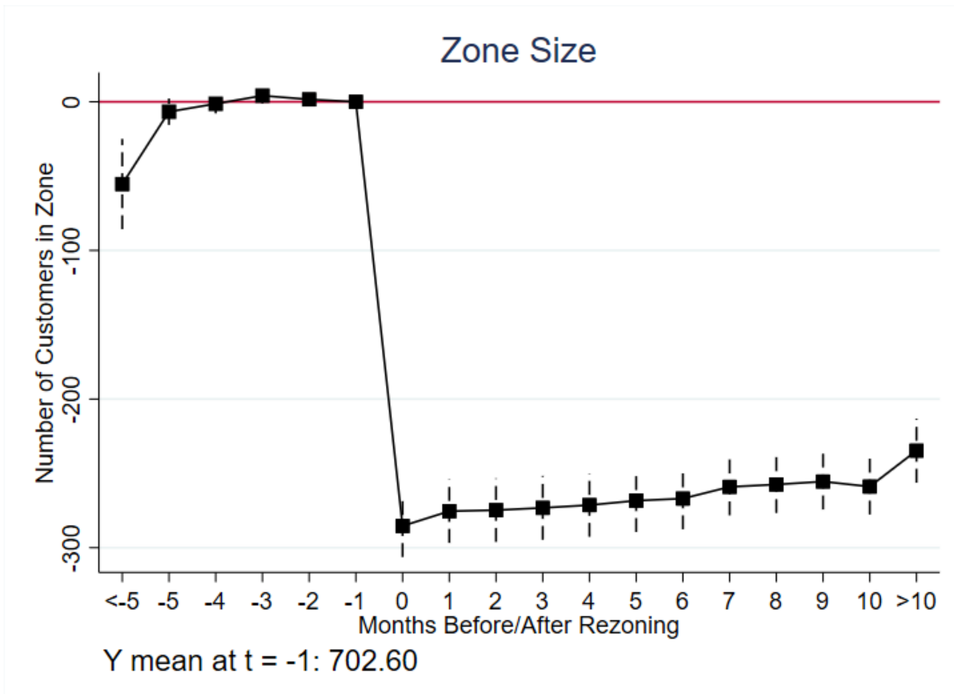


Figure 13: Experimental Variation

(a) Zone 2 in August of 2015 (b) Zone 2 in April of 2019

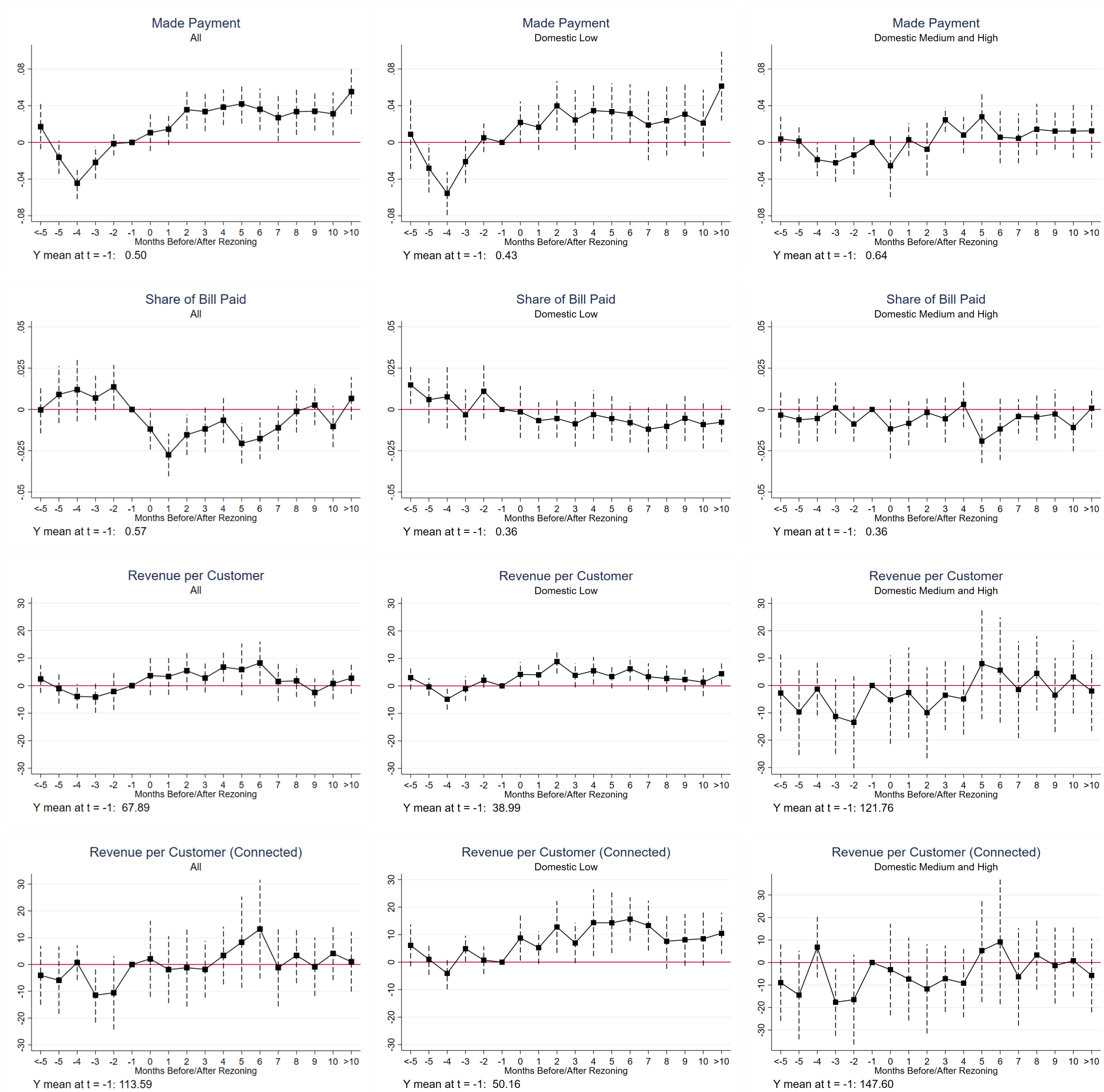
Notes: This figure shows the administrative rezoning event experiment variation. Panel (a) shows the households that are in administrative Zone 2 in August of 2015, and panel (b) shows the households that are in administrative Zone 2 in April of 2019. The two middle subzones were reassigned in November of 2015.

Figure 14: Administrative Rezoning Event Magnitude



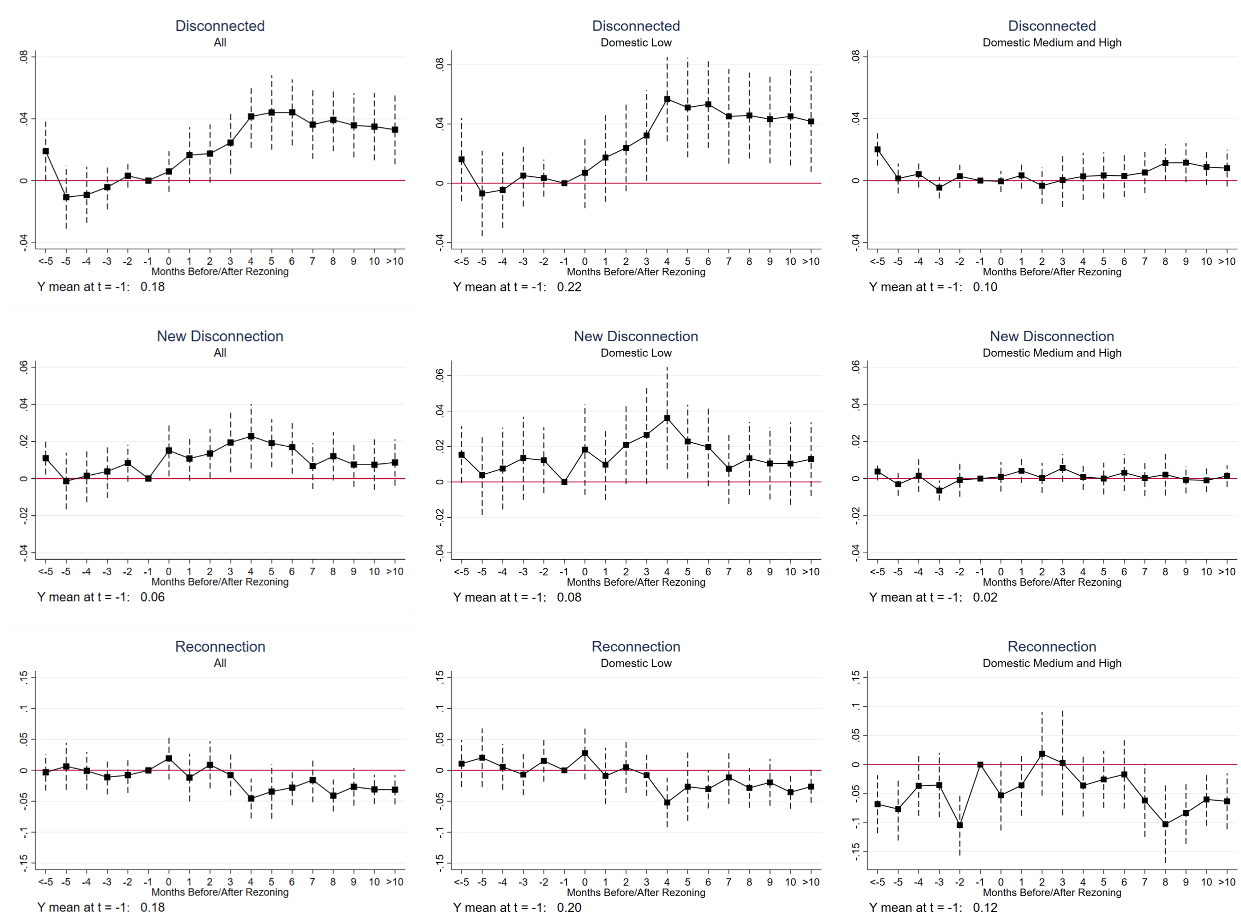
Notes: This figure plots point estimates and 90 percent confidence intervals for event-time dummies in estimating equation 13. The dependent variable is the size (number of customers) in the full administrative zone. The regression includes customer fixed effects and year-by-month fixed effects. The regression controls for changes in metering status, whether the account is new (less than four months old), and the number of customers in a household's 100-meter neighborhood. The omitted event-time dummy is $t = -1$ (the time period immediately before rezoning). Standard errors are clustered at the subzone level.

Figure 15: Event Study Results of Rezoning Events: Payments



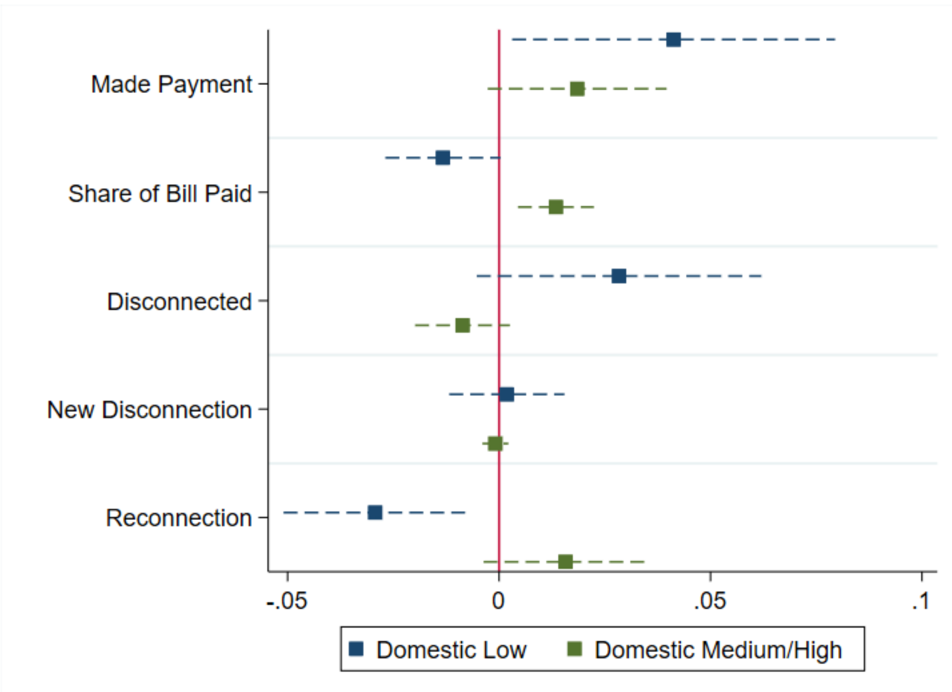
Notes: This figure plots point estimates and 90 percent confidence intervals for event-time dummies in estimating equation 13. All regressions include customer fixed effects and year-by-month fixed effects. All regressions control for changes in metering status, whether the account is new (less than four months old), and the number of customers in a household's 100-meter neighborhood. The omitted event-time dummy is $t = -1$ (the time period immediately before rezoning). The share of current bill paid is the share of the bill paid conditional on making a payment in that month. Regressions of revenue per customer include all connected and disconnected customers in the third panel and only always-connected customers in the forth panel. Standard errors are clustered at the subzone level.

Figure 16: Event Study Results of Rezoning Events: Disconnections



Notes: This figure plots point estimates and 90 percent confidence intervals for event-time dummies in estimating equation 13 separately for Domestic Low and Domestic Medium and High customers. All regressions include customer fixed effects and year-by-month fixed effects. All regressions control for changes in metering status, whether the account is new (less than four months old), and the number of customers in a household's 100-meter neighborhood. The omitted event-time dummy is $t = -1$ (the time period immediately before rezoning). Regressions of new disconnections limit the sample to connected households and the first month of disconnection, and reconnected regressions limit the sample to disconnected households and the first month of reconnection. Standard errors are clustered at the subzone level.

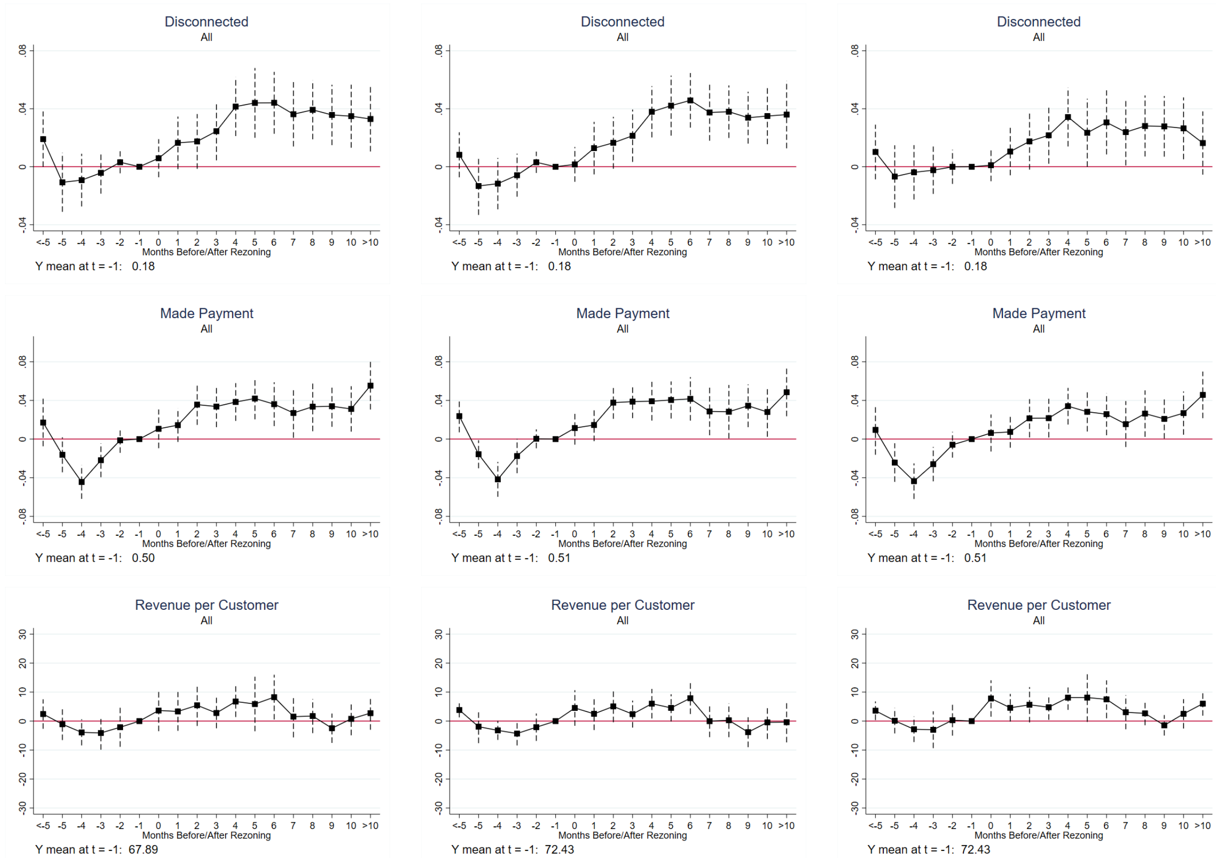
Figure 17: Post Rezoning Event Regressions (Coefficient on Post)



Notes: This figure plots point estimates and 90 percent confidence intervals for the coefficient on $Post_{it}$ in estimating equation 15. The left-side variables are the dependent variables in estimating equation 15, Y_{it}. All regressions include customer fixed effects and year-by-month fixed effects. All regressions control for changes in metering status, whether the account is new (less than four months old), and the number of customers in a household's 100-meter neighborhood. The share of current bill paid is the share of the bill paid conditional on making a payment in that month. Regressions of new disconnections limit the sample to connected households and the first month of disconnection, and reconnected regressions limit the sample to disconnected households and the first month of reconnection. Standard errors are clustered at the subzone level.

Figure 18: Event Study: Robustness to Alternative Models

(a) Original Model (b) Interaction Weighted Estimator (c) Rezoning Events Defined by Area



Notes: This figure presents point estimates and 90 percent confidence intervals for event-time dummies in estimating equation 13 for alternative models. Panel (a) presents results of the model used in the main paper. Panel (b) presents results using the interaction-weighted estimator following the approach detailed in Sun and Abraham (2021) and using the program developed by Sun (2020). Panel (c) presents results when rezoning events are defined by the largest area change that a subzone experiences. All regressions include customer fixed effects and year-by-month fixed effects. All regressions control for changes in metering status, whether the account is new (less than four months old), and the number of customers in a household's 100-meter neighborhood. The omitted event-time dummy is $t = -1$ (the time period immediately before rezoning). Standard errors are clustered at the subzone level.

Table 1: Summary Statistics

Variable	Mean	Std. Dev.	P10	P50	P90
Panel A: Administrative Data (Billing level)					
Comsumption (cubic meters)	19.8	22.88	0	17	37
Total Current Charges (ZMW)	99.96	127.62	0	76.62	210.8
Comsumption|Connected (cubic meters)	23.69	23.11	6	17.33	39.81
Total Current Charges|Connected (ZMW)	119.88	131.66	31.27	90.48	226.8
Outstanding Balance (ZMW)	494.39	896.59	43.89	225.67	1260.79
Total Payments (ZMW)	88.31	184.1	0	50	211
Unmetered	.35	.48	0	0	1
Disconnected	.18	.38	0	0	1
Panel B: Administrative Data (Customer level)					
Domestic Low	.65	.48	-	-	-
Domestic High	.21	.4	-	-	-
Connected to Sewer	.4	.49	-	-	-
Distance to a Pay Station (km)	1.11	.73	.34	.99	1.95
Age of Account (months)	65.09	21.2	29	78	78
Has a Private Borehole	.02	.13	-	-	-
Panel C: Household Survey Data					
Monthly Income (ZMW)	2654.35	3059.83	500	2000	6000
Water Bill Share of Income	.11	.09	.02	.07	.3
Household Owns Property	.55	.5	-	-	-
Household Size	4.83	2.04	2	5	7
Rooms in Household	4.74	2.3	2	5	8
Years of Schooling	12.28	2.38	9	12	16
Number of Sharing Households	.29	1.17	0	0	1
Number of Flush Toilets	.61	.76	0	0	2
Number of Bathtubs/Showers	.61	.76	0	0	2
Indoor Plumbing	.47	.5	-	-	-
Septic Tank	.41	.49	-	-	-
Electricity Connection	.9	.31	-	-	-
Piped Water Primary Source	.98	.14	-	-	-

Notes: Panel A presents summary statistics of the administrative data at the billing level of residential customers from January 2013 to June 2019. Panel B presents summary statistics of the 21,314 residential customers of SWSC as of June 2019. Panel C presents summary statistics of the 2019 randomized survey of 808 households. Water quantity variables are calculated using only metered households. All income, charges, outstanding balance, and payment variables are expressed in Zambian Kwacha (ZMW). 10 ZMW $\approx$ 1 USD. Outstanding balance is the unpaid balance for each customer at the end of the sample period (June 2019). Distance to a Pay Station represents the minimum distance from the household to one of nine pay stations in Livingstone. Water bill share of income represents the average (connected) monthly bill in 2019 divided by the household's monthly income. Years of Schooling is for the household member with the highest education level. Household Size represents the total number of adults and children living in the household at the time of the survey. Number of Sharing Households is the number of additional households that are drawing water from the respondent household's water source.

Table 2: Comparison of Domestic Low and Domestic Medium and High Households

Variable	(1) Domestic Low Mean/SD	(2) Domestic Medium/High Mean/SD	(3) t-test difference (1)-(2)
Panel A: Administrative Data			
Comsumption (cubic meters)	16	27	-11***
	[14.5]	[32.2]	(1.58)
Total Current Charges (ZMW)	71.6	153	-81.7***
	[78.4]	[176]	(10.9)
Outstanding Balance (ZMW)	462	555	-93.2
	[644]	[1236]	(57.1)
Total Payments (ZMW)	60.8	140	-79.1***
	[111]	[265]	(9.87)
Unmetered	.434	.186	.249***
	[.496]	[.389]	(.0406)
Disconnected	.226	.0968	.129***
	[.418]	[.296]	(.0236)
Connected to Sewer	.376	.442	-.0662
	[.484]	[.497]	(.115)
Distance to a Pay Station (km)	1.12	1.08	.0449
	[.71]	[.757]	(.164)
Age of Account (months)	65.3	64.8	.5
	[20.6]	[22.3]	(3.04)
Panel B: Household Survey Data			
Monthly Income (ZMW)	1986	4054	-2068***
	[1628]	[4537]	(328)
Water Bill Share of Income	.126	.076	.0499***
	[.087]	[.0713]	(.00948)
Household Owns Property	.572	.508	.0638
	[.495]	[.501]	(.0472)
Household Size	4.88	4.73	.152
	[2.03]	[2.07]	(.168)
Rooms in Household	3.92	6.34	-2.42***
	[1.98]	[2.03]	(.227)
Number of Sharing Households	.316	.25	.0663
	[1.09]	[1.3]	(.119)
Number of Bathtubs/Showers	.3	1.21	-.907***
	[.563]	[.729]	(.0757)
Indoor Plumbing	.254	.877	-.623***
	[.436]	[.329]	(.0494)
Septic Tank	.312	.598	-.287***
	[.464]	[.491]	(.0573)
Electricity Connection	.861	.964	-.104***
	[.347]	[.186]	(.0267)

Standard errors in parentheses
*p<0.1, **p<0.05, ***p<0.01

Notes: Columns (1) and (2) present the means and standard deviations (in brackets) for relevant administrative and household survey variables for Domestic Low households and Domestic Medium and High households. Column (3) presents the difference in means between Domestic Medium and High households and Domestic Low households and the standard error of this difference. All monetary values are expressed in Zambian Kwacha (ZMW) (10 ZMW $\approx$ 1 USD).

Table 3: Cross Sectional Results

	Made Payment			Revenue per Customer			Disconnection		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ln(Size of Zone)	-0.092***	-0.071**	-0.087**	-5.744	-4.957	-6.763*	-0.054**	-0.058**	-0.059***
	(0.034)	(0.029)	(0.036)	(3.933)	(3.645)	(4.055)	(0.025)	(0.024)	(0.021)
Connections in Neighborhood		0.008***	0.001*		-0.025	-0.299**		-0.000	0.000
		(0.001)	(0.000)		(0.161)	(0.133)		(0.001)	(0.000)
Unmetered		-0.073***	-0.125***		-7.673***	-4.621*		0.075***	0.114***
		(0.013)	(0.010)		(1.840)	(2.391)		(0.008)	(0.008)
New Account		0.186***	0.154***		-26.470***	-39.841***		-0.101***	-0.101***
		(0.012)	(0.017)		(3.314)	(4.982)		(0.018)	(0.018)
Domestic Low			-0.088***			-35.132***			0.056***
			(0.020)			(5.746)			(0.018)
Connected to Sewer			0.095***			28.594***			-0.055***
			(0.019)			(4.318)			(0.015)
Distance to Pay Station			-0.081***			-8.471			0.038**
			(0.022)			(6.685)			(0.018)
Constant	1.211***	0.754***	1.295***	126.858***	125.603***	165.334***	0.500***	0.521***	0.446***
	(0.214)	(0.178)	(0.228)	(24.580)	(22.722)	(27.894)	(0.154)	(0.157)	(0.132)
Year-by-month FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Customer FEs	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Subzone FEs	No	No	Yes	No	No	Yes	No	No	Yes
Observations	1239183	1236747	1236801	1233569	1231211	1231266	1244735	1242211	1242267
Y Mean	0.64	0.64	0.64	90.95	90.92	90.92	0.16	0.16	0.16
$\alpha ln(1.5)$	-0.037	-0.029	-0.035	-2.329	-2.010	-2.742	-0.022	-0.024	-0.024
R Squared	0.38	0.38	0.12	0.21	0.21	0.09	0.44	0.45	0.11

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: The dependent variable in columns (1) - (3) is an indicator for making a payment in that month, the dependent variable in columns (4) - (6) is the total revenue collected per customer, and the dependent variable in columns (7) - (9) is an indicator for the customer being disconnected. The independent variable of interest is the natural log of the size (number of customers) in the full administrative zone. All regressions in columns (2) - (3), (5) - (6), and (8) - (9) control for the number of customers in the household's immediate neighborhood of 100 meters, whether the household has a new account of less than four months, and whether the household is unmetered. All regression results include year-by-month fixed effects. Columns (3), (6), and (9) include subzone fixed effects, and columns (1)- (2), (4) - (5), and (7) - (8) include customer fixed effects. Standard errors are clustered at the subzone level.

Table 4: Comparison of Treated and Control Subzones

Variable	(1) Rezoned Mean/SD	(2) Not Rezoned Mean/SD	(3) t-test difference (2)-(1)
Growth in Subzone (past 3 months)	.0283	.0227	-.00557
	[.0718]	[.175]	(.0213)
Growth in Subzone (past 6 months)	.1	.0498	-.0505
	[.239]	[.313]	(.0381)
Growth in Subzone (past 9 months)	.132	.0779	-.0544
	[.272]	[.461]	(.056)
Growth in Subzone (past 12 months)	.253	.106	-.147
	[.464]	[.609]	(.09)
Share Domestic Low	.571	.621	.0507
	[.471]	[.451]	(.051)
Share Disconnected	.161	.174	.0125
	[.159]	[.142]	(.0161)
Share Unmetered	.514	.386	-.128***
	[.337]	[.318]	(.036)
Share New Accounts	.0388	.0169	-.022***
	[.119]	[.06]	(.00689)
Share Connected to Sewer	.329	.468	.14***
	[.391]	[.405]	(.0458)
Average Distance to Pay Station	1.51	1.16	-.35***
	[1.06]	[.949]	(.107)
Observations	79	7,589	8,138

Standard errors in parentheses
*p<0.1, **p<0.05, ***p<0.01

Notes: Columns (1) and (2) present the means and standard deviations (in brackets) for relevant administrative variables for subzones that were rezoned and subzones that were not rezoned in the three months before or after. Column (3) presents the difference in means between the rezoned and not rezoned subzones and the standard error of this difference. Growth variables indicate the growth in the number of customers over the past x months and is calculated as follows: $(Y_t - Y_{t-x})/Y_{t-x}$.

Table 5: Post Rezoning Event Regression Results

	Made Payment			Revenue per Customer			Disconnection		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Post Rezoning Event	0.070***	0.036**	0.036***	3.320	1.927	8.833***	0.007	0.019	0.010
	(0.018)	(0.017)	(0.011)	(2.175)	(2.147)	(2.586)	(0.014)	(0.014)	(0.011)
Connections in Neighborhood		0.008***	0.001		-0.044	-0.322**		-0.001	0.000
		(0.001)	(0.000)		(0.164)	(0.133)		(0.001)	(0.000)
Unmetered		-0.070***	-0.113***		-7.541***	-2.758		0.076***	0.118***
		(0.013)	(0.010)		(1.861)	(2.680)		(0.009)	(0.009)
New Account		0.188***	0.169***		-26.431***	-40.874***		-0.101***	-0.071***
		(0.012)	(0.018)		(3.287)	(4.829)		(0.018)	(0.011)
Domestic Low			-0.087***			-35.190***			0.056***
			(0.020)			(5.880)			(0.018)
Connected to Sewer			0.095***			28.333***			-0.055***
			(0.019)			(4.256)			(0.015)
Distance to Pay Station			-0.081***			-8.505			0.038**
			(0.023)			(6.699)			(0.018)
Constant	0.616***	0.317***	0.888***	89.906***	94.765***	62.963	0.163***	0.157***	0.145
	(0.006)	(0.061)	(0.266)	(0.686)	(7.055)	(50.580)	(0.004)	(0.039)	(0.174)
Year-by-month FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Customer FEs	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Subzone FEs	No	No	Yes	No	No	Yes	No	No	Yes
Observations	1239182	1236746	1236800	1233568	1231210	1231265	1244734	1242210	1242266
Y Mean	0.64	0.64	0.64	90.95	90.92	90.92	0.16	0.16	0.16
R Squared	0.38	0.38	0.12	0.21	0.21	0.09	0.44	0.45	0.11

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: The dependent variable in columns (1) - (3) is an indicator for making a payment in that month, the dependent variable in columns (4) - (6) is the total revenue collected per customer, and the dependent variable in columns (7) - (9) is an indicator for the customer being disconnected. The independent variable of interest is an indicator for periods after the subzone is rezoned. All regressions in columns (2) - (3), (5) - (6), and (8) - (9) control for the number of customers in the household's immediate neighborhood of 100 meters, whether the household has a new account of less than four months, and whether the household is unmetered. All regression results include year-by-month fixed effects. Columns (1)- (2), (4) - (5), and (7) - (8) include customer fixed effects. Columns (3), (6), and (9) include subzone fixed effects and additionally control for whether the customer is Domestic Low, has a sewer connection, and the distance to the nearest pay station. Standard errors are clustered at the subzone level.

Table 6: Back of Envelope Calculations of Net Revenue

	Revenue per Customer				
	(1)	(2)	(3)	(4)	(5)
Post Rezoning Event	3.050	3.320	1.928	9.272***	8.830***
	(10.353)	(2.175)	(2.147)	(2.594)	(2.591)
Year-by-month FEs	Yes	Yes	Yes	Yes	Yes
Customer FEs	No	Yes	Yes	No	No
Subzone FEs	No	No	No	Yes	Yes
Controls	No	No	Yes	No	Yes
Total Additional Monthly Revenue	2813	3062	1778	8551	8144
Additional Monthly Enforcement Costs	5651	5651	5651	5651	5651
Net Revenue From Enforcement	-2838	-2589	-3873	2900	2493
Observations	1233624	1233569	1231211	1231266	1231266
Y Mean	90.95	90.95	90.92	90.92	90.92
R Squared	0.01	0.21	0.21	0.09	0.09

* $p < .10$, ** $p < .05$, *** $p < .01$

Notes: The dependent variable in all regressions is total monthly payments made. All columns include year-by-month fixed effects. Columns (2) and (3) include customer fixed effects, and columns (4) and (5) includes subzone fixed effects. Columns (3) and (4) control for metered status of the customer, whether the account is new, and the number of local connections in the household's neighborhood. Column (4) additionally controls for whether the household is Domestic Low, is connected to the sewer, and the distance to the nearest pay station, and column (5) additionally controls for the share of unmetered and new accounts in the subzone. Total additional monthly revenue is calculated by multiplying the regression coefficient by the average number of treated residential customers in the month of the rezoning event. Additional enforcement costs are calculated using the CSA wage in 2016 multiplied by 1.9 (the average number of additional enforcement agents hired during rezoning). Net revenue from increase enforcement represents the difference between the total additional monthly revenue and addition enforcement costs. All monetary values are expressed in Zambian Kwacha (ZMW). 10 ZMW $\approx$ 1 USD.

Table 7: Household Survey Balance Checks

Variable	(1) Unsurveyed Mean/SD	(2) Surveyed Mean/SD	(3) t-test difference (2)-(1)
Total Current Charges (ZMW)	141	139	-1.68
	[122]	[96.1]	(5)
Outstanding Balance (ZMW)	494	493	-1.57
	[894]	[966]	(32.7)
Total Payments (ZMW)	95.3	94.7	-.658
	[109]	[91.2]	(4.12)
Domestic Low	.652	.663	.0108
	[.476]	[.473]	(.0183)
Unmetered	.295	.286	-.0081
	[.456]	[.452]	(.0133)
Disconnected	.226	.213	-.0135
	[.418]	[.41]	(.0153)
Connected to Sewer	.397	.467	.0705***
	[.489]	[.499]	(.0171)
Age of Account (months)	65	68	3***
	[21.3]	[18.3]	(.71)
Has a Private Borehole	.018	.0107	-.00729
	[.133]	[.103]	(.00481)
Observations	20,616	747	21,363

Standard errors in parentheses
*p<0.1, **p<0.05, ***p<0.01

Notes: Columns (1) and (2) present the means and standard deviations (in brackets) for relevant administrative data for unsurveyed and surveyed customers from January, 2019 to June, 2019. Outstanding balance represents the remaining unpaid balance for customers at the end of the survey period (June, 2019). Column (3) presents the difference in means between the unsurveyed and surveyed population and the standard error of this difference. Standard errors are clustered at the randomization stratification variable level, the administrative billing zone. All income, charges, outstanding balance, and payment variables are expressed in Zambian Kwacha (ZMW). 10 ZMW $\approx$ 1 USD.

D Mathematical Appendix

I solve the first order condition of equation 7 below.

$$0 = \frac{\partial V(A_t, d_t)}{\partial p_t} = \frac{\partial u_t}{\partial p_t} + \beta \frac{\partial \mathbb{E}_t V(A_{t+1}, d_{t+1})}{\partial A_{t+1}} \frac{\partial \phi}{\partial p_t}$$

$$0 = -1 - \beta \frac{\partial}{\partial A_{t+1}} \Big[(1 - P_{t+1}) V(A_{t+1}, 0) + P_{t+1} V(A_{t+1}, 1) \Big]$$

$$\frac{-1}{\beta} = \lambda_A (1 - P_{t+1}) V(A_{t+1}, 0) + (1 - P_{t+1}) V'(A_{t+1}, 0) - \lambda_A (1 - P_{t+1}) V(A_{t+1}, 1) + P_{t+1} V'(A_{t+1}, 1)$$

$$P_{t+1} = \frac{\lambda_A V(A_{t+1}, 1) - \lambda_A V(A_{t+1}, 0) - V'(A_{t+1}, 0) - \frac{1}{\beta}}{\lambda_A V(A_{t+1}, 1) + V'(A_{t+1}, 1) - \lambda_A V(A_{t+1}, 0) - V'(A_{t+1}, 0)}$$

$$1 - exp(-\lambda_A (A_t + a_t w_t - p_t - \underline{A}) - \lambda_e e_{t+1}) \\ = \frac{\lambda_A V(A_{t+1}, 1) - \lambda_A V(A_{t+1}, 0) - V'(A_{t+1}, 0) - \frac{1}{\beta}}{\lambda_A V(A_{t+1}, 1) + V'(A_{t+1}, 1) - \lambda_A V(A_{t+1}, 0) - V'(A_{t+1}, 0)}$$

$$-\lambda_A (A_t + a_t w_t - p_t - \underline{A}) - \lambda_e e_{t+1} \\ = ln \left(\frac{\frac{1}{\beta} + V'(A_{t+1}, 0) + \lambda_A [V(A_{t+1}, 0) - V(A_{t+1}, 1)]}{\lambda_A [V(A_{t+1}, 1) - V(A_{t+1}, 0)] + V'(A_{t+1}, 1) - V'(A_{t+1}, 0)} + 1 \right)$$

$$p_t^* = A_t + a_t w_t - \underline{A} + \frac{\lambda_e}{\lambda_A} e_{t+1} \\ + ln \left(\frac{\frac{1}{\beta} + V'(A_{t+1}, 0) + \lambda_A [V(A_{t+1}, 0) - V(A_{t+1}, 1)]}{\lambda_A [V(A_{t+1}, 1) - V(A_{t+1}, 0)] + V'(A_{t+1}, 1) - V'(A_{t+1}, 0)} + 1 \right) / \lambda_A$$