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Financing Municipal Water and Sanitation Services in Nairobi's Informal Settlements

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Abstract

This study estimates the impacts of two interventions implemented as field experiments in informal settlements by Nairobi's water and sanitation utility to improve revenue collection efficiency and last mile connection loan repayment: (i) face-to-face engagement between utility staff and customers to encourage payment and (ii) contract enforcement for service disconnection due to nonpayment in the form of transparent and credible disconnection notices. While there is no effect of the engagement, the study finds large effects of enforcement on payment. There is no effect on access to water, perceptions of utility fairness or quality of service delivery, on the relationships between tenants and property owners, or on tenant mental well-being nine months after the intervention. To counterbalance the increase in payments, property owners increased rental income by renting out additional space. Taken together these results suggest that transparent contract enforcement was effective at improving revenue collection efficiency without incurring large social or political costs.

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1 Introduction

Some 844 million people lack clean drinking water and 2.4 billion people do not have improved sanitation, most of which are living in low- and middle-income countries (LMICs).[1] An estimated US$ 1.7 trillion is needed to finance the goal of universal access by 2030 (Hutton and Varughese, 2016). With two-thirds of the world's population expected to live in cities by 2050, finding scalable and sustainable solutions to expand reliable urban water and sanitation services is critical. However, basic service provision is not keeping up with rapid urbanization. Africa's cities, for instance, grew by 80% between 2000 and 2015, while access to piped water declined from 40% to 33% (World Bank, 2017).

The primary route for expanding services in urban areas is through public utilities, but utilities are struggling to deliver reliable services to connected households let alone increase coverage (Trimble et al., 2016; World Bank, 2017; Soppe et al., 2018). Revenue collection has become a major stumbling block for utility performance (Ahluwalia, 2002; World Bank, 2017). Losses from nonpayment of service use bills are significant. Utilities worldwide failed to collect an estimated US$ 39 billion of billable water and US$ 96 billion in electricity charges each year (Liemberger and Wyatt, 2019; Northeast Group, 2017). Nonpayment for services lowers effective prices, and when effective prices fall below marginal cost, each new customer becomes a financial liability and may lead to rationing (Burgess et al., 2020; McRae, 2015).[2] Water rationing is not only inconvenient but can have negative impacts on health (Galiani et al., 2005; Ashraf et al., 2021). There is well-documented concern over service quality degradation worldwide from poorly maintained infrastructure, and the vicious cycle between low payment and deteriorating quality of services (Jiménez and Pérez-Foguet, 2011; Cronk and Bartram, 2017; Foster et al., 2020; Dzansi et al., 2018; World Bank, 2017).

More financial stress comes from the problem of paying for the significant last mile connection costs that constrain household access to the utility's services (WaterAid, 2007; Golumbeanu and Barnes, 2013; Lee et al., 2020). Significant investments in urban trunk infrastructure are underutilized when households close to water and sewer lines do not connect (Kennedy-Walker et al., 2020). While subsidies have been effective at increasing household connections (Lee et al., 2020; Guiteras et al., 2015), they are costly, potentially regressive, and are limited by public budget constraints (Abramovsky et al., 2020).

Providing credit to households to amortize upfront connection costs offers an attractive

[1] World Bank (water): https://www.worldbank.org/en/topic/watersupply; World Bank (sanitation): https://www.worldbank.org/en/topic/sanitation

[2] Many utilities have tariffs that even when fully paid do not cover operating costs, and, in settings where only a minority have access to piped services, introduce a regressive subsidy in favor of connected households (Abramovsky et al., 2020).

alternative to subsidies. For example, the provision of credit increased piped water connection rates in Morocco by 69% (Devoto et al., 2012). To overcome thin credit markets, utilities are taking out commercial loans that they use to finance loans from the utility to customers. Customers then repay these loans through additional installment payments to their monthly bills. There is, however, an inherent financial risk to utilities if customers do not repay their loans. Nonperforming loans must be paid for through either service degradation or out of general tax revenues.

In Nairobi, until recently, household-level piped water and sanitation were not available to residents living in informal settlements. Settlement residents, who make up an estimated 60% of Nairobi's population, typically live in multi-household compounds with a shared pit latrine and purchased water from utility public water kiosks and private vendors. In 2014, Nairobi's utility began expanding compound-level piped water and sanitation services to informal settlements. Compounds were offered a combination of subsidies and loans to finance the US$ 1,100 cost of connection to the new trunk lines. This consisted of a US$ 750 (69%) subsidy and a loan for the rest. The utility obtained a commercial loan that they used to finance the loans to property owners. Property owners then agreed to repay the loan to the utility over time by adding installment payments to their monthly water and sewerage bills. Between 2014 and 2018, the utility expanded services to 137,000 previously unconnected people in informal settlements (World Bank, 2019).

However, after the expansion, the utility experienced significantly lower revenue collection than originally anticipated. In 2016, 40% of the newly connected property owners had yet to make a single service or loan payment and the average share of bills and loans paid fell from above 65% in 2014 to below 50% in 2018 (Figure 1). Service quality also deteriorated over this period from 95% of compounds with piped water reporting having received service in the past week in 2014 to 40% in 2018. In response, the utility considered two strategies to improve revenue collection: (i) an engagement approach to encourage payment; and (ii) service contract enforcement that allowed for disconnection for nonpayment.[3] Both approaches are commonly used by utilities around the world to improve revenue collection efficiency, but limited evidence exists on their costs and benefits (Hernandez and Laird, 2019; Szabó and Ujhelyi, 2015). In this paper we report on the results of a field experiment designed to test both strategies.

The first approach was a face-to-face meeting between tenants and the utility's existing outreach team to explain the financial status of the water and sewer bill, the consequences for

[3]The utility requested support from the research team based on a long-standing relationship that began in 2012 related to the last mile connection issues. See appendix for a description of the other interventions designed to enhance revenue collection considered at the time.

the utility, and discuss what they could do to encourage property owners to make payment. The idea was to empower renters to discuss such matters with property owners because service disconnection would be a violation of their rental agreements as 93% of tenants had piped water included in their rent. While the utility had primarily targeted property owners in their previous outreach efforts, this new approach was designed to strengthen bottom-up accountability.

The second approach was to systematically enforce the terms of the contract that the property owners had signed with the utility, specifying service disconnection for property owners with significant payment arrears.[4] Prior to the study, 82% of property owners were eligible for disconnection under the contract's terms, which made implementation of the *de jure* policy infeasible. As a result, the *de facto* application of the disconnection policy was *ad hoc*, which could potentially limit contract enforcement effectiveness and create opportunities for extortion (Ashraf et al., 2016). Given the significant subsidy and loans given to property owners for last mile connections and the importance of the sustainability of service quality, the utility was in the process of systematizing contract enforcement to improve revenue collection.

Contract enforcement is key to sustaining the rule of law and the process of economic development (Glaeser and Shleifer, 2002). However, contract enforcement was potentially risky for both the utility and for its customers. From the utility's perspective, enforcement would be effective if it improved payment and social costs were low. Currently connected residents would benefit if the utility used the new revenues to improve service quality. Currently unconnected residents would benefit if enhanced revenue collection were used to expand connections. However, households that are disconnected could face added burdens in the form of increased cost and reduced access to water sources. The utility might also face increased customer dissatisfaction with perceived fairness and service quality leading to loss of political support for the utility and government.

These potential risks motivated the utility to pilot enforcement to better understand the costs and benefits. In practice, this meant exempting from disconnection a set of compounds who otherwise would have been considered for disconnection to serve as a control group, while ensuring compounds in the treatment group followed a clearly articulated contract enforcement implementation plan. The criteria for disconnection were set at a substantially higher level of nonpayment than specified in the contracts for more selective targeting. Enforcement was then implemented along a strict selection protocol governed by (1) systematic identification of all disconnection-eligible compounds, (2) randomly selecting a subset to receive

[4]Service disconnection for nonpayment was explicitly specified in the contract signed by property owners when they agreed to receive the infrastructure upgrades to their property.

disconnection notices with clear instructions on how to pay or appeal for a financial hardship exemption, (3) allowing a reasonable period of time for property owners to pay or appeal, and (4) disconnecting services if they did not pay at least some of their outstanding bill in a timely fashion or apply for a financial hardship exemption.

The intervention was implemented in a context where water and sanitation charges were affordable, i.e., significantly below the 3% (water) and 5% (water and sanitation) thresholds of monthly income for service affordability set by the United Nations (United Nations, 2010). In addition, alternative water sources were available through utility-run public kiosks and private vendors, which were the primary sources of water prior to the 2014 expansion of utility piped water. During the intervention rollout, the utility maintained a transparent and convenient process through which property owners could delay payment and disconnection in the case of financial distress.[5]

Using administrative data from the utility's electronic billing and payment system, we find that contract enforcement significantly increased both the likelihood of property owners making a payment, and the overall amount paid. However, most of the change in payment behavior took place shortly after enforcement took place, with no evidence of further increases over time. This could be because the enforcement intervention was implemented as a one-time policy and not as a permanent change. We also find no evidence of spillover effects in the form of improved payment behavior among control property owners with compounds in treatment clusters. The face-to-face engagement intervention had a precisely estimated null effect.

In addition to the observed payment behavior, we did not find evidence that tenants were negatively affected nine months after implementation of the enforcement intervention. Using survey data, we find that water and sanitation service connections were not meaningfully different between treatment and control compounds. This is because most property owners whose service was disconnected were reconnected after agreeing to a payment plan. During service interruptions tenants had access to water from kiosks operated by the utility and private vendors and reported no reductions in water use nor increase in spending on water. Moreover, we do not find evidence that the disconnection policy negatively affected either tenants' or property owners' perceptions of fairness and quality of water service delivery, nor did the policy affect the relationships of tenants and property owners. Finally, tenants were no more likely to move out.

To counterbalance the effective increase in utility fees paid, property owners increased their rental income predominantly by renting out additional space. Together, these results suggest that the transparent contract enforcement of the disconnection policy increased pay-

[5]More details related to the study's ethical considerations can be found in the appendix.

ment and improved the financial position of the utility without incurring any observed social costs on the tenants and property owners or political costs to the utility.

2 Contributions to the Literature

A significant body of research explores approaches to expanding access to services. With a few exceptions (Devoto et al., 2012; Galiani et al., 2005), this work predominantly focuses on rural settings (Lee et al., 2020; Whittington et al., 2020).[6] Problems with both expanding access and service quality can be linked back to financial constraints. Our work adds to the literature testing strategies to improve payment behavior and thereby relaxing financial constraints on service delivery.

Despite the frequent use of service disconnections for nonpayment by utilities worldwide,[7] to our knowledge, there are no experimental studies that estimate their potential impact. Jack and Smith (2020) explore the role of pre-paid electricity meters on service payments and consumption patterns in South Africa. Pre-paid meters offer a technical solution to payment problems by ensuring that customers only receive service if they provide upfront payment rather than more standard post-paid systems and can be programmed to include loan repayments. In effect, users are disconnected if they do not prepay. The study found that switching to pre-paid meters reduced electricity usage by 14 percent, but still increased overall municipal revenue through improved revenue collection. Pre-paid meters for water were piloted in a few middle-income neighborhoods in Nairobi but were abandoned because of vandalism and high fixed costs of installation (Heymans et al., 2014).

There is some limited evidence that outreach campaigns improve service payment. Szabó and Ujhelyi (2015) find that simply delivering a payment "education campaign" increased payment rates by 25% in an informal settlement in South Africa, although the effects were short-lived. Rockenbach et al. (2019) find that information campaigns designed using psychological commitment techniques increase payment by between 30-61%, but again only had short run effects. More broadly, interventions that try to improve bottom-up accountability – typically from communities to place pressure on service providers - have mixed results that may be influenced by the heterogeneity of these groups and the existing top-down accountability measures in place (Björkman and Svensson, 2010; Olken, 2007; Serra, 2012).

[6]Increasing sanitation coverage in rural area has been challenging when relying purely on behavioral change approaches (Briceño et al., 2017; Cameron et al., 2019), and there has been more traction when this is combined with financial subsidies, although this increases program costs (Clasen et al., 2014; Guiteras et al., 2015).

[7]For example, an estimated 15% of households in the United States received service disconnection notices and 3% were disconnected in 2015 (Hernandez and Laird, 2019).

Observational studies provide insights into determinants of service payment behavior such as households strategically delaying payment as a form of credit (Violette, 2020) or the perceived ease of payment and social pressure being associated with prompt payment (Mugabi et al., 2010). While experimental work on improving utility revenue collection has started to grow, these papers mostly rely on administrative billing and basic demographic data to assess impacts and typically limit their attention to two dimensions – payment and consumption behavior (Allcott, 2011; Jack and Smith, 2020; Szabó and Ujhelyi, 2015; Rockenbach et al., 2019). Our study combines five years of daily administrative billing data with rich primary survey data from property owners and tenants over the course of three years on a range of outcomes that helps present a more comprehensive assessment of the potential welfare implications of utility interventions.

Our study also contributes to the high-stakes contract enforcement approaches to improving regulatory compliance. The evidence on high-stakes contract enforcement is particularly limited, especially when compared to lighter-touch information/engagement interventions. The existing evidence on enforcement is mostly limited to developed country settings, most prominently in the tax evasion literature (Slemrod et al., 2001; Kleven et al., 2011), and to a lesser extent in environmental protection (Telle, 2013; Duflo et al., 2018). The small number of studies exploring high-stakes enforcement in developing countries find significant impacts. In Brazil, de Andrade et al. (2016) randomize inspections and fine firms if they are found to be operating without a business license and find that the intervention increases business registrations. In Costa Rica, Brockmeyer et al. (2019) find significant increases in tax payments from credible enforcement emails. In Kenya, Bedoya et al. (2021) randomize a regime of high-intensive inspections of health facilities with enforcement of warnings and sanctions, including the risk of closure if they do not have a license to operate. These inspections successfully increase compliance with minimum patient safety standards for all types of facilities without increasing patients' payments or reducing facility use.

3 Institutional Context

Like many LMICs, Kenya's constitution established the right to "reasonable standards of sanitation" and "clean and safe water in adequate quantities", and Kenya's Vision 2030 set a goal of universal water and sanitation coverage. Achieving this vision faces important challenges. Nairobi's urban population has tripled over the past 25 years,[8] but access to safely managed water fell from 62% in 2000 to 50% in 2017.[9] Water supply for existing customers

[8] UN population dynamics data 2021

[9] Joint Monitoring Program data: https://washdata.org/data/household!/

was only able to meet about 70% of demand and even that is with intermittent supply (NCWSC, 2017).[10] Like in many developing countries, sanitation coverage is significantly lower than water access, with approximately 18% of Kenya's urban residents having a sewer-connected facility (Kenya National Bureau of Statistics et al., 2015).

3.1 Expansion into Informal Settlements

Nairobi's water services board, Athi Water Works Development Agency, expanded water and sanitation trunk lines into many of Nairobi's informal settlements between 2012 and 2016. After the trunk infrastructure was in place, Nairobi's water and sanitation utility could offer compound-level connections to the piped system. Property owners were able to connect their compounds to the trunk lines by signing a contract agreeing to be responsible for paying water and sanitation consumption and loan charges, and to service disconnection in the event of nonpayment. The utility offered each property owner a comprehensive infrastructure upgrading package including (i) upgrading of existing latrines to be connection-ready including filling pit latrines and building superstructures where needed; (ii) a single piped water connection to the compound; (iii) a wash basin; (iv) a 400-liter water storage tank for when supply was temporarily unavailable; and (v) the physical connection of the latrine(s) to the newly built sewerage line.[11]

The unsubsidized cost of this full package was approximately US$ 1,100 – twice the average monthly income of property owners in the target areas. The World Bank provided grant financing to reduce the connection costs by 69%, and the utility took commercial loans to finance loans from the utility to property owners for the rest. Property owners paid off the loans in monthly installments of US$ 6 (US$ 4.50 for sewer and US$ 1.50 for water) added to the monthly service use bills.[12] This was offered to property owners on a voluntary opt-in basis, if they agreed to the terms of the contract and paid a US$ 16 upfront deposit. Since these monthly loan installments were highly affordable – representing 1.1% of property owner income on average – over 90% of property owners agreed to participate.[13] This resulted in an estimated 137,000 people living in Nairobi's informal settlements gaining

[10]While significant investments to expand water supply to the city are underway, rationing is expected to continue. This limited supply is exacerbated by cartels that damage utility infrastructure and control water supply in some parts of the city. Cartels were not active in the specific study areas during the time of the research (World Bank, 2019).

[11]The water connection program started prior to the sanitation expansion. Compounds started receiving water connections from 2014, but only started receiving sanitation connections from 2016. Investment in the water connection was a prerequisite for sanitation upgrading.

[12]We use an exchange rate of 1 USD = 100 KES throughout.

[13]These loan installment payments were lower than the drudging cost of pit latrines, about US$ 8.00 per month, that many residents used prior to trunk line services.

access to compound-level piped water and sewer services between 2014 and 2018 (World Bank, 2019).

The model to finance the last mile connection costs relied on the assumption that property owners would repay their loans and pay the monthly service fees. During the course of the program, however, it became clear that that the utility faced critical nonpayment issues. In 2016, 40% of connected property owners had yet to make a single service payment or loan installment even though the average property owner had already been connected for 1.3 years. Moreover, the average share of bills and loans paid fell from above 65% in 2014 to below 50% in 2018 (Figure 1).[14] Service quality deteriorated substantially over this time period, including a city-wide rationing program that started in early 2017. Based on data collected from a panel survey of 587 households from one of the settlements, the proportion of compounds that received water from their water point in the week prior to the survey fell from 95% to 40% between 2014 and 2018.[15]

3.2 Compounds and Residents

Characteristics of property owners and tenants living in one such informal settlement, Kayole Soweto, are presented in Table 1 for owners and Table 2 for tenants.[16] In Kayole Soweto, almost all property owners are sole owners of their compounds with self-reported sales' values of about US$ 20,000 on average. Property owners are 51 years old, are 60% male, 54% have completed secondary education or higher, and make US$ 551 in income per month on average from all sources.

Property owners rent out space in 86% of the compounds and make the compound their principal residence in about half. On average, the rental compounds have 7.7 distinct rental rooms, and generate US$ 115 per month in total rent per compound, or US$ 83 in income after deducting expenses. Approximately three quarters of tenants have written or verbal month-to-month rental agreements and paid a deposit in 47% of the cases. Eighty percent of individual tenancy rents fall between US$ 15 and US$ 35 per month and averages US$ 25. A tenant makes US$ 137 on average in income per month which translates into an average total compound renter income of US$ 1,306.

The primary source of water in the informal settlement is piped water. The utility connects a single piped water and sewer line that serves the entire compound which is considered a single customer. The property owner is responsible for paying the water and

[14]The program target was an 80% collection rate, which is consistent with the Kenyan regulator guidelines.

[15]We use data from a listing exercise that we conducted in 2014 and combine this with an updated listing exercise conducted by the utility in 2018 which is described in further detail in Section 7.

[16]Based on a survey of property owners and a random sample of their tenants conducted in Kayole Soweto in 2015/2016.

sanitation bill, and these services are explicitly included in the rent in 93% of the compound rental agreements. Customers use Jisomee Mita, a web-based ICT platform that enabled property owners to use a mobile phone to self-read meters, receive and pay water bills, and check their current balance at any time. While 80% of compounds have a piped water connection, 7% report that their connection is not working. Because many households are unable to access piped water in their homes, the utility also operates water kiosks where residents can purchase clean water at a regulated price of US$ 0.2 per kiloliter.

3.3 Utility Charges and Reasons for Nonpayment

Piped water is affordable relative to income in this setting. In 2016 the average monthly water service bill for Kayole Soweto property owners was US$ 4.20, which accounts for 3.6% of compound rent, 0.3% of total compound resident income, or 1.1% of property owner income. An additional US$ 6 per month was charged by the utility to repay the water connection loan (US$1.50 for 30 months) and the sanitation loan (US$ 4.50 for 60 months). Sanitation services were charged at 70% of the water consumption bill. Even with the inclusion of the loan repayment, the total monthly contribution is significantly lower than the 3% threshold used by the United Nations to assess water affordability and 5% threshold including sanitation (United Nations, 2010). However, even with reliable service and affordable tariffs, nearly 40% of property owners had yet to make a single payment for services since being connected 1.3 years ago on average and the average time since the last payment was made was 6 months. As a result of this nonpayment, property owners owed US$ 24 on average for past water use and behind on US$ 38 of their infrastructure loan repayments.

Why did property owners not pay their loans or consumption bills? Figure 2 presents property owner self-reported reasons for (i) not making a payment in the last 2 months and (ii) never making a payment based on self-reported data collected from a 2018 survey of 5,091 property owners in six settlements. Service quality was the most cited reason for nonpayment, reported by about half of respondents, lack of liquidity was the second most cited reason, and third was not knowing how to make payments. The payment system and billing infrastructure were not a perceived constraint.

Next, we look at correlates with payment behavior within a regression framework, using the 2018 survey data merged with the utility administrative billing data. The sample consists of compounds that (i) have a water connection and (ii) have tenants. The dependent variables include whether the property owner ever made a payment; (ii) the proportion of bills paid; (iii) the outstanding proportion of water connection loan; and (iv) whether the loan has been fully paid.

Two takeaways are clear from the results presented in Table 3. First, the associations are consistent with reasonable priors: Property owners receiving better service, living on the property, and more knowledgeable about payment procedures have better payment practices – for both loans and consumption charges. Second, self-reported reasons for nonpayment appear consistent with actual behavior measured in the regression analysis but also overestimate the role of some factors. Service quality is presented as the single most important self-reported reason for nonpayment. While the regression analysis identifies this as an important contributor, it explains a substantially smaller amount of variation in payments than the self-reported reasons for nonpayment.

Another factor that may influence payment behavior is accountability and enforcement. The official policy of the utility allows for disconnection of water services if a property owner is more than 30 days in arrears and has not responded to a formal notice after 15 days. Property owners are notified and given at least 15 days to pay before service is cutoff or to appeal for a delay in payment based on financial difficulty. Property owners are informed of and consent to this remedy in their service contracts that they sign at the time of connection. In practice, implementation of the disconnection policy was partial and *ad hoc* in terms of determining which of the eligible property owners would be disconnected. The disconnection policy is challenging to implement in informal settlements because of the potential for social and political costs associated with disconnections, the potential for some property owners not to be able to pay due to financial constraints, and the sheer size of the problem: 82% of property owners were eligible for disconnection based on the formal policy, as of July 2018.

4 Interventions

To ensure basic information constraints were not to blame for low payment rates, an initial awareness campaign was rolled out by the utility to all property owners in the six targeted Nairobi informal settlements in August and September 2018. The utility delivered the following activities in sequence: (i) A phone call to the property owner to collect up-to-date contact information, provide basic information on how to read meters and pay bills, and share their latest account balance on record; (ii) an on-site meter reading to ensure accurate billing records; and (iii) an SMS to property owners providing the account balance based on the meter reading.

Two additional approaches to encourage payment were rolled out experimentally by the utility. The first was an engagement intervention in which compounds in payment arrears received a face-to-face visit from the utility informing tenants about the current balance, how payments could be made, and the importance of ensuring the property owner makes

payment for the utility to be able to provide quality service and avoid disconnection. Utility staff followed a specific script loaded onto a tablet during each visit to ensure uniformity in intervention delivery (see appendix). This intervention took place during September and October of 2018 after the initial awareness campaign described above.

The second approach applied contract enforcement of the disconnection policy for non-paying property owners. Compounds in payment arrears were given official notification that they had to make payment, or their services would be disconnected.[17] This intervention included the following steps to ensure enforcement was targeted, transparent, fair and credible:

Targeting: Among disconnection-eligible property owners in treatment areas, a tighter selection rule was applied than the official policy to target those in significant arrears. Disconnection eligibility was determined by the number of months a property owner had not paid, and the outstanding balance. This differed slightly by settlement. All property owners needed to have an outstanding consumption balance of more than US$ 25, or around six months of consumption charges for the average compound. This typically meant that they would also be behind in paying their service connection loan. In addition, property owners in two settlements where the program had first started operating needed to have missed at least the past three months of service payments, while property owners in the remaining settlements needed to have missed at least one month of service payment. The average service balance among those presented with a disconnection notice was US$ 76 or around 18 months of the average consumption bill.

Transparency: Property owners were contacted by utility community-development agents, or CDAs, a minimum of five times over a four-month period to alert them about their arrears and eligibility for disconnection. Communication campaigns were designed by sociologists employed by the utility that had been working in the study settlements for many years and had long-term relationships with community leaders.[18] The communication started with the awareness phone call from the utility in August/September 2018. This was followed in October/November 2018 by a notice posted to the compound door and next to the water point warning property owners of disconnection if payment is not made by a specified deadline and providing a contact number for coordinating a payment arrangement or disputing the

[17]The study was designed specifically to measure the impacts of tenant engagement and disconnection policy enforcement. Of course, these two options are not exhaustive and there may be other policy avenues that could be more effective. In fact, the government considered a broader set of options before ultimately settling on studying engagement and enforcement.

[18]These sociologists had also been responsible for leading regular community meetings prior to, and during the infrastructure construction activities, and worked with the CDAs to deliver general awareness campaigns on how to effectively utilize the upgraded water and sanitation facilities. This meant that the utility had a daily presence in the settlements through the CDAs, and this was the primary route of communication between the utility and communities.

bill (see appendix for example). The notification ensured that tenants were also informed about the procedure. Third, an SMS warning and fourth, a phone call warning was made to the property owner prior to the notification deadline, alerting them to pay within 48 hours or be disconnected. Finally, the utility visited the compound on the deadline and made a last request for payment before proceeding with disconnection.

Fairness: All property owners agreed to the utility's disconnection policy in writing at the time of receiving their water and sanitation infrastructure upgrade. Poster notifications included a contact number for property owners or tenants to contact the utility and dispute their balance or provide justification for why they were unable to afford to pay for the service and agree on a payment plan. If property owners were found to be indigent and/or agreed to a flexible payment plan, they would not be disconnected. Tenants were made aware of the outstanding balance and could also pay the bills themselves to avoid disconnection. If none of these remedies were taken and service was disconnected, tenants could revert to the status quo prior to receiving the piped services - purchasing water from various water kiosks operated privately or by the utility in the settlement. Since piped water was intermittent, these were the same water sources tenants were currently using in conjunction with their piped services.

Credibility: The utility followed through with disconnections if there was no attempt by the property owner or tenants to make any payment. However, although the official policy requires property owners to pay a reconnection fee and the full outstanding balance, this was not enforced in this setting, and property owners that showed a willingness to cooperate with the utility could be reconnected. Since the reconnection process was quick and low-cost this meant that people could be reconnected soon after disconnection with limited cost.

The implementation of disconnections in this setting are low-cost, reversible activities. The disconnection costs the utility approximately US$ 3.30.[19] Reconnection costs are similar in magnitude to disconnection costs. The disconnection notices were delivered from 29 October to 7 November of 2018, with follow ups and disconnections taking place during November and December of the same year.

[19]Disconnection costs include communication costs of notifying the customer (printing the poster notification, the phone call reminder and the SMS reminder) of about US$ 0.30 plus labor costs of the disconnection of about US$ 3.00. The disconnection is conducted by a trained utility staff member who is paid approximately US$ 30 a day.

5 Experimental Design

All informal settlement property owners in the utility database were first called to confirm contact details and receive the base intervention. Eligibility criteria into the study included: (i) property owners were able to be contacted and their contact details could be updated; (ii) their payment accounts were in arrears and (iii) property owners did not hold multiple accounts (multiple-property owners). All eligible property owners then received the basic information intervention and contact details were updated.

Figure 3 describes the experimental design and sample selection. Starting from the group of 5,091 property owners that completed the phone survey in August 2018, just over 50% (2,584) indicated that they had tenants residing in the property. These 2,584 accounts were randomly assigned into a group of 1,292 who received the engagement treatment and an equally sized control group. The engagement intervention was successfully implemented in 885 (69%) of the 1,292 accounts assigned to the treatment group. Reasons for non-compliance included not being able to find the property, tenants being unavailable at the time of visit, and incorrect recording of the compound as having tenants when this was not the case.

For the enforcement intervention, we started with the same 5,091 accounts used for the engagement intervention and removed two informal settlements because these settlements are characterized by multi-story apartment blocks where individual disconnections pose a technical challenge. The remaining sample of 3,253 accounts from 4 settlements (which included compounds with and without tenants) were then clustered by street using GPS and address data. This generated 147 distinct street clusters. We then randomized 73 clusters consisting of 1,584 accounts into the treatment group, while the remaining 74 clusters (1,669 accounts) were left as pure controls. Within the treatment clusters there were 649 compounds eligible for disconnection, and 327 of these were randomly assigned to receive the disconnection notifications, following the protocols described in Section 4. The remaining 322 control compounds in the treatment clusters, as well as the 674 disconnection-eligible compounds in pure control clusters were exempted from the policy for the period of the study. Figure 4 illustrates how the two-stage randomization was applied in one settlement to allow us to test for direct and spillover effects associated with the enforcement intervention. The disconnection notices were ultimately delivered to 299 compounds (91.4%). In the remaining cases (28), compounds were found to have already had their services disconnected by the utility in which case no notice was delivered. The number of compounds actually disconnected was 96 or 2.9% of the 3,253 compounds eligible for disconnection in the study.[20]

[20] In six additional cases, despite property owners not coming to an agreement with the utility, enforcement was not possible because of of the technical complexity of the connection.

Of these, 74% had tenants.

The two interventions were implemented sequentially. The engagement intervention was implemented in September and October 2018, while the enforcement intervention was implemented in November and December of the same year.

6 Empirical Strategy

The engagement intervention was individually randomized among compounds with tenants, and we estimate the intention to treat (ITT) effect by means of its sample analog:

$$ITT = E(Y_{it}|T_i = 1) - E(Y_{it}|T_i = 0) \tag{1}$$

where Y_{it} is the outcome of interest for compound i at month t ($t = 1, 9$) after the intervention was completed; and T_i is equal to 1 if compound i is assigned to receive treatment and 0 otherwise. Note that treatment status does not change over time. We condition the analysis on settlement fixed effects and estimate robust standard errors.

The enforcement intervention was delivered as a clustered randomization. In this case we estimate the ITT by means of its sample analog:

$$ITT = E(Y_{ijt}|T_{ij} = 1, C_j = 1) - E(Y_{ijt}|C_j = 0) \tag{2}$$

where C_j is the cluster j indicator which is equal to 1 if the cluster was assigned to treatment and 0 otherwise. The sample in both treatment and control clusters includes only disconnection-eligible compounds. Finally, to measure spillovers to the non-treated units (SNT) for the enforcement intervention, we estimate the sample analog of:

$$SNT = E(Y_{ijt}|T_{ij} = 0, C_j = 1) - E(Y_{ijt}|C_j = 0) \tag{3}$$

In the estimation of the sample analogs of equations [2] and [3] we condition on settlement fixed effects given that the randomization was stratified at that level. Standard errors are clustered at the street level, which was the level at which the randomization was assigned.

7 Data and Outcomes

We use high-frequency administrative billing and payment data from the utility to measure our primary payment outcomes. Jisomee Mita is a web-based ICT platform that enabled property owners to use a mobile phone to self-read meters, receive and pay water bills, and

check their current balance at any time. Jisomee Mita data contains water consumption, invoice amounts, payment history, current balance, and contact information of the property owner. When payments or balance checks are submitted, the Jisomee Mita data are updated automatically. However, monthly standing charges are applied to each account independent of whether a property owner made a payment or billing enquiry which means that each property owner's balance is updated at least once a month.

The billing data is complemented with tenant and property owner survey data. A short baseline listing phone survey of property owners was conducted in August and September 2018. This captured ownership and water/sanitation connection status, property owner residency and number of paying tenants in the compound.

From August to October 2019 a follow up survey of both property owners and tenants included in the enforcement intervention captured data on rent, service-level satisfaction, political engagement, property owner-tenant interactions, water use and practices, mental well-being and general demographic measures of one randomly selected tenant and the corresponding property owner from each compound in the sample.

We use utility billing data to generate payment outcomes. This includes: (1) the proportion of property owners making a payment for water/sewer charges since the intervention, (2) the total amount paid by property owners' post-intervention and (3) the proportion of outstanding service charges paid post-intervention. The data spans the entire period from when the first property owners were connected in 2014 up to nine months after the interventions were implemented (September 2019).

We rely on the follow up tenant and property owner survey to measure a range of outcomes that assess the possible welfare effects of the enforcement intervention. We collect measures related to water and sanitation infrastructure and use to assess how the intervention may have affected access: whether the compound had a pour-flush toilet and piped water connection at the time of the endline, whether the water connection was working, the main source of water used by compound residents, the amount of time spent fetching water in the last week, the amount spent on water in the last month, and the overall piped water consumption in the compound. We also capture a range of outcomes that may be affected by the intervention and changes in water and sanitation access. Here we combine like outcomes into weighted, standardized indices following Anderson (2008) to reduce the potential for false positives from multiple hypothesis testing. We generate the following indices (full list of sub-indicators is presented in the appendix Tables A1 and A2):

Tenant-Property owner relationship: For the property owner index this includes property owner perceptions on whether tenants complain about the water and sewer facilities or about the general conditions of the compound, and whether tenants keep the compound in

a good condition. For tenants, we simply ask how they would rate their relationship with the property owner from 1 (very poor) to 10 (excellent).

Perception of service quality: Tenant / Property owner agrees or strongly agrees that they are satisfied with utility services, the utility services improve people's lives and provides clear communication, the government is trying to improve their lives, and (reverse coded) the government is not interested in helping the community.

Perception of service fairness: Tenant / Property owner agrees or strongly agrees that the utility enforcement mechanisms are fair and bills are accurate and fair.

Activism: Whether the compound has a committee, tenants have reached out to community leaders, participated in community meetings, or are members of community committees.

Psychological well-being: We include a set of standardized measures to capture different dimensions of psychological well-being among tenants, including Cohen's four-item stress scale (Cohen et al., 1983), depression (Center for Epidemiologic Studies Depression (CES-D) seven-point scale (Radloff, 1977)), optimism (Rosenberg optimism questionnaire (Rosenberg, 1965)), and the World Value Survey (WVS) measures of happiness, trust and life satisfaction. The psychological well-being index in turn is a standardized weighted average of these sub-indices.

In addition to the indices, we measure rent and rental income, migration and general socioeconomic measures of property owners and tenants to explore possible effects on rent and associated gentrification. We report the results from the indices in the main paper and include the results of all sub-indicators in the appendix Tables A1 and A2.

8 Results

8.1 Baseline Balance

We present descriptive statistics and baseline comparisons between treatment and control groups for our primary outcome measures using the administrative payment data on 6 August 2018 and 28 October 2018 to coincide with the download dates for the data sets used for the randomized assignment of the engagement and enforcement interventions respectively. Appendix Table A3 presents comparisons for each group and we find balance on most key measures covered.[21] Only 2 out of 45 comparisons are statistically significantly different from zero at conventional levels.

[21] Regressions used to estimate the treatment effects reported below are replicated including variables that are not balanced as covariates and neither the sign nor significance of any of the estimates change.

8.2 Payment Behavior

We find a precisely estimated null effect of the engagement intervention for all primary payment outcomes and time periods measured in Table 4. The control group payments increase steadily over the nine-month period from 30.1% of property owners having made payments one month after the intervention to 55.8% having made at least one payment by nine months (cumulative). However, compounds being exposed to the engagement intervention track almost the exact same trajectory as their control comparison. The total amount paid, and proportion of balance paid off are similarly indistinguishable across treatment and control group.

In contrast to the engagement intervention, we find a sharp increase in payment behavior among compounds exposed to the disconnection notices (Table 5). The likelihood of payment within one month almost quadruples - increasing by 30 percentage points from 11 percentage points (p-value < 0.001). This difference in payment likelihood sustains through the nine-month period, although with a slight decline relative to the control group. A similar pattern is found for the total payments after one month, which increases by US$ 8.80 (p-value < 0.001) from a base of US$ 5.02. After this sharp initial increase, the difference remains roughly constant between treatment and control groups while both increase over time. Treatment compounds have paid off 11.3 percentage points more of their balance than control compounds after the first month of intervention (p-value < 0.001). Control compounds begin to catch up gradually over the nine months, closing this gap to 7.8 percentage points (p-value $= 0.005$).

Figure 5 presents the full time series data available from the daily payment information extracted from the utility billing database. The visualization strengthens the main messages identified through the regression results. First, we find strong evidence of balanced payment practices across treatment and control groups from 2014 when property owners first started connecting to October 2018 just before the enforcement intervention. Second, we see that the payment trajectories continue to overlap after November 2018 when comparing the engagement intervention group to the control. Third, we see a sharp jump in the enforcement intervention group immediately after the intervention was delivered, which then stabilizes over time, suggesting that most of the impact identified in the regressions is driven by the behavior change in the first month after the intervention.

8.3 Spillovers

To test for spillovers on the payment behavior of disconnection-eligible property owners we compare control compounds in treatment clusters to the equivalent disconnection-eligible

property owners in control clusters and find no significant difference between the groups, suggesting no discernible spillover effects from the program using our originally specified empirical strategy for estimating spillovers (Table 6, Panel A). In Table 6, Panel B we report similar results for disconnection-ineligible property owners suggesting that the enforcement intervention had no observable spillovers on paying property owners either.

8.4 Heterogenous Treatment Effects on Payment Behavior

We consider two sets of sub-group analysis. First, the calculus for resident property owners is likely to be different to that for non-resident property owners (the former would be more directly affected by service disruption in the enforcement intervention, and potentially more accessible in the engagement intervention). Second the constraints and decisions to make payment may be different when considering the intensive (getting payers to pay more) versus the extensive margin (inducing those that have never made a payment to start paying). The appendix Tables A4 and A5 present sub-group analyses for property owner residency status and the intensive vs. extensive margin of payment respectively. In both cases we find no clear evidence of strong differences across these subgroups.

8.5 Water Access and Use

To measure social and economic costs of the enforcement intervention we use survey data collected nine months after the intervention, as reported in Section 7. Estimated impacts are presented in Table 7. The enforcement intervention had little effect on compound connections to water and sanitation services. The majority of the 96 disconnected compounds were reconnected after agreeing to pay a portion of their balance. We observe 27 of these compounds made a payment after being disconnected, with 20 of these payments being made within one month of the disconnection. The remaining compounds were reconnected without requiring a payment if they agreed on a plan with the utility. Compounds receiving the enforcement intervention have statistically indistinguishable piped water and sanitation connection rates at endline. This remains true when considering whether the piped water connection is currently working. We also find little evidence of illegal connections based on enumerator observation (3 cases across the sample).

Many households with piped water do not report this as their primary water source. Only 30.6% of control households report using piped water as their main source of water, which is 4.4 percentage points higher among treatment households, but non-significant (p-value=0.243). Many households in both groups are more likely to rely on water kiosks or boreholes (40%) than piped water. Both groups report spending similar amounts on water

for all uses in the last month (Control: US$ 6.62; Treatment: US$ 6.86; p-value = 0.803) and total time spent collecting water in the past week (Control: 118 minutes; Treatment: 100 minutes; p-value = 0.388), although this measure is noisy. Unsurprisingly then, we find no changes in overall piped water consumed based on meter readings at compounds during the endline survey. Overall, nine months after the interventions, access to water and sanitation were indistinguishable between treatment and control groups.

The study had originally intended to include child health as a secondary outcome and had collected maternal-reported illness symptoms for children under five. However, we choose not to include analysis of these outcomes for two reasons. First, sample sizes were very low since not all surveyed households had children under five. Second, it is unlikely that there would be any impact on health since there was no impact on the primary mechanism through which the intervention could have impacted health, i.e., access to water and sanitation services.

8.6 Performance Perceptions and Political Costs

We find no effect of the intervention on perceptions of service delivery quality and fairness among property owners or tenants (Table 7). Similarly, we find no impacts on the strength of the relationship between property owners and tenants, as reported by either group. Community activism among tenants, too, does not differ across groups. All indices have effect size point estimates with small absolute values, and the signs of these differences vary, suggesting no obvious pattern. The full set of indicators from which these indices are calculated is presented in the appendix, which similarly finds no discernible pattern (Appendix Tables A1 and A2). The only significant difference found is an 11.3-percentage point improved perception among property owners that "water bills are accurate". Given the high number of variables and potential for false positives, we interpret the results overall as showing no meaningful impact of the intervention on any of the outcomes measured.

8.7 Psychological Well-Being

In total we measure seven constructs (depression, life satisfaction, stress, happiness, self-esteem, trust, and life orientation), collected among tenants. We find no impact of the intervention on the overall psychological well-being index which combines these sub-indices (Table 7). The full set of seven constructs is presented in the appendix, which finds no statistically significant differences across these either (Table A6).

8.8 Rental Market

We find that property owner rental income increases significantly from US$ 62.58 by US$ 23.88 (p-value = 0.019; Table 8). Interestingly, this does not appear to be driven by increases in tenant rental prices. Control households report paying US$ 33.06 a month in rent, which is indistinguishable from treatment household rents. While property owners in treatment areas are slightly more likely to have increased rent in the past six months, this is only 3.6 percentage points higher and borderline significant (p-value = 0.091) in the treatment group which cannot explain the significant increases in rental income that they receive. However, we find a large and significant increase in the proportion of property owners renting out at least part of their compound, which increases from 58.9% by 13.5 percentage points (p-value < 0.001). Since there is a small imbalance in this indicator at baseline, we rerun the analysis, including this measure as a lagged dependent variable and find that the significant increase holds, although with a reduced point estimate on both the proportion of property owners renting out their compound, and rental income. The results suggest that property owners responded to an increase in effective water and sanitation service charges from increased contract enforcement by becoming more likely to rent out parts of their compound. This increased rental income to cover the increased costs.

9 Conclusion

The status quo in delivery of basic services excludes millions of poor households. Achieving universal access to improved water and sanitation requires innovations in service delivery approaches to help reduce the gap between available resources and the estimated costs of achieving national and global targets. Low-income households in urban centers facing high growth rates and stressed infrastructure are of particular concern. While providing credit to overcome high upfront costs to water and sanitation infrastructure connections has been shown to substantially increase take up in some settings, the sustainability of this model of infrastructure expansion is predicated on the repayment of loans by customers. In six of Nairobi's informal settlements where compounds received comprehensive water and sanitation infrastructure upgrades, we find repayment on these loans, and payment of general service charges, is well below targets, despite these charges being affordable under standard global benchmarks.

We test two common interventions used by utilities to improve revenue collection efficiency. The first – a face-to-face engagement intervention aimed at spurring bottom-up accountability from tenants to property owners, had a precisely estimated null effect on pay-

ment behavior in our setting. The second intervention – contract enforcement in the form of targeted, transparent, flexible and credible disconnection notices quadrupled the likelihood of property owners making a payment in the month of the intervention. We see limited evidence of further increases nine months after the intervention, and no evidence of potential spillover effects of the enforcement intervention on other property owners. This is possibly attributable to the fact that owners viewed the enforcement intervention as a onetime event rather than a permanent change in policy.

We did not find evidence that residents were negatively affected by the contract enforcement intervention nine months after implementation. Water and sanitation service connections and water consumption were not meaningfully different between treatment and control compounds. This is because most property owners whose service was disconnected were quickly reconnected after agreeing to a payment plan and during service interruptions residents had access to water from kiosks operated by the utility and private vendors. Moreover, contract enforcement did not affect either tenants' or property owners' perceptions of fairness and quality of water service delivery, nor affect the relationships of tenants and property owners. Finally, tenants were no more likely to move out. Taken together these results suggest that transparent contract enforcement was effective at improving revenue collection efficiency without incurring large social or political costs.

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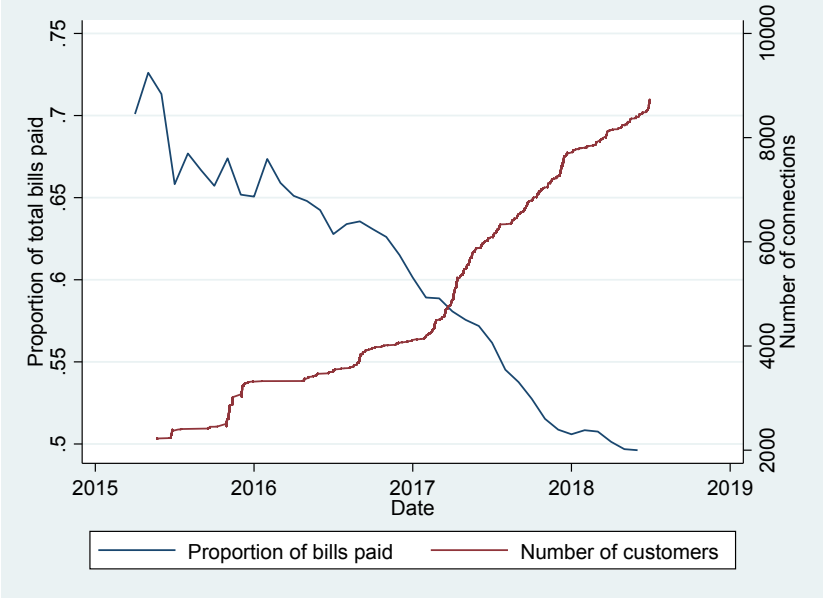
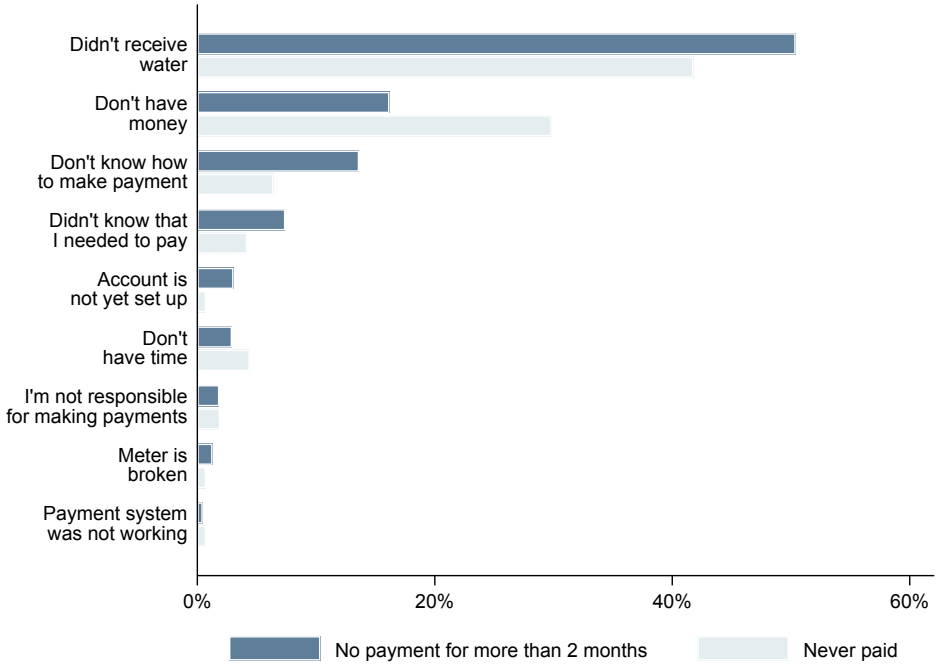
Figures and Tables

Figure 1: Revenue Collection Efficiency and Number of Utility Customers



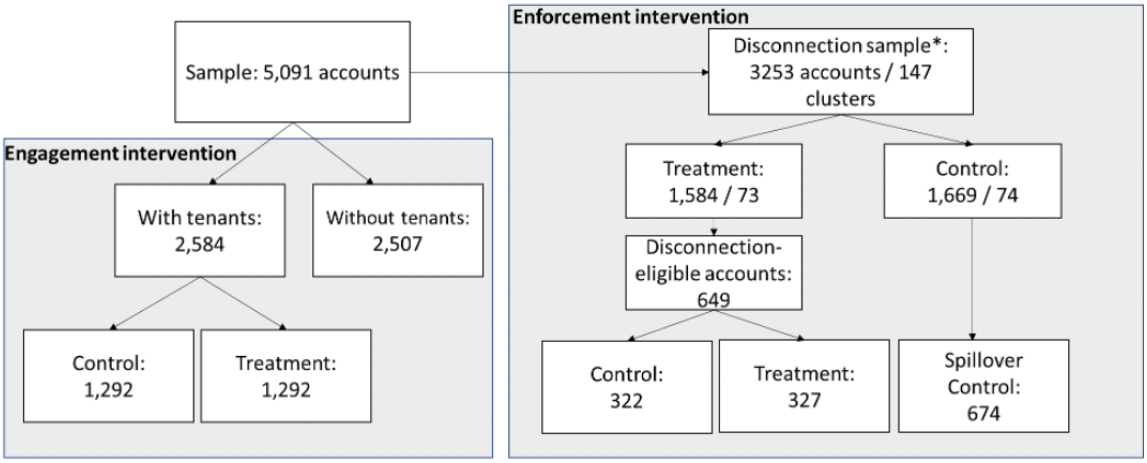
Notes. Blue line shows the proportion of payments received from total bills (including consumption and loans) over time; Red line shows total number of utility customers in informal settlements having either a piped water connection or both a water and sewer connection.

Figure 2: Self-reported Reasons for Nonpayment



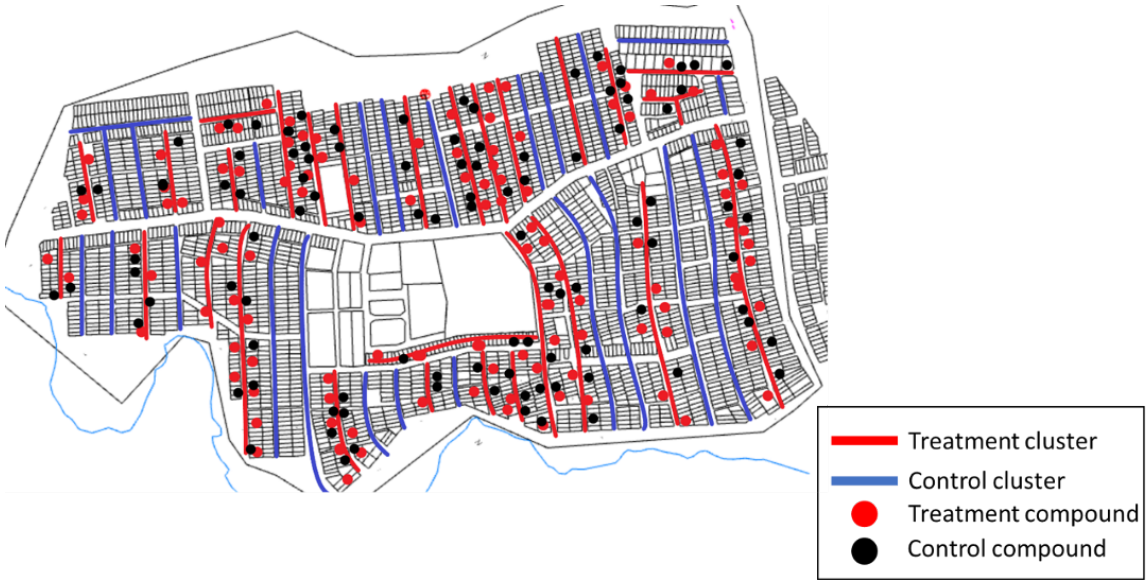
Notes. Based on property owner self-reported reasons for not paying, captured during the August/September 2018 listing exercise. Multiple choices were allowed. N is 2,488 for not making in more than 2 months and N is 1,387 for never paying.

Figure 3: Experimental Design and Sample Sizes



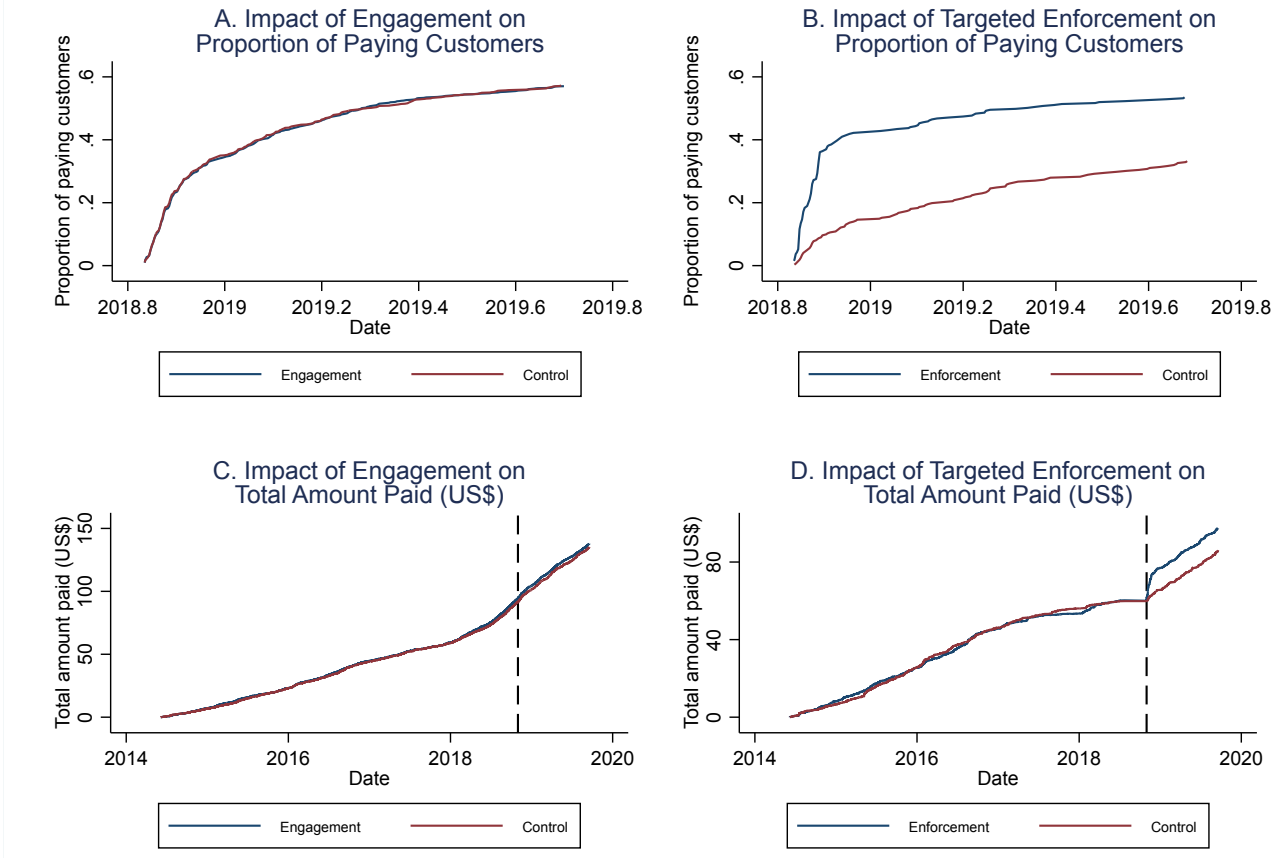
Notes. This figure presents the sample selection and randomization assignment for the engagement and enforcement experiments. Two settlements were excluded from the enforcement intervention because of housing density and compound design.

Figure 4: Example of Two-stage Randomization for Disconnection Notices in One Settlement



Notes. Map represents an example of random assignment in one settlement for illustrative purposes. Actual assignment is not reported to maintain confidentiality.

Figure 5: Intervention Impacts on Payment Behavior



Notes. All figures present the impacts of the experimental interventions on payment behavior using utility billing data over time. Panel A shows the cumulative distribution function (CDF) of the proportion of people making at least one payment over time (post-intervention), comparing property owners in the control (red) and engagement intervention (blue) group. Panel B shows the CDF comparing property owners receiving the enforcement intervention vs. control. Panel C shows the total cumulative amount paid by property owners over time, comparing the engagement and control groups. Panel D shows the cumulative payments of the enforcement vs. control group. Black dashed vertical line is the date at which the enforcement intervention began. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated.

Table 1: Property Owner Baseline Summary Statistics

	Units	N	Mean	Median	SD
	(1)	(2)	(3)	(4)	(5)
Owner demographics and income					
Age	Years	2255	51.25	50.00	13.55
Male	%	2287	59.73	-	49.06
Secondary education or higher [1]	%	2266	54.50	-	49.81
Monthly income [2]	US$	1633	550.70	250.00	825.27
Property wealth					
Property owner is sole owner of compound	%	2287	94.23	-	23.33
Property is fully paid off [3]	%	2275	98.51	-	12.14
Estimated property sale value	US$	1759	20000.00	17500.00	16400.50
Rental activity					
Owner occupied without tenants	%	2287	13.77	-	34.47
Rental property with resident property owner	%	2287	33.58	-	47.24
Rental property with non-resident property owner	%	2287	48.67	-	49.99
# of rental dwellings in compound [4]	No.	1881	7.68	7.00	5.25
Rental income					
Monthly rental income [5]	US$	1722	114.54	90.00	108.88
Monthly profit (revenue – expenditure)	US$	1648	83.31	60.00	106.75
Monthly electricity bill	US$	1543	12.26	5.00	19.65
Property owner pays electricity bill	%	1943	44.47	-	49.71
Monthly water bill [6]	US$	3318	4.20	2.54	9.18
Property owner pays water bill	%	1525	91.93	-	27.24
Water repayment practices					
Length of time being a customer	Years	3324	1.31	1.63	0.64
Current balance	US$	3324	23.66	9.82	48.08
Outstanding water connection loan	US$	3327	38.30	46.58	25.47
Number of unique payments made	No.	3324	3.96	2.00	5.08
Time since most recent payment	Years	3324	0.50	0.36	0.50
Percent that have ever made a payment	%	3324	60.74	-	48.84
Toilet facilities and sanitation services					
Number of toilets in compound	No.	2281	1.53	1.00	1.18
Current toilet type [7]					
Pour-flush	%	2287	36.99	-	48.29
Pit latrine	%	2287	59.34	-	49.13
Monthly expenditure on sanitation [8]	US$	1133	8.19	5.83	15.27

Notes. 2016 property owner baseline survey data used except for "Water payment practices" which uses March 2016 utility billing data. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated. [1] Includes some secondary education or higher. [2] Estimated as rental income divided by the percentage rent of total income. [3] Includes property that is received for free or inherited with a mortgage paid off. [4] Assumes 92% reduction factor from dwellings to households, and assumes households equals 1 if property owner resides in the compound and does not rent out dwellings. [5] Includes actual rental income received. When including all rental that was not received for the month prior to the survey, the average monthly rental income would be US$ 134.42. [6] Using billing and payment data as of March 2016. [7] Options do not sum to 100% as some compounds have multiple types. [8] Conditional on having a pit latrine.

Table 2: Tenant Baseline Summary Statistics

	Units	N	Mean	Median	SD
	(1)	(2)	(3)	(4)	(5)
Demographics and water access					
Household size	No.	4178	3.23	3.00	1.57
Household total income	US$	3208	136.77	100.00	137.71
Compound total income (at compound level)	US$	1673	1308.27	985.50	1307.96
Compound has piped water					
Yes	%	2097	73.06	-	44.38
Yes, but not working	%	2097	6.29	-	24.29
No	%	2097	20.65	-	40.49
Main source of water					
Piped into compound	%	1844	72.78	-	44.52
Public tap/standpipe	%	1844	5.15	-	22.11
Water kiosk, tube well, or borehole	%	1844	20.23	-	40.18
Other	%	1844	1.84	-	13.46
Rental market					
Deposit was paid	%	3958	46.97	-	49.91
Deposit amount	US$	1841	29.80	25.00	19.35
Monthly rent amount	US$	4154	25.16	25.00	16.77
Does the rent include water?					
Including with unlimited water usage	%	3164	79.52	-	40.36
Including with limited water usage [1]	%	3164	13.53	-	34.21
Not including water bill	%	3164	6.95	-	25.44
Type of tenancy agreement					
Written agreement	%	3920	7.63	-	26.55
Verbal agreement	%	3920	68.52	-	46.45
No agreement	%	3920	23.75	-	42.56
Rental agreement is month-to-month	%	2985	99.53	-	6.83
Years living in compound	Years	4176	2.98	2.00	3.78

Notes. 2015/2016 baseline data from a sample of 2 to 3 tenant households reported in this table. Responses include property owners when they live in the compound. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated. [1] Incurs additional charge after certain amount.

Table 3: Correlates with Payment Behavior

	Ever made a payment	Proportion of invoices paid	Proportion of loan outstanding	Connection loan fully repaid
	(1)	(2)	(3)	(4)
Property owner resides in the compound	0.034**	-0.029*	0.080***	-0.054***
	(0.014)	(0.017)	(0.026)	(0.015)
	[0.017]	[0.087]	[0.002]	[0.000]
Compound received water last week	0.169***	0.191***	-0.276***	0.125***
	(0.012)	(0.015)	(0.023)	(0.013)
	[0.000]	[0.000]	[0.000]	[0.000]
Property owner knows how to pay the bill	0.215***	0.224***	-0.204***	0.090***
	(0.015)	(0.018)	(0.027)	(0.016)
	[0.000]	[0.000]	[0.000]	[0.000]
Compound has tenants	0.006	-0.005	-0.032	0.013
	(0.013)	(0.015)	(0.023)	(0.014)
	[0.661]	[0.744]	[0.157]	[0.342]
Property owner pays water bills	-0.004	0.020	-0.034	0.002
	(0.018)	(0.022)	(0.034)	(0.020)
	[0.827]	[0.378]	[0.309]	[0.911]
Years with a water and/or sewerage connection	0.208***	0.127***	-0.050***	0.116***
	(0.006)	(0.008)	(0.011)	(0.007)
	[0.000]	[0.000]	[0.000]	[0.000]
Property owner knows how to read the meter	0.012	-0.006	-0.014	0.011
	(0.014)	(0.017)	(0.026)	(0.015)
	[0.410]	[0.727]	[0.577]	[0.466]
Property owner knows how to check balance	0.004	0.032	-0.056*	0.045***
	(0.016)	(0.020)	(0.030)	(0.018)
	[0.818]	[0.108]	[0.059]	[0.010]
Observations	4175	4164	4175	4175
R-squared	0.432	0.237	0.148	0.209

Notes. Standard errors in parentheses; P-value in brackets. *** p<0.01, ** p<0.05, * p<0.1. Payment outcomes are derived from the billing data and compound outcomes come from the property owner listing exercise in August/September 2018. Settlement fixed effects included.

Table 4: Impacts of Engagement on Payment

	Made at least one payment within...		Total amount paid within...		Proportion of balance paid within...	
	1 month	9 months	1 month	9 months	1 month	9 months
	(1)	(2)	(3)	(4)	(5)	(6)
Coefficient	-0.005	-0.002	0.049	-0.575	0.013	0.008
	(0.018)	(0.019)	(0.642)	(2.011)	(0.017)	(0.015)
	[0.776]	[0.928]	[0.939]	[0.775]	[0.436]	[0.616]
Observations	2584	2584	2584	2584	2584	2584
Control Mean	0.301	0.558	6.958	38.343	0.497	0.484

Notes. Standard errors in parentheses; P-value in brackets. *** p<0.01, ** p<0.05, * p<0.1. Sample includes all compounds that were included in the randomization procedure to assign the tenant-level engagement intervention. Time periods are based on the end date of the intervention (November 2018) and use data downloaded from the Nairobi Water billing data for December 2018, and September 2019 to estimate impacts 1 and 9 months after the intervention respectively. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated.

Table 5: Impacts of Contract Enforcement on Payment

	Made at least one payment within...		Total amount paid within...		Proportion of balance paid within...	
	1 month	9 months	1 month	9 months	1 month	9 months
	(1)	(2)	(3)	(4)	(5)	(6)
Coefficient	0.300***	0.195***	8.783***	9.078**	0.113***	0.078***
	(0.039)	(0.043)	(1.714)	(4.154)	(0.025)	(0.027)
	[0.000]	[0.000]	[0.000]	[0.031]	[0.000]	[0.005]
Control Mean	0.110	0.334	5.026	24.722	0.268	0.300
Observations	1001	1001	1001	1001	1001	1001
Number of Clusters	142	142	142	142	142	142

Notes. Clustered standard errors based on the level of randomization (street) in parentheses and associated p-value in brackets. *** p<0.01, ** p<0.05, * p<0.1. Sample includes all compounds that were included in the randomization procedure to assign the disconnection notices (enforcement) intervention. Time periods are based on the end date of the intervention (November 2018) and use data downloaded from the Nairobi Water billing data for December 2018, and September 2019 to estimate impacts 1 and 9 months after the intervention respectively. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated.

Table 6: Spillovers from Contract Enforcement

	Made at least one payment within...		Total amount paid within...		Proportion of balance paid within...	
	1 month	9 months	1 month	9 months	1 month	9 months
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Spillovers on compounds eligible for disconnection						
Coefficient	0.010	-0.020	-0.424	-1.721	0.019	0.008
	(0.023)	(0.039)	(1.353)	(3.924)	(0.025)	(0.027)
	[0.681]	[0.610]	[0.754]	[0.662]	[0.449]	[0.760]
Control Mean	0.110	0.334	5.026	24.722	0.268	0.300
Observations	996	996	996	996	996	996
Number of Clusters	144	144	144	144	144	144
Panel B: Spillovers on compounds not eligible for disconnection						
Coefficient	-0.015	-0.009	-0.340	0.303	-0.002	0.006
	(0.023)	(0.029)	(0.723)	(3.617)	(0.025)	(0.026)
	[0.507]	[0.752]	[0.639]	[0.933]	[0.924]	[0.815]
Control Mean	0.409	0.734	8.544	51.156	0.722	0.655
Observations	1930	1930	1930	1930	1930	1930
Number of Clusters	143	143	143	143	143	143

Notes. Clustered standard errors based on the level of randomization (street) in parentheses and associated p-value in brackets. *** p<0.01, ** p<0.05, * p<0.1. Panel A includes all compounds that were eligible for the enforcement intervention. The comparison is between compounds assigned to the control group in treatment clusters with all disconnection-eligible compounds residing in control clusters. Panel B includes all compounds that were not eligible for the disconnection intervention. The comparison is between disconnection-ineligible compounds in treatment clusters with all disconnection-ineligible compounds residing in control clusters. Time periods are benchmarked on the end date of the intervention (November 2018) and use data downloaded from the Nairobi Water billing data for December 2018 and September 2019 to estimate impacts 1 and 9 months after the intervention respectively. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated.

Table 7: Effect of Contract Enforcement on Owner and Tenant Outcomes

	N	Control mean	Treatment coefficient	Standard error	p-value
	(1)	(2)	(3)	(4)	(5)
Water and Sanitation Access					
Compound has a piped water connection	600	0.916	-0.036	0.024	0.135
Main toilet facility is a pour-flush system in the compound	608	0.942	-0.014	0.019	0.471
Compound has a *working* piped water connection	591	0.573	-0.033	0.041	0.423
Main source of water is piped water to compound	589	0.306	0.040	0.037	0.286
Piped water consumption (meter reading)	474	169.554	2.583	20.684	0.901
Amount household spent on water for all uses last month (US$)	334	6.617	0.664	1.005	0.509
Time spent fetching water in a week [1]	601	118.187	-17.569	21.682	0.418
Somewhat or very satisfied with main water source	608	0.443	0.004	0.040	0.924
Property owner					
Index: Perceptions of service delivery fairness	570	-0.000	0.070	0.084	0.404
Index: Perceptions of service delivery quality	589	0.000	-0.016	0.079	0.840
Index: Relationship with tenants	371	-0.000	-0.043	0.105	0.680
Tenant					
Index: Perceptions of service delivery fairness	357	0.000	0.030	0.107	0.779
Index: Perceptions of service delivery quality	402	0.000	0.086	0.101	0.395
Index: Psychological well-being	403	0.000	0.139	0.105	0.186
Index: Community activism	403	0.000	-0.084	0.101	0.411
Relationship with property owner (scale of 1 to 10)	403	8.266	0.232	0.241	0.337

Notes. *** p<0.01, ** p<0.05, * p<0.1. Sample includes all compounds that were included in the follow up survey: control and treatment compounds in enforcement-treatment clusters. Property owner and compound water outcomes are from the property owner survey. Tenant outcomes are from the tenant survey. Indices are computed following Anderson (2008), normalized by the control group. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated. [1] In minutes.

Table 8: Effect of Contract Enforcement on Rental Market Outcomes

	N	Control mean	Treatment coefficient	Standard error	p-value
	(1)	(2)	(3)	(4)	(5)
Total rent from compound last month (US$)	525	62.575	23.880**	10.127	0.019
Average monthly rent paid by tenants (US$)	395	33.011	-1.845	2.576	0.474
Does compound have rental dwellings	568	0.589	0.135***	0.038	0.000
Number of rental units in compound	566	3.290	0.381	0.377	0.312
Property owner increased rent in the last 6 months	371	0.018	0.036*	0.021	0.091
Paying tenants have moved out in last 6 months	364	0.697	-0.059	0.053	0.264

Notes. *** p<0.01, ** p<0.05, * p<0.1. Sample includes all compounds that were included in the follow up survey: control and treatment compounds in disconnection-treatment clusters. "Have you increased rents" and "Paying tenants have moved out" are estimated only on the sub-sample of compound property owners that report having tenants. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated.

Appendix

A Ethical considerations

A.1 Project timeline, evolution, and question selection process

The project originated in 2012 where government partners gathered at an impact evaluation workshop in Kenya to discuss how to provide evaluation support to water and sanitation investments in Nairobi. At the time, the government partners and operations team determined that last mile connections were the most pressing concern that the impact evaluation could support. Large investments in trunk infrastructure were being made, but the household connection costs to water and sewer lines could cost over $1,000 – significantly more than anticipated willingness/ability to pay.

The project aimed at reducing last mile connection costs in Nairobi's informal settlement by offering subsidies to property owners for part of the connection costs and a loan for the rest. Property owners would then be required to repay the loan through their monthly water bills at $4.50 per month for the sanitation upgrade and $1.50 per month for the water connection. The water connection provided a single piped water tap to a compound. The sanitation investment upgraded existing latrines, providing a water tank, wash basin and a pour-flush toilet system connected to the sewer line (where previously compounds typically had a pit latrine). This investment in the physical upgrading of the actual compound went beyond the scope of a typical connection and included infrastructure retrofitting/improvements. Customers would then sign an agreement with the utility that they understood that services would be disconnected in the event of non-payment.

The subsidy was made possible through a World Bank grant and the ability to amortize the remaining upfront connection costs was made possible through a commercial loan that the utility was able to use to then on-lend to customers. The commercial loan was secured on the basis that customers would repay their loan and service charges. The piped water and sanitation expansion under consideration in the study would not have taken place without this assumption and associated loan/grant since public funds were not available for this investment.

The original design was developed in 2013 and focused on estimating price elasticity of demand for sanitation take up and received IRB approval in December 2013. The trial was registered later in the AEA trial registry and planned to provide randomly offered top-up subsidies beyond the base project subsidy as a way to estimate demand elasticities.

From 2014 – 2016 the research team worked with the utility sociologists responsible for

community engagement to begin sensitization in the study communities and begin collecting baseline data for the project.

By 2016, using baseline data from the impact evaluation, the overall project was revised, and additional funding was provided to the project to ensure it would be able to provide an offering to customers in line with, or below, their existing water and sanitation expenses.

By 2018, through tracking applications and connections, the research team found that the revised base subsidy was enough to reach high coverage rates (90%). This project was thus successful in significantly increasing water and sanitation services to an estimated 137,000 people in informal settlements, but this high base take up rate also meant that the original proposed research design was no longer an option – randomizing top-up subsidies on such a high base connection rate would not have the statistical power to draw conclusions about demand for sanitation.

At the same time as customers were being connected, the utility found that many customers were not repaying their loan or service charges despite the fact that service charges represented approximately 1.1% of landlord monthly income, significantly below the 3% threshold for affordability determined by the United Nations. Since sustainability (proxied through customer repayment levels) was a key measure of program success, the utility looked to understand how to effectively increase revenue collection efficiency. This was important because the use of a commercial loan had the opportunity to unlock demand and expand services to informal settlements within the context of stretched public funds but could only be a viable and replicable model if customers repaid their commitments.

Since the research team had already collected significant primary data in the project areas, the project team requested the research team to participate in a series of workshops in May and June 2018 that included World Bank project staff, the utility and community engagement officers.

All the existing utility efforts to improve repayment behavior were discussed: (i) information campaigns to improve knowledge and use of the "jisomee mita" payment system; (ii) community barazas; (iii) pre-paid meter installation; (iv) SMS reminders; (v) meter readings followed by payment requests; (vi) warnings and follow up disconnections in case of continuous non-payment; and (vii) guidance on financial arrangements / planning that could help customers repay over time.

The utility rolled out the interventions that were deemed unambiguously useful like jisomee mita training, reminders, and meter readings, and dismissed the use of pre-paid meters in this setting because of their previous experiences finding them to be difficult to maintain and costly to deploy. Guidance on alternative financial arrangements for customers was originally considered to be tested, however it was ultimately decided that anybody that

needed this support / guidance in developing alternative payment strategies would receive it, rather than limiting access experimentally. Improving service supply reliability and tackling cartelization were important considerations within the broader dialog of ensuring sustainable water and sanitation provision. While exploring the question "does improved service reliability improve repayment behavior?" would be an important policy contribution, this was not viable in the project setting given the network structure of the infrastructure. It would, however, be an important potential area of future research. The discussion concluded that the team would prioritize impact evaluation questions around the benefits and costs of the disconnection policy because of the unknown impacts – both for the utility and its customers. The impact evaluation would also look into alternative approaches to community outreach that had yet to be attempted.

The engagement intervention design started by assessing the existing utility outreach efforts and combined this with an assessment of the data and literature of what may be missing in this existing outreach – specifically incorporating the tenant-landlord relationship into the outreach efforts as a way to strengthen bottom-up accountability.

Once the utility had settled on the interventions to be tested, the research team followed procedures to obtain new local and international IRB approvals and a local research permit in July/August 2018. Details of the ethical considerations are described in the following section. The study interventions took place between September and November 2018.

A.2 Transparency and ethics

The study originally received a research permit from the Kenyan National Commission for Science, Technology and Innovation (NACOSTI) in 2014 as well as international ethical clearance from Innovations for Poverty Action International Review Board in December 2013 for the subsidy experiment. Additional local IRB approval was received from Maseno University in 2015, prior to the baseline landlord and tenant surveys. The IRB proposals were amended in 2018 to include the repayment experiments, which were approved prior to study commencement, through Maseno and IPA IRBs and NACOSTI. The overall design, interventions, primary and secondary outcomes, and power calculations for both the subsidy and repayment experiments were published in the American Economic Association RCT registry (AEARCTR-0002063 and AEARCTR-0003556).

The Belmont Report (1979) ethical principles of respect for persons, beneficence and justice were designed to guide clinical and behavioral research. Recent literature has identified the tradeoffs with transposing the application of these principles directly from clinical work

to field experiments (Glennerster and Powers, 2016; Humphreys, 2015; MacKay, 2020) and offered practical guidance on how to assess and communicate the ethical considerations of a study more comprehensively (Asiedu et al., 2021; Evans, 2021). We find this to be a useful starting point to frame the ethical considerations of this research and describe how each principle guided the research process before discussing the ethical considerations of randomization of government policies.

Respect for persons: The primary approach to respecting participants during research is to ensure they have autonomy over their participation wherever possible. While this is not always possible (Humphreys, 2015) or necessarily always the best approach to respecting participant autonomy (MacKay and Chakrabarti, 2018), it does provide an important starting point for following the guiding principle of respect for persons. All collection of primary survey data used in this research required consent from households – both landlords and tenants - after describing the broad research objectives, data storage and confidentiality procedures and possible risks and benefits. Only participants that agreed to participate in the research are included in any of the primary data analysis for the study.

Administrative billing data from the utility includes a broader set of people than those where primary data were collected. To respect customers that did not participate in any primary data collection, but were included in billing analysis, no identifiable administrative data is presented in any analysis, in accordance with the utility agreement. Participants also consented to the two interventions included in this study. In the engagement intervention, tenants were offered the opportunity to refuse the intervention prior to its delivery, and in practice this happened in only 2 of 893 cases. For the enforcement intervention, all customers agreed to the terms and conditions of receiving utility infrastructure upgrades of a toilet, water point, wash basin and water tank at the time of becoming a customer, which included the utility's disconnection policy in case of nonpayment of the infrastructure loan and service charges in the form of a written contract.

Beneficence: While assessing ethical questions relating to RCTs, (Deaton, 2020) makes clear: "Beneficence is one of the basic requirements of experimentation on human subjects.". In practice, this does not mean ensuring improvement for all individuals in the study, which would make most field (and clinical) research impossible, but rather that risks are minimized, and the benefits of the research outweigh these risks (Glennerster and Powers, 2016). A thorough assessment of potential risks and benefits is critically important for studies that may pose important risks for certain individuals in order to benefit the broader community – a common challenge for all compliance-related interventions (de Andrade et al., 2016; Brockmeyer et al., 2019).

For the enforcement intervention, the study minimizes risk to participants in the following

ways: (i) the work was conducted in a setting where access to communal water sources was available, ensuring that people had access to water regardless of having an individual piped water service; (ii) we implement a stricter set of conditions for applying the disconnection notices than the existing policy uses, which reduces disconnection-eligible customers from 82% to 41% and improves targeting on observables; (iii) we explicitly exclude customers in control clusters and control customers within treatment clusters from being exposed to the enforcement intervention, which reduces the disconnection-eligible sample further to 9.2%; and (iv) among the disconnection eligible sample, we employ a rigorous process of contact and awareness creation to help customers avoid disconnection, which included 5 contacts with landlords to provide warning, guidance on how to pay, and the opportunity for customers to appeal to ensure that those unable to pay for hardship reasons would not be disconnected. Tenants also received notification and feedback in this process when notifications were provided at the compounds 2 weeks prior to any enforcement. This effort to minimize the disconnection risk for customers ultimately resulted in 2.9% of customers in the study sample being disconnected. Although the study unambiguously reduced risk to customers for being disconnected when compared to the prevailing policy, another important question is whether the study reduced risk to customers compared to actual implementation of the policy at the time. Here we rely on information from non-study areas collected during the same time (October 2018) as part of a meter reading exercise. Two settlements were originally planned to participate in the study but were excluded for logistical reasons. In these settlements, based on the meter reading exercise, we observe 8% of 1,384 compounds visited were found to be disconnected at the time of the reading, providing a counterfactual assessment of the potential disconnection rate absent the study, and consistent with the utility's plans to implement enforcement as the sanitation expansion program neared an end as a way to improve financial sustainability and use the model to illustrate how services could be further expanded.

We now turn to the potential benefits. While disconnection policies are applied by utilities all around the world to varying degrees, no experimental evidence exists on whether the benefits of more financially sustainable services are outweighed by the potential costs, and what may be effective strategies for reducing risks/costs. Given the multiple potential outcomes affected – for the utility, customer and residents – it is not feasible to determine the implications of the policy without rigorous evidence. The study helps directly answer 3 questions important for balancing the risks and benefits of utility policies: First, can alternative interventions that do not require enforcement yield positive changes in repayment behavior? This would help utilities direct efforts towards more effective and less costly interventions. Second, can targeted enforcement improve repayment behavior of non-enforced

customers? This would help utilities understand how to minimize risk through effective targeting. And finally, what are the actual costs and benefits of enforcing repayment? While quasi-experimental evidence may help to estimate the potential repayment benefits, it is unlikely that this would generate robust evidence on other impacts that customers and residents may face given the selection process inherent in the intervention. Thus, the study was designed to generate evidence that could help expand sustainable water and sanitation services while minimizing the risk associated with policies designed to facilitate financial sustainability of these services.

Justice: The third guiding principle for ethical research is ensuring fair distribution of the risks and benefits of the research. An important concern in the burgeoning field of development economics experiments is the link between the evidence being generated and the study group used to conduct the research. This becomes a concern especially when the research is designed to test specific academic questions or theories, and the sample used to conduct the research is used for convenience purposes, rather than because the study group will be beneficiaries of the research. From a justice perspective, this may result in the study population bearing all the risks of the research, with the benefits accrued elsewhere, effectively instrumentalizing study participants (Belmont Report, 1979; Baele, 2013; Deaton, 2020). This particular research explores the impacts of existing policies applied to those living in the study area and the primary goal of the work was to support the utility and improve the functioning of the water and sanitation investments in order to provide more accessible and reliable services to the communities included in the research. While the research conducted here has broader application to other settings, the reason for conducting the research in the specific study area was to learn about how to support the ongoing investments in these communities.

To ensure fair burden sharing, the study interventions only included compounds that were eligible for disconnection based on their arrears and ensured that there was a process for which customers that were not able to pay charges due to extenuating circumstances were provided the contact information and could engage with the utility to agree to flexible repayment options over time. Since tenants would also be directly affected by the interventions, the following protections were put in place: tenants were provided (i) prior warning through written notices at their property; (ii) guidance on how they could pay charges directly if needed; and (iii) contact details of the utility for any required follow up. In addition, the study was conducted in locations where utility-provided and private water services were available through kiosks and other vendors across the informal settlements so that households would have access to alternative water sources – those used by the majority of informal settlement dwellers, given the limited coverage of private piped services. This is consistent

with the objective of Kenya's Water Services Regulatory Board (WASREB) and the 2016 Water Act to provide communal water access, while ensuring a "balance of social, commercial, and ecological interests" in revenue collection as a means to promote the government's 2030 goal of universal access to water and sanitation services enshrined in Kenya's Constitution (WASREB, 2016).

Randomization of government policies: A final ethical concern is conducting research on potentially sub-optimal government interventions. If there are known policies that are better and can be provided by the government, then testing inferior policies would be unethical in many cases (MacKay, 2020). For this particular setting we see that (i) providing water and sanitation services without requiring repayment is not a sustainable policy option – public funds do not allow for this, and participants were only able to access the services because commercial funding was unlocked on the basis of the utility attaining revenue through service charges and loan repayments; and (ii) there was genuine ex ante equipoise[22] regarding the costs and benefits of the different interventions tested, given the wide range of outcomes and stakeholders that could be affected in different ways. Alternative interventions to improve revenue collection efficiency exist – the most similar in nature being the deployment of pre-paid meters. However, this was not considered a viable option by the utility in this context, presents similar ethical concerns around equitable treatment to customers, and there is no existing evidence to suggest this would be a superior approach. It is within this context, and with the understanding that the government was working towards the ultimate goal of expanding services to improve lives, that the study was conducted.

The work tackles a sensitive, but important topic that makes it crucial that all ethical concerns are thoroughly considered when undertaking the research. The work was guided by these concerns and principles by: making a concerted effort to minimize potential risk, building in a framework for respecting participants while still maintaining the credibility of the research, and ensuring that the work was undertaken with the utility and in the communities who would be the direct primary beneficiaries of the evidence generated from the research.

[22]Equipoise refers to the genuine uncertainty about the relative merits of each arm in a study trial

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B Interventions

B.1 Script for engagement intervention

Firstly, we would like to make you aware of the importance of paying for water/sewer service charges and help you take the necessary steps to avoid being disconnected. You may not be responsible for making water payments, but you can still make a difference by helping your landlord or caretaker remember when and how to take action. Today we would like to explain to you how you can help ensure payments are made and how to avoid being disconnected.

Now I would like to give you some information about the outstanding bill for this compound, and understand if there has been any trouble with making payments.

From our records as of [DATE], the outstanding balance on this compound was [BALANCE]. This is your balance for water and sewer fees only, not the outstanding balance for your loan.

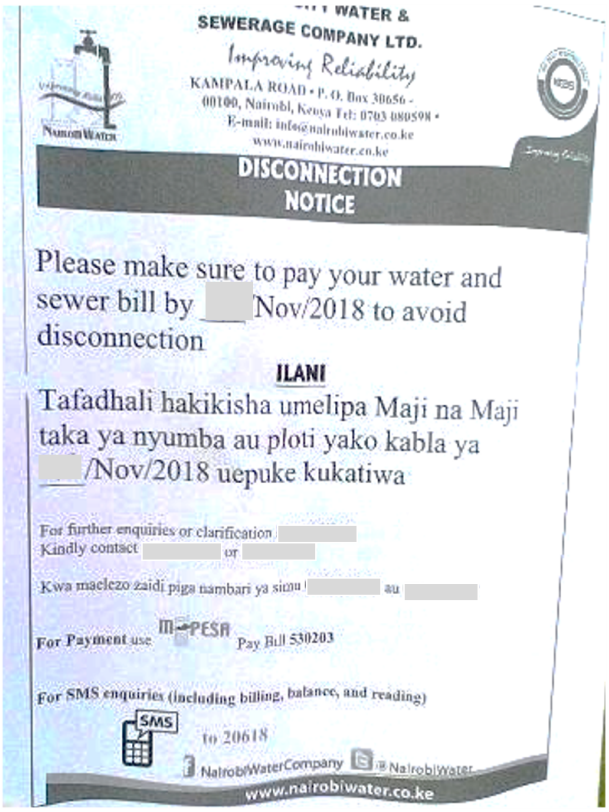
Now I would like to give you some information on your water meter, and answer any questions you might have about how to use it.

Now we I will explain how to read the meter [proceeds to explain how to read the meter]

Now I will explain how to check the balance [proceeds to explain how to check balances]

B.2 Example of disconnection notice

Notices were placed on the front door of the compound and next to the water point. Each notice provided (i) details on how to pay; (ii) a deadline for making payment (14 days after notification); and (iii) a contact number for utility zonal coordinators to dispute the bill or request a payment arrangement.



Tables

Table A1: Individual Variables Composing Property Owner Indices

	Index	N	Control mean	Treatment coefficient	p-value
	(1)	(2)	(3)	(4)	
Tenant engagement					
Have tenants ever complained about the water and sewer facilities in the compound	relationship	371	0.746	0.057	0.215
Tenants keep the compound in a good condition	relationship	371	0.775	0.024	0.595
Tenants complain about conditions in the compound	relationship	371	2.249	-0.104	0.358
Perceptions of service quality and fairness					
The water and sanitation fees applied by Nairobi Water are fair	fairness	537	0.447	-0.021	0.626
The approach Nairobi Water uses to enforce repayments is fair	fairness	544	0.513	0.044	0.313
The water bills are accurate	fairness	463	0.349	0.113**	0.014
I am satisfied with the water and/or sanitation services I receive from Nairobi Water	quality	573	0.317	-0.020	0.583
The government is interested in improving the living conditions of our settlement	quality	551	0.721	0.000	0.992
Water and sanitation fees are affordable	quality	536	0.603	-0.007	0.863
Nairobi Water provides clear communication to us	quality	555	0.498	0.013	0.750
The water and sanitation services provided by Nairobi Water improve people's lives	quality	573	0.760	-0.007	0.836
The government is not interested in helping us	quality	551	0.299	-0.013	0.745
Tenants appreciate the water and sanitation services provided in my compound	quality	359	0.472	0.030	0.573

Notes. *** p<0.01, ** p<0.05, * p<0.1. Binary outcomes are generated by assigning "strongly agree" and "agree" responses from a 4-point Likert scale.

Table A2: Individual Variables Composing Tenant Indices

	Index	N	Control mean	Treatment coefficient	p-value
	(1)	(2)	(3)	(4)	
Political involvement / community engagement					
Does your compound have a committee / group responsible for dealing with general issues	activism	399	0.070	0.008	0.773
Did you ever approach a leader in this community about your needs or community issues in the past 6 months	activism	403	0.080	-0.017	0.528
Did you attend any community meetings for this community in the last 6 months	activism	403	0.128	-0.025	0.423
Is anyone in your household a member of a community committee	activism	403	0.037	0.013	0.536
Relationship with property owner					
On a scale of 1 to 10 where 1 is very poor and 10 is excellent how would you rate your relationship with the property owner	relationship	403	8.266	0.232	0.337
Perceptions of service quality and fairness					
The water and sanitation fees applied by Nairobi Water are fair	fairness	268	0.636	-0.086	0.187
The water bills are accurate	fairness	223	0.594	0.035	0.628
The approach Nairobi Water uses to enforce repayments is fair	fairness	314	0.628	0.011	0.852
I am satisfied with the water and/or sanitation services I receive from Nairobi	quality	388	0.393	0.031	0.560
The government is interested in improving the living conditions of our settlement	quality	369	0.678	0.015	0.769
Water and sewer fees are affordable	quality	269	0.669	-0.034	0.597
Nairobi Water provides clear communication to us	quality	297	0.490	0.022	0.728
The water and sanitation services provided by Nairobi Water improve people's lives	quality	377	0.782	-0.014	0.760
The government is not interested in helping us	quality	364	0.407	-0.088*	0.091
Tenants appreciate the water and sanitation services provided in my compound	quality	381	0.528	-0.009	0.863

Notes. *** p<0.01, ** p<0.05, * p<0.1. Binary outcomes are generated by assigning "strongly agree" and "agree" responses from a 4-point Likert scale.

Table A3: Baseline Balance

	Engagement					Enforcement							
	(1) Control		(2) Treatment		(3) t-test p-value (2)-(1)	(4) Control		(5) Spillover control		(6) Treatment		(7) t-test p-value (6)-(4)	(8) t-test p-value (6)-(5)
	N	Mean	N	Mean		N	Mean	N	Mean	N	Mean		
Payment data													
Ever made a payment	1292	0.603	1292	0.616	0.493	322	0.494	674	0.509	327	0.502	0.844	0.907
Years as a customer of the utility	1292	2.137	1292	2.160	0.688	322	2.261	674	2.309	327	2.272	0.926	0.884
Number of unique payments made	1292	5.801	1292	5.362	0.204	322	3.531	674	3.010	327	3.477	0.905	0.436
Total amount paid (USD)	1290	62.791	1289	64.386	0.674	322	49.142	673	40.880	326	48.847	0.967	0.408
Current outstanding balance (USD)	1292	40.317	1289	39.581	0.720	322	62.567	674	61.069	327	59.617	0.526	0.799
Months until first payment	779	0.702	796	0.685	0.591	159	0.644	343	0.683	164	0.673	0.684	0.877
Compound data													
Compound has a water connection	1280	0.988	1279	0.991	0.432	316	0.994	653	0.992	314	1.000	0.158	0.020**
Compound has a sewer connection	1273	0.973	1273	0.978	0.372	315	0.959	650	0.978	315	0.965	0.678	0.298
Property owner pays water/sewer bills	1282	0.846	1286	0.838	0.613	316	0.829	658	0.845	316	0.842	0.668	0.908
Compound received water last week	1091	0.478	1070	0.443	0.107	269	0.349	556	0.338	273	0.337	0.761	0.983
Property owner resides in compound	1280	0.554	1282	0.555	0.972	316	0.506	653	0.533	313	0.505	0.969	0.409
Compound has paying tenants	1282	1.000	1286	1.000	.	316	0.639	658	0.634	316	0.712	0.051*	0.033**
Number of paying tenant households	1282	4.245	1286	4.592	0.317	172	4.814	360	4.764	192	4.875	0.888	0.771
Reason bill has never been paid													
Lack of money	472	0.146	455	0.114	0.150	142	0.204	300	0.193	143	0.189	0.744	0.913
Owner doesn't know how to pay	472	0.117	455	0.095	0.276	142	0.148	300	0.093	143	0.133	0.716	0.240
Compound didn't receive water	472	0.492	455	0.523	0.337	142	0.500	300	0.527	143	0.497	0.953	0.632

Notes. *** p<0.01, ** p<0.05, * p<0.1.. Payment outcomes are derived from the billing data and compound outcomes come from the property owner survey in August 2018. Baseline balance comparisons for the engagement intervention use administrative billing data from August 2018 - the data used to draw the original sample for the property owner updating survey. Balance tests for the enforcement intervention use October 2018 administrative billing data - the dataset on which the targeted enforcement randomization was conducted. P-values for t-test comparisons between the engagement group treatment and control are presented in column (3). Comparison tests between the targeted enforcement treatment group and controls within treatment clusters are presented in column (7). Comparisons between the targeted enforcement treatment group and controls in control clusters are presented in column (8).

Table A4: Differential Payment Behavior by Property Owner Residence Status

	Engagement			**Enforcement**		
	Made at least one payment within 1 month	Total amount paid within 1 month	Proportion of balance paid within 1 month	Made at least one payment within 1 month	Total amount paid within 1 month	Proportion of balance paid within 1 month
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment coefficient	0.012	-0.809	0.039	0.249***	9.406***	0.111***
	(0.027)	(0.950)	(0.025)	(0.049)	(2.764)	(0.043)
	[0.647]	[0.395]	[0.125]	[0.000]	[0.001]	[0.010]
Property owner resides in compound	0.043	-2.108**	-0.002	-0.004	-2.598	0.007
	(0.026)	(0.935)	(0.025)	(0.025)	(1.623)	(0.020)
	[0.103]	[0.024]	[0.943]	[0.866]	[0.112]	[0.739]
Treatment x Property owner resident	-0.028	1.414	-0.044	0.093	-1.151	0.002
	(0.036)	(1.276)	(0.034)	(0.065)	(3.127)	(0.053)
	[0.431]	[0.268]	[0.195]	[0.153]	[0.713]	[0.969]
Observations	2562	2562	2562	966	966	966
Control Mean	0.294	8.855	0.546	0.115	6.563	0.273
Number of Clusters				141	141	141

Notes. Standard errors in parentheses (clustered standard errors for enforcement regression); P-value in brackets. *** p<0.01, ** p<0.05, * p<0.1. Sample in columns (1) - (3) includes all compounds that were included in the randomization procedure to assign the engagement intervention and sample in columns (4) - (6) includes compounds assigned to treatment in treatment clusters and compounds in control clusters for the targeted enforcement intervention. Time periods are based on the end date of the intervention (November 2018) and use data downloaded from the Nairobi Water billing data for December 2018 to estimate impacts 1 month after the intervention. The control mean reported is the mean of the outcome for control compounds where the property owner is not a resident. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated.

Table A5: Differential Payment Behavior by Property Owner Payments Prior to Treatment

	Engagement			**Enforcement**		
	Made at least one payment within 1 month	Total amount paid within 1 month	Proportion of balance paid within 1 month	Made at least one payment within 1 month	Total amount paid within 1 month	Proportion of balance paid within 1 month
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment coefficient	0.004	0.546	-0.002	0.256***	6.381***	0.134***
	(0.027)	(1.023)	(0.023)	(0.053)	(2.312)	(0.037)
	[0.884]	[0.593]	[0.928]	[0.000]	[0.007]	[0.000]
Owner has ever made payment	0.276***	4.295***	0.497***	0.049	0.760	0.383***
	(0.026)	(0.971)	(0.022)	(0.032)	(1.407)	(0.026)
	[0.000]	[0.000]	[0.000]	[0.130]	[0.590]	[0.000]
Treatment x Owner ever made payment	-0.020	-0.895	0.015	0.081	4.608	-0.066
	(0.035)	(1.310)	(0.029)	(0.062)	(3.054)	(0.051)
	[0.563]	[0.495]	[0.619]	[0.193]	[0.134]	[0.197]
Observations	2584	2584	2584	1001	1001	1001
Control Mean	0.144	3.833	0.193	0.091	4.698	0.067
Number of Clusters				142	142	142

Notes. Standard errors in parentheses (clustered standard errors for enforcement regression); P-value in brackets. *** p<0.01, ** p<0.05, * p<0.1. Sample in columns (1) - (3) includes all compounds that were included in the randomization procedure to assign the engagement intervention and sample in columns (4) - (6) includes compounds assigned to treatment in treatment clusters and compounds in control clusters for the targeted enforcement intervention. Time periods are based on the end date of the intervention (November 2018) and use data downloaded from the Nairobi Water billing data for December 2018 to estimate impacts 1 month after the intervention. The control mean reported is the mean of the outcome for control compounds where the property owner is not a resident. All monetary amounts are in USD using an exchange rate of 100:1, unless otherwise stated.

Table A6: Impact of Enforcement on Psychological Well-being Indices

	N	Control mean	Treatment coefficient	s.e.
	(1)	(2)	(3)	(4)
Psychological Well-being Index	403	0.000	0.077	0.104
Life Satisfaction (WVS) Index	401	-0.000	0.128	0.106
Happiness (WVS) Index	403	0.000	0.077	0.098
Depression (CESD) Index (Reverse Coded)	387	0.000	0.041	0.102
Self-esteem (Rosenberg) Index	379	0.000	-0.066	0.102
Stress (Cohen) Index (Negatively Coded	387	-0.000	0.079	0.107
Trust (WVS) Index	403	-0.000	-0.021	0.097
Life Orientation Test (LOT-R) Index	393	-0.000	0.037	0.105

Notes. Coefficients report the standard deviation of each outcome of the control group at follow-up. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Each column presents an aggregate result following Anderson (2008), derived using the standardized measures from the respective indices. Column 1 presents the overall psychological well-being index that combines all other indices.