Environment for Development

Discussion Paper Series February 2023 ■ EfD DP 23-03

The coping costs of dealing with unreliable water supply in the Nairobi commercial sector.

An Analysis of Coping Mechanisms for Kenyan Businesses

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Keywords: Coping Cost, Commercial Sector, Water Supply, Kenya

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1. Introduction

In Kenya, as in many low-and middle-income countries (LMICs), the reliability of water supply in towns and cities remain a key problem. WASREB (2016) impact report shows that on average water utilities in Kenya are only able to supply water for up to 18 hours in a day, with substantial variation across utility areas. In Sub-Saharan Africa, nearly a quarter of firms experience water insufficiencies (World Bank, 2017). In the case of Kenya, a third of firms lack sufficient water for their businesses.

Commercial businesses for whom water is a significant input and water prices and quality are likely to be salient (restaurants, hotels, laundries, bottlers, abattoirs,carwashes, etc.) are particularly vulnerable to shortages or reliability in water supply. Depending upon their ability to substitute to alternative forms of water sources, reliance on municipal supplied water may result in commercial businesses incurring additional coping costs to secure the reliability and quality of water they require. This includes extra costs incurred due to the need to re-arrange economic activities, purchase off-network water at much higher volumetric cost, or invest capital in self-supply (i.e. boreholes or small-scale private piped networks). If firms are to continue with their historic input mix against these realities, then they are likely to experience total factor productivity losses.

In order for water resource managers to better manage water resources and develop sustainable water infrastructure, it is important to assess the value commercial businesses place on improved water reliability (Whittington et al., 2006). Estimating commercial coping costs or "averting expenditure", similar to coping cost studies targeted to households (Cook et al., 2016; Orgill-Meyer et al., 2018), can provide a lower-bound estimate of willingness-to-pay for improved water infrastructure. Unlike households, however, one might expect that improved reliability will have more complex equilibrium effects for businesses. If all competing carwashes, for example, are provided more reliable but more expensive water supply, much of the producer surplus gain from the change will be competed away into lower prices for customers and higher consumer surplus.

We investigated these commercial coping costs by surveying a random sample of 400 commercial firms in Nairobi that had connections to the piped network. In addition to asking about basic firm characteristics, our survey asked about ongoing coping costs such as purchasing vended (delivered) water as well as capital investments such as private boreholes and storage capacity. In the next section, we briefly review the literature on coping costs and

commercial water use before presenting a theoretical framework for commercial coping mechanisms.

2. Literature Review

Coping costs are costs incurred by households or firms on different types of averting, mitigating and defensive activities to cope with a resource stress and by learning to live in harmony with the limited resource (Cook et al., 2016a). In the water sector, studies on coping cost have focused primarily on domestic water use. A comprehensive review of coping cost studies amongst the households is by Bansal, G., & Das, S. (2018).

In developing countries, Cook et al., (2016), in a study on the cost of coping with poor water supply in rural Kenya found that households spent considerable time resources in collecting water and many also invested in storage and rainwater harvesting facilities, construction of wells, or relied on water vendors. In Nepal, the monthly coping cost for water scarcity was estimated to be $2.94 (Pattanayak et al., 2005). Wu and Huang (2001) in a study on Taiwan found that final averting expenditure for each household, on average, was estimated to be NT $617.24 for every 2 months. In case of India, a study on Delhi reveals that the average monthly coping cost of households was Rs 187.

Studies have looked at the benefits of improved water infrastructure on water service delivery to enterprises (Davis et al.,2001; Islam, 2019). Davis et al. (2001) undertook a study of 360 MSEs in Uganda to determine how improved water infrastructure impacted on the water services to these enterprises. The type of MSEs studied included the retail establishments selling foodstuffs (retail, wholesale or both), service provision (restaurant/lodge, petrol station, and health care) and a small fraction dealing light manufacturing. In one of the regions in Uganda, a new water supply system had been completed with public taps. The improved system offered enterprises two new water supply options, using the public taps and having private connections. They found that two-thirds of the enterprises switched water sources. Using a behavior switching models, they determined the reported benefits of switching to include reduced expenditure on water (56%), improved reliability of water supply (56%), increased production (18%), increased demand for firm's products and production of new goods/services (13%). However, by interviewing medium and small enterprise owners and managers and comparing their enterprises water sources and water use, they find that improved water services was less important to medium and small enterprises than one would have expected when compared to studies on households in African towns.

Most research on small and medium-sized enterprises have concentrated on credit constraints and the effectiveness of microfinance programs in addressing them (Gohary et al., 1998). In contrast, less effort has been expended on understanding at the micro scale, the role that improved infrastructure plays in roads, power, water supply, sewerage and other forms of infrastructure. These investments account for a large share of expenditure by governments and development organizations in developing countries. Cross-country analyses report statistically significant associations between macroeconomic growth rates and quantitative measures of infrastructure development (Canning & Pedroni, 1999), but evidence at the micro level, particularly regarding water infrastructure, is thin.

Islam, (2019) studied the effects of poor water infrastructure on the productivity of informal firm across 12 developing economies in sub-Saharan Africa, East Asia, and Latin America for the period 2009 and 2014 using the World Bank's Enterprise Survey data of 710 firms which use water for business activities. In the sample for this study, a substantial proportion of the urban population had access to improved water sources: 8 out of the 12 economies had 90% or more urban population access to improved water in 2015. Three of the four remaining economies have at least 80% or more urban population access to improved water. The informal firms in their survey are defined as firms that are unregistered. In the case of Kenya, the survey was undertaken in five urban centers. The findings indicate that an increase in total duration of water shortages in a month can lead to annual average losses of about 14.5% of the monthly sales per worker for the average informal firm that uses water for business activities. The informal sector is likely to suffer productivity losses due to water scarcity.

Water shortages affect input choices, revenue, and productivity. One potential prior is that because water for the water-intensive firms is an essential input, shortages could significantly reduce output. On the other hand, many firms might insure themselves against unreliability by relying on off-network water. Such firms may invest in averting mechanism precisely because the potential losses are large. Foster and Steinbuks (2009) and others argue that the cost of self-generation is relatively small in the electricity sector where firms substitute away from grid electricity.

Islam and Hyland (2019) examine how water infrastructure copes with severe weather fluctuations and analyzes the effect of unreliable water supplies on the productivity of manufacturing firms, focusing predominately on firms in developing economies. They find that the quality of infrastructure matter in terms of business performance, particularly water and electricity. The duration of electricity and water services interruptions have significant

effect to improve firm performance. An elimination of all the existing duration of water interruption would lead to a 7% reduction in firms' operating costs. The one-hour improvement in water supply services is expected to have a much greater impact; it would save 4.4% of operating costs.

Bhat (2015) explored the impact of water and its scarcity on firms in a cross-country study of 55,000 firms in 100 countries. In their study, at the univariate level, they find that 1 in 3 firms under manufacturing and service sector require water. However, 1 in 4 firms requiring water experienced water scarcity problems. In evaluating whether firms not using water, firms using water, and firms using water and experiencing water insufficiency problem have different productivities, a major finding is that large firms have inherent advantage over medium and small firms. The sales per employee of the firms requiring water are higher than the sales per employee of the firms requiring no water. This signifies the importance of water for manufacturing and nonmanufacturing firms.

We know of no study that investigates what firms actually do to cope with insufficient water and what it costs these firms to cope with unreliable water.

3. Theoretical framework

We present a simple theoretical framework to illustrate the relationship between coping costs and the economic benefits of improved public water supply system. The theory underpinning the relationship between the coping costs incurred by firms dealing with unreliable water supply and demand for improved water supply comes from the environmental economics literature on the measurement of the benefits and costs of pollution control (Cropper and Oates, 1992). The costs of coping are used to estimate the value of environmental quality improvements.

Coping cost functions, similar to the cost functions of firms, depend on unit prices of inputs and outputs, conditional on production technology and firm's preferences or tastes. We estimate a linear regression model relating total coping costs to the set of observables in which we are interested. Considering a production function where X, G, t denotes production inputs, public infrastructure and technological changes respectively; A representative firm faces the following profit maximization problem:

$$\pi(P, W, G, t) = \max_{x}, [Pf(X, G, t) - wX)] \dots \dots \dots \dots \dots \dots \dots \dots (1)$$

Where P is the output price, W vector of the price of private inputs. Similarly, the above optimization could be expressed in terms of maximizing the difference between total revenues and the cost of producing the output level, Y.

$$\pi(P, W, G, t) = \max_{x}, [PY - C(W, Y, G, t)] \dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Cost savings due to public infrastructure akin to averting cost on the part of the firm is modelled following Morrison and Schwartz (1994) by total differentiating the cost function C (w, Y, G, t) in equation (2) that gives;

$$\pi(P, w, G, t) = \frac{\pi_p(P, w, G, t)P}{\pi(P, w, G, t)}\dot{P} + \sum \frac{\pi_{wi}(P, w, G, t)w_i}{\pi(P, w, G, t)}\dot{w}_i + \frac{\pi_G(P, w, G, t)G}{\pi(P, w, G, t)}\dot{G} + \frac{\pi_t(P, w, G, t)}{\pi(P, w, G, t)} \dots\dots\dots\dots (3)$$

The effect of public infrastructure on cost is derived as the difference between the total derivative of the cost function of equation 3 and the weighted average of the growth rates of input prices. The theoretical framework helps us answer the question about how firms value improved public infrastructure (water supply). Coping cost functions depends on unit prices of inputs and outputs, conditional on production technology and firm's preference. Equation 4 illustrates our coping cost model;

$$C_i = \beta_0 + \beta_i X_i + \mu_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

Where C_i is the current coping cost and X_i is a set of firm's observables characteristics. μ_i is the stochastic component that captures the idiosyncratic effects of unobserved factors. Important firm characteristics include; years in operation (age of the firm), number of employees, number of toilets, whether connected to public water network (PWN), Gender of owner, Monthly revenue, and water use intensity among other variables.

4. Methods

Study areas

We targeted commercial water users in the Nairobi City area served by the Nairobi City Water and Sewerage Company (NCWSC). The latest water services provision performance report indicates that current water coverage for Nairobi City is 79% (WASREB,2021). While some businesses within Nairobi do not receive network water at all, our focus was on firms with a connection to the piped network. These connected commercial customers comprise approximately 5% of all accounts (including residential customers) in the NCWSC billing records but consume approximately 36% of the total billed water.

We used the NCWSC billing records for the period 2012-2017 both as a sampling frame and a source of data on water use from the network. NCWSC classifies business categories to include firm types such as Business & Office Block, Eating/Drinking places, Garage/Carwash, Market & Retail stores, etc.The billing data had telephone information and addresses of all the customers, allowing us to classify the businesses by NCWSC's service region, described more in the following section.

The service area for NCWSC is delineated into 13 hydraulic pressure zones. Because demand exceeds supply in all but one of these zones (pressure zone 1), NCWSC rations supply to customers in those zones. The prevailing tariffs at the time of the survey were comprised of a fixed "meter rent" charge (typically \$0.9 for a ¾" connection) and an increasing-block volumetric charge with four blocks. Consumption in the first block (up to 6 m^3) is charged at a flat rate of \$1.9 with no volumetric component. The price in second block (6–10 m^3) was \$0.6/m^3. The tariff information allows us to compare the cost of network water to alternative sources used by the businesses.

Sampling Strategy

The NCWSC billing data contains information on 9,518 commercial water users with georeferenced water meters, allowing us to place each users in a pressure zone (Figure 1). We used a stratified sampling design since it would be logistically difficult to employ a survey based on a simple random sample drawn throughout the entire city. In stage 1, the sampling area was divided into non-overlapping strata based on the 13 pressure zones. Zone 4 was dropped because it contained no commercial accounts.. A frequency weight was then used to determine the proportion of the sample to be assigned to each of the categories of commercial water users. This was largely done to avoid oversampling office blocks, which make up a significant share (15%) of commercial accounts. However, although water use in the office blocks may be substantial overall (for washrooms and toilets), owners or managers of office blocks may have fewer dimensions to manage water or may not be interested. For this reason, the frequency weight for office blocks was cut by 50%, with the sample weights then distributed equally across the remaining categories. The final sample (n=400) by business type is given in Figure 2.

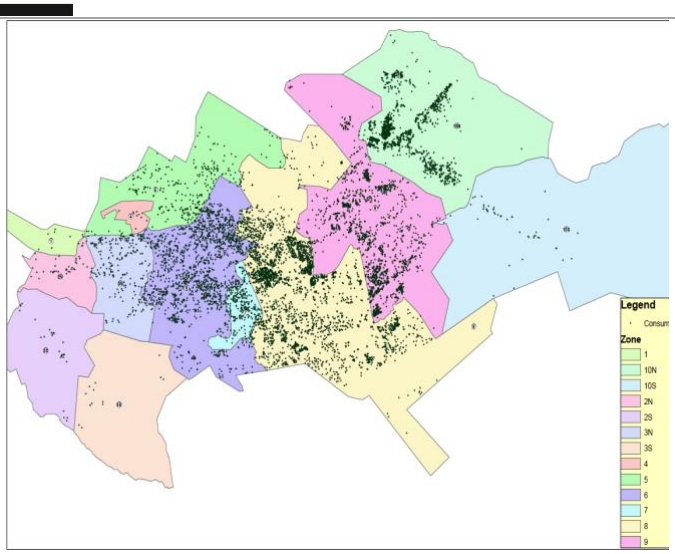

Figure 1: Distribution of commercial water users by pressure zones

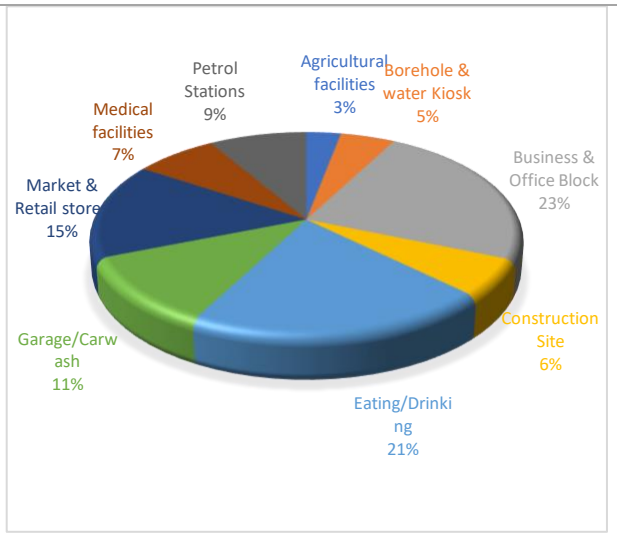

Figure 2: Final Sampling by category of businesses (n=400)

Survey administration and data collection process

The study was conducted at a time when a new wave of COVID-19 pandemic had been reported in Kenya. Most businesses were opening up after a complete shutdown due to the previous waves of COVID-19 pandemic. However, health restriction were still in place which necessitated that the survey be phone-based. This was possible because the NCWSC had all phone contacts of the commercial water users. The data collection exercise was preceeded by three focus group discussions which were also held by way of zoom. The FGDs were meant to provided a picture of how the respondents could react to the telephone interviews in the absence of the in person interviews. In order to provide an incentive to participants to participate in the telephone interviews, the respondents were rewarded with a $1worth of airtime.

The questionnaire was in eight parts. The first section set out to determine whether the businesses had piped water from NCWSC and if not, whether they had made an application for piped water or not. In part two, the section sought to understand ownership of the business premises, how water bills are received, whether the bills are shared with premise owners and whether they were in areas with bill payment. In section three, businesses with own connections were singled out. They were asked how much they pay for the water and whether they were in arears with the bills and what was the cause. They were also asked how COVID-19 had affected their operations including their water use. After being asked how regularly they received piped water, the businesses were asked about how they cope with water shortages. The coping options included water storage, drilling of boreholes, water vending, water kiosks and all the associated costs of coping. The final sections of the interview looked

at the water use and reliability issues as well as questions relating to business operations. Where capital costs were involved as was the case of borehole drilling and purchase of storage facilities, a 10% discounting factor was use to arrive at the amortized monthly coping cost associated with such facility.

5. Results

Profile of sampled firms

In table 1, we presents descriptive statistics. Businesses in our sample have been in existence on average 8 years, with agricultural-based businesses being in exstence for over 14 years. The monthly revenue of the businesses is $133,178 employing an average of 48 employees,and generate an average of $3142 per employee (Table 1)[1]. Firms that rely on the grid electricity paid an average of $130 for electricity each month. 46% of businesses own the business spaces they operate in while 52% of businesses rent the spaces they operate in, paying an average of $667 per month in rent.

Table 1: Descriptive statistics of sampled commercial businesses

Variable	Mean	Std. Dev.	Median	Max
Business Age (years)	8.3	6.5	7.0	49
Revenue/employee (US$/Month)	3142.1	13774.6	555.6	1.55E+05
Electricity Bill (US$/ Month)	130.5	564.1	27.8	5185.2
No. of Toilets	7.3	18.6	3.0	205
Monthly Rent (US$/Month)	667.3	1113	231.5	6435.2
No. of Employees (fulltime)	47.8	459.5	5.0	8959
No. of Employees (Parttime)	1.7	8.9	0.0	150
Number Tenants	54.2	88.2	20.0	400
No. of premises sharing water	3.7	2.7	3.5	10
Monthly payment for sharing (US$/Month)	5.2	3.9	4.6	16.7
Cost of Borehole construction (US$)	23205.1	20244.7	18518.5	73240.7
Monthly electricity-Borehole cost (US$)	54.4	40.6	45.4	131.5
Borehole treatment Cost (US$/Month)	248.6	498.8	74.1	1555
Borehole water drawn (m^3/month)	35.4	70.9	7.0	17.9
Borehole water drawn-rainy season (m^3/month)	2.2	2.7	1.5	5.9
Borehole water drawn-Dry season (m^3/month)	1.8	0.3	2.0	0.5
Number Storage Tanks	1.8	1.8	1.0	23
Volume of stored water (m^3)	17.6	40.2	8.2	399.8
Cost of storage tank (US$)	1073.1	2907.5	416.8	30544.4
Vendor Charges/unit (US$)	30.4	32.9	27.8	185.2
Monthly vending Cost (US$)	118.5	219.9	74.1	1664.4

It was also important to understand whether or not the firms were water intensive or considered water to be an important input in their production processes. The study found that 61% of the businesses interviewed considered their businesses to be water intensive, the remaining businesses relied on water, but did not consider themselves as water intensive. 87%

[1] Exchange rate $1=Kshs. 108

of the firms reported to be receiving their water bill electronically through mobile phones messages, while only 13% receive their water bills through their landlords.

It is also notable that the office blocks use $597.5 per month in treating the borehole water, followed by eateries/bars at $74 per month. In terms of drawing water, the agricultural facilities draw more water from the boreholes compared to others (180m^3). This is followed by eateries which draw 15m^3 per month.

All businesses have storage facilities, however, businesses/offices have about 3 storage facilities on average. In terms of water storage, the agricultural facilities store the most water (62.9m^2 per month), an indication that they have bigger storage capacity compared to the rest. This is followed by the construction sites which store 35.3 m^3 per month. The cost of water storage varies across firms, however, the agricultural facilities incur the most in water storage ($4,804 per month). This is followed by the construction sites and the business/offices.

The businesses also rely on water vendors to cope with shortages. The study shows that it water truckers charge an average of $43 per trip. This is generally for the boreholes/kiosks. A more detailed descriptive statistics is given in Table 3 for each of the firm category.

Comparing billing records of Firms' use of piped water with reported coping costs

As indicated earlier, all the interviewed firms relied on the network water as the primary source of water for the firms. Therefore, in this section we highlight water consumption behaviour for the month June 2021 prior to the survey which was undertaken in the month of July, 2021. In table 2, we outline monthly water consumption and cost of network water to the firms.

Table 2: NCWSC-Water Use by Sampled Commercial Firms

Variable	Mean	Std. Dev.	Min	Max
Water Consumption (M3)/Month	168.6	505.71	0	5,002
Billed amount ($/month)	130.0	463.3	1.7	5,182.1
Bill amount paid ($/month)	189.7	618.6	-2,173.7	5,182.1
Bill Arrears ($/month)	59.8	421.7	-2,260.0	4,732.9

Source: Billing Records (2021)

On average firms use around 168.6 m^3/month. Comparing this to the amount of water stored, bought from vendors or drawn from the boreholes, it is clear that the amount of water for coping is relatively lower than what the average firm needs for the production processes. The total amount billed for water use is about $130 and firms pay an average of $189.7. It is interesting to note that most commercial firm pay more than is billed. This is also indicated by average arrears which is $59.8.

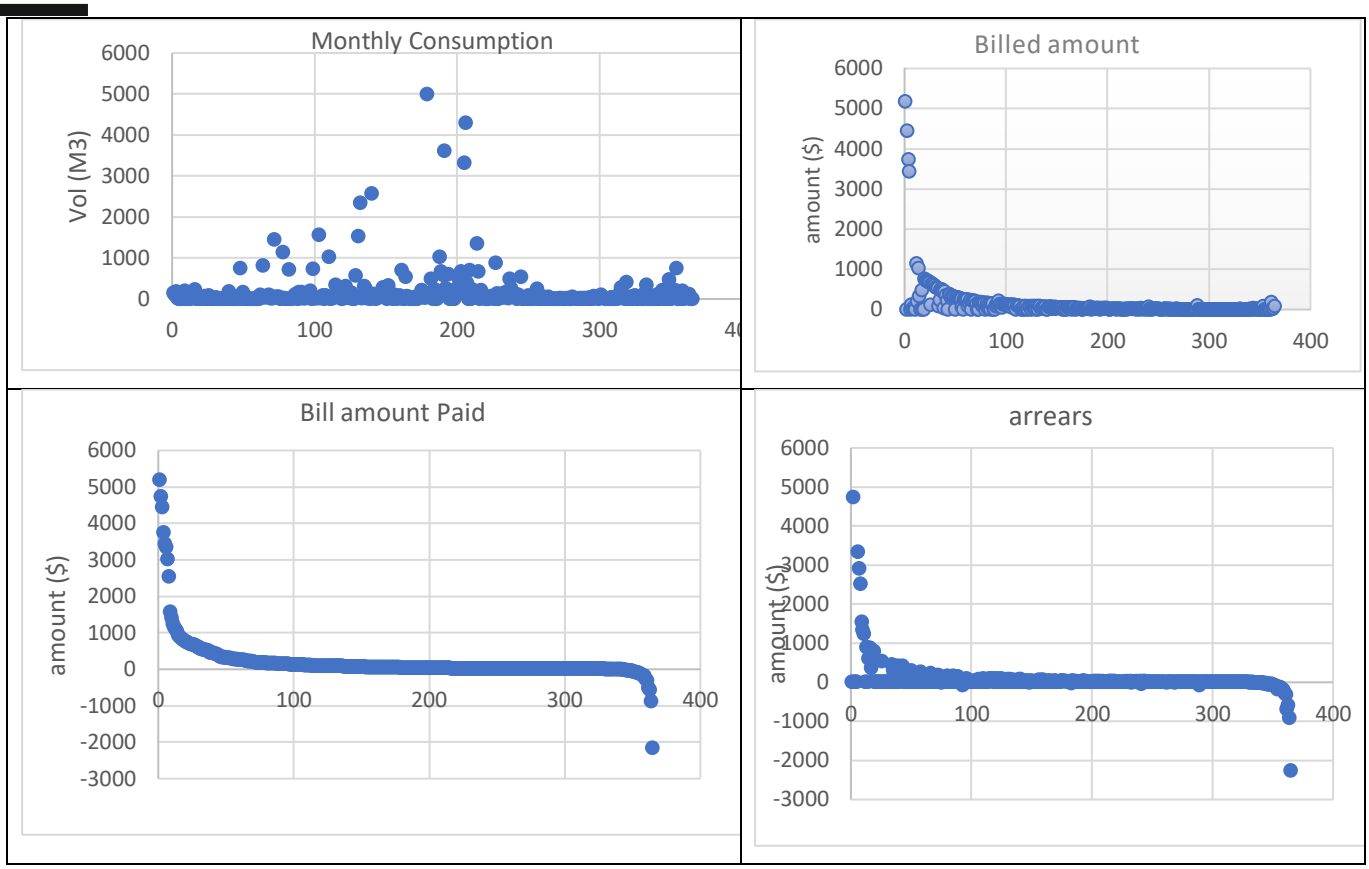

Figure 3a-c give the distribution of water consumption, billed amount, billed amount paid and the arrears.

Water Use and Reliability

Water reliability depends more on the pressure zones in the NCWSC service regions. Most of the pressures zones in our survey had water demand outstripping supply leading to water rationing programmes by the water service provider. Respondents were therefore asked about how regularly they received water from the piped network. 20% received 7 days a week, 13% got water for 2-days in a week, 34.5% received water for 3-4 days a week, while 28% receive water for 5-6 days and only 4.5% receive water once a week.

Firms were asked about how they use water within their premises. Based on the options read out to them, table 3 captures the feedback from the firms:

Table 3: Water use by firms

Water use	**Reponses (%)**
Restrooms/lavatories for employees	73.0%
Restrooms/lavatories for customers	53.8%
Use water as part of a process of producing something, including food preparation.	43.0%

Cleaning (floors, equipment, etc.)	85.5%
Serving water to customers	35.0%
Using water outside for plants or gardens	11.0%

The primary source of water was noted to be NCWSC piped water, however, firms were asked if they use water from different sources for different uses. 26% of the firms use water for different source for different uses for example using bottled water to serve customers. Based on the prevailing water situation, firms were asked whether they had plans to change the way they use water or source water, 94% of the respondents had no intentions of changing how they source water or use water. The percentage of respondents (6%) who said they would consider changing how they use water or source water felt that buying storage facilities (48%), relying more on venders (19%) and sinking own borehole (38%) would be a better way of addressing their current water problems.

In order to understand how businesses, respond to increases in the cost of water, for example if the water bills were to more than double in a month. 29% reported that they would use less water, 25% of businesses would react by buying more vended water, while 10% said they would pass the cost on to the customers. The rest of the respondents (36%) would react by either splitting the water bill with the customers or not paying the increased water bill.

Since most firms considered water as an important input in their production processes, they were asked about what proportion of their production cost was the monthly water bill. In figure 4, we outline the monthly water bill as a percentage of the production cost. Based on the reported monthly revenues, the average proportion of water bill to revenue was found to be 5.7%.

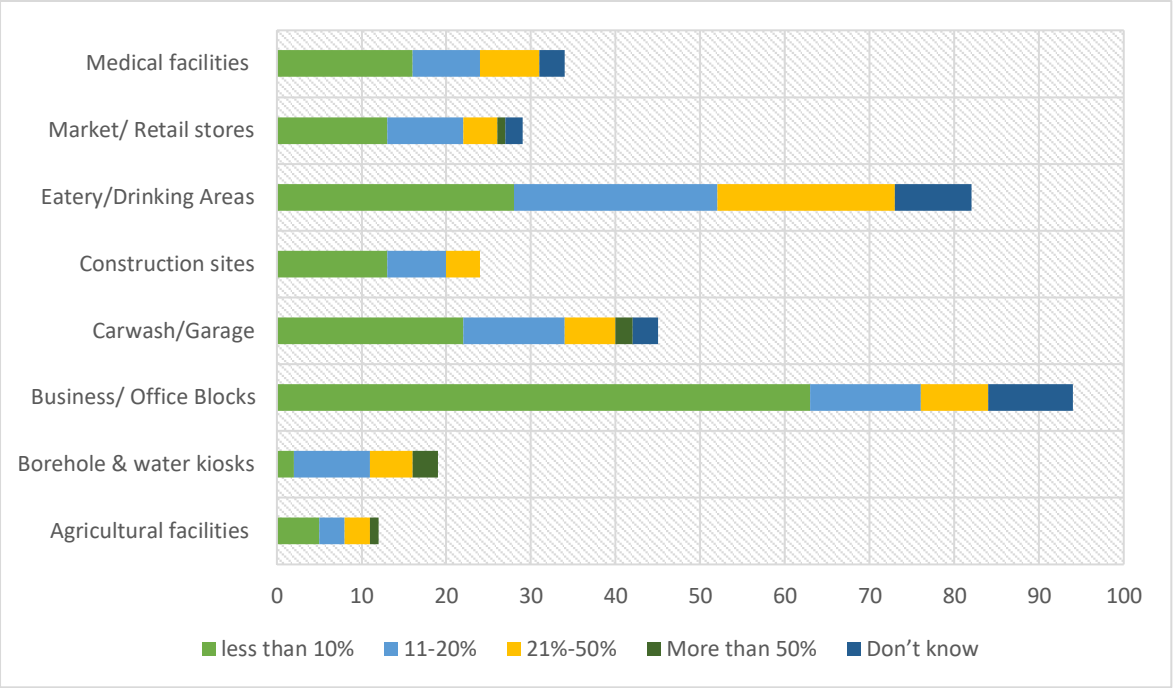

Figure 4: Water bill as a percentage of production cost

A detailed descriptive statistics for the various businesses is in table 4.

Table 4: Descriptive statistics by firm categories

Variable	Pooled (means)	Agric-facilities (means)	Borehole/ Kiosks (means)	Business/office Block (means)	Carwash/Garages (means)	Construction sites(means)	Eateries/Drinking (means)	Markets/ Retails (means)	Medical Facilities (means)	Petrol Stations (means)
Business Age (years)	8.3	14.7	5.4	7.9	12.3	9.1	6.4	8.0	7.3	8.3
Revenue (US$/ Month)	133178	617.3	41,250.00	209,259	333,333	14,101	10,922	2,950	312,037	12,654
Electricity Bill (US$/Month)	130.3	218.3	20.6	241.1	54.6	128.5	37.5	21.7	591.8	104.8
No. of Toilets	7.3	11.3	1.4	14.1	3.3	15.3	4.2	2.2	9.8	2.9
Monthly Rent (US$)	667.6	34.3	133.7	702.0	895.5	1,087.9	418.7	637.9	753.7	1,080
No. of Employees (fulltime)	47.8	5.2	2.4	149.7	19.4	8.4	11.2	5.1	70.0	7.6
Number Tenants	54.2	-	5.0	40.0	-	102.8	3.5	12.0	-	-
No. of premises sharing water	3.7	-	3.5	5.6	2.5	-	2.0	3.9	-	-
Monthly payment for sharing (US$)	5.2	-	4.6	4.1	5.6	-	9.7	3.9	-	-
Cost of Borehole construction (US$)	23,205	74,074	-	19,611	15,710	926	17,593	-	46,296	-
Monthly electricity-Borehole cost (US$)	54.4	52.8	-	89.5	25.9	32.4	38.9	-	45.4	-
Borehole treatment Cost	248.6	277.9	-	597.5	44.0	0.6	74.1	-	4.6	-
Borehole water drawn (m^3/month)	35.4	180.0	-	4.8	1.0	-	15.0	-	-	-
Borehole water drawn-rainy season (m^3/month)	2.2	-	-	3.0	0.5	-	2.4	-	-	-
Borehole water drawn-Dry season (m^3/month)	1.8	-	-	2.0	1.5	-	2.0	-	-	-
Number Storage Tanks	1.8	1.9	1.0	2.3	1.9	2.0	1.8	1.4	1.7	1.4
Vendor Charges/unit (US$)	30.4	-	42.8	34.8	42.1	23.2	31.8	1.5	22.3	32.4
Monthly vending Cost (US$)	118.5	-	83.3	75.6	186.0	115.7	159.8	9.8	61.9	78.2
Vendor Charges/20l (US$)	0.3	-	-	0.5	-	-	0.1	-		-
Volume of stored water (m^3)	17.6	62.9	10	23.4	11.1	35.3	14.6	8.7	19.6	8.5
cost of storage tank (US$)	1,073.1	4,804.4	418.3	1,361.6	550.0	1,554.9	1,037.5	571.9	1,343.4	483.5

Coping with unreliable piped network water

In order to address issues of unreliability, firms were asked about how they coped with unreliable water supply services. The following were some of the reported coping strategies;

Sharing Water with neighbouring sources

When asked how they coped with unreliability, 26% reported sharing water with neighboring businesses which had access to piped water and were not experiencing. The firms paid $5 per month in return for the shared water.

Water treatment

As part of coping with the unreliability, firms were asked about how they treat water. 75% of those businesses that they did not treat water. 20% added chlorine/aquaguard or pur as a treatment option. The remaining 5% either boil or let the water to settle before it can be used.

Water Storage

As part of coping with unreliability, about 80% of firms store water from the piped-network. Most of these firms store water in either large tanks (≥50liters) or in smaller buckets (15%) or both 8%. Around 58.3% of businesses have at least one storage tank, 24% have 2 storage tanks, 10.70% have 3 storage tanks, 3.64% have 4 storage tanks, 1.11% have 5 storage tanks, 0.74% have 6 storage tanks, 0.74% have 8 storage tanks, 0.37% have 11 storage tanks and 0.37% have 24 storage tanks.

Private Boreholes

As part of coping with reliability, about 6.3% of the firms reported to have drilled their own boreholes to supplement water from the piped network. It costs an average of $23,241 to set up a borehole system. 90% of the boreholes pump water by way of electric pumps while the rest use solar systems. It costs an average of $46.3 to pump water by way of electricity. In terms of treatment of water from the boreholes, about 60% of businesses treat water by adding chlorine/Aquaguard/Pur before drinking, 10% boil water before use, 10% allow water to settle, and 20% do not treat water. It costs an average of $11 to treat water. The monthly abstraction from the boreholes were reported to be 35.4m^3 per week. During the rainy season, the abstraction is 15.7m^3 per week and 12.8m^3 per week during the dry days.

Water vending

In terms of water vending, around 25% of businesses buy water from vendors who delivers water either on foot, bicycle or using a truck. 31% of firms source their water from different service providers, while 69% source water from the same providers anytime a need arises. Most respondents' belief that sourcing from different venders is more reliable (27%), while 18% use different vendors because they are more available. 16% report that relying on different venders ensures quality of water, while another 15% rely on different vendors because it is cost effective. Asked about what determined the choice of vendors, the respondents stated that the choice was influenced by vendor reliability (27%), availability (18%), quality of water vended (16%), cost of water (15%), timeliness of delivery (6%), consistency of a vendor (6%), distance of the vendor from the business (3%), knowledge of the vendor (2%), vendor loyality (2%), getting water on credit (1%) and finally no apparent preference (3%).

It is interesting to note that about 30% of the respondents do not know the source of vended water sold to them, while more than 44% believe that water comes from the boreholes. On average, the firms use about $3m^3$ of vended water on a weekly basis costing on average $41 per week. About 41% of businesses buy water from vendors once a week, 20% buy water 2-3 times a week, 1% buy water 4 times a week, 6% buy water every day of the week, and 31% buy water in no apparent consistent order.

Estimating coping costs

We calculate the coping costs by disaggregating the cost associated with coping behaviors. These included construction and operation of private boreholes, obtaining water from a shared neighboring connection and paying for the same, monetary payment to water vendors and other informal suppliers and purchase of water storage containers.

Coping Costs associated with boreholes and water storage containers

The monthly business costs of borehole consist of capital, operation and maintenance expenses. The annual capital costs were estimated by multiplying the value of the capital asset (as estimated by the respondent to be the present-day replacement value of the capital good) by a capital recovery factor based on the life of the asset and a real discount rate of 10% (Cook et al.,2016). In order to standardize the useful life of a borehole, we used the lifespan of 40 years as provided for in the valuation manual. It is reasonable to anticipate that borehole owners may not be technically aware of the lifespan of the asset. It is for this reason that we

rely on the valuation report for boreholes in Nairobi City areas. Operation costs include self-reported monthly electricity use and treatment. Amortized over the useful life, the monthly cost of a borehole was determined to be $297.8.

Monthly capital costs of water storage assets are calculated based on reported replacement costs which is a factor of the economic life of the containers (10-20 years) and a discounting factor of 10%. The average monthly capital cost of containers is $11 with an average storage capacity of 15.9m^3 per month (This is about 10% of NCWSC water consumed).

Monetary Payments to Water Vendors and kiosks

To calculate total firms coping costs, we added the monetary payments the firms made to private water tankers, and water kiosks. On average the monthly monetary payment (vending charges) was $118.5. In figure 5 we present average coping costs by business categories. Businesses that rely on boreholes seem to incur higher coping costs compared to others. Agricultural facilities and office blocks predominantly rely on boreholes. This indicates the needs for more reliable source of water due to the nature of their businesses and water use.

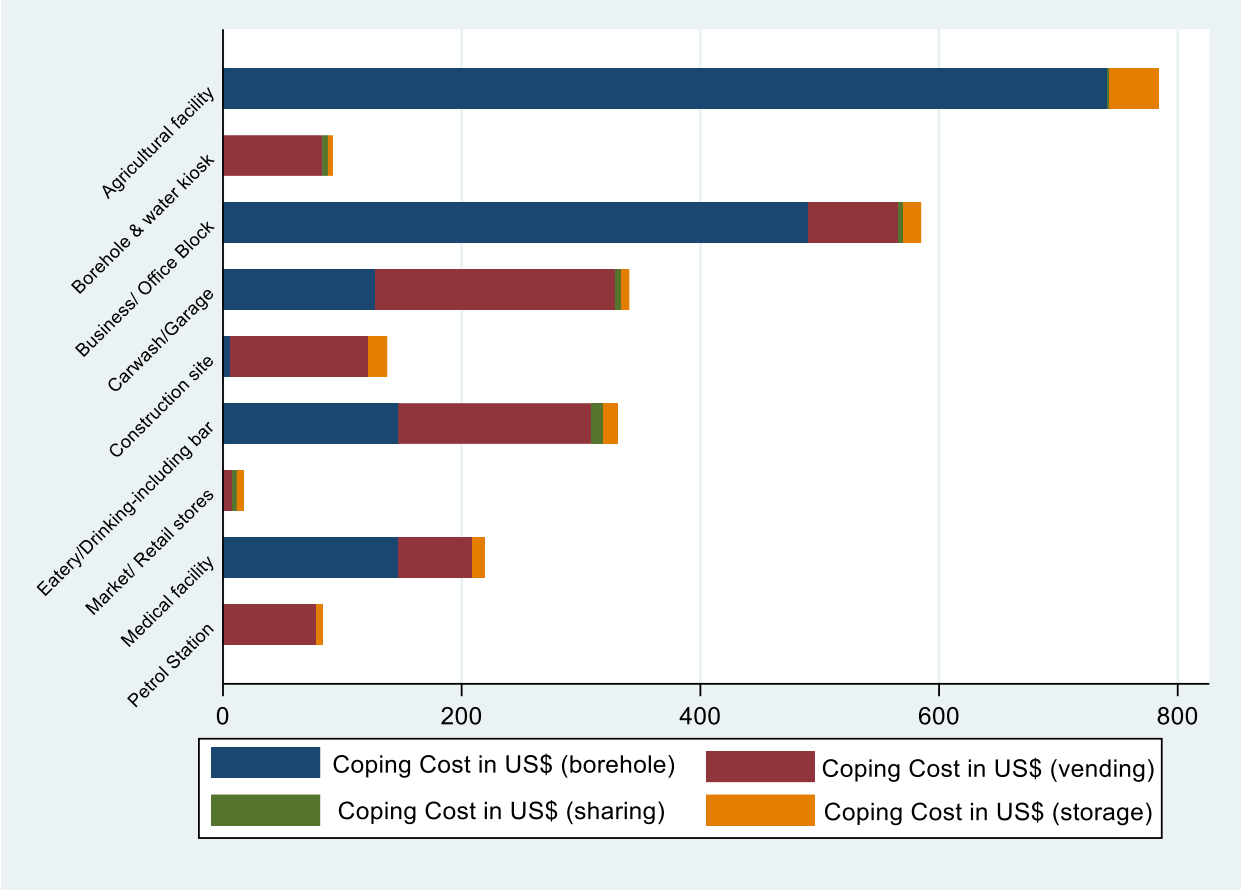

Figure 5: Average Coping Cost by Business Categories (US$)

Multivariate analysis-regression model results

Coping cost functions depends on unit prices of inputs and outputs, conditional on production technology and firm's preference. After estimating the coping costs, we now turn to estimating the factors correlated with the coping costs.

Table 5 presents the regression results for model specification described in section 3. We regress total monthly coping costs on the characteristics of the firms. We control for connectivity to piped water network. We also control for the number of toilets because this has a direct influence on the amount of water used and therefore the coping cost.

Table 5: Regression Results

	Coef.	St. Err.	t-value	p-value	Sig
Business Age (years)	-0.058	0.023	-2.50	0.014	**
No. of employees	-0.001	0.001	-1.34	0.182	
No. of Toilets	0.016	0.004	4.08	0.000	***
Connection to PWN	-2.2	0.535	-4.11	0.000	***
Gender	0.465	0.441	1.06	.294	
Revenue	0.204	0.097	2.11	.037	**
Water Storage	-0.602	0.673	-0.89	.373	
Constant	7.336	1.521	4.82	0.000	***
Mean dependent var		7.593	SD dependent var		1.884
R-squared		0.260	Number of obs		109
F-test		9.816	Prob > F		0.000
Akaike crit. (AIC)		429.661	Bayesian crit. (BIC)		451.192
*** $p<.01$, ** $p<.05$, * $p<.1$					

Comparing piped water use and the coping costs

All businesses interviewed relied on the NCWSC network water as the primary source of water. On average, the businesses source additional 10% (17m^3/month) from the secondary sources as part of coping. However, businesses that have boreholes source up to 84% (141.7m^3) additional water per month for their coping. Those whose secondary sources are vendors source additional 12% (19.8m^3) of their current monthly water use. In figure, we compare current monthly water use from the primary source and the alternative sources by business categories. From the figure, it is clear that medical facilities, eateries and water kiosks rely more on network water. Water kiosks are likely reselling water to other users and rely more on vendors in case the network water is unavailable.

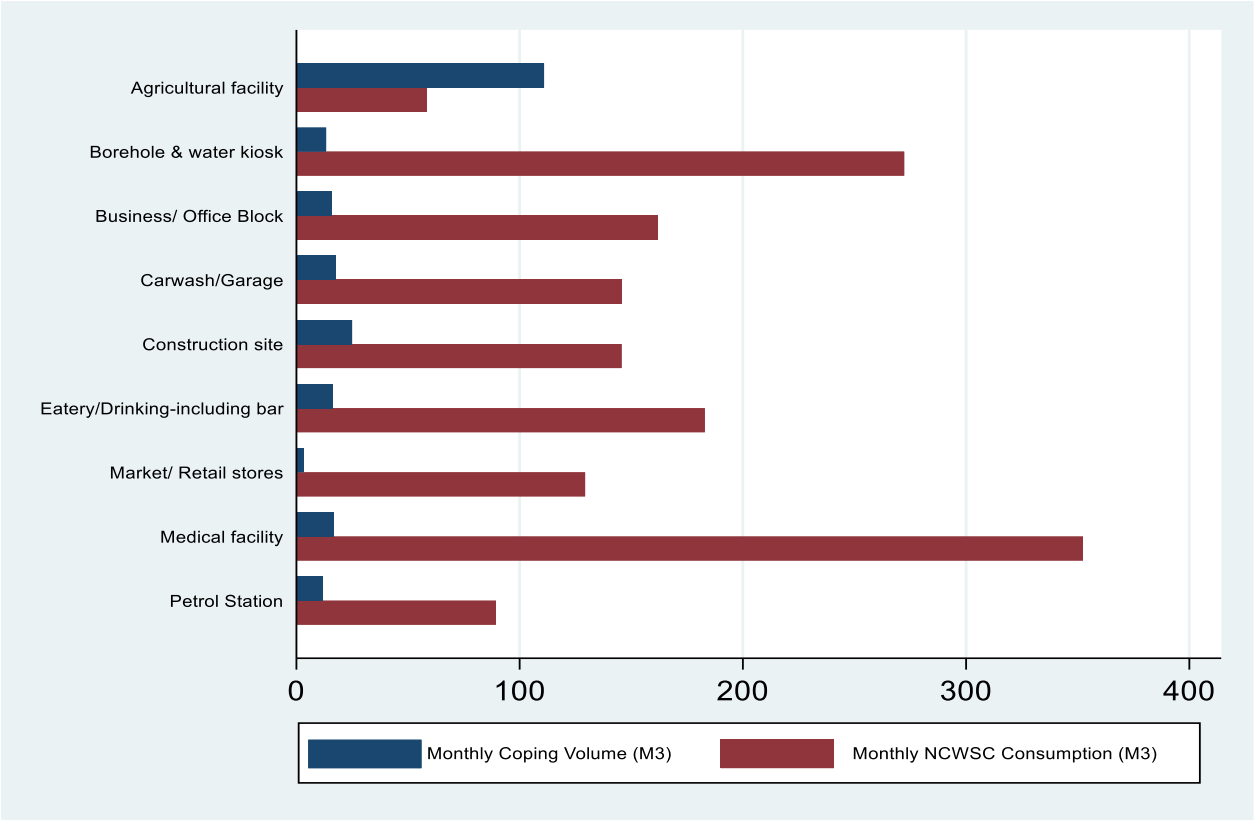

Figure 6: Monthly Water Use from NCWSC against secondary sources

In figure 7, it is again evident that those businesses which rely more on NCWSC are highly billed.

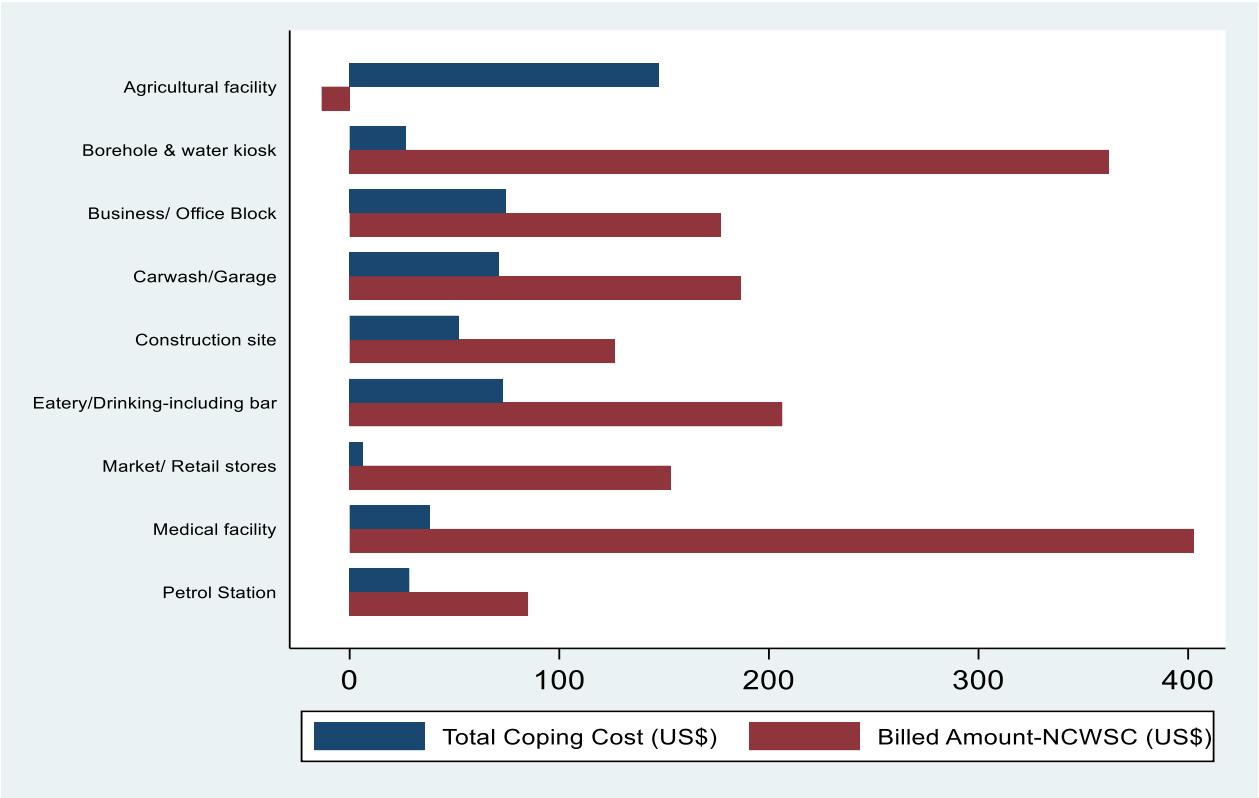

Fig 7. Total coping cost against the NCWSC billed amount (US$)

6. Conclusion

Water is a constitutional right in Kenya (Article 43, Constitution of Kenya, 2010). However, water supply reliability in towns and cities remain a problem and clearly the achievement of such rights remain a challenge to both households and firms. Firms for whom water is important input in their production processes are particularly vulnerable to shortages or reliability. Depending on their ability to substitute to alternative forms of water sources, reliance on municipal supplied water has been shown to result to commercial businesses incurring additional coping costs to secure the reliability and quality of water they require.

Commercial water customers comprise approximately 5% of all accounts in the NCWSC billing records, but are shown to consume 36% of the total billed water averaging about 168m^3/month per firm. Commercial firms are also shown to pay their water bills promptly and sometimes hold credit on overpayment of bills. Therefore, it is clear that the commercial businesses have an important role in ensuring the water service providers are financially sustainable. What is interesting is that more than 94% of commercial firms have no intentions to completely move away from NCWSC even when they are faced with reliability challenges.

Coping mechanisms reported by firms are comparable to those of households as explained in various literature, however, the scale of coping strategies are more pronounced than in the case of households. Firms use bigger and many storage facilities, rely on venders with capacity to deliver more water, drill boreholes, treat water, and also rely on neighbouring businesses that do not face reliability issues. Even though 61% of the businesses consider themselves water intensive, only 43% use water in their production processes. The remaining businesses use water for cleaning purposes within their premises, which is equally important in maintaining a clean working environment for both staff and customers.

The monthly coping costs for firms with storage facilities was found to be about $11. This is fairly low and may indicate outlier situation given that some of the firms have up to 24 containers. The use of treatment was found not to be predominant in the commercial sector, this is probably because water is used in the production process or cleaning. Only 25% of the reported treating water. These were largely eateries, offices and medical facilities. Only 6.3% of the respondents had boreholes which cost about $23,241 to drill and equip. When amortized, the monthly coping costs average $297.8. This is higher than the $130 paid per month for the network water. More than 25% of the respondents depended on vended water.

Vendors supply water using tracks, foot or bicycles. Monetary payments made by firms to vendors averaged $118.5. It is clear that the coping cost for firms is very high considering that the water they pay for is about than 10% of what they receive from NCWSC. The commercial firms have also shown willingness to pay for water they receive both from alternative sources and NCWSC. It is therefore possible to assume that with improved water infrastructure, they would have the ability to pay and equally willing to pay for the cheaper water. After estimating the total coping costs, it was determined that coping costs reduce with the number of years a firm has been in business and also relying on network water as primary source. However, the total coping costs for office blocks seem to be driven by the number of toilets.

Coping cost analysis helps in revealing a lot of information on peoples' and firms' water use related behavior and accordingly and policy formulations. To design policies for improved municipal water services, it is crucial to have a clear and conclusive evaluation of social benefits which in turn depends on information about peoples' demand for improved water supply services (Whittington et al., 2006). While firms are willing to pay for the utility water, it is clear that the reliability is a challenge and most firm have opted for non-network water which is expensive but reliable. Compared to households, the coping costs are far more expensive for firms than the households. The tariff structure in Nairobi is much too low to cover operations and maintenance, let alone capital depreciation, and many firms in Nairobi likely incur their own costs in coping with intermittent supply. But the comparison highlights an easily overlooked fact: the economic burdens of poor water supply often falls more heavily on firms than on households with piped connections. The coping behaviour of firms is akin to those of households, but at higher cost. Vasquez (2012) shows almost 80% of households to use at least one storage device. We find 94% of the firms to use at least one storage facility.

Acknowledgments

We acknowledge the support of the Environment for Development network with financial support from the Swedish International Development Cooperation Agency (SIDA). We also acknowledge the support of the Nairobi City Water and Sewerage Company.

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Appendix 1: Sample Distribution across pressure zones and commercial water use categories

	ZONE												
CATEGORIES	**1**	**2S**	**2N**	**3N**	**3S**	**5**	**6**	**7**	**8**	**9**	**10 N**	**10S**	**Total Sample**
Agricultural facility							3		7	1	1		12
Borehole & water Kiosk		1				1	2	1	4	3	2	5	19
Business & Office Block		10	3	4	10	3	23	6	22	4	6	3	94
Construction Site	1				1	3	4	2	5	4	4		24
Eating/Drinking		2	2	2		1	16	2	30	14	12	1	82
Garage/Carwash			2		2		6	1	26	5	3	0	45
Market & Retail stores		2	3	2	9	2	9	2	24	5	3	0	61
Medical facility				1	1	3	2	1	7	4	10		29
Petrol Station				1	2	1	4		21	3	2	0	34
Total Sample	**1**	**15**	**10**	**10**	**25**	**14**	**69**	**15**	**146**	**43**	**43**	**9**	**400**