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Water and Sanitation Service Delivery, Pricing, and the Poor

An Empirical Estimate of Subsidy Incidence in Nairobi, Kenya

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Water and Sanitation Service Delivery, Pricing, and the Poor: An Empirical Estimate of Subsidy Incidence in Nairobi, Kenya

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Abstract

The increasing block tariff (IBT) is among the most widely used tariffs by water utilities, particularly in developing countries. This is in part due to the perception that the IBT can effectively target subsidies to low-income households. Combining data on households' socioeconomic status and metered water use, this paper examines the distributional incidence of subsidies delivered through the water tariff in Nairobi, Kenya. Contrary to conventional wisdom, we find that high-income residential and non-residential customers receive a disproportionate share of subsidies and that subsidy targeting is poor even among households with a private metered connection. We also find that stated expenditure on water, a commonly used means of estimating water use, is a poor proxy for metered use and that previous studies on subsidy incidence may dramatically underestimate the magnitude of the subsidy delivered through water tariffs. These findings have implications for both the design and evaluation of water tariffs in developing countries.

Key Words: water tariff, water pricing, increasing block tariff, subsidy targeting, water utilities, Kenya, developing countries

JEL Codes: Q25, L95, D63

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1. Introduction

The increasing block tariff (IBT) is among the most widely used tariffs by water utilities, particularly in developing countries. According to a recent survey of water utilities across the globe, 53% percent of utilities in the sample implement an IBT, with 74% percent of utilities in developing countries doing so (GWI 2013). The popularity of the IBT reflects two widely held perceptions about its potential merits. First, policy makers believe the lifeline block of the IBT can be used to ensure low-income households have access to a certain quantity of water at a price deemed affordable. Second, they believe that higher prices in the upper block(s) of the IBT can both prevent wasteful or extravagant water use and provide an opportunity to improve cost recovery from households who use more water. The intuitive appeal of the IBT rests on the implicit assumptions that all households have a private piped connection to the water network and that low-income households use less water than high-income households.

Scholars have long questioned whether these assumptions are valid in low and middle-income countries (Whittington 1992; Boland and Whittington 2000; Komives et al. 2005). This has led to a body of empirical work that has challenged common intuition about the poor, access to water and sanitation services, and the relationship between income and water use (e.g., Komives et al. 2006; Komives et al. 2007; Banerjee et al. 2008; Banerjee and Morella 2011; Barde and Lehman 2014). In this paper, we examine the distributional incidence of subsidies delivered through the water tariff in Nairobi, Kenya. In particular, we combine socioeconomic data from a household survey with data on metered water use to estimate the distribution of

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subsidies among residential customers with a private metered connection in Nairobi. We then use a complete set of individual billing records from Nairobi City Water and Sewer Company (NCWSC) to estimate the distribution of subsidies among all residential customers, including those with shared connections. Finally, we expand the scope of our analysis and examine the distribution of subsidies among residential and nonresidential customers in Nairobi.

Our analysis departs from existing studies in the subsidy incidence literature in three ways. First, studies in the literature typically use stated expenditure on water to estimate water use. To our knowledge, this study is the first to combine household-level socioeconomic data with data on metered water use to estimate subsidy incidence in the water sector. Second, unlike the majority of studies in the literature, we use empirical city-specific estimates of the cost of providing water and wastewater services to estimate subsidy incidence. Finally, all studies in the literature focus on the distribution of subsidies among residential customers. Our study extends the literature by examining the distribution of subsidies among all customer classes.

Overall, we find that the IBT implemented in Nairobi is not effectively targeting subsidies to low-income households. Among households with a private metered connection, households in the lowest wealth quintile receive less than 20% of the subsidies delivered to these customers. Subsidy targeting improves slightly when we examine subsidy incidence among all residential customers, but higher-income customers still receive a disproportionate share of subsidies. Our analysis of subsidy incidence among all customer classes indicates that non-residential customers, who constitute 5% of customer accounts, receive over a third of the subsidies delivered through the tariff. We also find that stated expenditure is a poor proxy for metered water and that the magnitude of the subsidy delivered through the water tariff is substantially larger than previous studies would suggest.

The remainder of the article is organized as follows. The second section of the paper discusses the issue of subsidy incidence and provides a review of the subsidy incidence literature in the water sector. The third and fourth sections describe our empirical strategy and the data used in our analysis, respectively. The fifth section presents our results. The final section provides a discussion of our results and some concluding remarks.

2. Background and Literature Review

Despite the intuitive appeal of IBTs, there are a number of reasons why the IBT may not effectively target subsidies to low-income households in these contexts. For example, in order for a household to receive a subsidy that is delivered through the water tariff, it must have a piped connection. However, poor households often lack a piped water connection.[1] Similarly, low-income households are also more likely than wealthier households to have a shared connection to the piped water network (e.g., a yard tap) and to live in multi-unit dwellings that are served by a single meter. Households that share a connection or live in a multi-unit dwelling served by a single meter pay a higher volumetric price for water than if they had an individual meter because the collective water use of those who share a connection falls in the upper, more expensive, blocks of the IBT. Finally, the extent to which income and water use are highly correlated is an empirical question, even among households with a private connection.[2] Indeed, the limited empirical evidence in the literature suggests that the correlation between income and water use may not be as strong as many assume (Whittington et al. 2015).

Concerns about the extent to which the IBT, and utility tariffs more broadly, can be used to effectively target subsidies to low-income households has led to a body of empirical research on subsidy incidence. (See Appendix 1 for a summary of studies that have been published on subsidy incidence since 2000.) To calculate the distributional incidence of subsidies delivered through the water tariff, the analyst needs information on the magnitude of the subsidy received by each household and the relative income or wealth of each household. The subsidy received by each household is simply the difference between what it costs to provide the particular household a particular level of service (e.g., water or water and wastewater service) and what the household actually pays for this service.

The cost of serving each household is a function of households' water use, whether the household has only water or water and wastewater service, and the unit cost of providing water and wastewater services. The amount households pay for water and sanitation service is a function of households' water use, their level of service, and the tariff the utility uses to assess

[1] The fact that the poorest residents in the city, who lack access to piped water and sanitation services, cannot benefit from subsidies delivered through the water tariff is not a sufficient argument against subsidizing water use among some segment of the population. The lowest-income residents in a city are often concentrated in informal settlements. It can either be physically difficult or not possible to service informal settlements due to their density and it may not be legally possible to service them due to issues related to land tenure. In both instances, there can be little a water utility can do to extend services to these households. Thus, whether, to what extent, and how a utility or government should subsidize water use should be evaluated on other criteria (e.g., subsidy incidence, economic efficiency, fiscal viability, etc.).

[2] One reason for this is that household size and income may be inversely related. Thus, even if wealthier individuals use more water than poor individuals on a per capita basis, it does not necessarily follow that the poor households use less water than non-poor households.

fees for water and sanitations service. Thus, in total the analyst must have five pieces of information to estimate subsidy incidence: households' water use, households' service level, the unit cost of providing water and wastewater services, the tariff, and some measure of households' wealth or socioeconomic status. Assembling this information can be quite difficult in practice. In particular, the analyst faces two primary challenges. (See Gomez-Lobo et al. (2000) for an overview of information and modeling challenges associated with designing water and sanitation tariffs.)

First, it can be difficult or expensive to obtain accurate measures of water use and income for the same household. Data on households' socioeconomic status and demographics are typically available in secondary household survey data, such as national income and expenditure surveys, World Bank Living Standards Measurement Study (LSMS) data, and some national censuses. However, these surveys typically do not contain information on household water use. Similarly, utility billing records contain information on household water use, provided customers are metered, the meters are working, and the utility regularly reads customers' meters. Due to confidentiality requirements, however, it is typically not possible to match household level socioeconomic data in nationally representative household income and expenditure surveys and customer data in utility billing records.

The second challenge facing analysts is associated with estimating the cost of providing water and wastewater service. To do this, the analyst must first define cost, which can range from financial operations and maintenance (O&M) costs, financial O&M costs and capital costs,[3] and full economic costs.[4] The analyst must then estimate the appropriate cost of providing each level of service.[5]

Studies in the subsidy incidence literature have addressed these two challenges in a variety of ways. Because it can be difficult or not possible to obtain good measures of both

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[3] Capital costs are not consistently defined in the literature. For example, capital costs may include the financial depreciation of historical investments, the current financial costs of repairing and replacing the existing capital stock, and the financial costs of expanding the existing water and wastewater networks.

[4] Economic costs include the opportunity cost of the raw water supply, the shadow price of all inputs, the economic costs associated with wastewater discharge, and the opportunity cost of capital.

[5] Estimating the cost of providing water and sanitation services can be difficult. One reason for this is the way in which capital projects are financed in many countries. Financing for large water and sanitation projects often comes in a variety of forms (e.g., fiscal transfers, grants, and loans) from a variety of sources (e.g., national or sub-national governments and international donor organizations). Indeed, in many countries, national ministries or asset holding companies, not utilities that provide water and sanitation services, are responsible for capital projects.

socioeconomic status and water use for the same household, studies in the literature typically use a single data source to obtain information on both households' socioeconomic status and water use. In particular, most studies use households' stated expenditure on water to estimate households' water use.[6] They collect this information either through primary household surveys (e.g., Foster 2004, Bardasi and Wodon 2008, and Angel-Urdinola and Wodon 2012) or from nationally representative household budget and expenditure surveys (e.g., World Bank LSMS data).

To estimate household water use from stated expenditure on water and sanitation services, the analyst must have three types of information. First, she must be able to identify whether or not a household is connected to the piped network, and whether or not the household receives only piped water services or piped water and sewer services. Second, the analyst must also be able to identify which utility serves each household. This information is typically not contained in household income and expenditure survey data, but rather must be inferred based on the geographical extent of utilities' service areas. Third, the analyst must have information on the tariffs applied by each of the utilities that serve the households in the survey data. Once the analyst has this information, she can back calculate (impute) water use from stated expenditure on water and sanitation services by applying the official tariff of the relevant water utility.

There are a number of reasons why imputed water use may not be a good proxy for metered water use. Households may not be able to accurately recall how much they spend on water and sanitation services.[7] Even if households can perfectly recall their monthly expenditure on water and sanitation services, there are additional reasons why expenditure on these services might be a poor proxy for actual water use. For example, income and expenditure surveys often do not contain information on whether a household connection is metered. If households do have

[6] Some studies use alternative means to estimate water use. For example, some studies that use primary data collected through household surveys obtain water use data by asking households to show a recent copy of their water bill (e.g., Walker et al. 2000 and Foster 2004). However, even when analysts obtain information on household water use from previous water bills, some households may not be metered, may not have functioning meters, or may not be able to produce copies of previous water bills during the interview.

[7] Households incur a variety of expenses each month and throughout the year and survey evidence suggests that water constitutes a very small portion of monthly household expenditure (often less than 3%) for households with piped connections (Appendix C.4 in Komives et al. 2005). Thus, it is possible that households may have difficulty recalling expenditure on water and sanitation services because they do not represent a major portion of their total expenditures. Indeed, in a 2,500 household survey conducted in Argentina, Foster (2004) reports that only 30% of the households were able to recall the amount of their most recent bill.

metered connections, the meters may not be working or the utility may not read them on a regular basis. Households may also have a shared connection. In these instances, households' water bills will not reflect their metered water use.

Additionally, household budget and expenditure surveys ask households how much they spent on water last month. They typically do not ask households specifically how much they spent on piped water services, nor do they ask households how much they spent on sanitation services.[8] Thus, household recall of expenditure on water in these surveys may include the amount they spent on water from vendors and sewer services.

Water bills may also include fees that are unrelated to water consumption in the most recent billing period. This could include fees for other services (e.g., solid waste collection[9]), pro-rated connection charges, arrears, or penalties for non-payment. Additionally, countries in Latin America and elsewhere are experimenting with including payment for environmental services in water bills to promote watershed protection (see Whittington and Pagiola 2012).

Studies in the literature address the issue of cost in three general ways. (See Appendix 2 for a summary of cost estimates used in the literature.) First, studies may use generic cost estimates, or international benchmarks, to calculate subsidy incidence (e.g., Komives et al. 2005, Komives et al. 2006, Foster and Yepes 2006).[10] Common sources for generic cost estimates include GWI (2004) and Kingdom et al. (2004). Other studies use empirical, site-specific cost estimates (e.g., Groom et al. 2008, Banerjee and Morella 2011, Walker et al. 2000). However, these studies typically do not explicitly state what the cost estimates include or precisely how they were derived. Finally, studies may make ad hoc assumptions about the cost of providing water and wastewater services. For example, Barde and Lehmann (2014) assume that the average tariff currently implemented in Lima, Peru (approximately 0.64 USD/m3[11]) represents full cost recovery.

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[8] For example, the most recent Kenya Integrated Household Budget and Expenditure survey asks households "What was the total cost of water for your household last month?" (KNBS 2006).

[9] See Gomez-Lobo et al. (2000).

[10] For example, Foster and Araujo (2004) state, "[a]lthough there is no available information about the cost of potable water in Guatemala, international benchmarks would suggest a full cost of around 0.30 to 0.40 USD/m3, exclusive of sewerage" (35). The authors do not explicitly state whether this "full cost" is for O&M costs or for O&M and capital costs. They also do not indicate the source for the international benchmarks to which they refer.

[11] Assuming an exchange rate of 0.36 USD/PEN.

There is broad consensus in the literature that de facto subsidies delivered through the water tariff are poorly targeted and largely regressive. Indeed, many studies find that subsidies delivered through the water tariff perform worse than if the subsidies were equally distributed among the population. This is principally due to the fact that low-income households are less likely to have a private connection to the piped water network and, thus, do not receive subsidies delivered through the water tariff.

Studies that examine subsidy incidence only among households with a piped connection also find that subsidies are poorly targeted. This is primarily due to facts that income and water use are often not highly correlated and that the tariff implemented by many utilities is not sufficient to cover the cost of providing service. These empirical results are supported by simulations conducted by Whittington et al. (2015) that suggests little can be done to improve subsidy targeting when tariffs are not sufficient to cover costs.

A careful review of the literature highlights three gaps. First, studies in the literature either focus only on subsidies associated with the delivery of piped water service or do not explicitly state whether they include subsidies associated with wastewater service. Wastewater service is often more expensive to provide than water service. To the extent that wastewater services are sold below cost and to the extent that higher-income households are more likely to have connections to the piped wastewater network, estimates in the literature may overestimate the performance of subsidies delivered through the tariff.

Second, nearly all of the studies in the literature use stated expenditure to estimate water use. As discussed above, there are several reasons why stated expenditure may be a poor proxy for metered water use. Thus, it is unclear whether the broad consensus in the literature is attributable to the fact that studies use the same, potentially flawed, measure of water use.

Finally, all of the studies in Appendix 1 focus on subsidy incidence only among residential customers. This is not surprising given that these studies use data from household surveys. As a result, however, the literature ignores the distributional issues between residential and non-residential customers. Depending on the tariff applied to non-residential customers, failing to include non-residential customers may over or understate the magnitude of total subsidies delivered through the water tariff.

3. Empirical Strategy

This study was designed to fill the gaps in the subsidy incidence literature highlighted in the previous section. Our empirical strategy proceeds in three analytical steps. In the first step of our analysis, we combine socioeconomic and demographic data from a survey of 656 households with data on metered water use from NCWSC billing records. We use these data to: 1) estimate the distribution of subsidies among households with a private metered connection, and 2) examine the extent to which stated expenditure is an accurate proxy of metered water use.

According to the most recent census, less than a quarter of households in Nairobi reported using a private connection to the piped water network as their primary drinking source (KNBS 2009). Approximately half of households used piped water that is not piped into their dwelling as their primary drinking water source. Thus, in the second step of our analysis, we examine the distribution of subsidies among all NCWSC's residential customers, including residential customers with shared connections.[12] In the third, final, step we expand the scope of our analysis to examine the distribution of subsidies among residential and non-residential customers in Nairobi.

Subsidy Incidence

We obtain information on customer water use directly from 21 months of NCWSC's billing records. Like many utilities, NCWSC does not read each meter every month.[13] To address this, we calculate monthly water use directly from actual meter readings in the NCWSC billing data as described in Equation 1.

$$WUSE_{i,t} = \left[\frac{READING_{i,t} - READING_{i,t-1}}{RDATE_{i,t} - RDATE_{i,t-1}}\right] \cdot 30.5\ days \quad (1)$$

where:

- $WUSE_{i,t}$ is the water use for household i in month t;
- $READING_{i,t}$ is the meter reading for household i in month t;
- $READING_{i,t-1}$ is the previous actual meter reading for household i;
- $RDATE_{i,t}$ is the date on which NCWSC read the meter for household i in month t; and
- $RDATE_{i,t-1}$ is the date of the previous actual meter reading for household i.

[12] Seventeen percent of households cited water vendors as their primary water source. Thus, the 52% noted above reflects households that obtain water from a shared connection or a neighbor.

[13] NCWSC attempts to read 75% of customer meters each month. When the company does not read a customer's meter, it estimates the customer's water bill for that billing period.

We then use the estimates of households' monthly water use obtained in Equation 1 to calculate households' average monthly water use over the period covered by the billing records.[14]

We define the subsidy received by each customer as the difference between the cost to serve each household and what the households pay for service. We calculate how much a customer pays by applying NCWSC's official tariff to our estimates of customers' average monthly water use. We define the cost of serving a particular customer as in Equation 2.

$$COST_i = WUSE_i \cdot WCOST + I_{ww,i} \cdot (WUSE_i \cdot WWCOST) \qquad (2)$$

where:

- $COST_i$ is the average monthly cost of serving household i (USD/month);
- $WUSE_i$ is the average water use of household i from Equation 1 (m3/month);
- WCOST is the average volumetric cost of providing water service (USD/m3);
- WWCOST is the average volumetric cost of providing wastewater service (USD/m3); and
- $I_{ww,i}$ is an indicator variable that takes the value 1 if a household has wastewater service and 0 otherwise.

We develop empirical estimates of the average cost of providing water and wastewater services. Our cost estimates include both operations and maintenance as well as capital costs. They do not include the opportunity cost of the raw water supply.

We use subsidy shares, the share of subsidies received by different groups of customers, to assess subsidy incidence.[15] Equation 3 defines the share of subsidies going to a particular group of customers.

$$S_j = \frac{\sum_{i=1}^{n_j} SUB_i}{\sum_{j=1}^{J} \sum_{i=1}^{n_j} SUB_i} \qquad (3)$$

[14] Metered water use may not reflect the total amount of water households use. For example, due to the fact that NCWSC does not provide 24x7 water supply, households may purchase water from vendors or have a private borehole to supplement their piped water supply. Households might also purchase bottled water for drinking even if they receive an adequate supply from their piped connection. Finally, water meters may themselves not accurately record actual water use when water supply is intermittent.

[15] Coady et al. (2004) and Van de Walle (1998) provide a comprehensive overview of alternative measures of subsidy targeting.

where:

- S_j is the share of subsidies received by customer group j (j=1…J), and
- SUB_i is the share of subsidies received by household i.

We calculate the distribution of subsidies among residential customers of different income levels. Our analysis of subsidy incidence among all customer classes examines the distribution of subsidies among residential and non-residential customers.

Stated Expenditure as a Proxy for Water Use

Nearly all studies in the subsidy incidence literature use stated expenditure to estimate household water use (see Appendix 1). We examine whether stated expenditure is an accurate proxy for metered water use by estimating household water use from households' stated expenditure on water and comparing this to their metered water use. To do this, during the household survey we ask households if they can recall the amount of their last bill from NCWSC and the number of months of service the bill covered. Equation 4 shows how we impute water use for customers with only piped water service. We use an analogous approach to impute water use for customers with both water and sewer service.

$$IMPUSE_i \tag{4}$$

$$= (EXPS_i - RENT)/p1 \; if \; EXPS_i > 0 \;\&\; EXPS_i \leq b1max_w$$

$$= b1 + (EXPS_i - b1max_w)/p2 \; if \; EXPS_i > b1max_w \;\&\; EXPS_i \leq b2max_w$$

$$= b2 + (EXPS_i - b2max_w)/p3 \; if \; EXPS_i > b2max_w \;\&\; EXPS_i \leq b3max_w$$

$$= b3 + (EXPS_i - b3max_w)/p4 \; if \; EXPS_i > b3max_w$$

where:

- $IMPUSE_i$ is the imputed water use for household i (m3/mo.);
- $EXPS_i$ is the stated expenditure for household i (Ksh/mo.);
- RENT is the monthly meter rent charged in the NCWSC tariff (Table 1);
- pX is the volumetric price for water in the Xth block in the NCWSC tariff (Table 1);
- bX is the volumetric upper bound for the Xth block in the NCWSC tariff (Table 1); and
- $bXmax_w$ is the amount a water customer would be charged for consuming the maximum amount in the Xth block of the NCWSC tariff.

4. Data

The first step of our analysis examines subsidy incidence among households with a private connection to the piped water network. For this analysis, we use data from a sample of 656 households that were randomly drawn from two of Nairobi's six service regions.[16] The survey was conducted between November 2013 and January 2014 and collected a range of socioeconomic and demographic information from households, including data on monthly income, household expenditure, and asset ownership. Following Filmer and Pritchett (2001) and Filmer and Scott (2008), we use principal component analysis to construct an asset index to serve as a proxy for wealth.[17]

We obtain information on customer water use from 21 months of NCWSC's billing records. The billing data cover the period from August 2012 to May 2014. The principal challenge in our empirical strategy was to identify households in our survey sample in the billing records. Like many cities in developing countries, Nairobi does not have a formal system of addresses. Thus, it was not possible to first construct our sample from the billing records and then locate households to conduct the household survey.[18] To address this, we used households' account numbers to identify households in our sample in the billing records. Because households do not typically know their NCWSC account number, however, we obtained households' account numbers by matching the serial number on the households' water meter with the account number on the NCWSC marketing assistant's itinerary.

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[16] Each day, survey enumerators were paired with NCWSC marketing assistants (meter readers). Each pair of enumerators would then shadow a marketing assistant on their meter reading route for that day. Starting at the beginning of the itinerary the marketing assistant was reading that day, the enumerators were instructed to select the tenth customer account as the first household. The marketing assistant would then introduce one of the enumerators to the household and continue on his meter reading route. The second enumerator would select the twentieth account on the list and do the same. Once the enumerators completed an interview, they would call the marketing assistant and meet them where they were in their current meter reading route. The enumerator would then use the next account as a sample household. If nobody was at the household, enumerators were instructed to note the address and attempt two call-backs. If someone from the household was home, but did not have time to complete the survey, or the head of household or spouse was not home, enumerators were instructed to take the contact information of the head of household and attempt to schedule a call-back two times before replacing the household in the sample.

[17] Assets included in the index include: LPG as a main cooking fuel, biomass or kerosene as a main cooking fuel, separate kitchen, security guard, connection to the electricity grid, mobile phone, internet connection, TV, radio, computer, private car, washing machine, refrigerator, borewell, and additional land in/out of Nairobi.

[18] The survey team attempted to do this during three days of the survey pre-test. However, it proved logistically infeasible.

Our analysis of NCWSC's billing records confirms that the utility implements the official tariff to calculate customers' water and sewer bills. Thus, we use the official tariff to calculate customers' water bills (Table 1).[19] NCWSC implements an IBT with 4 usage blocks. In addition to the fixed charge for meter rent, NCWSC applies a minimum charge for 10 m3/mo. Households that use less than 10 m3/mo. are charged for 10 m3/mo. NCWSC charges customers with a connection to the sewer network an additional 75% of the volumetric portion of their water bill for wastewater service.

We use data from five years of audited financial statements (FY 2007 to 2012) to estimate NCWSC's average operations and maintenance costs. We derive capital cost estimates from data in NCWSC's water master plan (MoWI & AWSB 2014) and interviews with senior water and sanitation engineers at NCWSC, Athi Water Services Board, and local engineering firms. Table 2 presents the cost estimates we use in our analysis. Assuming 35% non-revenue water, we estimate the full cost (O&M plus capital costs) of water service to be 1.40 USD/m3 and 1.46 USD/m3 for wastewater service. These estimates are higher than the cost estimates used in many studies, but of similar magnitude to the cost estimates in GWI (2004) and Kingdom et al. (2004) once non-revenue is accounted for (see Tables A2.1 and A2.2 in Appendix 2).

For the analysis of subsidy incidence among all residential customers and among all customer classes, we obtain information on customer water use from NCWSC billing records. However, NCWSC does not have socioeconomic or demographic information about its customers. In the absence of household-level data on income or socioeconomic status, one could potentially use household budget and expenditure survey data or recent census data to obtain aggregate data on household characteristics. This is not possible in Nairobi for two reasons. First, the most recent Kenya Integrated Household Budget and Expenditure Survey (2005-6) contains only 685 observations from Nairobi. Second, data from the most recent census are not publicly available.

To address this, we obtain information on household socioeconomic status in the following manner. NCWSC groups customers into itineraries that marketing assistants (meter readers) use to read meters on a daily basis. NCWSC has over 2000 itineraries, with each itinerary having approximately 100-200 accounts. We asked the staff in charge of billing in each of NCWSC's six service regions to work with their marketing assistants to rank each itinerary as

[19] Throughout the analysis, we assume a conversion rate of 90 KSH/USD.

predominantly low-income, middle-income, high-income or mixed income. For itineraries that were mixed income, the regional teams were asked to indicate which incomes were represented. We also asked the regional teams to indicate whether the itinerary included accounts in informal settlements. Finally, because NCWSC does not have information on whether meters are shared or individual connections, we asked the regional teams to approximate the percent of accounts on the itinerary that are served by shared meters.

This method of obtaining information on the socioeconomic status of each household has both strengths and weaknesses. The regional teams' classification of itineraries into different socioeconomic strata relies on their perceptions of what constitutes low, middle, and high-income in Nairobi. While this approach does not provide an objective measure of households' socioeconomic status, it does take advantage of the meter readers' and regional teams' in-depth, local knowledge of their service area.

NCWSC has approximately 180,000 active residential accounts. NCWSC staff in the regional offices were able to provide an income classification for itineraries serving approximately 90% of the residential accounts. Approximately 15% of NCWSC accounts are located on itineraries that NCWSC staff indicated are predominantly low-income. Twenty-five percent of NCWSC accounts are located in itineraries identified as predominantly high-income. The remaining accounts are located in itineraries classified as middle-income. Only 3% of accounts are located in itineraries that primarily serve informal settlements.[20]

The income classifications at the itinerary level reflect the fact that low-income households are more likely than wealthier households to have a shared connection. According to NCWSC's classifications, 94% of accounts in itineraries characterized as high-income are served predominantly by individual meters.[21] Over 70% of households characterized as low-income are predominantly served by shared meters.

The income classifications of itineraries also comport well with the household level asset index we construct for our survey sample. Indeed, 80% of households in our survey sample located on itineraries characterized as high-income are in the top two wealth quintiles. Similarly,

[20] Approximately 95% percent of itineraries that serve informal settlements are in itineraries characterized as low-income.

[21] We characterize an itinerary as being predominantly served by individual (shared) meters if NCWSC staff indicate that more than 80% of accounts on the itinerary have individual (shared) meters.

80% of households in our survey sample located on itineraries characterized as low-income are in the bottom two wealth quintiles, with nearly 60% in the lowest wealth quintile.

For our analysis of subsidy incidence among all customer classes, we obtain water use data from the same set of NCWSC billing records described above. NCWSC billing data include 13 different customer classes. We group these customer classes into four general types: residential, non-residential, bulk, and kiosk. Our non-residential customer type includes, but is not limited to, accounts classified as government, community, and industrial.

5. Results

Household Survey—Subsidy Incidence

Table 3 presents some basic characteristics of households in our sample. The average household in our sample has four members, which is consistent with the average household size in Nairobi from the latest census. Approximately half of the households in our sample rent their home. Seventy-eight percent of households in our survey report using their piped water connection as their primary drinking water source. The remaining 22% report using bottled water for their primary drinking water source. Over a quarter of households in our sample report purchasing water from a vendor in the previous year, which reflects the fact that NCWSC does not provide customers 24x7 water service.

Mean and median water use in our sample are 19 m3/mo. and 13 m3/mo., respectively (Figure 1). Average water use among all residential customers in the NCWSC billing data is 31 m3/mo. However, the mean water use of households on itineraries with 100% individual meters is 20 m3/mo., similar to what we find in our sample of households. Nearly 40% of households in the sample fall in the lifeline block (0 to 10 m3/mo.). Over 80% of the sample's water use falls in the first two usage blocks (below 30 m3/mo.). Only 4% of the sample falls in the upper-most block of NCWSC's tariff (>60 m3/mo.).

We find considerable heterogeneity in water use, both within and across wealth quintiles. Figure 2 plots household water use versus the wealth index score. The correlation between a household's wealth index score and water use in our sample is 0.20. Mean water use is 16 m3/hh/mo. for households in the first (lowest) wealth quintile and 30 m3/hh/mo. for households in the fifth (highest) wealth quintile (Table 4).

Table 4 also shows the monthly bill for households in the five wealth quintiles.[22] The mean bill for households in the lowest quintile is 931 Ksh/hh/mo. (approximately 10 USD/hh/mo.). The mean bill for households in the highest wealth quintile is 1509 Ksh/hh/mo. (approximately 17 USD/hh/mo.). As a point of comparison, these representative bills are a fraction of what households report spending on electricity. The mean water and sewer bill for households in the lowest quintile is nearly 60% of what these households report paying for electricity. For the wealthiest households in the sample, the mean bill is less than a quarter of what they report spending on electricity.

Table 4 presents the average price paid by households in each wealth quintile. For the full sample, the mean average price ranges from 79 Ksh/m3 (0.90 USD/m3) to 50 Ksh/m3 (0.56 USD/m3). The mean average price for households in the lowest wealth quintile is 70 Ksh/m3 (0.79 USD/m3) and 50 Ksh/m3 (0.56 USD/m3) for households in the highest wealth quintile. These average price estimates reflect the fact that over 90% of households in our sample have a sewer connection.

Figure 3 shows the distribution of subsidies across wealth quintiles. If the subsidy were evenly, or randomly, distributed among the population, each wealth quintile would receive 20% of the total subsidy. A well-targeted subsidy would deliver a substantial share of the total subsidies to low-income households. In our sample, households in the lowest quintile receive 16% of the total subsidy. Households in the top three wealth quintiles receive nearly 70% of the total subsidy, with households in the highest wealth quintile receiving almost 30% of the total subsidy.

Household Survey—Stated Expenditure as a Proxy for Metered Water Use

During the survey, we asked households if they can recall the amount of their last bill from NCWSC. Nearly 85% of households in our sample indicated that they could recall the amount of their last bill.[23] Figure 4 presents a scatter plot of metered versus imputed water use for households who could recall the amount of their previous water bill. The 45 degree line in Figure 4 traces a line of equality for which imputed and metered water use would be the same for

[22] "Representative bill" here refers to the amount a household would pay per month based on its average water use and NCWSCs tariff.

[23] This percentage is much higher than the 30% percent reported in Foster (2004).

each household. The scatter plot in Figure 4 displays a high degree of dispersion, indicating that stated expenditure does not provide an accurate proxy for metered water use in our sample.

We find that stated expenditure typically overestimates households' water use, often by a substantial amount. This is reflected in Table 5, which provides summary statistics of metered water use and imputed water use from households in our sample. Average metered water use among households who could recall the amount of their last water bill was approximately 19 m3/mo. The average water use imputed from stated expenditure among the sample, however, was 27 m3/mo (42% higher).

Subsidy Incidence among all Residential Customers

Table 6 provides a summary of water use among residential accounts of different income levels. Average water use among residential accounts located on high-income itineraries is 44 m3/mo. with a high degree of heterogeneity. By contrast, average water use among residential accounts located in itineraries characterized as low-income is 28 m3/mo. Average water use among accounts on itineraries that serve informal settlements is 37 m3/mo.

Figure 5 provides a summary of subsidy incidence among all NCWSC's residential customers. Accounts on high-income itineraries constitute 26% of residential accounts, but receive 35% of the total subsidies delivered to residential customers. Middle-income customers represent 58% of the residential accounts, but they receive only 49% of the subsidies delivered to residential customers. Accounts on low-income itineraries constitute 16% of the total residential accounts and receive 16% of the total subsidies delivered to residential customers through the water tariff. Residential accounts on itineraries that serve informal settlements constitute 3% of residential accounts and receive 4% of the total subsidies received by residential customers. Thus, low-income customers receive approximately the same amount of subsidies that they would receive if the subsidy were evenly distributed among the population.

Subsidy Incidence among all Customer Classes

We now turn to the results for subsidy incidence among all customer classes. Residential accounts constitute 94% of NCWSC customers (Table 7). Nonresidential accounts represent 5% of NCWSC customers. The remaining 1% of accounts are official public kiosks and bulk customers.

Despite the fact that residential accounts make up the vast majority of NCWSC customers, they account for only 57% of the overall water use and 56% of total billings (Table

7). Non-residential customers, on the other hand, account for 35% of the overall water use and 41% of total billings.

With respect to subsidy incidence, we find that non-residential customers, who account for only 5% of accounts, receive 31% of the total subsidy. By contrast, residential customers, who constitute the vast majority of accounts, receive 63% of the total subsidy delivered through the water tariff. Among residential customers, accounts in high-income itineraries represent 21% of accounts and receive 19% of the total subsidy. Accounts in low-income itineraries represent 14% of total accounts and receive only 9% of the total subsidies, far less than if subsidies were randomly distributed among customers.

6. Discussion and Conclusions

Our analysis of subsidy incidence among households in Nairobi with a private metered connection indicates that households in the lowest wealth quintile receive only 15% of the total subsidies delivered to households in our sample. In contrast, households in the highest wealth quintile receive nearly 30% of the subsidies. Thus, among customers with a private metered connection, the current tariff performs worse than if the subsidy was randomly distributed among households.

In Nairobi, the poor targeting of the subsidies even among households with a private metered connection is driven by three factors. First, very few customers' water use falls in the uppermost blocks of NCWSC's IBT (Figure 1). Second, at current prices nearly all customers are being subsidized. The average price paid for water and sanitation services among the wealth quintiles in our sample ranges from 0.56 USD/m3 to 0.90 USD/m3. In contrast, we estimate the full cost of providing water and sanitation services in Nairobi to be approximately 2.86 USD/m3. With such high errors of inclusion, it is simply not possible for a subsidy delivered through the tariff to effectively target subsidies to intended beneficiaries. Finally, contrary to common intuition, we find a low correlation between our wealth proxy and water use. This finding is consistent with the limited data that exist in the literature (Whittington et al. 2015).[24]

[24] To the extent that low-income households are more likely to have a shared connection, the relationship between income and metered water use is likely to be weaker than we find in our sample of households with a private connection.

Using our survey sample, we also examine the extent to which stated expenditure on water and sanitation services is an accurate proxy for metered water use. We find that stated expenditure is a poor proxy for metered water use.[25] This is striking given that nearly all studies in the subsidy incidence literature use stated expenditure to estimate water use.

Despite the significant measurement error associated with using stated expenditure as a proxy for water use, we find that using stated expenditure to estimate subsidy incidence does not change the policy implications of our results. This is true in our sample because the majority of NCWSC customers have arrears or credits on their accounts and we find a low correlation between income and whether customers have arrears or credits. This may not be true in other locales. Thus, our findings suggest that researchers should exercise caution when using stated expenditure to estimate water use.

When we expand our analysis to the distribution of subsidies among all NCWSC's 180,000 residential customers, we find that customers located on itineraries classified as low-income account for approximately 16% of total residential accounts and receive 16% of the total subsidies delivered to residential customers. While subsidy targeting among all residential customers is slightly better than when we examine subsidy incidence among only households with a private connection, errors of inclusion remain high and customers in low-income itineraries receive the same amount of subsidies as if subsidies were randomly distributed among residential customers.

Finally, our analysis of subsidy incidence among all customer classes indicates that non-residential customers receive over one-third of the total subsidies delivered through NCWSC's tariff. Residential customers, who represent 94% of NCWSC accounts, receive only 63% of the total subsidies. This is not surprising given that non-residential customers account for nearly 40% of total water use and over 40% of the total billings for NCWSC. However, policy makers often implement an IBT with a lifeline block specifically to target subsidies to low-income, residential customers. We find that this is not occurring in Nairobi. Our results highlight the

[25] Close inspection of the billing data reveals that over 70% of NCWSC's residential customers have arrears or credits on their accounts. Indeed, we find that the arrears or credits on customers' accounts are often more than double the charge for the customers' previous month of service.

importance of examining subsidy incidence among all customer classes, which has largely been ignored in the literature.

In addition to our findings related to subsidy incidence, our analysis raises important issues about the magnitude of the subsidy delivered through the water tariff. Most studies on subsidy incidence focus on subsidies associated with piped water service among only residential customers. They do not examine subsidies associated with sewer service or subsidies delivered to non-residential customers. Our analysis suggests that limiting the scope of subsidy incidence in this manner would lead to a substantial underestimate of the magnitude of the subsidy delivered through the water tariff.

In Nairobi, examining subsidies associated with piped water service among residential customers would result in a total subsidy that is approximately 40% less than the subsidy associated with both piped water and sanitation services for residential customers. Similarly, we find that examining subsidies associated with both piped water and sewer services among only residential customers would underestimate the total subsidy delivered through the water tariff by 45%. In total, focusing only on subsidies associated with providing water service to residential customers would underestimate the magnitude of the subsidy delivered through the water tariff by 65%. We estimate that the total subsidy delivered through the tariff is approximately one and half times NCWSC's total billings. Thus, such errors in estimating the total subsidy delivered through the water tariff can be substantial.

Policy makers in the water sector often express concern about the affordability of water and wastewater services, especially for low-income households. This concern is often used to justify keeping water prices low and for implementing an IBT that includes a lifeline block. Our findings add to a growing body of empirical literature that suggests that IBTs implemented by many utilities do not effectively target subsidies to low-income households. In Nairobi, we find this is particularly true when examining subsidy incidence among all customer classes, but also when we restrict our analysis to households with private metered connections. This is striking given that the poorest households often lack access to piped water and sanitation services altogether. This growing body of evidence suggests that the IBT is an ineffective and often expensive means of delivering subsidies to low-income households. Thus, if policy makers want to subsidize water and sanitation services for low-income households, they should explore alternative subsidy delivery mechanisms, including both connection subsidies and means-tested subsidies.

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Tables and Figures

Table 1. Summary of the Tariff Implemented by NCWSC

Tariff Component	USD/m3[a]
Residential, Commercial, and Industrial	
0 to 10[b] m^3/mo.	0.22
11 to 30 m^3/mo.	0.45
31 to 60 m^3/mo.	0.50
> 60 m^3/mo.	0.63
Water Kiosk	
All units	0.18
Bulk Supply	
All units	0.31
Other Charges	
Sewerage[c]	75%
Meter Rent	0.59
Connection Charges	29

[a] Conversion rate = 90 KSH/USD.

[b] Customers charged for a minimum of 10 m3/mo.

[c] Applied to the volumetric component of the water bill.

Table 2. Summary of Cost Estimates Used to Calculate Subsidy Incidence

Cost Component	USD/m3 [a]
Water Service[b]	**1.40**
O&M	*0.30*
Capital Costs[c]	*1.10*
Water & Wastewater Service[b]	**1.46**
Operations & Maintenance	*0.30*
Capital Costs[c]	*1.16*

[a] Conversion rate = 90 KSH/USD.

[b] Cost estimates assume 35% non-revenue water.

[c] 10% real discount rate; 30-year average useful life of capital.

Table 3. Basic Characteristics of Survey Households

Household Characteristic	Value
Household size *(s.d.)*[*]	4
	(1.78)
Home owner	51%
Primary drinking water source	
Piped water connection	78%
Bottled water	22%
Water vendor (previous year)	26%
Household water treatment	68%
Sewer connection	93%

[*] *Standard deviation*

Table 4. Water Use, Representative Bill, and Average Price among Wealth Quintiles

		Wealth Quintile					
	Unit	1	2	3	4	5	Overall
Mean water use (*s.d.*)[*]	m3/hh/mo.	16	14	14	24	30	19
		(30)	*(15)*	*(17)*	*(25)*	*(32)*	*(26)*
Representative water bill	USD/hh/mo.	10.35	8.39	8.19	14.18	16.76	11.58
Average price	USD/m3	0.79	0.90	0.83	0.62	0.56	0.74

[*] *Standard deviation*

Table 5. Summary Statistics for the Distributions of Metered and Imputed Water Use

Water Use	Unit	Mean	Std. Dev.	Min	Max
Metered	m3/mo.	19	24	0.7	292
Imputed	m3/mo.	27	34	0.3	436

Table 6. Summary of Water Use Among NCWSC Residential Customers

Income Classification	Water Use (m3/acct./mo.) Mean	Median	Std. Dev
High Income	44	16	322
Middle Income	25	12	107
Low Income	28	10	186
Informal	37	11	196
All residential	**31**	**12**	**194**

Table 7. Summary of the Share of Accounts, Water Use, Billings, and Subsidies Among Four NCWSC Customer Classes

Customer class	% Total Accounts	% Total Water Use	% Total Billings	% Total Subsidy
Residential	94%	57%	56%	63%
Non-residential	5%	35%	41%	31%
Kiosk	1%	3%	1%	2%
Bulk	0%	4%	2%	3%
Total	100%	100%	100%	100%

Figure 1. Distribution of Water Use among Survey Sample with NCWSC Tariff Blocks

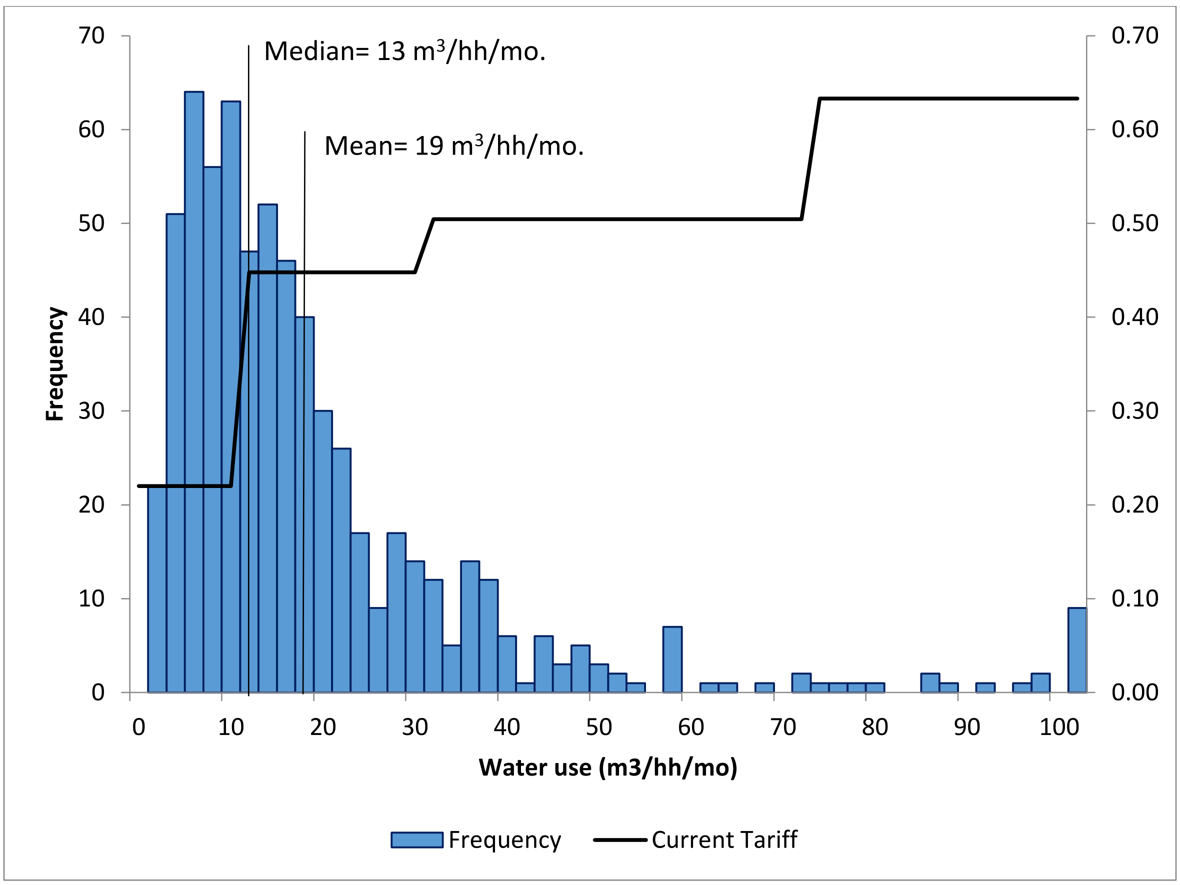


Figure 2. Scatter Plot of Monthly Household Water Use Versus Wealth

* Nine observations with water use above 100 m3/mo. not shown on the graph for scale purposes.

Figure 3. Share of Subsidies Received by Each Wealth Quintile

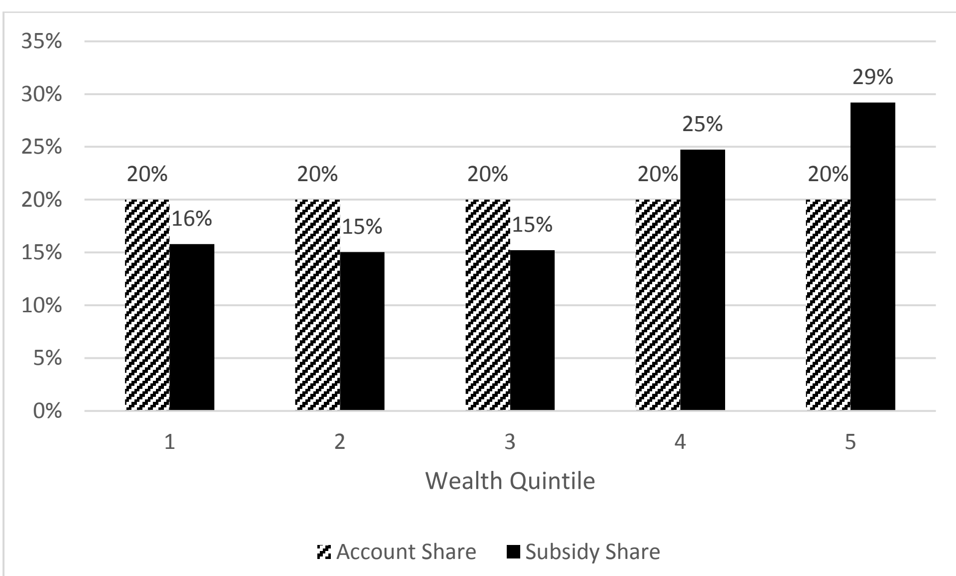


Figure 4. Imputed Versus Metered Water Use

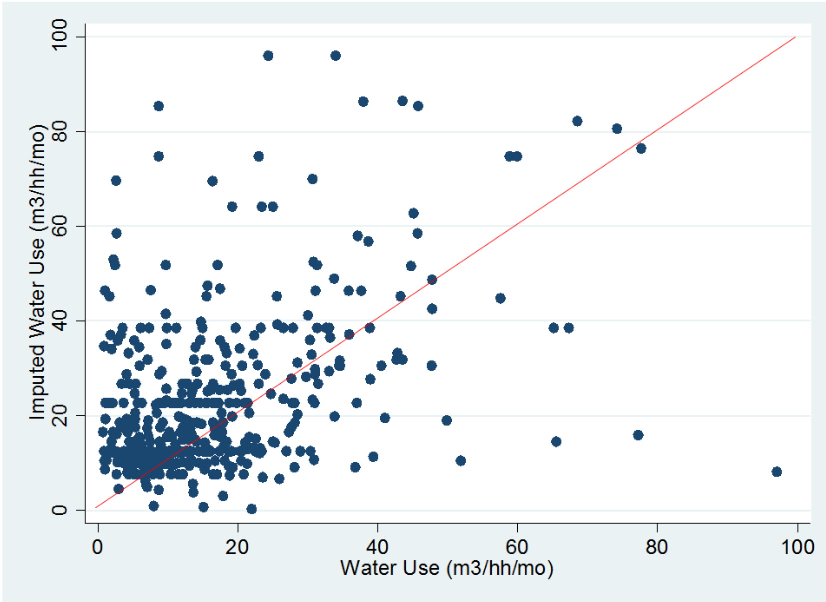
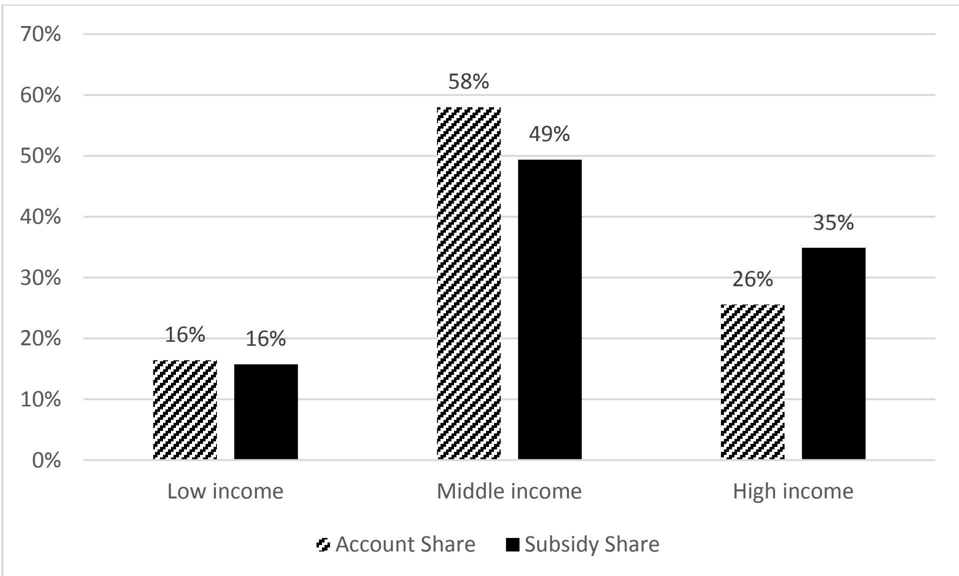


Figure 5. Share of Total Residential Accounts and Subsidies Received by Each Income Group



Appendix 1. Summary of Subsidy Incidence Literature

Table A1. Summary of Studies in the Subsidy Incidence Literature (Adapted from Whittington et al. 2015)

Study	Country	Service	Data Source**	Data Year	Sample Size	Water Use Measure**	Indicator(s)***
Barde and Lehmann (2014)	Lima, Peru	Water*	Billing data, expenditure survey, tariff	2010	2570	Stated expenditure	Affordability; subsidy share; EOI; EOE; Leakage rate
Angel-Urdinola and Wodon (2012)	Nicaragua	Water	HH survey data and tariffs	2001 & 2005	3641 (2001) 6102 (2005)	Stated expenditure	Concentration coefficient
Banerjee and Morella (2011)	Multi-country - Africa	Water*	HH surveys and tariffs	Varies	Varies	Stated expenditure	Affordability (share of HH total expenditure); Concentration coefficient
Banerjee et al. (2010)	45 utilities in 23 African Countries	Water	LSMS and tariffs	Varies	Varies	Stated expenditure	Affordability (share of HH total expenditure); Concentration coefficient
Garcia-Valinas et al. (2010)	Spain	Water	Municipal surveys	2005	301 municipalities	Aggregate	Affordability
Diakite et a.l (2008)	Cote d'Ivore	Water	HH panel data	1998-2002	780 total in panel (aggregate)	Aggregate	Welfare gain/loss

*Study did not clearly state whether it focused only on water service. Service level inferred from text of the study.
** Aggregate refers to data averaged over a geographic area (e.g., service region, metropolitan area, county, etc.).
*** EOE=Errors of exclusion. EOI=Errors of inclusion.

Table A1. Summary of Studies in the Subsidy Incidence Literature (Adapted from Whittington et al. 2015)

Study	Country	Service	Data Source**	Data Year	Sample Size	Water Use Measure**	Indicator(s)***
Ruijs (2009)	Sao Paolo, Brazil	Water	HH data	1997-2002	63 MRSP	Aggregate	Welfare gain/loss
Ruijs et al. (2008)	Sao Paolo, Brazil	Water	Aggregate panel data for demand est.	1997-2002	Panel of 39 MRSPs (aggregate data)	Aggregate	Affordability
Bardasi and Wodon (2008)	Niger	Water	HH survey	1998	533	Stated use	Average price
Groom et al (2008)	Beijing, China	Water	HH income and expenditure survey - Panel 1987 2002	1987-2002	645 HH plus aggregate data on quintiles	Stated expenditure	Welfare gain/loss
Fankhauser and Tepic (2007)	Transition countries	Water*	LSMS	Varies	Varies	Stated expenditure	Affordability, % of HH expenditure
Angel-Urdinola and Wodon (2007)	Cape Verde, Sao Tome, Rwanda	Water	Nationally rep HH surveys	Varies 1999-2002	Varies	Stated expenditure	Concentration coefficient
Foster and Yepes (2006)	Multi-country Latin America	Water*	LSMS	Not stated	Not stated	Stated expenditure	Affordability (% of HH that would spend more than x% if tariffs were raised)

*Study did not clearly state whether it focused only on water service. Service level inferred from text of the study.
** Aggregate refers to data averaged over a geographic area (e.g., service region, metropolitan area, county, etc.).
*** EOE=Errors of exclusion. EOI=Errors of inclusion.

Table A1 (cont'd). Summary of Studies in the Subsidy Incidence Literature (Adapted from Whittington et al. 2015)

Study	Country	Service	Data Source**	Data Year	Sample Size	Water Use Measure **	Indicator(s) ***
Komives et al. (2006)	Multi-country	Water	Secondary literature	Varies	Varies	Stated expenditure	EOE; Concentration coefficient
Komives et al. (2005)	Multi-country	Water	LSMS	Varies	Varies	Stated expenditure	Omega; EOI, EOE; "Material impact"
Foster and Araujo (2004)	Guatemala	Water	LSMS style national survey (ENCOVI 2000)	2000	7,276	Stated expenditure	EOE, EOI
Foster (2004)	Argentina	Water	Primary HH Survey (2500 HH)	2002	2,500	Previous bill; Stated expenditure; Imputed using regression	Cumulative dist; concentration coefficient; EOI; EOE
Gomez-Lobo and Contreras (2003)	Chile and Columbia	Water	National HH surveys (Chile - CASEN 1998; Columbia - 1997 NQLS)	1997/98	Chile 48,107; Columbia 4,094	Stated expenditure	Concentration curves; EOI; EOE
Foster et al. (2000)	Panama	Water	LSMS	1997	n.a.	Stated expenditure	EOE; EOI
Walker et al. (2000)	Central America	Water	Household survey	Varies 1995-1998	Varies	Previous bill	EOI; EOE; Average subsidy per HH per mo; subsidy share

*Study did not clearly state whether it focused only on water service. Service level inferred from text of the study.
EOE=Errors of exclusion. EOI=Errors of inclusion.

Appendix 2. Cost Estimates Used in the Literature

Table A2.1. Summary of Cost Estimates Used in the Literature

Study	Location	Cost Estimates (USD/m3)	Service	Includes	Source
Foster and Araujo (2004)	Guatemala	0.30 - 0.40	Water	Indicates "full cost"	Cites "international benchmarks"
Komives et al. (2005)	Multi-country	See Table A2.2	Water	Varies	Not stated
Komives et al. (2006)	Multi-country	See Table A2.2	Water	Varies	Not stated
Foster and Yepes (2006)	Multi-country	0.30	Water	O&M	Kingdom et. al (2004)
Foster and Yepes (2006)	Multi-country	0.90	Water	O&M plus capital costs	Kingdom et. al (2004)
Groom et al. (2008)	China	0.85	Water	“Full financial” cost recovery	Not stated
Walker et al. (2000)	Multi-country	0.09 - 0.27	Water	O&M	Not stated
Walker et al. (2000)	Multi-country	0.17 - 0.47	Water	Capital costs including "financing charges plus depreciation"	Not stated
Barde and Lehman (2014)	Peru	0.64	Water	Not stated	Average tariff

Table A2.2. Cost Estimates from GWI (2004)

	Developing country	Industrialized countries
<0.20 USD/m3	Tariff *insufficient* to cover basic O&M costs	Tariff *insufficient* to cover basic O&M costs
0.20 - 0.40 USD/m3	Tariff *sufficient* to cover operation and some maintenance costs	Tariff *insufficient* to cover basic O&M costs
0.40 - 1.00 USD/m3	Tariff *sufficient* to cover operation, maintenance, and most investment needs	Tariff *sufficient* to cover basic O&M costs
>1.00 USD/m3	Tariff *sufficient* to cover operation, maintenance, and most investment needs in the face of extreme supply shortage	Tariff *sufficient* to cover full cost of modern water systems in most high-income cities

Source: GWI (2004) in Komives et al (2005)