Water supply services for Africa's urban poor: the role of resale

Valentina Zuin, Leonard Ortolano, Manuel Alvarinho, Kory Russel, Anne Thebo, Odete Muximpua and Jennifer Davis

ABSTRACT

In sub-Saharan Africa only 35% of the urban population has access to a piped water connection on their premises. The majority of households obtain water from public standpipes or from neighbors who are connected to the municipal network. Water resale is often prohibited, however, because of concerns about affordability and risks to public health. Using data collected from 1,377 households in Maputo, Mozambique, we compare the microbiological quality, as well as the time and money costs of water supply from individual house connections, public standpipes, and water obtained from neighbors. Households with their own water connections have better service across virtually all indicators measured, and express greater satisfaction with their service, as compared with those using other water sources. Households purchasing water from their neighbors pay lower time and money costs per liter of water, on average, as compared with those using standpipes. Resale competes favorably with standpipes along a number of service quality dimensions; however, after controlling for water supply characteristics, households purchasing water from neighbors are significantly less likely to be satisfied with their water service as compared with those using standpipes.

Key words | Africa, Mozambique, urban water supply, water quality, water resale

Valentina Zuin
Emmett Interdisciplinary Program in Environment and Resources, Stanford University,
Stanford, CA 94305,
USA

Leonard Ortolano
Kory Russel
Anne Thebo
Jennifer Davis (corresponding author)
Dept. of Civil and Environmental Engineering,
Stanford University,
Stanford, CA 94305,
USA
E-mail: *jennadavis@stanford.edu*

Manuel Alvarinho
Water Regulatory Council (CRA),
Maputo,
Mozambique

Odete Muximpua
Water and Sanitation Program,
The World Bank,
Maputo,
Mozambique

Jennifer Davis
Woods Institute for the Environment,
Stanford University, CA 94305,
USA

INTRODUCTION

In sub-Saharan Africa (SSA), only 35% of the urban population has access to a piped water connection on their premises, and this percentage has decreased by 3% over the past 3 years (WHO 2010). Municipal governments are struggling to overcome the financial, institutional and technical constraints to providing water supply services to rapidly growing populations, many of whom live in unplanned settlements (Moe & Rheingans 2006; Ali 2010). The urban population of SSA has more than doubled in 2 decades, from 135 million in 1990 to 308 million today, and another 122 million people are expected to be added to the cities of SSA in the next 10 years (Kessides 2006). Unlike other regions, urbanization in Africa has not been accompanied by increases in wealth. Indeed, as of 2010, SSA had the highest percentage (61%) of urban residents living in slums among all world regions (UN-HABITAT 2010).

Confronted with increasing demand for water supply services in the face of limited financial resources, municipal governments often invest in shared water points such as standpipes, which generally have initial capital costs that are 60–70% lower than installing an equivalent number of household water connections (WHO 2000). Currently, 49% of the urban population in SSA relies on this type of shared source for their water supply (WHO 2010). Despite the fact that many utilities subsidize standpipe supply, the price paid per unit volume of water from standpipes has been found to be three to four times higher than that paid by households with individual water connections (Keener

doi: 10.2166/wh.2011.031

et al. 2010). The reasons for this price differential vary by location, but include the cost of standpipe attendants (Whittington *et al.* 1998); lax enforcement of so-called 'social tariffs' for standpipes (Keener *et al.* 2010); and rent-seeking by private standpipe operators (Gulyani *et al.* 2005).

In addition, because of the time cost and physical burden associated with fetching water from standpipes, households who rely on them typically use less than half of the water used by those with individual connections. For example, research in Kenya, Tanzania, and Uganda found that standpipe users have access to an average of 24 liters *per capita* per day (LPCD) – slightly more than the 20 LPCD that the World Health Organization-UNICEF Joint Monitoring Program (JMP) considers to be 'minimum access' (WHO 2000). By contrast, households with private connections use 64 LPCD, or three times the JMP standard (Thompson *et al.* 2000). Finally, several recent studies have concluded that, compared with unimproved water sources such as rivers and open wells, shared water points actually deliver limited health benefits (Fewtrell *et al.* 2005; Zwane & Kremer 2007) or time savings (Thompson *et al.* 2001; WHO 2010).

For many households without an individual water connection, an alternative to using public taps or standpipes is the purchase of water from neighbors who are connected to the municipal network. Water resale from neighbors represents an important source of supply in many developing-country cities, particularly those in which few standpipes exist (Fass 1993; McPhail 1994; Solo 1999; Collignon & Vézina 2000; Pattanayak *et al.* 2005; Davis 2005). Indeed, analysis of World Health Organization/UNICEF data from 17 countries in the SSA region indicates that an average of 18% of households classified as having access to improved water supply rely on their neighbors. Water resale has been estimated to account for as much as 50% of water supply obtained by urban populations in SSA, and up to 80% of supply to the urban poor (Keener *et al.* 2010). Other researchers have also documented the substantial share of the urban water market captured by resale (Whittington *et al.* 1991; Collignon & Vézina 2000).

Notwithstanding the prevalence of water resale, little information on the practice has been systematically collected through national surveys or scholarly research. Crane's (1994) analysis of water resale legalization in Jakarta, Indonesia, which was based on data collected from 29 households, concluded that this policy change generally benefited consumers by lowering the time and money costs of water supply. Boyer (2007), who interviewed 45 consumers of resold water in Maputo, Mozambique, found that the prices for such water were comparable with those charged at standpipes, but that resale provided time savings to consumers.

The paucity of published information about water resale is understandable given its illegal or ambiguous legal status in many settings. Whereas no known review of the legality of water resale exists, the practice is reportedly prohibited in cities such as Accra, Ghana (Kjellén & McGranahan 2006), Dakar, Senegal, and Bamako, Mali (Collignon & Vézina 2000). In many other African cities the legal status of resale is ambiguous; there is no law that either allows or prohibits it (Keener *et al.* 2010). The rationales for prohibiting or discouraging resale are not well supported empirically, but typically center on concerns about affordability of the supply to consumers, as well as the risk to public health of permitting essentially unregulated water service provision (Kjellén & McGranahan 2006; Collignon & Vézina 2000). The present study seeks to compare the quality, quantity, time and money costs, reliability, and accessibility of water supplied through resale with that provided through public standpipes and private household connections. An additional objective is to model the determinants of satisfaction with water supply services among peri-urban households using a variety of water sources. The study is based in the city of Maputo, Mozambique, and uses data collected from 1,377 households between January and March 2010. This research complements efforts by Mozambique's Water Regulatory Council (CRA) to assess the potential of water resale and the implications of its legalization for currently unconnected and low-income households.

STUDY SITE, DATA COLLECTION AND ANALYSIS METHODS

Maputo, the capital of Mozambique, had an estimated 1.1 million inhabitants in 2007 (INE 2009). Maputo's population increased by 42% in the 15 years between independence from Portuguese colonial rule in 1975 and the end of its subsequent civil war in 1991 (CEDH 2006). As a result of this rapid growth, the majority of Maputo's residents live in unplanned areas and have limited access to housing and infrastructure. Continued growth of Maputo has resulted in a minority of households (44% in 2008) having an individual water connection (INE 2009).

Water resale to unconnected households is commonplace in Maputo: in 2006, an estimated 26% of the city's population relied on their neighbors' private water connections for their supply (Conselho de Regulação do Abastecimento da Água 2007). As in many other cities in SSA, the legal status of resale is uncertain in Mozambique; it is not deemed legal or illegal by sector policy or national law. At the time of the survey, however, 73% of households interviewed said they believed it was illegal to re-sell water in Maputo; 13% said they believed it to be legal, and 14% said they did not know.

Sample frame

Data were collected in six peri-urban neighborhoods (*bairros*) of Maputo with a combined population of 106,000 inhabitants. Because of information and resource constraints, it was not possible to draw a random sample of households from each neighborhood. Using mapped roads, each bairro was subdivided into parcels averaging approximately 1.5 to 2 hectares. Each parcel was classified in terms of its distance to a working standpipe and to the water utility's piped network. No secondary information was available that allowed classification of parcels in terms of water resale activity. A stratified random sample was drawn of 225 out of 313 parcels that were: (1) within 100; and (2) within 250 meters of a working standpipe; and (3) within 100 and (4) 300 meters of the municipal network. This strategy resulted in a sample of households whose nearby water supply options ranged from a single standpipe to multiple resellers and standpipes.

Within each sampled parcel, every fourth household was approached for an interview until the target number of interviews had been completed (between four and eight households in each parcel). Three attempts were made to complete an interview with a sampled household before replacing it with another household in the same parcel. Free and informed consent of each participant was obtained, and the study protocol was approved by the Institutional Review Board of Stanford University, California, USA. In addition, all data collection instruments were reviewed and approved by the National Statistical Institute of Mozambique.

Survey data collection

Sixteen college-educated Mozambican enumerators were recruited and intensively trained over a three-week period in interviewing skills, the objectives and content of the household survey, and the use of personal digital assistants (PDAs) for data collection. The survey was coded for the PDAs using The Survey System software package (Creative Research Systems, Petaluma, CA, USA). The survey, which was developed, pre-tested, and translated over the course of several weeks, included four sections: (1) characteristics of and satisfaction with existing water supply services; (2) attitudes toward and practices related to water resale; (3) household socio-economic and demographic characteristics; and (4) measures of community networks and social capital. Each survey was administered in Portuguese or Shangana and took a median of 50 minutes to complete.

Water sample collection and processing

Two 500-milliliter (mL) water samples were collected from a subsample of 62 households and 27 public standpipes. No water point was sampled on more than one occasion. Water points were only sampled during the morning hours when water was typically moving through the piped network. In addition, water samples were only collected on weekdays to comply with operating hours of the laboratory where samples were analyzed. Within these constraints, field team members attempted to sample every household tap and standpipe in their study area on each day of the investigation.

At the time of sampling it was not known whether a household from whom a sample was collected engaged in reselling; however, the sampled taps were located in the same neighborhoods in which resellers (using the same piped network) resided. Samples from households and standpipes in the same neighborhood were collected on the same day, i.e., sampling was carried out as the interview teams moved through the study area, identifying households for interview. All samples were collected over the course of a six-week period during Mozambique's rainy season.

Each sample was collected in a 500 mL Whirl-Pak Thio-Bag© (NASCO Corp., Fort Atkinson, WI, USA) using sterile technique. Each sample bag contained sodium thiosulfate to neutralize chlorine. Water was allowed to flow from each tap or standpipe for several seconds before the sample was collected. Samples were placed on ice and transported to the laboratory for analysis. All samples were processed within 6 hours of collection.

Tests for fecal indicator bacteria (FIB) (*Escherichia coli*, fecal streptococcus and fecal coliform) were carried out on the water samples collected from household taps and standpipes. Microbiological assays were run at the National Institute for Food and Hygiene (NIFH) in Maputo using membrane filtration methods as described in *Standard Methods for the Examination of Water and Wastewater* (Eaton 2005). Specifically, *E. coli* analysis was carried out using assay 9225 differentiation of the coliform bacteria in *Standard Methods*; fecal streptococcus analysis using assay 9230 fecal streptococcus and enterococcus groups in *Standard Methods*; and fecal coliform using assay 9222, fecal coliform membrane filter procedure in *Standard Methods*. For both *E. coli* and fecal coliform analyses, a volume of 100 mL was processed by membrane filtration, providing a lower and upper detection limit of 1 and 100 CFU/plate, respectively. For fecal streptococci analysis, 250 mL were filtered, providing a lower detection limit of 1 CFU/plate and an upper detection limit of 100 CFU/plate; results were subsequently converted to CFU/100 mL. If no CFUs were visible on a plate, then a value of 0.5 CFU was assigned to the plate. If there were too many CFUs to count, then the value of the upper detection limit was assigned to the plate.

Data analysis

Independent sample *t*-tests were used to compare mean values of continuous variables related to household and water supply service characteristics; non-normally distributed continuous variables were natural log transformed for these tests. A binary logistic regression model was fit to identify factors associated with households' satisfaction with their water services. Model fit was evaluated using Cox and Snell's 'pseudo r-square' (Cox & Snell 1981). The variable hours of water supply service per day was normalized for each water supply source sub-sample (own tap, neighbor's tap, or standpipe). Fecal indicator bacteria concentrations from water samples were log10 transformed prior to analysis. The units of reference for FIB concentrations are colony forming units (CFU) per 100 mL. The chi-square test was used to evaluate differences in the number of standpipes and private connections with any FIB contamination. All statistical analyses were performed with SPSS Statistics 18.0 (SPSS Inc., Chicago, Illinois, USA).

RESULTS

Household characteristics and water supply services

A total of 1,377 of the 1,429 households interviewed relied on at least one of the following sources for their water supply: their own private piped water connection, a communal public standpipe, or water resale from a neighbor with a piped water connection. The remaining 52 households use other water sources, including neighbors' borewells or mobile vendors, and were excluded from analysis. Ninety percent of households use only one water source on a regular basis. The remaining 10% were classified as users of the water source that provided the greatest share of the family's water supply on an annual basis. This determination was made using detailed information on the volume of water obtained from each source in both the rainy and dry seasons (additional information provided in the Supporting Information, available online at: http://www.iwaponline.com/jwh/009/031.pdf).

In total, 644 (47%) of households have their own water tap; 419 (30%) obtain water from a neighbor's tap; and 314 (23%) are standpipe users. Among households with their own taps, 77% receive water supply from the municipal utility, Águas de Moçambique (AdeM), while another 23% are supplied by private, small-scale providers who operate their own small networks. Among households using standpipes, 64% patronize an AdeM standpipe and 36% use a standpipe operated by a small-scale provider. All households using a neighbor's tap obtain water from households with a private connection from the municipal water utility; none is supplied by a household with a connection to a small-scale private provider's network.

The typical sample household has a median of 6 members; 69% of households have lived in their neighborhoods for at least 20 years (Table 1). Eighty-four percent of households reported using improved sanitation facilities, and 16% had non-improved facilities on their premises (Following the premises, as per the Joint Monitoring Program (2010) classifications). Eighty-nine percent are homeowners, and 86% have electricity service. Ninety-three percent of the households in the sample have at least one head of household who has completed primary education, and 51% have at least one head of household who has completed secondary education. The average reported monthly expenditure is US$191 (median of US$168), which is about 40% the average monthly expenditure of all Maputo residents (Instituto Nacional de Estatistica 2009).

Households using standpipes and neighbors' taps are similar along all socio-economic variables measured, with the exception of electricity. By contrast, there are several significant differences between households with their own private water connection and those using a neighbor's tap. Households with a private connection have higher mean and median monthly incomes and higher regular weekly expenditures. They are also more likely to be homeowners and have at least one head of household who has completed secondary education; to use improved sanitation facilities; to have electricity; and to own assets such as a refrigerator or a car (all $p < 0.01$). A higher proportion of households with a private connection have lived in their neighborhood for at least 20 years, and the average number of community groups in which they participate is greater (all p-values < 0.01). Moreover, households with their own water connection report giving and receiving assistance from their neighbors less frequently than those who use a neighbor's tap ($t = -2.46$, df $=$ 1,057, $p < 0.01$).

Water quality

Survey respondents were asked whether they thought the water obtained from their principal source was safe for consumption without treatment. Eight-five percent of neighbor's tap users reported their water to be safe for consumption, which was not significantly different from the 89% of standpipe users ($t = -1.54$, df $= 710$, $p = 0.12$) but was

Table 1 | Household characteristics for full sample, by principal water source

	Full sample ($n = 1,377$)	Neighbor's tap ($n = 419$)	Standpipe ($n = 314$)	Own tap ($n = 644$)
Household size	6.44 (3.0)	6.2 (3.11)	6.43 (3.18)	6.59 (2.91)
% with1+ head who completed primary school	93	93	89	95
% with1+ head who completed secondary school	51	46[b]	45	57
% homeowners	89	82[b]	87	95
% living in neighborhood for >20 years	69	63[b]	67	73
% with improved sanitation facilities	84	77[b]	76	94
% with electricity	86	81[a,b]	71	97
Mean reported monthly income (USD)	242 (365)	213[b] (381)	158 (140)	301 (417)
Median reported monthly income (USD)	144	144[c]	112	200
Mean reported monthly expenditure (USD)	191 (115)	168[c] (112)	167 (90)	216 (123)
Median reported monthly expenditure (USD)	168	144[c]	152	191
% owning a fridge	64	46[b]	45	86
% owning a car	13	7[b]	4	22
% owning a cell phone	92	89[b]	91	100
Mean number of community group memberships	1.52 (1.30)	1.41[b] (1.26)	1.42 (1.26)	1.64 (1.33)

Note: Standard deviations in parentheses.
[a]Mean is significantly different from that of standpipe group (*t*-test, $p < 0.01$).
[b]Mean is significantly different from that of own tap group (*t*-test, $p < 0.01$).
[c]Median is significantly different from that of own tap group (Mann–Whitney test, $p < .01$).

significantly higher than the 75% of households with a private connection ($t = -3.97$, df = 1,001, $p < 0.01$).

With respect to measured bacteriological quality, no *E. coli* were detected in 60 of the 62 samples (~97%) taken from household water connections and 25 of the 27 samples (~93%) taken from standpipes ($\chi^2 = 0.86$, df = 1, $p = 0.35$). Among the samples with detectable *E. coli*, a mean of 1.28 and 2.00 log CFU/100 mL were observed in household connection and standpipe samples, respectively. Fecal streptococcus was not detected in 53 out of 62 (~86%) household connection and 25 of 27 (~93%) standpipe samples ($\chi^2 = 0.88$, df = 1, $p = 0.35$). Among positive samples, the mean contamination for household connection and standpipe samples was 0.73 and 0.70 log CFU/100 mL, respectively. Fecal coliforms were not detected in 88% of household connection and 82% of standpipe samples ($\chi^2 = 0.61$, df = 1, $p = 0.44$). For samples with detectable coliforms, a mean of 0.76 log CFU/100 mL was found in household connection samples, compared with 1.04 log CFU/100 mL in standpipe samples.

In summary, no significant difference was found in rates or levels of contamination between standpipes and private connections with respect to the FIB measured. Nor was any significant difference found in water quality among households with private connections that do and do not re-sell water to neighbors (all $p > 0.30$). Note that samples were collected directly from each tap or standpipe, and not from households' stored water supplies. The data presented thus refer to measured water quality at point of collection, rather than at point of use.

Time and money costs of water supply

Respondents using neighbor's taps and standpipes were asked detailed questions regarding the frequency and time requirements of water fetching. Time expenditures were averaged on a weekly basis because not all households fetch water every day. All respondents were asked about the time requirements of filling water storage containers for their households; standpipe and neighbor's tap users were asked additionally about the typical duration of queue time at their water points.

Households using a neighbor's tap devote significantly less time walking to their water point per day as compared

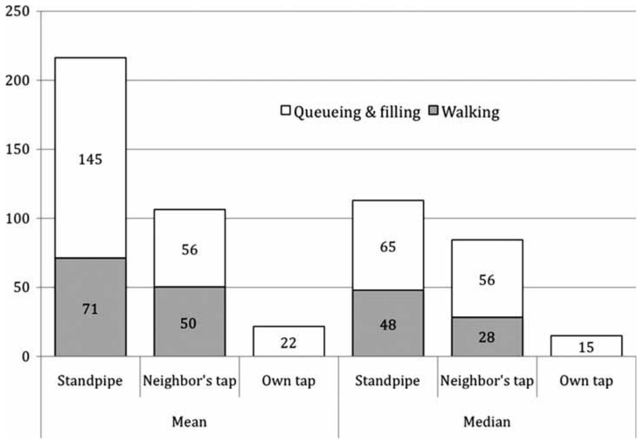

Figure 1 | Mean, median water fetching time (minutes per day), by principal water source ($n = 1,377$).

with standpipe users (Figure 1), regardless of whether mean or median values are compared (*t*-tests of means and Mann–Whitney tests of medians $p < 0.01$). Similarly, the mean and median number of minutes that households using a neighbor's tap spend queuing and filling water containers is significantly less than those obtaining water from standpipes (both $p < 0.01$). The lower time cost of water supply for neighbor's tap users is the result of shorter walking distances and waiting time at the water point, not of differences in the number of trips made to the water point. Neighbor's tap users devote an average of 6.6 minutes in walking time per roundtrip, as compared with 9.6 minutes per roundtrip for standpipe users ($t = 8.0$, df = 704, $p < 0.01$). Households with their own connection, not surprisingly, face the smallest time cost of supply among study participants.

Money costs

Monetary costs analyzed include only the price paid per unit volume of water obtained, and did not consider ancillary costs such as the purchase of storage containers or inputs for water treatment. Comparisons across service type of mean price paid per cubic meter (m^3) are complicated by the fact that some households are charged by the 20-L jerrican and others pay flat monthly fees for water supply, and also that 17.7% of neighbor's tap users and 0.6% of standpipe users reporting paying no money at all for their water services.

Across all households that purchase water from a neighbor, the mean price/m^3 paid is US$1.02/m^3, 17% less than the mean price paid by all households using standpipes, $1.23/m^3 ($t = -7.30$, df = 666, $p < 0.01$) (Table 2). A similar result is obtained when comparing median prices for the two groups ($p < 0.01$). When households in both groups who reported making no payment for water are excluded, the mean price for neighbor's tap users increases to US$1.25/m^3 and is no longer significantly different from the price of water from standpipes ($p > 0.70$, details provided in the Supporting Information, available online at: http://www.iwaponline.com/jwh/009/031.pdf). Restricting the analysis to either users of standpipes of the water utility or users of standpipes of small-scale providers does not lead to substantively different conclusions, regardless of whether households who reported making no payment are included (details in the Supporting Information, available online at: http://www.iwaponline.com/jwh/009/031.pdf).

Including households with a private connection makes the price comparison more complicated, because customers supplied by small-scale, private providers pay higher unit prices than those served by the municipal utility AdeM (additional information provided in the Supporting Information, available online at: http://www.iwaponline.com/jwh/009/031.pdf). Including households who do not pay for water, those with a private connection from the municipal utility spend US$1.06/m^3, significantly less than households using a neighbor's tap ($t = -4.32$, df = 553, $p < 0.01$). By contrast, households with a connection to a small-scale private provider spend US$1.67/m^3, significantly more than those using a neighbor's tap, ($t = 3.52$, df = 212, $p = <0.01$). In addition, 31% of sample households with connections were willing and able to supply their water bills during their interview, while others estimated their water usage. Despite comparable mean household sizes of these two groups, the average estimated water usage (39.5 LPCD) was significantly lower than the average billed volume of 89.2 LPCD ($t = 12.4$, df = 545, $p < 0.01$), indicating likely data quality problems with the estimated volumes.

Water usage, other service characteristics

Detailed information about water fetching practices collected in the household survey was used to estimate water usage for standpipe and neighbor's tap users. For households with a private connection, respondents were asked for a copy of the last water bill they received, whether from AdeM or a private provider. For respondents who did not share their bill (or if the bill did not have water usage information), self-reported information on the number of jerricans used per day in the rainy and dry seasons was used (Table 3).

On average, households who obtain water from their neighbors consume an average of 28.3 LPCD (median of 24), which is not significantly different from the amount used by households obtaining water from standpipes (all $p > 0.20$). As expected, water usage by neighbor's tap users is significantly less than that of households with a private connection, who use an average of 54.7 LPCD ($t = 11.56$, df = 978, $p < 0.01$). Note that the estimated volumes presented in Table 3 include total household usage from a private connection, a neighbor's tap, public standpipes, and own or a neighbor's borehole. Restricting the analysis to only the principal water source did not lead to substantively different conclusions about the differences in water usage across the groups.

Respondents were asked how many hours per day, and how many days per week, water is available at each source

Table 2 | Price per cubic meter of water supplied (US$), by water source

	Standpipe ($n = 301$)	**Neighbor's tap ($n = 402$)**	**Own tap: AdeM ($n = 298$)**	**Own tap: Private provider ($n = 137$)**
Mean (St. dev.)	1.23 (0.42)	1.02[a,b] (0.72)	1.13 (1.13)	1.67 (1.56)
Median	1.20	1.07[c]	0.74	1.33

Note: Standard deviations in parentheses.
[a]Mean is significantly different from that of standpipe (t-test, $p < 0.01$).
[b]Mean is significantly different from that of both own tap groups (t-test, $p < 0.05$).
[c]Median is significantly different from that of standpipe group (Mann–Whitney, test $p < 0.01$).

Table 3 | Service characteristics by principal water source

	Standpipe ($n = 314$)		Neighbor's tap ($n = 419$)		Own tap ($n = 644$)	
Percentage of users reporting service is reliable	89 (31)		76[a] (43)		81 (40)	
Percentage reporting water is safe for consumption	89 (31)		85[b] (36)		75 (43)	
Percentage reporting availability of credit	25 (43)		66[a] (47)		N/A	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
Liters per capita per day	27.5 (13.1)	25	28.3[b] (16.6)	24[d]	54.7 (72.5)	36
Water availability (hours per day)	7.9 (4.8)	7	5.8[a,b] (4.2)	5[c,d]	10.3 (6.8)	7.5

Note: Standard deviations in parentheses.
[a]Mean is significantly different from that of standpipe group ($p < 0.01$).
[b]Mean is significantly different from that of own tap group ($p < 0.01$).
[c]Median is significantly different from that of standpipe group (Mann–Whitney, test $p < 0.01$).
[d]Median is significantly different from that of own tap group (Mann–Whitney, test $p < 0.01$).
N/A: Question about consumer credit not asked of respondents with private connections.

available in their neighborhood. On average, households using a neighbor's tap have access to water for 2 fewer hours per day than do standpipe users, 5.8 versus 7.9 hours ($t = -8.65$, df $=$ 714, $p < 0.01$). Neighbor's tap users also receive fewer hours of supply per day than households with a private connection, who have water available for an average of 10.3 hours/day ($t = 4.40$, df $= 833$, $p < 0.01$). The comparatively small number of hours' supply for neighbor's tap users can be explained in large part by the perceived illegality of water resale in Maputo; most resale occurs in the early morning hours so as to minimize the likelihood of detection by utility staff.

Respondents were also asked whether they typically know when their water source will have water available, i.e., whether its supply follows a predictable schedule. A smaller share (76%) of neighbor's tap users said their supplies were reliable as compared with 89% of standpipe users ($t = -4.79$, df $= 727$, $p < 0.01$). Eighty-one percent of private connection users reported their source to be reliable, which is statistically equivalent to that of neighbor's tap users ($p > 0.05$).

Respondents using neighbors' taps and standpipes were asked whether they would be able to obtain credit and delay the payment of their water fees to the individual from whom they normally obtain water. Sixty-six percent of neighbor's tap users as compared with only 25% of standpipe users reported that they would be able to obtain such credit if needed ($t = 11.45$, df $= 613$, $p < 0.01$). Similar data were not collected from households with their own water connections; however, it can be noted that 52% of the 332 water bills presented by members of this group indicated some unpaid balance.

User satisfaction

Following the detailed questions about the characteristics of each water source available in their neighborhood, respondents were asked how satisfied their households are overall with their current water supply situation. Answers were coded as 'very satisfied', 'satisfied', 'neither satisfied nor dissatisfied', 'dissatisfied', or 'very dissatisfied'. Twenty-two percent of neighbor's tap users, 28% of standpipe users, and 70% of private connection owners self-reported being 'satisfied' or 'very satisfied' with their water supply situation. Answers were dichotomized into two categories ('satisfied' and 'neutral/dissatisfied') for multivariate analysis purposes. Using a binary logit model, we examine factors that are associated with respondents' satisfaction with their water supply service. The reduced model results of this analysis are presented in Table 4 (full results available in the Supporting Information, available online at: http://www.iwaponline.com/jwh/009/031.pdf).

In accordance with *a priori* expectations, time and money costs are significantly and negatively associated with user satisfaction. For each additional household-hour of water fetching effort per day, a respondent is 1.15 times

Table 4 | Users' satisfaction with water supply services (binary logit model)

	β	Standard error	Odds ratio
Total fetching time (household-hours/day)[d]	−0.14[c]	0.05	0.87
Price per cubic meter (USD)	−0.27[c]	0.07	0.76
Supply is perceived to be reliable (dummy)	1.34[c]	0.20	3.80
Hours of availability (normalized)	−0.04	0.19	0.96
Has own private connection	2.30[c]	0.21	10.00
Uses public standpipe	0.59[c]	0.24	1.80
Standpipe[a] Hours of availability	0.07	0.28	1.07
Private connection[a] Hours of availability	0.50[b]	0.23	1.66
Perceives water as safe (dummy)	0.30	0.19	1.35
Provider (1 = private, 0 = utility)	−0.28	0.22	0.75
Number of water sources used	−0.36[c]	0.11	0.70
Expresses high level of trust in neighbors (dummy)	0.31[b]	0.16	1.37
Owns an automobile (dummy)	−0.58[c]	0.22	0.56
Constant	−1.76[c]	0.36	–
Number of observations = 1,189 Quasi R^2 (Cox & Snell) = 0.29			

[a]$0.05 < p <= 0.10$. [b]$0.01 < p <= 0.05$. [c]$p <= 0.01$.
[d]19 observations with values >10 person-hours per day were censored to a value of 10.

less likely to report satisfaction with water supply services, all else held constant. A US$1 increase in the price per cubic meter paid is associated with a 1.3-fold decrease in the odds of being satisfied. In addition, having predictable water services is positively associated with user satisfaction; respondents who reported that their water supply is reliable are almost four times more likely to be satisfied with their service as compared with households without a reliable water supply.

The interaction of number of hours for which water is available and having a private water connection is significantly associated with satisfaction for private connection users, suggesting that these households attach a greater value to an additional hour of service as compared with neighbor's tap users. This result is unexpected given the much higher average number of hours of service that private tap owners enjoy relative to neighbor's tap users. By contrast, the interaction of number of hours of service and having a standpipe as the principal water source is not significant.

All else held constant, households relying on a greater number of water sources are less likely to be satisfied ($p < 0.01$). Consumers obtaining water from small-scale private providers are as likely to be satisfied with their water supply as consumers relying on the municipal water utility AdeM ($p > 0.1$). Wealthier households – as measured by automobile ownership – are 1.8 times less likely to express satisfaction with their water services ($p < 0.01$).

Even after controlling for these water service and household characteristics, neighbor's tap users are 1.8 times less likely to be satisfied with their water service than standpipe users ($p < 0.01$). This surprising result is discussed further in the following section. More consistent with expectations, neighbor's tap users are ten times less likely to be satisfied with their water supply service as compared with households with individual connections ($p < 0.01$).

Respondents who said they were dissatisfied with their household's water supply situation were asked follow-up questions about the reasons for their discontent (Table 5). Multiple responses were permitted to this unprompted question. Sixty-three percent of dissatisfied neighbor's tap users indicate that they dislike being dependent on their neighbors for water supply services. The other two most commonly cited reasons for dissatisfaction of neighbor's tap users are the time at which water is supplied (33%) and the long time needed to fetch water (31%). Similarly, dissatisfied standpipe users also complain about the time needed to fetch water (52%), and the time at which water is supplied (26%). The second most commonly cited reason for dissatisfaction in this group, however, is the limited quantity of water their households are able to obtain (27%). For the

Table 5 | Reasons for dissatisfaction with water supply services (multiple responses permitted)

Service level	Reason for dissatisfaction	% citing
Neighbor's tap users ($n = 319$)	Dependency on neighbors	63
	Timing of supply	33
	Time needed to fetch water	31
Standpipe users ($n = 227$)	Time needed to fetch water	52
	Insufficient quantity of water	27
	Timing of supply	26
Own tap users ($n = 193$)	Timing of supply	67
	Unpredictable supply	30
	High cost of water	26

30% of private connection users who were dissatisfied with their water supply, the key factor is the time at which water is supplied (67%).

DISCUSSION

As expected, households participating in this investigation who have their own water taps face significantly lower time and money costs, enjoy a greater number of hours of service per day, use more water, and express greater satisfaction with their service as compared with those without connections. What has been poorly understood prior to this study is how standpipe and neighbor's tap service – two different types of shared point sources – compare along a number of service quality dimensions.

In Maputo, households purchasing water from resellers face lower time costs of supply, on average, and report a higher likelihood of obtaining credit from their supplier, as compared with those using standpipes. No significant difference in the quality of water at source between neighbor's taps and standpipes was identified. Most households who purchase water from neighbors pay lower average prices per as compared with households that use standpipes; however, these comparisons depend critically on both payment modality and, in the case of standpipe users, whether the supplier is a private-sector provider or the municipal utility.

Notwithstanding the lower average time costs and reduced physical burden of fetching water from a neighbor's tap as compared with a standpipe, the quantity of water that neighbor's tap customers use is not significantly greater than that of standpipe users. This outcome is an unexpected finding that contradicts the well established idea that water quantity is elastic with respect to both money and time costs (Nauges & Strand 2007). The result is particularly surprising given that 32% of households who use a neighbor's tap pay a fixed monthly fee, i.e., the reseller does not limit the amount of water they can obtain. It may be that, while comparatively lower than standpipes, the typical costs and physical burden of obtaining water from a neighbor's tap still exceed some critical threshold. Prior research has suggested, for example, that water demand is comparatively inelastic when the water source is located more than 100 meters away from the home (Howard & Bartram 2003; Larson *et al.* 2006). In this study information was not collected about the physical distance between each household that buys from a neighbor and that reseller's home; however, the average reported one-way walk time by resale customers was 3.3 minutes. Assuming 80 meters/minute as the average adult walking speed on level surfaces, this average travel time equates to 264 meters, more than twice the 100-meter threshold.

Water use among households with their own private connections is on average twice that of other households in the sample. Nonetheless, consumption among households with their own taps is much lower than values reported in other studies (Thompson *et al.* 2001; Basani *et al.* 2008; Cheesman *et al.* 2008; Nauges & van den Berg 2009; Nauges & Whittington 2009). This discrepancy might reflect the relatively high price per cubic meter of water in Maputo *versus* other developing-country cities (Keener *et al.* 2010). It may also be the result of some respondents' being asked to estimate water usage in their households because they were unable or unwilling to show their water bills to enumerators. Average *per-capita* usage among households that shared their water bill with an enumerator during the interview is more than twice that of households who estimated their consumption. Assuming that water bills provide a more reliable measure of consumption than respondents' estimation, and given that only 31% of the respondents with a private connection provided a bill to study enumerators, the survey results are likely to underestimate consumption by households with private connections overall. Future studies might consider relying on households' bills to the extent possible.

Standpipes outperform resale with respect to both the number of hours of service per day and the predictability of supply. Formal legalization of water resale would be expected to impact both of these service features favorably, as resellers would no longer be concerned with concealing their activities from utility staff by selling only during the early morning hours. Legalization might also be expected to reduce the time and money costs of supply, if more households with private connections entered the resale arena and/or current resellers expanded the time during which they provide water. Currently, households that use a neighbor's tap spend an average 109 minutes per day fetching water. Although this is only half the time spent by standpipe users, it is still equivalent to 27 person-days per year, a substantial investment for securing a household's water supply. If tariff accommodations were made for legalized resellers, e.g., exempting them from the increasing block structure of current domestic water tariffs, prices for their customers might also decrease. It is unclear, however, whether legalization of water resale would affect the issue of dependency on neighbors that was cited by many respondents as a source of dissatisfaction with their water service.

The study findings regarding the correlates of satisfaction with water services revealed unexpected insights. User satisfaction is strongly associated in the expected direction with water service characteristics that are commonly measured, such as fetching time, price per cubic meter, and reliability of supply. After controlling for these service features, however, neighbor's tap users are significantly less likely to report satisfaction with their water services as compared with standpipe users. Focus group discussions with resellers and consumers suggest that such dissatisfaction might be caused by feelings of indebtedness or obligation toward their neighbor-reseller, and humiliation associated with relying on neighbors for water service. These results suggest that there exist important attributes of water services that matter to users, but that are not normally measured by water planners and policy makers. Future research should build on these findings by further exploring the features of water supply services that households value.

Finally, the findings from this work can contribute toward the ongoing debate over what constitutes 'access to improved water supply'. A household that obtains water from a neighbor's network connection could be considered, within the Millennium Development Goal (MDG) framework, to have access to improved water supply so long as the reseller is located within 1 km of the household and supplies at least 20 LPCD. Nevertheless, in Mozambique and many other SSA countries, resale has historically not been considered as a form of improved supply (nor accepted as 'coverage' for MDG accounting purposes). The findings from this work provide preliminary evidence that regularizing resale could benefit low-income, unconnected households in Maputo, but only if careful consideration is given to policy design issues such as metering, pricing, and the time availability of water supplies.

ACKNOWLEDGEMENTS

Funding for this work was provided by the Woods Institute for the Environment, Stanford University. Graduate funding for Valentina Zuin was provided by the Ewing York Foundation Fellowship, at Stanford University. We are indebted to the staff of the Water Regulatory Council (CRA) of the Government of Mozambique, and in particular Berta Macheve, for excellent support during the course of the project. We thank Peter Hawkins of the Water and Sanitation Program in Maputo for useful feedback on earlier version of this paper and overall project support. We thank Águas de Moçambique, and in particular Manuel Thomaz, Jânio Langa and Lidia Salatiel, for assisting with development of the sample frame and field support. Kyle Onda provided outstanding research assistance. We thank Christina Stamatakis for her review of the JMP data on water resale. We are grateful for the thorough and thoughtful comments provided on the original manuscript draft by two anonymous reviewers. Finally, we extend a sincere thanks to the members of our enumerator team and the neighborhood guides for their hard work and dedication to this investigation, and to the participating households for sharing their time and perspectives.

REFERENCES

Ali, S. I. 2010 Alternatives for safe water provision in urban and peri-urban slums. *Journal of Water and Health* **8** (4), 720–734.

Basani, M., Isham, J. & Reilly, B. 2008 The determinants of water connection and water consumption: empirical evidence from a cambodian household survey. *World Development* **36** (5), 953–968.

Boyer, A. 2007 *Questioning the Value of Standpipe Water Supply for the Unconnected: A Case Study of the Efficacy of Standpipes and Household Water Resale in Maputo, Mozambique.*

Centro De Estudos De Desenvolvimento Do Habitat (CEDH) - Universidade Eduardo Mondlane 2006 Moçambique Melhoramento dos Assentamentos Informais, Análise da Situação e Proposta de Estratégias de Intervenção.

Cheesman, J., Bennett, J. & Son, T. V. H. 2008 Estimating household water demand using revealed and contingent

behaviors: evidence from Vietnam. *Water Resources Research* **44** (11), 1–11.
Collignon, B. & Vézina, M. 2000 *Independent Water and Sanitation Providers in African Cities*. Water and Sanitation Program.
Conselho de Regulacao do Abastecimento da Agua (CRA) 2007 Avaliacção de Satisfação dos Consumidores: Abastecimento de Água na Aglomeração de Maputo (p. 100).
Cox, D. R. & Snell, E. J. 1981 *Applied Statistics: Principles and Examples*. Chapman and Hall.
Crane, R. 1994 Water markets, market reform and the urban poor: results from Jakarta, Indonesia. *World Development* **22** (1), 71–83.
Davis, J. 2005 Private sector participation in the water and sanitation sector. *Annual Review of Environmental Resources* **30**, 145–83.
Eaton, A. 2005 *Standard Methods for the Examination of Water & Wastewater*. American Public Health Association, Washington, DC.
Fass, S. M. 1993 Water and poverty: implications for water planning. *Water Resources Research* **29** (7), 1975.
Fewtrell, L., Kaufmann, R., Kay, D., Enanoria, W., Haller, L. & Colford, J. 2005 Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet Infectious Diseases* **5** (1), 42–52.
Gulyani, S., Talukdar, D. & Kariuki, M. 2005 Universal (non) service? water markets, household demand and the poor in urban Kenya. *Urban Studies* **42** (8), 1247–1274.
Howard, G. & Bartram, J. 2003 *Domestic Water Quantity, Service Level and Health*. World Health Organization, Geneva, Switzerland.
Instituto Nacional de Estatistica (INE) 2009 Mozambique Census.
Keener, S., Luengo, M. & Banerjee, S. 2010 Provision of Water to the Poor in Africa Experience with Water Standposts and the Informal Water Sector. *Policy Research Working Paper 5387*.
Kessides, C. 2006 *The Urban Transition in Sub-Saharan Africa. Implications for Economic Growth and Poverty Reduction* (p. 113). The Cities Alliance.
Kjellén, M. & McGranahan, G. 2006 Informal water vendors and the urban poor. *Human Settlements Discussion Paper Series*, International Institute for Environment and Development (IIED).
Larson, B., Minten, B. & Razafindralambo, R. 2006 Unravelling the linkages between the millennium development goals for poverty, education, access to water and household water use in developing countries: evidence from Madagascar. *The Journal of Development Studies* **42** (1), 22–40.
McPhail, A. 1994 Why don't households connect to the piped water system? Observations from Tunis, Tunisia. *Land Economics* **70** (2), 189–196.
Moe, C. L. & Rheingans, R. D. 2006 Global challenges in water, sanitation and health. *Journal of Water and Health* **4** (Supplement 1), 41–57.
Nauges, C. & Strand, J. 2007 Estimation of non-tap water demand in Central American cities. *Resource and Energy Economics* **29**, 165–182.
Nauges, C. & Whittington, D. 2009 Estimation of water demand in developing countries: an overview. *The World Bank Research Observer* **25** (2), 263–294.
Nauges, C. & van den Berg, C. 2009 Demand for piped and non-piped water supply services: evidence from Southwest Sri Lanka. *Environmental Resource Economics* **42**, 535–549.
Pattanayak, S. K., Yang, J.-C., Whittington, D. & Kumar, K. C. B. 2005 Coping with unreliable public water supplies: averting expenditures by households in Kathmandu, Nepal. *Water Resources Research* **41** (1), 1–11.
Solo, T. M. 1999 Small-scale entrepreneurs in the urban water and sanitation market. *Environment and Urbanization* **111**, 117–132.
Thompson, J., Porras, I. T., Wood, E., Tumwine, J. K., Mujwahuzi, M. R., Katui-katua, M. & Johnstone, N. 2000 Waiting at the tap: changes in urban water use in East Africa over three decades. *Environment and Urbanization* **12**, 37–52.
Thompson, J., Porras, I. T., Tumwine, J. K., Mujwahuzi, M. R., Katui-katua, M., Johnstone, N. & Wood, L. 2001 *Drawers of Water II* (p. 122). International Institute for Environment and Development, London, United Kingdom.
UN-HABITAT 2010 *State of the World's Cities 2010/2011*. Earthscan.
Whittington, D., Lauria, D. & Mu, X. 1991 A study of water vending and willingness to pay for water in Onitsha, Nigeria. *World Development* **19** (2–3), 179–198.
Whittington, C., Davis, J. & McClelland, M. 1998 Implementing a demand-driven approach to community water supply planning: a case study of Lugazi. *Water International* **23**, 134–145.
WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation 2010 *Estimates for the use of Improved Drinking-Water Sources – Mozambique*.
World Health Organization (WHO) 2000 *Global Water Supply and Sanitation Assessment 2000 Report*.
World Health Organization (WHO) 2010 *Progress on Sanitation and Drinking Water. 2010 Update*.
Zwane, A. & Kremer, M. 2007 What works in fighting diarrheal diseases in developing countries? A critical review. *The World Bank Research Observer* **22** (1), 1–24.

First received 10 February 2011; accepted in revised form 29 June 2011. Available online 7 September 2011