Resources, Conservation & Recycling 141 (2019) 410–417

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Measuring affordability of access to clean water: A coping cost approach

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ARTICLE INFO

Keywords:
Sustainable Development Goals
Coping Cost
Affordability
Urban Water

ABSTRACT

Sustainable Development Goal 6.1 is "to achieve universal and equitable access to safe and affordable drinking water for all". To measure affordability of accessing clean water, coping cost approach has been adopted, and this paper contributes to the burgeoning empirical literature on measuring affordability. The objective of this paper is to estimate coping costs related to the erratic, unsafe, and inadequate water supply in the metropolitan area of Chennai, India. Based on the data collected from 423 households, we find that households in Chennai city resort to five main types of coping behaviors: collecting, pumping, treating, storing, and purchasing. We employ the multiple regression with robust errors, to estimate the determinants of the coping costs. We obtain the mean coping costs as INR (Indian Rupee) 553, and INR 658 per month for piped and non-piped households in this sample. For non-piped households, collection costs (time costs in traveling and queuing for collecting water) constitute 22% of the coping costs, while collection costs for piped households are less 2% of the coping costs. One interesting finding is the variation of coping costs with household income—these costs are roughly 1% of income for the high income households to as high as 15% for the low income households. The results outline the need of policy intervention to enhance affordability.

1. Introduction

From early times, water has been central for social and economic progress of mankind. However, with increasing variability in availability of water and urbanization, access to safe water is becoming increasingly difficult. Increasing scarcity of water is affecting populations across the globe, especially in the developing countries. This problem was recognized by the international community, and improving access to safe water access was declared as one of Millennium Development Goals (MDGs) in 2000. MDG-7.C aimed to cut in half the proportion of people in the world without sustainable access to safe drinking water relative to 1990 levels. Post 2000, significant progress has been made—population with access to water through piped (non-piped) connections increased from 3.5 (1.65) billion in 2000 to 4.6 (3.5) billion in 2015 (https://washdata.org, August 2018). However, it has been observed that improved accessibility does not guarantee quality, affordability, and reliability (Guardiola et al., 2010; Martínez-Santos, 2017).

Since 2015, MDGs have been succeeded by Sustainable Development Goals (SDGs). SDG 6.1 is "to achieve universal and equitable access to safe and affordable drinking water for all". Smiley (2017) notes that the SDGs overcome the limitations of the earlier focus on water source, and instead offer a broad policy that considers the quality and accessibility of water. At present, the situation is far away from the goal. Nearly one billion people lack access to an improved water source within one kilometer of their house. In 2015, in India, 568 million have water access through pipes, while 633 million have non-piped access (https://washdata.org, August 2018). People with access to piped water also has intermittent supply, which results in storage costs and also contaminate drinking water. Contaminated water needs to be boiled or treated. Concerns on measuring quality, reliability, and affordability are increasing. Majuru et al. (2016, p. 17) note, "In the context of SDG target 6.1, …, indicators on water quality, reliability, collection time, and affordability will need to be measured." Estimating coping costs of accessing safe water is one such measurement of affordability (Majuru et al., 2016). These are tangible and intangible costs of the coping strategies, like collecting or treating water, employed by the households.

This paper contributes to the emerging literature of estimating coping costs as a measure of affordability and their relevance to SDGs. In this paper, we estimate coping costs of accessing safe water in the city of Chennai, the capital of semi-arid state of Tamil Nadu, India. As per 2011 census, Chennai city has population of 4.6 million with 1.1 million households.[1] The main source of water for Chennai city is met through Chennai Metropolitan Water supply and Sewerage Board

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[1] In 2011, the area under Corporation of Chennai was increased from 176 km^2 to 426 km^2 with an increase in population to 8.7 million.

https://doi.org/10.1016/j.resconrec.2018.11.003
Received 15 December 2017; Received in revised form 17 October 2018; Accepted 5 November 2018
Available online 15 November 2018

(CMWSSB) distribution mechanism which is mandated to provide water to consumers in areas under Corporation of Chennai. CMWWSB provides water at 87 lpcd, which is less than 120 lpcd necessary in a metropolitan area, to its consumers at an average of 5 h per day to 89.3% of the population in its service area (Asian Development Bank, 2007). We conducted four *Focus Group Discussions* (FGDs) in different parts of Chennai. From FGDs, we conclude that the consumers have to depend on other sources and strategies to cope with unreliable and unsafe public supplies—collecting through public taps, collecting and buying through tanker water, storage and treatment of water, buying bottled water, pumping from a well/bore-well. Furthermore, FGDs reveal that the supply time of 5 h per day is exaggrerated. Vaidyanathan and Saravanan (2004) observe that groundwater extracted by privately owned wells and bore wells was the main private source. They estimate 420,000 wells in Chennai with total extraction to be about 170 MLD. Venkatachalam (2012) reports that the city of Chennai is heavily dependent on the water tankers for household consumption. These trucks obtain water from the peri-urban areas of Chennai. Briscoe and Malik (2006) note that the number of Indian cities and towns falling into similar circumstances is growing rapidly. Based on the above discussion, the objectives of the study are: to study different coping strategies used by water users to cope with unsafe and intermittent supply; estimate the coping costs, and determine the factors influencing them; and analyze the policy implications of the coping costs in the context of SDG 6.1 on safe and affordable access to water.

Based on the primary data collected from 423 households, we estimate the components and amount of coping expenditure for water service improvements. Further, we use the multiple regression method, with robust errors, to estimate the determinants of the coping costs. We obtain the mean coping costs as INR 553, and INR 658 per month for piped and non-piped households in this sample. The non-piped connections incur higher collection costs than the piped households. Furthermore, for poor households with income less than INR 10,000, the collection cost is a major constituent of the coping cost; and, for these households, coping costs is as high as 15% of their income. These results are akin to the results from previous studies. Allen and Bell (2011, p. 1) note, "Being outside the formal systems of water provision through centralized pipe networks, the poorest often pay the highest price of water". Zerah (2000) computes that the coping costs constitute 15% of income for lower income households in Delhi. For Kenya, Cook et al. (2016) report time spent collecting water is a major component of coping costs and coping costs exceed 10% of monthly income in over 50% of households. From the regression model, we find that income is positively correlated to the coping costs, while the piped connection is negatively correlated to the coping costs. These observations are similar to Cook et al. (2016).

The above discussion indicates that the households in Chennai have significant coping costs, which are higher for non-piped connections and regressive for poor households. Similar observations have been made in other studies. The policy implications of these findings, in the context of SDG, are discussed in Section 6. The remainder of the paper is organized as follows. In Section 2, we present the related literature. Section 3 provides the description of the study area and the sample design; whereas, the sample descriptives are summarized in Section 4. Section 5 discusses the results.

2. Theoretical background and related literature

The theoretical underpinnings of this research start from elementary microeconomics—for market goods which are traded through prices, demand function provides the change in goods' valuations with changes in prices. For nonmarket goods, there is no price; and, hence, there are methods of estimating valuation in these cases. These methods are based on substitutability of goods; and, the valuation is expressed in terms of willingness to pay (WTP), or willingness to accept (WTA). There are two basic approaches to measure valuation: *revealed preferences* and *stated preferences*. Both the approaches are inductive in nature. In revealed preferences approach, consumer preferences are deduced using the actual expenditure on environmentally related private good; while, in stated preferences approach, consumers are directly asked about values they place on hypothetical improvements or reduction in environmental services (Young, 2005). Mendelsohn and Olmstead (2009) note that economists generally rely primarily on revealed preference approaches to estimate *use* value and reserve stated preference methods for *nonuse* value. Furthermore, World Water Development Report (2012) mentions that, in spite of its relevance, valuation methods are controversial. They are site and context-specific. World Water Development Report (2012) emphasizes on valuation methods, like averting cost, which are not sensitive to value judgments.

In this research, we use revealed preference approach—defensive[2] behavior method to infer willingness to pay for accessing safe water in Chennai. This is based on the premise that a rational agent will take averting behavior if the value of the damage avoided exceeds the cost of the averting action (Dickie, 2003). The early papers are Grossman (1972), Cropper (1981) and Harrington and Portney (1987). This approach has been used for estimating valuations in different domains—Dickie and Gerking (1991), Gupta (2011) and Gerking and Dickie (2013). In the literature, there are multiple defensive behavior approaches—consumer-market study; health production function study; demand for a necessary defensive input study; and, defensive expenditure study. We are following "health production function study". It is assumed that health is an input in household production functions; and, changes in health due to environmental factors allow us to measure and value the changes in the productive activity. This approach has the most stringent data requirements among the four approaches, as well as the most complicated model estimation. Using the health production function, Freeman et al. (2014) give marginal willingness to pay, as a measure of valuing morbidity under pollution, as

$$w_c = p_w \frac{\mathrm{ds}}{\mathrm{dc}} + p_b \frac{\partial b^*}{\partial c} + p_a \frac{\partial a^*}{\partial c} - \frac{1}{\lambda}\frac{\partial u}{\partial s}\frac{\mathrm{ds}}{\mathrm{dc}} \tag{1}$$

where a is the amount of averting activity, b is the amount of mitigating activity, c is the concentration of the pollutant, s is the number of sick days, u is the utility function, p_w is the wage rate, p_a is the price of averting activities, and p_b is the price of mitigating activities.

Pattanayak et al. (2005) modify Eq. (1) to estimate WTP for improved water services. They note coping costs and WTP have the same underlying preferences; however, the empirical estimates of coping costs are only a lower bound for exact WTP.

The standard practice in the literature on evaluating the economic impact of irregular water supplies is to examine the strategies employed by the households and these studies mainly based on the experience of developed countries concentrated on understanding the treatment behavior (Larson and Gnedenko, 1999; Um et al., 2002). Larson and Gnedenko (1999) report the types and costs of averting measures undertaken by the households in Moscow to improve drinking water quality. They show that majority of the households use boiling of water due to concerns about water quality. Other strategies regularly adopted are filtering and buying bottled water. Um et al. (2002) estimate the WTP for improved water quality in Pusan, Korea using averting behavior method. They attribute the averting behavior of the households to the perceived pollutions levels rather than the actual pollution levels.

In the case of developing countries, coping strategies go beyond in-home treatment of water. Often, due to the unreliable and poor quality of existing water supplies, households often spend time traveling and waiting for water from other sources (tankers, public taps) to obtain better quality water. Cook et al. (2016), Orgill-Meyer et al. (2018), Pattanayak et al. (2005) and Zerah (2000) are some of the major studies that estimate coping costs in developing countries and consider

[2] We assume terms *coping*, *defensive*, and *averting* are same.

collection costs.

Zerah (2000) studies the coping strategies of households due to inadequate water supply in the city of Delhi, India. The study was based on a cross-sectional data of 700 households. It was observed that that household adopted multiple coping strategies. Using a logit model, the study finds that the adoption of coping strategy is influenced by the income, location of the residence, duration of water supply, and the ownership of the house. Zerah (2000) estimates of coping costs with irregular water supplies vary from 15% of income for lower income households compared to 1% for rich households. Pattanayak et al. (2005), based on a household level data from Nepal, examine the coping behavior and averting expenditures to cope up with unreliable water quality. The study finds that household adopted various mechanisms to cope with unreliable water supplies. The results of the study show that households spend almost 1% of the income in the form of coping costs. Pattanayak et al. (2010) analyze the benefits of improved water supply and sanitation based on the experience of Maharashtra. The study employs propensity score matching and panel data methods for the empirical analysis. The study finds that the number of households using piped water and private pit latrines had increased by 10%. The study estimates that the adoption of the community driven sanitation program led to reduction in the coping costs by $7 per month. Cook et al. (2016) estimate the coping costs of poor water supply in rural Kenya. The coping costs include collection costs, treatment costs, purchase costs, and costs of treating diarrhea. They estimate median total coping costs are US$20 per month; and, coping costs exceed 10% of income for over half of households. Orgill-Meyer et al. (2018) compare contingent valuation (stated preferences) and averting behavior (revealed preferences) to measure willingness to pay for improved reliability in Jordan. They estimate mean monthly averting expenditure (or coping cost) is 4% of income; and, includes purchases of water sourced from tankers, as well as costs in terms of water collection time, storage and in-home treatment.

Other studies that dovetail with this literature are Katuwal and Bohara (2011), Othman et al. (2014) and Rosado et al. (2006). Katuwal and Bohara (2011) examine the averting behavior with respect to water quality in Nepal. They use a cross-sectional data of 2000 households. The study found different treatment practices adopted by household to deal with the problem of poor water quality. The empirical analysis using binomial, ordered and multinomial probit finds that that the majority of households practice either one or more than one treatment method to make the water safe for drinking. The adoption of treatment behavior was significantly influenced by wealth, education level, exposure to information, and opinion on water quality. Othman et al. (2014), using the avoidance cost method, estimate that households in Kajang Municipality in the state of Selangor, Malaysia were willing to pay MYR 322 annually for improved drinking water quality. Rosado et al. (2006) analyze the averting behavior in Brazil as a function of costs of each choice and household characteristics. They estimate the WTP values for safe drinking water using defensive inputs as US$6.56.

The literature review points that the households employ various strategies to cope with unreliable and unsafe water in developing countries. Pattanayak et al. (2005) emphasize the need of empirical literature on coping costs for constructing theories of coping costs and behavior, while Majuru et al. (2016) highlight the relevance of coping costs of accessing safe water in the context of SDGs, especially the "affordability" criterion. This paper is an attempt to contribute to this literature by estimating coping costs of accessing safe water in Chennai, and to determine the factors influencing them.

3. Description of the study site and sample design

Since 2011, Chennai has been divided into 15 zones with 200 wards (earlier, there were 155 wards). CMWSSB is mandated to provide water to all the wards in Chennai. We have collected ward-wise information about water supply in Chennai, shown in Table 1 (our compilation based on the information provided by the zonal engineers of CMWSSB). It can be observed that there are many wards in Chennai, which are not connected through pipe; and, the residents have to depend on alternative sources to meet their daily water requirements. We conduct four focus group discussions (FGD) at Washermenpet, Velachery, Tondiarpet, and Thiruvanmiyur; and a qualitative survey to understand the coping behavior of the residents. From the FGDs and the survey, we find that CMWSSB provides water to only 2–3 h every alternative days in the piped area; or, through public taps or tankers in the unpiped areas. The residents, in unpiped areas, spend considerable time in collecting water. Dependence on bore-well water and can water is pervasive. Majority of the participants perceive that water quality is poor from all the sources.

From these discussions, it can be inferred that Chennai has variability with respect to water supply, income, coping behavior etc. The objective of the sampling, for the household survey, is to capture the variability in the population. We use purposive sampling to select 12 wards (see Table 2) which are segregated into four groups based on the average income per household and piped connection. For income, we used average property tax per household[3] in each ward as a proxy. Due to the lack of street-wise household information, we could not use systematic sampling within each ward; and, has used random sampling within each ward. From Babbie (2014),[4] we estimate a representative sample of size 384 can capture the variability in coping strategies and coping costs in Chennai. The survey instrument was designed with pretests, and was administered on 435 households equally distributed in the 12 wards (see Fig. 1); 12 households were removed due to incorrect entries, which gives a sample of 423 households. The survey instrument contains detailed questions, in Tamil (local language) and English), on demographic details, income, current water sources, coping behaviors and their monetary and labor costs, perceptions of water quality, and expenditure on treating water-borne diseases. The survey was conducted with the assistance of three trained field investigators. All the respondents consented to participate in the survey.

4. Sample descriptives

4.1. Description of the sample households

Table 3 provides the demographic and socioeconomic profiles of the sample households. The modal household size is 4 persons with the modal monthly income INR 25,000. Almost quarter of the respondents reside in rented houses.

4.2. Description of water sources used

Our preliminary surveys in Chennai conclude that the major sources of water in Chennai are piped connections, public taps, public tanks, bore wells, public wells, can water; with less than 10% dependence on other sources. Table 4 shows the source-wise distribution of households. It can be observed that only 27.66% of the households are connected through pipe; they have to depend on other sources.

We also checked, from the respondents, the reasons for using the available sources. The results are summarized in Table 5. It can be observed that only 54% of the households using piped water perceive that the piped water is safe; moreover, majority of the households consider it as insufficient and unreliable. Majority of the households use bore wells because of convenience, sufficiency, and reliability; however, only 3% of those households consider it safe with good smell/color. More than half of the sample households are dependent on can water for drinking purpose, as more than 99% of those households perceive it is safe.

[3] This information was provided by the Revenue Department, Corporation of Chennai.

[4] $n = \frac{z^2 P(1-P)}{D^2}$.

Table 1
Ward-wise information about water supply in Chennai.
Source: Based on the Field Survey).

Wards	Main sources	CMWSSB water supply	Remarks
1–14	CMWSSB water, bore well	4 h on every alternative days	Unconnected by pipe.
15–21	CMWSSB water, bore well	2 h on every alternative days	Unconnected by pipe.
20–33	CMWSSB water, bore well	3 h on every alternative days	CMWSSB pipe connection is available for wards: 22, 24, 26, and 33. Other wards are unconnected by pipe.
34–48	CMWSSB water, bore well	5 h on every alternative days	Connected by pipe.
49–63	CMWSSB water, bore well	5 h on every alternative days	Connected by pipe, except wards 49, 50, 53, and 63.
64–78	CMWSSB water, bore well	4 h on every alternative days	Connected by pipe.
79–93	CMWSSB water, bore well	4 h on every alternative days	Connected by pipe.
94–108	CMWSSB water, bore well	5 h on every alternative days	Connected by pipe.
109–126	CMWSSB water, bore well	3 h on every alternative days	Connected by pipe.
127–142	CMWSSB water, bore well	4 h on every alternative days	Connected by pipe.
143–155	CMWSSB water, bore well	4 h on every alternative days	Connected by pipe.
156–167	CMWSSB water, bore well	2 h on every alternative days	Connected by pipe.
170–182	CMWSSB water, bore well	4 h on every alternative days	Connected by pipe.
168, 169, 183–191	CMWSSB well, bore water	4 h on every alternative days	Unconnected by pipe.
192–200	CMWSSB water, bore well	4 h on every alternative days	Unconnected by pipe.

Table 2
Sampled wards.

	Piped	Not-piped
High income	26, 59, 86	5, 63, 197
Low income	33, 139, 178	10, 53, 186

5. Results and discussion

5.1. Estimation of coping costs

Our preliminary survey and the FGDs show that per capita availability of safe water is low in Chennai. Residents are engaged in variety of coping strategies, like collecting, pumping, treating, storing, and purchasing, to cope with low availability and poor quality. Therefore, our survey questionnaire includes detailed questions related to the each of the identified coping behavior. The following paragraphs explain the

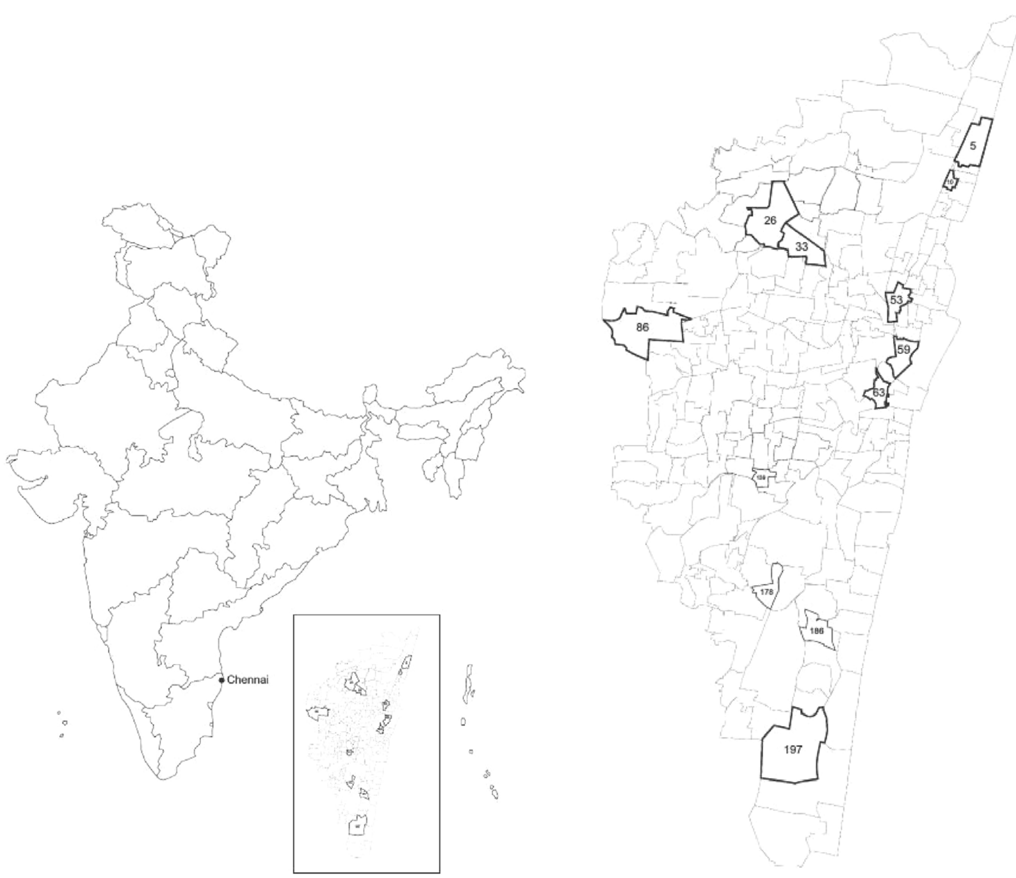

Fig. 1. Selected wards in Chennai.

Table 3
Demographic and socioeconomic profile of the sample households.

Modal age of respondents, years	45
Percentage of male respondents	43.26
Percentage of graduates in respondents	20.57
Modal family size, #persons	4
Modal monthly income, INR	25,000
Percentage of respondents in rented house	26.00
Average number of rooms	3

Table 4
Source-wise distribution of households.

Source of water	%Households
Piped water	27.66
Public tap	49.65
Public tank	18.68
Bore well	69.03
Public well	1.65
Neighbors	1.42
Can water	56.50
Tanker	7.09

Table 5
Reasons for using the available sources (in number of households).

Source	No. of HH using	Safe	Convenient	Good smell/ color	Sufficiency	Reliability
Piped	117	64	74	17	8	5
Public tap	210	94	111	23	20	13
Public tank	79	29	44	24	7	4
Bore well	292	11	199	13	136	115
Public well	7	0	4	0	3	3
Neighbors	6	0	3	1	0	1
Can water	239	237	18	23	0	0
Tanker	30	19	6	8	0	0

Table 6
Average monthly coping costs by user category (in INR).

Cost	Average value	No. of HH
coping_cost PC	553	117
coping_cost NPC	658	306
collection_cost PC	8	05
collection_cost NPC	146	169
purchase_cost PC	299	103
purchase_cost NPC	230	243
pumping_cost PC	127	48
pumping_cost NPC	154	160
treatment_cost PC	29	39
treatment_cost NPC	43	113
storage_cost PC	89	117
storage_cost NPC	85	306

procedures to estimate coping costs, associated with different coping strategies. Table 6 shows these costs for piped (PC) and non-piped connections (NPC). The average monthly coping cost is computed as INR 629.

Collection costs: From Table 4, more than 60% of the sample households are dependent on public taps or public tanks. They incur time costs (traveling and waiting) in collecting water. In our sample, the maximum collection time is 2250 min per month. These time costs are converted to monetary values by multiplying with the hourly wage rate INR 30 (≊ US$ 0.5). We have used the average of the minimum hourly wage rates mandated by the Government of Tamil Nadu. From Table 6, average collection cost for piped and non-piped connections is INR 8 and 146, respectively.

Purchase costs: The piped households has to pay a fixed charge to CMSWWB, which is approximately INR 100 per month in Chennai. However, from Table 4, households are buying can water for drinking water needs. A 20 litre can of water costs approximately INR 30 in Chennai; the sample average is 12 cans per month, with the maximum of 30 cans per month. Furthermore, unconnected households are paying a small amount (≊ INR 0.5 per kodum (plastic pot)) for collecting water through public taps or public tanks. The average purchase cost for piped and non-piped households is INR 299 and 230, respectively.

Pumping costs: For convenience and reliability, the use of bore wells is abundant in Chennai to meet water requirements. We asked the households to report the cost of installing the bore well and monthly operating and maintenance costs. The installation costs are amortized to monthly costs, assuming 15 years lifespan of bore wells. The average pumping cost for the piped and non-piped households is INR 127 and INR 154 per month, respectively.

Treatment costs: Table 5 shows that majority of the sampled households perceive water quality from all the major sources as poor. Prouty and Zhang (2016) note that the perceptions of water quality influence choices for household treatment methods. They use boiling (133 households), manual filtration (69 households), and reverse osmosis/ultraviolet (RO/UV) based electric filters (47 households) for mitigating poor quality. 11 households use both boiling and electric filters. The monthly cost of boiling is imputed using the cost of the fuel (mainly LPG) and cooking hours. The installation costs of RO/UV filters are amortized to monthly costs, assuming 10 years lifespan; the annual maintenance costs of these filters are converted to monthly costs. The average treatment costs is estimated for piped and non-piped households as INR 29 and INR 43, respectively.

Storage costs: As the supply of water is intermittent in Chennai, a large number of households use storage tanks (mainly overhead tanks) to store water. The tank size varies from 500 litres to 5000 litres. The households were asked about the installation cost of the storage tank; these costs are amortized to monthly costs, assuming 30 years lifespan. Furthermore, we convert the cost of utensils used for storage to monthly costs. These storage costs add up to INR 89 and 85 for piped and non-piped households, respectively.

Using the costs, associated with each coping strategy, the total coping cost is computed as INR 553 for piped households, and INR 658 for non-piped households. This is in tandem with the previous literature (Pattanayak et al., 2005); and, also the intuition—the non-piped households incur more intangible costs in accessing safe water. This is evident from high collection costs for the non-piped households.

We also asked households to report the sickness and hospitalization details, for last six months, due to water borne diseases. Thirty households reported some water borne diseases, with the average monthly sickness cost as INR 512. This includes the opportunity costs of lost working hours and medical expenditures.

5.2. *Variation of coping costs with income*

Fig. 2 shows the distribution of coping costs across different income ranges. For poor households (monthly income < 10,000), the collection costs and the purchase costs are the constituents of coping costs. The collection and storage costs are decreasing with income, while the pumping costs are increasing with income. Furthermore, the ratio of coping cost to income decreases with income—the poor households spend a substantial portion of their income to access safe water compared to the rich households (Fig. 3). However, the magnitude of coping costs increase with income for both the piped and the non-piped households (Fig. 4). Moreover, for all the income ranges, non-piped

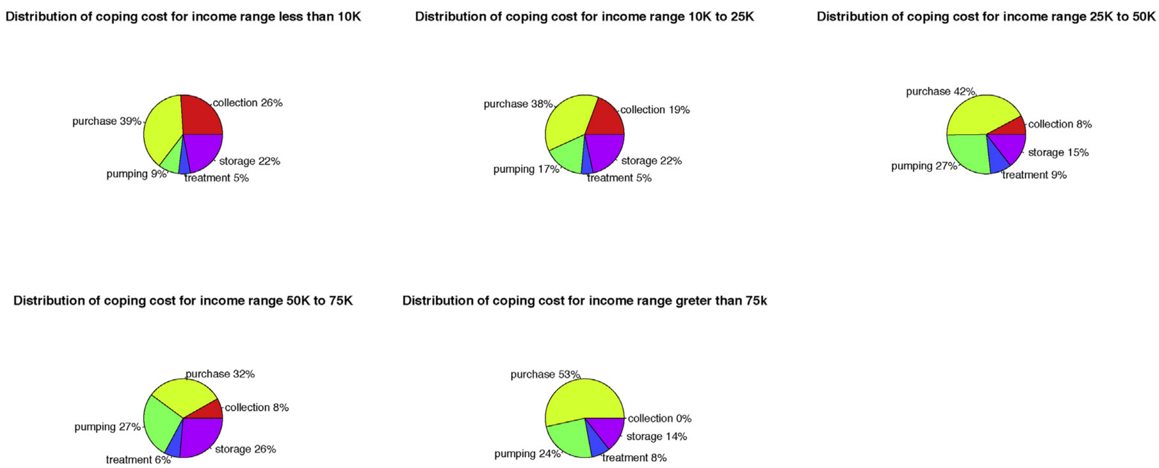

Fig. 2. Distribution of coping costs for different income ranges.

households incur higher coping costs compared to piped households. These observations are in sync with Cook et al. (2016), Pattanayak et al. (2005) and Zerah (2000).

5.3. Multiple regression model

After estimating the coping costs, the next step is to determine the factors correlated with the coping costs. We carry out a multiple regression following Abdalla et al. (1992) and Pattanayak et al. (2005); and, obtain White's heteroskedasticity-consistent variances and standard errors to account for heteroskedasticity. It is assumed that the coping mechanisms adopted by the households depend on the income, education, age, family size (Zerah, 2000; Pattanayak et al., 2005). Family size is a good indicator of water consumption (Mostafavi et al., 2018). In addition, we capture the effect of type of sanitation, piped connection, and the perception of the household regarding water contamination through corresponding dummy variables. The definition of the variables are provided in Table 7. Three separate models were estimated with total coping costs, collection costs, and purchase costs as the dependent variables. Collection costs and purchase costs are chosen as they constitute more than 50% of the estimated coping costs for the majority of the income groups (Fig. 2). Furthermore, we observe more variations in these costs between piped and non-piped households (Table 6). The results of these estimations are reported in Table 8. The details of the number of observations, predictive power and the overall significance of the model are reported in the bottom of the table. For coping cost and collection cost, R^2 is reasonable for such a cross-sectional data. Pattanayak et al. (2005) and Cook et al. (2016) report R^2 in the same range for their multiple regression models of coping costs.

We begin by analyzing the determinants of total coping costs. We find that income is positive and significantly related to the coping costs. Families with higher income bear higher coping costs. Higher income households have the financial resources, and therefore tend to spend more on various mechanisms like storing, purchasing, treatment etc. Similarly, those households that perceive water contamination as a serious problem have higher coping costs. Those households which are connected to the piped network have lower coping costs. This result can be attributed to the fact that households connected to the piped network have lower opportunity costs in terms of collection time and purchasing water from other sources.

Coefficients of the other variables like education, age and family size have the expected sign. The positive association of the education level of the household head might play an important role in decision to treat water. The educated household head will certainly be aware of the health benefits of clean water and therefore will be willing spend more on coping activities. The positive association between age and coping results from the fact older households do care about the quality of water due to health reasons. Similarly larger family size has a positive effect on coping costs reflecting both the “demand and supply effects” (Alam and Pattanayak, 2009). As the size of the family increases the household need to invest more in terms of collection, purchase and treatment.

6. Conclusions

With increasing concerns about water availability and accessibility, Millennium Development Goal (MDG-7.C) was adopted in 2000. The goal aims to half the proportion of people in the world without sustainable access to safe drinking water relative to 1990 levels. Following

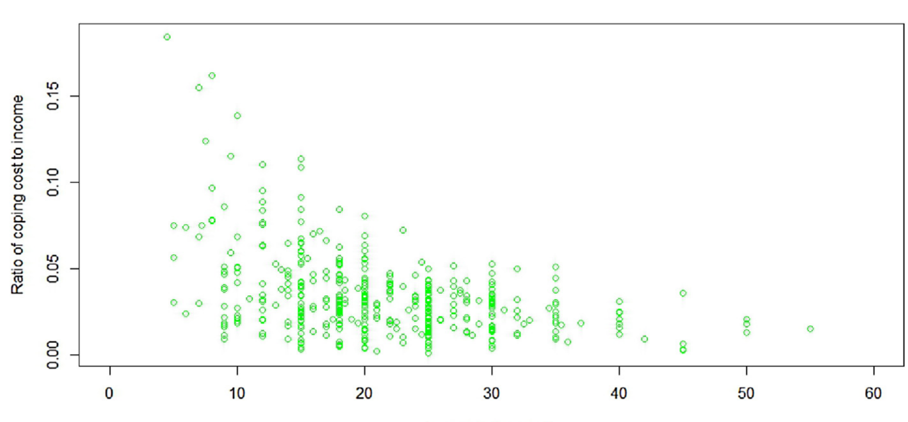

Fig. 3. Variation of the ratio of coping costs to income with income.

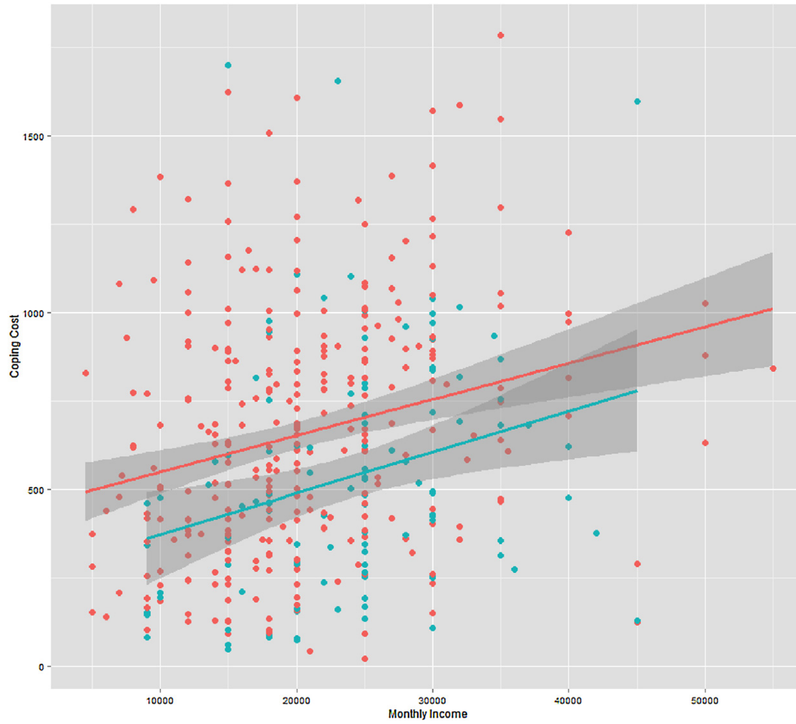

Fig. 4. Variation of the coping costs for piped and non-piped households with income.

Table 7
Variables' definition.

Variable	Definition
Coping cost	Total coping cost (INR/month)
Collection cost	Total collection cost (INR/month)
Purchase cost	Total purchase cost (INR/month)
lnincome	Log of monthly income
Piped	Connected to pipe (1 if household has water piped water connection; 0 otherwise)
toil	Toilet attached (1 if toilet attached; 0 otherwise)
qual	Education of the respondent (0 (illiterate)—5 (Postgraduate))
perception	perception(1 if the household perceive that water is poor; 0 otherwise)
lnage	Log of age (in years)
family_size	Total number of members in the household

MDG-7.C, significant progress has been made on this front. However, the goal was criticized for not considering quality, affordability, and reliability of water (Guardiola et al., 2010; Martínez-Santos, 2017; Smiley, 2017). In 2015, United Nations replaced MDGs with Sustainable Development Goals (SDGs). SDG 6.1 is "to achieve universal and equitable access to safe and affordable drinking water for all". A methodological note by World Heath Organization (WASH Post-2015, 2015) defines

Access	Sufficient water to meet domestic needs is reliably available close to home
Safe	Safe drinking water is free from pathogens and toxic chemicals
Affordable	Payment for water services does not prevent people from meeting other basic human needs
Drinking water	Water used for drinking, cooking, and hygiene

In developing countries, people employ various strategies to cope with unreliable and unsafe water. In the context of SDG 6.1, coping costs associated with the coping strategies are good measure of affordability of water services.

Table 8
Regression model of coping costs.

Variables	Coping cost	Collection cost	Purchase cost
lnincome	0.178**	−0.789***	0.301
	(0.0764)	(0.255)	(0.225)
Piped	−0.291***	−2.481***	0.580**
	(0.0759)	(0.191)	(0.238)
toil	0.0800	0.0424	0.242
	(0.0633)	(0.249)	(0.242)
qual	0.173***	0.0496	0.196**
	(0.0284)	(0.102)	(0.0993)
perception	0.0927*	0.654***	0.395**
	(0.0505)	(0.184)	(0.169)
lnage	0.295***	−0.00677	0.200
	(0.111)	(0.419)	(0.399)
family_size	0.0269*	−0.0326	−0.0406
	(0.0155)	(0.0609)	(0.0543)
Constant	2.797***	9.828***	−0.379
	(0.726)	(2.617)	(2.344)
Observations	423	423	423
R-squared	0.187	0.254	0.058

Robust standard errors in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

This paper identifies the coping strategies, and estimates associated coping costs for erratic, unsafe, and inadequate water supply in the city of Chennai, India. From Focus Group Discussions, we observed that people have to depend on other sources and strategies to cope with unreliable and unsafe public supplies—collecting through public taps, collecting and buying through tanker water, storage and treatment of water, buying bottled water, pumping from a well/bore-well. We collected primary data from 423 households using a comprehensive survey questionnaire. One of the surprising observation is that only 117 households in the sample has piped connections, which has unreliable supply. Around 50% of the households use public tap for meeting their water requirements. Water quality from most of the water sources is perceived as poor, and households have strong preference for can water as a major source of safe and reliable water.

We obtain the mean coping costs as INR 553, and INR 658 per month for piped and non-piped households, respectively. For non-piped households, collection costs (time costs in traveling and queuing for collecting water) constitute 22% of the coping costs, while collection costs for piped households are less 2% of the coping costs. We observed the collection time for non-piped households as high as 75 min per day. WASH Post-2015 (2015)WASH Post-, 2015WASH Post-2015 (2015) recommends collection time, including queuing, should be less 30 min from basic water sources. One interesting finding is the variation of coping costs with household income—these costs are roughly 1% of income for the high income households to as high as 15% for the low income households. For poor households (monthly income < INR 10,000), collection costs and purchase costs constitute 65% of the coping costs. As the income increases, collection costs decreases. Furthermore, the magnitude of coping costs increase with income for both the piped and non-piped households. We use regression models to identify the factors influencing the coping costs. Total coping costs, collection costs, and purchase cost are regressed against various factors like income, piped/non-piped, qualification, and family size. The regression results show that total coping cost and collection costs are negatively related with piped connection. Furthermore, income is positively related with total coping cost and negatively related with collection costs. These results are consistent with the results from earlier studies on coping studies like Cook et al. (2016), Orgill-Meyer et al. (2018), Pattanayak et al. (2005) and Zerah (2000).

The results of this study indicate that we are still distant from meeting the criteria of SDG 6.1 mentioned in WASH Post-2015 (2015) WASH Post-, 2015WASH Post-2015 (2015). The results point that the water supply is unreliable, availability is insufficient, water quality is poor, and households incur substantial proportion of their incomes to access improved water services. As mentioned earlier, low income households spend as high as 15% of their monthly income to access water in Chennai. Similar estimates are reported in Cook et al. (2016) and Zerah (2000). This brings us to the earlier question of affordability. Coping costs provide a measure of affordability. Cook et al. (2016) propose “5% rule”—households’ monthly expenditure on water and sanitation services should not exceed 5% of their monthly income. The estimates of coping costs from this study as well as Cook et al. (2016), Orgill-Meyer et al. (2018), Pattanayak et al. (2005) and Zerah (2000) violate the 5% rule. These costs are likely to increase with increasing variability of water availability due to climate change and increasing wages. This study reinforces the relevance of SDG 6.1, especially enhancing affordability of water services in developing countries. One of the policy implications emerging from the present study is to enhance affordability by reducing collection time and increasing reliability of water supply. This may be achieved through piped connections.

We acknowledge that coping costs may vary with seasons. One of the limitations of this study is that the variation of coping costs with seasons is not considered. The future studies may address this concern. Given the connections between water and energy (Yu et al., 2018), and as the energy costs are increasing, it is important to examine further the relationships between energy and coping costs.

Acknowledgements

We acknowledge the financial support from South Asian Network for Development and Environmental Economics (SANDEE). We thank Professor Subhrendu K. Pattanayak, Duke University and Celine Nauges, Toulouse School of Economics for their support during the research.

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