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Water and time use: evidence from Kathmandu, Nepal

Yvonne Jie Chen[a,*], Namrata Chindarkar[a] and Jane Zhao[b]

[a]*Lee Kuan Yew School of Public Policy, National University of Singapore, Singapore*

**Corresponding author. E-mail: sppcj@nus.edu.sg*

[b]*Department of City and Regional Planning, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA*

Abstract

In this paper, we examine the effect of private tap water reliability on time spent on water collection and total water consumption among urban households in Kathmandu, Nepal. Although the majority of households in Kathmandu are connected to a private tap, they experience intermittent water supply. We link a unique time diary dataset collected between 2014 and 2015 to household water consumption and tap water reliability data. Our empirical analyses demonstrate that improved reliability of private tap water connection (PWC), measured as self-reported reliability and an objective measure of 'probability of getting tap water in the next hour', leads to increased time spent on water collection. Households with more reliable PWC also consume more water overall and from their own taps. Further investigation demonstrates that when private taps became more reliable, households substituted water collected from outside the household, such as water from public taps and public wells, with water from their own private taps. Our results proved robust to additional specification checks.

Keywords: Nepal; Tap water; Urban

1. Introduction

Access to water is costly in many developing countries. Households in these countries spend time and effort on collecting water, often on a daily basis, resulting in productivity and welfare losses. On average, the persons responsible for water collection (usually women and girls) spend 36 min per trip for water collection activities in rural Sub-Saharan Africa and approximately 23 min per trip in rural Asia (Cheung, 2010). In water-scarce regions in India, a woman could spend up to 3 out of her 15 productive hours per day collecting water (Sijbesma *et al.*, 2009).

As a result, many developing countries have implemented large-scale programmes to provide tap water connections to households. The motivations underlying these programmes include the provision of safe and convenient water supply and consequently improve household welfare. However, rapid expansion of tap water connections can lead to inadequate supply if it is not accompanied by

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improvements to the supporting water infrastructure, thus undermining the effectiveness of providing tap water connections.

In this paper, we study the effect of reliability of private tap water connections (PWCs) on household time allocation and household welfare measured as volume of water consumed in Kathmandu, Nepal[1]. The importance of infrastructure on development and growth has been demonstrated in the existing literature. However, the importance of infrastructure quality has not received adequate attention, due to the thinking that quality will eventually catch up. In reality, in many countries, it takes decades, if not longer, for the infrastructure to operate at optimal capacity. During this lengthy period of catching up, households usually rely on existing sources of water supply, such as public taps or wells and private water markets to manage their household water supply. An interesting question that arises is whether access to tap water, even though unreliable, is better than nothing?

Tap water systems provide treated water from public sources to end users. The provision of tap water requires supporting infrastructure, such as water pipelines that link end users directly to the water source. However, as in many developing countries, the tap water system in Kathmandu suffers from intermittent service and poor reliability. Although over 70% of households had access to tap water in 2001, water pressure and running time varied significantly, owing mainly to weak supporting water infrastructure, such as aging and broken pipes, and depleting water sources (Whittington *et al*., 2002; Pattanayak *et al*., 2005). A majority of households get tap water only for a few hours every day. Under these conditions, it is unclear what effect improved reliability would have on water collection times. At the time of the writing of this article, we were unaware of any other study examining time use patterns under conditions of unreliable water supply.

We use unique household data collected in the Kathmandu Valley for our analyses. Kathmandu Valley is the economic and political centre of Nepal. With its rapid urbanisation and growing population, Kathmandu Valley has experienced significant water shortages. Although in our sample, 87% of households had access to tap water, the connections can be highly unreliable. Data on household water usage collected by the authors from 2014 to 2015 indicate that, on average, households with tap water connectivity received water from their tap for only 9 days out of a month, and for the days when water was available, it only runs for less than 100 min. Tap water reliability contributes significantly to household time allocation decisions. During our survey, many respondents suggested that they often needed to leave work early in order to turn on the tap when the water became available.

We provide a simple theoretical model that illustrates the effect of increased productivity of household water production (that is, when tap water is more reliable) on households' time use and water consumption. Our model shows that without imposing specific functional forms on households' water production, the effects remain ambiguous. If a linear production function is imposed, households would be expected to consume more water but the amount of time they spend on collecting water still remains ambiguous.

We use a subsample of 819 households connected to tap water for our empirical analyses. Using the detailed household survey and time diary, we first demonstrate that the time spent on water collection activities is negatively correlated with productive activities. For every one minute increase in time spent on water collection, there is about half a minute reduction in time spent on work. However, we find no evidence that time spent on water collection affects the probability of employment. We also demonstrate that the reliability of tap water was positively correlated with time spent on water collection. In particular, if a household had regular tap water, water collectors spend 17–23 min more on water collection per

[1] For simplicity, private tap water connections are referred to as 'tap water' hereafter.

day (compared to a household with less regular tap water). Further analysis suggested that this increase was largely driven by the increase in time spent on collecting water from the private tap. In estimating the relationship between tap water reliability and water consumption, we find the reliability measure to be positively correlated with total water consumption and water consumed from the tap. In the meantime, households with reliable tap water consume less water from public sources (such as public wells and public taps) and water vendors. Note that the empirical findings we present in this paper can only be interpreted as correlations and not causal relationships owing to potential endogeneity in access to tap water as well as its reliability. We perform additional robustness checks to confirm if our estimates were sensitive to the choice of control variables or different fixed effects.

Our study adds to the current literature on reliable access to water and time use in a number of ways. First, this study contributes to the understanding of tap water reliability and time use in urban areas of a less developed country. As women are usually responsible for water collection in developing countries, most of the existing literature has tended to focus on the effects of improved access to water on female labour markets and domestic labour supply outcomes (Ilahi & Grimard, 2000; Koolwal & van de Walle, 2013). Little is known, empirically, about how access to tap water affects time spent on water collection and other daily activities[2]. Second, we provide new evidence that can be added to the existing literature on infrastructure reliability and intermittent water supply. Past literature that evaluated the effect of infrastructure tended to focus on a categorical change, and less attention has been paid to its quality and reliability (Chen *et al.*, 2019). Our results indicate that intermittent water supply could hurt labour productivity if water becomes available during working hours. It also suggests that there might be a welfare effect of improved reliability of tap water. Households with more reliable tap water spend less time outside the house collecting water and consume more from the tap. Therefore, although the total amount of time they spend on collecting water is more, they can probably accomplish other things alongside water collection at home, leading to a potential welfare gain. This study is also the first to use a detailed time diary to estimate the effect of reliable tap water on time use. It allows us to disaggregate time allocation across broad activity categories.

2. Conceptual framework

In this section, we present a simple theoretical model that links the productivity of household water production with time use and water consumption. Suppose a household is set out to maximise $U(c_1; c_2; l)$, where c_1 is the consumption of water, c_2 is the consumption of other market goods and l is leisure. Suppose water can be collected from a private tap or other sources (such as a private well or a public tap). The household's problem can be written as follows:

$$\begin{aligned} &\mathrm{Max}_{t1,t2,tw} U(c_1, c_2, l) \\ &\text{s.t.:} \quad c_1 = g(t_1; \theta_1) + v(t_2; \theta_2) \\ &pc_2 = wt_w \\ &t_1 + t_2 + t_w + l = T \end{aligned} \tag{1}$$

[2] Studies on this topic in the existing literature have usually focused on rural households. For example, Gross *et al.* (2018) demonstrated that the installation of public water access points significantly reduced time spent on water collection in rural Benin. Meeks (2017) discovered that improved water access in rural Kyrgyzstan increased the time spent on market activities and leisure.

where $g(t_1; \theta_1)$ is the production function of water from a private tap and $v(t_2; \theta_2)$ is the production function of water from other sources. θ_1 and θ_2 are parameters in the production functions, which indicate the productivity of water production from various sources. p is the price for market goods. Household is endowed with time T, which can be allocated to the production of water from the private tap (t_1) or other sources (t_2) to the labour market at wage rate w (t_w) and leisure (l).

Note that Equation (1) is equivalent to maximising $U(g(t_1) + v(t_2),\ wt_w/p, T - t_1 - t_2)$. The research question of interest is as follows: What is the effect of θ_1 on time allocation and water consumption? We can show that these effects are ambiguous, that is, the signs of the partial derivatives $\partial t_1/\partial\theta_1$, $\partial t_w/\partial\theta_1$ and $\partial c_1/\partial\theta_1$ cannot be determined[3]. Intuitively, this is because as the productivity of tap water production increases, there are two forces driving time t_1 allocated to this activity. On the one hand, the substitution effect will lead to an increase in t_1 compared to other activities, as the production of tap water becomes more efficient in terms of labour (hence per unit price becomes cheaper). However, this substitution effect can be bounded above as the quantity of water consumed in a household cannot increase infinitely. On the other hand, an increase in tap water productivity will have an income effect. This income effect will push demand for all consumption upwards, including demand for market goods and leisure. This income effect will induce households to supply more labour to the labour market in exchange for market goods. In equilibrium which effect dominates is ambiguous.

Koolwal & van de Walle (2013) discussed a special case of the model presented in Equation (1), where the tap water production function is assumed to be linear, that is, $g(t_1) = \rho t_1$. Under this assumption, if a household reallocates time spent on producing water from a private tap, t_1, to the labour market, it can earn a wage income of wt_1. If the price of a market good is assumed to be numerarie, the reallocation of time results in wt_1 units of additional consumption of the market good, but now the household produces t_1 units of water from its private tap. Therefore, the relative price of water produced from the private tap to market good is w/ρ. Applying the Slutsky equation, it can be shown that $\partial c_1/\partial\rho$ is always negative. Therefore, the authors conclude that under the assumption of a linear production function, as ρ increases, the consumption of home-produced water will always increase. Nonetheless, even under this restrictive assumption, the sign of $\partial t_1/\partial\rho$ remains ambiguous.

To summarise, when tap water becomes more reliable, it is unclear from the model whether time spent on water collection will increase or decrease. This lack of clarity is due to the fact that the substitution effect and income effect from such a change work in opposite directions. However, if stricter assumptions on the water production function are imposed, an increase in total water consumption should be expected while the effect on time allocation remains ambiguous.

3. Data and outcome variables

Data for the empirical analyses presented in this paper were drawn from a household survey of 1,500 households in five municipalities in the Kathmandu Valley in 2014 and 2015 (Kathmandu, Lalitpur, Bhaktapur, Kirtipur and Madhyapur). This was a follow-up survey of the 2001 wave in the same area. The two waves were merged to construct a panel. Details of the sampling strategy and data for the 2001 wave can be found in Whittington *et al.* (2002) and Pattanayak *et al.* (2005), and details of the 2014–2015 survey can be found in Yogendra *et al.* (2017). In this paper, we only use data from the 2014–2015 wave. The survey

[3] The proofs are omitted here.

was conducted using a multi-stage clustered sampling method, and the sample is representative of the population of Kathmandu in 2001 but not of the population in 2014–2015. The 2001 survey collected information on household characteristics and water usage as well as perceptions of tariffs and willingness-to-pay. In 2014–2015, an attempt was made to re-survey all the households in the 2001 sample to construct a panel. If a household could not be located in the 2014–2015 survey, the current resident or the immediate neighbour was interviewed. In total, 61.8% of households were successfully re-surveyed. We only use households that were surveyed in both rounds for our analyses.

The 2014–2015 survey included a time diary module. The time diary was distributed at the time of survey, and in it, household members were asked to reflect on the activities that they performed in a typical day over a 24-hour period, using 30 min as the smallest block (see Figure 1). Following the standards of the established literature, we provided 26 types of activities for respondents to choose from Devoto *et al.* (2012). The respondent of the main survey, spouse of the respondent, and the person most responsible for water collection (if different from respondent or spouse) filled out the time diary. We grouped the 26 activities into seven broad categories: work, leisure, household chores, social activities, rest, water collection and meal times.

Literature on survey methods and cognitive psychology has highlighted potential bias that might be introduced in time use data arising from recall and salience of activities (Menon, 1993; Beegle *et al.*, 2012; Arthi *et al.*, 2018). In particular, the concern is that respondents are likely to

3. TIME-USE SCHEDULE (Imagine a normal 24-hour day)
Respondent: (1) Respondent from first part survey OR (2) his/her spouse
About Whom: (1) Respondent from first part of the survey (2) Spouse of the respondent (3) Person most responsible for collecting water for the household (if different from the respondent or spouse) and (4) children aged 7-15 years who mostly assists in collecting water for the household

301. Respondent's name: ______________ .... ID (From HH Roster) ☐☐

302. Who are other responsible for collecting water in your household? (Check the boxes by √ that applies)

1. Respondent................ ☐ 2. Spouse of respondent ...... ☐ 3. Other family member (if different)..... ☐ 4. Children (7-15 yrs) .... ☐

303. Among them, who is the most responsible person for collecting water? **Name:** ______________......ID (From HH Roster): ☐☐

304. TIME	305. CODE				304. TIME	305. CODE			
	Ask for the boxes in Q302 are checked					Ask for the boxes in Q302 are checked			
	Respondent	Spouse	Other	Children		Respondent	Spouse	Other	Children
ID					ID				
5:00 - 5:30					17:00 - 17:30				
5:30 - 6:00					17:30 - 18:00				
6:00 - 6:30					18:00 - 18:30				
6:30 - 7:00					18:30 - 19:00				
7:00 - 7:30					19:00 - 19:30				
7:30 - 8:00					19:30 - 20:00				
8:00 - 8:30					20:00 - 20:30				
8:30 - 9:00					20:30 - 21:00				
9:00 - 9:30					21:00 - 21:30				
9:30 - 10:00					21:30 - 22:00				
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10:30 - 11:00					22:30 - 23:00				
11:00 - 11:30					23:00 - 23:30				
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13:00 - 13:30					1:00 - 1:30				
13:30 - 14:00					1:30 - 2:00				
14:00 - 14:30					2:00 - 2:30				
14:30 - 15:00					2:30 - 3:00				
15:00 - 15:30					3:00 - 3:30				
15:30 - 16:00					3:30 - 4:00				
16:00 - 16:30					4:00 - 4:30				
16:30 - 17:00					4:30 - 5:00				

SCHEDULE CODES	
1	Sleep
2	Bathing and freshening
3	Tea time/breakfast
4	Read newspaper
5	Dressing, getting ready
6	Commuting to/from work/school/college
7	At work (include self-employment/own business)
8	Eat meals
9	Cooking
10	Washing and cleaning
11	Collecting water
12	Other domestic chores
13	Resting
14	Go to the market
15	Take care/help children and aged in the family
16	Spend time with persons in the household
17	Socialize with friends, neighbors, community
18	Professional training
19	Religious and spiritual activities
20	Entertainment – TV, DVDs, radio, internet, movies
21	Phone calls, letters, emails
22	Exercise – walking, jogging, gym, sports
23	At school/college, doing homework, studying
24	Playing (indoors or outdoors)
25	Pursue hobbies – reading, writing, drawing, music, dance
26	Other (Specify)

Fig. 1. Time use survey (time diary) for the 2014–2015 survey.

over(under)-report time spent on different activities depending on the recall period and whether the activities are salient and regular. For instance, if time spent on collecting water is less salient but regular, such as ‘every afternoon’, then respondents may not respond with precise recall-and-count strategy but instead just recall the periodicity (Menon, 1993).

We designed the time use module acknowledging these limitations. First, we did not impose a specific recall period; instead, we asked the respondents about a ‘typical day’. Second, we did not explicitly highlight certain activities, such as ‘how much time do you spend on collecting water’. Instead, we let the respondents recall their daily activities chronologically over a 24-hour period, and then we post-coded those activities. It is possible that our survey data collection method may have introduced bias such as respondents sub-consciously reporting more time spent on collecting water since they were informed *a priori* that the survey was about water supply. However, taking into consideration the resource and time constraints of implementing the survey, this was the best way forward.

Similarly, the data we constructed for the quantity of water consumed from various sources are subject to measurement errors. Existing literature has usually relied on self-reported water usage or imputed data from recalled water expenditure to infer household water consumption volumes (Fuente *et al*., 2016; Apoorva *et al*., 2018). The difficulties in accurately estimating the quantity of water consumed are twofold. First, confidentiality concerns prevent disclosure of socioeconomic status in water bills. As a result, researchers are not able to link metered water usage to household characteristics in many countries. In addition, households in developing countries usually gather water from various sources, many of which are not metered. Water consumption from these sources can only be estimated based on recall data. In our survey, we also relied on the recall method to gather information on the amount of water consumed. We asked households about their water consumption from 11 sources. For consumption from sources other than private taps, we follow the standard practices of the existing literature and asked respondents to report the size of their containers and the number of containers they retrieved per trip (Apoorva *et al*., 2018).

The two sets of outcome variables of interest are time spent on collecting water and total water consumption from various sources. We discuss the main variables used in the empirical analyses in the following paragraphs.

3.1. Time spent on water collection

We constructed two variables to measure time spent on water collection. The first variable is ‘activity_water’. This variable was constructed from the time diary module. Respondents only reported the amount of time they spent on collecting water (if at all) during the day and did not differentiate it by source. Therefore, we could not disaggregate time spent on collecting water from a private tap or from other sources. To supplement this, we constructed a second variable ‘activity_water_outside’ using information from the household survey. This variable measures the time (minutes per day on average) spent on collecting water from a public tap, public well or a stone tap. Time spent on collecting water from outside the household was computed by adding up round trip time plus waiting time for collection from these sources. This number was reported by the main survey respondent, and he or she could be different from the person who was most responsible for water collection activities in the household. Our data indicated that out of the 1,500 respondents for the main household survey, 412 filled out the time diary module (out of a total of 819 time diaries). Hence, the variable activity_water_outside is subject to measurement errors, and the results need to be interpreted with caution.

3.2. Water consumption from various sources

We collected data for water consumption from the following sources: a private tap, any public sources (including public tap, public well and stone tap), a private well, water vendors and total water consumption from all sources. These variables were constructed from the main household survey conducted in the 2014–2015 period. In particular, in the main household survey, each respondent (usually the head of the household who may not be the person most responsible for water collection) was questioned about the availability of various water sources. We constructed the water consumption variables by adding up consumption in the corresponding categories.

3.3. Measures of productivity of home water production

We constructed two measures of reliability for tap water connection. The first measure is a qualitative, ordinal measure of reliability. The respondent of the household survey was asked to judge the reliability of tap water on a scale of 1–4, with 1 being ‘very regular’ and 4 being ‘unreliable’, for both the dry and rainy seasons. We generated a dummy variable that is equal to 1 if the respondent reports that the tap water connection is ‘very regular’ or ‘regular’. We used the responses for reliability of tap water in the dry season in our main results.

The second reliability measure uses Hashimoto *et al.* (1982)’s definition of a system in water resources planning: the frequency or probability that a system is in a satisfactory state. We calculated the probability of getting tap water in the next hour. Specifically, we computed the following measure:

$$\text{reliable\_hrs} = \frac{\text{tap\_minutes}/60}{24 \times (1 + \text{tap\_gap})}$$

tap_minutes are the number of minutes of tap water a household expects to receive every time they receive water from the tap. tap_gap is the number of days between the time tap water is received. Therefore, the measure reliable_hrs computes the probability that a household receives tap water in the next hour. For example, if a household receives uninterrupted tap water supply 24 hours a day, 7 days a week, the household’s probability of getting tap water in the next hour would be $((24 * 60)/60)/(24 * (1 + 0)) = 100\%$.

Summary statistics for the sample used in the analysis are presented in Table 1. Since only the person most responsible for water collection answered the time diary, there were some missing observations if this person were absent or unavailable at the time of the survey. Out of the time diaries distributed to 1,500 households in the original sample, 819 of them were collected. We compared household income and household size of the 819 households against those that were missing from the original sample. Our *t*-test indicated that although the logarithm of household income was not statistically different between the two groups (P-value $= 0.82$ for two-sided test), households that answered the time diary survey had a slightly smaller household size (difference $= 0.2$, P-value $= 0.037$). We attempted to address the sample selection issue by including household controls and individual characteristics. We also performed additional robustness checks which are discussed in Section 5.

As shown in Table 1, although all households are connected to a private tap in our sample, on average, the probability for a household to receive tap water in the next hour is extremely low at only 2%. Households waited an average of 5 days for tap water to become available; these periods of availability

Table 1. Summary statistics.

Variable	Description	Observed	Mean	Standard deviation	Minimum	Maximum
Key variables						
Time spent on water collection						
Activity water	Time spent on collecting water per day (minutes)	819	43.7	41.5	0.00	240
Activity water outside	Time spent on collecting water outside household per day (minutes)	819	8.70	34.1	0.00	540
Water consumption – dry season						
Water total dry	Total water consumption per day in the dry season (litre)	819	301	362	6.70	2,775
Water pipe dry	Total water consumption per day from pipe in the dry season (litre)	819	78.6	136	0.00	2,000
Water public dry	Total water consumption per day from public well, tap or stone tap in the dry season (litre)	819	23.4	51.3	0.00	500
Water priwell dry	Total water consumption per day from private well (priwell) in the dry season (litre)	819	136	318	0.00	2,500
Water vendor dry	Total water consumption per day from vendors in the dry season (litre)	819	55.0	139	0.00	1,667
Water consumption – rainy season						
Water total rain	Total water consumption per day in the rainy season (litre)	819	361	413	5.00	2,917
Water pipe rain	Total water consumption per day from pipe in the rainy season (litre)	819	160	269	0.00	2,500
Water public rain	Total water consumption per day from public well, tap or stone tap in the rainy season (litre)	819	25.5	57.5	0.00	500
Water priwell rain	Total water consumption per day from private well in the rainy season (litre)	819	133	308	0.00	2,000
Water vendor rain	Total water consumption per day from vendors in the rainy season (litre)	819	26.7	82.6	0.00	800
Reliability measures						
Reliable dry	Self-reported reliability of tap water connection in the dry season	819	0.24	0.43	0.00	1.00
Reliable rain	Self-reported reliability of tap water connection in the rainy season	819	0.75	0.44	0.00	1.00
Reliable hours	Probability of getting tap water in the next 24 h	575	1.56	1.89	0.06	20.8
Control variables						
hhsize	Household size	819	4.96	2.05	1.00	15.0
Age	Age of the respondent	819	46.3	14.0	13.0	90.0
Gender	Gender of the respondent	819	1.77	0.42	1.00	2.00
Education	Whether respondent has received middle school education	818	0.65	0.48	0.00	1.00
Inschool	Whether respondent is currently enrolled in school	819	1.97	0.18	1.00	2.00
Married	Whether the respondent is married	819	0.81	0.39	0.00	1.00
Lnincome	Logarithm of monthly household income (Rs)	795	10.4	1.28	6.21	16.1
Other time use variables (minutes per day)						
Work	Time spent at work	819	131	198	0.00	750
School/training	Time spent at school	819	7.22	50.0	0.00	570
Bathing/dressing	Time spent on taking a bath or dressing	819	36.7	19.3	0.00	150
Meals	Time spent on eating meals	819	136	44.8	0.00	270
Commute	Time spent on commuting	819	10.5	31.4	0.00	600
Sleep	Time spent on sleeping	819	441	50.4	270	630
Chores	Time spent on running household chores other than water-related activities	819	313	183	0.00	810
Leisure	Time spent on leisure activities	819	319	177	0.00	870

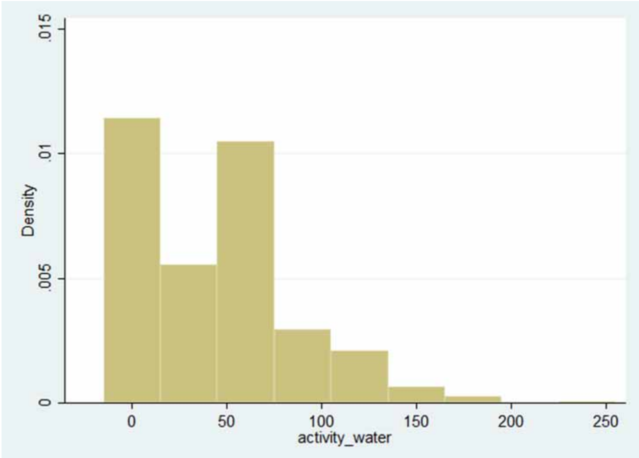

Fig. 2. Distribution of time spent on water collection. *Note*: This figure shows the histogram of water collection activities (minutes/day) among the 819 respondents that completed the time diary in the 2014–2015 survey.

on average lasted for approximately 100 min. A typical respondent still spent about 40 min on water collection activities every day. This included all water-related activities, including fetching water from the tap and from other resources within and outside the household. This number suggests that although households were 'connected' to a private tap, they still spent a great deal of time on collecting water. Figure 2 plots the histogram of time spent on water collection among the 819 households. The figure suggests that there was significant variation in time spent on collecting water among these households, and one possible explanation for this is the reliability of tap water connections across these households.

4. Descriptive analyses of tap water reliability, time use and water consumption

In this section, we present descriptive analyses of tap water reliability and time use. In particular, we examine the time use patterns across different household activities for households with good and poor connections.

4.1. Water collectors

We paired the time diary records of the person most responsible for collecting water for the household with information in the household roster in the main household survey. Therefore, we had detailed data about who these water collectors were. Table 2 demonstrates that 43.8% of main water collectors were spouses and 28.9% were heads of households. It can be seen that 76.8% of water collectors were female. Daughters-in-law were also frequently tasked with collecting water. We also observed that sons, daughters, parents and other family members participated in collecting water. While the majority of water collectors were female, male water collectors made up 23% of the sample. Figure 3 shows the distribution of the age of water collectors. They had a mean (and median) age of 46. Only 11 households (out of 819) reported water collectors under the age of 18. We saw no significant participation of

Table 2. Water collector's household role.

	Male	Female	Total
Spouse	1	358	359
Head	143	94	237
Son/daughter-in-law	1	121	122
Son/daughter	39	34	73
Father/mother	0	6	6
Other non-relative	2	4	6
Brother/sister-in-law	0	5	5
Grandchild	2	2	4
Brother/sister	0	3	3
Other relative	1	1	2
Nephew/niece	1	0	1
Father/mother-in-law	0	1	1
Total	190	629	819

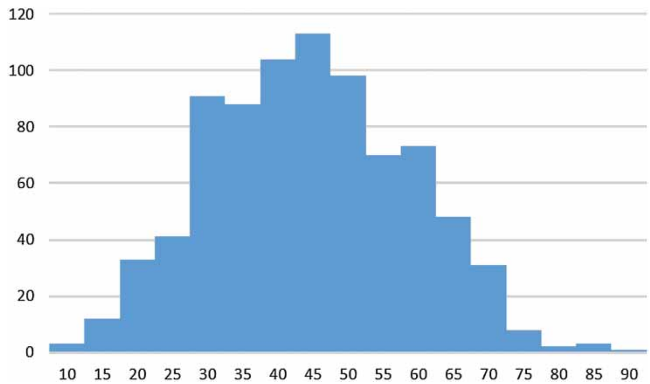

Fig. 3. Age distribution of water collectors.

children in the collection of water. Our results, therefore, differed from much of the trend observed in the literature, as we have a significant portion of male collectors and few collectors who were children.

Additionally, households often included more than one member responsible for collecting water. The results revealed that 82% of households had one main water collector, 18% had two collectors and 0.4% had three. Of the main collectors, one-third (33%, $N = 276$) reported working in a typical day.

4.2. Water collection and work

Next, we examined the water collection time patterns throughout the day. Figure 4 demonstrates the water collection patterns for the entire sample and contrasts it with working hours. Each bar represents the number of households reporting water collection during that half hour. It can be observed that a large portion of the water collection (in blue) occurs in the morning before 10:00 am. There is also a

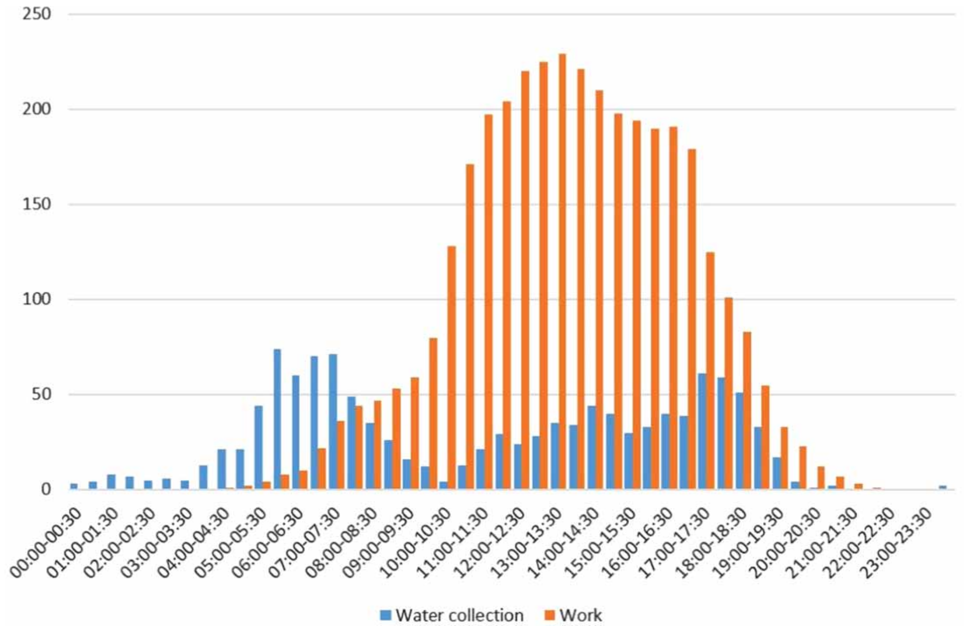

Fig. 4. Water collection time. *Note*: This figure displays frequencies of time intervals for water collection and work for all 819 respondents that completed the time diary in the 2014–2015 survey. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/wp.2019.082.

significant portion of water collection that occurs during work hours (illustrated using orange bars) and in the evening. Two smaller peaks can be observed at 2:00 pm and 5:00 pm.

Because much of the literature has tended to focus on labour supply outcomes, we examined the relationship between water collection and work. First, we examined the observable socioeconomic differences between water collectors who work more and those who work less. We run regressions of the number of hours worked in a typical day on socioeconomic variables and on hours spent on collecting water and water reliability. In Table 3, it can be observed that in regressions (1) and (2), which controls only for socioeconomic characteristics, females, older people, individuals from bigger households and those currently enrolled in school work fewer hours. Marital status and education had no significant impact on hours worked. Fixed effects for municipality or ward or both were included in all models. Regressions (3)–(8) build upon models (1) and (2) by including variables related to tap water reliability and hours spent on collecting water. There was a significant negative coefficient on time spent on collecting water – more time spent on collecting water was associated with less time spent working. Reliability did not have a significant effect on hours worked. Table 4 presents the effect of time spent on water collection on the probability of employment. The coefficients on activity_water were significant when municipality fixed effects were controlled for but became insignificant when ward fixed effects were controlled for instead. This trend suggests that the observed correlation between water collection activities and the probability of employment might be driven by unobserved ward characteristics.

We investigated the time trade-off between work and water collection more closely by looking at the subset of participants who both worked and collected water in a typical day. Figure 5 shows the patterns of work and water collection only for the subset of those who both worked and collected water ($N = 167$).

Table 3. Regressions of time spent on water collection on hours worked.

	Dependent variable = activity prod							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Activity water			−0.773***	−0.497***	−0.789***	−0.517***	−0.727***	−0.440**
			(0.156)	(0.172)	(0.160)	(0.173)	(0.189)	(0.204)
Reliable dry			2.371	−1.326				
			(15.698)	(17.651)				
Reliable rain					7.180	11.496		
					(15.814)	(16.268)		
Reliable hours							0.827	0.122
							(4.429)	(5.085)
Lnincome	12.053***	11.605***	12.413***	11.844***	12.334***	11.817***	13.788***	14.174***
	(2.553)	(2.580)	(2.492)	(2.533)	(2.499)	(2.535)	(3.262)	(3.390)
Household size	−13.909***	−14.050***	−13.553***	−13.461***	−13.456***	−13.387***	−13.888***	−15.060***
	(3.115)	(3.095)	(3.015)	(3.049)	(3.020)	(3.048)	(3.700)	(3.553)
Age	−3.014***	−3.051***	−3.164***	−3.112***	−3.149***	−3.103***	−3.425***	−3.338***
	(0.483)	(0.481)	(0.483)	(0.480)	(0.482)	(0.481)	(0.587)	(0.598)
Gender	−150.921***	−148.143***	−158.654***	−151.675***	−159.009***	−152.037***	−171.595***	−167.033***
	(18.790)	(18.318)	(18.445)	(18.191)	(18.425)	(18.168)	(22.020)	(21.981)
Education	−2.727	−0.658	3.797	2.764	4.367	3.734	5.376	0.712
	(14.146)	(14.266)	(14.000)	(14.259)	(14.126)	(14.378)	(16.726)	(16.913)
In school	130.100***	112.464***	132.422***	112.067***	133.105***	113.871***	151.471***	137.258**
	(42.344)	(42.440)	(42.779)	(42.808)	(42.953)	(43.108)	(51.691)	(54.015)
Married	−24.381	−18.112	−26.140	−19.753	−25.904	−19.947	−32.121	−25.213
	(18.467)	(18.563)	(18.320)	(18.555)	(18.260)	(18.530)	(22.241)	(22.319)
Observations	790	790	790	790	790	790	556	556
R^2	0.137	0.192	0.161	0.200	0.161	0.200	0.171	0.219
Municipal FE	Y	N	Y	N	Y	N	Y	N
Ward FE	N	Y	N	Y	N	Y	N	Y

Notes: ***, ** and * denote significance level at 1%, 5% and 10%, respectively. Robust standard errors are in parentheses. Activities are measured in minutes/day. See Section 3 for more details on variable definitions. Y, yes; N, no.

Table 4. Regressions of time spent on water collection on the probability of employment.

	Dependent variable = employed							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Activity water			−0.001***	−0.001	−0.001***	−0.001	−0.001***	−0.001
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Reliable dry			0.044	0.032				
			(0.039)	(0.043)				
Reliable rain					0.006	0.004		
					(0.038)	(0.039)		
Reliable hours							0.010	0.012
							(0.010)	(0.012)
Lnincome	0.031***	0.029***	0.031***	0.029***	0.031***	0.029***	0.034***	0.033***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.009)	(0.009)
Household size	−0.034***	−0.034***	−0.033***	−0.033***	−0.033***	−0.033***	−0.027***	−0.030***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.010)	(0.009)
Age	−0.008***	−0.008***	−0.008***	−0.008***	−0.008***	−0.008***	−0.008***	−0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Gender	−0.334***	−0.322***	−0.346***	−0.326***	−0.346***	−0.326***	−0.372***	−0.356***
	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.047)	(0.047)
Education	−0.016	−0.005	−0.005	0.000	−0.005	−0.001	0.034	0.029
	(0.034)	(0.035)	(0.034)	(0.035)	(0.034)	(0.035)	(0.040)	(0.041)
In school	0.430***	0.381***	0.439***	0.383***	0.434***	0.381***	0.450***	0.404***
	(0.107)	(0.110)	(0.107)	(0.110)	(0.107)	(0.111)	(0.134)	(0.141)
Married	−0.034	−0.010	−0.039	−0.015	−0.036	−0.012	−0.044	−0.024
	(0.044)	(0.045)	(0.044)	(0.045)	(0.044)	(0.045)	(0.052)	(0.053)
Observations	790	790	790	790	790	790	556	556
R^2	0.137	0.176	0.148	0.179	0.147	0.178	0.157	0.186
Municipal FE	Y	N	Y	N	Y	N	Y	N
Ward FE	N	Y	N	Y	N	Y	N	Y

Notes: ***, ** and * denote significance level at 1%, 5% and 10%, respectively. Robust standard errors are in parentheses. Activities are measured in minutes/day. See Section 3 for more details on variable definitions. Employed = 1 if the individual has a valid occupation code in the household roster and is not a student/retiree/housemaker. Y, yes; N, no.

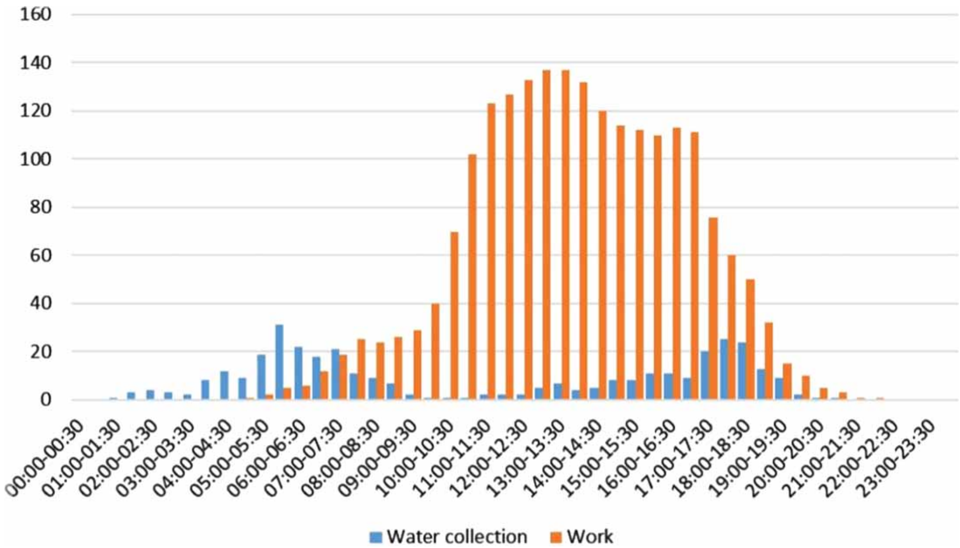

Fig. 5. Water collection time for workers. *Note*: This figure displays frequencies of time intervals for water collection and work for 167 (out of all 819) respondents that both worked and were the person most responsible for water collection.

Of these 167 water collectors, 26 worked right before water collection, four worked right after water collection and seven worked both before and after water collection. It is for these 37 water collectors (22% of this subsample) that time spent on collecting water was likely to directly affect the amount of time spent working. These were people who collected water in the afternoon, as shown in Figure 4 as the areas where water collection and work overlap. Of those who both worked and collected water, 41% worked in retail, 17% in other industries, 14% in government positions and 11% in wage labour. Out of 167 water collectors, 93% ($N = 155$) were employed (which meant that they were not in school or retired). In addition, almost none of these people (less than 2%) worked as wage labourers. Water collectors are also less likely to be employed. Out of the 819 water collectors, two-thirds reported not having a full time job (no occupation code was identified), while the proportion was only one-third of the entire sample. Hence, estimates presented in Tables 3 and 4 might be subject to selection bias as people who self-select themselves for water collection duties might have differed from the general population.

An ideal analysis would have estimated the correlation between time spent on water collection and the productive time of all household members. However, due to the restrictions of the survey, we were unable to perform this analysis. Alternatively, in Table 5, we estimate the correlation between time spent on water collection and the fraction of household members that were employed. We discovered no correlation between the two. In summary, our results suggest that for those water collectors that do work, the time they spent on productive activities were negatively correlated with time spent on water collection. However, there is limited evidence that time spent on water collection affects employment decisions.

4.3. Water collection and other activities

In our time diaries, we not only asked respondents to recall the time they spent on water and work but also collected information on other activities performed throughout the day. Therefore, we had the

Table 5. Regressions of time spent on water collection on the percentage of household members employment.

	Dependent variable = % adult household members that are employed							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Activity water			−0.000	0.000	−0.000	0.000	−0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Reliable dry			0.021	0.031				
			(0.020)	(0.022)				
Reliable rain					0.007	0.010		
					(0.018)	(0.019)		
Reliable hours							−0.006	−0.005
							(0.004)	(0.004)
Lnincome	0.027***	0.025***	0.027***	0.025***	0.026***	0.025***	0.029***	0.028***
	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.006)	(0.007)
Household size	−0.016***	−0.016***	−0.016***	−0.016***	−0.016***	−0.016***	−0.017***	−0.018***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
Age	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender	−0.014	−0.007	−0.015	−0.005	−0.015	−0.005	−0.011	−0.004
	(0.020)	(0.020)	(0.020)	(0.020)	(0.021)	(0.020)	(0.024)	(0.024)
Education	−0.025	−0.020	−0.024	−0.021	−0.023	−0.021	−0.024	−0.023
	(0.016)	(0.017)	(0.016)	(0.017)	(0.016)	(0.017)	(0.020)	(0.020)
In school	0.065	0.037	0.068	0.040	0.066	0.039	0.060	0.049
	(0.054)	(0.055)	(0.055)	(0.056)	(0.054)	(0.055)	(0.070)	(0.067)
Married	−0.058**	− 0.044*	−0.060**	− 0.046*	−0.058**	− 0.043*	−0.049	− 0.033
	(0.024)	(0.025)	(0.024)	(0.025)	(0.024)	(0.025)	(0.031)	(0.032)
	(0.042)		(0.043)		(0.042)		(0.057)	
Observations	790	790	790	790	790	790	556	556
R^2	0.092	0.124	0.094	0.127	0.093	0.125	0.097	0.139
Municipal FE	Y	N	Y	N	Y	N	Y	N
Ward FE	N	Y	N	Y	N	Y	N	Y

Notes: ***, ** and * denote significance level at 1%, 5% and 10%, respectively. Robust standard errors are in parentheses. Activities are measured in minutes/day. See Section 3 for more details on variable definitions. A dependent variable is computed as the number of household members employed/ household size. Y, yes; N, no.

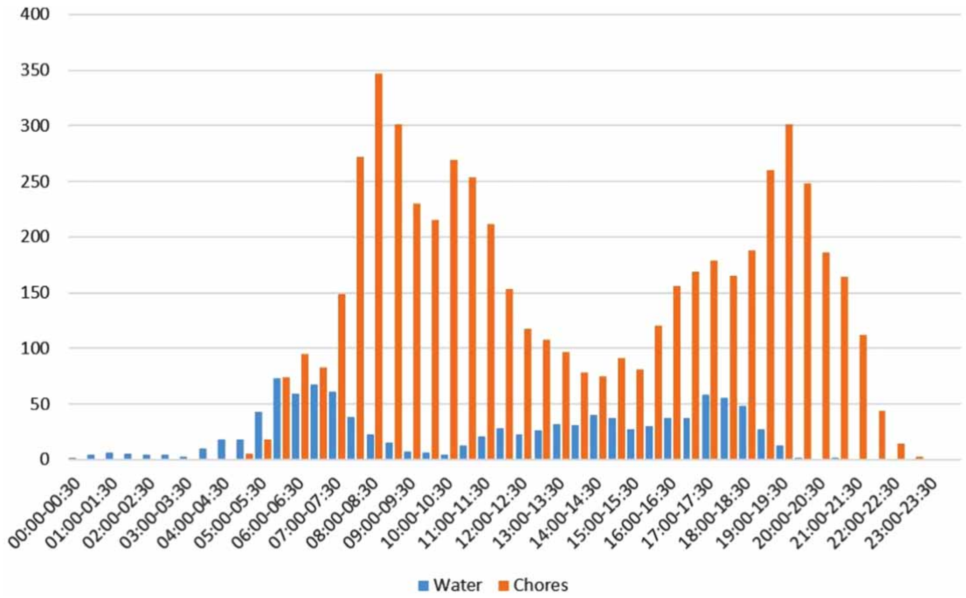

Fig. 6. Chores and water collection. *Note*: This figure displays frequencies of time intervals for water collection and non-water chores for all 819 respondents that completed the time diary in the 2014–2015 survey.

opportunity to examine the relationship between tap water reliability and a wide range of activities, including non-water collection chores, leisure, eating meals, having tea, bathing and sleeping.

First, we examined the distribution of time spent on non-water collection chores and water collection (Figure 6). Water collection tended to occur in the morning before all other chores. Most of the chores occurred in the morning, between breakfast and lunch, when water collection activities were also low. Some water collection took place in the afternoon and increased at approximately noon, 2:00 pm and the late afternoon. Thereafter, another large portion of the chores was completed, from late afternoon through the evening. Trade-offs between water collection and other chores did not seem likely.

Figure 7 shows the time distributions for leisure and water collection. We observed significant overlaps between peak water collection times and peak leisure times, which make direct trade-offs between leisure and water collection more likely.

4.4. Aggregate daily time use patterns

This section of the analysis separates the households into four categories based on combinations of: if they have a private well, a PWC, and if the PWC is reliable or not. Figure 8 illustrates the proportions of the subsample that participate in each activity type during each half hour. These figures provide an idea of which activities are occurring during which times, on aggregate.

Figure 8 shows that daily time use patterns are broadly similar across the four types of households. It can be observed that water collection usually occurs in the morning or in the late afternoon. If the person most responsible for water collection was not collecting water in the morning, she or he spent time sleeping, bathing, eating meals and doing leisure activities. If water collection did not happen in the afternoon, then the person most responsible for water collection spent time reaching the end of their

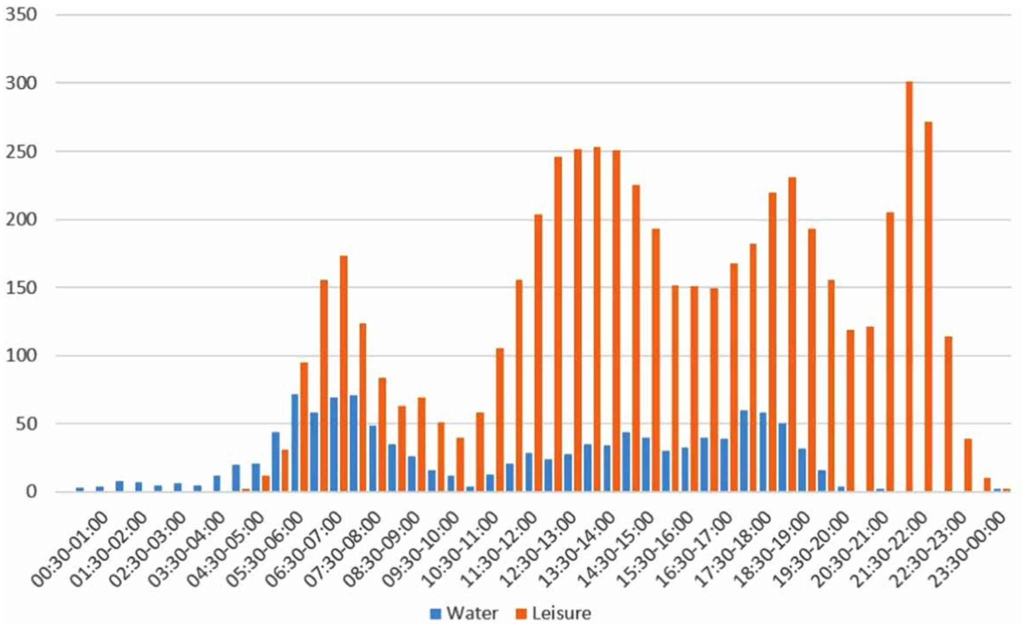

Fig. 7. Leisure and water collection. *Note*: This figure displays frequencies of time intervals for water collection and leisure for all 819 respondents that completed the time diary in the 2014–2015 survey.

work day, working on other chores or engaging in leisure activities. Right before and after water collection in the evening, many households ate meals, worked on other chores and engaged in leisure activities.

According to these results, it appears that water collectors in households with reliable connections spend more time on collecting water and less time working than do water collectors in households with unreliable connections. This is confirmed with average hours spent (Table 6). It shows that, interestingly, water collectors in households with unreliable connections work more than water collectors from the other subsamples (148.6 and 121.34 min per day vs. 122.14 and 115 min per day). They also spent less time on chores (315.32 and 295.17 min per day vs. 357.32 and 304.64 min per day). Households with unreliable water connections also slept more (450.13 and 439.83 min per day vs. 429.38 and 423.14 min per day). At the same time, we observed more water collectors who attend school or other training in the reliable subsamples than in the unreliable subsamples. Households with both a tap water connection and a private well spent the most amount of time on collecting water (59 min per day). Water collectors from these households also worked the least and spent more time eating meals. Water collectors from households without either a reliable tap water connection or a private well spent the least time on water collection and school/training and spent the most time sleeping and commuting compared to other household types.

Theories outlined in Section 2 provide explanation for these seemingly counterintuitive results. Regression analyses in Section 5 also confirm the descriptive findings presented here.

4.5. Summary of findings

From the results, we draw three conclusions. First, households' daily time use patterns are very similar. Second, while water collection time patterns closely reflect leisure and chore time patterns, the

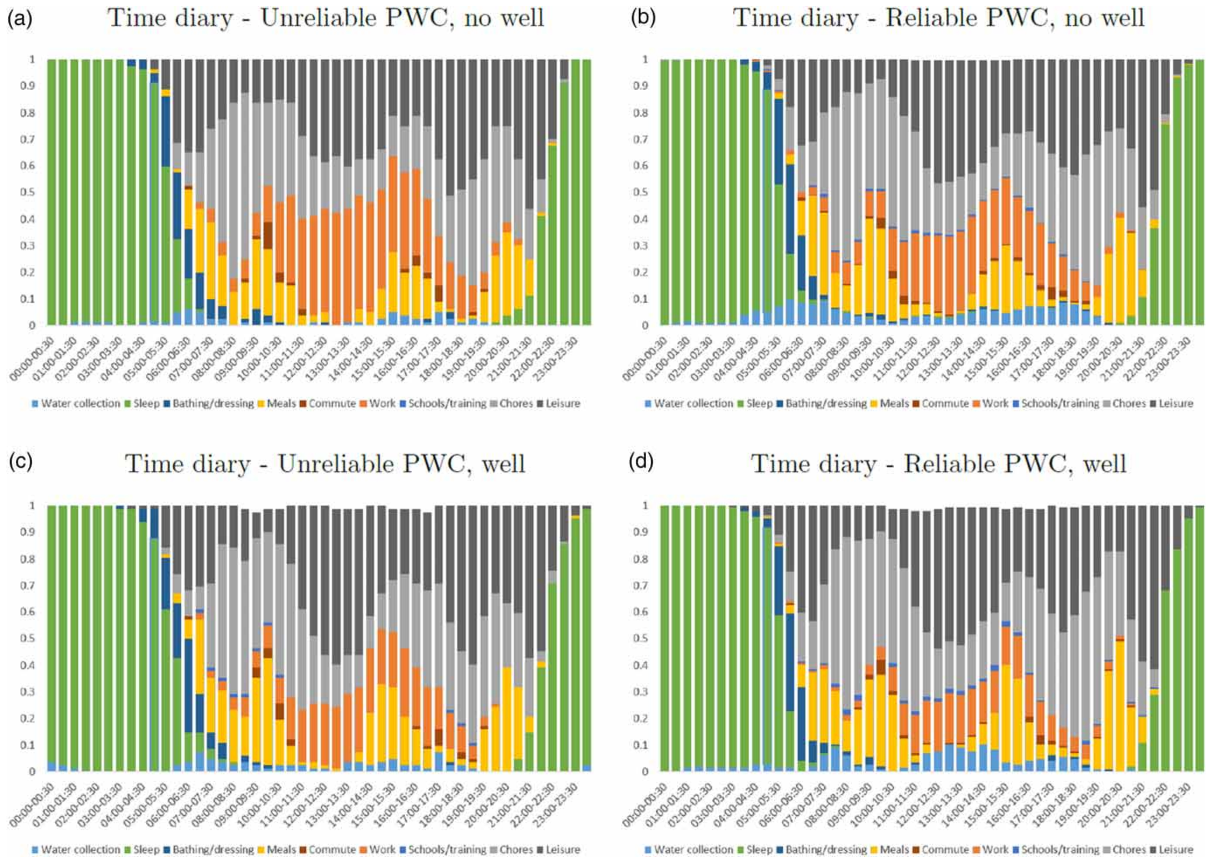

Fig. 8. Time diary. *Note*: These figures display aggregate daily time use patterns for households with an unreliable PWC and no private well (a), a reliable tap water connection and no private well (b), an unreliable private water connection and a private well (c) and a reliable private water connection and a private well (d).

Table 6. Average time spent on activities by connection type (minutes/day).

Variables	Unreliable, no well	Unreliable, well	Reliable, no well	Reliable, well
Activity water	37.91	36.88	56.25	59.64
Work	148.60	121.34	122.14	115.00
School/training	2.55	5.96	5.09	11.07
Bathing/dressing	34.72	37.40	34.82	37.50
Meals	128.17	138.29	135.80	146.79
Commute	11.23	10.17	4.55	9.29
Sleep	450.13	439.83	429.38	432.14
Chores	315.32	295.17	357.32	304.64
Leisure	309.32	350.96	294.64	322.50
Observed	235	292	112	84

overlap with work time in the afternoons is concerning from a policy perspective. Finally, while households with unreliable tap water connections spend the least time on collecting water, these households also purchase much more water from private vendors (tankers and jar water), suggesting that households substitute tap water with vended water.

5. Regression analyses of tap water reliability, time use and water consumption

5.1. Empirical specification

In this section, we use ordinary least squares (OLS) regressions to estimate the correlation between time spent on water collection, water consumption and reliability of tap water in more detail. The baseline OLS regression is as follows:

$$y_{\mathrm{iwm}} = \alpha_0 + \alpha_1\,\mathrm{Reliability}_{\mathrm{iwm}} + \alpha_2 X_{\mathrm{iwm}} + \alpha_3 \tau_{\mathrm{m}} + \alpha_4 \sigma_{\mathrm{w}} + u_{\mathrm{iwm}} \tag{2}$$

where y_{iwm} are the two sets of outcomes on time allocation and water consumption as described in Section 3. $\mathrm{Reliability}_{\mathrm{iwm}}$ is the self-reported tap water reliability measure, which takes value 1 if it is regular and 0 otherwise, or the probability of getting tap water in the next hour. For household i, in ward w, and municipality m, X_{iwm} is a set of individual and household characteristics as observed in 2014–2015, which includes gender, education, age, age-squared, log of household income and its quadratic form and household size. We also include municipality or ward fixed effects (or both) to capture any municipality-specific or ward-specific characteristics that would affect time spent on water collection.

5.2. Results

Table 7 presents the OLS results of tap water reliability on time spent on collecting water and time spent on collecting water outside the household. Recall that while activity_water is reported by the person most responsible for water collection, activity_water_outside is reported by the main survey respondent. In panels A, B and C, we report the effect of three reliability measures, that is, the reliability of tap water in the dry season, in the rainy season and the probability of getting tap water in the next hour. Results in panel A indicate that greater reliability of tap water in the dry season is significantly correlated with more time spent on water collection and less time spent on water collection activities outside the household. Results in panel B demonstrate that greater reliability of tap water in the rainy season increases total time spent on water collection but is uncorrelated with time spent on water collection outside the household. Results in panel C suggest that an increase in the probability of getting tap water in the next hour is positively correlated with time spent on water collection activities and negatively correlated with water collection outside the household.

In summary, results in Table 7 suggest that more reliable tap water is positively correlated with time spent on water collection. There is also some evidence that this increase is mainly driven by time spent on collecting water from a private tap within the household.

Table 8 shows the effect of tap water reliability on water consumption. Similar to the previous table, we group results into four panels with respect to the three reliability measures. Panels A and B report the effect of reliability in the dry season and the rainy season on water consumption in dry and rainy seasons, respectively. Panels C and D report the effect of 'reliable_hrs' on water consumption in dry and rainy seasons, respectively. Column (1) shows a positive and significant correlation between reliability

Table 7. Effect of reliability on time use – OLS.

Variables	(1) Activity water	(2) Activity water	(3) Activity water outside	(4) Activity water outside
Panel A				
Reliable dry	16.812*** (3.411)	7.405** (3.742)	−6.607** (2.831)	−3.421 (2.379)
N	766	766	766	766
R^2	0.107	0.284	0.151	0.102
Panel B				
Reliable rain	22.824*** (2.811)	12.160*** (2.909)	1.766 (1.663)	3.004 (2.375)
N	766	766	766	766
R^2	0.135	0.293	0.144	0.102
Panel C				
Reliable hours	1.905* (0.980)	1.113 (1.033)	−0.562*** (0.179)	−0.624** (0.273)
N	766	766	766	766
R^2	0.107	0.284	0.151	0.102
Municipal FE	Y	N	Y	N
Ward FE	N	Y	N	Y
Household controls	Y	Y	Y	Y
Individual controls	Y	Y	Y	Y

Notes: ***, ** and * denote significance level at 1%, 5% and 10%, respectively. Robust standard errors are in parentheses. Each cell reports the coefficient from a separate regression. Activities are measured in minutes/day. See Section 3 for more details on variable definitions. All regressions control for log household income, household size, individual age, gender, education, whether in school and marital status. Y, yes; N, no.

and total water consumption for three out of the four reliability measures when municipality fixed effects are included. In column (2), the probability of getting water in the next hour was still positively correlated with total water consumption when ward fixed effects are controlled for. The magnitude of coefficients in panel C suggests that a 1 percentage point increase in the likelihood of receiving water in the next hour leads to 47.5 more litres of total water consumption per day. Columns (3)–(10) present the results for each water source. As columns (3) and (4) indicate, unsurprisingly, reliability of tap water is associated with more water consumption from the private tap. These results are significant with or without the ward fixed effects. Results in columns (5)–(10) suggest substitution of consumption between water received from the tap and that from other sources. Furthermore, tap water reliability is negatively associated with water consumed from a private well, public tap (or stone tap) or from water vendors.

6. Robustness checks

We conducted two robustness checks to confirm whether our results were sensitive to the choice of control variables and sample selection. Results are presented in Tables 9 and 10.

Table 9 presents our results after we re-run our OLS regressions by adding more household control variables, including age square, survey month and gender of the household head. Each cell in the table is a separate regression, and we report coefficients for reliable_dry, reliable_rain and reliable_hrs in panels A, B, C and D. Columns (1)–(4) of panel D are intentionally left blank as these coefficients are the same as columns (1)–(4) in panel C. Columns (5)–(8) in panel C estimate the effect of 'reliable_hrs' on water consumption in the dry season. Columns (5)–(8) in panel D estimate its effect on water consumption in

Table 8. Effect of reliability on water consumption – OLS.

Variables	(1) Water total	(2) Water total	(3) Water pipe	(4) Water pipe	(5) Water public	(6) Water public	(7) Water priwell	(8) Water priwell	(9) Water vendor	(10) Water vendor
Panel A										
Reliable dry	60.538**	−22.641	122.607***	79.474***	−17.716***	−3.624	−10.956	−69.339***	−29.138***	−25.849*
	(27.713)	(31.040)	(17.206)	(17.274)	(4.090)	(3.947)	(22.885)	(25.294)	(9.503)	(13.585)
N	766	766	766	766	766	766	766	766	766	766
R^2	0.128	0.273	0.179	0.238	0.196	0.233	0.101	0.300	0.051	0.089
Panel B										
Reliable rain	42.567	−39.219	120.961***	64.537***	2.753	8.116*	−47.430	−79.885***	−29.205***	−33.001***
	(33.630)	(28.466)	(16.342)	(17.727)	(3.657)	(4.285)	(29.677)	(24.434)	(7.902)	(8.430)
N	766	766	766	766	766	766	766	766	766	766
R^2	0.129	0.298	0.117	0.223	0.184	0.285	0.095	0.296	0.068	0.099
Panel C										
Reliable hours (dry)	36.603**	34.918**	27.647***	22.379**	−1.662***	−1.140*	8.625	11.757	2.661	2.411
	(14.709)	(14.440)	(10.335)	(10.063)	(0.510)	(0.597)	(8.671)	(7.962)	(6.752)	(6.167)
N	542	542	542	542	542	542	542	542	542	542
R^2	0.130	0.320	0.154	0.341	0.125	0.315	0.090	0.300	0.047	0.088
Panel D										
Reliable hours (rain)	66.104***	57.141***	67.267***	53.079***	−1.856***	−1.127**	3.812	7.617	−1.736	−1.860
	(20.077)	(19.236)	(17.872)	(16.490)	(0.493)	(0.535)	(7.214)	(6.607)	(2.632)	(2.575)
N	542	542	542	542	542	542	542	542	542	542
R^2	0.171	0.392	0.235	0.406	0.156	0.408	0.076	0.301	0.066	0.090
Municipal FE	Y	N	Y	N	Y	N	Y	N	Y	N
Ward FE	N	Y	N	Y	N	Y	N	Y	N	Y
Household controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Individual controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: ***, ** and * denote significance level at 1%, 5% and 10%, respectively. Robust standard errors are in parentheses. Each cell reports the coefficient from a separate regression. Activities are measured in minutes/day. See Section 3 for more details on variable definitions. Panel C estimates the effect of reliable hours on dry season water consumption. Panel D estimates the effect of reliable hours on rainy season water consumption. All regressions control for log household income, household size, individual age, gender, education, whether in school and marital status. Y, yes; N, no.

Table 9. Robustness checks – adding more control variables.

Dependent variables	(1) Activity water	(2) Activity water	(3) Activity water outside	(4) Activity water outside	(5) Water total	(6) Water total	(7) Water pipe	(8) Water pipe
Panel A								
Reliable dry	16.593***	6.136*	−7.398***	−4.046**	62.930**	−27.188	122.006***	79.622***
	(3.258)	(3.685)	(2.433)	(1.970)	(26.617)	(30.470)	(15.880)	(16.205)
N	819	819	819	819	819	819	819	819
R^2	0.085	0.255	0.102	0.068	0.072	0.228	0.156	0.208
Panel B								
Reliable rain	23.260***	12.176***	2.966* (1.754)	5.229* (2.866)	38.742	−50.418*	119.722***	60.933***
	(2.679)	(2.818)			(32.969)	(28.565)	(16.112)	(16.832)
N	819	819	819	819	819	819	819	819
R^2	0.117	0.266	0.096	0.070	0.084	0.255	0.096	0.190
Panel C								
Reliable hours (dry)	1.980**	1.068 (1.006)	−0.504***	−0.558**	42.231***	38.723**	28.821***	23.089**
	(0.979)		(0.164)	(0.249)	(15.737)	(15.121)	(10.309)	(9.927)
N	575	575	575	575	575	575	575	575
R^2	0.099	0.294	0.108	0.086	0.084	0.279	0.134	0.344
Panel D								
Reliable hours (rain)					72.435***	61.018***	70.629***	55.251***
					(20.847)	(19.688)	(18.064)	(16.522)
N					575	575	575	575
R^2					0.141	0.363	0.226	0.406
Municipal FE	Y	N	Y	N	Y	N	Y	N
Ward FE	N	Y	N	Y	N	Y	N	Y
Household and individual controls	Y	Y	Y	Y	Y	Y	Y	Y
Additional controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: ***, ** and * denote significance level at 1%, 5% and 10%, respectively. Robust standard errors are in parentheses. Each cell reports the coefficient from a separate regression. Activities are measured in minutes/day. See Section 3 for more details on variable definitions. All regressions control for log household income, household size, individual age, gender, education, whether in school and marital status. In addition, we also control for age square, gender of head of household and survey month.

Columns (1)–(4) of panel D are left blank purposely as these coefficients are the same as columns (1)–(4) in panel C. Columns (5)–(8) in panel C estimate the effect of reliable hours on dry season water consumption. Columns (5)–(8) in panel D estimate the effect of reliable hours on rainy season water consumption. Y, yes; N, no.

Table 10. Robustness checks – drop observations surveyed in August.

Dependent variables	(1) Activity water	(2) Activity water	(3) Activity water outside	(4) Activity water outside	(5) Water total	(6) Water total	(7) Water pipe	(8) Water pipe
Panel A								
Reliable dry	18.442*** (3.932)	6.806 (4.562)	−2.746 (1.960)	−3.167* (1.855)	34.699 (28.386)	0.064 (33.337)	119.274*** (21.009)	85.893*** (22.447)
N	556	556	556	556	556	556	556	556
R^2	0.115	0.329	0.218	0.103	0.083	0.216	0.180	0.222
Panel B								
Reliable hours (dry)	3.176** (1.412)	1.099 (1.564)	−0.658*** (0.183)	−0.311** (0.143)	63.703*** (19.813)	50.154** (20.165)	39.407*** (12.862)	33.286** (14.070)
N	387	387	387	387	387	387	387	387
R^2	0.145	0.360	0.121	0.157	0.158	0.277	0.222	0.378
Municipal FE	Y	N	Y	N	Y	N	Y	N
Ward FE	N	Y	N	Y	N	Y	N	Y
Household and individual controls	Y	Y	Y	Y	Y	Y	Y	Y
Additional controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: ***, ** and * denote significance level at 1%, 5% and 10%, respectively. Robust standard errors are in parentheses. Each cell reports the coefficient from a separate regression. Activities are measured in minutes/day. See Section 3 for more details on variable definitions. We only report the effect of reliability in dry seasons in this table as all samples included in this table are surveyed in the dry season. All regressions control for log household income, household size, individual age, gender, education, whether in school and marital status. Y, yes; N, no.

the rainy season. We reported both results with municipal fixed effects or ward fixed effects. As observed, with these additional controls, our main results were largely consistent other than the effect of reliable_rain on total water consumption in column (6). When ward fixed effect was controlled for, the effect was negative and statistically significant. A possible explanation is that households without reliable tap water might store extra water or over-consume during the rainy season when water is relatively cheap, while consumption decisions are less affected for households with reliable tap water.

Table 10 presents the results when households surveyed in August are excluded. We performed this analysis in August as it is typically the last month of the rainy season in the Kathmandu Valley. By retaining results for dry season water consumption and dry season reliability, we sought to reduce potential recall errors due to the timing of survey. We ran the regressions again using the main specification, and the results were similar.

7. Conclusion

In this paper, we analysed the relationship between household time allocation, reliability of tap water and water consumption patterns under conditions of intermittent supply. We discover that time spent on productive activities is negatively correlated with time spent on water collection for the person most responsible for water collection in the household. We also demonstrate that when tap water connections become more reliable, households spend more time on collecting water. As a consequence of this time investment, households consume more water both from their private tap and overall.

From a policy perspective, because an increase in reliability leads to an increase in collection time inside the home, it is important to arrange water supply schedules in a way that minimises disruptions that can affect work, leisure and other activities. For cities with intermittent supply, more research is needed to understand how individuals and households prioritise different activities in order to identify which times of day would be the most conducive to water collection. Additionally, since we were unable to record simultaneous activities within the same time block, it may be relevant to determine what other activities occur while the tap is turned on and the water collector is waiting for the storage containers to be filled. Finally, with households with unreliable water connections shifting away from collecting water outside the home to vended water, there is room to examine the trade-offs between collecting and buying water.

References

Apoorva, R., Biswas, D. & Srinivasan, V. (2018). Do household surveys estimate tap water use accurately? Evidence from pressure-sensor based estimates in Coimbatore, India. *Journal of Water, Sanitation and Hygiene for Development 8*(2), 278–289.

Arthi, V., Beegle, K., De Weerdt, J. & Palacios-Lopez, A. (2018). Not your average job: measuring farm labor in Tanzania. *Journal of Development Economics 130*, 160–172.

Beegle, K., Carletto, C. & Himelein, K. (2012). Reliability of recall in agricultural data. *Journal of Development Economics 98*(1), 34–41.

Chen, Y. J., Chindarkar, N. & Xiao, Y. (2019). The effect of reliable electricity on health facilities, health information, and health services utilization: evidence from rural Gujarat, India. *Journal of Health, Population and Nutrition 38*(1), 7.

Cheung, P. (2010). *The World's Women 2010 Trends and Statistics*. Department of Economics and Social Affairs, the United Nations, Washington, DC.

Devoto, F., Duo, E., Dupas, P., Pariente, W. & Pons, V. (2012). Happiness on tap: piped water adoption in urban Morocco. *American Economic Journal: Economic Policy 4*(4), 68–99.

Fuente, D., Gatua, J. G., Ikiara, M., Kabubo-Mariara, J., Mwaura, M. & Whittington, D. (2016). Water and sanitation service delivery, pricing, and the poor: an empirical estimate of subsidy incidence in Nairobi, Kenya. *Water Resources Research 52*(6), 4845–4862.

Gross, E., Gunther, I. & Schipper, Y. (2018). Women are walking and waiting for water: the time value of public water supply. *Economic Development and Cultural Change 66*(3), 489–517.

Hashimoto, T., Stedinger, J. R. & Loucks, D. P. (1982). Reliability, resiliency, and vulnerability criteria for water resource system performance evaluation. *Water Resource Research 18*(1), 14–20.

Ilahi, N. & Grimard, F. (2000). Public infrastructure and private costs: water supply and time allocation of women in rural Pakistan. *Economic Development and Cultural Change 49*(1), 45–75.

Koolwal, G. & van de Walle, D. (2013). Access to water, women's work, and child outcomes. *Economic Development and Cultural Change 61*(2), 369–405.

Meeks, R. C. (2017). Water works: the economic impact of water infrastructure. *Journal of Human Resources 52*(4), 1119–1153.

Menon, G. (1993). The effects of accessibility of information in memory on judgments of behavioral frequencies. *Journal of Consumer Research 20*(3), 431–440.

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*(2), 1–11.

Sijbesma, C., Verhagen, J., Nanavaty, R. & James, A. J. (2009). Impacts of domestic water supply on gender and income: results from a participatory study in a drought-prone region in Gujarat, India. *Water Policy 11*(1), 95–105.

Whittington, D., Pattanayak, S., Yang, J. C. & Kumar, K. C. B. (2002). Household demand for piped water services in Kathmandu, Nepal. *Water Policy 4*(6), 531–556.

Yogendra, G., Zhao, J., KC, B. K., Wu, X., Suwal, B. & Whittington, D. (2017). The costs of delay in infrastructure investments: a comparison of 2001 and 2014 household water supply coping costs in the Kathmandu Valley, Nepal. *Water Resource Research 53*(8), 7078–7102.