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TRAVEL DISTANCE AND HOUSEHOLDS' DEMAND FOR WATER IN GHANA

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Abstract

High sunk costs are generally required to transport pipe-borne water services to residential areas in developing countries but the prices paid by households for water at the point of collection are relatively low. However households spend considerable amount of travel time hauling water from long distances, indicating the shadow price of water could be considerably higher than the price paid at the point of collecting it. In this paper a simple model for households' demand for water is estimated using the sum of actual price paid for water at the point of collection and the travel distance cost as the shadow *price* of water. In addition, the impact of travel distance on demand for water has been investigated. The price and income elasticities of demand are estimated to be between -0.14 and -0.16; and 0.12 and 0.13 respectively, depending on how the value of the opportunity cost of the travel time to haul water is valued. Furthermore, the elasticity of demand for water with respect to the distance traveled to haul it is calculated to be between -0.008 and -0.121. Consequently policies aimed at bringing water closer to households could have similar impact on water demand as poverty reduction policies.

Keywords: water, elasticity of demand, travel time cost, Ghana

1. Introduction

In developing countries the average water usage per individual per day is 10 liters which constitute approximately 3% of the corresponding quantity in the developed world. This is just one-half of the minimum safe water requirements for short term survival: i.e., drinking and cooking (World Health Organization, 2005). The limited supply of portable water for residential use has contributed to high rates of diseases and mortality. The World Health Organization has estimated that over 80 percent of diseases in developing countries are related to unsafe drinking water and poor sanitation (Chandrakumar and Mukundan, 2006). In addition, 3 million people die annually from waterborne diseases such as diarrhea and a total of 12 million people die from unsafe drinking water. In Africa, where the problem is endemic more than half of the population lack access to safe drinking water although 96 percent of the renewable water resources are not utilized due to lack of infrastructure to access and transport them. Extending water services to households involves high sunk costs and it is important to determine the maximum amounts that the potential beneficiaries in developing countries are willing to pay for the services. This research adds to the thin literature on residential water demand in developing countries by investigating the impact of travel distance to haul water on residential water use using data on Ghana.

Although some studies have found that households could only spend 3-5% of their income on improved water services, studies in Africa found evidence to the contrary. For example, in a recent study in Nepal, household with metered connection that was working paid an average water bill of $2.19 while the mean income of the sample studied was $230.00 (Pattanayak et al, 2006). On the contrary, Whittington et al. (1991) found the proportion of income a household spends on water could depend on the income level of the household as well as the season in sub-Sahara Africa. About 58 percent of their sample at Onitsha in Nigeria spent 18 percent of their income on water during the dry season. In addition, a study by Cairncross and Kinnear (1992) in Sudan found that households in Karton Kassala spent as much as 56 percent of their income on water for domestic consumption. A significant portion of the expenditure on water is made up of coping cost, which includes the cost of collecting water. Pattanayak et al. (2006) found an average coping cost that exceeded average water bill for households with working pipe water connections. Forty-five percent of the coping cost is attributed to the time spent collecting water. Since many of the households in rural areas in Ghana do not have water connections, they travel varying distances to haul it. Currently the mean distance travel (i.e., the distance walked) to haul water is about a quarter of a kilometer with a very high standard deviation. The imputed cost of travel time therefore constitutes an integral part of the price they pay for water. Estimates of the value of time obtained from studies on individual's travel mode choices in developed countries indicate that people typically value travel time savings at less than market wage rate (see e.g. Bruzelius, 1979). Accordingly, in a recent randomized control trial examining WTP for improved drinking water sources in Kenya, it has been found that the value of travel time to haul water is about 7 % of wage rate (see Kremer, et al., 2010). In contrast, Whittington et al. (1991) found that, regarding water collection, households in a rural community placed a surprisingly high value, equivalent to wage rate of unskilled labor.

In this paper we estimate the demand for residential water use in Ghana using the travel time cost and the actual price paid for water at the point of collection as the shadow *price* of water. The travel time cost was computed from data on *travel distance* (i.e., distance walked) to the point of hauling water. Furthermore, the elasticity of household's residential water demand with respect to travel distance has been computed.

Although several empirical studies exist on residential water demand in developed countries (see Arbués-Gracia et al., 2003; and Schleich and Hillenbrand, 2009 for complete survey of the relevant works), studies on developing countries, especially in Africa, are limited and fragmented. Secondly, most of the studies employed non-market valuation techniques such as contingent valuation and hedonic price methods to value improved water services (see e.g. Whittington et al. 1989, 1990, 1991, 1993, 2002; Daniere 1994; Pattanayak et al. 2006). The numerous limitations associated with stated preference method limit the benefit transfer from such works (Whittington, 1998). It a recent study it was found that mean willingness to pay was significantly higher than the sum of average coping cost and coping costs, including cost of collecting and storing water, in Nepal (Pattanayak et al. 2006). On the other hand, lack of data on travel distance or time hinders the use of revealed preference methods in estimating the maximum willingness to pay for water. Also, water consumption may not always be metered and some households may not pay actual price for water at the point of collection (Nauges and van den Berg, 2009) making it impossible to obtain price data to estimate demand functions. An exception is a recent study by Nauges and van den Berg (2009) that used a travel time cost as an imputed price of water to estimate the demand for piped and non-piped water in Sri Lanka.

Like the previous studies in both developed and developing countries, we find that the elasticity of demand for water for the residential use is -0.14 and -0.16 (i.e., inelastic). Secondly, we find that the elasticity with respect to travel distance is between -0.008 and -0.121. Further, as found in other studies, the income elasticity of demand is positive (0.14 and 0.13 respectively) in the two regressions. In addition, households that have indoor water plumbing, or have flushing toilet, or reside in the savannah zone or wash clothes for relatively more hours, on the average, use more water. On the other hand, male headed households use less water on the average.

The remainder of the paper is organized as follows. Section 3 presents a description of the water market and the data. Section 3 contains the specification of an empirical model and the estimated results and the final Section, i.e., Section 4, concludes the paper.

2. The Water Market and Data Description

In Ghana, like other developing countries, about 70% of diseases are attributable to lack of clean drinking water and inadequate sanitation systems (Ministry of Health, 2001). According to the Ghana Living Standard Survey (GLSS) report of 2006, only 14 percent of rural households have access to pipe-borne water compared to 73 percent of urban households (Ghana Statistical Services, 2008). Households that do not have access to reliable flow of portable water have to travel varying distances to haul it from less reliable and unhygienic sources such as open wells and streams. Almost a decade prior to 1997, when the Public Utility Regulatory Commission (PURC) was established to examine and approve public utility tariffs, the government of Ghana pegged urban water tariffs between US$0.10 and US$0.15 per m^3. After the formation of the PURC a block tariff was introduced. In 2006 the tariff began at US$0.55 per m^3 for the first $20m^3$ and increased to US$0.76 for each m^3 exceeding $20m^3$ in a month (Doe, 2007). With regards to rural areas however, in 1994, the government founded a fully semi-independent agency called the Community Water and Sanitation Agency (CWSA) which works with the District Assemblies to price water (WaterAid, 2005). The Agency is to ensure that water tariffs in rural areas meet the supply cost of the service. As an upper limit, the tariffs cannot exceed US$1 per

m^3. The tariffs are generally uniform per m^3 or the water usage is charged on pay-as-you-fetch basis. Surveys done in the Ashanti region in 2003 and Brong Ahafo region and Volta region in 2006 revealed tariffs of US$0.60 per m^3 and US$0.99 per m^3 respectively. These figures are generally higher than the rates in urban areas but not enough to cover the cost of providing the services (Nyarko, et al., 2006; Komives et al., 2008).

In urban areas of the country, the Ghana Water Company Ltd. (GWCL) is responsible for providing, distributing, and conserving water for domestic, public, and industrial purposes. Although about 73 percent of households in the urban areas have access to pipe-borne water, in most cases, the source is from outside the house. In addition, 16% of the households in the urban areas fetch water from wells and the remainder (11%) obtains water from natural and other sources. The treated water from outside the house is obtained from stand-pipes, pipes in neighboring households or private water tanker operators who haul the water from the GWCL and retail it at mark-up rates. Whereas wells in urban areas are usually private properties, water from natural sources such as streams and impoundments from dams are open-access.

Rural communities, on the other hand, obtain their water supply mainly from surface and groundwater sources. Recent estimates indicate that 59 percent of the households in rural areas access water from wells and boreholes, and the remainder access surface water (GSS, 2008). The surface water sources include dug-wells, ponds, dugouts, impoundments from dams, ephemeral streams, and rainwater harvesting from roofs. The groundwater sources include hand-dug wells with or without hand pumps, boreholes fitted with hand pumps, and springs. With the exception of ephemeral steams and impoundments from dams, which are typically owned by the public, the remainder of the surface water sources could either be a private property or publicly owned. Regarding groundwater, hand-dug wells could either be private or public property but boreholes in rural communities are publicly owned. Public ownership implies the water supply system is owned and managed by a community on a demand-driven basis. Such systems do not receive any cross-subsidies and 5% of the cost of providing the facility, e.g. a borehole or hand-dug well, is paid by the operating community (Nyarko, 2004). The community elects a water and sanitation board that includes one or two caretakers to independently operate and maintain the water system. The caretakers receive special training in repair and maintenance and the membership of the board is voluntary.

As noted earlier, the PURC regulates pipe-borne water tariffs but private water tanker operators and water vendors sell water at unregulated prices. The private water market is imperfect with prices being very diverse and far in excess of the regulated tariffs for treated water. For example Arhin-Tenkorang et al. (2002) surveyed Accra and found that as a result of the market imperfections, some residents pay rates that are approximately twice as high as what others pay. The rates are on per liter, gallon or 34 cm bucket basis and are generally lower in rural areas. Households who patronize these services include those who are not connected directly to piped water systems, and those who are connected but receive irregular services. In rural areas, the water tankers operate in coastal but not savannah and forest zones, whereas other private water vendors operate in coastal and forest areas but not in the savannah zone (GSS, 2008).

The data for the statistical analysis is taken from the Ghana Living Standard Survey 5 (GLSS5), which was collected over a period of 12 months - September 2005 to September 2006 - by the Ghana Statistical Services (GSS). It is a nation-wide survey that includes detailed household information including demographic characteristics, education attainment, employment status, household income, housing conditions, water sources and usage, time spent on water collection, and distance traveled to collect water. The total sample size is 8,700 households containing 37,128 household members, and within 580 enumeration areas. Of the total number, 8,687 households (i.e., 99.85%) were successfully interviewed. The descriptive statistics of the data for the estimation is presented in Table 1.

Table 1. Descriptive Statistics of Variables used for Estimating the Demand for Water in Ghana

Variable	**Observations**	**Mean**	**SD**
Water Usage (in liters)	3472	1.723	0.993
Price Paid for Water	4610	0.40	2.07
Shadow Price of Water (Travel Cost + Price Paid for Water)	3574	0.41	1.85
Per Capita Income per Day (a proxy for Wage rate)	6777	43.81	160.92
Male (0/1)	6791	0.743	0.437
Cement Bricks House (0/1)	6791	0.421	0.494
Flushing Toilet (0/1)	6791	0.111	0.314
Urban Location (0/1)	6791	0.439	0.496
Hours spent on Washing Clothes in a day	3791	3.842	0.951
Coastal Zone (0/1)	6791	0.314	0.464
Forest Zone (0/1)	6791	0.450	0.498
Indoor Plumbing (Water) (0/1)	6791	0.044	0.204

The variable water usage in liters is measured by the quantity of water (in 15-liter buckets) for general use per head within each household. Price paid for water denotes price paid for water at the point of collection. This does not include the travel cost to haul the water. The shadow price of water is the sum of the price paid at the point of collecting it and the travel distance cost. The travel distance is converted to travel time by using an average travel time of 20 minutes per mile following the estimates from previous studies (see e.g. Calvo, 1994; Dennis, 1998). Drawing on the findings of Whittington et al. (1991) and Kremer, et al., (2010) the travel time is valued at approximately the wage rate; and 7 percent of the wage rate, respectively. This provides the lower and upper bounds of the estimates. On the average, an individual travel about a quarter of a kilometer to haul water. A study by Pattanayak et al. (2006) valued travel time to haul water at 50 percent of wage rate.

The per capita income is the total income of the household divided by the members of the household. The income of the household is computed as the sum of income from primary and secondary sources, which includes any bonuses, commissions, allowances and tips; value of subsistence production; transfer payments or cash remittances received by the households; the value of food remittances received by the households; and miscellaneous income of the households, which includes inheritance, donations, dowry, state pension, social security, and interest earnings. Other variables considered for our analysis include the number of hours spent on washing clothes, since this may affect water usage; whether or not the house has a flushing toilet; whether or not the household has indoor plumbing for water supply; if the gender of the household is *male* or otherwise; whether or not the house is made up of bricks or other materials; whether or not the house is in an urban area; and finally the ecological zone where the household resides within the country (which could either coastal, forest, or savanna zone).

From the data, the average quantity of water used per person is 25.85 liters (i.e., 1.723 buckets) with a standard deviation of 0.99. The mean shadow price per bucket of water is GH¢0.41[1] and per capita household monthly income is approximately GH¢43.81.[2] Seventy-four percent of the households are headed by males and 42% of the houses are made of bricks. Furthermore, the statistics indicate that although 44% of the sample is located in urban areas,

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[1] At the time of the data collection, GH¢1.00 was approximately US$1.00.

[2] The income is computed by adding up income from primary and secondary occupations, and transfer incomes received by the household.

only 11% of the households had flushing toilets. In addition, on the average, each person in a household spent 3.8 hours within a week washing clothes. Furthermore, 31% and 45% of our sample live in the coastal and forest zones respectively.

3. Empirical Specification and Estimations of the Model

As noted in the introduction, households in developing countries usually travel long distances to haul water for domestic use. Moreover, a study by Whittington et al. (1991) found that the opportunity cost of the travel time to haul water could be valued at wage rate. Therefore we surmise that the shadow price of water is the sum of the actual price paid at the point of collection and the opportunity cost of travel time valued at wage rate. This shadow price denotes the individual's willingness to pay for water connection to the household. Let A be the quantity of water consumed by a household; ρ and ϕ be the price paid for water at the point of collection and the opportunity cost of making the round-trip valued at the wage rate within the household, respectively; m and w are exogenous income and wage income, respectively; and $\mathbf{s}$ is a vector of individual specific characteristics of the household that scales water usage across households up or down. Note that the opportunity cost of the round trip depends on the distance travelled (i.e., $\phi(\tau)$). The demand function for water could be specified as

$$\ln A_i = \theta + \mathbf{b}\mathbf{s}_i + a_1 \ln(m+w)_i - a_2 \ln \mathbf{c}_i + \varepsilon_i \quad , \tag{1}$$

where $\theta, \mathbf{b}, a_1, a_2 > 0$ are the parameters to be estimated; i is household specific index. $\mathbf{c}_i = \left(\rho + \phi(\tau)\right)$ is the total cost of fetching water for household use; and ε_i is independent and identically distributed error term. The individual specific characteristics (i.e., $\mathbf{s}_i$) considered for the analysis are gender, the structure of the dwelling (i.e., whether or not the house is made of bricks), whether or not the dwelling has a flushing toilet, whether or not the dwelling is in an urban location, the number of hours the household spends washing, and the ecological zone within which the resident is located. From equation (1), the partial elasticity of demand for water with respect to the distance traveled to fetch water is $\eta_\tau = -a_2 \left(\frac{\tau}{\rho + \phi(\tau)} \right) \frac{\partial \phi(\tau)}{\partial \tau}$.[3]

An ordinary least square (OLS) regression has been estimated and the results have been presented in Tables 3. The regression 1 values the travel time to haul water at 7 percent of the wage rate within the household and regression 2 values the time at the wage rate. This gives us the lower and upper bounds of the estimated coefficients. The coefficient of determination (i.e. R-squared) indicates that 17% of the variability in the quantity demanded of water for residential use is explained by the explanatory variables. In addition the F-statistics indicate that the line is a good fit (i.e., F (10, 2059) = 33.17 , Prob>F= 0.000). Furthermore, Breusch-Pagan / Cook-Weisberg test was employed to investigate the presence of heteroskedasticity and we failed to reject homoskedascitity (Prob.>0.53).

[3] Although data was collected on time spent and the distance traveled to haul water, information on the number of trips made in a day was not collected. From personal communications, although some individuals make 2 to 3 trips in a day, on the average, due to division of labor within the household, the water is used by all individuals in the household. Hence, for the purpose of our analysis, it is implicitly assumed that each individual within a household makes a trip within a day.

Table 3: OLS Estimation of Determinants of Quantity of Water Used per Person per Household per Day

Variables	**Regression 1** (Opportunity Cost of Travel Time = 7% of Wage Rate)		**Regression 2** (Opportunity Cost of Travel Time is Wage rate)	
	Coefficient	Elasticity	Coefficients	Elasticity
Log (Distance Travel Cost + Price of Water)	**-0.143**	**0.143**	**-0.158**	**0.158**
	(0.013)***		(0.014)***	
Log (Per Capita Disposable Income)	**0.117**	**0.117**	**0.134**	**0.134**
	(0.015)***		(0.015)***	
Male	**-0.100**	**0.206**	**-0.095**	**0.196**
	(0.033)***		(0.033)***	
Cement Bricks House (=1, 0 otherwise)	**-0.034**	**0.070**	**-0.046**	**0.094**
	(-0.03)		(-0.03)	
Flushing Toilet (=1, 0 otherwise)	**0.321**	**0.663**	**0.309**	**0.638**
	(0.050)***		(0.049)***	
Urban Location (=1, 0 otherwise)	**0.016**		**0.001**	
	(-0.034)		(-0.034)	
Log (Hrs spent washing)	**0.15**	**0.15**	**0.144**	**0.144**
	(0.016)***		(0.016)***	
Coastal Zone (=1, 0 otherwise)	**-0.129**	**0.267**	**-0.138**	**0.285**
	(0.047)***		(0.047)***	
Forest Zone (=1, 0 otherwise)	**-0.190**	**0.392**	**-0.192**	**0.397**
	(0.046)***		(0.046)***	
Indoor Plumbing (Water) (=1, 0 otherwise)	**0.189**	**0.390**	**0.179**	**0.370**
	(-0.067)***		(0.067)***	
Constant	**-0.776**		**-0.791**	
	(0.104)***		(0.104)***	
Observations	2070		2070	
R-squared	**0.171**		**0.173**	

** significant at 5%; *** significant at 1%. Robust standard errors in parentheses

From both regressions, the price of water is negatively related to quantity of water used by each household and the household's income per head has positive impact on quantity of water used. The price elasticity coefficient ranging between -0.14 and -0.16 for the lower and upper limits of the opportunity cost of the travel time implies that the demand for water is inelastic and e.g. a 1% increase in the shadow price of water will decrease the quantity demanded between 0.14 and 0.16%. The numbers are similar to the recent findings of Nauges and van den Berg (2009) for demand for pipe water in Sri Lanka. From the regression results, the elasticity of demand for water with respect to the distance travelled is estimated at between -0.008 and -0.121. This implies that, on the average, if the water company brings the water 10 % closer to households, the water consumption will increase by 1.2 percent at the maximum. It is noteworthy that the impact of a percentage increase in income on demand for water is similar to that of the same percentage reduction in distance travel to haul water, if travel distance is valued at wage rate. This finding is significant and intriguing and confirms travel time cost constitute a significant coping cost if water supply is unreliable (Pattanayak et al., 2006). This, however, contrasts an earlier finding that a decrease in the distance to water source increases the quantity of water collected only modestly or not at all (Warner, 1973). Furthermore, if household's income increases by 1 percentage, all other things being equal, will increase water usage by 0.12-0.13%.

Second, on the average, male-headed households use less water than female-headed counterparts. The elasticity coefficient is between -0.2, and it is significant at 1% level. Third, households with flushing toilets or with water connectivity use more water, all else equal, with elasticity coefficients of 0.66 and 0.4 respectively. Further, households that spend more time washing clothes use more water on the average. From the elasticity coefficient of 0.15, 1 percent increase in the average number of hours spent on washing clothes will increase water usage by at least 0.15%. This indicates bringing water closer to the house or increasing the quantity of water available to the household is likely to increases personal and household hygiene (Rosen and Vincent, 1999). Finally, all else equal, households within the savanna zone of the country use more water than their counterparts in the forest and coastal zones, and those in the forest zone use the least amount of water. The finding that households in the savannah zones use more water is possibly due to the relatively warmer temperature within that zone.

4. Conclusions

This study has contributed to the thin literature on demand for water for residential use in developing countries by investigating the impact of travel distance to haul water in Ghana, a typical; developing country in sub-Sahara Africa. Water services are generally underpriced in developing countries making it impossible to extend pipe borne water services to all households. As a result, most individuals travel long distances to haul water community pipes, water tankers, etc for residential use which involves high opportunity cost of travel time. The opportunity cost of travel time, though noted in the literature, is hardly counted for when putting economic value on residential water demand. Lack of data on developing countries on the issue has constrained such important studies necessary to inform water management policies.

In this study, the price elasticity of demand for water is found to be within the range of -0.14 and -0.16; and the income elasticity of demand is positive, with estimated elasticity coefficients being close to what has been found in some previous studies. Perhaps very significant is the finding that the upper bound of price elasticity of demand with respect to average distance travel to haul water for residential use is close to income elasticity of demand. This indicates any water management policy which reduces the average distance travel to collect water by a marginal proportion may have a similar impact on water demand as an alternative policy that increases average income of households by a similar proportion. This finding confirms a recent study in Nepal which found average coping cost (of which travel time cost is the main constituent) to be similar to average water bill paid by households with working water connection (Pattanayak et al. 2006).

In addition, we have found a positive relationship between water demand and hours spent washing and households with flushing toilets using more water. This confirms that water availability increases personal hygiene. Furthermore, we found that residence located within the savannah zone of the country use relatively more water on the average. This is not surprising since for most part of the year the savanna zone is much warmer than the coastal and forest zones. Finally, female headed households on the average use more water than their male counterparts. This simply buttresses the fact that females care more about personal hygiene than their male counterparts.

It is important to note that this study is not without limitations, some of which are not peculiar. The notable ones relate to the data which has always proven difficult to collect and or organize. Moreover, the values of most variables were calculated based on some assumptions. A typical example is the opportunity cost of travel time which, like other studies, was computed based on an average travel speed and opportunity cost of time for collecting water. In addition, personal communication with a senior statistician at the Ghana statistical services, which was responsible for collecting the primary data, helped to clean the data to minimize errors and outliers. Notwithstanding these limitations, the findings are significant and calls for further research on this important issue.

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