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THREE ESSAYS ON WATER SERVICE: A CASE STUDY OF THE RESIDENTIAL SECTOR OF CAIRO

By

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ABSTRACT

THREE ESSAYS ON WATER SERVICE: A CASE STUDY OF THE RESIDENTIAL SECTOR OF CAIRO

By

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The first essay reports on research that found that households in Cairo are willing to pay to avoid unreliable water service[1] with those who are hurt the most willing to pay the highest amount. Further, willingness to pay consists of a risk premium (fixed across households) paid to entirely eliminate unreliability and an amount that varies by household paid to reduce unreliability. Conservation efforts in Cairo provide a limited amount of water such that eliminating the unreliability problem entirely is infeasible. Accordingly, the magnitude of the total benefits of conservation efforts, as measured by the summation of households' willingness to pay, depends on the manner in which the conserved water is utilized. Total benefits are underestimated when the conserved water is allocated equally among households suffering from unreliable service but maximized when the limited conserved water is allocated starting with those having the least unreliability problem. The latter allocation allows more households to eliminate unreliability and captures the fixed risk premium component of willingness to pay.

The second essay reports on research that found that when water service is unreliable, Cairo households invest in water-improving technologies (WIT) such as storage tanks and electrical pressure boosting pumps. Households' willingness to pay for water improvement programs is higher the higher the ongoing costs of defensive technologies and lower the higher the technologies' ability to mitigate the risk of inadequate water service. Households

with both a pump and a tank are willing to pay LE 5.05[2] ($1.53) while those using only a pump are willing to pay LE 3.18 ($0.96) per week for a water reliability improvement program. These amounts are 2.4 and 1.5 percent of average household monthly income. These findings indicate that the upward effect on willingness to pay of higher operating costs associated with two technologies is higher than the downward effect of more risk mitigation using them. The essay also finds that the current household weekly cost of operating and maintaining a pump of LE 1.04 ($0.32) and both a pump and a tank of LE 1.27 ($0.38) constitute a lower bound on willingness to pay implying that the defensive technologies are not successful in eliminating the risk of inadequate water service.

The third essay reports on research that found that females are willing to pay less than males for residential water connections. This is despite the fact that such connections provide females with substantial benefits in the form of time and effort savings as well as improved health status. The data did not support the hypothesis that the lower female willingness to pay results from controlling only a fraction of the total household income.

Notes

1. Characterized by frequent water cutoffs and/or incidents of low water pressure such that the household's water needs cannot be met from the tap at home.
2. LE denotes Egyptian Pounds. The 1995 exchange rate was 1$=3.3 LE. The 1995 average household yearly income was LE 10447.

DEDICATION

To Abdalla, my husband and my best friend, for all his support and to my family for helping me achieve my goals.

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INTRODUCTION

1. THE CHALLENGES AHEAD

More than twenty percent of Egypt's population, currently estimated at around 60 million people, lives in Cairo in densities as high as one hundred thousands people per square kilometer [United Nations, 1990]. Furthermore, Cairo's population is estimated to grow at its present rate of at least three percent per year. The size of municipal water needs in Cairo is directly related to the population size, since the latter constitutes the main variable responsible for the increase in municipal water demands [Khouzam, 1995; CH2M Hill International, 1990]. The fresh water shortages facing Egypt at large impact all sectors, including the municipal sector of Cairo. The arid climate of Egypt, characterized by negligible rainfall (5-200 mm/year) and high evaporation rates (1500-2400 mm/year), means the river Nile is the main source of fresh water contributing to 98 percent of the country's total water supply [Ministry of Public Works and Water Resources, 1996]. Egypt already needs more than its annual allotted Nile share of 55 billion cubic meters to meet the competing water uses including those for municipal purposes. The country's water requirements for all purposes (including water losses) are estimated at 63 billion cubic meters per year. Further, it is unlikely that Egypt Nile water budget will increase in the near future due to natural and political reasons in the Nile basin [ibid.]. For example, reducing losses in the river course by building the Jonglei Canal in Sudan can result in an extra availability of 10-15 billion cubic meters per year. This work, however, is halted due to civil war in the project area. Also, due to expected economic development Ethiopia will be claiming more Nile water in the future.

Shortages of water quantities are not the only concerns around the Greater Cairo area. Due to high population densities, the Nile River has been subjected to considerable pollution stemming from man made conditions. These include effluents from untreated/semi treated domestic and industrial wastewater as well as raw sewage from the rapidly growing unconnected areas. They also include fertilizer and pesticide leaching and irrigation return flows from the agricultural sector as well as river traffic and waste from tourist and other activities [United Nations, 1990; Ministry of Public Works and Water Resources, 1996].

The lack of fresh water is only one factor determining the amount of treated water available to consumers. Due to the lack of production as well as storage capacity and the aging distribution system of Cairo (first built in 1865), treated water fell short of daily maximum demand in the municipal sector of Cairo. The maximum daily demand for treated water in some parts of Cairo water supply and distribution system was about 3.09 million cubic meters for the year 1990. This amount exceeded the available supply (estimated at 2.27 million cubic meters per day for the same year). Further, the quantity demanded was projected to increase to 5.7 and 7.1 million cubic meters per day for the years 2000 and 2010 respectively due to the ongoing rapid population growth and the change in consumption rates and development patterns [CH2M Hill International, 1990].

Other challenges facing GOGCWS include a lack of financial resources. GOGCWS collects revenue through lump sum administrative charges rather than quantity based prices. In 1994, administrative charges yielded average revenue of approximately $37 per thousand cubic meters of processed water. The revenues collected by GOGCWS were the lowest compared to other water networks of the same size and population coverage [Hoehn and

Krieger, 1996]. These low revenues are due to charging low subsidized water fees as well as problems with enforcing and collecting such fees.

2. POLICIES IN THE PAST

The General Organization for Greater Cairo Water Supply (GOGCWS) is faced with two challenges in the municipal sector: to close the rapidly increasing gap between the limited water resources and the increasing demands on the one hand and to achieve such an objective using its limited financial resources on the other.

To manage its limited water resource, both supply oriented (such as developing new sources) as well as demand oriented (such as increasing the efficiency of water use) measures were utilized by GOGCWS [Ministry of Public Works and Water Resources, 1996]. A twenty years program was launched in the seventies with an estimated cost of 2.9 billion dollars [United Nations, 1990]. The main objective of this effort was to expand the Cairo's water system's production and storage capacity, extend and upgrade its distribution network, and bring the Cairo's water system up to existing engineering standards for urban water supply [Hoehn and Krieger, 1996]. The latter included efforts to improve the quality of treated water, increase water pressure through out the service area, and strengthen the management capacity of the GOGCWS [CH2M International, 1990]. Also, detecting and enhancing the use of ground water was included as part of the policy [United Nations, 1990].

On the other hand, demand management efforts such as using water more efficiently and reducing water losses were taken [United Nations, 1990; CH2M Hill International, 1990]. However, policies regarding more efficient use of water resources targeted other sectors with little attention given to the household sector [Richards, 1995]. Other means to conserve water used by GOGCWS were increases in the lump sum administrative charges and public information campaigns. In mid-1985, the flat fee per ton of water in Cairo was raised from 1.2 to 3 piasters[1]. Despite this increase, the new water fees were way below the cost of production estimated at 8 piasters per cubic meter. Also, efforts were neither taken to change the structure of water pricing (exchange subsidized flat fees with prices that reflect the value of water in the municipal sector) nor metering was implemented to make sure that customers pay for the water actually consumed. Due to this customers had little or no incentives to conserve and only half of the average per capita supply actually reached their households due to leaking and broken pipes and poor household fittings [Rada, 1994; CH2M Hill International, 1990; Hoehn and Krieger, 1996; United Nations 1990].

Also, GOGCWS still faces the financial challenge of expanding water supplies to meet the growing needs. This challenge makes it rely heavily on foreign assistance. Efforts to expand the water system were usually multi-national including the United States, Germany, Japan, and France [United Nations, 1990; Hoehn and Krieger, 1996].

Despite all its efforts in the past, today twenty five percent of Cairo households, mainly on the periphery, have no access to piped water. More over the supply fluctuates over much of the urban area meaning many do not have water service all hours of the day or do not have full discharge pressure.

3. THE FINDINGS

The three essays presented in this dissertation had the broad objective of understanding consumers' preferences (as reflected by willingness to pay) regarding water service in the municipal sector of Cairo. The first essay reports on research that found that

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[1] Each Egyptian pound denoted as LE contains 100 piasters. The 1995 exchange rate is $3.3 to 1 LE.

households in Cairo are willing to pay to avoid unreliable water service[2] with those who are hurt the most willing to pay the highest amount. Conservation was seen as one way to increase water service reliability. Hence, the household willingness to pay for improvement in reliability was used to estimate the benefits from conservation efforts. The paper documented substantial conservation potential in Cairo through reducing domestic, institutional, and system wide leakage. The benefits of such efforts were estimated to be as high as three million dollars per month in terms of improved reliability for the households in the service area.

The second essay reports on research that found that when water service is unreliable, Cairo households invest in water-improving technologies (WIT) such as storage tanks and electrical pressure boosting pumps. The cost of these defensive technologies as well as their ability to mitigate the risk of unreliable service influence the magnitude of the households' willingness to pay for programs aiming at improving water service reliability. Households with both a pump and a tank were willing to pay up to $1.53 while those using only a pump were willing to pay only $0.96 per week for a program that improves water service to 24 hours a day at full discharge pressure. These amounts are 2.4 percent and 1.5 percent of average household monthly income. The essay also finds that the current household weekly cost of operating and maintaining a pump of $0.32 and both a pump and a tank of $0.38 constitute a lower bound on willingness to pay because the defensive technologies are not completely successful in eliminating inadequate water service.

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[2] Characterized by frequent water cutoffs and/or incidents of low water pressure such that the household's water needs cannot be met from the tap at home.

The third essay reports on research that found that households were willing to pay for residential water connections. Female heads of the household were willing to pay less than male heads for such connections (with willingness to pay estimated at $5.63 and $6.07 per month respectively). This finding was despite the fact that such connections provided females with substantial benefits in the form of time and effort savings as well as improved health status. 91 percent of the females interviewed did not work outside the home for cash. This finding implied that nonworking females obtained a fraction of the total household income from other members of the household who earned income. Lower female willingness to pay could be explained if females utilized such a smaller budget for domestic expenses including those for water needs instead of the total household income. The data, however, did not support such an explanation and the hypothesis that the lower female willingness to pay resulted from controlling a fraction of the total household income was rejected.

4. IMPLICATIONS FOR FUTURE WATER POLICY

The broad understanding of consumers' preferences for water service improvement is vital for policy makers in Cairo. Such an understanding can be utilized by GOGCWS to address its two challenges. Results reported in the first essay can address the water resource challenge while results reported in the second and third essays can address the financial resource challenge.

The first essay research provided a benefit side analysis of conservation efforts. This research can be used in a full benefit cost analysis to justify conservation programs. Conservation can play a substantial role in reducing the gap between the available supply and the municipal water needs. Suitable conservation programs that encourage reductions in domestic, institutional, and system wide leakage need to be identified and their cost quantified. Having an estimate of benefits in dollar terms available makes advocating conservation efforts more plausible. Due to the high value households place on reliability, household participation in conservation efforts can be enhanced if public campaigns emphasized and explained the relationship between reliability and conservation.

Previous literature emphasized the role of willingness to pay as a tool for sizing and financially planning water services. Willingness to pay is found to be a good indicator of the potential of cost recovery of investments aiming at improving water service [McPhail, 1993; MacRae and Whittington, 1988]. It also facilitates consumers' financial participation if needed. Using the research results reported in the second essay, comparing willingness to pay of those with both water tanks and pumps with that of those with only water pumps provides an idea of the magnitude of households' willingness to pay for private storage. This amount is equivalent to $2.3 per month per household. Engineering documents indicate that it costs GOGCWS $2.7 per month per household to provide system wide storage. This comparison indicates some cost savings if GOGCWS allows households in its service area to provide their own storage facilities. Although the difference in cost per household is not substantial (only $0.40), aggregating over the households in part of the GOGCWS service area (estimated at 2.09 million households in the year 2000) provides substantial amounts. GOGCWS cost savings might be as high as $836 thousands per month. This policy can also be advocated on the grounds of equity. The appendix of this essay shows that households investing in water improvement technologies are more affluent on average. Allowing them to provide their own storage provides GOGCWS with extra resource and alleviates its financial burden.

In the third essay, the information on willingness to pay can be used to determine the level of service provided (in terms of the number of connections) as well as design charges based on the value of willingness to pay. Females are the prime users of improved water sources. The data, however, did not support the notion that lower female willingness to pay resulted from controlling only a fraction of the total household income. Excluding the budget factor leaves many other reasons to justify the lower female willingness to pay. One of these is the lack of alternative opportunities and uses of female spare time. For example, if women attach a lower value to their time and effort because of the lack of available employment, then providing high levels of water connections based on their merit of saving women's time might overestimate the value of such connections.

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ESSAY 1:
URBAN WATER CONSERVATION: INCORPORATING HOUSEHOLD SERVICE RELIABILITY

1. INTRODUCTION

The evaluation of water conservation efforts in the municipal sector in previous literature emphasized the advantages of such efforts to households resulting from possible reductions in quantities used or wasted, while system reliability is held constant[1] [Maddaus, 1987; Planning and Management Consultants Ltd., 1993; Seattle Public Utilities, 1998; Renwick and Archibald, 1998; Male, Noss, et al., 1985; Moyer, 1985]. Accordingly, a significant proportion of the households' benefits was attributed to reductions in water fees resulting from the water utility's ability to avoid long and short run costs of production due to conservation[2] [Moyer, 1985; American Water Works Association, 1999].

Water conservation may also be valued for the role it plays in mitigating water service unreliability. In a context of a residential water system, reliability is measured by the degree to which households receive their water service within acceptable standards such as adequate quantity, good quality and maximum and minimum pressure[3] [Harberg, 1997]. The lack of reliability implies losses or damages to households the magnitude of which is determined by the length of duration of water cutoffs and incidents of low pressure[4].

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[1] Conservation refers to water demand management efforts that aim to reduce usage and losses of water. The water authority and/or the household can take such efforts. In this essay we address efforts taken by the water authority to reduce losses from leakage.
[2] These costs include those for water acquisition, treatment, power and pumping, transmission and distribution, and support services. They also include capital and wastewater costs [10].
[3] In this essay unreliability only refers to water cutoffs and incidents of low pressure. Quality issues are not addressed.
[4] Duration of water cutoffs is not the sole determinant of damages or losses associated with unreliability. The frequency as well as the timing of water cutoffs and incidents of low pressure are other determinants. More frequent cutoffs as well as those occurring at bad timing (when the household needs water the most) are associated with more damage.

The unreliability losses and damages to households include the households' efforts to secure water from alternative sources that are more expensive, less convenient, and of lower quality and their attempts to adapt their water-related activities to variable service and complete domestic chores at less favorable times when water is more available. In cases when water cutoffs and low pressure are severe these losses or damages can be substantial [Hoehn and Krieger, 1996].

The purpose of this paper is to conduct a household level benefit assessment of possible reductions in household, institutional, and system-wide leakage and waste in Cairo, Egypt[5]. By making an extra quantity of water available for use, conservation efforts mitigate water cutoffs and reduce incidents of low pressure, and hence reduce their associated damages or losses to households. The households' benefits from conservation efforts can be quantified by determining the degree by which conservation can facilitate full water service and by measuring the amounts that households are willing to pay to receive such service and avoid the losses or damages associated with unreliability.

The paper proceeds by testing the following hypothesis:

1. Households that are hurt the most by water service unreliability (those facing cutoffs and low-pressure incidents that are of longer duration) are willing to pay the highest amount to receive full water service and avoid the losses or damages associated with unreliability.

2. The households' willingness to pay for full service consists of a risk premium, fixed across households, paid to eliminate unreliability and an

[5] Our choice of household assessment stems from the fact that the majority of the water processed in Cairo is destined for the residential sector [11]. Thus the primary beneficiaries from programs that enhance water service are households [9].

amount that varies by household paid to reduce unreliability. The latter increases with the severity of the households' unreliability problem (as measured by water cutoffs duration).

3. Eliminating the unreliability problem in Cairo is infeasible through water conservation alone. Hence, allocating the conserved water equally among households suffering from unreliability underestimates the total benefits of conservation. Households' benefits from conservation are largest when the limited conserved water is allocated starting with those having the least unreliability problem (shortest duration of water cutoffs). Using the conserved water in this manner allows some households to eliminate unreliability. Eliminating water service interruptions gains an extra premium in terms of willingness to pay.

4. Conservation analysis suggested in previous literature underestimates the total benefits of conservation. It limits households' benefits to fee reductions resulting from the water utility's cost savings and ignores the benefits resulting from mitigating or eliminating unreliability.

This paper is divided into six sections. The background section explains the household problem under excess water demand and describes the conservation potential in Cairo. The theory section explains how to derive a measure equivalent to the maximum amount a household would pay to avoid unreliability. The data section discusses data collection procedures. The empirical methods section describes the probit model used to reach empirical results. The results section describes the current water service received by the household and tests the above four hypotheses. The conclusion section provides a summary of the final findings.

2. BACKGROUND

The maximum daily demand for treated water in the East Bank[6] water supply and distribution system was about 3.09 million cubic meters for the year 1990. This amount exceeded the available supply (estimated at 2.27 million cubic meters per day for the same year). Further, the quantity demanded was projected to increase to 5.7 and 7.1 million cubic meters per day for the years 2000 and 2010 respectively due to the rapid population growth and the change in consumption rates and development patterns [CH2M Hill International, 1990].

The increase in available supplies was not as rapid [ibid.]. Hence, a situation resulted in which many locations of the East Bank's service area were not supplied with water at adequate pressure nor in adequate quantity. Water was available only some part of the day and typically at inconvenient hours [Hoehn and Krieger, 1996; Rada Research and Public Relations Co., 1994]. Unannounced water cutoffs and incidents of low pressure impose a risk on the households residing in the area (estimated at 2.09 million households) since these households neither know when and how often would a cutoff or an incident of low pressure occur nor for how long would they last [Rada Research and Public Relations Co., 1994]. Cutoffs and incidents of low pressure that are of longer duration are associated with more losses or damages since adapting to them requires substantial money, time, and effort

[6] The Nile divides the water supply system of Cairo into the East Bank and the West Bank water supply and distribution networks. These two networks are operated independently from each other's with interconnecting service provided only on emergency basis. This study is concerned only with conservation efforts in the East Bank.

[Nadim, et al., 1980; Hoehn and Krieger, 1996]. These losses or damages include, but not limited to, buying water from alternative sources, collecting water from sources outside the home, storing water, and adapting household activities to less favorable times when water is more available (for example finishing the laundry very late at night).

A number of studies were conducted to project future water demand for Cairo in general and the East Bank in particular and find the necessary means of meeting it [ES-Parsons, 1979; American British Consultants, 1981; Sanyu Consultants Inc., 1986]. An underlying theme of most studies, however, is their advocacy for establishing new supplies and expanding the Cairo water system. For example, in 1990 it was suggested that for the year 2000 maximum daily treated water demand to be met, a total of 3.5 million cubic meters were to be obtained from expansion and rehabilitation of treatment plants existing in 1990 and from the construction of new treatment facilities. It was also suggested that for the year 2010 maximum daily treated water demand to be met, the East Bank sources of supply will have to be nearly tripled by the year 2010 [CH2M Hill International, 1990]. Expanding a water system as large as Cairo's is not limited to securing additional sources of fresh water and enlarging treatment plants, a difficult task in itself, but extends further to updating storage capacities, transmission lines, and distribution and pumping facilities. These expansions are expensive to implement, as they involve substantial capital investments, and require time to complete [CH2M Hill International, 1990].

Supply augmentation, however, is not the only available water management practice. Conservation (or demand management) often constitutes a cheaper and quicker alternative [Planning and Management Consultants Ltd., 1993]. Substantial conservation potential exists in the East Bank. Although this water distribution system does not suffer from excessive leakage at the transmission line level, it records high leakage rates at the service line level due to poor plumbing [Pitometer Associates, 1988; CH2M Hill International, 1990]. Previous studies provided different estimates of leakage and waste rates in the East Bank area depending on the estimation technique utilized in the analysis. ES-Parsons Master Plan estimates that domestic plumbing leakage is approximately 50% of total residential demand [ES-Parsons, 1979]. Another study concluded that domestic (residential) plumbing leakage is approximately 35% of total residential demand [Sanyu Consultants Inc.,1986] while a third study provided a range of 38%-47% as an average for the entire East Bank service area [Montgomery, 1986]. Table 1.1 provides estimates of past, current, and projected leakage and waste rates in the East Bank water distribution system as calculated by previous studies [CH2M Hill International, 1990].

Table 1.1 Past, Current, and Projected Leakage and Waste Rates for the East Bank

Year	Domestic* (High)**	Domestic (Medium)	Domestic (Low)	Institutional***	System****
1987	38	47	47	50	17.43
1990	38	47	47	45	16
2000	34	36	34	30	13
2010	30	25	20	15	10

*Measured as a percent of total residential demand.
** High, medium and low refer to the water consumption category is associated with specific education level and a housing standard of the area in which they are located [CH2 Hill International]
***Measured as a percent of total institutional demand. Institutional demand refers to water used by occupants of governmental buildings, schools, hospital, mosques, and small commercial establishments. It also includes irrigation of public green spaces.
****Measured as a percent of combined residential and industrial demand.

Table 1.1 shows that previous studies identify three areas as targets for conservation. The first area is household plumbing leakage and waste, defined as "domestic" in the table and refers to the amount of water delivered to residential buildings served by the network, but not beneficially used by their occupants. The second area is institutional plumbing leakage and waste. This is defined as the amount of water delivered to governmental buildings, schools, mosques, and small commercial establishments, but not beneficially used by their occupants. The third area is system wide leakage. This is defined as the amount of water which is lost from the network prior to reaching the end user and is more related to the condition of transmission and distribution lines rather than poor plumbing.

Available literature emphasizes that these levels for each category are reasonable targets [CH2M Hill International, 1990]. The levels targeted for domestic leakage and waste are found to reflect the relative financial ability of the consumption category to improve residential building plumbing and reduce leakage. The targets for institutional leakage and waste are thought of being reasonable as future building plumbing is repaired and upgraded. This is particularly true for new buildings that are projected to develop. The targets for system wide leakage are assumed to be reasonable due to suggested government efforts to replace corroded pipes and repair and replace the leaky ones [Pitometer Associates, 1988]. Although the specific methods by which the General Organization of Greater Cairo Water Supply can achieve these reductions are not identified in this study, a number of measures are available to ensure household and government entities' participation in reducing leakage [Maddaus, 1987; Planning and Management Consultants Ltd., 1993; Seattle Public Utilities, 1998; American Water Works Association, 1985]. For system wide leakage, leak detection programs, pipe replacement, rehabilitation, and repair are highly relevant for the East Bank [Pitometer Associates, 1988].

3. THEORETICAL MODEL

The purpose of this section is to provide a characterization of the household preferences in a situation involving a risk of water cutoffs or low pressure incidents. Assume that the household derives utility from consuming a numeraire good X and that there is an adverse event (a water cutoff or an incident of low pressure) over which the household has no control. Let $C = C^*(D)$ represents the occurrence of a water cutoff that of duration D and $C = 0$ represents the absence of a water cutoff[7]. Duration (D) measures the severity of the cutoff with longer water cutoffs being more severe.

C takes the value $C^*(D)$ with some probability (π) and the value of zero with a probability ($1-\pi$). The household utility conditional on C is:

$$\begin{aligned} u &= U(X,C) \\ u(X,0) &> u(X,C^*(D)) \\ U_x &> 0 \\ U_{c(D)} &< 0 \end{aligned} \tag{1}$$

The household receives an income (M) with certainty out of which it pays a fixed fee (F) for water[8]. Suppose that the household makes a choice about whether or not to pay for a program to receive full water service before the program is actually implemented (i.e. an ex-anti choice). Also, assume that the household makes its choice so as to maximize its expected utility given its budget constraint:

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[7] In this section, the word water cutoff is used interchangeably to refer to both situations when the household does not get water at all or get water with a level of pressure that is too low to fulfil the household's water needs.

[8] Water is not currently priced in Cairo, the household pays a fixed fee that does not change with the quantity it consumes [Hoehn and Krieger].

$$\begin{array}{ll} \text{Maximize:} & E(U) = \pi \circ u(X, C^*(D)) + (1 - \pi) \circ u(X, 0) \\ \text{subject to:} & M = F + P_x X \end{array} \tag{2}$$

Since X is a numeraire good, its price is suppressed in the following analysis. Given utility maximization, there is an indirect utility function $V = v(M\text{-}F, C)$ which measures the maximum attainable utility given $M^* = M\text{-}F$, and C. This indirect utility function has the properties:

$$\begin{array}{l} v_{M^*} > 0, v_{M^*M^*} < 0 \\ v_c < 0, v_c > 0 \end{array} \tag{3}$$

Define an option price (OP) to be the maximum payment the household would make to change from the status quo risk to a situation in which $C = C^*(D)$ would not occur. This option price is a form of compensating surplus where the reference point is the household expected utility [Freeman, 1993]. Option price is the solution to the following equation:

$$v(M^* - OP, 0) = \pi \circ v(M^*, C^*(D)) + (1 - \pi) \circ v(M^*, 0) \tag{4}$$

For equation (4) to hold, the household will be willing to pay a higher option price to avoid a longer cutoff.

4. DATA[9]

Contingent valuation was used to estimate option prices for improved water service. The contingent valuation method uses survey questions to directly elicit people's preferences for non-marketed goods by finding out what they would be willing to pay (in money terms) for specified improvements in them. Respondents are presented with a hypothetical setting in which they have the opportunity to trade money payments for such improvement [Mitchell and Carson, 1989]. In this study water reliability is the non-market good and the specific improvement valued is an increase from current reliability levels to daily 24 hours water service at full discharge pressure.

In comparison with other survey methods, the contingent valuation is particularly demanding in terms of questionnaire development and survey design and implementation [Arrow, Solow, et al., 1993]. Issues of questionnaire development were particularly important in Cairo due to language and cultural differences and lack of previous research [Hoehn and Krieger, 1996]. Hence, a multi-stage process of questionnaire design and reliability testing was incorporated. A total of nine focus groups were conducted with 69 heads of Cairo households (to establish background information necessary to develop a draft questionnaire), the draft questionnaire was pre-tested in two phases and 57one-on-one interviews were completed in the offices of a research company in Cairo[10]. A field pretest tested the semi-final questionnaire under conditions similar to those proposed for the final survey. Fifty in-home interviews were conducted to finalize the development of the

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[9] Hoehn and Krieger collect the data used in this study in 1995. For a detailed account of survey design and data collection refer to the original work by the two authors [Hoehn and Krieger].

[10] Rada Research and Public Relations in Cairo organized and conducted focus groups and facilitated data collection.

questionnaire. The purpose of this multistage process was to construct a plausible, intelligible, and meaningful questionnaire to the respondent, reduce miscommunication between the researcher and the respondent, and train interviewers.

GIS was used to establish a database, update Cairo maps, and draw random primary sampling units (PSU) by utilizing landscape maps from the year 1968 and combining them with information on administrative units and urban boundaries, population and population growth rates, and water service conditions. A total of 25 households were interviewed in each PSU. Eight hundreds and ninety three heads of households completed the final questionnaire to value 24 hours of reliable water service, 50% of them were females. The response rate for this questionnaire was 84%.

The final questionnaire had a total of 75 questions that spread into 13 sub-sections. It contained four separate sections each collecting different type of information. The screening section determined the eligibility of the household to complete the questionnaire. The questionnaire was to be completed by households that are connected to the water system but had unreliable water service (defined as having water cutoffs and/or a level of water pressure that is too low to obtain water for meeting household needs for all or part of the day, once a week, several times a week, and everyday). The second section collected information on the level of current water service, duration, timing and frequency of water cutoffs. The third section collected data on health status, housing, and socio-economic characteristics of the household.

The fourth section, the valuation scenario, allowed households to elicit their choice for reliability improvement (in the form of receiving daily 24 hours of service at full discharge pressure) and obtained the maximum amount of money they would be willing to give up to receive it. The valuation scenario expressed the possibility of improved service, described the hypothetical program that would lead to such improvement, reminded the respondent with baseline conditions (current water pressure and payment) and the post program conditions (including the elimination of water cutoffs and low water pressure and the change in payments to the water authority). The decision setting included reminders of some of the reasons other respondents accepted or rejected the program, of budget constraints, and of program costs.

The total sample of respondents was subdivided into 9 sub-samples each randomly receiving the program at a different initial cost. Respondents in each sub-sample were asked to accept or reject the program at the proposed program cost. Each sub-sample was proposed the program at only one of the following nine costs: 20, 40, 60, 80, 100, 175, 250, 400 or 600 piasters[11] paid weekly for five years. These costs were based on a distribution of value responses obtained during the pre-testing stage [Hoehn and Krieger, 1996]. The lowest cost threshold was selected so that approximately 90% of the respondents would accept the project if they were offered it at that cost. The highest cost threshold was selected so that approximately 90% would reject the project if they were offered it at that cost. A respondent rejecting the program at the initial cost was offered it again at a lower cost and that accepting the program at the initial cost was offered it again at a higher cost. A debriefing section followed to allow the respondents the chance to discuss the reasons for their choice decision. This open-ended section encouraged respondents to reflect upon the scenario, slowed the

[11] One Egyptian pound (denoted as LE) contains 100 piasters. The 1995 exchange rate was approximately 3.3 LE to 1 US dollar.

pace of the interview, and provided later information to judge if respondents gave careful consideration to the economic tradeoffs and consequences of their decisions.

5. EMPIRICAL METHODS

The data collected provided a set of 893 accept/reject responses based on 9 different cost categories. The probit model is used to analyze the data, calculate the mean willingness to pay for obtaining 24 hours of water service, and test if it varies by duration of cutoffs and low pressure incidents. In this section we assume that the unobserved willingness to pay (w) can be explained using the variable *D* representing duration, according to the following equation:

$$w_i = w(D_i, \epsilon_i) \qquad (5)$$

Where *i* goes from 1 to *N*, and ϵ_i is an error term. In this section we argue that household *i* accepts (votes yes) for the reliability improvement program if its willingness to pay is greater than the cost (Y_t) at which the program was offered to it. The (t) goes from 1 to 9 in our analysis depending on the sub-sample interviewed. The household will reject (votes no) otherwise. Hence, the following must be true for a household that accepts the improvement program:

$$w(D_i, \epsilon_i) \succ Y_i \qquad (6)$$

If we choose a linear function to represent the relationship between willingness to pay and duration, the probability of the respondent accepting the program at a given program cost could be presented as follows:

$$Prob_i(Yes/Y_t) = Prob[\beta_0 + \beta_i D_i + \epsilon_i) \succ Y_t] \tag{7}$$

We assume that ε_i is identically and independently distributed as normal with a mean of zero and a standard deviation of σ, move Y_t to the other side of the inequality, and use a standardized normal distribution to obtain the following equation:

$$Prob_i(Yes/Y_t) = Prob[(\beta_0 + \beta_i D_i - Y_i)/\sigma] \succ g_i\sigma) \tag{8}$$

The probit regression is used to estimate the values of the coefficients in equation (8) and the standard deviation (σ) which maximize the log likelihood function:

$$LogL = \sum_{i=1}^{n} \{d_i \log[1 - \Phi((Y_i - D_i\beta)/\sigma)] + (1 - d_i)\log[\Phi((Y_i - D_i\beta)/\sigma)]\} \tag{9}$$

Where (n) is the total sample size (equals to 893), d_i is a dummy variable (equals one if the respondent accepts the program and zero otherwise), D_i is a vector representing duration, Y_i is the cost threshold, s is the standard deviation of the estimated distribution, and $\Phi(.)$ is the cumulative density function of the normal distribution [Cameron and James, 1987].

6. RESULTS

6.1. Current Water Service[12]

Seventy three percent of the households reported witnessing water cutoffs or low pressure incidents within the last four weeks prior to the interview. The average duration of water cutoffs or low pressure incidents is 11.4 hours per day, with a minimum of one hour

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[12] In this section water cutoffs and incidents of low pressure are used interchangeably.

and a maximum of 23.9 hours. Table 1.2 provides the percentage of households at each cutoff or low pressure incidents' duration. The table shows lower concentration of households at extreme water cutoffs or low pressure incidents' duration (too short or too long).

Table 1.2 Percentage of Households in Each Duration

Duration of Cutoffs (Hours per Day)	Percentage of Households (%)
1 To 3 Hours	6.98
3.5 To 6 Hours	14.82
6.5 To 9 Hours	18.62
9.5 To 12 Hours	17.73
12.5 To 15 Hours	15.99
15.5 To 18 Hours	15.26
18.5 To 21 Hours	7.12
21.5 To 24 Hours	3.48

Table 1.3 provides information about the frequency of water cutoffs for the households interviewed. The table shows that more than 70% of the cutoffs and low pressure incidents occurred every day and only around 3% occurred less than once a week.

Table 1.3 Frequency of Water Cutoffs

Frequency of Cutoff And Low Pressure	**Percentage of Cutoffs (%)**
Less Than Once Each Week	2.60
About Once Each Week	5.40
Several Times Each Week	19.60
Every Day	72.18
Other	0.22

Table 1.4 provides information about the timing of the water cutoffs and low pressure. The table shows that 96% of the cutoffs and low pressure occurred during the day, and only 4% occurred when household members are asleep (between 9 p.m. to 5 a.m.). Focus groups' participants provided an example of how this affected the household's activities.

Women in focus groups reported that they were often forced to do the laundry late at night, when water was available. This meant that some of them stayed awake all night. This was reported to cause headache and fatigue and affect women's productivity the next morning [Rada Research and Public Relations Co., 1994].

Table 1.4 Time When Cutoff or Low Pressure Starts

Time Cutoff Starts	Percentage of Cutoffs (%)
Day (5 a.m. to 9 p.m.)	96.37
Night (9:05 p.m. to 4:55 a.m.)	3.63

Within the day, water cutoffs do not carry the same weight. Focus group participants provided some examples of inconvenient times in which water cutoffs occurred when the household needed water the most. These included times around meals, Muslim prayers[13], and when household members are preparing to go to school or work. Table 1.5 provides information about the timing of water cutoffs and low pressure incidents during the day. The table indicates that the majority of the cutoffs (more than 78%) start in the morning between five and eleven o'clock and 92% of the cutoffs start prior to two in the afternoon.

Table 1.5 Timing of Water Cutoffs During the Day

Time Cutoff or Low Pressure Starts	**Percent of Cutoffs (%)**
0:00 a.m. to 5:00	3.45
5:05 a.m. to 8:00 a.m.	36.90
8:05 a.m. to 11:00 a.m.	41.52
11:05 a.m. to 2:00 p.m.	13.66
2:05 p.m. to 5:00 p.m.	3.32
5:05 p.m. to 9:00 p.m.	1.15

[13] Muslim prayers require washing one's self five times a day. The Friday noon prayer (equivalent to Sunday church in Christian religion) has special importance and most Muslims shower or wash themselves extensively prior to practicing it. Focus group participants specifically distinguished the time around the Friday noon prayer to be a hard time for obtaining water [13].

6.2. Testing the Hypothesis: Hypothesis One and Two

One: Households that are hurt the most by water service unreliability (those facing cutoffs and low-pressure incidents that are of longer duration) are willing to pay the highest amount to receive full water service and avoid the losses or damages associated with unreliability.

Two: The households' willingness to pay for full service consists of a risk premium, fixed across households, paid to eliminate unreliability and an amount that varies by household paid to reduce unreliability. The latter increases with the severity of the households' unreliability problem (as measured by water cutoffs duration).

To test these two hypothesis a relationship between willingness to pay to receive full service (daily 24 hours water service at full discharge pressure) and duration of water cutoffs is estimated[14]. Table 1.6 shows the probit estimates of this relationship.

Table 1.6 Willingness to Pay to Eliminate Water Cutoffs

Variable	Estimates (Standard Errors)
Intercept	137.28 (11.23)*
Duration of Cutoff (hours)	4.18 (2.13)*
Log-likelihood Function Value	-372.30
McFadd	0.22
Incremental Chi-Square (df)	208.7(2)
Correct Predictions (%)	74

•N=688. (*) Indicates significantly different from zero at less than 5% level.

[14] In addition to duration the variables timing and frequency of water cutoffs determine the magnitude of the households' losses and damages. The latter two variables are dropped assuming that reducing the duration of water cutoffs to zero (by providing daily 24 hours of water service) automatically eliminates the risks associated with frequency and timing. Also, this step is taken to simplify the following conservation analysis of the different allocation mechanisms.

Table 1.6 shows that households that are hurt the most, those with longer water cutoffs are willing to pay the highest amount to receive full water service and avoid unreliability losses since the coefficient on "duration of cutoffs" is positive and significantly different from zero at less than 5% level. The intercept can be interpreted as measuring what the household is willing to pay to obtain daily 24 hours of water service regardless of its cutoff duration. It is a measure of the risk premium to completely avoid cutoffs and low pressure. This amount is fixed across households including those with the minimum duration of cutoffs (one hour). The intercept is positive and significantly different from zero at all levels.

Table 1.6 also shows that the willingness to pay equation contains an amount that varies by household. It is represented by the coefficient on "duration of cutoffs" multiplied by the number of hours during which the household currently does not obtain water. Since the coefficient on "duration of cutoff" is positive, this amount increases with the length of duration.

6.3. Conservation Analysis: Hypothesis Three and Four

> Three: Eliminating the unreliability problem in Cairo is infeasible through water conservation alone. Hence, allocating the conserved water equally among households suffering from unreliability underestimates the total benefits of conservation. Households' benefits from conservation are largest when the limited conserved water is allocated starting with those having the least unreliability problem (shortest duration of water cutoffs). Using the conserved water in this manner allows some households to

eliminate unreliability. Eliminating water service interruptions gains an extra premium in terms of willingness to pay.

To support the first part of the above hypothesis, the amount of water saved through conservation is calculated, reduced to quantities received at the household tap, and transferred to additional hours of service. Table 1.7 shows the feasible suggested reductions[15] in leakage and waste for the East Bank water system for the years 1990-2000. Also, a combined program is evaluated assuming that all the leak reduction efforts are taken simultaneously. All estimates are per day.

Table 1.7 Estimates of Conserved Water Translated to Number of Hours of Additional Service for the Years 1990 to 2000

Leakage Source	Percent Reduction	Cubic Meters at the Tap	Additional Hours of Service
Domestic	9.33	316,962.20	3.63
System Wide	3	78,478.93	0.90
Institutional	15	91,883.89	1.05
Combined	-	576,384.90	6.60

The column "cubic meters at the tap" records the estimates of cubic meters per day that are made available to the household (at the tap within the household dwelling) as a result of the conservation efforts. These are not equal to the saved cubic meters from conservation. This is because the leakage and waste savings occur at different stages of the water network prior to the household dwelling. Hence, it was necessary to calculate savings in cubic meters after accounting for possibility of leakage and waste at each stage prior to the household dwelling.

[15] These reductions were suggested in engineering documents that were conducted between the years 1979-1990 and were seen as feasible given the technical conditions of the East Bank area [15, 17, 19, 12].

To translate the conserved water to number of hours of additional service (or inversely to cutoff duration), an assumption was needed as to which amount of water constitutes 24 hours of water service. The General Organization for Greater Cairo Water Supply estimated the required average daily demand for the East Bank area. This estimate specified the projected amount of water required to meet the full average day domestic demand (after accounting for household leakage) to be 2,096,582 cubic meters per day for the year 2000. This amount is assumed to be what is needed (at the household tap) to achieve daily 24 hours of service [12]. In this study we assume that if the water authority is able to deliver this amount to the household at the tap, then this amount can be used as a base to calculate the additional number of hours that could be made available through conservation. This, however, does not say anything about the logistics of making this amount available at the household's tap i.e. no assumptions are made as to how the water authority would go about producing, storing, and transporting the water needed to achieve this goal[16]. Table 1.7 shows that conservation provides a limited amount of water such that eliminating the unreliability problem entirely is not feasible. Although, each household can obtain some extra hours of service and reduce their duration of water cutoffs as a result of the conservation efforts, not every household is able to enjoy full service. Only households with water cutoff duration less than or equal to the additional hours of service provided through conservation will be able to enjoy 24 hours of service and eliminate their unreliability losses or damages entirely.

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[16] Knowing the logistics of providing water at the household tap is necessary if future research is concerned with the cost side of this analysis.

To test the second part of hypothesis three above the paper uses Table 1.6 to calculate willingness to pay at each cutoff category and obtains benefit estimates associated with three mechanisms, the first two of which allow for equal allocation of the conserved water among the households suffering from unreliability. In the first mechanism, conservation benefits the household by providing every household with an equal number of extra daily hours of service. This valuation does not account for the households that are able to leap the daily 24 hours service threshold as a result of obtaining extra hours of service. Hence, the marginal value of extra hours (as described by the coefficient of the "duration of cutoffs" variable in Table 1.6) is used to calculate the household benefits. A marginal value of 4.181 is multiplied by the third column of Table 1.7 for each household in the service area.

In the second allocation mechanism, every household obtains the same number of daily extra hours of service. This brings some households, those with current daily hours of cutoffs equivalent to or less than the extra hours provided, to 24 hours of water service. The water provided to this percentage of households will be evaluated at the marginal value of hours plus the risk premium of completely eliminating water cutoffs (as measured by the intercept in Table 1.6). The rest of the households, with cutoffs that of longer duration than the extra hours of service provided through conservation, drive a marginal value similar to that obtained in the first mechanism.

In the third mechanism, water saved from conservation is allocated starting with those with the shortest cutoffs. The percentage of households in each cutoff category obtains water that brings it up to 24 hours of service until all the water is utilized. Since the conserved water is not enough to provide all the households with daily 24 hours of service, some households are left at their initial reliability level. The benefits in this case are calculated as the risk premium plus the marginal value for all the households achieving daily 24 hours of water service. Table 1.8 provides benefits estimates of each of the leakage reduction efforts and for each water allocation mechanism. All figures are in US dollars per month for the specific percentage of households accommodated under each allocation mechanism.

Table 1.8 Estimated Household Benefits for Different Water Allocations (Per Month in U.S. Dollars)

Leakage Source	Equal Allocation (100% at Marginal Value)	Equal Allocation (Some % at Marginal Value)	Allocation Minimum Cutoff (Some % at 24 Hours Service)
Domestic	403,234.82	654,444.80	2,228,129.51
System Wide	100,021.56	116,126.10	882,006.06
Institutional	116,691.82	132,721.96	967,769.29
Combined	733,268.60	1,471,978.00	3,425,765.82

Under the first mechanism, 100% of the households are included in the analysis with each getting the marginal value from reducing their current cutoff duration by the extra hours of service provided through conservation. Under the second mechanism, the percentage of households taken over the 24 hours of service threshold depends on the number of extra hours made available through conservation. This is 7.14 % for domestic, 0.44% for both the institutional and system wide leaks, and 21.82% for the combined effort. The remaining households obtain a marginal value similar to that in the first mechanism. Under the third mechanism, 21.43% (for system wide), 23.38% (for the institutional), and 73.87% (for the combined program) of the households are brought over the daily 24 hours water service threshold with no one else getting additional hours as a result of reducing domestic leakage and waste.

In conclusion, Table 1.8 shows that equal allocations of the conserved water among households suffering from unreliability underestimate the total benefits of conservation while the allocation that utilized the conserved water starting with households with the least unreliability problem (shortest cutoff duration) maximizes such benefits. This is because the latter mechanism allows the maximum number of households to enjoy daily 24 hours of service, completely eliminates their unreliability problem, and captures their risk premium.

> Four: Conservation analysis suggested in previous literature underestimates the total benefits of conservation. It limits households' benefits to fee reductions resulting from the water utility's cost savings and ignores the benefits resulting from mitigating or eliminating unreliability.

Previous literature emphasized the household benefits from conservation resulting from possible reductions in quantities used or wasted while system reliability is held constant. Under such an analysis, conservation benefits the household through a reduction in water fees resulting from the cost savings from avoided production. The water authority does not re-distribute the water saved through conservation. Water production is reduced by the amount of water conserved and so is the water authority's cost. It is assumed that the water authority distributes the cost savings equally among the households served[17]. Table 1.9 provides a comparison between the water allocation mechanism that starts with households having the least cutoffs and the per capita cost savings suggested in previous literature. All figures are in US dollars per month for the percentage of households accommodated under each analysis.

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[17] For a detailed analysis of the calculations involved in this hypothesis refer to Appendix A.

Table 1.9 Per Capita Cost Savings as a Form of Benefit

Leakage Source	Per Capita Cost Savings	Allocation Minimum Cutoff (Some % at 24 Hours Service)
Domestic	929,072.50	2,228,129.51
Institutional	471,289.10	967,769.29
System Wide	291,647.60	882,006.06
Combined	1,526,176.67	3,425,765.82

Table 1.9 shows that the per capita cost savings produce a lower estimate of the household benefits. This is despite the fact that 100% of the households are provided with per capita cost savings but only 73.87% to 21.43% are provided with daily 24 hours of water service under the second allocation mechanism.

7. CONCLUSION

This study estimated the benefits of reducing domestic, institutional, and system wide leakage and waste in mitigating the household's water service unreliability in the residential sector of Cairo. It shows that households are willing to pay for daily 24 hours of water service and eliminate the risks of unannounced water cutoffs and low pressure incidents. Households are willing to pay more to avoid longer cutoffs and low pressure incidents.

Due to water quantity limitations, the mechanism taken to allocate the conserved water among the households with unreliable service affects the value of the estimated total households' benefits. Allocating the limited conserved water equally among households with unreliable water service does not bring maximum benefits. The maximum benefit is obtained when the households are ranked and the conserved water is allocated starting with those with the least unreliability problem. Such allocation allows more households to obtain daily 24 hours of water service and captures the risk premium they are willing to pay to entirely eliminate unreliability.

Limiting conservation benefits to supply cost savings, suggested in previous literature, is found to underestimate the value of conservation programs to the household. Such an analysis does not account for those households that are willing to pay to completely eliminate the risks associated with unreliability.

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Appendix 1. Per Capita Cost Savings as a Form of Household Benefits

Three steps are taken to estimate per capita cost savings as a form of household benefits. In the first step, a water authority's cost function is estimated using regression analysis. This cost function relates total maintenance and operation costs to the quantity of water produced. In the second step, the estimated cost function is used to calculate cost savings due to conservation. In the third step, a rule is developed to allocate the cost savings among the households in the service area.

Theoretical Background

Physically, it is possible to separate the water supply system into two components: the treatment plant and the delivery (transmission and distribution) system [Clark, 1976; Clark and Stevie, 1981; Koenig, 1966]. Economies of scale (at the treatment plant level) may be offset by diseconomies of dispersion and spatial arrangement at the distribution level [Dajani and Gemmell, 1973; Marks, Revelle, et al., 1970; Linaweaver and Clark, 1964; Ford and Warford, 1969].

Despite that, empirical studies suggest that the relationship between costs (TC) and the amount of water produced (Q), given input prices, can be reduced to an exponential function of the following form [Clark and Gillean, 1977]:

$$\begin{aligned} &TRC = TC(Y) = \alpha Q^{\beta}, \text{ and} \\ &\partial TC / \partial Q > 0 \\ &\alpha > 0 \text{ and } 1 \geq \beta \geq 0 \end{aligned} \tag{10}$$

Estimates of the cost function's parameters (α and β) are obtained by using a logarithmic functional form in which the log of the dependent variable (TC) is regressed on the log of the independent variable (Q). After estimating the parameters, it is a matter of substituting data on Q (the quantity of water conserved) to obtain the cost savings required.

Second, a rule is established to distribute the estimated cost savings among the households in the service area. The rule applied in this analysis assumes that the water authority divides the cost savings of not producing the conserved water equally among the households served:

$$\begin{aligned} f &= \psi \, TC(Q) \\ \text{where, } 0 &< \psi \; 1 \\ \psi &= 1/N \end{aligned} \tag{11}$$

Where N is the total number of households receiving water in the service area.

Data Requirement

With the exception of one year, detailed cost data was not available from the General Organization of Greater Cairo Water Supply [Center for Development Information and Evaluation, ; CH2M Hill International, 1990]. Available cost data was not adequate to estimate both the parameters (α and β) of the cost function specified in equation (1). The following two steps were taken instead: First, the parameter β is estimated using detailed US data. The β parameter reflects the returns to scale to the technology employed by the water authority. In Cairo, such a technology is mostly supplied through U.S. investments in capital and personnel training [CH2M Hill International, 1990]. Hence, U.S. data provides a close substitute for Cairo data. The American Water Works Association collected detailed data on cost and quantities of water produced from 898 member water utilities. Utilities used in this analysis were closer to that of Cairo's in their sources of supply (the use of ground and surface water) and their size ranging to those serving 16 million people [American Water Works Association, 1996].

Second, after the parameter β is estimated, data obtained from the Central Organization of Greater Cairo Water Supply is used to calculate the parameter α in equation (1). This parameter reflects the level of cost rather than the type of technology and how it is utilized in the production process. Hence, the use of Cairo data was required to obtain a reliable estimate.

Results

The following cost function was estimated using a combination of US and Cairo data[18]:

$$\begin{aligned} TC &= 801.1\ Q^{0.83} \\ N &= 579 \\ R^2 &= 0.73 \end{aligned} \qquad (12)$$

Where TC represents operating and maintenance costs (including routine and preventive maintenance, salaries, wages, and benefits, chemicals, power, and other process inputs, but do not include funds to replace capital investments)[19]. Q is the quantity of water produced in million gallons per day and N is the number of water utilities used in the estimation. The cost function in equation (12) is used to obtain per capita cost savings based on the projected population of the East Bank for the year 2000 (estimated at 12,531,032

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[18] Results are also checked against the cost of water per cubic meter in Cairo as reported in USAID documents [31]. Results obtained from the cost estimates in this study were within $0.0026 of those reported in USAID documents.

[19] The assumption of using operation costs rather than total costs stems from the fact that capital costs do not change by much with the change in output for water utilities in the short run [Clark and Gillean].

people) and using an average household size of 6 individuals (average family size in the sample).

ESSAY 2:
WILLINGNESS TO PAY FOR WATER RELIABILITY IMPROVEMENT: A CASE STUDY OF DEFENSIVE TECHNOLOGIES IN CAIRO, EGYPT

1. INTRODUCTION

In the presence of adverse environmental effects, households affected often take voluntary defensive measures, including the adoption of technologies, that can help reduce the risk of such adverse effects. In previous literature the cost of technology and its ability to mitigate the risk faced by those affected were emphasized as major determinants of adopting defensive technology [Courant and Porter, 1981; Gerking and Stanley, 1986; Harford, 1984; Bartik, 1988; Murdoch and Thayer, 1990]. Adopting defensive technologies affects the value of the household benefits (as measured by willingness to pay) derived from programs aiming at reducing the adverse environmental effects [Abdalla, 1990; Lee and Moffitt, 1993; Dardis, 1980; Watson and Jaksch, 1982; Jakus, 1994]. A review of the previous literature identifies two issues of interest regarding the relationship between willingness to pay, cost, and risk mitigation.

First, a tradeoff exists between defensive technologies' cost and their ability to mitigate risk and the value of willingness to pay. On the one hand the defensive expenditure literature argues that the higher the ongoing costs of defensive technologies, the higher are the benefits from programs aiming at reducing the adverse environmental effects, and the higher is the willingness to pay for them. Hence, higher ongoing costs have an upward effect on willingness to pay [Courant and Porter, 1981; Gerking and Stanley, 1986]. On the other hand, the technology adoption literature argues that the higher the ability of defensive technologies to mitigate the risk associated with the adverse environmental effects, the higher will be the demand for such technologies. In that case, willingness to pay for programs aiming at reducing the adverse environmental effect is reduced since households already obtain the program's benefits from investing in defensive technologies. Hence, the higher ability of defensive technologies to mitigate risk have a downward effect on willingness to pay.

Second, the costs of defensive technologies can be used to obtain some information on the magnitude of willingness to pay for programs aiming at reducing adverse environmental effects[1]. The defensive expenditure literature argues that the cost of defensive technologies may constitute an upper or lower bound on willingness to pay depending on their success in mitigating the risks of the adverse environmental effect compared to proposed programs aiming at achieving the same purpose. If defensive technologies are not successful in reducing the adverse environmental effect, then their costs constitute a lower bound on willingness to pay. Willingness to pay for programs aiming at reducing the adverse environmental effects exceeds the defensive technologies' on going costs to reflect the willingness of households to pay a premium to enjoy more protection against risk [Harford,1984].

The purpose of this paper is to address how households' adoption of defensive technologies, such as water storage tanks and electrical water pressure boosting pumps, affects their willingness to pay for a program that aims at reducing water service

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[1] One of the major benefits of defensive expenditure models is that they allow willingness to pay be estimated using only information on protective opportunities. This benefit is particularly useful when prior information on protective opportunities is more reliable than information on willingness to pay or if it is costly to collect willingness to pay data directly [Bresnahan and Dickie].

unreliability. It collects data from heads of households in Cairo, Egypt to test the following two hypothesis:

1. Willingness to pay for better water service is lower for households investing in two defensive technologies if compared with willingness to pay of households investing in only one technology. This indicates that the upward effect of higher costs (associated with a double technology) on willingness to pay is stronger than the downward effect of more risk mitigation using two technologies.
2. Operation and maintenance costs of defensive technologies constitute a lower bound on willingness to pay for more reliable water service. Willingness to pay will be higher than such costs implying that defensive technologies are not entirely successful in eliminating the risk of inadequate water service.

This paper is divided into six sections. The first section provides a background of the problem. The second section develops a theoretical model. The third section discusses the data. The fourth section describes the empirical methods. The fifth section presents the results. The sixth section provides some concluding remarks.

2. BACKGROUND

The one certainty in Cairo today is its critical residential water shortage. The demand for residential water exceeds the system's capacity. The available water is barely enough to meet the growing uses [Hoehn and Krieger, 1996]. Those who are connected to the municipal service often receive water only part of the day and typically at inconvenient hours. Inadequate water service is characterized by routine reductions in water pressure or complete cutoffoffs. Low water pressure and complete cutoff off in service are frequent enough that households need to supplement from other sources outside the home [Tecke, Oldham and Shorter, 1994]. Sources outside the home are often of lesser quality and of higher cost. In an effort to protect themselves against inadequate water service, Cairo households often engage in voluntary defensive actions to mitigate or totally avert the consequences of poor water service [Hoehn and Krieger, 1996; Rada Research and Public Relations Co., 1994].

Households have a set of defensive actions available to them to reduce the effects of inadequate service. Households adapt their activities by performing water intensive chores at less convenient times when sufficient water is available, often late at night [Hoehn and Krieger, 1996]. In addition, households buy bottled water and store water for essential uses such as drinking or cooking [Tecke, Oldham and Shorter, 1994]. They also store larger amounts of water for other uses. Storing water is messy, takes up space, inconvenient, and time consuming [Hoehn and Krieger, 1996]. Storing can also reduce the quality of water as well as involve the cost of purchasing storage containers [Rada Research and Public Relations Co., 1994]. Households also buy larger amounts of water and obtain free water from areas with more adequate supply. The effort, time, and money to haul and purchase water are significant costs.

Households with unreliable service often invest in water improving technologies (WIT). The main WIT used in Cairo are rooftop tanks and electrical pumps. Rooftop tanks fill when water pressure is high and provide water when system pressure fell [Hoehn and Krieger, 1996]. Electrical pumps boost pressure and are connected directly in the household dwelling [Tecke, Oldman and Shorter, 1994]. Tanks are expensive to install, difficult to maintain, and leak substantial amounts of water [CH2M Hill International, 1990]. They are also associated with lower water quality. Electrical pumps are expensive to install, maintain, and operate. They also create noise, increase electricity bills [Hoehn and Krieger, 1996]. Installing, maintaining, and operating both an electrical pump and a storage tank (a double investment) is more costly than a single investment [Rada Research and Public Relations Co., 1994]. Also, both the water tanks and electrical pumps involve substantial fixed costs at the installation phase.

3. THEORATICAL MODEL

The model discussed in this section is designed to obtain a relationship between the cost of defensive technologies, their ability to mitigate unreliability, and the household benefits (as described by its willingness to pay) from obtaining full water service. A proposed water reliability improvement program is assumed to change the water service level from a lower level of W^0 to a full level of W^{24}[2]. W^0 is the level of water service initially delivered by the water authority. W^{24} is the water level that is proposed with the reliability improvement program and is equivalent to water service 24 hours a day at full pressure. The current level of water service received by a household is denoted by $\tilde{W}$ and can be any where between W^0 and W^{24} depending on whether the household invested in a WIT and on whether such a WIT is successful in providing more reliable service. It can be described by the following equation:

$$\tilde{W} = \beta W^0 + (1 - \beta) W^{24} \tag{1}$$

[2] Water service can be viewed as the number of hours water is available at good discharge pressure.

Where $0<\beta<1$ (i.e. β can fall any where between 0 and 1). The level of β determines the success of the WIT in mitigating the household risk of unreliability. If $\beta=1$, then household's WIT is totally failing in mitigating unreliability, and the household receives a level of water service equals to W^0. If $\beta=0$, then the household's WIT it totally successful and the household is able to reduce all its risk to zero and receives W^{24} i.e. the household is able to replicate the level of water service available after the improvement program.

Assume that a household that uses a WIT derives its utility from consuming a current water service level $\tilde{W}$), and a good (X) according to the utility function:

$$U = U(\tilde{W},X) \tag{2}$$

The household decision to use the WIT depends on whether such a use improves its well being. The household optimizes its position by maximizing utility subject to a budget constraint:

$$\max\ U = U(\tilde{W},X) \text{ subject to } M = P_x X + q\tilde{W} + K \tag{3}$$

Where M is total income, q is ongoing operating and maintenance costs of providing additional water using a WIT, and K is the fixed installation cost of the WIT. The optimal level of X consumed will then be defined by:

$$X = x(P_x, M-q-K, \tilde{W}) \tag{4}$$

3.1. Willingness to Pay Calculations

The value of the water service reliability improvement program, as reflected by the household's willingness to pay, stems from the households' ability to trade some of the desirable goods and services it currently consumes to enjoy the new level of water service [Hoehn and Krieger, 1996]. If the household is willing to pay for the reliability improvement program, then a comparison of its current level of indirect utility with its post improvement program indirect utility will be a good estimate of its Hicksian[3] compensating measure of benefits [Freeman, III, 1993]. Substituting back the level of optimal X from equation (4) into the utility function provides the indirect utility function which measures the maximum level of well-being the household achieves given M, P_x, q, K, and $\tilde{W}$. This indirect utility function is defined by:

$$V = v(P_x, M - q - K, \tilde{W}) \tag{5}$$

The household's willingness to pay (wtp) solves the following equation:

$$V = v^0(P_x, M - K - q, \tilde{W}) = v^1(P_x, M - K - \text{wtp}, W^{24}) \tag{6}$$

Note that households that invested in a WIT have already suffered a sunk cost of (K) whether or not they get improved water service from the water agency. In the above equation (wtp) for full water service will include both the value of eliminating the ongoing cost of operating the defensive technology (q) as well as the value of obtaining an additional level of water service (reliability gains) measured by the difference between $\tilde{W}$ and W^{24}. From the above equation, the higher the ongoing operating costs of the defensive technology (q) the higher is willingness to pay. On the other hand, the smaller the reliability gains from

[3] Hicksian measures, as compared to Marshalian measures, assume that the individual's level of utility is kept unchanged. For more details refer to references [Freeman, III; Nicholson].

the water improvement program (i.e. the higher the defensive technology's ability in mitigating unreliable service) the lower is willingness to pay.

4. DATA

Contingent valuation was used to estimate wtp required to solve equation (6). The contingent valuation method uses survey questions to directly elicit people's preferences for non-market goods by finding out what they would be willing to pay (in money terms) for specified improvements in them. Respondents are presented with a hypothetical setting in which they have the opportunity to trade money payments for such improvements [Mitchell and Carson, 1989]. In this study, water reliability is the non-market good and the specific improvement valued is an increase from current reliability levels to daily 24 hours water service at full discharge pressure.

In comparison with other survey methods, the contingent valuation is particularly demanding in terms of questionnaire development and survey design and implementation. Issues of questionnaire development were particularly important in Cairo due to language and cultural differences and lack of previous valuation research [Hoehn and Krieger, 1996]. Hence, a multi-stage process of questionnaire design and reliability testing was incorporated. A total of nine focus groups were conducted with 69 heads of Cairo households (to establish background information necessary to develop a draft questionnaire), the draft questionnaire was pre-tested in two phases and 57 one-on-one interviews were completed in the offices of a research company in Cairo[4]. A field pretest tested the semi-final questionnaire under

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[4] Rada Research and Public Relations in Cairo organized and conducted focus groups and facilitated data collection.

conditions similar to those proposed for the final survey. Fifty in-home interviews were conducted to finalize the development of the questionnaire.

The purpose of this multistage process was to construct a plausible, intelligible, and meaningful questionnaire to the respondent, reduce miscommunication between the researcher and the respondent, and train interviewers. GIS was used to establish a data base, update Greater Cairo maps, and draw random primary sampling units (PSU) by utilizing landscape maps from the year1968 and combining them with information on administrative units and urban boundaries, population and population growth rates, and water service conditions. A total of 25 households were interviewed in each PSU. Eight hundred and ninety three heads of households completed the final questionnaire to value 24 hours of reliable water service, fifty percent of which were females.

The final questionnaire had a total of 75 questions that spread into 13 sub-sections. It contained four separate sections each collecting different type of information. The screening section determined the eligibility of the household to complete the questionnaire. The questionnaire was to be completed by households that are connected to the water system but had unreliable water service (defined as having water cutoffs and/or a level of water pressure that is too low to obtain water for meeting household needs for all or part of the day, once a week, several times a week, and everyday). The second section collected information about the level, cost, and quality of the water service currently received by the household, whether the household invested privately in an electrical pump to boost water pressure, a tank to store water or both, and the expenses incurred to improve current water service reliability (including the cost of operating and maintaining water-improving technologies).

The third section collected data on health status, housing, and socio-economic characteristics of the household.

The fourth section, the valuation scenario, had the central objective of allowing households to elicit their choice for reliability improvement and obtaining the maximum amount of money they would be willing to give up to receive it. The valuation scenario expressed the possibility of improved water service, described baseline conditions (current water pressure and payment), and post program conditions (including the elimination of water pumps or storage tanks usage, and the change in payments to the water authority). The decision setting included reminders of some of the reasons other respondents accepted or rejected the program, of budget constraints, and of the cost of the program.

The total sample of respondents was subdivided into 9 sub-samples each randomly receiving the proposed maintenance program at a different initial cost. Respondents in each sub-sample were asked to accept or reject the program at the proposed program cost. Each sub-sample received only one of the following nine costs: 20, 40, 60, 80, 100, 175, 250, 400 or 600 piasters[5] paid weekly for five years. These costs were based on a distribution of value responses obtained during the pre-testing stage [Hoehn and Krieger, 1996]. The lowest cost threshold was selected so that approximately 90% of the respondents would accept the project if they were offered it at that cost. The highest cost threshold was selected so that approximately 90% would reject the project if they were offered it at that cost. A debriefing section followed to allow the respondents the chance to discuss the reasons for their choice decision. This open-ended section encouraged respondents to reflect upon the scenario,

[5] One Egyptian pound (denoted as LE) contains 100 piasters. The 1995 exchange rate was approximately 3.3 LE to 1 US dollar.

slowed the pace of the interview, and provided later information to judge if the respondents gave careful consideration to the economic tradeoffs and the consequences of their decisions.

5. EMPIRICAL METHODS

The data collected provided a set of 893 accept/reject responses based on 9 different cost categories. The probit model is used to analyze the data, calculate the mean willingness to pay for the water reliability improvement program, and test if it varies by the usage of WIT. Assume that the unobserved willingness to pay (w) can be explained using a set of indicator variables S (whether the household uses a WIT, and which one they use if any) and Y (demographic and socio-economic characteristics):

$$w_i = w(S_i, Y_i, \epsilon_i) \tag{7}$$

Where i goes from 1 to N, and ϵ_i is an error term. In this section we argue that respondent i accepts (votes yes) for the improvement program if her willingness to pay is greater than the cost (C_t) at which the program was proposed to her. The (t) goes from 1 to 9 in our analysis depending on the sub-sample interviewed. She will reject (votes no) otherwise. Hence, the following must be true for a respondent who accepts the water improvement program:

$$w(S_i, Y_t, \epsilon_i) > C_t \tag{8}$$

If we choose a linear function to represent the relationship between willingness to pay and its explanatory variables, the probability of the respondent accepting the program at a given program cost could be presented as follows:

$$Prob_i(Yes/C_t) = Prob[(\beta_0 + \beta_1 S_i + \beta_2 Y_i + \epsilon_i) > C_t] \tag{9}$$

We assume that ϵ_i is identically and independently distributed as normal with a mean of zero and a standard deviation of σ, move C_t to the other side of the inequality, and use a standardized normal distribution to obtain the following equation:

$$Prob_i(Yes/C_t) = Prob\{[(\beta_0 + \beta_1 S_i + \beta_2 Y_i - C_t)/\sigma] > -\epsilon_i/\sigma\} \tag{10}$$

The probit regression is used to estimate the values of the coefficients in equation (10) and the standard deviation (σ) which maximize the log likelihood function:

$$LogL = \sum_{i=1}^{n} \{d_i \log[1 - \Phi((K_i\beta - C_i)/\sigma)] + (1 - d_i)\log[\Phi((K_i\beta - C_i)/\sigma)]\} \tag{11}$$

Where (n) is the total sample size (equals to 893), d_i is a dummy variable (equals one if the respondent accepts the program and zero otherwise), K_i is a vector of explanatory variables (S_i, Y_i), σ is the standard deviation of the estimated distribution, and Φ(.) is the cumulative density function of the normal distribution [Cameron and James, 1987].

6. RESULTS[6]

In our sample 19.6% reported using some form of a WIT to improve their water service (a pump, a tank, or both). The capital cost of installing a water pump or a storage tank ranged from 1400 LE ($424.24) to 500 LE ($151.52) depending on capacity (equivalent to 160%-57% of average monthly income)[7]. Operating costs are usually higher for a double investment (both a pump and a tank). It costs an average of 4.35 LE ($1.32) per month to maintain and operate water pumps and 5.35 LE ($1.62) to operate both water storage tanks and pumps. These costs are for achieving the current level of water service (less than 24 hours).

Table 2.1 provides the percentage of households at each cutoff duration. The table shows lower concentration of households at extreme water cutoffs duration (too short or too long). The table also indicates that using defensive technologies does not necessarily eliminate the unreliability problem since not even a single household in the sample reported a zero cutoff duration.

Table 2.1 Percentage of Households in Each Duration

Duration of Cutoffoffs (Hours per Day)	Percentage of Households (%)
1 to 3 hours	6.98
3.5 to 6 hours	14.82
6.5 to 9 Hours	18.62
9.5 to 12 Hours	17.73
12.5 to 15 Hours	5.99
5.5 to 18 Hours	15.26
8.5 to 21 Hours	7.12
1.5 to 24 Hours	3.48

[6] For descriptive statistics see appendix A.

[7]7 Based on an annual income of 10447LE ($3165.76) in 1995 prices.

6.1. Testing the Hypothesis:

One: Willingness to pay for better water service is lower for households investing in two defensive technologies if compared with willingness to pay of households investing in only one technology. This indicates that the upward effect of higher costs (associated with a double technology) on willingness to pay is stronger than the downward effect of more risk mitigation using two technologies.

Table 2.2 provides the probit estimates of willingness to pay as a function of selected independent variables.

Table 2.2 Probit Estimates of Willingness to Pay

Variable Definition Probit on Accept/Reject Base Group: Used both a Pump and a Tank N=175	**Estimated Coefficients and Standard Errors** Significant at a= 0.00, 0.05* Significant at a= 0.10**
Constant Term	5.83 (1.5)*
Used only a Pump	-1.87 (1.1)**
University Degree	1.75(0.80)*
Large Apartment	1.78(0.81)*
Frequent Water Bills	-4.31(2.1)*
Standard Deviation	3.39(0.66)*
Log Likelihood Value	-120.95
McFadden's R Square	0.20
% Correct Predictions (Total)	71%
% Correct Predictions (Accept)	77%
% Correct Predictions (Reject)	65%
Chi-square (df)	47.73 (5)

The coefficient on "used only a pump" variable was negative and significantly different from zero at less than the 10% level indicating that respondents who used only a pump are willing to pay less for the water reliability improvement program compared to those who used both a pump and a tank. Since it costs less to operate only a pump than both a pump and a tank and since it is expected that a double technology is more successful in mitigating unreliable service when compared to a single investment, the results indicate that the upward effect of higher costs on willingness to pay is stronger than the downward effect of more risk mitigation using two technologies.

Those with a university degree were willing to pay more for the reliability improvement program. Having higher education might imply that the respondent earns more income. Also, it might imply that the value of the respondent's time is higher. Since adapting to water shortages requires a lot of time and effort, the respondent with a university degree might value water reliability more. Also, a more educated respondent might have more concerns about water quality. In the case of unreliable water service, respondents might need to store water and rely on other sources that are of lesser quality. Respondents with larger apartments were willing to pay more for the reliability improvement program. This might be due to the fact that respondents with larger apartments needed more water to clean, or due to the fact that having a larger apartment indicates earning more income.

Finally, if the respondent paid for piped water more frequently (once or twice a month) she will be willing to pay less for the reliability improvement program. Water is not metered in Cairo and respondents have to pay a fixed water fee regardless of the amount of water they actually consume. If the fixed fee is paid more often the amount of money available for other goods, including the reliability program, is reduced. If the respondent had to pay for water according to the amount she consumes, then unreliable water service implies lesser quantities consumed, and frequent water bills need not necessarily mean higher water cost. However, when water is not metered and fixed fees are paid, the higher frequency of water payments implies a higher water cost. Note that the cost at which the reliability program was proposed does not include paying for the water consumed and hence the household needed to set aside some money for paying for water before eliciting its willingness to pay.

> Two: Operation and maintenance costs of defensive technologies constitute a lower bound on willingness to pay for more reliable water service. Willingness to pay will be higher than such costs implying that the defensive technologies are not entirely successful in eliminating the risk of inadequate water service.

Using the estimated coefficients, a mean willingness to pay value was calculated for those who used only a pump and those who used both a pump and a tank. The former group is willing to pay LE 3.18 ($0.96) per week for the water reliability improvement program compared to LE 5.05 ($1.53) for those with both a pump and a tank. The average yearly income for the household is reported to be LE 10,447 ($3165.76). Using this figure, the willingness to pay amounts are 2.4% of monthly income for those who used both a pump and a tank, and 1.5% for those who used only a pump. These willingness to pay figures are higher than the ongoing costs of operating and maintaining defensive technologies reported above. These results imply that the defensive technologies are not entirely successful in eliminating the risk of inadequate service. This is also supported in table 1 using sample data.

7. CONCLUSION

In the case of unreliable water service, Cairo households invest in water improving technologies (WIT) to defend themselves against the adverse effects of not having enough water. The defensive expenditure literature suggests that the higher the costs currently incurred by the household when using defensive technologies, the higher would be the household's benefit from a program that improves reliability. On the other hand, the technology adoption literature suggests that risk reduction is a major determinant for the demand for technology. If the technology is successful in mitigating the risk (in our case inadequate water service), the household's willingness to pay is less likely to be high for a program that provides more reliable water service. The household already obtains the program's benefit through their investment.

This paper finds that willingness to pay for full water service is lower for those households investing in two WIT as compared to willingness to pay of those investing in single WIT. Households with both a water storage tank and an electrical pressure boosting pump are willing to pay LE 5.05 ($1.53) while those using only a pump are willing to pay LE 3.18 ($0.96) per week. These estimates are found to be 2.4% and 1.5% using average household income in Cairo. A double technology (both a pump and a tank) costs more to operate and maintain but is more likely to be successful in mitigating inadequate water service. The findings, however, indicate that the upward effect of higher costs of a double investment on willingness to pay is stronger than the downward effect of more risk mitigation using two technologies.

The defensive expenditure literature also suggests that the cost of defensive measures constitutes a lower bound on willingness to pay to avoid adverse environmental effects if the defensive measure is not successful in totally eliminating the adverse environmental effects.

The paper finds that operation and maintenance costs of defensive technologies constitute a lower bound on willingness to pay for full water service. Willingness to pay for both groups (those investing in a single and a double technology) was higher than the costs incurred by the household to obtain the current level of water service (less than 24 hours).

It costs an average of LE 1.04 ($ 0.32) per week to maintain and operate water pumps and LE 1.27 ($0.38) per week to operate both water storage tanks and pumps. Such finding imply that the defensive technologies used by households are not completely successful in eliminating the risk of inadequate water service.

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Appendix 2

Table A2.1 provides some family characteristics of interviewed households. The table shows that those who used a double investment were on average more educated. The table also shows that those with a double investment had smaller families with a lower number of children under the age of 5.

Table A2.1 Selected Family Characteristics of Sample Households

Characteristic	Whole Sample	Using a Pump	Using a Pump and Tank
Senior Female:			
Age (Years)	40	39	40
Completed at Least Primary Education (%)	60	72	84
Obtained at Least a University Degree (%)	20	27	50
Senior Male:			
Age (Years)	44	44	49
Completed at Least Primary Education (%)	69	79	87.5
Obtained at Least a University Degree (%)	35	47	62.5
Number of Household Members:			
All Ages (Number)	4.7	4.7	4.6
Females 14 Years of Age or Older (Number)	1.7	1.6	1.9
Males 14 Years of Age or Older (Number)	1.6	1.6	1.7
Less Than 5 Years Old (Number)	0.4	0.5	0.3

Table A2.2 shows some selected characteristics of the households' dwellings. On average, a higher percentage of those with a double investment lived in apartments as opposed to rural houses. They also had a higher percentage of owners as opposed to renters. Their dwellings were larger on average (more number of rooms) and more likely to have special use rooms such as dining rooms. The table also shows that this group had a higher percentage of dwellings with finished floors (either wood, stone, tiles, carpet, or linoleum) and with finished walls (either plaster, paint, wallpaper, or wood). The table indicates that those with a double investment had more access to public infrastructures and services such as paved streets, public transportation, and sewer connections.

Table A2.2 Selected Characteristics of Respondents' Dwelling

Dwelling Characteristics	Whole Sample	Using a Pump	Using a Pump and a Tank
Apartments (%)	89	94	97
Rural Houses (%)	10	6	3
Owner Occupied (%)	47	45	59
Renter Occupied (%)	53	55	41
Number of Rooms	5.8	6.1	6.3
Separate Dining Room (%)	22	34	41
Finished Floors (%)	96	100	100
Finished Walls (%)	92.4	92.7	100
Building Facing Paved Street (%)	42	48	81
In-home Sewer Connection (%)	81	84	100
Average Walk Time from Nearest Public Transportation (min)	11.1	10.3	7.2

Table A2.3 provides information on some of the variables that might approximate the household's income level.

Table A2.3 Some Variables to Approximate Household's Income

Variable	Whole Sample	Using a Pump	Using a Pump and Tank
Head Female Employed as a Professional (%)	4	6	9
Head Male Employed as a Professional (%)	17	24	31
Number of Earners in the Household	1.2	1.3	1.2
Total Annual Expenditure (000LE)	6.9	7.2	7.5
Value of Occupied Dwelling (000LE)	44.3	47.8	76.7

Table A2.3 shows that on average households that used both a water pump and a tank did not have more members working outside the home for cash. However, this result does not mean they might have a lower household income. This conclusion is because the heads of households in this group had higher quality jobs. A higher percentage of heads in this group are employed as professionals (for example doctors, engineers, and accountants) . On average, those who employed a double investment had more valuable dwellings (in terms of expected selling price). Total annual expenditure for those with both a pump and a tank was higher than the rest of the groups. Hence, on average it can be argued that households with a double investment were more affluent that other groups.

ESSAY 3:
WILLINGNESS TO PAY FOR WATER CONNECTIONS: A FEMALE PERSPECTIVE

1. INTRODUCTION

In most cultures, fetching water and adapting to inadequate water service is a job for women (Whittington et. al, 1990; Narrowe, 1989; Nadim et. al, 1980). When their households are not connected to the municipal water system, women are the prime suppliers of water for domestic use (IWTC, 1990). Hence, the provision of improved water sources, such as residential water connections, often have complex direct and indirect effects on many facets of women's lives, their households, and the community's economy (Swarna and Whittington, 1994; Bolt, 1994).

The direct benefits of a residential water connections include the reduced time and effort spent by women hauling water from remote sources to the home and the improved health and socio-economic status. A chain of indirect benefits can also be initiated. For example, if women are no longer spending time fetching and hauling water from traditional sources, they may reallocate the saved time to different activities such as food preparation, agricultural work, childcare, and leisure. The time saving reallocated to childcare, food preparation, and agricultural work may reduce child mortality and morbidity, and increase the household's income (MacRae and Whittington, 1988; Blumberg, 1989).

Despite that, direct and indirect benefits do not always translate into women's higher willingness to pay for improved water sources. A mixed evidence is found in the literature. Some studies found that females are willing to pay more for improved water sources compared to males (Whittington et al 1990; Ministry of Energy and Water Resources, Zimbabwe ,1985), while others documented the opposite results (Hoehn and Krieger 1996; Krieger and Hoehn, forthcoming).

In some communities males dominate market-oriented production and achieve effective ownership of and control over the household resources (Fernandez-Kelly, 1981; Nash, 1977; Caulfield, 1981; Afonja, 1981; Linares, 1984; Bossen, 1984). This is especially true when females do not contribute to any of the household earnings. When that happens, women might receive a fraction of the household income which they spend on purchasing items for domestic consumption including water needs (Schuster, 1982; Browner 1986; Nash, 1977). If willingness to pay estimates are conditional on the income distribution as suggested in previous literature (Swarna and Whittington, 1994), one reason for lower female willingness to pay for improved water sources might be the females' lack of control over household resources.

This paper has the broad objective of adding to the limited literature by helping explore some of the determinants of female willingness to pay for improved water sources. The program under study provides residential water connections. The paper specifically answers the following two questions:

1. Do the high female benefits from obtaining residential water connections in Cairo translate into higher willingness to pay for such connections?
2. If not, does the female lower willingness to pay for residential water connections results from controlling a fraction of the total household monthly income[1].

[1] In Egyptian culture it is not unusual for non-working women (housewives) to receive a certain fraction of the total household income. This smaller budget is used to cover domestic needs such as paying for water, buying food items, and other household needs.

This paper is divided into five sections. The first section outlines the theoretical model. The second section describes data collection procedures. The third section provides the empirical methods used to reach final results and the fourth section lays out the results. The fifth section discusses the results and provides concluding remarks.

2. THEORETICAL MODEL

The absence of a residential water connection imposes substantial costs on individuals. These costs include the money, time, and effort required to obtain water from other sources. Furthermore, the lack of a residential water connection forces individuals to consume less water than they would do if they had a water connection at home. These factors affect the individual's utility. We can define the individual's utility level prior to obtaining a residential water connection (U^0) using the following equation[2]:

$$U^0 = u^0(Y-c, E-e, W^0) \tag{1}$$

Where, Y is total income, E is the effort endowment, (c) is the money cost, and (e) is the amount of effort required to obtain water from current sources. W^0 is the amount of water the individual consumes at the present and prior to obtaining a residential water connection.

If the individual obtains a residential water connection, the money cost and effort required to obtain water from available sources will reduce to zero. The individual will pay a fixed fee (F) for consuming the new level of water[3]. Also, the individual will be able to

[2] For similar formulation see Krieger and Hoehn, forthcoming.

[3] Water is not currently priced in Cairo. Consumers are charged a fixed fee that does not vary with the amount of water they consume.

consume a higher level of water service W^1. The individual's utility after obtaining such a connection can thus be described by the following equation[4]:

$$U^1 = u^1(Y-D,E,W^1) \tag{2}$$

The economic value of a residential water connection is measured by the maximum amount of income the individual is willing to sacrifice to obtain such a connection and still maintains her pre connection level of utility. Such an economic value will be equivalent to the willingness to pay (wtp) that satisfies the following equation:

$$u^0(Y-c,E-e,W^0) = u^1(Y-F-\mathrm{wtp},E,W^1) \tag{3}$$

In this formulation, willingness to pay for a residential water connection includes the value of money cost and effort minimized (c, e), plus the value of the higher level of water the individual is able to consume as measured by the difference between W^1 and W^0. Willingness to pay will be higher the higher is the amount of water consumed with the residential water connection (W^1) and the larger the money cost (c) and effort (e) minimized.

The general equation provided in (3) can be specified for male and female heads of households as follows:

$$\begin{aligned} u^0(Y_m-c_m,E-e_m,W^0) &= u^1(Y_m-F-wtp_m,E,W^1) \\ u^0(Y_f-c_f,E-e_f,W^0) &= u^1(Y_f-F-wtp_f,E.W^1) \end{aligned} \tag{4}$$

[4] Water quality is kept constant in this analysis. We assume that the water the individual consumes now has the same quality as the water she will get with the residential water connection. This might not be true in the real analyzed situation.

Where Y_m and Y_f are income for males and females respectively, (c_m) and (c_f) are the male and female money cost and (e_m) and (e_f) are the male and female amount of effort required to obtain water from current sources. Willingness to pay by males and females are denoted by wtp_m and wtp_f respectively.

If females and males are endowed with the same effort E, and if W^0 (the amount of water used before residential water connections), W^1(the amount of water used after residential connections), and the amount of income (I) do not differ by gender (i.e. if $Y_m = Y_f = Y$), then we expect wtp_m to be less than wtp_f. This is because the money cost and effort minimized due to residential connections are higher for females (i.e. $c_f >$, $e_f > e_m$). However, if data reveals that wtp_m is more than wtp_f, then equation (4) indicates that $Y_f < Y_m$. In this paper we hypothesize that female respondents control only a fraction of total household income (such that $Y_f = \alpha Y$) where $0<\alpha<1$, while male respondents control the total household income (such that $Y_m = Y$). Hence, $Y_m > Y_f$.

3. DATA[5]

Three aspects are of interest in this section: questionnaire design and development, sample selection, and survey administration and implementation. Contingent valuation was used to estimate (wtp) required to solve equation (4) above. The contingent valuation method uses survey questions to directly elicit people's preferences for non-market goods by finding out what they would be willing to pay (in money terms) for specified improvements in them. Respondents are presented with a hypothetical setting in which they have the opportunity to

[5] The data used in this paper was collected by Hoehn and Krieger. Summary provided in this section is obtained directly from the original work of the two authors. For more details refer to Hoehn and Krieger, 1996.

trade money payments for such improvements (Mitchell and Carson, 1989). In this study a residential private water connection is the non-market good.

In comparison with other survey methods, the contingent valuation is particularly demanding in terms of questionnaire design and development, sample selection, and survey administration and implementation. Issues of questionnaire design and development were particularly important in Cairo due to language and cultural differences and lack of previous valuation research (Hoehn and Krieger, 1996). Hence, a multi-stage process of questionnaire design and reliability testing was incorporated. A total of six focus groups were conducted with 46 heads of Cairo households who are not connected to the municipal water system (to establish background information necessary to develop a draft questionnaire), the draft questionnaire was pre-tested in two phases and 50 one-on-one interviews (37 in the first phase and 13 in the second) were completed in the offices of a research company in Cairo[6].

The purpose of these pre-tests was to improve the questionnaire, especially the valuation scenario and enhance the interviewers' skills and information delivery. A field pretest tested the semi-final questionnaire under conditions similar to those proposed for the final survey. Approximately 50 residential interviews were conducted to finalize the development of the questionnaire. The purpose of this multistage process was to construct a plausible, intelligible, and meaningful questionnaire to the respondent, reduce miscommunication between the researcher and the respondent, and train interviewers.

The sample selection stage was also challenging due to the lack of updated Cairo maps. GIS was used to establish updated Greater Cairo maps and draw random primary

[6] Rada Research and Public Relations, Heliopolis, Cairo, Egypt organized and conducted focus groups, and facilitated data collection.

sampling units (PSU). Landscape maps constructed in 1968 (the most recent at the time of the survey) were combined with information on administrative units and urban boundaries, population and population growth rates, water network connection rates to establish the GIS database. A total of 25 households were chosen in each PSU. Candidate PSU had a water connection rate of less than 40%. One thousand and two respondents completed the final questionnaire to value the provision of water network services to households previously not connected to the water system. The response rate was 73%.

The final questionnaire had a total of 74 questions that spread into 12 sub-sections. It contained four separate sections each collecting a different type of information. The screening section determined the eligibility of the household to complete the questionnaire. The questionnaire was to target households that are not connected to the government piped water system. The second section collected information about the sources of both free and purchased water, the money, time and effort cost of acquiring water from current sources, and the perceptions of the respondents regarding piped water and how it compares to water obtained from current sources. The third section collected data on the characteristics of the respondent's housing and property value, family composition and health status, and characteristics of family heads. The questionnaire also provided the interviewers the chance to collect visual observations about the respondent's building and neighborhood.

The fourth section, the valuation scenario, had the central objective of allowing respondents to elicit their choice for having a residential water connection and obtaining the maximum amount of money they would be willing to sacrifice to receive it. The valuation scenario expressed the possibility of residential connections, described a hypothetical program that would install a water network in the respondent's neighborhood. It further described baseline conditions (current water sources with no payments to the water authority) and the post program conditions (including renewed payments to the water authority for the coming five years).

The decision setting included reminders of some of the reasons other respondents accepted or rejected the program, of budget constraints, and of the cost of the program. The total sample of respondents was subdivided into 9 sub-samples each receiving the program at a different initial cost. Respondents in each sub-sample were asked to accept or reject the program at the proposed program cost. Each sub-sample received only one of the following nine costs: 100, 150, 200, 250, 300, 450, 600, 750, or 900 piasters[7] paid weekly for five years. These costs were based on a distribution of value responses obtained during the pre-testing stage (Hoehn and Krieger, 1996). The lowest cost threshold was selected so that approximately 90% of the respondents would accept the project if they were offered it at that cost. The highest cost threshold was selected so that approximately 90% would reject the project if they were offered it at that cost. In addition to covering the cost of network installation, these payments covered the cost of the water consumed.

The provision of water service was conditional upon the continuity of payments. Also, to reduce free riding, respondents were assured that other households in the neighborhood will pay their share of the program cost. A debriefing section followed the valuation process to allow the respondents the chance to discuss the reasons for their choice decision. This open-ended section encouraged respondents to reflect upon the scenario, slowed the pace of the interview, and provided later information to judge if the respondent

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[7] One Egyptian pound (denoted as LE) contains 100 piasters. The 1995 exchange rate was approximately 3.3 LE to 1 US dollar.

gave careful consideration to the economic tradeoffs involved and the consequences of their decisions.

4. EMPIRICAL METHODS

4.1. The General Empirical Model

The data collected provided a set of 1002 accept/reject responses based on 9 different cost categories. The probit model is used to estimate the mean willingness to pay for the water connection and test if it varies by gender. We assume that the unobserved willingness to pay (w) can be explained using a set of indicator variables S (gender) and Y (other characteristics):

$$w_i = w(S_i, Y_i, \epsilon_i) \tag{5}$$

Where i goes from 1 to N and ϵ_i is an error term. In this section we argue that respondent i accepts (votes yes) for the improvement program if her willingness to pay is greater than the cost (C_t) at which the program was offered to her. (t) goes from 1 to 9 depending on the sub-sample interviewed. She will reject (votes no) otherwise. Hence, the following must be true for a respondent who accepts the improvement program:

$$w(S_i, Y_i \epsilon_i) \succ C_i \tag{6}$$

If we choose a linear function to represent the relationship between willingness to pay and its explanatory variables, the probability of the respondent accepting the program at a given program cost could be presented as follows:

$$Prob_i(Yes/C_t) = Prob[(\beta_0 + \beta_1 S_i + \beta_2 Y_i + \epsilon_i) \succ C_t] \tag{7}$$

We assume that ϵ_i is identically and independently distributed as normal with a mean of zero and a standard deviation of σ, move C_i to the other side of the inequality, and use a standardized normal distribution to obtain the following equation:

$$Prob_i(Yes/C_i) = Prob\{[(\beta_0 + \beta_1 S_i + \beta_2 Y_i - C_i)/\sigma] > -\epsilon_i/\sigma\} \tag{8}$$

The probit regression is used to estimate the values of the coefficients in equation (8) and the standard deviation (σs) which maximize the log likelihood function:

$$LogL = \sum_{i=1}^{n} \{d_i \log[1 - \Phi((K_i\beta - C_i)/\sigma] + (1 - -d_i)\log[\Phi((K_i\beta - C_i)/\sigma)]\} \tag{9}$$

Where (n) is the total sample size (equals to 1002), d_i is a dummy variable (equals one if the respondent accepts the program and zero otherwise), K is a vector of explanatory variables ($S_{i,}$, Y_i), σ is the standard deviation of the estimated distribution, and Φ(.) is the cumulative density function of the normal distribution.

4.2. Using the Estimated Model to Address the Questions of Interest:

Cameron and James, 1987 argued that the above empirical formulation produces a willingness to pay equation that can be interpreted analogously to the results obtained from ordinary least squares OLS regression. This willingness to pay equation takes the following general form:

$$wtp_i = \beta_0 + \beta K + \epsilon_i \tag{10}$$

where K_i is a vector of explanatory variables (S_i, Y_i).

Substituting for some of the variables in the vector (K), two of the resulting equations are of interest:

$$wtp = \beta_0 + \beta_1 \text{ household cash income}_i + \beta_3 \text{ other factors} + \epsilon_t \qquad (11)$$

where "household cash income" is a continuous variable that measures the monthly household cash earnings.

If female =1, then the above equation reduces to:

$$wtp_i = [\beta_0 + \beta_2] + \beta_i \text{ household cash income}_i + \beta_3 \text{ other factors} + \epsilon_i \qquad (12)$$

The intercept is now $[\beta_0 + \beta_2]$ instead of β_0. The intercept is smaller than that in equation (11) if females are willing to pay less for residential connections (i.e. if $\beta_2 < 0$). The marginal effect of the variable "household cash income" is the same for male and female respondents and is measured by the coefficient (β_1).

The assumption that females lower willingness to pay results from controlling a fraction (α) of "household cash income", can be tested using the following equation:

$$\begin{aligned} wtp_i = \beta_0 + \beta_1 \text{ household cash income}_i + \beta_2 \text{ female}_i + \\ \beta_1(1-\alpha) \text{ female}_i * \text{ household cash income}_i + \beta_3 \text{ other factors} + \epsilon_i \end{aligned} \qquad (13)$$

or alternatively,

$$\begin{aligned} wtp_i = \beta_0 + \beta_1 \text{ household cash income}_i + \beta_2 \text{ female}_i + \\ \delta \text{ female}_i * \text{household cash income}_i + \beta_3 \text{ other factors} + \epsilon_i \end{aligned} \qquad (14)$$

when female =1, then equation (13) reduces to:

$$wtp_i = [\beta_0 + \beta_2] + (\beta_1 * \alpha) \text{ household cash income}_i + \beta_3 \text{ other factors} + \epsilon_i \tag{15}$$

In this formulation, we assume that the intercept $[\beta_0 + \beta_2]$, and the marginal effect of the variable "household cash income" as measured by (β_1) are the same for male and female respondents. Equation (15) estimates (*wtp*) if female respondents control a fraction (α) of the household cash income. Hence, to answer the second question of whether lower female willingness to pay results from controlling a fraction of total household income, the coefficient on the interaction term "female*household cash income" as measured by (δ^*) in equation (14) needs to be negative and statistically significant.

5. RESULTS

5.1. Numerous Benefits[8]

The benefits from residential water connections to women in Cairo are mainly the elimination of the time and effort required to secure water from sources outside the home and the potential reduction in adverse health impacts. Table 3.1 shows the current sources of water used by the households in the sample.

[8] Results reported here are from sample data, focus group and qualitative results, and previous research.

Table 3.1 Current Water Sources

Current Water Sources	Responses
Water At Cost	
All Sources (%)	18
Filled Containers at a Private Tap (%)	2
From A Vendor (%)	66
Paid Someone to Fill Containers (%)	31
Paid Someone to Fill Water Tanks (%)	1
Total for Water At Cost (%)	100
Water At No Cost	
All Sources (%)	82
From Hand Pumps (%)*	60
From Local Property Owners** (%)	25
From Public Taps (%)	8
From A Mosque or School (%)	7
Total for Water At No Cost (%)	100
Total for All Current Water Sources (%)	100

* These are usually installed inside the household premises.
** From a neighbor, shot, café, or garage.

The table indicates that only 18% of the households in the sample obtained their water at a monetary cost. This cost is either to cover the purchase of water, the labor to transport it, or both. In the above table, only the three categories: paying someone to fill containers, paying someone to fill water tanks, and obtaining water from hand pumps require minimum or no household labor. Hence, the current water sources utilized by the sample place a heavy demand on the household's labor as they depend on household members transporting water from the source to the home. In Cairo, 90% of this labor is provided by females with more than 80% of the household water supplied by adults and 10% by female children (Nadim et.al, 1980; Rada, 1994).

The time and effort spent collecting water are determined, among other things, by the number of trips completed to the water source, the number of people available to help bring water to the home, the distance to the water source, the terrain to be traversed, and the waiting time at the water source. Table 3.2 provides information on some of these factors.

Table 3.2 Factors Affecting Effort and Time

Factor	Water At No Cost	Water At Cost
Trips Per Week	10	5
Help in Last Trip (Persons)	1.5	1
Time Last Trip (Min.)	56	48
Hours Spent Per Week (HH)	8.4	4
Hours Spent Per Week (fem.)	7.56	3.6

Those who obtained water at no monetary cost completed more trips to water sources outside the home but at the same time they had a larger number of household members to help transport the water they needed. They also spent more time per trip on average. This might be due to the fact that they used public taps for 8% of their water. In addition to the substantial waiting time, it might take more than 15 minutes or a kilometer to walk to the nearest public tap (ibid).

Obtaining water at no monetary cost does not mean that it is cost-less. Other costs, although difficult to quantify in money terms, can be substantial. In addition to the time and effort, the embarrassment and humiliation of asking for free water and the inadequate water quality of some of the free sources are a major concern. Women in focus groups repeatedly complained about being embarrassed and humiliated when they asked for free water. They also complaint about the quality of pump water and described it as being "chemically harder" than network water. Pump water tasted bad, lessened appetite when used for cooking, and changed color when boiled and used for tea or drinking. Its chemical properties caused hair loss and made it coarse and dry, and wasted soap if used for washing clothes as it did not generate any lather (Rada, 1994).

The walk to and from the water source is often over rough terrain and in temperatures as high as 110^0 Fahrenheit in the summer. 99% of the households in the sample lived in buildings that faced unpaved streets. In addition to increasing the effort of walking, dirt streets can be slippery (especially close to the water source) increasing the risk of falling while carrying water. This creates a health hazard for the female and her children when they accompany her to the water source.

The slope of the terrain over which water is transported substantially increases the amount of effort required by women to haul water. Previous research considered the maximum possible distances to walk to water sources carrying an average weight in terms of calories of food energy consumed per day. It was found that the distance has to be shortened by almost 70% for an increase in slope of only 12 degrees (White et al., 1972). In some Cairo neighborhoods, women have to walk up the hill carrying their water containers (Nadim et. al, 1980; Rada, 1994) as well as carrying water to upper floors using the stairs. The average height of the buildings in the sample was 2.97 levels and only 2% of the sample lived in buildings with elevators. In addition to such effort, the waiting time at the water source might be substantial, especially at public taps. In some Cairo neighborhoods it sometimes takes a woman an hour to gain access to a tap (ibid).

Adverse health impacts associated with the lack of a residential water connection can result from injury due to carrying water loads, injury due to other accidents (at the water source or during transportation), intake of contaminated water, and possible reductions in water use for personal hygiene. The last two factors affect women directly and indirectly through their effect on other members of the household (especially children). In Cairo 98% of the women transport water using a cylindrical container with two handles at the top usually made of zinc or tin known as the "*bastilla*". These containers usually hold 20 to 25 liters and when filled with water weigh more than 20 kilograms (Hoehn and Krieger, 1996; Rada, 1994; Nadim et.al, 1980). Head loading is the most popular method of carrying among women in Cairo. Medical studies found that this method is one of the least efficient in terms of Oxygen consumption per minute (Curtis, 1986). The heavy jars that women balance on their heads may eventually cause pelvic disorders, complications at childbirth, headaches, and hair loss and bald spots (Rada, 1994). Also, load carrying might cause knee problems and feet ache. Women in focus groups repeatedly complained about fatigue and loss of energy due to hauling water (ibid).

Injuries due to other accidents during transportation include slipped discs, paralysis, injury to carried children, and broken backs. These are particularly probable when women walk along slippery terrain. Injuries due to other accidents at the water source can occur due to violence or effort needed to secure one's turn in line and successfully bring water to the home. Violence and fights at the water source are frequent in Cairo due to congestion. Women in focus groups reported that in the process of getting water, they are exposed to pushing, stepping on each other's feet, spilling water on one another, and getting hit by water containers. To avoid congestion times, women sometimes adapt by obtaining water very late at night (Nadim et al., 1980; Rada, 1994). In Cairo, several women reported that they had suffered miscarriages (due to being exposed to violence at the tap and being pushed by other women), bruises, cuts, and wounds (ibid). This violence, although not quantified in money terms, is a major psychological burden on women.

Table 3.3 provides some family characteristics from the sample and compares them to characteristics of other households in Greater Cairo that are connected to the water system[9].

Table 3.3 Family Characteristics

Characteristic	Connected	Sample
Average Family Size (#)	4.7	5.5
Household Water Consumption (Lit/day)	263	115.5
Per-capita Consumption	56*	21**
Females Older than 14 years (#)	1.6	1.6
Children less than 5 years (#)	0.4	0.7
Children less than 5 With Diarrhea in Last 24 Source (%)	13	23

* Lowest estimate for Liters per day for connected households in Cairo (CH2M Hill International, 1990).
** Lowest estimate for Lters per day for unconnected neighborhoods in Cairo (Nadim et al., 1980).

The average household size of the sample is higher than that of connected households. Despite the fact that the sample has a larger family size, total household water consumption is lower. Per-capita water consumption is 50% lower than the connected households. Lower water consumption rates can be justified on two grounds: it is not only that obtaining water is difficult but also disposing of it after use. Only 12% of the sample reported being connected to the sewer system (as compared to 88% in connected neighborhoods). Amounts used for personal hygiene might be affected if the household is not able to secure enough water for daily usage and this affects the health of its members (IWTC, 1990).

The table also shows that households in the sample reported a lower female to child ratio of 0.7 than those connected to the water system of 1.6. This might indicate that lesser

[9] Information on connected households is obtained from Hoehn and Krieger, 1996.

care is provided to children (if females are the prime providers of childcare). The lack of enough females to care for children is especially intensified if the limited number of available females is heavily engaged (in terms of time and effort) with water collection. The lower ratio might also indicate that children are more often taken to the water source, increasing their risks of injuries and attracting diseases.

The table also shows that the sample reported 10% higher incidents of diarrhea disease among children below the age of five. The lack of clean and adequate water is one of the major causes of incidents of diarrhea and death among children (Oduor, 1992; IWTC, 1990). This affects women indirectly since they are assumed as having the prime role in health care of children in Egypt (El-Katsha and Watts, 1993). The sample reported an average travel time to medical facilities to treat diarrhea of 44 minutes and an average waiting time of 102 minutes to receive such treatment. This time cost, to women and their households, does not include the money required to receive the treatment. Also, women might get emotionally distressed when their children get sick or die due to illness.

In the sample respondents had unambiguous positive expectations of the water they would received after installing a residential water connection. This was especially true for women. Table 3.4 shows how respondents perceived piped water in comparison to their current sources.

Table 3.4 Piped Water Compared to Current Sources

Perception	Female (% yes)	Male (% yes)
Piped Water Makes It Easier to Clean Clothes	95	91
Piped Water is Less Likely to Make Someone Sick	93	91
Piped Water Saves a Lot of Time	94	90
Piped Water is Less Likely to be Dirty	92	84

An average female respondents had higher expectations of the quality and convenience of piped water. Compared to male respondents, a higher percentage of females believed that piped water cleans clothes easier, reduces the risk of getting sick, saves a lot of time and effort, and contains lesser dirt. This table also suggests the possibility that a female might be willing to pay more (a premium) for piped water based on her perception of its quality and convenience.

5.2. Lower Willingness to Pay

The objective of this section is to answer the question "do the high female benefits, as described above, translate into higher willingness to pay for residential water connections compared to male respondents?". To test if willingness to pay differs by gender a probit model is used to estimate willingness to pay for residential water connections using the following independent variables: 1) *Household Cash Income*: is monthly household cash income (in Egyptian pounds) as measured by the pooled cash earnings of all household members who worked outside the home for cash. The average number of those who worked outside the home for cash was two persons per household. This variable does not include household assets, remittances received from abroad, and other forms of household income. The average monthly household income for the sample is $213.25. 2) *Female*: is an indicator variable that equals one if the respondent is a female. Since the interview was conducted with heads of households, female refers to the female head of the household. 3) *Rough Terrain*: is an indicator variable that describes the topography in the street where the respondent lived. This variable was based on interviewers' observations. Interviewers were asked to note whether the street facing the respondent's residence is rough or smooth. Hence, the variable rough terrain equals one if the interviewer reported a rough street. This was seen as an important factor to include based on previous literature (Curtis, 1986; IWTC, 1990). 4) *Elevator*: is an indicator variable that equals one if the respondent lived in a building with an elevator and is used to capture some of the workload required to haul water to upper floors. It is assumed that if those hauling water used the stairs, instead of an elevator, this increases their workload substantially. 5) *Interaction Term*: This variable is generated by multiplying the variables "female" and "household cash income". Table 3.5 provides the results of using these variables to estimate willingness to pay for residential water connections.

Table 3.5 Probit Estimates of Willingness to Pay

Variable Name	Estimates (standard errors)
Constant	504.63 (37.14)*
Household Cash Income	0.14 (0.07)*
Female	-84.82 (38.03)*
Rough Terrain	144.83 (78.40)*
Elevator	-264.6 (136.39)*
Interaction Term	0.05 (0.10)
Log-likelihood Function Value	-407.23
McFadden R^2	0.22
Incremental Chi-Square (df)	227.10 (6)
Correct Predictions (%)	75

•N=792. (*) indicates significantly different from zero at 5% level.

Table 3.5 shows that all the variables used (other than the interaction term) were statistically significant at the 5% level and had the expected signs as explained below. Those who lived in buildings with elevators were willing to pay less for residential connections than those without ones. The existence of an elevator reduces the effort required to haul water to upper floors and hence reduces willingness to pay for residential connections. Those with higher pooled household cash income and lived in building facing rough streets were willing to pay more for an in-home water connection. The higher the household income the higher is the willingness to pay. This finding is supported by previous literature (Swarna and

Whittington, 1994). Also, rough terrain increase the effort of hauling water and hence their existence increases willingness to pay for residential connections.

The table also indicates a difference in willingness to pay between male and female respondents keeping the level of income and other variables constant i.e. it measures the *ceteris paribus* effect of changing the gender of the respondent. The coefficient on "female" is negative. The hypothesis that the difference in willingness to pay due to gender is not significantly different from zero was tested using a student-t test and was rejected at the 5% significance level. The above estimated equation assumes a constant willingness to pay differential across different levels of income and hence represents a difference in intercepts between male and female respondents. The intercept for male respondents is 504.62 while that for female respondents is 419.80. This can be seen graphically in Figure 1.

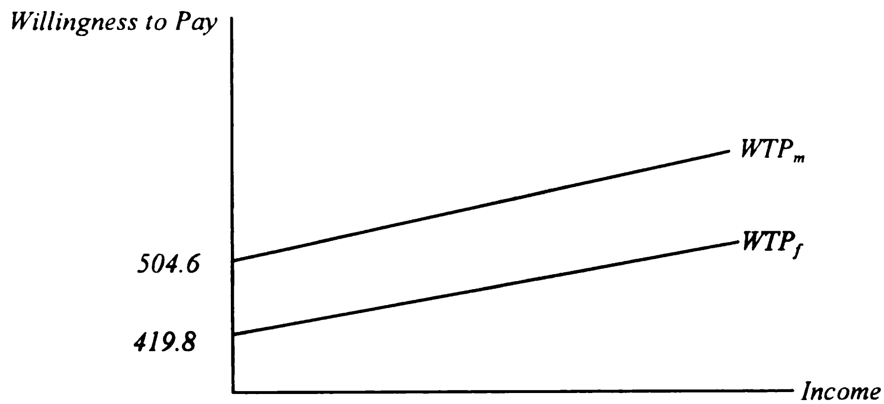

Figure 1. Willingness to Pay Differentials by Gender

Using the estimated equation in Table 3.5, willingness to pay for residential water connections for male respondents and female respondents are calculated. Table 3.6 provides the estimated results. The table shows that the estimated female willingness to pay for residential connections is lower than that of males.

Table 3.6 Mean Willingness to Pay (WTP) (Per month)

Category	LE	$
Male WTP	20.28	6.07
Female WTP	16.72	5.63

5.3. Female Control Over Budget

Tables 3.7 and Table 3.5 shows that all the variables used (other than the interaction term) were statistically significant at the 5% level and had the expected signs as explained below. Those who lived in buildings with elevators were willing to pay less for residential connections than those without ones. The existence of an elevator reduces the effort required to haul water to upper floors and hence reduces willingness to pay for residential connections. Those with higher pooled household cash income and lived in building facing rough streets were willing to pay more for an in-home water connection. The higher the household income the higher is the willingness to pay. This finding is supported by previous literature (Swarna and Whittington, 1994). Also, rough terrain increase the effort of hauling water and hence their existence increases willingness to pay for residential connections.

The table also indicates a difference in willingness to pay between male and female respondents keeping the level of income and other variables constant i.e. it measures the *ceteris paribus* effect of changing the gender of the respondent. The coefficient on "female" is negative. The hypothesis that the difference in willingness to pay due to gender is not significantly different from zero was tested using a student-t test and was rejected at the 5% significance level. The above estimated equation assumes a constant willingness to pay differential across different levels of income and hence represents a difference in intercepts between male and female respondents. The intercept for male respondents is 504.62 while that for female respondents is 419.80. This can be seen graphically in Figure 1.

Using the estimated equation in Table 3.5, willingness to pay for residential water connections for male respondents and female respondents are calculated. Table 3.6 provides the estimated results. The table shows that the estimated female willingness to pay for residential connections is lower than that of males.

5.3. Female Control Over Budget

Tables 5.7 and 5.8 indicate that those with no water connections lived in below average conditions compared to the typical resident of Greater Cairo and that within this sample females had lesser favorable conditions. Table 5.7 compares the sample to typical housing conditions in Greater Cairo[10].

Table 3.7 Characteristics of Dwellings

Characteristic	Typical	Sample
Living in Rural Houses(%)	8	2
Living in Apartments(%)	88	64
Number of Rooms	5.6	5.5
Finished Floors (%)	93	79
Finished Walls (%)	93	76
Building Faces Paved Street(%)	38	1
In Home Connection to Sewer(%)	88	12

Sample respondents are more likely to live in rural houses in the less densely settled agricultural-urban fringe of Cairo. Although the sample has below average dwellings (in terms of structure and access to infrastructures) compared to typical conditions, individuals in the sample pay higher rent for those dwellings. The average rent paid is LE 40 per month

[10] Information on typical conditions were obtained from Hoehn and Krieger, 1996.

compared to LE 22 for a typical rented dwelling[11]. The expected selling price of owner occupied dwellings, however, gave a better indication of dwellings' values and reflected local economic conditions. The mean value of owner occupied dwellings is LE 25.4 thousands for the sample compared to LE 37.3 thousands for the typical case. Table 8 provides a comparison between male and female respondents.

Table 3.8 Characteristics of Interviewed Respondents

Characteristic	Female	Male
Number Interviewed	501	501
Age (years)	37	41
University Degree (%)	5	10
Primary Education[1](%)	33	48
Professional Employment (%)	1	3
Housewives	91%	-

The sample is 50% divided between male and female respondents. These respondents are heads of households in the sense of making the financial decisions for the family. On average male respondents were older and had more education. The level of education is also reflected in employment opportunities. The majority (91%) of the female sample are housewives who do not work for cash outside the home. Only 1% of females worked as professionals.

The information presented in the above table indicated that females might be facing a tighter budget. The fact that 91% of the females interviewed reported they were housewives and did not work outside the home for cash suggested that they may be bidding from a fraction of the total household budget that is allocated for them from earners in the household for the purpose of domestic spending including water needs.

[11] Rent control laws are less in effect in the urban fringe of Cairo. Hence, landlords are able to charge higher rents therein (Hoehn and Krieger, 1996).

To test for whether lower willingness to pay resulted from only controlling a fraction of the household total budget as measured by the variable "household cash income", the interaction term defined in the above section is used. From equation (14), the coefficient on the interaction term (δ) needed to be negative and statistically significant to support the tested hypothesis. Using the results reported in table (5), the coefficient on the interaction term had the wrong sign and was not significantly different from zero at all levels. Hence, the data failed to support the hypothesis that females lower willingness to pay for residential connections results from controlling a fraction of the total household income.

6. DISCUSSION

Female respondents are willing to pay less than male respondents for residential water connections. This is despite the fact that such a program provides female respondents with substantial benefits in the form of time and effort savings as well as improved health status. The data did not support the hypothesis that the lower female willingness to pay results from controlling only a fraction of the total household income.

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