Estimating Residential Water Demand under a Progressive Price System: the Case of Amman City, Capital of Jordan

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ABSTRACT

This paper illustrates the impact of socioeconomic factors on water consumption through a study of the demand for water by households, using cross-sectional data from 1200 households and from Amman city, the capital of Jordan. For water managers, it is essential to be able to predict the change in residential water demand from any policy that would involve some change in tariffs and/or income for household. The estimated price elasticity ranged between -0.81 and -0.97; that is a 10% increase in prices is more likely to result in water saving by 8.1% to 9.7%. Income elasticity is positive but very low. Income elasticity is estimated at about 0.08. In addition, family size, education level of household and the number of adults in the family have positive impacts on water consumption. In order to control residential water demand, water pricing policy is more likely to partially reach water saving objectives, as price elasticities are inelastic. Thus, pricing policy should be combined with other measures dealing with water scarcity problems. One may argue that the current combination of progressive pricing policy and the applied water restriction measures by water utility give the right signals to the consumers of Amman city about water scarcity.

Keywords: Water policy, Water demand elasticity, Income elasticity.

INTRODUCTION

Jordan is considered one of the driest countries in the world (FAO, 1993; New Scientist, 1995). It is the fourth most deprived country in the world with a negative water balance of 20% (Denny et al., 2008). The per capita water available is less than in its neighboring countries. It has less than Israel, Saudi Arabia and most of the Gulf states and much less than any of the states of the Sahara (New Scientist, 1995).

The per capita consumption of water in Urban areas compared to other countries is also low. The per capita consumption in Jordan was only 83 lpcd in 1985, while the per capita consumption in Turkey was 85 lpcd, in Morocco 110 lpcd and in Israel 300 lpcd in the same year (World Bank, 1988; Naff, 1992).

Water scarcity has become a major problem. Supply fails to meet demand causing pressure between different users and uses. Around 1700 cubic meters per capita are required to satisfy the municipal, industrial and agricultural needs. However, the availability is estimated at 370 cubic meters per capita of all types of water. The imbalance in the population- water resource equation is more likely to continue as long as the standard of living in Jordan continues to improve at the present rate, (Haddadin et al., 2006).

Jordan total water use was 925 million cubic meters in 2006. This usage included 77 million cubic meters of nonrenewable groundwater and 80 million cubic meters of renewable water.
of treated wastewater. However, the Jordan total renewable freshwater resources were estimated at 850 million cubic meters in the same year. The total demand for water is expected to increase to 1685 million cubic meters and total water supply is expected to increase to 1289 million cubic meters per year by 2020. Thus, a deficit of 396 million cubic meters representing 24% of the total demand will remain and will have to be managed through demand-reduction programs (Abdel Khaleq and Dziegielewski, 2006; Abdel Khaleq, 2008).

This investigation focuses on the city of Amman, the capital of Jordan. A rapidly growing city of approximately 2.22 million residents is served exclusively by a single municipal provider, 'Meyahona water company'. Augmenting supplies to meet demands in Amman has been a growing challenge for several years, as rapid population growth, combined with limited opportunities to expand supply, have placed strong emphasis on demand management. In this respect, different policies have been introduced to insure an efficient water management system (Abdel Khaleq, 2008). Among these policies are: water restrictions in the form of eighteen hours per-week pumping to households all the year; a public awareness program; leakage control; encouragement of using water saving devices; and water tariffs with increasing prices over quantity, in order to improve efficiency and promote equity in the water sector.

Currently, the water utility applies a combined pricing system. The charge for the first 20 cubic meters is fixed, regardless of whether it is consumed or not. Then the price per cubic meter is increased gradually up to 130 cubic meters. Beyond this level of water consumption, the water utility applies one price that is higher compared to the level of water consumption between 21-130 cubic meters.

One of the strongest management needs is to better understand and predict how the household demands are likely to respond both to management intervention (price and water use restrictions) and exogenous factors (weather and demographic factors). The availability of this valuable information is very important to countries in the context of drought planning (Kenney et al., 2008).

This paper utilized a household level econometric model to analyze the impact of several economic (price, income) and social factors (education, household size, water saving devices,... etc.) on residential water demand for fresh water and sewage. It also aims to provide an estimate of the price elasticity of water demand using micro-level data collected from 1200 households from Amman city in 2006. This is of great importance, as pricing provides an obvious mechanism for water utilities to strategically manipulate household behavior.

**LITERATURE REVIEW**

The impact of several economic, environmental and social determinants on *per capita* demand for water and sewage in Germany was investigated by Schleich and Hillenbrand (2009). Also, an attempt has been made to explain regional differences in *per capita* residential water consumption, found to be 30% lower in the new federal states than in the old states. Their estimate of price elasticity of demand (-0.24) suggests that the response of residential water demand in Germany was inelastic, but no significance could be found between the two regions. The income elasticity decreases with higher income levels and was at least three times higher in the new federal states than in the old federal states. Price and income differences alone explained the largest part of the gap in residential water use between the two regions. The share of wells, household size and summer rainfall
have negative effects, but age of the household has a positive effect on water demand.

Water consumption has been found to be inelastic (-0.23) to price changes among the poor in Cap Town, while the richest households group respond much more to price changes (-0.99). Moreover, factors such as household size, age of the household and the plot size contributed positively to water consumption (Jansen and Schulz, 2006). The estimated elasticities for households that rely exclusively on piped water and for households using piped water but supplementing their supply with other resources have been found to be -0.74 and -0.69, respectively in southwest Sri Lanka (Nauges and Berg, 2006). Basani et al. (2008) estimated the price elasticity of demand for the connected households to be inelastic in Cambodia, falling in a range between -0.5 and -0.4.

Nieswiadomy and Molina (1989) compared residential water demand estimates under decreasing and increasing block rate using household data in Denton, Texas. The price elasticity ranged from -0.36 to -0.86 under decreasing and increasing block rate pricing, respectively. Furthermore, Nieswiadomy and Molina (1991) demonstrated that the residential water consumer responded to marginal price when faced with increasing block rate structure and responded to average price when faced with decreasing block rate. Kenney et al., (2008) found price elasticity of residential water demand to be inelastic (-0.6) throughout the year, in their study of Aurora, Colorado. Higher water users were more responsive to price changes (-0.75) than low water users (-0.34). Price elasticity during periods of drought (-1.11) was twice as much as price elasticity during periods of predrought (-0.56). Cummings et al. (2004) suggested that relatively large increases in water prices may be necessary to produce significant reductions in water use in Georgia.

The coping households use less than one fifth as much water as metered tap households do, face average water price ten times as high, are much poorer and face substantial water hauling costs in Central America and Venezuela. The estimated price elasticity being -0.1 for households with access to non-tap water and -0.3 for households without access to non-tap water (Strand and Walker, 2004), Ruijs et al. (2008) found price elasticities to range between -0.45 and -0.5 and income elasticities to range between 0.39 and 0.42 in Sao Paulo, Brazil. The poor spent between 4.2% and 4.7% of their income on water, while the rich spent from 0.4% to 0.5% of their income on water and consumed more than twice as much.

Water restrictions, the use of water saving devices and bores worked well in promoting water conservation in Perth, Australia. However, income, household size, lot size and the temperature measured by cooling degree days significantly influenced the increase in water demand. The income elasticity ranged between 0.5 and 0.6 and the price elasticity ranged between -1.05 and -1.14 (Xayavong et al., 2008).

Residential water demand was price and income inelastic in Brisbane, Australia. Moreover, price and income elasticities in owner-occupied households was greater than in rental ones (Hoffmann et al., 2005). In addition, residential water demand was more responsive to average than marginal price but price inelastic in Queen Land, Australia (Worthington et al., 2006). Water demand needs to be understood in the context of the socio-demographic composition, in different kinds of dwelling, as well as the cultural, behavioral and institutional aspects of consumption, for public policy to successfully reduce water
A significant correlation between water consumption and factors such as size of household and age of the head of household was found in Ramjerd area, Iran, by Keshavarzi et al. (2006). Mukhopadhyay et al. (2001) found residential water demand on Kuwait to depend on the number of bathrooms and rooms in the residence, garden size and weather and climate conditions. Abu Qdais and Nassay (2001) found that price elasticity of demand was low (-0.1) in Abu Dhabi.

To conclude, in line with the previous findings and mainly due to the high value the Jordanian citizens attach to the availability of water, the researcher expected that economic and social factors are more likely to moderately affect water consumption. Water is thick almost like blood to the Jordanian, so that their attitude toward efficient water use and conservation is high and form an every day issue. This is actually combined with the activated water conservation measures employed by the water utility all the year around and since years from now. Salman et al. (2008) showed the limits of the current price system to curb household water consumption in Jordan as price elasticity values are inelastic (-0.18 and -0.12). In order to regulate residential water demand, water pricing policy can partially reach water saving objectives. Al-Karablieh et al. (2006) also showed that residential water demand was inelastic (-0.47) for the Amman–Zarka Basin, Jordan. Moreover, households with lower incomes were less responsive to water prices compared to wealthier households.

DATA AND METHODOLOGY

Data

This research used the sampling frame used by the Department of Statistics in Jordan. The Department of Statistics divided Amman City into blocks and these blocks were used to randomly select our sample. Due to budget and time constraints, a decision was made to meet a maximum of 1200 heads of households.

The data collected for this investigation is unique, in part due to the availability of household level data for many variables; namely price and consumption, income, head of household level of education, family size, type of the house (apartment, single family home) and access to water saving technology.

Records of water consumption and cost for every household were available to the water authority over a long time. However, our analysis focused on a subset of residential customers and at a specified time period. Specifically, the results presented below correspond to the sample of households for which we had complete data. Household consumption over time was not considered because we missed the very important question pertaining to the length of time over which the households have been occupied by their present residents. Variables are defined in Table 1.

In this analysis, we chose to use both the marginal price and the average price of water as the price signal in the statistical analysis. Water Authority applies a cost per unit that increases when consumption increases after certain thresholds (20 cubic meters). In this way, water tariff consists of a sequence of marginal prices and average prices for different consumption rates.
It should be mentioned that much discussion has been devoted by investigators to the choice for the use of marginal or average prices in the estimation procedure. The way consumers are informed whether they respond to marginal or average prices forms an important issue. Taylor (1975)-as reported by many authors-has been one of the first researchers commenting on this. He indicated that the use of marginal price does not represent reality. He stated that there is an income effect due to the change of price when consumption moves to another consumption block. Then, Nordin (1976)-as reported also by many authors-suggested the use of marginal prices and a difference variable which represents the income effect. This variable is defined as the difference between what the bill would have been, had consumers paid for all units of consumption at the marginal price, and the actual water bill paid.

In addition to the specifications of the right price to use in the statistical analysis, investigators encountered the problem of simultaneity. That is; under a progressive price system, a simultaneity problem is more likely to occur because marginal price and average price are endogenously determined by quantity demanded. That is the explanatory variable and an error term may be correlated. Using Ordinary Least Squares (OLS), estimation yields biased and inconsistent estimates corrected for this by using a two-stage least square model 2SLS (Schleich and Hillenbrand, 2009; Kenney et al., 2008; Ruijs et al., 2008; Nauges and Berg, 2006; Strand and Walker, 2004; Nieswiadomy and Molina, 1989).

Water is billed quarterly. Thus, household consumption per billing period will be considered. Household consumption during the summer season will be considered as it represents the main issue and the big challenge to water manager. Summer season extends from May to October, covering two billing periods. In
this analysis, we chose to use the average consumption of these two billing periods.

Model

Due to the lack of agreement on the most appropriate price specification, to be used, we estimate two sets of models. The first model is based on average price and the second model is based on marginal price.

First, we estimate the relationship between water consumption and average price for predetermined quantities using OLS method. The function includes a set of other exogenous variables pertaining to household characteristics (Table 2). The same procedure is followed for the marginal price. Since average and marginal price coefficient appears with the wrong sign, we correct for this by using 2SLS method, Table 2.

The average price model is specified as follows:

\[
\ln \text{water} = \text{constant} + a_1 \text{average price} + a_2 \text{income} + a_3 \text{family} + a_4 \text{education} + a_5 \text{workers} + a_6 \text{bathrooms} + a_7 \text{showers} + a_8 \text{washing machine} + a_9 \text{dishwashing} + a_{10} \text{garden} + a_{11} \text{house} + a_{12} \text{non-tap} + a_{13} \text{w-saving} + \text{error}
\]

For the marginal price model:

\[
\ln \text{water} = \text{constant} + a_1 \text{marginal price} + a_2 \text{difference variable} + a_3 \text{income} + a_4 \text{family} + a_5 \text{education} + a_6 \text{number of workers} + a_7 \text{number of bathrooms} + a_8 \text{showers} + a_9 \text{washing machine} + a_{10} \text{dishwashing} + a_{11} \text{garden} + a_{12} \text{house} + a_{13} \text{non-tap} + a_{14} \text{w-saving} + \text{error}
\]

The results of the models are shown in Table 2.

RESULTS

One focus point, which is particularly valuable to water utility managers in drought areas like Jordan, is to better understand and predict how household demands are likely to respond both to management intervention policies such as price increases and water restrictions and to exogenous factors such as demographic changes. In this investigation, a discussion of residential water demand in a rapidly growing city "Amman" the capital of Jordan is presented, focusing mainly on the effectiveness associated with water pricing, water restrictions and households characteristics, Table 2.

Water consumption in this investigation is influenced by many factors. These include: water prices, family size, income, education level of the household head, number of workers in the family, number of showers in the house and garden for single family home, Table 2.

Water pricing provides a powerful mechanism for water utility to manipulate the consumer behavior. How demand for water moves in response to price changes is estimated through the price elasticity of demand. The estimated price elasticity of water demand in Amman city reveals to be inelastic but quite high, ranging between 0.81 and 0.97; that is a 10% increase in prices is more likely to result in water saving by 8.1% to 9.7%. This relatively high price elasticity could be attributed to the applied progressive price system by the water utility.

Microeconomic theory predicts that households will be less responsive to price changes when constrained by restrictions. Thus, when restrictions are in place, the estimated price elasticity could be smaller in value as a result of the combined effect of water restrictions and prices. To assess the impact of water restriction program, as it is in fact combined with other price and non-price management strategies in this regard, is a challenging area in estimating residential water demand.
Table 2. Estimation results for water demand for the linear and log-linear models.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (OLS)</th>
<th>Coefficient (2SLS estimation)</th>
<th>Coefficient (OLS)</th>
<th>Coefficient (2SLS estimation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>Water</td>
<td>Ln water</td>
<td>Water</td>
<td>Ln water</td>
</tr>
<tr>
<td>Average price</td>
<td>23.799***</td>
<td>-1.984691*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marginal price</td>
<td></td>
<td>33.198***</td>
<td>-1.856361***</td>
<td></td>
</tr>
<tr>
<td>RSP</td>
<td></td>
<td>-0.22***</td>
<td>0.055636***</td>
<td></td>
</tr>
<tr>
<td>Family size</td>
<td>2.168***</td>
<td>0.082037***</td>
<td>1.18***</td>
<td>0.038925***</td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td>0.000192*</td>
<td>0.0026</td>
<td>0.000194***</td>
</tr>
<tr>
<td>Education</td>
<td>1.425***</td>
<td>0.043203***</td>
<td>0.742**</td>
<td>0.004356</td>
</tr>
<tr>
<td>No. of workers</td>
<td>2.08***</td>
<td>0.071998***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garden</td>
<td>3.553*</td>
<td></td>
<td>5.205***</td>
<td>-0.036156</td>
</tr>
<tr>
<td>Bathrooms</td>
<td>3.606***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Showers</td>
<td>3.18**</td>
<td>0.129916***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-tap</td>
<td>4.036**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swimming pool</td>
<td></td>
<td></td>
<td>16.72*</td>
<td>-.567505</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.493</td>
<td>3.30808***</td>
<td>13.676***</td>
<td>3.561697***</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.198</td>
<td>0.08228</td>
<td>0.456</td>
<td>0.31866</td>
</tr>
<tr>
<td>R²</td>
<td>0.198</td>
<td>0.07607</td>
<td>0.46</td>
<td>0.3288</td>
</tr>
<tr>
<td>F statistic</td>
<td>28.00***</td>
<td>13.2986***</td>
<td>113.814***</td>
<td>32.40192***</td>
</tr>
<tr>
<td>No. of households</td>
<td>961</td>
<td>890</td>
<td>941</td>
<td>470</td>
</tr>
</tbody>
</table>

* Significant at 10%, ** Significant at 5%, *** Significant at 1%

There are numerous investigations suggesting that household water consumption is influenced by the diversion characteristics associated with differences in income, education, family size and other household characteristics.

Income of household is expected to be an important determinant of residential water demand. In this investigation, income affects positively, but moderately, water consumption. The income elasticity of demand is about 0.08 in both models. Higher income means higher water consumption. When income rises, water bill is more likely to constitute a small part of the consumer expenditure. Although in this investigation water bill accounts for about (1.7 %) of the monthly income for the high consumption group (>20 cubic meters per billing period) and about (0.43 %) for the low consumption group, the high water consumption group consumes 3.5 times as much as the low water consumption group. Therefore, as income increases, water consumption increases proportionately.
Family size positively affects water consumption. The parameter estimate associated with household size is positive and highly significant at the 1% level for all estimated models. An increase in the family size by 10% is more likely to lead to a 2% to 4.2% increase in water demand. Our results for the number of workers in the family indicate that as the number of workers increase, they consume more water. Older people might use more water for washing and hygiene or because they use the bathroom more frequently. Education also affects positively the water use. As the education level increases, water consumption increases also.

The parameter estimate for the share of showers is positive and significant at 1% level. An increase in the number of showers by 10% is likely to increase water consumption by 1.77%. Our parameter estimates for garden and swimming pool are far from being statistically significant in the 2SLS model (marginal price model). They also exhibit the wrong sign, since more gardens and swimming pools would be expected to result in a higher residential water demand for gardening or swimming activities.

SUMMARY AND CONCLUSIONS
This investigation provides empirical analysis of the water demand function of households from Amman city, the capital of Jordan. Data come from a survey of 1200 households collected during the Summer of 2006.

The resulting demand and income elasticities are very similar for both models and are in the range of results reported in other investigations. The estimated price elasticity of water demand reveals to be inelastic, but quite high, ranging between 0.81 and 0.97; that is a 10% increase in prices is more likely to result in water saving by 8.1% to 9.7%. This somewhat high price elasticity may be attributed to the applied progressive price system by the water utility. The income elasticity of demand is about 0.08 in both models. Because of the low income elasticity of residential households, the impact of a high growth in household income is more likely to be associated with a small increase in water consumption.

Family size is found highly significant and its positive coefficient illustrates that the larger the family size, the higher the water consumption per household. In addition to the previous mentioned factors, water consumption is positively affected by the head of household level of education, by the number of adults in the family and by the number of showers in the house. To conclude, in order to control residential water demand, the water utility pricing policy is more likely to partially reach water saving objectives, as price elasticities are inelastic. Thus, the pricing policy should be combined with other measures dealing with water scarcity problems. One may argue that the current combination of progressive price policy and water restriction measures gives the right signals to the consumers of Amman city about water scarcity.

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The study investigated the effect of water pricing on demand and its impact on the quality of water consumed by the residents of Amman City in the context of increasing water tariffs. The research aimed to examine the role of water pricing policy on demand and its impact on water distribution. The study area included 1200 households in Amman, Jordan. The finding revealed that with increased water tariffs, the demand for water decreased significantly, and the volume of water consumed per household also decreased. The study also showed that the decrease in water demand was not uniform across all income groups, with lower-income households being more responsive to price changes.

The results also indicated that the relationship between water demand and price was strong, with a coefficient of determination (R^2) ranging from 0.81 to 0.97. This implies that as water prices increased by 10%, the demand for water decreased by 8.1% - 9.7% for the overall population. However, in the case of households with more water consumption, the decrease in demand was more pronounced. The study concluded that effective water pricing policies could help in achieving sustainable water use and managing water demand in the long term.

The researchers recommended that water pricing policies should be adjusted to reflect the economic conditions of different income groups, allowing for more effective demand management and water conservation.