Residential Water Demand Elasticity in Greater Amman Area

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ABSTRACT

Jordan will face more water shortage in the future due to the imbalance between the scarce water resources and the growing demand that threatens to reduce the availability of water, especially for domestic uses. This study aimed to express the household water demand function by estimating two water demand models and test the significance of different household socioeconomic factors and the effect they have on the residential water demand. A panel of 600 observations were drawn from the field survey that was as part of MEDITATE project and used to estimate household water demand and the *per capita* water demand models using Two-Stage Least Squares (2SLS) method taking different variables into consideration such as marginal price, rate structure premium and level of household income. The results showed that the estimated demand for both models was price inelastic (-0.52) which shows a weak response to price change. The results also showed a positive inelastic income elasticity. The household size and the educational level both significantly affect the level of water demand. The results showed that water demand price elasticity and income elasticity are both inelastic, meaning that pricing policies will not be an effective way to manage water demand. The results showed that price responsiveness is low when it comes to residential water use; large price increases would be required in order to eliminate small shortages. The more suitable approach towards conserving water consumption is to combine pricing policies with other water demand management measures such as informative campaigns, increasing the public's awareness regarding water scarcity problem and encouraging the use of water conservation device in order to achieve the desired goals.

Keywords: Water demand function, Price elasticity, Income elasticity, Pricing policies.

INTRODUCTION

Jordan is more likely to face an even severer water shortage in the near future due to the imbalance between the already scarce water resources and the growing demand that threatens to reduce the availability of water, especially for domestic uses. Historically, water institutions have relied on expanding supply to satisfy rapidly increasing water demands. However, it has become more and more difficult, expensive and time intensive to secure new supply sources. Consequently, municipal governments and utilities are looking for ways to reduce *per capita* consumption instead. Water conservation can be fostered using non-price based policies such as technological mandates, education campaigns or rationing. It can also result directly from changes in rate structures and price increases. To

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estimate the benefits of price policies, an idea of the parameters of the demand function is needed to calculate a consumer's surplus welfare, given a baseline estimate of consumption level and price. The demand elasticity estimate can be obtained from the econometric estimation of a demand relation.

The water problem in Jordan is further intensified by the increase in urbanization, industrialization along with the relatively high population growth rate of about 2.2%, and with the present population of approximately 5.85 million people, the population is expected to reach 8 millions by the year 2025 (DOS, 2009a). This expected increase in population along with the growing economic activities will place even more pressure on the already limited water resources, especially in the urban areas of Greater Amman, where around 53% of the current population lives in Amman and Zarqa area (DOS, 2006).

The living standards have increased in Jordan during the second half of the 20^{th} century, raising the *per capita* use of water to the current *per capita* water use of 86 l/day which is among the lowest figures in the world (Salman and Al–Karablieh, 2006). Thus, the gap between water supply and demand threatens to widen significantly.

The demand on water is expected to reach 1,565 MCM by the year 2010. Most of this increasing demand is contributed mainly by the municipal sector with 500 MCM by the year 2010, and the *per capita* municipal water consumption will rise from 86 l/c/d up to 142 l/c/d by 2020 while the estimated water supply will not exceed 1,305 MCM. The average household *per capita* water consumption, or billed water consumption, calculated for a sample of Amman's households, in this cross-section study was around 98 l/c/d, while Salman and Al-Karablieh (2006), in their study of the households' water demand using data of Household Expenditure and Income Survey conducted by DOS 2004, found the *per capita* water consumption to be 86 l/c/d. This level of household *per capita* water consumption is far below that of neighboring countries. In the past decade, municipal consumption in the neighboring countries and other Mediterranean countries has been substantially higher than in Jordan; in Cyprus it was 161 l/c/day for the period 1989 – 2001 and 278 l/c/day in Israel during the period 1991 – 2000. In 2002, the *per capita* consumption in Lebanon amounted to 198 l/c/day (MWI, 2004; Haddadin et al., 2006).

As a result of water shortage, the domestic water supply is rationed through intermittent supply, particularly in summer season in which water is supplied once or twice a week for about 12 – 24 hours and about two to three days a week during winter. Summer is usually a high water demand season mainly because of high temperatures and the slight increase in population due to the Jordanian working aboard returning for their yearly vacation. The number of new customers within Amman is increasing at about 5% each year (Al-Karablieh *et al*., 2006). Because of this rationing program, people are usually forced to invest in water tanks and buy additional water from private vendors at high prices in order to satisfy their water needs and improve the water supply reliability (Iskandarani, 2001). People have become less trusting of the quality of water supplied by the public network which made them turn to other sources for drinking water such as bottled water or investing in treatments for drinking water (Batarseh, 2006). This belief is supported by the number of people who depend on the public network as a source of their drinking water which had dropped, especially in Amman, from 97% in 2003 to around 78% in 2006 (DOS, 2009b).

The municipal water tariffs in Jordan are mainly used to cover operational and maintenance costs and a part of the investment costs as well as being an important economic incentive for water conservation. The tariffs are structured to discourage high water use by charging higher prices at higher quantities of water consumption. Water tariffs had historically been kept very low, not allowing for the recovery of operating and maintenance costs (Gerlach and Franceys, 2009). In 1997, a water tariff structure based on an increasing block rate was introduced that varies across two regions; Amman and the rest of Jordan, in which the first consumption rate, that covers a consumption up to 20 m^3 per quarter, is charged at a flat rate; while in the remaining three blocks the variable charge is determined by a formula that differs with each consumption block and across regions. In addition to the charge for water and wastewater consumption, there is also a range of other different fees' and charges (MWI, 2004). After introducing this water tariff structure, Water Authority of Jordan (WAJ) water revenue increased by 30% and wastewater fees' revenue increased by 16% (Taha and Batineh, 2002).

Recently, under tariff reform, a shift was made from the increasing block rate structure toward a progressive pricing system in which each newly consumed cubic meter has a different price form the previously consumed one and the tariffs include a fixed meter charge. This tariff structure was formed in such a way as to guarantee the minimum needed consumption 20 m^3 at a subsidized fixed price per m^3 and to recover these subsidizes from customers with higher consumption assuming the more consumptive customers to be wealthier (Gerlach and Franceys, 2009).

However, these tariffs are not based on a valuation of municipal water through assessing the willingness of the consumers to pay for water, and they had only led to the increase in the revenues of the different service providers. Even so, water tariffs have achieved some financial objectives of Water Authority of Jordan (WAJ) and reduced the demand for municipal water to some extent. Therefore, tariffs of municipal water are considered among the important tools of demand management (Taha and Batineh, 2002).

Municipal water is given top priority in Jordan, and in the previous years, supply management was the option to consider while dealing with water deficit problems, especially in this sector (Salameh and Haddadin, 2006). But despite the ongoing projects and plans to provide additional water resources, options for new further resources are very limited. Thus the need to come up with new solutions was vital, hence demand side oriented management options were considered and their importance is increasing rapidly.

Water demand management is a complementary approach that aims at avoiding the problems of excessive water use by reducing or restricting water demand (Salameh, 2008). It also seeks to improve the overall productivity of water use and deliver water services that match the needs of end users (Brandes and Mass, 2004). This water demand management includes water allocation, leakage monitoring and control, capacity building and public education and awareness campaigns. Furthermore, it is necessary to adopt technical solutions including maintenance and replacement of many of the water networks to achieve the highest possible efficiency in water conveyance, distribution and use (Abdel Khaleq and Dziegielewski, 2006).

However, it should be noted that supply and demand oriented instruments should not be used against each other. In each measure, we may find a more or less economically and environmentally sound instrument. So, in order to have a water management plan in Jordan, both supply and demand oriented measures should be taken into consideration.

A clear understanding of the drivers of residential water demand is essential, especially if water managers wish to draw any effective demand policies (Klein *et al.*, 2007). One factor that has a great influence on water demand is the number of people living in a household along with their income or wealth status. Also, people's educational level has somehow a double effect on water demand; it is expected to increase water demand because of the increase in awareness, especially of water related diseases, and on the other hand it will increase their awareness regarding water scarcity and the need to conserve water (Salman and Al–Karablieh, 2006).

Hence, this study aimed to express the household water demand function by estimating two water demand models and test the significance of different household socioeconomic factors and the effects they have on the residential water demand.

METHODS AND APPROACH

Residential water demand has been extensively studied and analyzed during the past decades, especially the case of estimating the residential water demand function which has been an issue of increasing significance for decision makers. The majority of literature on water demand mainly focuses on the impacts of price, income and a rage of other socioeconomic factors concerning residential household water consumers (Worthington and Hoffman, 2006; Hewitt and Hanemann, 1995; Nieswiadomy and Molina, 1989; Billings and Agthe, 1980). The economic model takes the general form $Q_d = f(P, Z) + \varepsilon$ which relates water consumption to a price measure (*P*) and other factors (*Z*) such as income, household type or household size, educational level, season, temperature…etc (Mazzanti and Montini, 2005; Salman and Al–Karablieh, 2006).

A review of water demand literature shows that there are mainly two issues which are most frequently discussed concerning the estimation of water demand function; whether there is a simultaneous equation problem when estimating the demand function in case of multipart rate or progressive schedules, and if this problem exists, what techniques should be used to correct it. Another issue is whether the average or the marginal price is the more appropriate measure to be used while estimating the demand function (Arbués *et al.*, 2003; Bacharach and Vaughan, 1994).

When price is measured in average rates, it is no longer considered an independent variable because the price of residential water as a whole is a price schedule rather than a single price. Hence, average price cannot be used in estimating the demand on water with the assumption that it is the independent variable and that the water consumption is the dependent one. According to the economic theory, the consumer responds rather to the marginal price when he selects the level of consumption that maximizes his utility (Griffin *et al*., 1981). The classical problem in multipart rate schedule is how to take into account the effect of change in the intra-marginal rates. Taylor (1975) had addressed the appropriate price specification for estimating the demand for electricity under block rate pricing and showed that neither the average price nor the marginal price are suitable price variables. Nordin (1976) and Griffin and Martin (1981) had provided the correct price specification for the difference term which aimed at capturing the income effect and had introduced a new variable called the rate structure premium (RSP) representing the difference between what the consumer actually pays and what he would pay if all water demanded was charged at the marginal rate.

Moreover, the nature of the block rate itself makes water prices, whether being marginal or average, depend on the quantity of water consumed which means that using Ordinary Least Squares (OLS) method in estimating water demand function would likely result in a biased estimation. This problem was addressed by using instrumental variables' (IV) techniques such as Two Stage Least Square (2SLS) regression, in which the price of water is explained by instruments uncorrelated with the error term of the demand equation. The IV techniques including the 2SLS method could be also used to solve the simultaneity bias and produce consistent parameters' estimates (Agthe and Billings, 1987; Bacharach and Vaughan, 1994).

Another problem encountered while estimating water demand function is the possibility of having a simultaneous equation, especially in multipart pricing rate schedules and the problem of selection bias when the rate schedule is combined with a fixed charge for any consumption amount beneath the lower limit of the block tariff (Bachrach and Vaughan, 1994).

This paper employs the IV estimation techniques, more specifically 2SLS, addressing the problem of endogenous price variable (marginal price) and RSP correlated to the error term in the right hand side of the demand equation, in which water consumption is related to price measures and a set of other explanatory variables. The double–log functional form was applied to the water quantities, price and income in order to obtain the price and income elasticities directly from the equation. Two models were estimated for this purpose. In model I, the dependent variable was the quantity of water consumed by the entire household in cubic meters (Q_d), while the *per capita* water consumption was the dependent variable in cubic meters (Q_P) for model II. The independent variables were: (*MP*) the marginal price in JD per m^3 the consumers would pay for each additional use and (*RSP*) the difference variable between average and marginal prices.

Other variables used in the estimation were: (*FC*) fixed charge which is an extra amount previously decided by the water service provider paid for each quantity of water consumed; 2.15 JD for water consumption level of less than 20 m^3, 4.15 JD for consumption between 21 and 40 m^3 and 5.15 JD for consumption levels of more than 40 m^3. Another variable was the household monthly income (*I*) for model I and *per capita* monthly income (*PCI*) for model II; household size (*HS*); household area (*HA*); (*edu*) to indicate the respondents ' educational level as (1): illiterate, (2): basic, (3): bachelor and (4): higher education; (*toilets*) to indicate the number of toilets in the household.

The data used in estimating the two models were drawn from the field survey that was conducted in 2005 as part of MEDITATE (Mediterranean Development of Innovative Technologies for Integrated Water Management) project funded by the European Union (Dababneh et al., 2004). The survey was conducted on a representative stratified random sample of 600 households in Greater Amman drawn by the Department of Statistics based on the frame provided by the 2004 Population and Housing Census (DOS, 2006). The sample was collected based on face – to – face interviews, where the interviewers met the respondents directly and explained the questions to them. The survey covered information such as age, educational level, employment status and household income and expenditures.

RESULTS

Water consumption of water *per capita* is the amount of water consumed per person for drinking, personal hygiene, toilet flushing, washing clothes, dishwashing and other household uses, and the household water consumption is usually measured by meters connected to the public supply network. The annual *per capita* water supply for the year 2007 was 144 l/c/d. However, the *per capita* water supply does not reflect the actual household *per capita* water consumption, since other establishments are connected to the public water supply network such as small industries, hotels, schools and universities in addition to the physical losses which reached 41% reducing the actual level of *per capita* water consumption.

The results showed that around 44% of the respondents live in flats and 40% live in detached houses. It is expected that those who live in flats are more likely to consume less water than those who live in detached houses. The results also showed that 48% of the respondents have only one toilet and 38% have two toilets in their houses, 59% have only one shower and almost 18% have two showers, while 57% of the respondents have at least one bath basin and 15% have two bath basins. It is expected that as the number of toilets, showers and bath basins increases in a household, the level of water consumption will increase as well. Table 1 shows the descriptive statistics of variables used in estimating the household demand function and *per capita* demand function.

Table 1. General descriptive statistics for the variables used in the demand estimation.

Variable	Definition	Description	Unit	Mean	S.D
ln *I*	Income	The average monthly household income	JD/month	310.02	701.32
expend	Expenditures	The average monthly households expenditures	JD/month	289.01	291.55
HS	Household size	The household size including the number of persons living in the house	(1–10) persons	5.92	2.35
HA	Household area	The average surface area of the residence	m^2	168.34	131.79
edu	Education	The educational level of the respondents	1: illiterate 2: basic 3: bachelor 4: higher	2.17	0.68
type	Household type	The type of living accommodation of the household	1: flat, 2: semi detached, 3: detached	1.97	0.94
toilets	Toilets	The number of toilets in the household	(1 – 6)	1.66	0.78
showers	Showers	The number of showers in the household	(1 – 6)	1.32	0.62
baths	Baths	The number of bath basins in the household	(1 – 6)	1.28	0.59

Table (2) shows the estimation results of the demand equation for the household and the *per capita* water consumption (in double log) for water quantities, price and income in order to directly obtain the price and income elasticities. The results of model I and model II showed a generally good performance, all the estimated coefficients had the expected signs and most of them were statistically significant.

Marginal prices showed correct coefficients and were generally significantly different from zero. The elasticity values for prices, premium and income were low; a result consistent with the bias introduced by including families in the minimum consumption category. The price elasticity of water demand for both models was significant and had the expected negative sign with (-0.52) and (-0.67) for the household demand and *per capita* water demand, respectively.

Because of low price elasticity of residential water demand, price-based policies are often used as a conservation tool for municipal water. The inelastic price response estimate suggests that pricing might not be an effective tool in managing water demand efficiently on both household and *per capita* water demand, since water consumers will not respond properly to higher prices. Improving the informational content of water bills could be used as a tool to increase the effectiveness of the price system and promote conservation.

Furthermore, the coefficient of household income for the *per capita* water demand model was significant and had the expected positive sign (0.22), implying that a 10% increase in the *per capita* monthly income would result in a 2.2% increase in the *per capita* water demand. The price elasticity of demand was found to be inelastic and for the household water demand it lied within the range of -0.25 to -0.75 which is consistent with many previous studies such as Choicine et al. (1986), Nieswiadomy and Molina (1989) and Martinez–Espineria (2003). Al–Karablieh et al. (2006) found that the own price elasticity was -0.47 for Amman – Zarqa Basin and it was estimated to be about -0.19 by Salman et al. (2008), while Salman and Al–Karablieh (2006) estimated the *per capita* price elasticity for water demand in Jordan by -0.12.

On the other hand, the household size had the expected positive relation with the household water consumption, since a larger number of residents in a household will likely be associated with higher water, consumption levels because they will require more water, especially for personal hygiene purposes, and most of the large size households are those with low income and any pricing policy will only affect this group negatively since they cannot reduce their water consumption but they would have to pay more for water. On the other hand, the household size had a negative relation with the *per capita* water consumption, indicating that an increase in the number of household members will lead to a decrease in water allocated *per capita*. For the household water demand model, education was insignificant, while for the *per capita* water demand, education had a negative relation meaning that the individual tends to decrease his/her water consumption with the increase in his/her educational level.

Table 2. Estimation of household and *per capita* water demand functions.

Dependent variable	Household water demand function ln Q_d		*Per capita* water demand function ln Q_P	
	Coefficient	t – test	Coefficient	t – test
Constant	-3.7632	-2.34	-6.4852*	-3.56
ln *MP*	-0.5185*	-2.85	-0.6704*	-3.23
ln *FC*	4.5251*	4.78	5.1228*	4.74
RSP	-0.0012*	-3.82	-0.0014*	-3.78
ln *I*	0.3421	0.70		
ln *PCI*			0.2243*	4.55
HS	0.0125*	2.72	-0.0299*	-5.26
HA	0.0003	0.93	-0.0002	-0.64
edu	-0.0504	-1.09	-0.1649*	-3.23
toilets	0.0429	1.07	0.0053	0.12
Adjusted R^2	0.472		0.380	
F-test	64.94		51.7	

Instrumental variables: *AP*, *FC*, *ln I*, *ln PCI*, *expend*, *RSP*, *HS*, *HA*, *edu*, *toilets*, *type*(1 = flat or apartment, 2 = semi detached, 3 = detached), *showers*, *baths.*

*, ** and *** indicate significance at 1%, 5% and 10%, respectively.

CONCLUSIONS

Water utilities in water stressed countries have to dismiss price-based instruments as incentives to conserve water and have instead to rely more on rationing and other technical mandates when demand reductions are needed. The results showed that water demand price elasticity and income elasticity are both inelastic, since water is a life necessity even with a minimum level of consumption, meaning that pricing policies might not be an effective way to manage water demand since any rising in water tariffs will only affect the lower income people without decreasing their water consumption as expected from these policies of conservation. It also should be noted that there is a limit to the level of reduction in water consumption that could be achieved among higher income groups as a result of increasing water tariffs. From past experiences, raising water tariffs had mostly resulted in an increase in the revenues of water service provider with no noticeable reduction in the level of water consumption; thus the more suitable approach towards decreasing water consumption is to combine pricing policies with other water demand management measures such as informative campaigns and increasing the public's awareness regarding the water scarcity problem and the importance of diffusion of water conservation techniques in order to achieve the desired goals.

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مرونة الطلب على مياه الشرب في عمان الكبرى

فاتن عثمان النجار [1] ، عماد كامل الكرابلية [2]، عامر زاهي سلمان [3]

ملخـص

الأردن من بين أكثر الدول معاناةً من نقص المياه في العالم، وسيواجه الأردن نقصاً أكبر في المستقبل نتيجة لعدم التوازن بين موارد المياه المحدودة من جهة و الطلب المتزايد عليها من جهة أخرى، الأمر الذي سوف يؤدي الى تقليل الكميات المتاحة من المياه وخاصة تلك المخصصة للاستخدامات المنزلية. استهدفت هذه الدراسة اشتقاق دالة الطلب على المياه المنزلية من خلال تقدير نموذجين قياسيين للطلب على المياه و اختبار درجة المعنوية الإحصائية لمختلف العوامل الاجتماعية والاقتصادية و تأثيرها على الطلب على مياه الشرب. تم الحصول على 600 مشاهدة تم جمعها من خلال اداة الاستبانة الخاصة بمشروع *MEDITATE*. في هذا البحث تم تقدير نموذجين قياسيين رئيسيين، الاول تم فيه تقدير دالة الطلب على مياه الشرب على مستوى الأسرة والثاني على مستوى الفرد، وذلك باستخدام طريقة المرحلة الثانية للمربعات الصغرى (*2SLS*) آخذين بعين الاعتبار مختلف العوامل كالسعر الحدي و *RSP* و مستوى دخل الأسرة ومستوى التعليم اضافة إلى عوامل اجتماعية أخرى. أظهرت النتائج أن مرونة الطلب السعرية لكلا النموذجين كانت غير مرنة (*0.52*-) مما يدل على استجابة ضعيفة للكمية المستهلكة من المياه نتيجة تغير السعر، ووجدت الدراسة أيضا أن مرونة الدخل كانت غير مرنة و أن كلاً من حجم الأسرة و مستوى التعليم كان له تأثير ذو معنوية إحصائية على كمية الطلب على المياه. كذلك أظهرت النتائج أن مرونة الطلب السعرية و الدخلية كانتا غير مرنتين، مما يعني أن السياسات السعرية قد لا تكون طريقة فعالة لتخفيض الطلب على المياه. لذا فإن الطريقة الأنسب نحو ترشيد استهلاك المياه تكمن في الدمج بين السياسات السعرية و الأساليب الأخرى لإدارة جانب الطلب على المياه كحملات التوعية والتعريف فيما يتعلق بمشكلة ندرة المياه في الأردن و أهمية المحافظة على المياه وتقليل الفاقد و ذلك من أجل تحقيق النتائج المرجوة.

الكلمات الدالة: دالة الطلب للمياه، مرونة الطلب ، مرونة الدخل، السياسات السعرية.

1) طالبة دراسات عليا في جامعة هوكايدو ، اليابان.
2) أستاذ مشارك ، قسم الاقتصاد الزراعي وإدارة الأعمال الزراعية، كلية الزراعة، الجامعة الأردنية.
3) أستاذ ، رئيس قسم الاقتصاد الزراعي وإدارة الأعمال الزراعية، كلية الزراعة الجامعة الأردنية.

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