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The estimation of domestic water demand function of urban households (case study: Tabriz city)

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Key words: Domestic water demand, Stone-geary utility function, Price elasticity, Income.

Abstract

The purpose of this study is to estimate the domestic demand functions of Tabriz city and the elasticity of water demand with respect to price and income. To do that, the model of drinking water demand is used based on time-series-cross-section data (TSCS) for a period five years from 1999 to 2003. The theory basics of the selected model, for estimating the coefficients of water demand, are based on Stone-Geary utility function. The per-capita water consumption, the minimum requirement of water, and excessive consumption are calculated after estimating the water demand in different conditions, determining the coefficients of demand functions, and the share of factors affecting water consumption level such as income, average price of water and meteorological factors. The findings show that the price elasticity of non-domestic consumption is two times more than domestic one. Meanwhile, the calculating of price elasticity of per-capita demand functions for Tabriz's households separately and in seasonal term, shows that maximum elasticity belongs to summer which has the highest consumption. The seasonal per-capita water consumption has a positive association with income and negative one with price. Based on the findings, the relative price of water can has more evident effect upon reduction of unnecessary consumption and this is more palpable in non-domestic consumption. In addition, with increase of prices of drinking water in summer the highest reduction of water consumption can occur which shows that the price increase policy for reducing consumption of inessential water in summer is effective.

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Introduction

Water economics deals with production, distribution, and consumption of water. When water as an economic product obtains economic aspect that it becomes a scarce resource without easy access the manufacturing of which has value added (Salvatore, 2011). In Iran, the legal system has confirmed this issue and the consumer should consider economic opportunities, compare them, and chooses the optimal consumption index because wastewater and service economy has chain effect on other economic sectors. Many researches have been conducted in this field. In other words, each person of households had 2.79 m^3 excess consumption in each season or 31.06 liters per day. Calculating the elasticity values of price and income for all members of households in Tabriz City during the study period, with ceteris paribus assumption, showed that 1% increase in water price will reduce the demand up to 0.0531 %. With ceteris paribus assumption, 1% increase of income of Tabriz households increased the water demand up to 0.1257%. Considering that there is not an alternative good for drinking water and drinking water is distributed by one producer, the price elasticity of the water demand is consequently very small. So price increase policy does not led to the desirable effect in short-run. The result of estimated drinking water demand function for non-domestic consumption showed per capita the minimum of necessary drinking water for households of Tabriz with considering meteorological factor was 12.75m^3 which is equivalent with 190.89 liters per day. Furthermore, each person of household in Tabriz had averagely 2.8 m^3 excess consumption that was equal 31.06 liters per day. Estimating the drinking water demand function for domestic consumption showed that per-capita the minimum drinking water was 8.81 m^3 which is equivalent with 97.89 liters per day. In addition, each household member of Tabriz City had 0.93 m^3 in winter which is 1.5 liters for each household. Comparing the results of two functions of domestic consumption and non-domestic consumption indicated that the excess consumption in non-domestic consumption was more than in domestic one. It indicated that the households in Tabriz City had the highest consumption level in non-domestic consumption such as yard washing and filling in the pool. As a result, the amount of estimated consumption in non-domestic consumption was two times more than domestic consumption. Calculation of the price elasticity for domestic and non-domestic consumptions showed the price elasticity for non-domestic consumption was twice more than domestic consumption. This implicates that increasing relative price of water would more likely have more impact upon reduce unnecessary consumption in non-domestic consumption compared with domestic one. The calculation of price elasticity of per-capita demand function of households in Tabriz based on each season showed the highest excess consumption and the maximum price elasticity occurred in the summer. This indicated that increasing the drinking water price in Tabriz city in the summer would have the highest reductive effect upon water consumption. It also confirmed the efficacy of price increase policy implementation for reducing unnecessary consumption in this season. In this study, per-capita consumption and seasonal consumption of urban households in Tabriz City had a direct relationship with income and the inverse relationship with price.

The purpose of this study is to estimate the domestic demand functions of Tabriz city and the elasticity of water demand with respect to price and income. To do that, the model of drinking water demand is used based on time-series-cross-section data (TSCS) for a period five years from 1999 to 2003.

Material and methods

Analysis of Findings

The result of estimating water demand function for Tabriz city from 1999 to 2003, for all observations, and based on GLS method is as follows:

$$\begin{array}{llllll} Q_{it} = 13.157 + & 0.000031M_{it} & - 5.992P_{it} & + 4.023W_t & + 0.881Ar(1) \\ t: \quad (64.73) & (7.56) & (-11.12) & (127.54) & (179.96) \end{array} \quad (1)$$

$$R^2 = \%87 \qquad F = 15342.17 \qquad D.W = 2.085$$

As shown in the above formula, all coefficients were significant at the level of 5%. (The t test values are in parentheses). The signs of estimated coefficients were based on expectation. The determination coefficient (R^2) was 0.87. In regard to estimated model for all of Tabriz city, the minimum water consumption of households in Tabriz with and without meteorological factors are shown in Table 1.

Table 1. Estimated Consumption, the Minimum Requirement Consumption and Excess Consumption of Tabriz City.

EQ		S_1^*		S_1		Q^*	
m³ per Season	Liter per Day	m³ per Season	Liter per Day	m³ per Season	Liter per Day	m³ per Season	Liter per Day
2.79	31.06	17.18	190.89	13.16	146.2	14.38	154.83

According to the results of Table 1, the minimum per capita drinking water for households of Tabriz with and without considering meteorological factors was respectively 17.8 and 13.16. In other words, the minimum per capita consumption of a household in Tabriz per day, with and without considering meteorological factors, were respectively 190.89 and 146.2 m³. Also, each person of a household in Tabriz had averagely 2.79 m³ consumption excess that it is equal 31.06 liters for each household.

Result and discussion

Calculating Price and Income Elasticity of Urban Households of Tabriz

Considering the coefficients M_{it}, P_{it}, and intercept of estimating total urban household demand function of Tabriz City, the price and income elasticity can be calculated. These elasticity values are extracted from relations 2 and 3.

$$E_{QP} = \frac{\partial Q_{it}}{\partial P_{1t}} . \frac{P_{1t}}{Q_{it}} = \frac{\partial Ln(Q_{it})}{\partial Ln(Pl_{1t})} = (-\frac{\theta_1 M_{1t}}{P_{1t}} - \frac{\theta_2 P_{2t}}{P_{1t}}) . \frac{1}{Q_{it}} \quad (2)$$

$$E_{QM} = \frac{\partial Q_{it}}{\partial M_{1t}} . \frac{M_{1t}}{Q_{it}} = \frac{\partial Ln(Q_{it})}{\partial Ln(M_{1t})} = \frac{\theta_1}{P_{1t}} . \frac{M_{1t}}{Q_{it}} \quad (3)$$

Table 2. Income and Price Elasticity of Urban Water Demand of Tabriz City.

Elasticity	Income	Price
Spring, 2008	0.1808	-0.0798
Summer, 2008	0.1230	-0.0555
Autum, 2008	0.1836	-0.0914
Winter, 2008	0.1843	-0.1053
Spring, 2009	0.1868	-0.0649
Summer, 2009	0.1308	-0.0481
Autum, 2009	0.1936	-0.0777
Winter, 2009	0.1972	-0.0890
Spring, 2010	0.0958	-0.0455
Summer, 2010	0.0786	-0.0390
Autumn, 2010	0.0994	-0.0525
Winter, 2010	0.0949	-0.0563
Spring, 2011	0.1143	-0.0304
Summer, 2011	0.0958	-0.0289
Autumn, 2011	0.1172	-0.0392
Winter, 2011	0.1195	-0.0489
Spring, 2012	0.0750	-0.0209
Summer, 2012	0.0654	-0.0200
Autumn, 2012	0.0770	-0.0258
Winter, 2012	0.0793	-0.0310
Average	0.1257	-0.0531

According to Table 2, the price elasticity of total water demand was low and it showed low inelasticity of water demand with respect to its own price. This result matches with earlier studies. The average value of price elasticity of water demand, during the study period, was -0.0531. Put it more simply, with ceteris paribus assumption and 1% increase of water price the water demand decreases up to 0.0531%. Furthermore, the income elasticity of water demand is low and less than 1 that shows water is a necessity good as seen in reality. Considering the estimated demand function for different years, constant coefficients in different seasons, based on the relations (2) and (3) and due to the fact that the numerators in different seasons were constant and average values of P and Q in the summer were the maximum, the price and income elasticity of water demand in this season has its maximum value respect to other seasons.

Estimation of drinking water demand function of Tabriz City in non-domestic consumption sector (non-winter period)

As mentioned above, domestic consumption and non-domestic consumption were respectively based on winter months and other seasons except the winter. For estimating the urban water demand function of Tabriz city for domestic and non-domestic consumption, one should just consider spring, summer, and winter. So, the non-domestic demand can be estimated as follows:

$$\begin{aligned} &Q_{it} = 11.35 + 0.0000211 M_{it} - 3.872 P_{it} + 4.19 W_t + 0.916 Ar(1) \\ &t: \quad (30.55) \quad (4.45) \quad (-5.8) \quad (147.51) \quad (178.48) \\ &R^2 = \%93 \qquad F = 22871 \qquad D.W = 2.06 \end{aligned} \tag{4}$$

According to the results, all coefficients at the 99% confidence level were significant. F-test (test of regression significance) showed the significance of the whole model at the 99% confidence level. In addition, the value of determination coefficient R^2 was 0.93. The values of minimum per capita consumption of Tabriz households, considering estimated non-domestic demand and with and without regarding meteorological factor are shown in Table 3.

Table 3. Estimated Consumption, the Minimum Requirement Consumption and Excess Consumption for non-domestic demand in Tabriz City.

EQ		S_1^*		S_1		Q^*	
m3 per Season	Liter per Day	m3 per Season	Liter per Day	m3 per Season	Liter per Day	m3 per Season	Liter per Day
2.8	2.8	12.75	141.63	11.35	126.11	15.54	172.72

As is shown in Table 3, the per capita minimum requirement of drinking water for non-domestic consumption among households of Tabriz City, with and without meteorological factor, were respectively 12.75 and 11.35 m3. In addition, each person of the household has averagely 2.8 m3 excess consumption which is equal 31.06 liters for each household.

Estimating drinking water demand function of Tabriz City for domestic consumption (winter intervals)

For determining non-domestic consumption demand function, from all seasons except winter were analyzed. As a result, the domestic consumption includes the winter season. This section of the paper this demand function is estimated.

$$\begin{aligned} &Q_{it} = 8.81 + 0.0000064 M_{it} - 0.605 P_{it} + 0.83 Ar(1) \\ &t: \quad (38.32) \quad (5.19) \quad (-3.36) \quad (176.18) \\ &R^2 = \%99 \qquad F = 76012 \qquad D.W = 2.12 \end{aligned} \tag{5}$$

According to above relation, all coefficients at the 99% confidence level were significant. F-test showed the significance of the whole model at the 99% confidence level. In addition, determination coefficient (R^2) was 0.99. Regarding the estimated model for domestic consumption of Tabriz city, the minimum per capita consumption was calculated and shown in Table 4. It should be noted that meteorological factor in the aforementioned model for estimating the domestic consumption demand function was not included. As a result, the minimum value of per-capita drinking water with and without considering meteorological factor were same.

Table 4. Estimated Consumption, the Minimum Requirement Consumption and Excess Consumption for domestic demand in Tabriz City.

EQ		S_1^*		S_1		Q^*	
m3 per Season	Liter per Day	m3 per Season	Liter per Day	m3 per Season	Liter per Day	m3 per Season	Liter per Day
0.13	1.5	8.81	97.89	8.81	97.89	8.94	99.39

As shown in Table 4, per-capita minimum drinking water necessary for domestic consumption of households in Tabriz City was 8.81 m3. Comparing the results of the domestic and non-domestic consumption demand functions showed that excess consumption, as expected, in non-domestic consumption was much more than domestic consumption. It also indicated that Tabriz households have the highest consumption in non-domestic applications such as washing yard of houses, and pool. As a result, the estimated consumption in non-domestic consumption was two times more than domestic one.

Calculating price and income elasticity of per-capita demand function of households in Tabriz City

Price and income elasticity of per-capita demand of households in Tabriz City for domestic and non-domestic consumption were calculated using relation (2) and (3) and shown in Table 5.

Table 5. Price and Income Elasticity of Water Demand for Tabriz City in Terms of Domestic and Non-Domestic Consumption.

Elasticity	Price	Income
Domestic	-0.013	0.034
Non-Domestic	-0.28	0.138

Based on Table 5, price elasticity in the domestic and non-domestic consumption was low which indicated that water was a necessity good for households in Tabriz. The price elasticity for non-domestic consumption was two times more than domestic one which shows that increasing relative price of water can reduce unnecessary consumption, especially for non-domestic applications. The income elasticity was less than 1 for two types of consumptions which suggests the necessity of this product for the households of Tabriz City.

Estimating drinking water demand function for four seasons of Tabriz City

As mentioned before, since the meteorological factor in same seasons had minimal change and were not significant in the model, the meteorological factor was deleted from estimating per-capita drinking water demand function of households in different seasons. It should be noted that the demand function in winter was estimated in the section of domestic consumption. As a result, its estimation in this section was not done and its results were only used in analysis and comparing the seasons. So, the per-capita drinking water estimated for Tabriz city was as follows:

Drinking water demand function in spring

$$\begin{array}{lllll} Q_{it} = 9.208 & + 0.000026 M_{it} & - 6.059 P_{it} & + 0.908 Ar(1) \\ t: \ (17.58) & (4.006) & (-5022) & (172.14) \end{array} \quad (6)$$

$$R^2 = \%98 \qquad F = 60789 \qquad D.W = 2.2$$

Drinking water demand function in summer

$$\begin{array}{lllll} Q_{it} = 12.638 & + 0.000092 M_{it} & - 17.37 P_{it} & + 0.926 Ar(1) \\ t: \ (15.99) & (9.19) & (-9.79) & (187.62) \end{array} \quad (7)$$

$$R^2 = \%98 \qquad F = 34210 \qquad D.W = 2.3$$

Drinking water demand function in autumn

$$\begin{array}{lllll} Q_{it} = 10.408 & + 0.000015 M_{it} & - 3.56 P_{it} & + 0.887 Ar(1) \\ t: \ (31.15) & (5.702) & (-9.77) & (146.47) \end{array} \quad (8)$$

$$R^2 = \%98 \qquad F = 34401 \qquad D.W = 2.3$$

As shown in above relations, all coefficients in all of the three models were significant at the 99% confidence level. The signs in 3 models were as expected. F-test (test of regression significance) showed generally the significance of the model in three models at the 99% confidence level. Also, the value of determination coefficient (R^2) in three models was 0.98 that indicated that in three models, approximately 98 % change in drinking water demand could be explained by the specified variables in the model. Considering estimated models for all of four seasons of Tabriz City, the minimum consumption, excess consumption, and amount of per-capita estimated consumption of households in Tabriz according to relations 3 and 5 were calculated the results of which can be seen in the table below.

Table 6. Estimated Consumption, Minimum Consumption and Excess Demand for Four Season in Tabriz City.

Season	EQ		S_1^*		S_1		Q^*	
	m³ per Season	Liter per Day	m³ per Season	Liter per Day	m³ per Season	Liter per Day	m³ per Season	Liter per Day
Spring	1.57	17.51	9.21	102.31	9.21	102.31	10.78	119.82
Summer	3.14	34.92	12.64	140.43	12.64	140.43	15.79	175.35
Autumn	1.79	19.89	10.4	115.64	10.4	115.64	12.19	135.54
Winter	0.13	1.5	8.81	97.89	8.81	97.89	8.94	99.39

As shown in Table 6, the highest minimum consumption of drinking water belongs to the summer with 12.64 m³. In summer, each person consumes 3.14 m³ of water which is 34.92 liters over the defined minimum. In addition, the estimated minimum consumption and the minimum drinking water consumed were respectively 8.94 and 8.81 which were associated with winter.

Calculation of price and income elasticity of per-capita demand of households in Tabriz for different seasons

In regard to the calculations for drinking water demand based on the four seasons, price and income elasticity for the four seasons were calculated and presented in Table 7.

Table 7. The Price and Income Electrifies of Water Demand in Tabriz.

Elasticity		Price	Income
Spring	1999	-0.1119	0.1517
	2000	-0.0978	0.1567
	2001	-0.0625	0.0803
	2002	-0.0504	0.0959
	2003	-0.0341	0.0629
Summer	1999	-0.1524	0.3650
	2000	-0.1305	0.3883
	2001	-0.1076	0.3188
	2002	-0.0771	0.2844
	2003	-0.0536	0.1942
Autumn	1999	-0.0846	0.0788
	2000	-0.0769	0.0842
	2001	-0.0406	0.0496
	2002	-0.0341	0.0587
	2003	-0.0216	0.0395
Winter	1999	-0.0695	0.0723
	2000	-0.0691	0.0610
	2001	-0.0394	0.0503
	2002	-0.0350	0.0472
	2003	-0.0219	0.0331

As shown in table 7, the price elasticity for four seasons is less than 1 which indicated inelasticity of water price with respect to demand. The highest elasticity belonged to the summer which also had the maximum excess consumption. This result indicated that increasing the price of drinking water in summer can lead to the highest reduction of water consumption in Tabriz City resulting from unnecessary consumption in this season. The minimum price elasticity in 2003 was -0.0216 which belonged to the autumn. This value shows that 1% increase of water price for autumn can result in reduction of water consumption up to 0.0216 %.

Literature review

Xayavong, Burton, and White (2008) in an article entitled"*Estimating urban residential water-demand with 87 increasing block prices: The case of Perth, Western Australia*" showed that price elasticity ranged from 0.7 to 0.94 and income elasticity was positive and varied from 0.5 to 0.6.

Ruijs, Zimmermann, and Berg (2008) indicated that price elasticity varies from 0.45 to 0.5 and income elasticity was positive ranges from 0.39 to 0.44.

Martinez (2002) in a paper entitled "*Residential water demand in the northwest of Spain*" used cointegration techniques and error correction through estimation of price elasticity of short- and long-term urban demand of drinking water by analyzing monthly time series data of price and urban total consumption in region of Seville in Spain. The estimated elasticity in short-run and long-run was respectively -0.1 and 0.5 which showed that elasticity in long-run is more than that in short-run.

Falahi, Ansari, and Moghaddas (2011) in an article entitled "*Evaluating effective factors on household water consumption and forecasting its demand: Panel data approach*" showed that price elasticity, income elasticity, and cross-elasticity were -0.15, 0.15, and -0.00025, respectively. Generally, their findings confirmed low elasticity of household water demand with respect to income and price along with complementary effect of water upon other goods.

Sajadifar and Khiabani (2011) indicated that price and income elasticity in summer (alternative of non-domestic consumption) were almost two times more than those in winter. Meanwhile the long-run elasticity was more than short-run one.

Mousavi, Mohammadi, and Boostani (2009) in an article entitled "*Estimation of Water demand function for urban households: A case study of Marvedasht City* " showed that according to the linear model, the explanatory variables were capable of respectively predicting 89, 85.5, 87.5, and 89.9% of the changes of water demand during spring, summer, autumn, and winter.

Abdoli and Dizaji (2009) studied this issue in a paper entitled "*Estimating the urban water demand function for Urmia City*". Their results showed that urban water demand of Urmia City is negatively associated with water price but positively associated with price of other products (considered in sum). In addition, the civil water demand of this city is inelastic with respect to water price and price of other goods but it is an essential product in relation to income. The variables of precipitation and temperature have no significant effects upon water demand of Urmia City.

The results of estimated drinking water demand function for all households member of Tabriz City showed that the estimated per-capita consumption of water by households was averagely 14.38 m^3 per season or 154.83 liters per day. Considering meteorological factors, the minimum per-capita necessary for households of Tabriz was 17.18 m^3 per season or 190.89 liters per day. In other words, each person of households had 2.79 m^3 excess consumption in each season or 31.06 liters per day. Calculating the elasticity values of price and income for all members of households in Tabriz City during the study period, with ceteris paribus assumption, showed that 1% increase in water price will reduce the demand up to 0.0531 %. With ceteris paribus assumption, 1% increase of income of Tabriz households increased the water demand up to 0.1257%. Considering that there is not an alternative good for drinking water and drinking water is distributed by one producer, the price elasticity of the water demand is consequently very small. So price increase policy does not led to the desirable effect in short-run. The result of estimated drinking water demand function for non-domestic consumption showed per capita the minimum of necessary drinking water for households of Tabriz with considering meteorological factor was 12.75m^3 which is equivalent with 190.89 liters per day. Furthermore, each person of household in Tabriz had averagely 2.8 m^3 excess consumption that was equal 31.06 liters per day. Estimating the drinking water demand function for domestic consumption showed that per-capita the minimum drinking water was 8.81 m^3 which is equivalent with 97.89 liters per day. In addition, each household member of Tabriz City had 0.93 m^3 in winter which is 1.5 liters for each household. Comparing the results of two functions of domestic consumption and non-domestic consumption indicated that the excess consumption in non-domestic consumption was more than in domestic one. It indicated that the households in Tabriz City had the highest consumption level in non-domestic consumption such as yard washing and filling in the pool. As a result, the amount of estimated consumption in non-domestic consumption was two times more than domestic consumption. Calculation of the price elasticity for domestic and non-domestic consumptions showed the price elasticity for non-domestic consumption was twice more than domestic consumption. This implicates that increasing relative price of water would more likely have more impact upon reduce unnecessary consumption in non-domestic consumption compared with domestic one. The calculation of price elasticity of per-capita demand function of households in Tabriz based on each season showed the highest excess consumption and the maximum price elasticity occurred in the summer. This indicated that increasing the drinking water price in Tabriz city in the summer would have the highest reductive effect upon water consumption. It also confirmed the efficacy of price increase policy implementation for reducing unnecessary consumption in this season. In this study, per-capita consumption and seasonal consumption of urban households in Tabriz City had a direct relationship with income and the inverse relationship with price.

Conclusion

The purpose of this study is to estimate the domestic demand functions of Tabriz city and the elasticity of water demand with respect to price and income. To do that, the model of drinking water demand is used based on time-series-cross-section data (TSCS) for a period five years from 1999 to 2003. The theory basics of the selected model, for estimating the coefficients of water demand, are based on Stone-Geary utility function. The per-capita water consumption, the minimum requirement of water, and excessive consumption are calculated after estimating the water demand in different conditions, determining the coefficients of demand functions, and the share of factors affecting water consumption level such as income, average price of water and meteorological factors. The findings show that the price elasticity of non-domestic consumption is two times more than domestic one. Meanwhile, the calculating of price elasticity of per-capita demand functions for Tabriz's households separately and in seasonal term, shows that maximum elasticity belongs to summer which has the highest consumption. The seasonal per-capita water consumption has a positive association with income and negative one with price. Based on the findings, the relative price of water can has more evident effect upon reduction of unnecessary consumption and this is more palpable in non-domestic consumption. In addition, with increase of prices of drinking water in summer the highest reduction of water consumption can occur which shows that the price increase policy for reducing consumption of inessential water in summer is effective.

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