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Estimating Residential Demand for Water in Kuwait: A Cointegration Analysis

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ABSTRACT

This paper aims to investigate the determinants of water demand in Kuwait and assess their impact on consumption. To do this, we applied the cointegration regression and the error correction model (ECM) on annual time series data, covering the period from 1972 to 2019. We found that the price elasticity for fresh water demand in Kuwait is negative and elastic in the long run (-1.095), which is consistent with the existing literature. Also, we found that the income elasticity for demand was positive in the long run (0.234), however, no short run effect was found for either price or income. Our results suggest that policymakers should expect a long run impact when using water prices to adjust the consumption behavior in Kuwait.

Keywords: Development, Structural Time Series Model, Energy Prices, Water Demand, Subsidies.
JEL Classifications: H20, Q25, L16, Q41

1. INTRODUCTION

Kuwait has very little naturally occurring fresh water or rainwater. Since the nation's inception, Kuwaitis have had to look for external sources to secure drinking water (Al-Mutairi and El-Sakka, 2002). According to Kuwait's Ministry of Electricity and Water (MEW, 2017), Kuwait continued to depend on rainwater and wells until the beginning of the 20th century in order to meet the need for drinking water. In the mid-1950s, the Kuwait Oil Company (KOC) established the first small water distillation plant in Kuwait with a production capacity of 80,000 gallons per day. Two years later, KOC built a larger new station with a production capacity of one million gallons per day. In the early 1990s, the installed capacity of Kuwait's water distillation plants reached 252 million imperial gallons per day and then reached 1191 million imperial gallons in 2019 (MEW, 2020).

A follower of fresh water consumption data in Kuwait will find that annual per capita consumption jumped from 9,252 imperial gallons in 1970 to 16,734 in 1980 and from 29,583 in 1992 to 39,631 in 2000. It finally reached 35,489 imperial gallons in 2019 - one of the highest per capita consumption rates in the world (MEW, 2020)

Kuwait is one of the few countries with deficient rainfall and a small percentage of groundwater (MEW, 2017), FAO[1] (2015), and Al-Mutairi and El-Sakka (2002). According to UNESCO[2] (Connor, 2015), population growth and increasing socio-economic pressures have reduced the availability of fresh water resources in the Arab region. Availability dropped from 921m^3 per capita per year in 2002 to 727m^3 per capita per year in 2012, with sixteen of twenty-two Arab countries falling below the water scarcity level of 1000m^3 per capita per year. Accordingly, about 75% of the Arab population live below the water scarcity level, and nearly half live under the extreme water scarcity level of 500m^3 per capita per year, Kuwait being one of these areas. According to FAO (2015), Kuwait has the lowest renewable internal fresh water resources per capita in the world, at the bottom of the list of 180 countries

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[1] Food and Agriculture Organization of the United Nations.
[2] The United Nations Educational, Scientific, and Cultural Organization.

studied in 2014. Table 1 presents the renewable internal fresh water resources per capita of twenty selected countries around the world.

Another problem that Kuwait faces when it comes to water is the consumption per capita. According to Alhumoud (2008), Kuwait had the highest increase in per capita water consumption globally from the 1960s until 2003. One key reason for this could be the low fresh water tariffs that represent only 10% of the real cost on the government, resulting in a lack of financial incentive for consumers to save water. The Ministry of Energy's (MOE) billing is poorly administered, with some Kuwaitis not paying water bills for more than 15 years with no action taken. Furthermore, in October 2005, the MOE decided to credit each household in Kuwait with KWD 2,000 (USD 6,800) on their water bill, which may have worsened the situation and the behavior of consumers (KUNA, 2005) Alotaibi and Almedeij (2007) stated that the current per capita fresh water consumption in Kuwait (535 liters per person per day in 2003) is one of the highest in the world; however, that paper predicts that the mean per capita consumption would drop from 560 liters per person per day in 2006 to 508 liters per person per day in 2010 if the current water rates were reconsidered. Al-Mutairi and El-Sakka (2002) also highlighted that Kuwaitis have paid a constant price for fresh water since the 1960s (KWD 0.80 or USD 2.64 per 1,000 imperial gallons). The real cost varied between KWD 2.264 (USD 7.47) and KWD 3.2 KD (USD 10.56) dependent on many factors such as fuel prices, number of employees in the MEW, and level of demand. The difference between prices and subsidized rates varied up to 75%, which directly and indirectly led to the increase in the consumption of fresh water in Kuwait.

2. LITERATURE REVIEW

Several papers studied the relationship between water consumption and other variables. Mukhopadhyay et al. (2000) applied several regressions to explore the relationship between water demand and other social and environmental factors in Kuwait. One of the main findings in this study was that consumption behavior patterns in Kuwait underwent an extreme change between the pre-Gulf War and post-Gulf War periods. Another interesting finding is the strong correlation between annual and daily consumption and the size of the fresh water network. This might explain the relatively low per capita consumption in the early years of development in Kuwait. In other words, when access to water became easier, consumption increased significantly. On the other hand, Mukhopadhyay et al. (2000) applied a different test to the monthly data, where they found that the average daily consumption over 1 month showed a positive correlation with monthly average temperatures and a negative correlation with relative humidity. In other words, they found that consumption is high during the hot, dry summer months of June to September and low during the winter months of December to March.

Table 1: Renewable internal fresh water resource per capita (km^3)

Country	Value	Rank2
Greenland	10,662,190	1
Iceland	519,264.7	2
Central African Republic	31,226.53	21
Russia	29,981.99	22
Georgia	15,597	41
Madagascar	14,285.83	42
Nepal	6997.79	61
Guatemala	6857.76	62
Japan	3378.49	81
Cuba	3332.24	82
United Kingdom	2244.13	101
Mauritius	2181.72	102
Ethiopia	1252.99	121
Nigeria	1252.41	122
Morocco	845.04	141
Rwanda	837.35	142
Djibouti	328.89	161
Pakistan	296.42	162
Bahrain	2.99	179
Kuwait	0.02	180

Source: The Food and Agriculture Organization of the United Nations (FAO, 2015)

Al-Mutairi and El-Sakka (2002) applied several methods to find the determinants of the demand for fresh water in Kuwait. On one hand, this paper found a positive relationship between income and fresh water consumption, in that the income elasticities of the demand for fresh water in Kuwait were 0.13036 in the short run and 0.2634 in the long run. That means that the consumption of fresh water in Kuwait is not very sensitive to changes in income. On the other hand, the price elasticities of demand for fresh water were -0.97803 in the short run and 1.9758 in the long run. Al-Mutairi and El-Sakka (2002) stated that this result might be surprising because fresh water is a necessary commodity and the demand for it should be less sensitive to changes in the real price. However, this result can be justified by the long-term subsidized prices of fresh water in Kuwait, which means that consumers are vulnerable to any changes, as they have been used to low prices for a long time. This study has an important implication for pricing policy, indicating that the price of fresh water is a useful tool for controlling over-consumption in Kuwait.

Alotaibi and Almedeij (2007) used a sinusoidal model to simulate and forecast the total monthly fresh water consumption in Kuwait, employing data from 1992 to 2005 to develop a time series model. Monthly data was used in order to find the effect of the weather on consumption rates. Alotaibi and Almedeij found that the data shows an increase in consumption in the summer and reaches peak value in July, when the temperature is very high. They then used their model to present a forecast for 5 years of water consumption in Kuwait, which suggested a high continuous increase in total monthly fresh water consumption compared to the previous years. This indicated that appropriate action should be considered urgently to overcome any consequences or difficulties.

Alhumoud (2008) stated that the main water consumption in Kuwait comes from the private sector (about 54% of the total consumption), while the agricultural sector represents 40% and the industrial sector represents only 6%. This study examined the relationship between consumption behavior and other variables and concluded that households that consumed large quantities of water in Kuwait were large in terms of family size, higher income, employed servants and drivers, and lived in villas. Alhumoud predicted that the annual water consumption in Kuwait will be much higher in the near future unless some action is taken to improve the efficiency of water consumption. He suggested several potential government actions, such as public awareness and education programs, changing the water tariff schemes, improving the use of brackish water for daily chores, and more efficient ways of reading the meters and paying the bills.

According to Fadlelmawla (2009), desalinated water covers all potable water needs in Kuwait, including domestic, industrial, and commercial requirements. After discussing the fresh water situation in Kuwait, Fadlelmawla puts forward three main water policy targets for Kuwait: reduction of demand, augmentation of supply, and maintenance of natural resources. Each aspect of these policies is discussed in detail and actions are suggested accordingly—a failure to implement these reforms would cost Kuwait around USD 1 billion every year.

Al-Damkhi et al. (2009) studied fresh water management in Kuwait, where they provided evidence showing a decline in water resources and deterioration of water quality, and emphasized that Kuwait suffers from fresh water scarcity, even though it has one of the highest per capita consumptions around the world. They used data from Kuwait's MEW to show a significant increase in the average daily consumption of potable water per capita in Kuwait from 1960 to 2006. One of the reasons behind this increase is that the Kuwaiti government subsidizes about 59% of the total cost of water in Kuwait, which makes people less concerned about saving water for financial reasons. Consequently, unless individuals suffer the burden of water scarcity, they will not feel any incentive to change their water consumption behavior (de Châtel, 2007).

Wood and Alsayegh (2014) stated the importance of forecasting the demand for water consumption, as production strategy development is based on demand analysis. This study used 10 years' worth of data (1998-2009) covering the Kuwaiti GDP, population, oil income, electricity, and water consumption to predict demand behavior, and the results were attained through the simulation of a model that was run under various scenarios. They created two different demand models, one for electricity and the other one for water, and stated that even though the models were not immune from the effect of unexpected and unprecedented changes in demand drivers, they represented the demand under the influence of the actual drive players. In addition to forecasting water demand until 2030, Wood and Alsayegh applied a simulation test by running the demand behavior model under three oil price cases (namely high, base, and low cases). The results showed that water demand is highly dependent on GDP.

Table 2: Summary statistics of the total water consumption in Kuwait (MIG per year)

Period	Mean	Max	Min	Standard Deviation
1972-1979	12,440.9	20,699	7688	4620.5
1980-1989	32,470.1	43,422	23,067	7360.2
1991-1999	53,229.8	72,596	30,814	13,144.9
2000-2009	97,473.9	120,005	77,885	13,890.7
2010-2019	136,293.1	150,208	122,904	10,069.3

Source: Author's calculations based on OAPEC and MEW dataset

In this paper, we are going to cover the most recent data set and apply difference types of regressions to find the long run and short run impact of price and income on water consumption.

3. MODEL

This paper employs standard demand equation (SDE), cointegration analysis and the error correction model (ECM) to test whether the time series of the variables are cointegrated and have a long-run relationship. Following Al-Mutairi and El-Sakka (2002), we assume that the demand for fresh water is expected to depend on the real price per unit of fresh water and real per capita income. Since the consumption of fresh water in Kuwait is mainly by the household sector, the following general formula for the demand equation will best suit this type of demand:

$$Q=f(P,Y) \tag{1}$$

where Q is the annual quantity of water consumed (millions of imperial gallons), P is the real price per unit of water (nominal price per 1000 imperial gallons divided by the consumer price index), and Y is the real per capita income (which in our case is the real GDP per capita). In linear terms, the demand function is expressed at time t as:

$$Q_t=\beta_0+\beta_1 P_t+\beta_2 Y_t+\mu_t \tag{2}$$

where we assume that $\beta_1 < 0$, and $\beta_2 > 0$, because the expected relationship between water prices and consumption is negative while the relationship between consumption and income is positive. Also, we consider μ as a random error term following a random distribution. Equation (2) can be re-written by using the log-linear terms for both sides:

$$LogQ_t=\beta_0+\beta_1 LogP_t+\beta_2 LogY_t+\mu_t \tag{3}$$

where the coefficients β_1 and β_2 are the long-run elasticities of the real price per unit and real per capita income, respectively. Finally, the following ECM will give us the estimated short-run relationship and the expected speed of equilibrium adjustment:

$$\begin{gathered}\Delta LogQ_t=\beta_0+\beta_{1i}\,\Delta LogQ_{t-i}+\beta_{2i}\,\Delta LogP_{t-i}+\beta_{3i}\,\Delta LogY_{t-i}\\ +\beta_{4i}\,ECT_{t-1}+\mu_t\end{gathered} \tag{4}$$

Table 3: Unit-root tests

	ADF test statistic		DF-GLS test statistic		Phillips-Perron test statistic	
	Level	First difference	Level	First difference	Level	First difference
Consumption	–0.008871	–0.959224***	–0.006854	–1.049531***	–0.061799	–1.051488***
GDP	0.001125	–0.964149***	–0.122055	–0.964159***	–0.195651	–0.966730***
Price	–0.026202	–1.113171***	0.024188	–0.735263***	–0.026202	–1.113171***

***, **, *Statistically significant at 1%, 5% and 10%, respectively where the coefficients β_2 and β_3 are the short-run elasticities of the real price per unit and real per capita income, respectively, while β_4 represents the speed of adjustment toward the long-run equilibrium, and where the *ECT* in our regression refers to the error correction term derived from the long-run cointegration relationship via the Johansen maximum likelihood procedure:

$$ECT_t = \log(Q_t) - \beta_0 - \beta_1 \log(p_t) - \beta_2 \log(y_t) \qquad (5)$$

Following Al-Mutairi and El-Sakka (2002), we ignore other variables that might be determinant of the consumption function in Kuwait (such as weather conditions). The reason for this is that use of this variable must be based on less than annual frequencies, and the income variable is not available for monthly or quarterly frequencies. We assume, like Al-Qunaibet and Johnston (1985) and Al-Mutairi and El-Sakka (2002), that other substitutes and complements are either nonexistent or have negligible effects on the demand for fresh water.

Before we estimate the demand equation, it is essential to conduct appropriate tests to ensure that all data used are covariance stationary, as using levels of economic time series that are nonstationary could lead to the false judgment of a significant correlation or spurious regression problem. We apply the Augmented Dicky-Fuller (ADF), DF-GLS, and Phillip-Perron tests to determine if each variable in the primary model is stationary.

4. DATA

The data used in this chapter are annual time series covering the period from 1972 to 2019. The GDP in current US prices, the total population series, and the CPI are taken from the World Bank Development Indicator database[3]. Data on residential water consumption (in imperial gallons) and total fresh water production (in imperial gallons) are from MEW[4] and the Organization of Arab Petroleum Exporting Countries (OAPEC) database[5]. Finally, the prices of residential fresh water in KWD per 1,000 imperial gallons are from the MEW.

4.1. Summary Statistics

Before applying the required test, we present the data on fresh water consumption per capita in different periods in order to show changes in consumer behavior (Table 2). We expect consumption behavior to change over time for various reasons including changes in income, technology, and advances in water network services (We excluded the years of the Iraqi invasion period "1990" for missing data).

5. RESULTS

Using data from 1972 to 2019, we applied the dynamic demand equation including the lagged variable that we presented earlier. Also, we applied Akaike's information criterion (AIC), and the Hannan–Quinn information criterion (HQ) for the lag selection, and then we applied the ADF, DF-GLS, and Phillips-Perron tests to determine if each variable in the equation was stationary. Table 3 presents the results of the tests, which shows that all unit root tests indicate that we fail to reject the null hypothesis of the unit root (non-stationary) for all the variables in the levels. When we take the first difference of the variables, we reject the null hypothesis of unit root at 1% significance level and we conclude that water consumption growth, GDP growth, and inflation of water (the price of water growth) are stationary.

Finally, the cointegration test shows that the trace statistic is statistically significant at 5% level when $r = 0$ and is not significant when $r \leq 1$. Therefore, there is only one cointegrating relationship at 5% level. Meaning that the null hypothesis of no cointegrating relationship is rejected and there is evidence of a stationary long-run equilibrium between water consumption, GDP per capita, and water price. Table 4 presents the cointegration results:

By applying equations (3) and (4), we found that the price elasticity in the long run is negative (-1.095), while it is insignificant in the short term, meaning that a higher price would lower demand for water consumption in Kuwait in the long run, but no effect is expected in the short term. Similar to Al-Mutairi and El-Sakka (2002), we found a very sensitive relationship between the price and the consumption of water in Kuwait (-1.095), which can be explained by the long-term stability of water pricing. Again, income elasticity to demand was significant only in the long run and was positive, which is consistent with the literature and with the hypothesis that we presented previously. However, the effect is not high (0.234), and one explanation for this result could be that income has little to no effect on the consumption of water in Kuwait, as water is not a substitutable good and cannot be replaced by another good. Also, because the price of water is relatively low, most Kuwaitis see no economic advantage to changing their usage of water with the change in their income. Table 5 presents the results.

Table 4: Johansen cointegration test

	r=0	r≤1	r≥2
Trace Statistic	24.8534	11.3361	3.044899
Probability	0.1668	0.1917	0.081

This table reports the trace test statistic for the Johansen cointegration test. r is the hypothesized number of cointegrating equations

Table 5: Short- and long-run elasticities of residential water consumption

Dependent variable	Price elasticity		Income elasticity	
	Long run	Short run	Long run	Short run
Consumption	–1.0947578*** (0.000)	0.31532 (0.14070)	0.23351721* (0.053321046)	–0.02142 (0.67960)

Standard Errors in Parenthesis; ***, **, *: Statistically significant at 1%, 5%, and 10%, respectively

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[3] www.databank.worldbank.org

[4] www.mew.gov.kw

[5] http://www.oapecorg.org

Table 6: Proposed reform plan for fresh water prices in Kuwait over the next 5 years

Year	Consumer Segments by Quantity (Gal/Per Capita/Y)			
	0-10,000	10,000-20,000	20,000-30,000	30,000 +
	Suggested prices			
2022	1 KD	1.5 KD	2 KD	2.5 KD
2024	1.2 KD	1.7 KD	2.2 KD	2.7 KD
2026	1.5 KD	2 KD	2.5 KD	3 KD

Source: Author's calculations. Prices per 1000 imperial gallon of water

6. CONCLUSION AND POLICY RECOMMENDATIONS

Kuwait is suffering from both low naturally occurring fresh water and a very high consumption per capita, meaning that the government should intervene with a reform plan to ensure a sustainable resource. To ensure compliance with the reform plan, basic principles of the reform process should be developed. First, an awareness campaign is an essential start to encourage rational consumption, as well as raise consciousness about the importance of water in Kuwait. Second, different fees should be determined according to varying consumer segments (considering other reform principles) in order to drive consumers toward more rational consumption. Third, applying a gradual increase in prices may reduce the impact of additional burdens associated with increasing prices on consumers and on the economy overall. Finally, pricing can be linked to production costs in terms of capital costs, production, and distribution inputs, considering the nature of water demand as a fundamental requirement for life. The ability of different sectors to absorb the increase in prices should be considered to try and reduce the negative effects that may result from that increase.

The recommended policy will be constructed according to the price and income elasticities found in the regression analysis. The average demand growth for all years (about 7.6%) will also be considered. The proposed reform schedule will be based on the following segments and prices, where today's prices are 0.8 KD per imperial gallon of water (Table 6).

Because the price elasticities in the results are quite high, the expected quantity of consumption will be significantly affected by price changes in Kuwait. Therefore, we suggested in Table 6 that the change in prices to be small, gradual, and varied according to the segments of consumption quantities. Furthermore, it might be appropriate to link energy subsidies with global oil prices, because they are highly correlated. Finally, this reform program must be accompanied by a mechanism to compensate Kuwaiti households according to their consumption rates or income levels.

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