Determinants of Urban Residential Water Demand in Libya

Mabroka Mohamed Daw, Elhadi Ramadan Ali, Mohd Ekhwan Toriman

Abstract:- This article analyzes the effect of several economic, environmental and social determinants for the per capita demand for water in Libya. Besides prices, income and population size, the article reflects the impact of urban population size, the temperature, summer temperature, and precipitation. The article also explores why the current per capita residential water demand in the urban areas is about more than in the other areas in Libya. In this study, the econometric model based on E-views method, instrumental-variable procedures, the ARDL model and the demand equation are applied. The co-integration analysis has shown a significant positive effect of temperature on water demand over the short and long term with partial flexibility of long-term temperature (5.44). Also, there is a positive relationship between rainfall and water demand in the long term and its less impact in the short term. There is a significant positive relationship between urban population and water demand. The greater urban population is greater the water demand and vice versa, partial flexibility of the urban population in the long term is at 0.23. On the other hand, there is a significant negative effect of income on water demand. Therefore, water demand is inflexible to changes in income. The study demonstrated that there is a negative effect on water price in relation to water demand. The estimated long-term variable of water value is 220.98, indicates that if the water price increases by 100%, the demand for water will go down by 221%.

Keywords: Urban Residential Water Demand, Water resources Libya, the Water situation in Libya, Determinants of water demand.

I. INTRODUCTION

For the first time in human history, over 50% of the global human population lives in urban regions. This increased human population in urban regions in the 21st century has several challenges and implications for managing urban water supply. The forecasting and managing water demand of urban areas is challenging due to the complicated relationship between the human and natural systems [14].

In Libya's urban areas, underground water is the major source for drinking and other consumptions, which also supplement the surface water sources. However, groundwater's availability and quality are greatly influenced by climate change and over-abstraction, especially in regions with a low water table [3]. The shortage of water creases the ability to maintain quality, especially if there are various sources of contamination. The frequently recurring droughts during the last decade have increased the competition for water among urban dwellers for industrial, commercial, and agricultural interests. Also, the increased inhabitants in the urban regions have led to increasing demand for water and, unfortunately, leading to more contamination, which ultimately affects the quality of the water. The scarce and contaminated water issues, among many others, serve as major drawbacks and challenges for the Libyan government. The rapid growth of population, urbanization, agricultural, and industrialization have increased great pressure on land, water and the environment, and quality of these.

Libya had witnessed rapid population growth during the period 1973-2012. The population was nearly 2,052,372 in 1973, 3,231,059, in 1984, and in 1995, the population reached 4,389,739. During the period 1995-2006, the population increased to 5,298,152 and in 2012, 5,363,369. The population is expected to rise more in the near future. However, it is not being matched with an increase in water supply, and consequently, the situation is deteriorating [2].

The concentration of the inhabitant's density in urban areas has led to the increases of building, road, and factories. These human activities result in several effects, including water waste and storm drain, smoke, and dust, and solid waste, which lead to severe water and air pollution. Evaluation and mapping of determinants of demand for water are an important aspect because the growth of population, urbanization and the other factors play an important role to determine the quality and quantity of demand water.

Today, Libya is facing one of the severest water shortage problems. Rainfall is scarce except for regions in the narrow coastal strip. In the coastal regions, the groundwater sources are renewed by rain yearly, but the vast groundwater reserves underlying the desert are not refilled. Over a long period, the country's demand for water has far exceeded supply, leading

to heavy over-drafting and mining of aquifers which is linked to the growing problems of aquifer diminution, quality worsening, and saltwater intrusion [9].

A. Water Resources in Libya

There are five sources of water in Libya, namely; groundwater (which is comprised of approximately 95% of the country's water), surface water (which includes rainwater and dams), desalinated seawater, recycled wastewater, and the Great Man River Project. A brief detail

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of each source of water is given in the following.

1) Country's groundwater is reserved in five basins namely; Jabal El-Akhdar, Kufra/as-Sarir, the JPR, Nafusah/al-Hamada and Murzek. The groundwater is further classified into two based on their renewability; renewable groundwater, which is found in shallow aquifers, and the non-renewable groundwater, usually referred to as fossil water source, which is found in deep aquifers. The characteristics of Libya's groundwater reservoir are summarised in (Table 1).

2) The annual rainfall in the north region of Libya ranges between 200 and 300 millimetres [12], with lower rainfall experienced within the southern regions. In South Kufra, Murzek and Sarir, almost no rainfall is recorded. In the absence of rainfall in the north, surface water is gathered and utilised through a few dams [20].

3) Desalination of seawater was adopted in the 1960s as an extra source of water in Libya [18]. Libya is one of the countries of the world depending heavily on thermal and membrane desalination technologies to provide desalinated water in the Mediterranean region. Libya's desalination plants provide an annual volume of 47,851,500 m3 desalinated water. However, the demand for water far outweighs this production, which can only supply a little of the total required municipal and industrial water to regions with water shortage. One of the major reasons plants cannot meet water demand is inefficiency. As only about 24% of the plants' capacity is being utilized due to out of date installations and other faults, causing the plants to function at reduced efficiency [4].

4)The Libyan population explosion resulted in the construction of infrastructures and sewage networks, which caused too much use of water and water treatment plants. In Libya, the first implementation of the wastewater treatment started in the early 1970s. Several implementation strategies were further introduced between this period and early 1990s to supply the water required for agriculture and protect the natural environment [11]. Generally, treated water is very affordable in Libya, thanks to the many recycling plants in major cities [20].

5) The Great Man River Project is globally regarded as one of the biggest water projects of all time [8]. The project is tasked with transferring groundwater from south Libya to the fertile north with dense population. Libya's groundwater reserve is fossil water up to 3,850 × 106 m3 found in deep aquifers beneath desert sands in the south, hence the reserve is non-renewable. With the GMRP project, urban residential areas, industries and agricultural regions can receive water for various uses. This project particularly helped to convert thousands of hectares of arid land to agriculturally productive lands [15]. The project

had the capacity of transferring over six mm3/day of water through the GMRP systems upon completion [21].

Table (1) Groundwater reservoirs characteristics

Basin	Area	Renewable	Non-renewable	Total dissolved
Catachrestic	(km)2	106 m3	106 m3	Solids, mg/1
Al-jabal alakhdar	145,000	200	50	1000-5000
Al-kufra, Al-sarir	700,000	-	1800	200-1500
Al Jafara Plain	18,000	200	50	1000-5000
Al Hamada	215,000	250	150	1000-5000
Murzek	350,000	-	1800	200-1500

Source: [20

B. Water Resource Situation

There is a high demand for water in urban regions due to their utilization in residential houses, gardens, hospitals, school and universities, public offices, hotels, cafes and commercial markets [19]. This high demand is due to the population explosion. Domestic water consumption account for 12% of all water consumed in Libya [1]. The GMRP, regional groundwater, and desalinated water are the three major sources of water supplied to urban areas in Libya. Between 1999 and 2008, the availability of other sources of the water supply has significantly reduced dependence on groundwater source. It presents a highlight of the reduced dependence on groundwater sources and the corresponding increased utilization of the GMRP water in Libya. Industries use 135.64 mm3 of water for air conditioning, refrigeration, manufacturing and the infrastructural development, and operations of factories. Within the industry, the oil and gas sector consumed most of the water (for 76%) in injectors, processors and for other domestic purposes [1]. CPPAP (2003) predicted that the population in Libya would rise to 11.7 million by 2025. Estimated volume of water reserve available for investing (with the exclusion of wastewater and their desalinated product) is 3,820 mm3, which consist of 170 mm3 surface water, 650 mm3 and 3,000 mm3 renewable and non-renewable groundwater respectively (with the inclusion of the GMRP water) [5]. The NENAR region had the least rate of renewable water and surface water per capita in Libya. Taking the population explosion trend into consideration, the per capita renewable water and surface water rate is expected to decline steadily from 170 m3 in 1995 to a projection of 70 m3 in 2025 (Figure1).

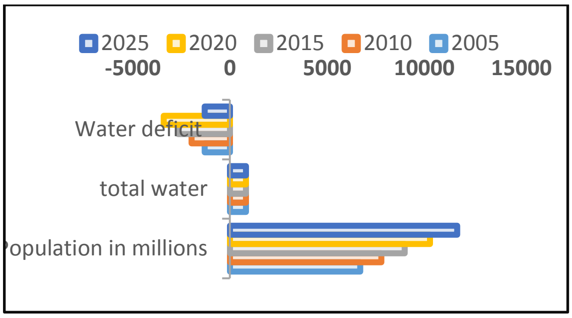

Figure (1) The water situation in Libya 2005–2025
Source: [5]

II. ESTIMATION OF RESIDENTIAL WATER DEMAND

This paper employs the Autoregressive Distributed Lag (ARDL) to determine the short term and the long-term integrative relationship of the dependent variable. The ARDL model can additionally determine the effect of independent variables on the dependent variable [10]. The ARDL analysis is a dynamic regression model, where there are time lag periods, the relationships can be measured in both long and short terms. The co-integration model utilizes to determine the variables influencing water demand in Libya during the period 1960-2015 using time series data.

A. Design of the Standard Model and Sources of Data

The Standard Model of the variables studied is formulated by converting the relationship between these variables to a standard formula, which is consistent with previous literature, studies and reality. The DW dependent variable can be expressed as independent variables in its traditional form as follows:

$$\mathrm{DW} = f(\mathrm{ST}, \mathrm{T}, \mathrm{RF}, \mathrm{POP}, \mathrm{UP}, \mathrm{IN}, \mathrm{WP}) \qquad [1]$$

By converting this function to a linear formula, the model form in the multi-regression function will take the following formula:

$$\mathrm{DW} = \beta 0 + \beta 1\mathrm{ST} + \beta 2\mathrm{T} + \beta 3\mathrm{RF} + \beta 4\mathrm{POP} + \beta 5\mathrm{UP} + \beta 6\mathrm{IN} + \beta 7\mathrm{WP} + \mathrm{ui} \qquad [2]$$

$$\mathrm{B} \neq 0, \beta 1 \neq 0, \beta 2 \neq 0, \beta 3 \neq 0, \beta 4 \neq 0, \beta 5 \neq 0, \beta 6 \neq 0\ \beta 7 \neq 0 \qquad [3]$$

Where:

•**DW** refers to the demand for water in Libya. The data was received from the General Ministry of Water, the Status of Water from 1960 to 2015 in Libya, Tripoli.

•**ST** refers to summer temperature. Demand for water is expected to increase according to summer temperatures. The summer temperature series and air reports from 1960 to 2015 were obtained from the National Observatory of Meteorology (NOM), Libya.

•**T** refers to temperature. Demand for water is expected to increase according to temperature and vice versa. The time series data on temperature and air reports in Libya from 1960 to 2015 was also obtained from the NOM, Libya.

•**RF** refers to the rainfall rate. It is expected that an inverse relationship exists between rainfall and demand for water. Rainfall data from 1960 to 2015 was also obtained from the NOM, Libya.

•**POP** refers to the population census in Libya. A positive relationship was expected to exist between the population census and the demand for water, i.e. the larger the population, the greater the demand for water. The population census data from 1960 to 2015 was supplied by the General Ministry for Planning and Economy, the Department of Statistics and Census.

•**UP** refers to the urban population in Libya. A positive relationship is expected to exist between the increase of the urban population and the demand for water in Libya. The researcher obtained a copy of the general population census from 1960 to 2015 from the Statistics and Census Authority. The results of the general population census are for the period between 1960 and 2015.

•**IN** refers to per capita income. A positive relationship is expected to exist between per capita income and demand for water as the economic theory shows and vice versa. Data on income was obtained from the Central Bank of Libya and the World Bank.

•**WP** refers to the price of water. A reverse relationship is expected to exist between the price and demand for water as the economic theory confirmed. The researcher obtained time series data of the water price and the situation of water in Libya in 2015 from the General Authority for Water, Tripoli.

•**Ui** indicates the random error limit.

Due to the heterogeneity of the study data, the logarithmic formula includes all variables except water price variable (WP) since it involves data less than one. Therefore, the proposed model is as follows:

$$\mathrm{Ln\,DW} = \beta 0 + \beta 1\mathrm{lnST} + \beta 2\mathrm{lnT} + \beta 3\mathrm{lnRF} + \beta 4\mathrm{lnPOP} + \beta 5\mathrm{lnUP} + \beta 6\mathrm{lnIN} + \beta 7\mathrm{WP} + \mathrm{ui} \qquad [4]$$

Before estimating the Model, it is necessary to examine the stability of the study to avoid spurious regression issues.

The Unit Root Test of Stationary: The study of stability is one of the important conditions in the study of simultaneous integration because its absence causes several standard problems. Its importance lies in verifying the stability or instability of the time series and identifying the type of instability, whether it is Trend Stationary TS or Difference Stationary DS. Data Non-stationary is a major crisis in the Standard Analysis. As a result of the dynamic nature of the mean and variance over time, most economic data suffer from this crisis. Therefore, the use of lower squares method will lead to biased results where the values of t-statistics, F-statistics and R2 can be statistically significant, though they do not provide statistical explanation and lead to misleading conclusions [16].

Correlation Analysis: The purpose of the correlation analysis is to show the individual relationships between the two variables. It is also studying the relationship between variables and detects the problem of self-correlation and tests the absence of a basic regression problem, i.e. linear multiplicity, which indicates a strong relationship between independent variables. This analysis is also used to identify the strengths and directions of the relationship between variables.

Co-Integration Test: To test the extent to which co-integration is achieved (which represents the long-term balanced relationship between the studied variables), the Bound Tests approach (which is based on PSS analysis) is used to calculate the statistical F- (PSS). If the value of the calculated F-statistics is more than the tabular critical values, the null hypothesis (H0) (which states that there is no relationship) is rejected and thus accepting the alternative hypothesis (H1). It means that the presence of a long-term relationship exists between the variables regardless of integration rank oI (0) or I (1). If the value of (F-statistics) calculated is less than the critical values, the null hypothesis (H0) is accepted.

Co-Integration Relationships in the Short Term: The error correction coefficient [CoinEq (-1)] has achieved the necessary and sufficient condition, where it is negative and significant at 1% which is needed by the dependent variable to be balanced with independent variables in the long term.

Co-Integration Relationships in the Long Term: Using SC, a sample of 1,0,4,1,4,2,1, the ARDL was tested to estimate the long-term balanced relationships as illustrated by the following equation:

$$\text{Cointeq} = \text{LDW} - (-0.667{*}\text{LST} + 5.4500{*}\text{LT} + 0.3186{*}\text{LRF} + 0.2356\ {*}\text{LUP} - 220.9876{*}\ \text{WP} - 0.3925\ {*}\text{LIN} + 0.0397{*}@\text{TREND}).$$

[5]

Normality Test: This test measures the natural distribution to ensure that the model takes the form of moderate natural distribution, through the Jarque - Bera test.

Stability Test: To ensure that the data used in this study is free of any structural changes, it is important to use the CUSUM test, which is related to the behaviour of the residues' cumulative total and the CUSUMQ test, which is related to the behaviour of the residual boxes cumulative sum. These tests are fundamental as they show any structural changes in data and the extent to which long-term parameters are consistent with short-term parameters. The structural stability of the self-regression model estimated coefficients of the distributed time gaps is achieved if the CUSUM and CUSUMQ test patterns are within the critical limits at 5%.

Testing the Predictive Relevance of the Model: The Theil Inequality Coefficient Standard was tested to determine the model's ability to predict the result accurately.

III. LITERATURE REVIEW

A review of literature on water demand reveals that demand for water for urban dwellers exceeds those in rural areas. Individual demand equations, integrated with different functional types, were used to determine the elasticity of water demand for income, price, household features, and structure among alternatives. These revisions use plate data, chronology, or cross-section data. The most important and modern studies carried out in this field are:

Schleich and Hillenbrand (2009) analyzed the impact of various economic, environmental and social determinants for water demand per capita is about 600 water supply areas in Germany, using a group of variables that were prices, income, household size, population age, the share of wells, housing patterns, precipitation and temperature. The results of the study show that the price elasticity of water demand in Germany is around −0.24 [17]. The income elasticity is positive, decreases with higher income levels and is at least three times higher in the new federal states than in the old federal states. Current differences in prices and income levels explain about one-third of the gap in residential water use between the two regions. The household size and the share of wells have a negative impact on per capita water demand, and water use increases with age. All outcomes are robust to a log-log and two types of semi-log specifications for the water demand function.

Dagnew (2012) investigated the factors that determined the water demand in residences in northwestern Ethiopia, Merhawi. The main aim of the study was to assess the factors capable of influencing water demand in residences. The variables were activities that guarantee an inflow of income, number of occupants, family demography such as size, age and sex composition, housing ownership and characteristics of the household head. The data collected from 200 households and analyzed by using SPSS, the main objective was to look at the pricing of residential water from three different point: The first, the change of price for the urban water; the second, if the price encourage the people to consume the water; the third, the impact of the price on water consumption. The study used the econometric analysis of a cross-sectional data set. The result shows that demand (with an estimated price elasticity of −0.2, is not yet very responsive with the price variation [6].

de Maria, André and Carvalho (2014) used three econometric models to study the spatial determinants of urban residential water demand in Fortaleza, Brazil. These were the Spatial Error Model (SEM), the Spatial Autoregressive model (SAR), and the Spatial Autoregressive Moving Average model (SARMA)The study variables include average/marginal price, the difference, income, number of male and female residents and the number of bathrooms. The results show that not controlling spatial effects is a key specification error, underestimating the effect of almost all variables in the model and also the results suggested that the (SARMA) model is the best as shown by a series of analysis [7].

Abdudayem and Scott (2014) studied the water infrastructure and the water situation in Jafara basin in Libya. The study examined the water shortage problem in Libya and the water infrastructural legislation, frameworks and the infrastructure surrounding the various water resources. The study also discussed the national strategy adopted in managing water resources and made important suggestions for addressing the overexploitation of water in the Jefara Plain Region (JPR). The part of the study provided details about the Great Man-made River Project (GMRP) and water investment in JPR's agriculture. The study identified issues and major drawbacks in the water sector investment.

Makki et al. (2015) used the novel bottom-up urban water demand forecasting model. It revealed the determinants, drivers and predictors of residential indoor end-use consumption. The purpose of this comprehensive study was to explore the principal determinants of six residential indoor water end-use consumption categories at the household scale (i.e. namely clothes washer, shower, toilet, tap, dishwasher, and bath), and to find an overarching research design and approach for building a residential indoor water end-use demand forecasting model in Australia. The principal determinants, main drivers, and predictors of residential indoor water consumption for each end-use category were revealed, and forecasting models have developed this study. The results demonstrated that the main drivers of higher end-use water consumption were households with higher frequency and longer end-use events which are most likely to be those larger family households with teenagers and children, with higher income, predominantly working occupants, and/or the higher educational level [13].

IV. RESULTS AND DISCUSSION

A. Unit Root Test

Estimation results for the Unit Root test is displayed in (Table 2). These show the stability of both LST and LT variables in their original forms (level 1 or 5%, 10% using the ADF and PP). The LRF variable is stable at the level when testing (PP) only. The LUP study variable stays at the level with the ADF test. All variables involved in the analysis achieved stability after the first difference at the level of 1% and 5% in the presence of constant Intercept function. According to these results, the best method to use for analysis of co-integration is the ARDL model, which permits diversity in the integration levels of variables.

Table 2 Unit Root Test Results of the Unit Root Test conducted on the variables of the study

Variables	On Levels Intercept and Trend		On First Differences Intercept & No Trend	
	ADF	PP	ADF	PP
LDW	-2.342078	-2.341571	-6.647591***	-6.800851***
LST	-5.175578***	-6.260680***	-7.296672***	-28.85912***
LT	-6.538780***	-6.670464***	-10.90640***	-15.88285***
LRF	-3.126239	-7.331652***	-9.752407***	-14.88550***
LUP	-3.974180***	-1.381384	-3.032759**	-0.748054
WP	-2.456956	-2.507173	-7.639173***	-7.699953***
LIN	-2.078317	-1.072419	-3.690111**	-7.728619***

, *, *** indicate the rejection of the null hypothesis of non-dormancy at a significant level of 10%, 5% and 1%, respectively.

Source: Prepared by the researcher based on the results obtained from the statistical program E- Views -9

B. Correlation Analysis

(Table 3) presents the results of correlation analysis for all study variables that show that there is a strong correlation between the POP and the UP variables. The POP variable is utilized to eliminate the problem of linear multiplicity. Also, it uncovers the correlation between the variables.

Table (3) Pairwise Correlation Matrix

	LST	LT	LRF	LPOP	LUP	WP	LIN
LST	1						
LT	0.70	1					
LRF	-0.06	-0.08	1				
LPOP	0.72	0.57	0.08	1			
LUP	0.65	0.48	0.10	0.98	1		
WP	0.80	0.67	0.04	0.91	0.86	1	
LIN	0.63	0.47	0.19	0.96	0.97	0.81	1

Source: The researcher, based on the results of the statistical program E-Views -9

C. Result of The Co-Integration Test

The calculated value of F-statistic is greater than the upper limit of (Table 4) value at a significant level of 1%, 5%, and 10%. Hence, the null hypothesis (H0) is rejected because there is no long relationship (H1), which means that there is a long-term relationship between the model variables. Therefore, it is necessary to follow the next step in the ARDL analysis in such a case.

Table (4) Critical Values for the F-test (k=6, n= 52)

	Case II (Restricted intercept and not a trend)		Case III (Restricted intercept and time trend)	
F-Statistic	=	1.881111	5.124481	
S. level	I(0)	I(1)	I(0)	I(1)
1%	3.15	4.43	3.27	4.39
5%	2.45	3.61	2.63	3.62
10%	2.12	3.23	2.33	3.25

Source: The researcher, based on the results of the statistical program E-Views -9

D. Result of Co-Integration Relationships in Short Term

(Table 5) shows the results of the model's short-term parameters assessment. The value of the error correction coefficient parameter in the Table indicates that 0.45 short-term errors can be corrected within one year, to return to the long-term balanced position.

Table (5) Short-Run Error Correction Representation for the Selected ARDL Model, Selected Model: ARDL (1, 0, 4, 1, 4, 2, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob
LST	-0.208064	0.123119	-1.689937	0.1011
D(LT)	0.601054	0.167204	3.594728	0.0011
D(LT) (-1)	-1.692100	0.274999	-6.153107	0.0000
D(LT) (-2)	-0.985577	0,198635	-4.961753	0.0000
D(LT) (-3)	-0.311116	0.145357	-2.140349	0.0403
D(LRF)	0.030199	0.018488	1.633449	0.1125
D(LUP)	-0.458285	0.302649	-1.514244	0.1401
D(LUP) (-1)	-0.677905	0.514470	-1.317677	0.1973
D(LUP) (-2)	0.569916	0.481842	1,182786	0.2459
D(LUP) (-3)	-1.129855	0.316648	-3.568177	0.0012
D(WP)	-70.391520	32,787800	-2.146881	0.0397
D (WP (-1)	114.238075	29.778422	3,836270	0.0006
D(LIN)	-0.040816	0.034553	-1.181248	0.2465
C	22.670738	3.209813	7.062947	0.0000
CointEq(-1)	-0.454568	0,065205	-6,971319	0.0000

Source: The researcher, based on the results of the statistical program E-Views -9

E. Result of Co-Integration Relationships in the Long Term

All variables used in this study were significant at 5% except for LST, which had a negative and insignificant effect at 5%. However, it was significant at 10%. Temperature (LT) has a positive and significant effect. This is in line with the hypothesis that there is a positive relationship between temperature and water demand. According to the variable temperature parameter LT, if the temperature is increased by one degree Celsius, demand for water (DW) will go up by 5.4%. The level of LRF and water demand were significant and positive. This is not consistent with the hypothesis of the study, which contends that there is a negative correlation between LRF and water demand. The LUP urban population has a positive and significant effect on water demand. This is in line with the hypothesis of the study. The larger the urban population is, the greater the demand for water. According to the capacities of the model shown in Table 6, if the LUP urban population is increased by one million people, the demand for water (DW) will increase by 23%. The WP variable had a negative and significant effect. It supports the hypothesis of the study and the economic theory, where the higher the price is, the lower the demand for water and vice versa. The income of the individual LIN was significant but had a negative impact on the demand for water. It contradicts with reality and economic theory, which states that income and the required commodity are positively related.

Table (6) The estimated coefficients of the model as follows: Selected Model: The ARDL (1, 0, 4, 1, 4, 2, 1)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob
LST	-0.667435	0.365524	-1.825969	0.0775
LT	5.449957	1.146040	4.755469	0.0000
LRF	0.318602	0.098220	3.243766	0.0028
LUP	0.235590	0.075935	3.102506	0.0041
WP	-220.9875	71,458658	-3.092524	0.0042
LIN	-0.392491	0.076712	5.116414	0.0000
@TREND	0.039718	0.002797	14.199524	0.0000

Source: Prepared by the researcher based on the results of the statistical program EViews -9

F. Result of Normality Test

As shown in (figure 2), the value of Jarque-Bera is insignificant at a level of 5% (H0); therefore, the distribution takes the normal temperate form.

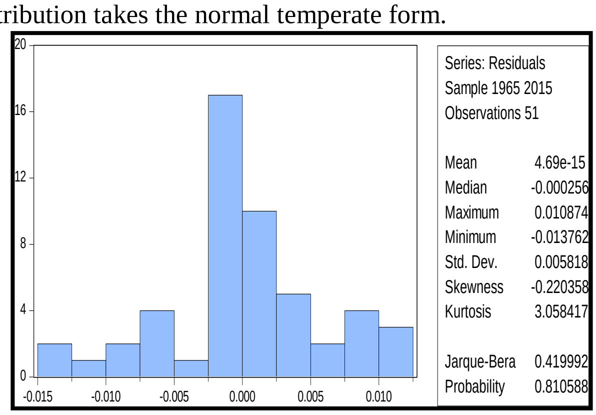

Figure (2) Histogram of Residuals and Jarque-Bera Test Values

Source: Prepared by the researcher based on the results of the statistical program E-Views-9.

G. Result of The Stability Test

As shown in (**Error! Reference source not found.**) and (Figure), both the residues sum and the sum of their squares are within the 5%, which means that the model is structurally stable.

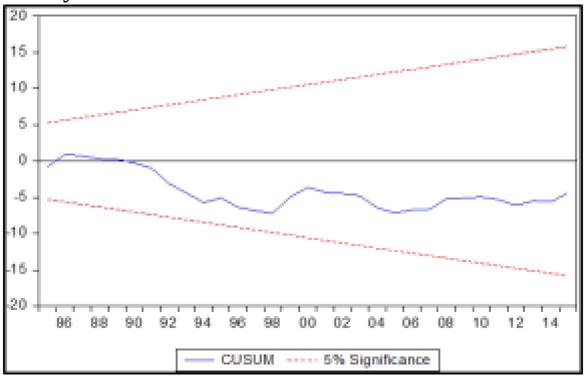

Figure (3) Plot of Cumulative Sum of Recursive Residuals

Source: Prepared by the researcher based on the statistical program E-Views -9.

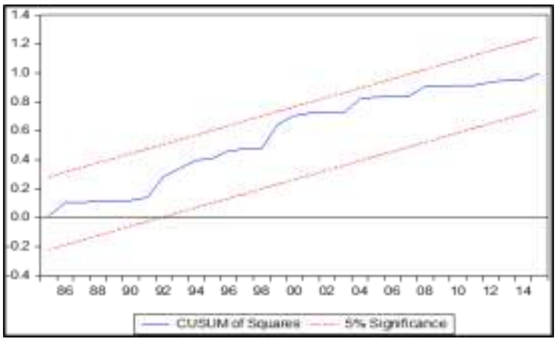

Figure (4) Plot of Cumulative Sum of Squares of Recursive Residuals

Source: Prepared by the researcher based on the results of the statistical program E-Views -9

Note: Redline refers to critical values, and the blue line refers to the residue curve. When it is within the red boundary, there is no serial correlation between the residues in the Cusum of Squares test at a level of less than 5%. It is clear from the previous tests results' presentation that the model used is suitable, and the results are of high quality.

H. Result of the Test of the Predictive Relevance of the Model

Note that the model has a good predictive ability, and this is done through the Theil coefficient, which is very close to zero, where its value was 0.000850. The two red lines close to the line of the logarithm of water demand (LNDW) confirms that the model has a good predictive capacity (see Figure 5).

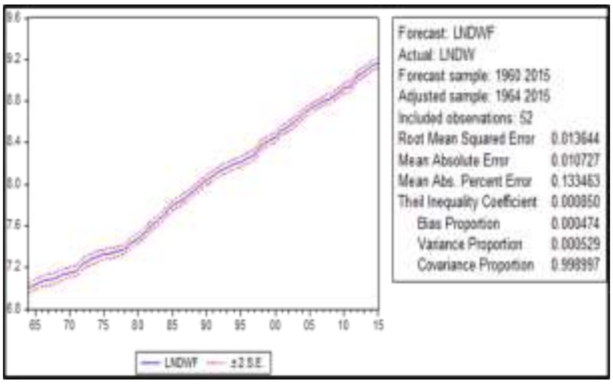

Figure (5) Results of the coefficient test

Source: Prepared by the researcher based on the statistical program E-Views -9.

V. DETERMINANTS OF URBAN RESIDENTIAL WATER DEMAND

A. The Temperature

The results of the co-integration test show a positive and significant effect of temperature (T) on water demand over the short and long term with partial flexibility of long-term temperature (5.44).

B. The Rainfall

There is a positive relationship between rainfall (RF) and demand for water in the long term and its less impact in the short term.

C. The Urban Population

There is a positive and significant relationship between urban population (UP) and the demand for water (DW). In Libya, the greater the urban population, the greater is the demand for water and vice versa. It means partial flexibility of the variable UP in the long term is at 0.23, that if the urban population increased by 100%, demand for water will increase by 23%.

D. The Income

There is a negative and significant effect of income (IN) on water demand in the long term and short-term impact. This is confirmed by the output of the model as the flexibility of income near zero in the short term (0.04) and was low in the long run (0.3)

E. The Water Price

There is a negative effect (WP) on demand in the short and long terms. The value of the estimated long-term variable of water value is 220.98, which means that if the water price increases by 100%, the demand for water will go down by 221%.

F. The Summer Temperature

There is a less effect of temperature in summer (ST) on the demand for water (DW) in the short term and the existence of a negative relationship between them according to the assessment results. It also shows a little impact in the long run.

In results of testing the variables by using the unit root of the time series data, the ADF and the PP, it is observed that all the variables were unstable at the level I (0). All variables in the logarithmic formula were stable at the first difference (I) and significant 1% and 5% in the presence of the constant function and the general Intercept and Trend. Thus, co-integration can be used through the ARDL model.

According to the ARDL model, in the co-integration test, they were not all stable at the level or integrated. One rank shows the existence of a co-integration relationship between them (balance relationship) in the long term based on the Bound Tests. There were short-term balanced relationships through using the ARDL model by the independent variable coefficients. The explanatory capacity of the estimated model is high, where the value of R-square is 99%. This means that 99% of the changes that occurred to the DW variable were caused by the change in independent variables in the estimated model. The F test value reflected the quality of the model as a whole. The Durbin-Watson test value indicated that the model did not have the problem of self-correlation. The results of the co-integration test showed a positive and significant effect of temperature (T) on water demand over the short and long term with partial flexibility of long-term temperature (5.44). It means that the rise in temperature by 100% increased the demand for water by 5.44%. At the same time, there is a positive relationship between rainfall (RF) and demand for water in the long term and its less impact in the short term, and the researchers attribute these results to the following reasons:

• Libyans do not rely on rainwater for consumption, especially for drinking and domestic use because many desalination plants on the coast feed the water network in Libyan cities and villages.

• The existence of a huge system of a human-made river in Libya that provides the necessary supply of water to cover the demand, especially in the main cities with high population density.

• The weakness of the infrastructure in Libya where there are no basins for collecting rainwater and benefiting from it, whether for drinking, irrigation or other purposes.

• Low rainfall rates in Libya where a large area of the country has a semi-desert dry climate and low rainfall. Therefore, rainwater does not constitute a major source of water in Libya.

There is a positive and significant relationship between urban population (UP) and the demand for water (DW). In Libya, where the greater the urban population is the greater the demand for water and vice versa, partial flexibility of the variable UP in the long term is at 0.23, that if the urban population increased by 100%, demand for water will increase by 23%. On the other hand, there is a negative and significant effect of income (IN) on water demand in the long term and short-term impact. The researchers explain the reasons for these results as the following:

• Water is a very necessary commodity that must meet the demand and stopping its consumption leads to death. Therefore, the demand for water (DW) is usually inflexible to changes in income (IN). It is confirmed by the output of the model as the flexibility of income near zero in the short term (0.04) and was low in the long run (0.3)

• The low impact of income in Libya on demand in general and water in particular, where the public sector has exploited the main source of income in Libya for many years, which monopolised the economic activity represented by government salaries. These salaries have been in a standstill for more than two and a half decades with slight increases.

• Increased income leads to diversifying the sources of drinking for individuals and the demand for other alternative goods such as soft drinks and juices while increasing their incomes

There is a negative effect (WP) on demand in the short and long terms. The value of the estimated long-term variable of water value is 220.98, which means that if the water price increases by 100%, the demand for water will go down by 221%. Also, there is a less effect of temperature in summer (ST) on the demand for water (DW) in the short term and the existence of a negative relationship between them according to the assessment results. It also shows the lack of impact in the long run. The researchers attribute these results to the following reasons:

• Libya's climate is moderately temperate. Therefore, the temperatures do not rise much in summer compared to other countries with a hot or tropical climate.

• Most of the population in Libya live in the coastal strip, which enjoys a relatively mild climate in summer.

The value of the error correction coefficient parameter in the long-term co-integration model indicates that 0.45 short-term errors can be corrected within one year to return to the long-term balance position which indicates that any water demand imbalance is corrected by an average of 45% per year. The results of the standard tests for the validity of the assessed model showed that there were no standard problems that might adversely affect the accuracy or bias in the test results. The results revealed that the assessed model was free from self-correlation of higher grades. The model is free from the heterogeneity of variance error limit and that the variables were distributed naturally as well as the stability of the model at the level of 5%. The results of the Stability Test for the ARDL model estimated that short-term and long-term relationships using CUSUM and SUSUMSQ have short and long-term parameters. The result of testing the model's ability to predict through the coefficient of inequality proved to have a strong predictive capacity for water demand.

G. Water policy implication

To preserve the quantities of water in the underground reservoir and reduce the excessive consumption of water, several resolutions and decisions were issued:

- Ministerial decree for banning the drilling of new water wells in the Gefara plain and the surrounding mountains by the Secretary of Dams and Water Resources (1979).
- Ministerial decree for controlling the plantation of citrus trees and banning plantation of tomatoes for manufacturing tomato paste and other crops demanding large supply of irrigation water (1976).

- Decision of General People's Committee for adopting certain measures concerning the re-planning and development of the coastal belt (1981).
- Decision of the Secretary of Agriculture for regulating irrigation (1983).

VI. CONCLUSION

This paper has assessed the main factors that led to an increase in the water demand in Libya. It focused on the main factors behind the serious problem of water in the country. Most of these factors strongly affect water demand, such as population, temperature, urban population, and summer temperature. The econometric model (water demand equation) was applied using the E-Views method to determine the main factors that impact on water demand and evaluate these factors.

Libyan's existing desalination and sewage treatment plants function at 39% and 32% of their installed capacity, respectively, which is far below the average production capacities of the plants. The plants should be improved to function at their installed capacity. If 50% of domestic water use is considered feasible for treatment, then by 2025, Libya should be able to produce around 500 Mm3 /y of wastewater which could effectively contribute to the irrigation water supply. On the other hand, desalination of seawater could offer the advantage of making almost unlimited amounts of water available, if costs were no constraints.

In this study, the co-integration analysis shows a significant positive effect of temperature on water demand over the short and long term with partial flexibility of long-term temperature (5.44).

Also, there is a positive relationship between rainfall and water demand in the long term and its less impact in the short term. The study has also found a significant positive relationship between urban population and water demand. The greater urban population is greater the water demand and vice versa, partial flexibility of the urban population in the long term is at 0.23. The study also shows a significant negative effect of income on water demand. Therefore, water demand is inflexible to changes in income. The study demonstrated that there is a negative effect on water price in relation to water demand.

The estimated long-term variable of water value is 220.98, indicates that if the water price increases by 100%, the demand for water will go down by 221%. The study concludes that various factors determine water demand in Libya, not a single factor affects the water demand; thus, the government should take into account all factors when managing the water resources.

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