Climate change and its impact on water consumption in Tunisia: Evidence from ARDL approach

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Abstract

This study aims to explore the link between weather and bottled water consumption in Tunisia using the Autoregressive Distributed Lag model (ARDL) between 1995 and 2020. Ours results show that the precipitation and labor rates in the three sectors have an impact in the short and long term. An increase of 1°C in temperature in the short term leads to an increase in consumption of more than 4 liters of bottled water. However, 1 % more rainfall means a decrease in long-term bottled water consumption of about a quarter of a liter. While in the short term the effect is mixed (both positive and negative). Temperature further increases bottled water consumption in rural areas and among climate-exposed professions.

Keywords : Climate Change, Bottled water, ARDL, Tunisia.

JEL Classification : Q25, Q54, Q56, Q57.

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1. Introduction

Climate change poses a significant challenge to human beings. It affects and interacts with environmental and anthropogenic systems. Among the variables of interest are environmental degradation, agricultural productivity, food security, population growth, and economic and social stability. Climate change is one of the greatest challenges facing humanity in the 21st century. Its concept refers to a sustained increase in the earth's average temperature. This is a real fact whose consequences for the good of humanity have become a threat.

This is based on the observation of rising average air and ocean temperatures around the world, widespread melting of snow and ice, and a rise in average sea level for many years now. Since then, the consequences of climate change, including droughts, floods, and the increasing frequency and intensity of severe weather events, have been felt around the world (IPCC 2007).

However, the record of climate governance remains marginal, although it has contributed to global awareness (Aykut et Dahan 2015). According to the 2018 IPCC report "Global warming is projected to reach the critical threshold of 1.5◦C between 2030 and 2052 if temperatures continue to rise at their current rate". The climate crisis is thus becoming real, deep, and long-lasting.

It is qualified as real because the current facts corroborate the warnings declared and reiterated by the IPCC since their first assessment report in 1990. Also, the climate crisis is becoming deep because its impact is becoming very important and affects all economic sectors, which generates very important costs at the human, economic and social levels. Finally, it is difficult with current means, in the short or medium term, to adapt or contain the costs generated by climate disruption, which makes the phenomenon sustainable (Diallo, 2021).

The effects of climate change are becoming more and more real and adaptation is becoming crucial. Some sectors, regions, nations, communities, and people will be more vulnerable to climate change than others (IPCC 2007). Vulnerability assessments are central to efforts to prioritize and deliver adaptation investments from limited global funding in ways that address those most in need. They can help decision-makers target and implement effective adaptation initiatives by identifying the particular places, people, or sectors where the impacts of climate change are likely to cause the most harm. Vulnerability assessments have received increasing attention from policymakers and academics (OECD 2015).

The economic impacts of climate change 60 are many and varied. It will have widespread economic consequences that will not only affect major economic sectors such as agriculture, energy, or health care, but will also lead to changes in the supply and demand for goods and services in all sectors of the economy, but with varying levels of intensity. Higher temperatures, sea level rise and other climate changes (changes in regional precipitation patterns, the water cycle, frequency and intensity of extreme events) will also affect aspects of life such as human security, health and well-being, culture, people's capabilities, and environmental quality (OECD 2015).

The economic impact of climate change is global and multi-sectoral. Several studies show that global warming has a very significant and negative effect on the wealth of nations. Using low-resolution data (1°lat x 1°long), Nordhaus (2006) finds that geographical variables including temperature and precipitation explain about 20% of the difference between the income level of Sub-Saharan African countries and industrialized European countries. The impact of climate change on income is also detected when looking at a more disaggregated analysis between localities within a country. Dell, Jones, and Olken (2009) analyze the relationship between temperature and income within several municipalities in 12 countries in the Americas. They find that increases in the average temperature level affect the difference in income between countries and between municipalities within each country. For example, a temperature increase of 1°C decreases income by 1-2% (intra-country) and 8.5% (inter-country). This negative relationship between global warming and income is corroborated by several other empirical analyses in different contexts (Hsiang 2010 ; Barrios et al 2010 ; Dell et al 2012).

In addition, other authors analyze the economic costs generated by extreme weather events such as droughts, cyclones, floods, and other similar events. Indeed, these extreme events are a major consequence of climate change (Knutson et al. 2020). The results of these studies are ambiguous. Some analyses find a positive effect of natural disasters on growth, while others find that natural disasters harm GDP growth. However, according to Raddatz (2009), these extreme events have generated significant macroeconomic costs in recent decades. The author shows that GDP per capita is reduced by at least 0.6% due to the occurrence of climate-related disasters. Cavallo et al (2013) show that natural disasters affect the economic growth of countries in the short and long term. Nakamura et al (2013) estimate the economic cost of disasters in 24 countries over 100 years. The authors find that disasters increase the volatility of consumption 94 growth, specifically, consumption falls by 30% in the short term before half of this decline is recovered in the long term.

In addition to the economic costs of climate change, some authors measure the social costs of climate change. These social effects of climate change are observed in the incidence of poverty (Hope 2009 ; Hertel and Rosch 2010 ; Skoufias et al 2011 ; Leichenko and Silva 2014 ; Stern et Fankhauser 2016 ; Hallegatte et al 2018), the incidence of crime (Jacob et al 2007 ; Ranson 2014) and conflict (Burke et al. 2009 ; Hidalgo et al. 2010 ; Hsiang et el 2013). These studies show that climate change increases poverty and inequality. One explanation is that climate change contributes to the increased vulnerability of households whose income is highly dependent on the agricultural sector.

At the same time, climate change is expected to increase the global average temperature and the frequency of heat waves. Although these two issues may seem unrelated, the potential link stems from an expected increase in water demand as average temperatures rise, particularly for human consumption. Although sustainable alternatives to bottled water consumption exist worldwide (e.g. reusable water bottles and increased provision of water fountains in public and private spaces), bottled water in many parts of the world may be perceived as the only safe source of water for human consumption (Díez et al., 2018 ; Ballantine et al., 2019 ; Grebitus et al., 2020). An upward trend in bottled water consumption is observed (Cohen and Ray, 2018), despite several studies questioning the quality of this type of water (Mason et al., 2018). However, higher temperatures and the incidence of heatwaves may boost bottled water consumption worldwide, especially where heatwaves are most expected.

Like all countries in the world, Tunisia is affected by the impacts of climate change. Irregularity of precipitation, rising temperatures, and recurrence and convergence of extreme weather events are all indicators that expose ecosystems and populations in all Tunisian regions to great vulnerability to the influence of climate variables. Climate projections and vulnerability studies to climate change carried out the show with certainty that the country is already suffering and will continue to suffer the effects of this phenomenon for a long time to come, in particular the impacts linked to the increase in temperatures and the decrease in precipitation (Labiadh 2021).

The indirect effects of climate change are also serious and are already causing major upheavals in the various socio-economic sectors. These impacts are essentially linked to the scarcity of water resources, particularly underground, as a result of drought and the overexploitation of groundwater. The draught, which translates into a decrease in rainfall and increasingly mild and dry winters throughout the country, causes a progressive decline in vegetation and the advance of the desert in the regions bordering the Saharan bioclimatic stage (arid and semi-arid) (Labiadh 2021).

According to the National Office of Thermalism and Hydrotherapy (ONTH), 1.5 billion bottles of water were sold in 2020, which makes Tunisia the 4th country in the world in terms of bottled water consumption with an average of 225 liters/person/year. Moreover, our country has 29 production units that generate an annual turnover of about 637 million dinars, produce 364,000 bottles per hour and employ about 3000 people.

After all that is discussed above and the important figures for bottled water consumption in Tunisia. We have noticed the importance of studying the impact of climate change on the consumption of bottled water and the individual expenditure on this product. This is the objective of our research.

2. Literature review

Although much research on the adverse effects of future climate change on physical and economic systems has been conducted and published, little has been said to date about the economic opportunities that may arise from these changes. The consumption of some products, particularly in the manufacturing sector, is strongly influenced by weather conditions and their sales are therefore likely to be favorably affected by future climate change (Mirasgedis et al 2014).

Another critical parameter is rainfall ; as bottled water is typically consumed outdoors during the summer, continuous or frequent rain events will decrease the number of people in and around the outdoors. The duration of sunshine may also be an additional variable that can be examined (British SoftDrinks Association, 2009 ; BCI, 2009).

Thus, to better estimate the risks and opportunities associated with climatic conditions, it seems important to better understand the role of climate on sales by developing a quantitative model to predict the level of sales/consumption of bottled water as a function of climatic and non-climatic parameters. Although major manufacturers have developed such models for their use, the information published in this issue is valid (Mirasgedis et al (2014).

According to the results of the study 161 by Zapata (2021) in Ecuador, the likelihood of consuming bottled water increases when the temperature also increases. While households living in rainy locations were more likely to consume bottled water and to consume more of it, those living in wetter locations were less likely to consume it. These results confirmed that households were more likely to consume bottled water and to consume more of it if the temperature increased. Precipitation and humidity increased and decreased the likelihood of buying it respectively. The amount of bottled water consumed decreased in places with higher rainfall and humidity.

Some authors have suggested that rising temperature levels will increase the demand for water for human consumption among day laborers and farmers in developing countries, where climate change is expected to hit populations hardest (Wesseling et al, 2016 ; Geruso et

Spears, 2018; Li et al, 2018; Dally et al, 2020 et Wagoner et al, 2020). An alternative to meet this increased demand for drinking water in areas without access to tap water is bottled water.

In the context of climate change, and due to rising temperatures and heat waves shortly, higher water consumption is expected (Zapata, 2015). This may be specifically the case in rural areas where people engage in more outdoor activities daily and where tap water is more scarce and of lower quality than in cities. Similarly, workers in the primary sectors of the economy, such as agriculture, fishing, and mining, might be expected to consume more bottled water because of their greater exposure to climatic conditions. In particular, one would expect to see a more significant effect of temperature on bottled water consumption in households residing in these geographical areas and whose members are employed in these economic sectors (Zapata, O. 2021).

According to Mirasgedis, S., et al. (2014), future bottled water sales in Greece for the period 2021-50 could increase significantly under a warmer future climate associated with the IPCC A1B global GHG emissions scenario. Specifically, on an annual basis, the increase in total sales volume attributed solely to climate was estimated at 1.1% for bottled mineral water. It is also worth mentioning that this variation is not uniform from a seasonal point of view and that in some months it exceeds 6%. The increase is more pronounced in autumn and spring than in summer, perhaps because in summer bottled water consumption is already high and there is therefore little room for a further substantial increase in sales. The expected rate of change in sales also depends on the type of packaging of the drink.

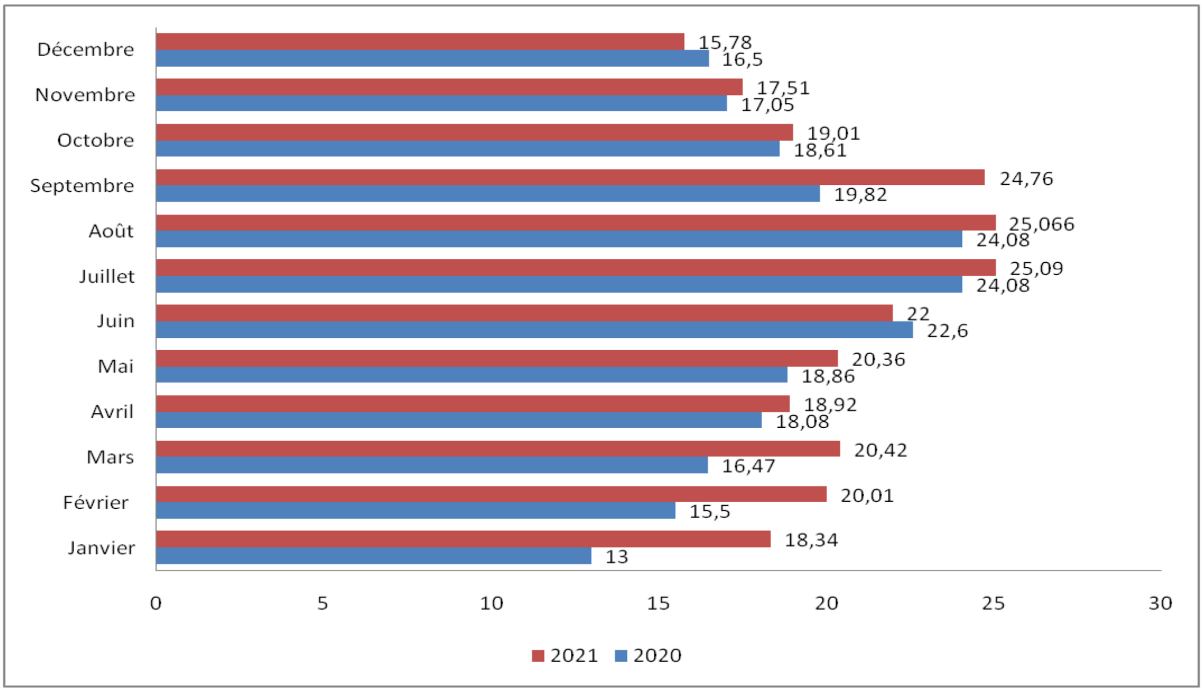
There is a link between climate change and plastic pollution through the effect of temperature on bottled water consumption, particularly in places where the average temperature is expected to rise rapidly, in rural areas, and in places where access to tap water is limited or water quality unreliable. However, promoting household measures to improve water quality (i.e. boiling water or using water filters) reduces the likelihood that households will purchase bottled water (Zapata, O. 2021).

Tunisia belongs to the category of countries with the least water resources and among the countries most severely affected by climate change (GIZ, 2011 ; Nefzi, 2012) in the Mediterranean basin (Khemiri et al. 2022). In a study by the National Institute of Meteorology (INM), the projections of average annual temperatures calculated according to the RCP 4.5 scenario show a clear increase by 2050 and 2100. This increase varies between +1°C and +1.8°C by 2050 and reaches 2°C and 3°C by the end of the century. Contrary to temperatures, which will increase, precipitation will decrease by 5 to 10% by 2050 and may reach a decrease of 5 to 20% by 2100. The projections foresee an average decrease in precipitation which would be more acute in the central part of the country and the desert area (governorate of Tataouine).

The decrease in average precipitation and the increase in the intensity and frequency of dry periods, combined with the increase in average temperature, are expected to have impacts on the reduction of soil moisture and the decrease in surface and groundwater stocks. These impacts of climate change are expected to be exacerbated by increased water requirements, especially for human uses, and particularly for agriculture, due to increased evapotranspiration and decreased soil moisture (UNFCCC, 2018).

According to the study by Abdeljabar 228 et Lamia (2019), high temperatures, lack of precipitation and evaporation will reduce water resources for the whole region in terms of quantity and quality. Bouchrika. et Issaoui (2013) state that in Tunisia, climate change has created an imbalance between water supply and demand.

Figure 1 : Individual and monthly consumption of bottled water in 2020 and 2021



Source: ONTH.

Figure 1 shows the monthly volume of bottled water consumption per capita in 2020 and 2021. According to the ONTH, the peak of bottled water consumption per capita in 2021 is during July, August, and September, which is explained by higher temperatures and lower rainfall during this period. This is due to higher temperatures and less precipitation during this period, while consumption is low during December and January, especially in 2020. This is due to the decrease in temperature during these two months and the increase in precipitation.

3. Data collection and methodology

3.1. Data collection

The current analysis used annual time series data from 1995 to 2020. The study uses important factors that affect bottled water consumption in Tunisia. Previous studies by Ward et al (2009), Mirasgedis et al (2014), and Zapata (2021) have indicated that natural factors, the labor rate in each sector of economic activity (Agriculture, Industry, and Service) and the inflation rate significantly affect bottled water consumption. We use a dataset from the National Office of Thermalism (ONTH) for bottled water consumption data, the National Institute of Meteorology (INM) for climatic data (temperature and precipitation), and the National Institute of Statistics (INS) for labor force data in the different sectors of economic activity and the inflation rate (see Table 1).

Table 1 : Description of the variable and data source

Variables	Descriptions	Unités de mesure	Sources
BWC	Bottled water consumption	Liter	ONTH
Rain	Rainfall	Millimeter (mm)	INM
Temp	Temperature	Derge Celsius C°	INM
Agr	labor rate in agriculture sector	Percentage	INS
Ind	labor rate in industry sector	Percentage	INS
Ser	labor rate in service sector	Percentage	INS
Inf	Infation	Percentage	INS

Source : Auteurs

3.2. Methodology

To explore the role of climatic and non-climatic variables on Bottled water consumption output, we used the ARDL model proved by Pesaran and al., (2001). This method permits for levels of interaction to be analyzed the variables at I (0), integrated at I (1), or not mutually cointegrated Pesaran and al., (2001); Keele et DeBoef (2008). Likewise, we employ Phillips-Perron (1988) to check the stationarity test and to guarantee that no variable is integrated into order 2. The ARDL technique is also examined to verify the cointegration in the short and long term of the specified variables. Nevertheless, Pesaran (1997) suggested the ARDL framework analyze long and short-run connections, as opposed to earlier techniques like Engle et Granger (1987) et Johansen et Juselius (1990). The ARDL procedure, which is a suitable method for short data sets, reduces endogeneity problems and is designed for improved long-run interpretation. The following equation 1 explains the impact of climate and non-climate factors on Tunisian Bottled water consumption:

$$BWC_t = f(Rain, Temp, Agr, Ind, Ser, Inf\,) \qquad (1)$$

Where BWC, Rain, Temp, Agr, Ind, Ser, and Inf represent Bottled water consumption, Rainfall, Temperature, labor rate in the agriculture sector, labor rate in the industry sector, labor rate in the services sector, and inflation rate respectively. t shows the time (1990-2020). All variables in this study were converted to natural log form for intuitive and suitable findings. Equation (1) becomes:

$$LnWc_t = \alpha_0 + \alpha_1 LnRain_t + \alpha_2 LnTemp_t + \alpha_3 LnAgr_t + \alpha_4 LnInd_t + \alpha_5 LnSer_t + \alpha_6 LnInf_t + \varepsilon_t \qquad (2)$$

The ARDL technique, evaluate the interaction of the short and long run as follows in Equation 3 and 4.

$$\Delta LnBWC_{t-i} = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta LnBWC_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta LnRain_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\, \Delta LnTemp_{t-i} + \sum_{i=1}^{q} \alpha_{4i}\, \Delta LnAgr_{t-i} + \sum_{i=1}^{q} \alpha_{5i}\, \Delta LnInd_{t-i} + \sum_{i=1}^{q} \alpha_{6i}\, \Delta LnSer_{t-i} + \sum_{i=1}^{q} \alpha_{7i}\, \Delta LnInf_{t-i} + \varepsilon_t \qquad (3)$$

Furthermore, the analysis employed an ECM technique to evaluate the short-run interaction among the factors. The following equation of the ECM model:

$$\Delta LnBWC_{t-i} = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta LnBWC_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta LnRain_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\, \Delta LnTemp_{t-i} + \sum_{i=1}^{q} \alpha_{4i}\, \Delta LnAgr_{t-i} + \sum_{i=1}^{q} \alpha_{5i}\, \Delta LnInd_{t-i} + \sum_{i=1}^{q} \alpha_{6i}\, \Delta LnSer_{t-i} + \sum_{i=1}^{q} \alpha_{7i}\, \Delta LnInf_{t-i} + \alpha_8\, ECT_{t-1} + \varepsilon_t \ (4)$$

Equations (3) and (4) stand for the short and long-term to evaluate the relationships between the selected variables of climate change, non-climate changes, and bottled water consumption in Tunisia. LnRain, LnTemp, LnAgr, LnInd, LnSer, and LnInf indicate the logarithm of the variables used in this paper at time t, ECT_{t-1}denote the

ECM's error correction model; Δ represents the first difference. $\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6 \text{ and } \alpha_7$ is the short-run and long-run coefficients, while is the error correction term's coefficient (ECT) and ε_t is the error term.

4. Results and Discussion

4.1. Descriptive analysis

The empirical study uses time series data to find the effects of climate variation, variation in the labor rate of different sectors, and inflation on bottled water consumption in Tunisia during the period 1995 to 2020. Table 1 presents the descriptive statistics of the main economic and climatic variables included in this study. The consumption of bottled water shows a wide dispersion with an average of about 79 liters per year and a maximum of 225 liters. Concerning climatic conditions, the average temperature is 19.8°C and an average maximum temperature of 21.7°C. Rainfall levels vary from 233.2 mm to 564.8 mm, with an average of 368.78 mm. During this period the average labor rate in the agricultural sector is 17.9% with a maximum of over 21% of the total labor force. While for the industry sector the rate varies between 30.65% to almost 34% with an average of 32.54%. On average, the tertiary 308 sector has half of the workforce. While for inflation, it varies between 2 and 7.3% with an average of almost 4%.

Table 2 : Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
BWC	26	78.94231	62.07001	12	225
Rain	26	368.7823	85.44281	233.2	564.8
Tem	26	19.83769	1.140177	17.28	21.7
Agr	26	0.1786962	0.0264223	0.133	0.2171
Ind	26	0.3253731	0.0099176	0.3065	0.339
Ser	26	0.4959346	0.0179619	0.4761	0.528
Inf	26	0.0399423	0.0139544	0.0198	0.0731

Source : Eviews 10

4.2. Correlation study

Before discussing the ARDL model and the stationarity of the variables, it is important to identify the degree of correlation between the endogenous and exogenous variables. Thus, through the correlation matrix shown in Table 1 below, we see that the dependent variable

(BWC) is highly correlated with the explanatory variables (Ind), (Ser), and (Inf), with rates of 80.06%, 94.71%, and 70.31% respectively. There is also a high correlation between the share of labor in the industry sector and that of the service sector of around 77.71%. The other explanatory variables are weakly correlated with each other.

Table 3 : Correlation matrix of variables

	BWC	**Rain**	**Temp**	**Agri**	**Ind**	**Serv**	**Inf**
BWC	1.0000						
Rain	0.2314	1.0000					
Temp	0.0107	0.0165	1.0000				
Agr	-0.9444	-0.1353	0.1070	1.0000			
Ind	0.8006	0.0681	-0.3869	-0.9040	1.0000		
Ser	0.9471	0.1612	0.0564	-0.9716	0.7771	1.0000	
Inf	0.7031	0.2198	0.1519	-0.5847	0.3927	0.6435	1.0000

Source : Eviews 10

4.3. Stationarity analysis

Time series with a time average and/or variance and which vary over time are considered non-stationary, if they are not treated (stationarisation), this non stationarity can lead to "false" regressions. Several tests can be used to check whether the character is stationary or not 326 (the existence of a unit root): Augmented Dickey-Fuller/ADF test (Dicky and Fuller, 1979, 1981) Phillippe-Perron test (Philippe, P., 1987) Andrews and Zivot test (Zivot et Andrews, 1992), Ng-Perron test (Ng, S., Perron, P., 1997), KPSS (Kwiatkowski et al, 1996), (Perron,1989), (Eliott et al,1996), etc. In fact, in this study, we used the ADF test and the PP test, and the results are as follows (the calculated statistics are student's t) :

Table 4 : Unit root test

Variables	**Test ADF**		**Test PP**		**Ordre I (.)**
	Au niveau	**En différence première**	**Au niveau**	**En différence première**	
Ln_BWC	-1.005 (0.734)	-3.233 ** (0.033)	-1.028 (0.726)	-5.228 *** (0.000)	I (1)
Ln_Rain	-4.894 *** (0.000)	--	-4.890 *** (0.000)	--	I (0)

Ln_Temp	-2.111 (0.242)	-6.037 *** (0.000)	-2.141 (0.231)	-6.026 *** (0.000)	I (1)
Ln_Agr	0.679 (0.989)	-6.564 *** (0.000)	1.979 (0.997)	-6.956 *** (0.000)	I (1)
Ln_Ind	-2.257 (0.193)	-7.807 *** (0.000)	-1.584 (0.475)	-9.881 *** (0.000)	I (1)
Ser	-0.181 (0.928)	-6.625 *** (0.000)	0.347 (0.976)	-6.625 *** (0.000)	I (1)
Ln_Inf	-0.031 (0.944)	-3.884 *** (0.009)	-2.424 (0.145)	-7.487 *** (0.000)	I (1)

Note: ***& **represents the 1 % and 5 %of significance level.

Source : Eviews 10

It is noted that the series of bottled water consumption, temperature, employment in the agricultural sector, employment in the industrial sector, employment in the service sector, and the inflation variable are integrated of order 1, i.e. are stationary after the first 1% differentiation ; while the precipitation variable remains stationary at the level (without differentiation).

We tested whether the selected study variables were stationary at the level/first difference. In the process, this study used the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the Phillips-Perron (PP) test (Phillips and Perron, 1987) in the form of unit root tests to confirm whether the study variables were stationary or not. The estimated empirical results of the ADF and PP unit root tests are described in Table 4 showing that all the variables studied were stationary combinations of I (0) and 345 I (1). This confirms the use of the ARDL-related test method suggested by Pesaran et al. (2001) and Pesaran and Shin (1998). These results show us that we are using the correct model as we cannot apply an ARDL model for integrated series at orders greater than 1.

4.4. Bounds Test of ARDL model

Before finding the long and short-term relationships between the variables, it is important to use the ARDL bound test (Pesaran et al. 2001) for the confirmation of cointegration. The results of the cointegration test at the bounds (Table 5) confirm the existence of a cointegrating relationship between the explanatory variables of the model. This is confirmed by the Fisher statistic which exceeds the upper bound statistic (10.331 > 4.43), thus confirming the long-run relationship between the series of study variables, namely : bottled water consumption, rainfall, temperature, labor share in the agricultural sector, labor share in the industrial sector, labor share in the service sector and inflation. To check the stability of the ARDL approach, several diagnostic tests were applied and verified. The R^2, adjusted R^2, and F statistic were valid, as shown in Table 5. There is cointegration between the variables of interest.

Table 5: ARDL-bounds test results

Function	**F-statistic**	
F_{LnBWC} (LnRain, LnTemp, LnAgr, LnInd, LnSer, LnInf)	**10.331**	
Bounds tests	I [0]	I [1]
10 %	2.12	3.23
5 %	2.45	3.61
1 %	3.15	4.43
R^2	97.155	
Adj. R^2	93.457	
F-statistic	26.274	
Probability (F statistic)	0.000	

Source : Eviews 10

Having established that the variables are integrated in the same order, it is important to determine whether there is a long-term equilibrium relationship between the series. Cointegration describes the existence of equilibrium or stationary relationship between two or more time series each of which is individually non-stationary. We conducted cointegration tests using Johansen's maximum likelihood procedure to determine the cointegration rank of the system and the number of common stochastic trends guiding the whole system. We have reported the trace and maximum eigenvalue statistics and its five percent (5%) critical values in Table 6.

The result of the Johansen-based cointegration test revealed that there are three cointegrating equations at the 5% level of significance, as indicated by both the trace and max-Eigen statistics. The Johansen cointegration test (Table 6) confirms the results found in the ARDL model. The Johansen test yielded three positive values of 90.497, 56.996 and 48.883 which are higher than the critical absolute values of 46.2314, 40.0775 and 33.8768 respectively, and with a probability of 0.0000, 0.0003 and 0.0004 respectively at the 5% significance level. From table (5) we see that the trace values are higher than the absolute values at the 5% significance level, therefore, we reject the null hypothesis H_0, i.e. the rank of the matrix equals

3 [H0: (r = 3)] against the alternative hypothesis [H1: (r>3)]. This means that there are three cointegrating relationships between the (independent) explanatory variables and the endogenous variable of the model in the long run.

Table 6 : Johansen cointegration tests

Hypothesized. No. Of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob. **
None *	0.976965	236.5489	125.6154	0.0000
At most 1 *	0.906972	146.0511	95.75366	0.0000
At most 2 *	0.869556	89.05473	69.81889	0.0007
At most 3	0.548560	40.17126	47.85613	0.2164
At most 4	0.437595	21.08376	29.79707	0.3524
At most 5	0.256789	7.270962	15.49471	0.5463
At most 6	0.006162	0.148345	3.841466	0.7001
		Max-Eigen statistic		
None *	0.976965	90.49777	46.23142	0.0000
At most 1 *	0.906972	56.99640	40.07757	0.0003
At most 2 *	0.869556	48.88347	33.87687	0.0004
At most 3	0.548560	19.08750	27.58434	0.4078
At most 4	0.437595	13.81280	21.13162	0.3806
At most 5	0.256789	7.122618	14.26460	0.4748
At most 6	0.006162	0.148345	3.841466	0.7001

Notes: * represent the denial of hypothesis at 0,05 level

Source : Eviews 10

4.5. Long-run coefficients and short-run dynamics

Table 7 explains the estimates of the long-term and short-term coefficients of the ARDL model. In the long term, precipitation harms bottled water consumption. A 1% increase in precipitation results in a 1.18% decrease in bottled water consumption. This means that a 1 mm increase in precipitation will decrease bottled water consumption by 0.254 liters. This decrease is due to the decrease in the number of sunny days. People will consume at least less bottled water. These results are consistent with the findings of Path (2009, 2011), Mirasgedis et al (2014), De Lira Azevêdo (2017), Feng and Fu (2013), Elliott et al (2014), and Zapata

(2021). Temperature also hurts bottled water consumption with a coefficient of -3.36. That is, a 1 C° increase in temperature will decrease bottled water consumption by 13.385 liters. The increase in temperature leads to an increase in water requirements, the degradation of water quality, and the overexploitation of groundwater. This increase modifies the chemical and biological balance of water : its quality decreases and impacts the quantity of water available for human consumption as well as the related ecosystems. The increase in the temperature of water in its natural state can favor the development of germs and bacteria. In case of contamination, the current disinfection process may become inadequate. All this will reduce the amount of bottled water consumed. These results are in line with the results of Darowska et al (2003), Kassenga (2007), Delpla (2009), Qiu et al (2019), Riedel (2019) and Barbieri et al (2021). Furthermore, in the long term, this research has revealed that labor in the agriculture, industry and service sectors harm bottled water consumption. A 1% increase in these sectors of economic activity will decrease bottled water consumption by 32.47, 39.74, and 89.68% (25.636, 31.374, and 70.802 liters) respectively. The workers are exposed to a temperature that exceeds the demand for bottled water and the depletion of resources. These results appear to be consistent with those of Darowska et al (2003), Kassenga (2007), Ellis et al (2008), Feng and Fu (2013), Elliott et al (2014) and Qiu et al (2019). Finally, despite its positive coefficient, in the long run, inflation does not have an impact on bottled water consumption.

In the short term, the rainfall variable can have both positive and negative impacts (-0.242 at time t and 0.303 at time t-1) on bottled water consumption. A 1 mm increase in rainfall can lead to a decrease in bottled water consumption of 0.052 liters (at time t) and an increase of 0.065 liters (at time t-1). This mixed effect can be explained by the decrease in sunshine days and thus the decrease in consumption and the increase and improvement of groundwater and various other sources of bottled water. The results of this research are consistent with the findings of Murray et al, (2010), British Soft Drinks Association, (2009) ; BCI, (2009) Mirasgedis et al (2014), and Zapata (2021).

Temperature positively influences the consumption of bottled water at time t-1. A 1% increase in temperature increases the demand for bottled water by 1.03%. In other words, a 1 C° increase in temperature leads to a 4.129-liter increase in bottled water consumption. Research by Mirasgedis et al (2014) and Zapata (2021) confirms these results. Labour in the agricultural, industrial, and service sectors negatively affects (-25.97, -43.36, and -79.96% respectively) the consumption of bottled water at time t. While its effect is positive (-10%), it harms the consumption of bottled water. While its effect is positive (10.64, 21.22, and 28.12%

respectively) at time t-1. At time t, a 1% increase in the workforce in the three sectors will decrease the consumption of bottled water 437 by 20.507, 34.232, and 63.129 liters respectively. Workers are exposed to temperature that exceeds the demand for bottled water and resource depletion. These results appear to be consistent with those of Darowska et al (2003), Kassenga (2007), Ellis et al (2008), Feng and Fu (2013), Elliott et al (2014) and Qiu et al (2019). While at time t-1, a 1% increase in labor in the three sectors will increase bottled water consumption by 8.401, 16.754, and 22.206 liters respectively. Rising temperature levels will increase the demand for water for human consumption among day laborers and farmers, which will increase the level of bottled water consumption. Studies by de Arbués and Villanúa (2006), Martins and Adelino (2007), Mirasgedis et al (2014), García-Trabanino et al, (2015), Wesseling et al, (2016), Baez et al, (2017), Geruso and Spears (2018), Li et al (2018), Dally et al, (2020), Wagoner et al, (2020) and Zapata, O. (2021) affirm these results. At time t-1, inflation positively impacts the demand for bottled water (0.1%). A 1% increase in inflation will increase the demand for bottled water by 0.086 liters. The access of demand over supply of bottled water by households caused by the increase in temperature will increase the prices of this product slightly. Despite this, the effect of the temperature increase is more important and the consumption of bottled water increases. This result is consistent with that of Ward et al (2009).

Tableau 7: Long- and short-terms outcomes tests

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run outcomes				
LN_Rain	-1.187910	0.386460	-3.073821	0.0372
LN_Temp	-3.363674	1.591506	-2.113517	0.1021
LN_Agr	-32.47459	9.043216	-3.591044	0.0229
LN_Ind	-39.74255	17.47813	-2.273844	0.0854
LN_Ser	-89.68866	25.58627	-3.505343	0.0248
LN_Inf	0.074440	0.300092	0.248057	0.8163
Constant	389.299	28.944	13.449	0.0002
Short Run outcomes				
D(LN_Rain)	-0.242329	0.035870	-6.755834	0.0025
D(LN_Rain(-1))	0.303485	0.032538	9.327011	0.0007
D(LN_Temp)	-0.223247	0.170314	-1.310796	0.2601
D(LN_Temp(-1))	1.037618	0.229847	4.514387	0.0107
D(LN_Agr)	-25.97695	2.442349	-10.63605	0.0004
D(LN_Agr(-1))	10.64178	2.310583	4.605670	0.0100
D(LN_Ind)	-43.36367	4.469204	-9.702771	0.0006
D(LN_Ind(-1))	21.22281	4.470807	4.746976	0.0090

D(LN_Ser)	-79.96849	7.638201	-10.46955	0.0005
D(LN_Ser(-1))	28.12941	6.843202	4.110563	0.0147
D(LN_Inf)	-0.050916	0.032222	-1.580186	0.1892
D(LN_Inf(-1))	0.109206	0.040141	2.720558	0.0530
CointEq(-1)*	-0.645684	0.048019	-13.44642	0.0002

Notes: *** and * show 1% and 10% level of significance, respectively

Source : Eviews 10

4.6. Diagnostic tests

Table 8: Residual Diagnostic test results

Diagnostic tests	F-statistics	Probability
Jarque-Berra	2.244	0.325
χ^2 SERIAL	0.729	0.718
χ^2 RESET	0.726	0.520
χ^2 ARCH	0.499	0.502
CUSUM	Stable	
CUSUMSQ	Stable	

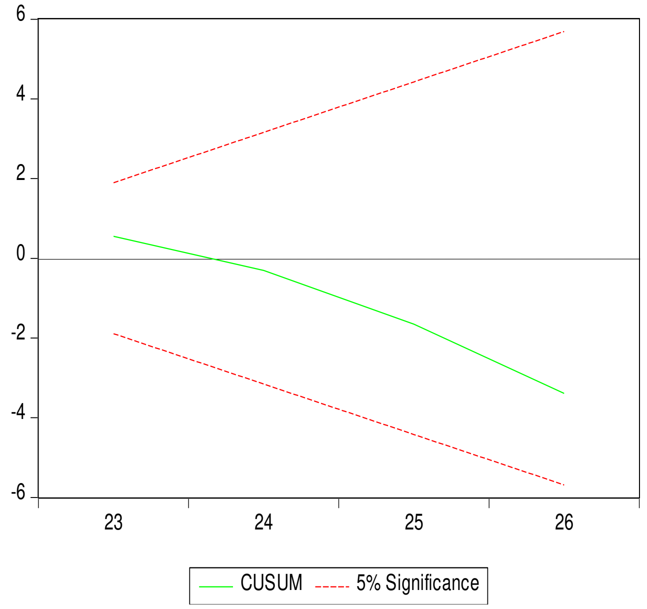
Source : Eviews 10

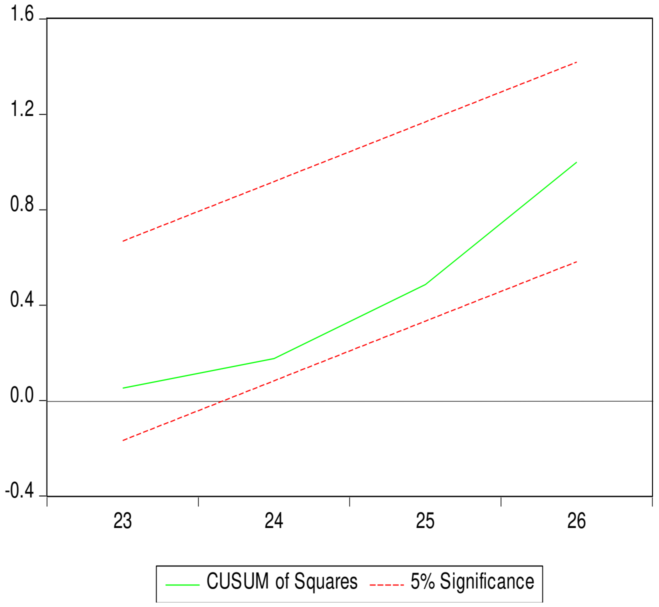
After studying the long- and short-run coefficients of the ARDL model, our research then performed various diagnostic tests (Table 8). Many diagnostic tests are used to find errors in the model presented. The projected Ramsey test ($\chi2$ RESET) illustrates that the functional form of the estimated model is correct. Our P-value of 0.52 leads to an acceptance of Ho which suggests the correct specification of the model. Similarly, the expected $\chi2$ ARCH result shows that there is no heteroscedasticity problem in the model. The estimated scores of the Jarque - Bera test ($\chi2$ normality) and serial correlation ($\chi2Sc$) imply that the existing model is normal and finds no serial correlation. The model is stable.

4.7. Stability check

To test the consistency of the ARDL model, the CUSUM and CUSUMSQ tests were used. In both graphs (Figure 2), the dotted lines represent the critical upper and lower limits at the 5% significance level. Visual inspection of the plots reveals that there is no evidence of parameter instability, as the cumulative sum of residuals and the cumulative sum of squared residuals move within the critical limits. The CUSUM and CUSUMSQ plots were within the 5% significance level (Figure 2) ; therefore, the ARDL approach is constant over the period.

Figure 2: CUSUM and CUSUM squares test for stability





5. Conclusion

In this paper, we analyze the effect of climatic variables on household decisions regarding bottled water consumption and the quantity to be consumed in Tunisia, a very geographically fragmented country with remarkable differences in climatic conditions between governorates and municipalities. We use a set of data from the Office National de Thermalisme (ONTH) for bottled water consumption data, the Institut National de Météorologie (INM) for climatic data (temperature and precipitation), and the Institut National de Statistique (INS) for labor force data in the different sectors of economic activity and the inflation rate. All these data are from the period 1995 to 2020. The ranking of bottled water consumption per capita in recent years (3rd in 2021 for 247 liters per capita) and the natural conditions of the country make it an ideal case to study the effects of climatic conditions on bottled water consumption. We study the impact of climate change on bottled water consumption using the lagged autoregressive model approach (ARDL).

The results show that temperature increases the probability of consuming bottled water and the volume consumed in the short run. While precipitation levels increase and reduce both the probability of consuming and the volume consumed of bottled water. This mixed effect is short-term. While in the long term precipitation negatively affects the consumption of bottled water. Interestingly, while temperature reduces the likelihood of purchasing bottled water among workers employed in the primary sectors of the economy, it increases the volume consumed among rural populations who may be more exposed to the country's climatic conditions. The increase in the labor force in the three sectors of economic activity affects the demand for bottled water in the short (positive-negative) and long term (negative). This effect is due to the excess demand for bottled water by workers and their exposure to temperature. While the increase in inflation has a positive short term effect on bottled water consumption.

The analysis in this paper does not take into account the effect of policies that governments at the national and local levels could implement to protect the bottled water sector. Improved consideration of ecosystems is essential to maintain the water cycle, (groundwater recharge, maximizing 509 the benefits of heavy rainfall, soil conservation, and filtration). Ecosystems are essential for the production of good quality bottled water.

The bottling, trade, and transport of water around the world have considerable environmental impacts, including pollution, contamination, climate change, and resource depletion (Gleick, 2006). Bottled water production and transportation also contribute significantly to climate change emissions, generating 180 times more CO2 emissions per liter than tap water. The sharp increase in the production and consumption of bottled water is a source of plastic pollution worldwide. As awareness of the problem of plastic pollution spreads around the world, voluntary decisions by households to reduce bottled water consumption can be expected. This, along with government efforts to improve the reliability of tap water supplies, can mitigate the effect of temperature on bottled water consumption and the resulting plastic pollution.

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