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Energizing Tunisia's Path to Prosperity: Unveiling the Intricate Link between Energy Consumption and Economic Growth

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Abstract

The crucial link between energy and economic growth has long been debated, with scholars trying to understand the impact of one on the other. In this groundbreaking study, we delve into the interplay between energy consumption and economic growth in Tunisia from 1971 to 2021. Rather than relying on conventional methodologies, we employ the advanced autoregressive distributed lag (ARDL) bounds testing approach, shedding new light on the relationship. Our findings reveal a stable long-term connection between energy consumption and economic growth, suggesting that as the economy flourishes, energy consumption also rises. This study not only contributes to the understanding of Tunisia's energy dynamics but also offers valuable insights into the determinants of energy consumption in the region.

Keywords: *Tunisia, Energy consumption, Economic growth.*

JEL Classification : B23, E01, K32, N17.

1. Introduction

A global call in the form of 17 Sustainable Development Goals (SDGs) was endorsed by the United Nations General Assembly in 2015 to protect the planet and ensure that all human beings live in peace and prosperity, and this at the heart of the 2030 agenda. These objectives respond to the challenges we face, in particular those related to climate change, clean energy at an affordable cost as well as decent work and economic growth which are among the pillars of the sustainable development.

Without a doubt, energy is a factor of crucial importance in life and for the socio-economic development of our society. A demographic explosion and a booming development mean that the world demand for energy is in very strong growth. In fact, The Global Distribution of Primary Energy Sources shows that over 80% of the energy used comes from three fossil fuels: petroleum, coal and natural gas (A. Demirbas, (2009)).

Suddenly, the increase in the consumption of fossil fuels, especially in the transport sector, will mean that their reserves may run out in the future. To this must be added the resulting environmental impact. In fact, these energy sources present pollution problems at different scales. The accumulation of CO2 in the atmosphere formed by the consumption of fossil fuels

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produces a greenhouse effect which is largely responsible for global warming (M. Philippe Rouvillois, (2005)). Energy consumption and economic growth are two crucial factors that play a pivotal role in the development and sustainability of any country. In recent years, the Middle Eastern nation of Tunisia has been witnessing a significant increase in energy consumption as it strives to achieve a sustainable growth trajectory. This article aims to explore and analyze the intricate relationship between energy consumption and economic growth in Tunisia, utilizing an Autoregressive Distributed Lag (ARDL) model. By employing this sophisticated econometric tool, we can identify the long-term and short-term dynamics that dictate the energy-growth nexus in Tunisia, providing policymakers and stakeholders with valuable insights and recommendations for effectively managing energy resources to foster robust economic development.

Thus, the energy context of our time lies in a contradiction between economic growth and energy consumption, since economic growth inevitably generates an occurring growth in energy needs. To do this, much effort is currently being carried out to research a link between economic growth and energy consumption especially for developing and underdeveloped countries.

The objective of this article is to explore the relationship between energy consumption and economic growth in Tunisia using an Autoregressive Distributed Lag (ARDL) model. The contribution of this study lies in its relevance to the current energy and economic challenges faced by Tunisia, as it provides valuable insights into the long-term relationship between these two variables. By employing an ARDL model, this article aims to provide robust empirical evidence to guide policymakers and stakeholders in formulating effective energy policies that promote sustainable economic growth in Tunisia. The findings of this research will contribute to the existing literature on energy-growth nexus, particularly in the context of developing economies like Tunisia, and can potentially inform future research and policy decisions in this field.

The remainder of the paper is designed as follows: Section 2 describes the literature and empirical review, while Section 3 describes the methodology. Finally, section 4 demonstrates results and discussion and section 5 concludes this work with a policy recommendations.

2. Relationship Between Energy Consumption and Economic Growth

2.1. Literature Review

Throughout the years, numerous studies have investigated the relationship between energy consumption and economic growth in various countries, including Tunisia. These studies have explored the interplay between energy consumption and economic indicators, shedding light on the complex dynamics that exist between these variables.

One study conducted by Moussa (2017) examined the causal relationship between energy consumption and economic growth in Tunisia using time series data from 1971 to 2013. The findings indicated a bidirectional causality between energy consumption and economic growth, suggesting that energy consumption positively affects economic growth while economic growth also stimulates increased energy consumption. This study highlights the crucial role of energy in driving economic activity in Tunisia.

In contrast, a study by Al-Mulali et al. (2015) explored the relationship between energy consumption and economic growth in Tunisia from 1980 to 2011 using the Cobb-Douglas production function model. The findings revealed a unidirectional causality running from economic growth to energy consumption, suggesting that economic growth drives increased energy consumption in Tunisia. The study emphasized the need for policymakers to consider energy-efficient strategies, technological advancements, and renewable energy sources to promote sustainable economic growth without raising energy consumption levels significantly.

Moreover, Ahmed et al. (2016) focused on assessing the impacts of energy consumption, energy prices, and economic growth on CO2 emissions in Tunisia. The study employed the autoregressive distributed lag (ARDL) model and found that energy consumption and economic growth positively affect CO2 emissions in Tunisia. However, the study also suggested that an increase in energy prices can lead to a decrease in CO2 emissions, indicating the potential role of energy pricing policies in curbing carbon emissions.

In summary, these studies provide valuable insights into the relationship between energy consumption and economic growth in Tunisia, illustrating both bidirectional and unidirectional causality between the variables. The findings highlight the importance of sustainable energy policies, renewable energy sources, and energy-efficient strategies to promote economic growth while mitigating the environmental impacts associated with increased energy consumption. Policymakers in Tunisia can draw upon these research findings to devise effective strategies for achieving sustainable economic development in tandem with efficient energy use.

In recent decades, Energy has been a major determinant for the socio-economic development of any community and a fundamental factor of production (Reilly, 2015). Several empirical and theoretical works have been launched to analyze the causal relationship between energy consumption and economic growth (GDP). The use of energy sources that exist in the world has improved the living environment. In addition, the type of energy and the quantity consumed are determinants of the level of socio-economic development. However, the relationship between energy consumption and economic growth has not been much studied in developing countries. Thus, we can consider energy as a key factor that stimulates the economic and social development of countries.

The objective of this work is to analyze the relationship between economic growth and energy consumption in Tunisia, whose national demand for primary energy has increased from 7.7 Mtoe in 2007 to 8.6 Mtoe in 2011. Taking into account that the average growth rate of energy demand does not exceed 2.8% per year in Tunisia, and this is thanks to the energy savings projected over the period 2008-2011. This confirms that the "energy-growth" decoupling already exists in the past between economic growth and energy consumption, and should therefore continue thanks to energy conservation.

The experience of developing countries is an indicator of the crucial role played by energy in economic development. In view of these preliminary considerations, it seems important to us to question the following questions:

- Is energy consumption the cause of GDP?
- What is the impact of energy policy in Tunisia on economic growth (GDP) in the short and long term?
- What is the impact of an energy conservation policy on economic growth (GDP) in the short and long term?

To answer these questions, let us use the ARDL "Staggered Autoregressive Time Delay" model and the Granger causality test technique using time series analysis. In this perspective, it is essential to know the direction of causality between energy consumption and economic growth. Indeed, it can facilitate the implementation of measures aligned with energy policies and economic growth. However, the difference found between the empirical results already published, as well as the major role that energy consumption has played in the socio-economic development of some countries, raise questions. Most of the conclusions on this question raise many ideas about the methods used. In fact, the difference between empirical results requires not only further research but also new econometric methods to better analyze the causal relationship between energy consumption and economic growth.

Looking at the results of articles on Sub-Saharan Africa (see Eggoh et al. (2011)), some heterogeneity emerges: the presence or absence of a causal relationship between the two variables and, if possible, its direction varies from country to country, even if they are studied with the same methodology within the same article. In particular, Mensah (2014) shows that economic growth is driven by one-way energy consumption in Kenya, while this relationship is true in the opposite direction for Ghana.

Caution should be exercised when interpreting the results, as different authors have found results in the opposite direction from the Granger causality test, citing the example of Kivyiro and Arminen (2014) who found a causal relationship between energy consumption and economic growth in the Republic of Congo, while Esso (2010) and Odhiambo (2010) identified an inverse relationship.

Similarly, Mensah (2014) and Odiambo (2010) found a link between energy consumption and economic growth for Kenya, while Kivyiro and Arminen (2014) and Esso (2010) found no link. Furthermore, in a review of 31 papers, Bhamiri (2013), and in a review of 26 papers, Saboori and Sulaiman (2013), noted this lack of consistent results on the link between energy consumption and economic growth.

Jumbe (2004) analyzed the case of Malawi, and concluded that there is a two-way causal relationship between energy consumption and economic growth. On the other hand, Ambapour and Massamba (2005), analyzed the case of Congo, and showed a one-way causal relationship from GDP to energy consumption. In addition, Ongono (2009), who studied the causal relationship between electricity consumption and economic growth in Cameroon, showed that there is no causal relationship at the global level between GDP and energy consumption. In contrast, in the secondary sector, causality arises from performance vis-à-vis energy consumption. Similarly, in the third sector, it is energy consumption that causes growth in the production of services.

Using panel data analysis for four West African Economic and Monetary Union countries (Benin, Côte d'Ivoire, Senegal, and Togo) over the period 1970-2005, Okey (2009) found a two-way causal relationship between oil consumption and GDP growth and no causality between electricity consumption and economic growth.

Table 1. Evolution of Energy Consumption and Its Main Determinants in Tunisia Before and After the Revolution.

Date	Energy consumption	GDP	Gross fixed capital formation	Foreign Direct investment	Trade openness
1971	94.3844492	325.564339	2317872433	1.36480935	12.1197945
1972	94.3844492	422.856453	2950315565	1.47487588	7.0803318
1987	97.3004973	1199.5619	3456302431	0.71222455	11.2522097
1988	98.7981304	1281.20146	3395759746	0.94486934	7.85981669
2014	96.3222893	4305.47417	1.2314 e+10	2.15138442	19.1836844
2015	95.6881737	3861.68853	1.2314 e+10	2.2479584	20.6548318
2016	96.0764383	3697.93083	1.2314 e+10	1.48935775	22.2694617

2.2. An overview of Energy Consumption in Tunisia

Tunisia is a small country located in North Africa sharing borders with Algeria and Libya. The country includes the northern part of the Sahara Desert and the eastern end of the Atlas Mountains and has a Mediterranean coast. Hence, the country has a brilliant diversity on climate and biosphere.

Since 1990, the consumption of primary energy in Tunisia has increased, with around 4,500 ktep in 1990, 6,700 ktep in 2000 and 8,300 ktep in 2010 (excluding biomass). As a result, the share of oil, including crude oil and petroleum products, fell slightly. The share of coal and peat has also been minimal and has now reached zero. The amount of biofuels and waste has increased slightly, and currently represents 15% of primary energy supply. In 2014, primary energy consumption was around 9,200 ktep, without biomass.

In Tunisia, the exploration and exploitation of conventional and unconventional fossil resources are carried out in order to meet demand and limit imports. In general, diversity should help protect Tunisia from the volatility of international prices and reduce its dependence on imports.

In order to reduce its dependence on Algerian gas, Tunisia must diversify its electricity mix and extend its interconnections. A gas interconnection with Italy already exists ("Gasoduc"), currently used to transport Algerian gas to Europe. However, this interconnection could be used for imports in the future. An electrical interconnection with Italy with a 400 kV submarine cable is currently under study. It can be used later for import and export: complementary daily and annual production and consumption profiles of North Africa and Europe can create synergies.

In addition, there is a strong need for institutional and budgetary reforms in the energy sector since the current situation is radically different from that of 20 years ago. Some of its aspects such as subsidies have become a burden hindering further development of the whole sector. In November 2014, the Minister of Industry called for drastic cuts for the year 2015. Subsidies should drop from 1.3 billion euros (2.7 billion TD) to 0.9 billion euros (1.96 billion TD) in order to use the money saved in the investment projects [20]. In 2014, energy prices were increased by around 10% in total to reduce subsidies. In June 2014, electricity price subsidies for cement producers were completely removed.

The ANME[4] forecasts predicted a doubling of consumption by 2030 without the implementation of a global action, therefore energy efficiency should be further enhanced. The measures taken since 2000 have borne fruit: Tunisia has reduced its energy intensity by 20%.

3. Estimation Techniques and Empirical Analysis

3.1. Data

The empirical work is based on annual data for the period from 1971 to 2017. Energy consumption (ENG) is accessible from the World Development Index (WDI) database. Growth rate (GDP) is available from the World Development Index (WDI) database and is used as a proxy for economic growth. Foreign direct investment (FDI) is available from the Trading Economics database. Gross fixed capital formation (FBCF) is extracted from the database of the Tunisian National Institute of Statistics (INS). And finally, trade openness (openness) is extracted from the World Bank database (WDI).

[4] **ANME** (Agence Nationale de la Maîtrise de l'Energie, National Agency for Energy Management). Created in 1985, this agency specialised in energy management supports the Industry Ministry on energy transition

Table 2 provides a summary of the different variables used.

Table 2. Summary of Variables Used and Data Sources.

Variables	Definitions	Data Sources
Energy consumption (ENG)	Energy consumption is the amount of energy used by an appliance or household	World Development Indicators, Banque mondiale (WDI).
GDP	Gross domestic product (GDP) is the economic indicator that quantifies the total value of the annual "production of wealth" by economic agents (households, businesses, public administrations) residing within a territory.It is an economic indicator used to measure the growth of a country's economy from one year to the next.	World Development Indicators, Banque mondiale (WDI).
FDI	Direct investment abroad is the international movement of capital to create, develop or maintain a subsidiary abroad or to exercise control or significant influence over the management of a foreign enterprise.	World Development Indicators, Banque mondiale (WDI).
FBCF	Gross fixed capital formation (GFCF) is defined as acquisitions less disposals of fixed assets plus major improvements in land and other non-produced assets and related disposal costs. Assets acquired may be new or used.	the Tunisian National Institute of Statistics
Openness	The concept of trade openness is much closer to the concept of external trade liberalization in that a country that is open to international trade will tend to have only weak barrières à la pénétration de son marché.	World Development Indicators, Banque mondiale (WDI).

3.2. Cointegration – ARDL Bounds Testing Procedure

The methodology used in this study is based on an estimation using the ARDL (Auto Regressive Distributed lags) model, which allows to analyze both the short term and long term relationship between energy consumption and its main determinants with both (0) and (1) order integrated variables.

However, the Co-Integration by Delay or Auto Regressive distributed Lags (ARDL) approach of co-integration proposed by Pesaran and al (1999, 2001) is increasingly used in research. This choice is justified by the fact that this technique has the advantage of being more efficient for studies with a small sample and is applicable to the series to be integrated in order 1, level 0 or mutually integrated, in contrast to Traditional integration tests such as those of Engle Granger

(1987), the Johansen test (1988), the Johansen and Juselius test (1990).However, the technique ceases to be applicable when the order of integration of the series is greater than 1. Another advantage of this method is that it makes it possible to estimate the dynamics of long and short term in the same econometric model (Akpan and al, 2012). Our ARDL specification of the relationship between energy consumption and growth variables is represented by equation (1):

$$\Delta(LNENG)_t = \alpha_0 + \sum_{i=0}^{n} \alpha_{1i}\Delta LNENG_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\Delta LNGDP_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\Delta LNIDE_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\Delta LNFBCF_{t-i} + \sum_{i=0}^{n} \alpha_{5i}\Delta LNOUVERT_{t-i} + \beta_1 LNENG_{t-1} + \beta_2 LNGDP_{t-1} + \beta_3 LNIDE_{t-1} + \beta_4 LNFBCF_{t-1} + \beta_5 LNOUVERT_{t-1} + \varepsilon_t \quad (1)$$

However, using the dependent variable in equation (1), at its long-term equilibrium level, may not be immediate due to a possible change in one of its determinants. Thus the speed of adjustment between the short and the long term levels of the dependent variables can be captured by estimating the following error correction model:

$$\Delta(LNENG)_t = \alpha_0 + \sum_{i=0}^{n} \alpha_{1i}\Delta LNENG_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\Delta LNGDP_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\Delta LNIDE_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\Delta LNFBCF_{t-i} + \sum_{i=0}^{n} \alpha_{5i}\Delta LNOUVERT_{t-i} + \theta\mu_{t-1} + \varepsilon_t \quad (2)$$

Where Δ represents the first difference operator and error correction term (ECT) of our model. The (ECT) in the equation measures the rate of adjustment of imbalance between the short and the long term of the dependent variable. We expect that the (ECT) will have a negative and significant value (Gujarati DN 2003).

To verify the existence of a cointegration relation, the first step consists in establishing the order of integration of each variable. To perform this task we will use the Dickey Fuller (ADF) test and the Phillips-Perron (PP) tests which are popular unit root tests used to verify the order of integration of the series. These tests are carried out with different specifications to check if the series is stationary at level or in difference. These tests have a null hypothesis of non-stationary against a stationary alternative. In the second step, we have to verify the existence of a cointégration relation; we will use the cointegration test of Bounds. This test is essentially based on the statistical F of Wald where null hypothesis is the absence of a relation of Co integration. The Bounds test consists of a first step estimated model (1) by the least ordinary square (LOS). We then test the joint nullity of the long-term multipliers using the F-test. So we consider the following two hypotheses:

H0 : $\alpha_{11}=\alpha_{21} = \alpha_{31} = \alpha_{41}= \alpha_{51}= 0$ against the alternative hypothesis

H1 : $\alpha_{11} \neq \alpha_{21} \neq \alpha_{31} \neq \alpha_{41} \neq \alpha_{51} \neq 0$.

Finally, the third step consists of comparing the calculated statistical F with the critical value. Indeed, Pesaran and al. (2001) report two sets of critical values for a given level of significance. The first level is computed by assuming that all the variables included in the ARDL model are integrated in order of zero I (0), while the second is calculated assuming that the variables are integrated of order I (1).If the calculated F statistics are above the upper critical limits, the non-Co-integration is rejected, indicating the existence of a Co-integration relation. If the calculated F statistics are lower than the lower critical value, we cannot reject the null hypothesis of non-co-integration. Finally, if the calculated test statistics lie between the terminals, a conclusive inference cannot be made without knowing the order of integration of the underlying repressors. Once estimated, co-integration equations are used to calculate long-run elasticity.

If the Co integration relation is not detected, the short-term causality relation is measured. After specifying our modeling, the general approach will be pursued by a number of specification tests, namely:: (i) residual normality (Jarque-Bera normality test); (ii) Series correlation (Breusch-Godfrey LM test); (iii) Heteroskedasticity (ARCH test); And (iv) model specification (specification of the Ramsey-RESET test regression error).These steps are followed by the CUSUM and CUSUM square test to analyze the stability of the model. The results are presented and discussed in the next section.

4. Empirical Analysis

Before analyzing these variables using the ARDL approach, we will present a descriptive study of annual data covering the period from 1971 to 2017 in table 3.

Table 3. Descriptive Statistics of the Study Data.

	LNER	**LNFBCF**	**LNGDP**	**LNIDE**	**LNOUVERT**
Mean	0.385274	22.43532	7.471274	0.638771	2.338696
Median	0.257630	22.39153	7.479250	0.695763	2.317361
Maximum	1.823208	23.23403	8.368033	2.243286	3.103216
Minimum	-0.733134	21.56392	5.785560	-0.510130	1.586002
Std. Dev.	0.721214	0.475729	0.667108	0.619797	0.384166
Skewness	0.429732	0.194988	-0.447372	0.065388	0.181871
Kurtosis	2.115095	2.079191	2.611963	2.676110	2.405560
Jarque-Bera	2.916661	1.916609	1.823019	0.233847	0.930862
Probability	0.232624	0.383543	0.401917	0.889653	0.627864
Sum	17.72259	1032.025	343.6786	29.38345	107.5800
Sum Sq. Dev.	23.40675	10.18433	20.02649	17.28667	6.641256
Observations	46	46	46	46	46

According to this table we can note that the average level of energy consumption was 0.38 in neperian logarithm. This shows that the average values of energy consumption in Tunisia are very high. Similarly, the average value of GDP and net inflows of foreign direct investment are very low. So overall, Tunisia's conditions are not up to par. Thus we move on to analyze the correlation between the variables presented in Table 4.

Table 4. Correlation Matrix.

	LNENG	**LNGDP**	**LNIDE**	**LNOUVERT**	**LNFBCF**
LNENG	1	0.3825561	0.249961	-0.11535	0.20769
LNGDP	0.382556	1	0.414460	0.64709	0.949697
LNIDE	0.2499613	0.4144600	1	0.1586398	0.4570208
LNOUVERT	-0.1153507	0.6470936	0.1586398	1	0.7256288
LNFBCF	0.2076926	0.9496976	0.4570208	0.7256288	1

4.1.1. Stationnarity Test

Before analyzing these variables using the ARDL approach proposed by Pesaran and al 2001, the stationarity of all variables was tested, first using ADF (Augmented Dickey-Fuller) and PP (Phillips - Perron). The results presented in Table 5 show that all variables are integrated in level

I (0) with the exception of the variable openness (Ouvert) and FBCF which is stationary of order 1 I (1). These results confirm that all variables have an order of integration of less than 2.

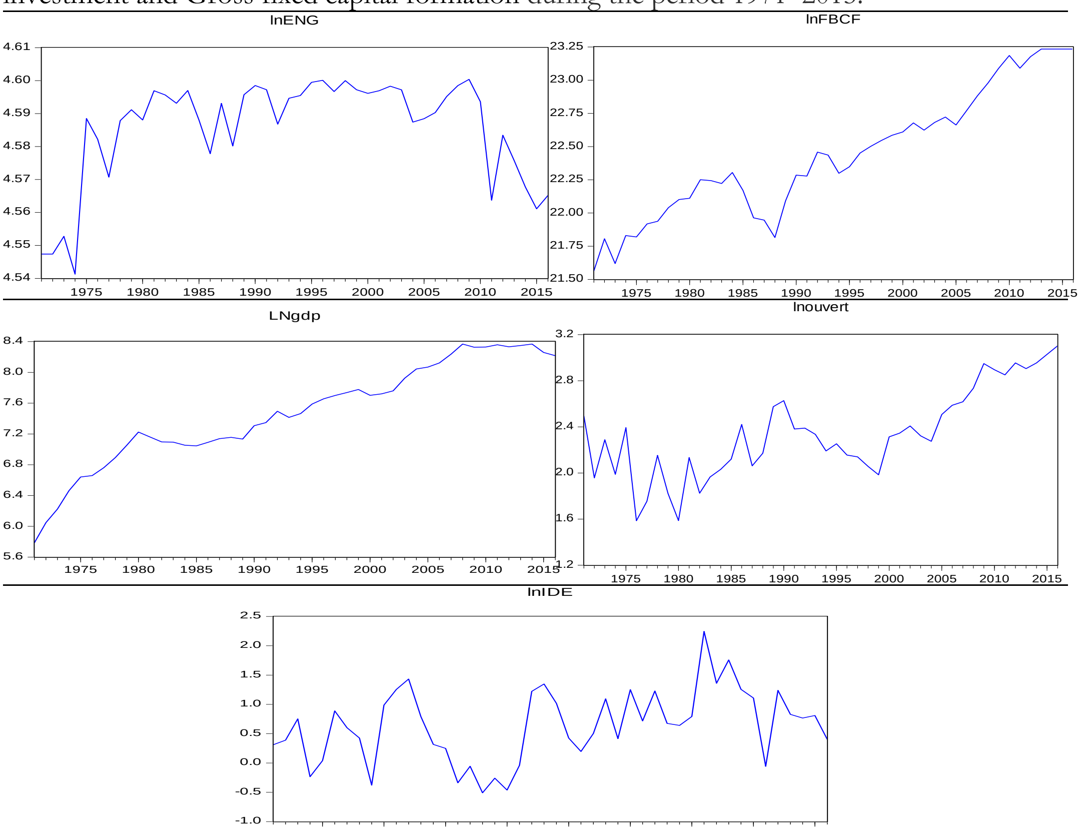
Table 5. Stationarity Test**.**

Variables	ADF Test		PP Test	
	In level	First difference	in level	First difference
LNENG	-3.118605**[0.0322]	-9.347914**[0.0000]	-2.939673[0.0487]	-9.786447**[0.0000]
LNFBCF	-0.936059[0.7675]	-4.115231**[0.0025]	-0.910348[0.7759]	-7.742308**[0.0000]
LNGDP	-3.980930**[0.0034]	-4.577319**[0.0006]	-3.356279**[0.0180]	-4.479028**[0.0008]
LNIDE	-3.841099**[0.0050]	-9.052335**[0.0000]	-3.829708**[0.0052]	-19.70388**[0.0001]
LNOUVERT	0.007068[0.9540]	-11.10112**[0.0000]	-1.483563[0.5327]	-11.50431**[0.0000]

SC is used to choose the number of optimal delays for the ADF tests, whereas « Bandwidh » is used for PP tests. The critical values related to ADF and PP tests were provided by MacKinnon (1996). The bracketed figures represent the delay levels based on the information criterion of Schwarz. Figures between square brackets represent Newey-West bandwidth's automatic selection using the Bartlett kernel. Note that only the constant is included in tests. (***), (**) and (*) denote statistical significance at the 1%, 5% and 10% levels respectively

Indeed, the evolution of the variables in time presented in graph 1 shows the existence of peaks, this led us to wonder about the existence of a change of regime.

Graph 1. Trends of energy consumption per capita, economic growth, openness, foreign direct investment and Gross fixed capital formation during the period 1971–2015.



The results of the stationarity tests lead us to study the relationship between energy consumption and socio-economic variables by applying the cointegration tests related to the ARDL approach. The Bounds test requires the selection of the appropriate degree of delay (Feridun and Shahbaz 2010). In our case, the AIC selection criterion is used. Table 6 shows the results of the Bounds integration test.

Table 6. Bounds Integration Test.

Dependant variable	lag selection	F-statistic	Decision
ENG	(2, 1, 0, 2, 2)	5.0309654	co integration
Significance	I0 Bound	I1 Bound	
10%	2.2	3.09	
5%	2.56	3.49	
2.5%	2.88	3.87	
1%	3.29	4.37	

The results in table 6 show that the calculated statistical F is of 5.0309654 which is higher than the critical value reported by Pesaran and al (2001) at 1% threshold. This confirms the existence of at least one long-term relationship between the variables in Tunisia for the period from 1971 to 2017.

The existence of a long-term relationship leads to estimate equation (1), using the ARDL technique. The results of the estimation are presented in Table 7:

Table 7. Long-Term Relation.

variable	Dependent variable LNENG		
	Coefficient	T-Ratio	Prob.
LNGDP	0.053915	3.701855	0.0008
LNIDE	0.006590	1.277683	0.2106
LNOUVERT	-0.015293	-1.146788	0.2600
LNFBCF	-0.076634	-2.993280	0.0053
C	5.931763	12.67943	0.0000

The results of our model describing the long-term relationship between energy consumption and its determinants are presented in Table 7. The existence of a long term relationship between energy and its fundamentals is confirmed for Tunisia. The results show that the growth rate has a positive and significant impact on energy consumption in Tunisia at the 1% threshold. Hence, an increase of 1% in the level of growth in Tunisia causes an increase of 0.05% of energy consumption. This means that having energy sources is a goal just as desirable as growing and becoming rich. Moreover, the effect of the evolution of gross fixed capital formation on energy consumption is negative and significant. Thus, an increase in gross fixed capital formation of 1% results in a decrease in energy consumption of 0.07%.

After identifying the long-run relationship between the variables, Table 7 presents the short-run model and shows that the coefficient (-3.340755) that indicates the speed of convergence to the long-run equilibrium "the error correction coefficient ECT(-1)" is negative and significant at 1%. Thus, in the short run, the ECM estimates are presented in Table 8:

Table 8. Short-Term Relation**.**

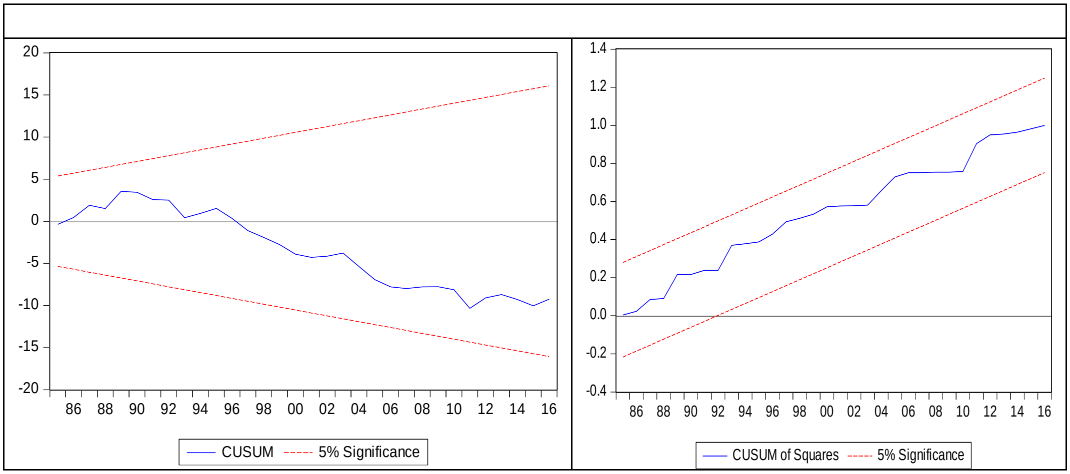
Dependent variable: LNENG			
Lag structure: (2, 1, 0, 2, 2)			
Variable	Coefficient	t-Statistic	Prob.
C	-3.340755	4.116493	0.0003
LNENG(-1)	-0.563198	-3.656971	0.0009
LNGDP(-1)	0.030365	2.764989	0.0094
LNIDE	0.003712	1.451383	0.1564
LNOUVERT(-1)	-0.008613	-0.999073	0.3253
LNFBCF(-1)	-0.043160	-3.124622	0.0038
D(LNENG(-1))	-0.282684	-1.726681	0.0939
D(LNGDP)	0.000484	0.025956	0.9795
D(LNOUVERT)	0.002069	0.252139	0.8025
D(LNOUVERT(-1))	0.016596	2.434930	0.0206
D(LNFBCF)	-0.00693	-0.375049	0.7101
D(LNFBCF(-1))	0.038075	2.648005	0.0125
Adj. R2=0.72			
AIC=-6.50			
F-stat.=-7.81, F-prob.=0.000002			

In fact, the existence of an equilibrium relationship between energy consumption and the different explanatory variables of the model allows us to highlight a long term relationship between them at least in one direction. For the short-run coefficients, we note that the lags of the "energy consumption" variable have a strongly significant and negative effect. Once the phenomenon of energy consumption has appeared in a given location, the speed of its propagation is increasingly rapid over time. Also the results show that the coefficient associated with the lagged growth rate of one period is higher than that associated with the same variable lagged by two periods. Thus, economic growth is increasingly becoming one of the main drivers of energy consumption. Furthermore, as for the growth rate used as a proxy for the development of the economy, it turns out to be a determinant of energy consumption in Tunisia. Its sign is positive and significant. Hence an increase in economic growth 'one percentage point undergoes an increase of 0.03% of energy consumption in Tunisia.

For the delays of the gross fixed capital formation, we notice that they affect negatively and significantly the consumption of energy in Tunisia. In addition, trade openness has a positive and significant impact at the 5% threshold. Hence a 1% increase in gross fixed capital formation undergoes an appreciation of energy consumption of 0.01%.

Table 9. Diagnostic Test.

χ2 (serial correlation)[1]	**5.320194[0.0105]**
χ2 (functional form)[2]	5.881256[0.0213]
χ2 (normality)[3]	0.964282[0.617460]
χ2 (heteroscedasticity)[4]	4.902670 [0.0324]



1 The Breusch–Godfrey LM test statistic for no serial correlation.
2 The White's test statistic for homoscedasticity.
3 The Jarque–Bera statistic for normality.
4 The Ramsey's Reset test statistic for regression specification error.

In order to validate the model, a series of econometric tests must be performed on the residual. Table (8) contains the results of the diagnostic tests of the selected ARDL model (2, 1, 0, 2, 2). The Jarque-Béra test of normality confirms that the distribution is normal. In addition, from the results of the Breusch-Godfrey Lgrage multiplier test of series correlation and the Breusch-Pagan-Godfrey test of heteroscedasticity, an absence of correlation of the residuals is shown, which means the absence of heteroscedasticity.

Moreover, the Ramsey Reset test confirmed the linear specification of our model.

Finally, in order to judge the structural stability of the model's coefficients, one of the econometric requirements for an ARDL model is to check the presence of parameter stability. In order to test the stability of the short-run and long-run coefficients estimated by the ARDL model, we apply the cumulative sum (CUSUM) and cumulative sum of squares (CUSUM Square) tests, performed on recursive residuals from the ARDL model estimated in this paper (Brown et al. 1975). The results of the tests are presented in Table 5. We note that the curves do not intersect the 5% confidence interval, taking into account that the CUSUM and CUSUM Square plots are located within the 5% critical limits. Thus, we have empirical evidence that the estimated coefficients of the ARDL (2, 1, 0, 2, 2) cointegration model are structurally stable.

5. Conclusion

In conclusion, the relationship between energy consumption and economic growth in Tunisia is crucial for the country's development and sustainability. The analysis conducted in this article has highlighted several key points.

Firstly, it is evident that Tunisia's economic growth is heavily dependent on energy consumption, primarily driven by the industrial and services sectors. The availability, affordability, and reliability of energy resources play a significant role in attracting both domestic and foreign investments, which contribute to the overall productivity of the economy.

Secondly, while increased energy consumption is indicative of economic growth, Tunisia faces several challenges in ensuring a sustainable energy future. The country remains heavily reliant on fossil fuels, particularly natural gas, which poses risks in terms of energy security and environmental concerns. It is imperative for Tunisia to diversify its energy mix and invest in renewable energy sources to mitigate these challenges and reduce its carbon footprint. Furthermore, addressing energy inefficiencies and promoting energy conservation measures is imperative. Adopting energy-efficient technologies and implementing policies to incentivize energy-saving practices can contribute to reducing energy consumption and promoting sustainable economic growth. Additionally, it is crucial for Tunisia to enhance energy infrastructure and modernize its electricity distribution networks. By improving transmission and distribution efficiency, the country can better meet the growing energy demand, reducing energy losses, and tackling issues such as power outages. Moreover, the government plays a vital role in fostering a conducive environment for investment in the energy sector. Implementing transparent and stable regulations, promoting public-private partnerships, and providing incentives for clean energy projects are essential steps to attract private investments and advance the country's energy transition.

Lastly, enhancing energy education and awareness among the population is crucial. Educating individuals about efficient energy consumption practices can lead to behavioral changes, reducing overall energy demand and promoting a culture of sustainability.

In conclusion, the relationship between energy consumption and economic growth in Tunisia is complex, but with the right strategies and policies, the country can harness its energy potential to drive sustainable economic development. By diversifying its energy mix, promoting energy efficiency, and improving energy infrastructure, Tunisia can achieve a balance between economic growth and environmental sustainability, ensuring a prosperous future for its citizens and generations to come. The present work constitutes an attempt to analyze energy consumption and its main determinants in Tunisia. The ARDL approach has been implemented for the period from 1971 to 2017 on the different time series of the following variables: energy consumption, growth rate, trade openness, foreign direct investment and gross fixed capital formation. The estimation results show the existence of a short-run and long-run relationship between the different variables.

In order to test the short-run as well as the long-run relationship between energy consumption and the explanatory variables of the model, the empirical analysis was first devoted to the examination of the relationship between energy consumption and socio-economic variables in Tunisia. The regression results suggest that economic growth and gross fixed capital formation significantly affect energy consumption. These results, while consistent with those found by several previous empirical studies, allow for a definitive conclusion regarding the determinants of energy consumption. Indeed, the low growth rate that affects Tunisia, allowed us to come up with two main ideas. Thus, in politically unstable Tunisia, the level of growth has a significant effect on energy consumption, while foreign direct investment and trade openness do not have a significant effect. Thus, these results also allowed us to empirically verify the theoretical and empirical link between GDP and energy consumption in Tunisia.

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