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Natural gas consumption and economic growth in Algeria: Bounds test cointegration and Toda-Yamamoto causality analysis

Hassiba ZIAN [1], Kamel Malik BENSAFTA[2]

[1] Hassiba BENBOUALI University of Chlef (Algeria), Ha.zian@univ-chlef.dz
Laboratory of Globalization and Economies of North Africa
[2] Hassiba BENBOUALI University of Chlef (Algeria), K.bensafta@univ-chlef.dz
Laboratory of Financial and banking systems

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Abstract:

This paper investigates the causal relationship between natural gas consumption and economic growth in Algeria for the period 1980–2019 using ADF test, Bouds test of cointegration and a modified version of the Granger (1969) causality test proposed by Toda and Yamamoto (1995). The empirical shows that there was a uni-directional causality running from economic growth to natural gas consumption.

Keywords: economic growth; natural gas; Algeria; ARDL; Toda-Yamamoto.
Jel Classification Codes: F43; Q42; B23,

الملخص:

الهدف من هذه الدراسة هو تقصي العلاقة السببية بين استهلاك الغاز الطبيعي والنمو الاقتصادي في الجزائر للفترة 1980-2019 باستخدام اختبار ADF واختبار الحدود Bouds Test للتكامل المشترك والنسخة المعدلة من اختبار السببية الذي اقترحه Toda و Yamamotoسنة 1995.
أظهرت نتائج الدراسة القياسية وجود علاقة سببية أحادية الاتجاه طويلة الاجل تمتد من النمو الاقتصادي إلى استهلاك الغاز الطبيعي.

الكلمات المفتاحية: النمو الاقتصادي ؛ الغاز الطبيعي؛ الجزائر؛ ARDL ؛ Toda-Yamamoto.

تصنيف Jel: F43 ؛ Q42؛ Q42؛ B23.

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*Corresponding author: **Hassiba ZIAN**, Email: Ha.zian@univ-chlef.dz*

1. Introduction.

Algeria depends on its own production of oil and natural gas for its domestic consumption, which is heavily subsidized. Natural gas and oil account for almost all of Algeria's total primary energy consumption.

Likewise, in 2014 the hydrocarbons represent 97% of Algeria's export earnings, with natural gas accounting for more than 40% of hydrocarbon exports. More than 80% of Algeria's gas exports are now absorbed by the European market. In addition, in terms of volume, natural gas is Algeria's main export product. Algeria's current hydrocarbon expansion strategy is largely dependent on its natural gas potential, which represents two-thirds of the total base of the country's hydrocarbon reserves. The prices of petroleum products and natural gas in Algeria are among the lowest in Africa and subsidies represent a significant share of the GDP. The 2016 budget law raised the prices of gasoline, diesel, natural gas and electricity for the first time in more than a decade, but the price increase was marginal and no significant impact on consumption patterns and excessive use (EIA, 2016, p. 02).

Almost half of the marketable natural gas produced in Algeria, apart from the quantities re-injected into the subsoil is mainly consumed locally by households and the transport sector, which reduces the exportations of natural gas part of the production (séréni, 2018, p. 15). The deterioration of Algeria's gas balance is not only due to declining or stagnating gas production, but also to the rapid growth in domestic gas consumption. Between 2008 and 2018, total gas consumption in the domestic market increased by 70% at an average annual growth rate of over 5% (Aissaoui, 2019, p. 07). This increase in natural gas consumption could affect economic growth depending on the nature of the relationship causality between them.

The relationship causality between natural gas consumption and economic growth described by four hypotheses; the first hypothesis is the Consumption hypothesis that assumes unidirectional causality running from economic growth to natural gas consumption. According to this hypothesis, energy policies purposing at affecting the use of natural gas will have no impact on the economy as a whole. The second hypothesis is the growth hypothesis, where the causality runs from natural gas consumption to economic growth. Energy policy makers should be careful to changes in the natural gas consumption since the effects on the macro-economy might be severe. The third hypothesis is the feedback hypothesis; this hypothesis implies that there is bidirectional causality between economic growth and natural gas consumption. If this hypothesis is confirmed then macroeconomic policies as well as energy policies should be coordinated accordingly because they can affect each other and. The fourth hypothesis is the neutrality hypothesis; this hypothesis stats there is no relationship at all between energy and economic growth (Chang, Gupta, inglesi-lotz, simo-kengne, smithers, & trembling, 2015, p. 1405). This study aims to answer at the following question:

What is the nature of the relationship between natural gas consumption and economic growth in Algeria?

1.1.Hypothesis:

To answer the problem, we suggest the following hypotheses

a. There is a unidirectional relationship causality raining from economic growth to natural gas consumption
b. There is no causality relationship causality raining from economic growth to natural gas consumption

1.2.Importance of study:

The importance of the research lies in knowing the nature of the causal relationship between natural gas consumption and economic growth in Algeria and assisting the policy maker's to make the appropriate policy to control economic growth and natural gas consumption.

1.3.Search divisions:

To answer on this question we devise the research on three axes the first axe is a literature revue, talking about the theoretical relationship between energy consumption and economic growth, the second axe is about the natural gas consumption and economic growth, the third axe is an empirical studies in this subject. The second axe is an empirical study to investigate the relationship between natural gas consumption per capita and economic growth per capita.

2. Literature revue.

In this part, we will discuss the relationship between energy consumption and economic growth in theory and in practice

2.1. Theoretical revue.

Classical and neoclassical economists did not explicitly consider the energy factor in the production function. In the days of the classics, the economy was linked to land, labor and capital (Behname, 2012, p. 162).
The importance of energy has been enhanced thanks to manufacturing, Indeed, the development model observed in Western European countries following the discovery of new energy sources in the 19th century (oil, natural gas, electricity, etc.) and based on the intensive use of resources exhaustible natural resources, has been accompanied by strong economic growth. These energy resources have become a real engine of growth allowing an increase in the production capacities in goods and services of companies, households and the State at the same time as they generate nuisances (pollution, global warming, etc.) (Palakiyem, 2016, p. 1).
D.I. Stern, C.J. Cleveland (2004) divides the growth models neoclassical economics through three thoughts. The first thought insists that technological variations are the most important factors influencing economic growth and the production function. In this case, first the economy reaches a level of equilibrium, Then it is the improvement of technology which develops economic growth rather than capital.
The second thought emphasizes the consumption of natural capital for determination of stable economic growth. The final thought considers the variation in technology and natural resources for the determination of economic growth. With the replacement between man-made capital and natural capital and the improvement of technology we can achieve stable growth. In these models, the share of energy for economic activity has been considered in proportion to the cost. these models consider energy as an intermediate good and not an input for production. On the other side, we see the reality in the case of energy efficiency in developed countries. After the oil shock of the year '70, energy consumption declined in the United States, while economic growth in the United States has grown. This case may be due to the substitution between capital and energy (Behname, 2012, p. 162).
Today, we cannot transform inputs into goods and services without consuming energy. Now economists include energy in the production function.
Energy consumption plays an important role in economic growth, both directly and indirectly. It is the complement of labor and capital in the production function. Stern (2000, a, b) and Lee and Chang (2008) present the production function like the following model:

$$Y = F(C, T, E(P))$$

$$\frac{\partial Y}{\partial C} > 0, \frac{\partial Y}{\partial T} > 0 \frac{\partial Y}{\partial E} > 0, \frac{\partial Y}{\partial E}\frac{\partial E}{\partial P} > 0$$

Where **Y** is gross domestic product, **C** is capital, **T** is labor and **E** is energy consumption which is itself a function of the price of energy (Costantini and Martini, 2010). In other words, the consumption of energy, itself in another function, depends on economic production, because it is the increase in production that attracts energy. In this case, there is a reaction relationship between energy consumption and market size. Pindyck (1979) believes that the effect of energy prices on economic growth depends on the role of energy in the structure of production. In industries where energy is used as an intermediate input, the increase in the price of energy (the decrease in consumption) influences the level of production (Behname, 2012, pp. 162,163).

For this, many empirical studies have been carried out to understand the link between energy consumption and economic growth, focus on more in the case of developed countries than in developing countries. These studies adopted several approaches; some have adopted the approach in terms of correlation and others in terms of causality, sometimes both. However, from an empirical point of view, the relationship boils down to in general on the question of the direction of causality.

2.2. Empirical revue

Numbers empirical studies have examined the nature of the relationship between energy consumption and economic growth using a variety of methodologies, mostly time series techniques to study the cointegration and causal link between these two variables for different time periods, using also aggregated data (total economic growth, total energy consumption) and disaggregated data (sectorial economic growth, oil consumption, natural gas consumption, electricity consumption….etc.).

Indeed, these studies have achieved mixed results and sometimes contradictory. Four categories of results can be distinguished, a relation of unidirectional causality from economic growth to energy consumption or from energy consumption to economic growth, a bidirectional causality relationship, or no causal relationship. A summary of the empirical research on the relationship between energy consumption and economic growth, according to alternative hypotheses, is as follows:

a. **Consumption hypothesis:** the existence of unidirectional causality were demonstrate the first time by Kraft et Kraft, (1978) in the United States, during the period 1947-1974, using the causality of Sims and a VAR model. They find that the gross national product causes the energy consumption (kraft & kraft, 1978). A similar empirical results found in M. Mehrara (2007) this study investigated the relationship between per capita energy consumption and the per capita GDP in a panel of 11 selected oil exporting countries by using panel unit-root tests and panel cointegration analysis. The results showed a unidirectional strong causality from economic growth to energy consumption for the oil exporting countries **(**Mehrara, 2007, p. 2939**).** The study of Souhila EDDRIEF-CHERFI & Baghdad KOURBALI (2012) indicate also that ther is a uni-directional causality running from the GDP per capita to the energy consumption per capita, during the period 1965-2008 in Algeria using the threshold cointegration and Granger causality tests (eddrief-cherif & kourbali, 2012, p. 238).

b. **Growth hypothesis:** This hypothesis supported by the empirical finding of Yang, (2000) in Taiwan supported this hypothesis by using Granger's causality test during the period 1954–1997 using, were he found a positive impact of energy consumption and unidirectional causality from natural gas to GDP (Yang, 2000, p. 317). The Toda and Yamamoto causality test show that a unidirectional causality running from NGC to real GDP in Saudi Arabia by Akadiri. A et all (2013) using time series data over the period 1968–2016 in a multivariate framework which incorporates total trade as additional variable using also the Autoregressive Distributed Lag method of cointegration (Akadiri, Akadiri, & Gungor, 2019, p. 230) .

c. **Feedback hypothesis:** The feedback hypothesis is supported by the empirical findings in Nachane and other (1988) studied the causal relationship between energy consumption and economic growth in 16 countries including 11 developing countries and 5 developed countries over the period (1951-1985) using the Engel-Granger cointegration test, the modified Sims causality test. (Nachan, Ramesh, & Ajith, 1988, p. 1511), the conclusion of Nachane and other study is supported by the empirical findings in Apergis, Nicholas & Payne, James E (2010) This study examined the relationship between natural gas consumption and economic growth for a panel of 67 countries within a multivariate framework over the period 1992–2005. The test of heterogeneous panel cointegration of Pedroni reveals there is a long-run equilibrium relationship between real GDP, natural gas consumption, real gross fixed capital formation, and the labor force. The results of the panel vector error correction model reveal that a bidirectional causality between natural gas consumption and economic growth in both the short- and long-run (Apergis & Payane , 2010, p. 2759).

d. Neutrality hypothesis: The neutrality hypothesis is the finding of [Song et al, 2008] for the United States, Thailand and South Korea in an empirical study they applied linear and non-linear Granger causality tests to examine the causality relationship between energy consumption and economic growth for a sample of newly industrialized Asian countries as well as the United States (Song, Chiou, & Zhen, 2008, p. 3063), a similar results were founded in the research of T. Chang and all (2015),This article examined the causality between natural gas consumption and economic growth in G7 countries over the period 1965-2011. We employ the Granger causality procedure proposed by Emir Mahmut Oglu and Kose (2011) which takes into account cross-sectional dependency and heterogeneity across countries. The empirical results support the neutrality hypothesis for the panel (Chang, Gupta, inglesi-lotz, simo-kengne, smithers, & trembling, 2015, p. 1405).

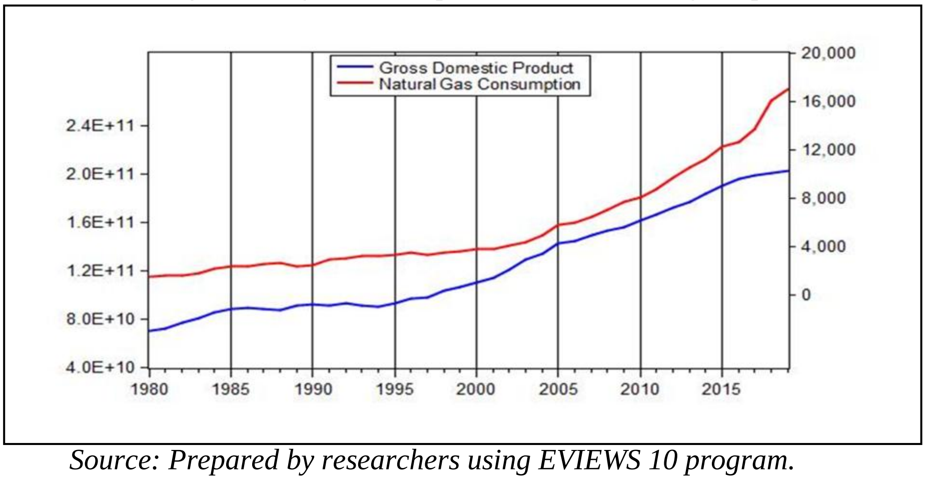
According to these studies we conclude that before taking any decision to affect economic growth through energy consumption, it should investigate the relationship between economic growth and energy consumption, and the decision-making is as follows:

- If the results of the study support the consumption theory, then the government policy targeting energy consumption will not have any impact on economic growth, and that controlling energy consumption is by controlling its prices, and these results often appear in the hydrocarbon exporting countries.
- If the results of the study support the theory of growth, then growth is controlled by policies that target energy consumption, and these results often appear in industrialized countries.
- If the results of the study support the feedback hypothesis, then macroeconomic policies as well as energy policies should be coordinated accordingly because they can affect each other
- If the study results support the neutrality hypothesis, it must to find another method to influence the economic growth.

3. Natural gas and economic growth in Algeria.

Indeed, natural gas consumption in Algeria is divided into four types of use; in the first place the electric stations which represent 43%, that is to say a volume of 7.2 GM3. Following Sonatrach customers with a share of 26%, public distributions come in third (21%) and finally industrial customers with a percentage of 10%. (Indicative program for the supply of the national gas market 2010-2019), the following graph shows the evolution of natural gas consumption and GDP during the period 1980-2019:

Figure 1. the evolution of natural gas consumption and GDP during the period 1980-2019



Source: Prepared by researchers using EVIEWS 10 program.

3.1.Natural gas consumption

We notice through the graphical representation that the consumption of natural gas in Algeria ranged between 1472-3781 KTEP during the period 1980-2000, after that it experienced a rapid growth up to 5, 4 % in 2005, this growth mainly due to:

a. Natural gas distribution networks: The natural gas distribution networks witnessed a great growth as they reached 64000 KM in 2010
b. Electricity: The per capita consumption of electricity increased by about nine times, as it moved from 111,6 KWh in 1980 to 994,4 KWh in 2010
c. Vehicles: As car imports increased by 620000 car in 2012 to be 6 million of vehicles at the end of 2017

3.2.Gross Domestic Product

through the graphical representation, we notice that the gross domestic product fluctuated between 7×10^{10} and 9×10^{10} million dollar during the period 1980-1995, after which it experienced a great growth 18×10^{11} million dollar, this is due to the rise in oil prices and the resort of the Algerian government to implement the Keynesian-oriented economic recovery policy, which aims mainly to raise economic growth by increasing the size of government investment spending in order to raise Internal demand and then raising the operating capacity available to the productive apparatus and increasing the rate of growth through three programs: the economic recovery support program during the period 2001-2004, the supplementary program to support economic growth during the period 2005-2009, and the five-year program during the period 2010-2014, Then it was known to be somewhat stable during the period due to the oil crisis in 2014 and Algeria's adoption of a policy of austerity

4. **Empirical results :** in this section we show the Approved statistical methodology to investigate the nature of relationship causality between natural gas consumption and its results

4.1.**Data and methodology:** The present study aims to investigate the relationship between natural gas consumption and Gross Domestic Product using Annual time series data from 1980 to 2019, the data of natural gas consumption have been obtained from Algerian energy budget and the data of GDP have been obtained from the World Bank data base.

The ADF has recently been used to study the stationarity of time series. The bounds test has been used to examine the cointegration between natural gas consumption and economic growth in Algeria, Toda-Yamaoto causality test has been used to testing the causality between natural gas consumption and economic growth in Algeria. Toda Yamamoto (1995) proposed an interesting simple procedure requiring the estimation of an augmented VAR which guarantees the asymptotic distribution of the Wald statistic (an asymptotic $\chi 2$-distribution), The TYDL procedure uses a modified-Wald test for restrictions on the parameters of the VAR(k) model. This test has an asymptotic chi-squared distribution with k degrees of freedom in the limit when VAR[k + d max] is estimated. Here, d max is the maximal order of integration for the series in the system. Following Dolado and Lütkepohl (1996) (Eugene, 2017, p. 104).

4.2.Result and discuss

a. **ADF test result:** The analysis of the data started with using ADF test stationary. The result show in the following table.

Table 1. ADF test result

Variable	At level				
	Model	**t-statistic**	**c-value (1%)**	**P-value**	**Result**
LGDP	None	2,743	-2,627	0,998	Non stationary

LNGC	None	7,298	-2,625	1,000	Non stationary
			At first deference		
DLGDP	None	-1,683	-2,630	0,086	Non stationary
DLNGC	None	-2,905	-2,627	0,004	stationary
			At second deference		
DDLGDP	constant	-8,742	-3,621	0,000	stationary

Source: Prepared by researchers depending on EVIEWS 10 program output.

According to the ADF test results we conclude that the LNGC time series stationary in the first differences while the LGDP stationary in the second differences

b. **Granger causality test:** the results of granger causality test showing in the following table

Table 2. Granger causality test result

Null Hypothesis	observation	F-statistic	probability
LGDP does not Granger cause LNGC	38	6,375	0,004
LNGC does not Granger cause LGDP		0,128	0,879

Source: Prepared by researchers depending on EVIEWS 10 program output.

According to the Granger causality test result there is uni-directional causality test running from LGDP to LNGC

c. **Bounds test cointegration:** In the ARDL model, the determination of the optimal lag length is crucial. For this purpose, the number of previous periods in which economic growth influences current economic growth can be determined. With an initial lag length of 4, the ARDL model automatically calculates the optimal lag lengths. According to AIC, SC and HC, the optimal ARDL model for the data is ARDL(1,0), the results in the appendices 1and 2 as show, The following table shows the results of Bounds test

Table 3. Bounds test result

Test statistic	***value***	***K***
F-statistic	7,799	1
Critical value Bounds		
Significance	|0 Bound	|1 Bound
10%	4,04	4,78
5%	4,94	5,73
2,5%	5,77	6,68
1%	6,84	7,84

Source: Prepared by researchers depending on EVIEWS 10 program output.

Table 3 shows that the F statistic of 07.79 exceeds the upper bound for I(1) = 5 at the 2,5% significance level. The results of the bounds test show that there exists long run cointegration for the variables, LGDP and LGC. Therefore,

d. **Residual diagnostic results:** The following table shows the results of Bounds test

Table 4. Residual diagnostic results

Test	statistic	Critical value	P-value
Breuch-Godfrey	F-statistic	1,248	0,307
Jarque-Bera	JB	3,472	0,176
ARCH	F-statistic	1,825	0,185

Source: Prepared by researchers depending on the appendices 3,4,5.

Table 4 shows that the probability of Breuch-godfrey test, Jarque-Bera test and ARCH test exceeds the 5% , According to this results we conclude that:

- Ther is no residual serial autocorrelation
- The resides follow the normality law
- The resides are Homogenous

e. **long run and short run relationship estimation**: the following table shows the long run and short run estimation results

Table 5. short run and long run relationship estimation results

Variables	Coefficient	T-statistic	P-vlue
	Cointegration form		
D(LGDP)	0,421	3,405	0,001
Cointeq(-1)	-0,185	-3,098	0,003

	Long run coefficients		
LGDP	2,270	14,80	0,000
C	-49,223	-12,75	0,000

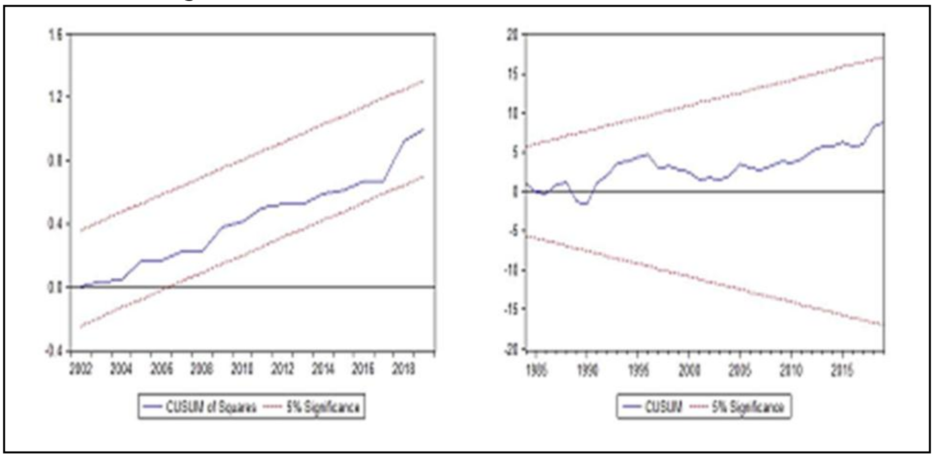
Source: Prepared by researchers depending on EVIEWS 10 program output.

The estimated results show that α = -0.1857 at the 1% significance level, which implies that natural gas consumption is able to adjust to the long run equilibrium after each short run shock that is created by GDP, with the time needed for adjustment being approximately 2 years. The coefficients of LGDP are positive at a significance level of 1%, implying that, in the short run, promoting GDP has positive impacts on economic growth.

The estimated results of long run coefficients show that LGDP has a positive impact, at a significance level of 1%, on economic growth. If the other conditions remain unchanged, a 1% increase in GDP would lead to a 2.270% increase in economic growth, on average

f. Stability test: The results of stability test shows in Figure 2

Figure 2. CUSUM and CUSUMSQ test results



Source: Prepared by researchers using EVIEWS 10 Program.

The figure 2 shows that both the CUSUM and CUSUMSQ lines (solid lines) are within the critical bounds at a significance level of 5% (dashed lines). Therefore, it can be that the estimated results are reliable for further analysis and prediction.

g. Toda-Yamamoto test: Based on the ADF test result, the maximum order of cointegration is one (dmax=2). The result of the VAR lag order selection indicates that the maximum lag length is 1 using both AIC, SIC, FPE and HQ information criteria see table 2. Based on this result, the optimum lag length is 1 (k=1).

Table 6. VAR order selection criteria

Lag	Logl	LR	FPE	AIC	SC	HQ
0	-1,3033	NA	0,0041	0,1887	0,2776	0,2194
1	100,5824	186,3054*	1,54e-05*	-5,4047*	-5,1380*	-5,3126*
2	102,3548	3,0383	1,76e-05	-5,2774	-4,8330	-5,1240
3	107,2461	7,8260	1,68e-05	-5,3283	-4,7062	-5,1135
4	107,6501	0,6001	2,09e-05	-5,1228	-4,3229	-4,8467
5	109,0454	1,9135	2,48e-05	-4,9740	-3,9963	-4,6365

Source: Prepared by researchers depending on EVIEWS 10 program output.

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hanna-Quinn information criterion

h. VAR residual serial aucorrelation test: The following table shows the result of the test for VAR residual serial aucorrelation using LM test.

Table 7. LM test for serial autocorrelation

Lags	LM-Stat	Prob
1	7,7455	0,1014
2	8,2133	0,0841
3	0,5558	0,9678
4	0,4636	0,9769
5	3,3446	0,5019

Source: Prepared by researchers depending on appendices 7.

The result of the test for VAR residual serial aucorrelation using LM test indicates that there is no serial autocorrelation in the model. This however implies that the variables included in the VAR model are well behaved, implying that the result of the VAR model has a high predictive ability; it also shows that the result can be relied on in making forecasting. The result in the table below showed a probability value greater than 0.05 so, we cannot reject the null hypothesis which states that there is no serial correlation in the model.

i. **Block exogeneity WALD test:** Having determined the maximum order of integration and the optimum lag length, with the result of VAR residual serial correlation indicating that the variables are well behaved, we ignored the test for co-integration as it will not affect any of the T-Y test procedures. The modified Wald test statistic was conducted with the addition of the optimum lag length with the maximum order of integration (k+dmax) in each of the exogenous variables included in the model. It is important to note that the k=2, while dmax=1. The result of the T-Y test using modified wald test statistic is presented on the table 8 below.

Table 8. Block exogeneity WALD test result

Depedent variable: LNGCC			
Excluded	Chi-sq	df	Prob
LGDPC	9,2066	2	0,0100
Depedent variable: LGDPC			
Excluded	Chi-sq	df	Prob
LNGCC	1,7660	2	0,4135

Source: Prepared by researchers depending on appendices 8.

The result of the Wald test as shown in table 8 above indicates that there is a uni-directional causality running from economic growth to natural gas consumption. This implies that increase in economic growth will lead to increase in natural gas consumption in Algeria. The research results strongly support the neoclassical perspective that energy consumption is not a limiting factor to economic growth in Algeria because in Algeria, government policies keep domestic prices below free market level, resulting in high levels of domestic natural gas consumption. The results imply that the natural gas conservation through reforming natural gas price policies has no damaging repercussions on economic growth for Algeria

The three main segments of domestic natural gas consumption in Algeria are power stations, the public gas distribution sector (supplying households, small and medium-sized commercial and industrial users) and large-scale industry. Currently, the electricity sector, where natural gas accounts for 98% of total fuel consumption, accounts for the largest share of total domestic gas consumption.

The public distribution sector has been a rapidly growing gas use segment, as the "gasification program" across the country remains a key government policy priority. At present, the national gas penetration rate is over 60%, with the northern coastal population centers having a penetration rate close to 100% (Aissaoui, 2019, p. 07).

Accordingly, an important policy implication resulting from this analysis is that government can pursue the conservation energy policies that aim at curtailing energy use for environmental friendly development purposes without creating severe effects on economic growth. The energy should be efficiently allocated into more productive sectors of the economy.

5. Conclusion.

The study investigated the relationship between natural gas consumption and economic growth in Algeria during the period 1980-2019. The study employed ARDL methodology and Toda Yamamoto causality test and found that there is a long run uni-directional causality running from economic growth to natural gas consumption.

This is the result of government policies maintaining domestic prices below the free market level, which leads to high levels of domestic consumption of natural gas, especially in non-productive sectors such as the transport sector and the family sector.

Accordingly, one of the important policy implications arising from this analysis is that the government can pursue energy conservation policies that aim to reduce natural gas consumption for environmentally friendly development by reforming natural gas price policies without having harmful repercussions on economic growth. Based on this result, we recommend that the government put in place policies and programs that reduce natural gas consumption and that it should be allocated efficiently in the most productive sectors of the economy and encourage investment in renewable energies.

In order to search for more results on the subject and guide government policies to adopt effective policies, we suggest the following topics:

- The relationship causality between Natural gas consumption and the economic growth in Algerian industry sector
- Natural gas domestic demand function in Algeria
- Natural gas international demand function in Algeria
- The effect of natural gas prices on natural gas consumption in Algeria

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Appendices

I. Model selection criteria of ARDL

Model Selection Criteria Table
Dependent Variable: LNGC
Date: 03/27/21 Time: 23:02
Sample: 1980 2019
Included observations: 39

Model	LogL	AIC*	BIC	HQ	Adj. R-sq	Specification
20	58.435634	-3.079757	-2.947798	-3.033700	0.993724	ARDL(1, 0)
19	59.293832	-3.071880	-2.895933	-3.010470	0.993829	ARDL(1, 1)
9	61.014668	-3.056370	-2.792451	-2.964255	0.994018	ARDL(3, 1)
10	59.827340	-3.045963	-2.826030	-2.969201	0.993816	ARDL(3, 0)
15	58.555725	-3.030874	-2.854927	-2.969464	0.993571	ARDL(2, 0)
14	59.378108	-3.021006	-2.801073	-2.944243	0.993660	ARDL(2, 1)
18	59.369667	-3.020537	-2.800604	-2.943774	0.993657	ARDL(1, 2)
5	60.165983	-3.009221	-2.745301	-2.917106	0.993729	ARDL(4, 0)
8	61.161410	-3.008967	-2.701061	-2.901500	0.993862	ARDL(3, 2)
4	61.082343	-3.004575	-2.696668	-2.897107	0.993835	ARDL(4, 1)
7	62.027879	-3.001549	-2.649656	-2.878729	0.993942	ARDL(3, 3)
17	59.971839	-2.998436	-2.734516	-2.906320	0.993661	ARDL(1, 3)
13	59.480271	-2.971126	-2.707206	-2.879011	0.993486	ARDL(2, 2)
16	60.257348	-2.958742	-2.650835	-2.851274	0.993546	ARDL(1, 4)
3	61.213935	-2.956330	-2.604437	-2.833510	0.993661	ARDL(4, 2)
2	62.087458	-2.949303	-2.553423	-2.811131	0.993738	ARDL(4, 3)
6	62.078575	-2.948810	-2.552930	-2.810637	0.993735	ARDL(3, 4)
12	59.983618	-2.943534	-2.635628	-2.836067	0.993447	ARDL(2, 3)
11	60.399408	-2.911078	-2.559185	-2.788258	0.993368	ARDL(2, 4)
1	62.170165	-2.898343	-2.458476	-2.744817	0.993527	ARDL(4, 4)

II. ARDL estimation output

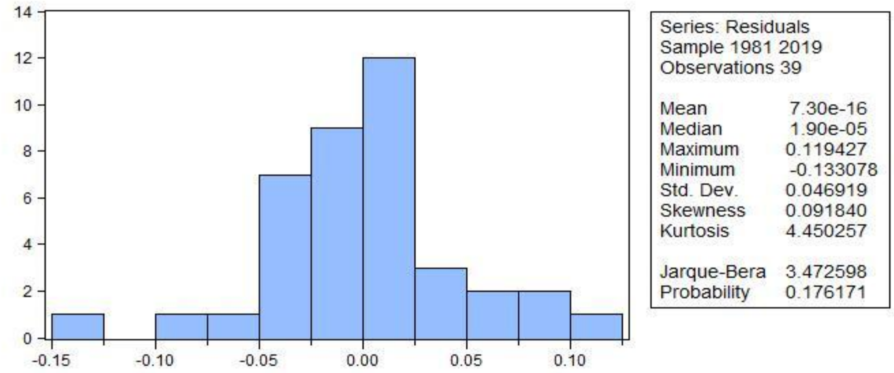
Dependent Variable: LNGC
Method: ARDL
Date: 03/24/21 Time: 22:06
Sample (adjusted): 1981 2019
Included observations: 39 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (4 lags, automatic): LGDP
Fixed regressors: C
Number of models evalulated: 20
Selected Model: ARDL(1, 0)
Note: final equation sample is larger than selection sample

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNGC(-1)	0.814217	0.059958	13.57989	0.0000
LGDP	0.421896	0.123870	3.405963	0.0016
C	-9.144849	2.669787	-3.425311	0.0015

R-squared	0.995147	Mean dependent var	8.427669
Adjusted R-squared	0.994877	S.D. dependent var	0.673506
S.E. of regression	0.048204	Akaike info criterion	-3.152937
Sum squared resid	0.083651	Schwarz criterion	-3.024971
Log likelihood	64.48227	Hannan-Quinn criter.	-3.107024
F-statistic	3691.081	Durbin-Watson stat	1.929981
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

III. Normality test result



IV. Breusch-Godfry serial correlation LM test result

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.248795	Prob. F(3,33)	0.3079
Obs*R-squared	3.976148	Prob. Chi-Square(3)	0.2641

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 03/25/21 Time: 18:22
Sample: 1981 2019
Included observations: 39
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGC(-1)	0.018801	0.071493	0.262977	0.7942
LGDP	-0.041867	0.149766	-0.279547	0.7816
C	0.910024	3.231491	0.281611	0.7800
RESID(-1)	0.043089	0.198324	0.217265	0.8293
RESID(-2)	-0.330857	0.186332	-1.775631	0.0850
RESID(-3)	0.104139	0.197335	0.527725	0.6012

R-squared	0.101953	Mean dependent var	7.30E-16
Adjusted R-squared	-0.034115	S.D. dependent var	0.046919
S.E. of regression	0.047712	Akaike info criterion	-3.106623
Sum squared resid	0.075123	Schwarz criterion	-2.850690
Log likelihood	66.57915	Hannan-Quinn criter.	-3.014797
F-statistic	0.749277	Durbin-Watson stat	1.962568
Prob(F-statistic)	0.592517		

V. Heteroskedasticity test: ARCH result

Heteroskedasticity Test: ARCH

F-statistic	1.825623	Prob. F(1,36)	0.1851
Obs*R-squared	1.834039	Prob. Chi-Square(1)	0.1757

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/25/21 Time: 18:27
Sample (adjusted): 1982 2019
Included observations: 38 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002679	0.000745	3.598227	0.0010
RESID^2(-1)	-0.219506	0.162458	-1.351156	0.1851

R-squared	0.048264	Mean dependent var	0.002198
Adjusted R-squared	0.021827	S.D. dependent var	0.004076
S.E. of regression	0.004032	Akaike info criterion	-8.138085
Sum squared resid	0.000585	Schwarz criterion	-8.051896
Log likelihood	156.6236	Hannan-Quinn criter.	-8.107419
F-statistic	1.825623	Durbin-Watson stat	1.868218
Prob(F-statistic)	0.185076		

VI. VAR model estimation result

Vector Autoregression Estimates
Date: 03/25/21 Time: 18:48
Sample (adjusted): 1983 2019
Included observations: 37 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	LNGC	LGDP
LNGC(-1)	0.825161	-0.037814
	(0.17174)	(0.07336)
	[4.80473]	[-0.51544]
LNGC(-2)	-0.316098	0.012717
	(0.22683)	(0.09690)
	[-1.39352]	[0.13124]
LGDP(-1)	0.266147	1.410040
	(0.40569)	(0.17330)
	[0.65603]	[8.13635]
LGDP(-2)	0.749985	-0.274426
	(0.70465)	(0.30101)
	[1.06434]	[-0.91169]
C	-10.49354	0.183853
	(4.68005)	(1.99920)
	[-2.24218]	[0.09196]
LNGC(-3)	0.276564	0.031060
	(0.15474)	(0.06610)
	[1.78733]	[0.46990]
LGDP(-3)	-0.531263	-0.144195
	(0.49652)	(0.21210)
	[-1.06997]	[-0.67984]
R-squared	0.995330	0.996294
Adj. R-squared	0.994396	0.995553
Sum sq. resids	0.069478	0.012678
S.E. equation	0.048124	0.020557
F-statistic	1065.654	1344.240
Log likelihood	63.63606	95.10689
Akaike AIC	-3.061409	-4.762535
Schwarz SC	-2.756641	-4.457766
Mean dependent	8.484853	25.53352
S.D. dependent	0.642853	0.308274
Determinant resid covariance (dof adj.)		9.78E-07
Determinant resid covariance		6.43E-07
Log likelihood		158.7620
Akaike information criterion		-7.824971
Schwarz criterion		-7.215435

VII. VAR residual serial correlation LM test result

VAR Residual Serial Correlation LM Test
Null Hypothesis: no serial correlation at l
Date: 03/25/21 Time: 23:33
Sample: 1980 2019
Included observations: 37

Lags	LM-Stat	Prob
1	4.377287	0.3573
2	3.954748	0.4122
3	2.263019	0.6875

Probs from chi-square with 4 df.

VIII. Block exogeneity Wald test result

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 03/25/21 Time: 18:50
Sample: 1980 2019
Included observations: 37

Dependent variable: LNGC

Excluded	Chi-sq	df	Prob.
LGDP	8.974254	2	0.0113
All	8.974254	2	0.0113

Dependent variable: LGDP

Excluded	Chi-sq	df	Prob.
LNGC	0.310104	2	0.8564
All	0.310104	2	0.8564