Econometric estimation of the impact of oil prices and economic growth on the diffusion of renewable electricity in Algeria: using VECM model

Saida Tayeb*

University of Relizane (Algeria)

Saida.tayeb@univ-relizane.dz

Mariem Bougueroua

University of Mostaganem (Algeria)

meriem.bougueroua@univ-mosta.dz

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Abstract:

The purpose of this article is to investigate the relationship between renewable electricity generation, oil price and economic growth in Algeria using the cointegration approach and Vector Error Correction Model (VECM). We examine simultaneously short-term and long-term impacts between the studies variables: renewable electricity generation, oil price and economic growth during the period 1990–2016. We propose also to forecast the renewable electricity generation to 2025 under different scenarios. The main results of the analysis show that the oil price influenced positively, in the short and long term, the renewable energy generation in Algeria. It implies that higher oil price allows more investment in the renewable energy. This result further confirms the strong dependence of Algerian economy on oil revenues and raises several questions about looking for new sources of financing to develop renewable energies and achieve the sustainable development.

Keywords: Electricity generation, Renewable energy, Oil price, Economic growth, VECM

Jel Classification Codes: F47; K32; Q43

*Corresponding author.

1. Introduction :

Algeria, a producer and exporter of hydrocarbons, is exploiting its natural wealth in order to provide the resources needed for its economic development through the expanding of the energy sector. Therefore, its economy is strongly dependent on fossil fuels exportation revenue, which account for about 30% of the country's Gross Domestic Product (GDP). However, the level of socio-demographic, economic and climatic changing requires a thinkable energy policy that takes into account the challenges of the future, including the decline of fossil resources, the volatility of oil price and the environmental issues. Indeed, the integration of renewable energies (RE) into the national energy-mix is a major challenge in terms of preserving the availability of the fossil resources, responding to the growing domestic energy demand and contributing to the sustainable development. In fact, the use of renewable sources aims not only to decrease the harmful environmental effects of using fossil fuels, but it can also delay the depletion of our hydrocarbon reserves. Furthermore, Algeria has a great potential for developing its share of RE as conditions especially for solar and wind energy are of outstanding quality (Hadj,L, 2016). Aware of these advantages, the Algerian authority adopted in 2011 its national renewable energy target. The RE program had an experimental phase devoted to testing the various available technologies and conducting pilot project. It included: Hybrid power plant (Gas-Solar) of Hassi R'Mel (150MW that includes 25 MWh of solar power capacity), operational since 2011, and the photovoltaic power station of Ghardaïa (1,1 MW) with the wind farm of Adrar (10 MW) operational since July 2014 (Abdeladim, K , 2014). The encouraging results of this phase, added to the significant technological progress (especially in photovoltaic and wind technologies) and the sharp decline of their costs (IEA& NEA, 2015), led the policy-makers to update and enlarge the program in May 2015. It envisions the installation of 22 GW of RE by 2030, which is almost double than what was set as a target before (12 GW), providing a share of 37% in the total installed capacity and 27% in the electricity generation. Of these 22 GW, about 4.5 GW are supposed to be installed by 2020 [4]. The RE program will be conducted in two phases.

First phase 2015 - 2020: The installation of 4000 MW shared between photovoltaic and wind power capacity, as well as 500 MW, between biomass, cogeneration and geothermal energy.

Second phase 2021 - 2030: The development of the electrical interconnection between the North and the Sahara (Adrar), which will allow the installation of large RE plants in the regions of In Salah, Adrar, Timimoun and Bechar and their integration in the national energy system.

The targets per technology are set according two phases as outlined in the table below:

Table N°01 Phases of the Algerian renewable energy program

Unit : MW	1st phase 2015-2020	2nd phase 2021-2030	Total
Photovoltaic	3 000	10 575	13 575
Wind	1 010	4 000	5 010
CSP	-	2 000	2 000
Cogeneration	150	250	400
Biomass	360	640	1 000
Geothermal	05	10	15
Total	4 525	17 475	22 000

Source: Algerian Ministry of Energy and Mines, «Programme National des Energies Nouvelles et Renouvelables,» [En ligne]. Available: http://www.energy.gov.dz.

Furthermore, to support investments in this sector, the authority implemented a Renewable Energy National Fund (RENF) in 2009, merged later with the National Energy Efficiency Fund (NEEF) in 2014, to provide financing through a 1% levy on oil tax revenues [4]. Other forms of State's assistance and incentive are carried out through a guaranteed purchase price mechanism (feed-in tariffs), for the projects connected to the network, over a period of 20 years for solar and wind and 15 years for cogeneration (MEM, 2016).

Even if policymakers keep on providing the necessary policies and subsidies, the RE program is slow to materialize (Haddoum, S , 2018) (only 3.19% of RE in the energy balance in 2016) (see Fig.2). According to the above and knowing the importance of fossil's revenue in the Algerian economy, we can think that the oil price is a determining factor, among others, in the development of the RE program. Thus, this paper attempts to examine empirically the nexus between these variables using an advanced econometric model.

Among the studies conducted in the developed economies, Chul-Yong and Sung-Yoon (L.Chul-Yong, 2017, p. 31) listed many studies exploring the relationship between oil prices and renewable energy diffusion and most perform panel data analysis.

These investigations present contrasting results (substitutive/complementary effect,or non-existent), and the authors suggest that an analysis of their relationship in each market is necessary.

In the case of Algeria, there have been no academic studies focusing on this in our best knowledge. Mostly, despite their rarity, the existing researches have dealt either with nexus of electricity consumption (renewable non-renewable) and the economic growth, or with renewable electricity consumption and the environmental degradation. Among the recent one, we can mention Belaïd and Abderrahmani (Belaid F, 2013) examined the causal relationship between economic growth, petroleum price, and electricity consumption using the 1971–2010 period. The results of the cointegration and causality tests confirm the presence of a bidirectional causal relationship between electricity use and economic growth. The authors indicate also the absence of causality across energy consumption and petroleum price.

Belaïd and Youssef (youssef Y. M. Belaïd F, 2017) explored the dynamic causal relationship between CO2 emissions, renewable and non-renewable electricity consumption and economic growth in Algeria over the period 1980–2012. The Cointegration approach revealed the existence of a long-run relationship among the variables. However, in the short-run, results proved unidirectional causality relationship running from GDP to non-renewable electricity consumption. Furthermore, results attest that renewable electricity generation has not a significant contribution to energy-based carbon dioxide emissions reduction target.

Amri (amri . F, 2017) analysed the relationship between economic growth and energy consumption (renewable and non-renewable) in Algeria between 1980 and 2012. The cointegration tests show the existence of long-run link between real gross domestic product, real capital and the two categories of energy consumption i.e. renewable energy per capita and non-renewable energy. Also, the estimations with long-run and the short-run autoregressive distributed lag (ARDL) indicate that only the non-renewable energy sort and capital can contribute to enhancing economic growth whereas renewable energy does not show any significant exect.

In addition to these studies, the nexus between energy and economic growth in Algeria has been also examined in other papers referred to several countries. Among these: (ziramba . E, 2013)investigated the relationship between economic growth and hydroelectricity consumption using series data from Egypt, Algeria, and South Africa over the period 1980-2009. The multivariate framework's results provide support for the neutrality hypothesis for Egypt. The feedback hypothesis is confirmed in Algeria while the conservation hypothesis is supported in South Africa. (sahbi ,f;shahbaz,m, 2014) explored the causal relationship between renewable and non-renewable electricity consumption, economic growth and CO2 emissions for 10 Middle East and North Africa (MENA) countries over the period of 1980–2009. Their short-run dynamics reveal the unidirectional causality running from renewable and non-renewable electricity consumption and economic growth to CO2 emissions. In the long-run, the results confirmed a bidirectional causality between electricity consumption (renewable and non-renewable) and CO2 emissions.

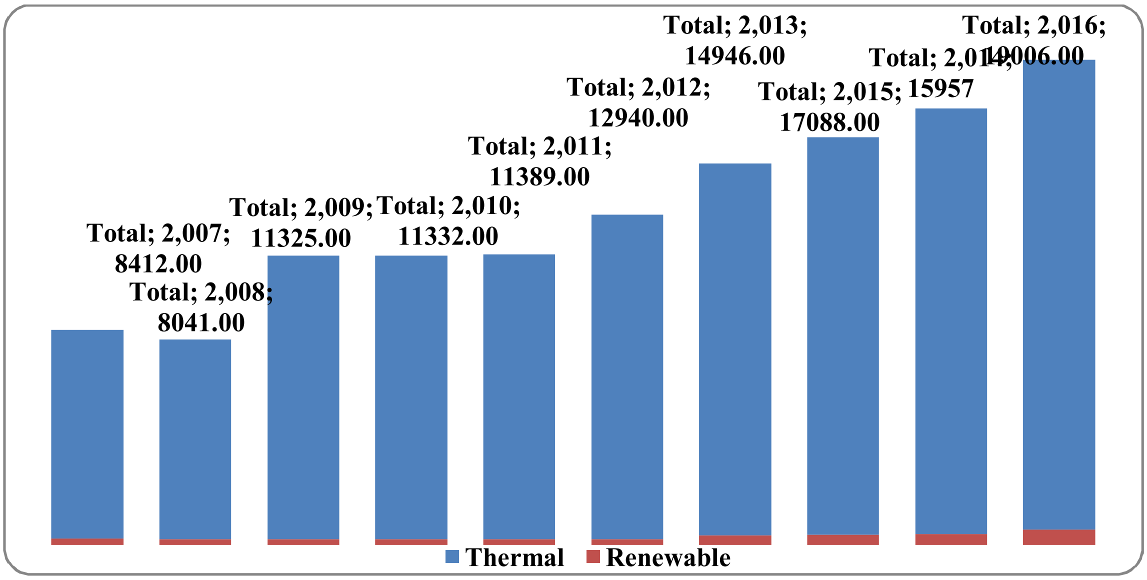
2. Algeria's electricity generation

To make electricity available to all, both for the benefit of the economy and citizens, Algeria provided a great means (financial and material) to develop its electricity network and improve its capacity.

Therefore, Algeria has a successful electrification rate of more than 99%, with 9 million customers connected to electricity network in 2016. (mem, 2018)

As illustrated in the Fig.1 below, the Installed capacity has steadily increased over the past decade to reach 19,006 MW in 2016. Electricity from renewable sources represented only a tiny fraction, representing 606 MW of the installed capacity in this year.

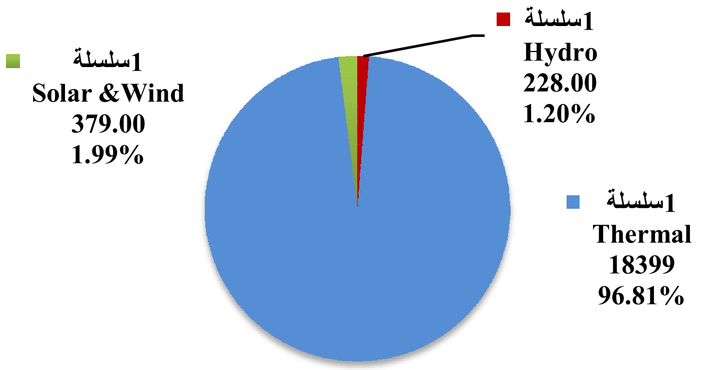
Figure N°01:. Installed Capacity of Generation in Algeria (MW)



Note: Renewable includes hydro, solar, wind and others sources; thermal includes diesel, combined cycle, gas and steam.

Algeria's electricity generation is mainly based on non-renewable sources. Out of the 19,006 MW worth of installed capacity registered in 2016, natural gas accounted for an astounding 95%, which by itself amounts to more than 18 GW. The RE (Hydroelectric, solar, wind) and the Diesel represent respectively 3% and 2% of the installed capacity.

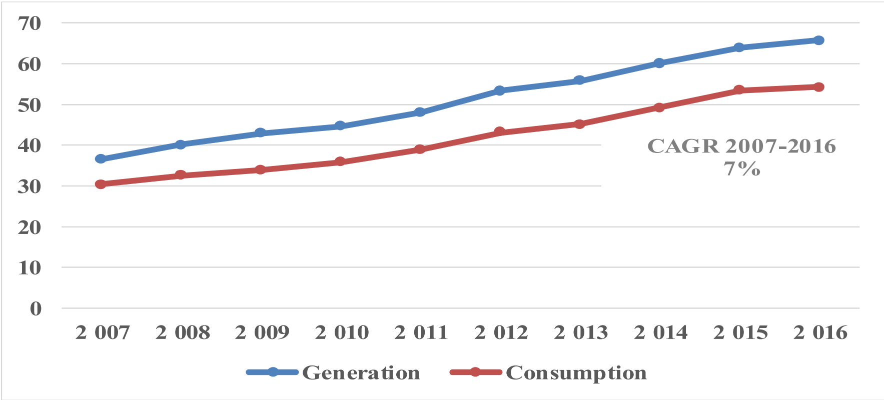
Figure N°01. Algeria Installed Energy Capacity (2016)



Source: Arab Union of Electricity, «Statistical Bulletins,» [En ligne]. Available: http://www.auptde.org/. [Accès le 2018].

In 2016, electricity consumption reached 54,149 GWh compared to 30,320 GWh in 2007. In parallel, electricity generation rose from 36,474 GWh to 65,686 GWh between 2007 and 2016. Both electricity generation and consumption have increased by an average of 7% per annum during this period.

Figure N°03: Growth in electricity generation and consumption in Algeria (TWh)



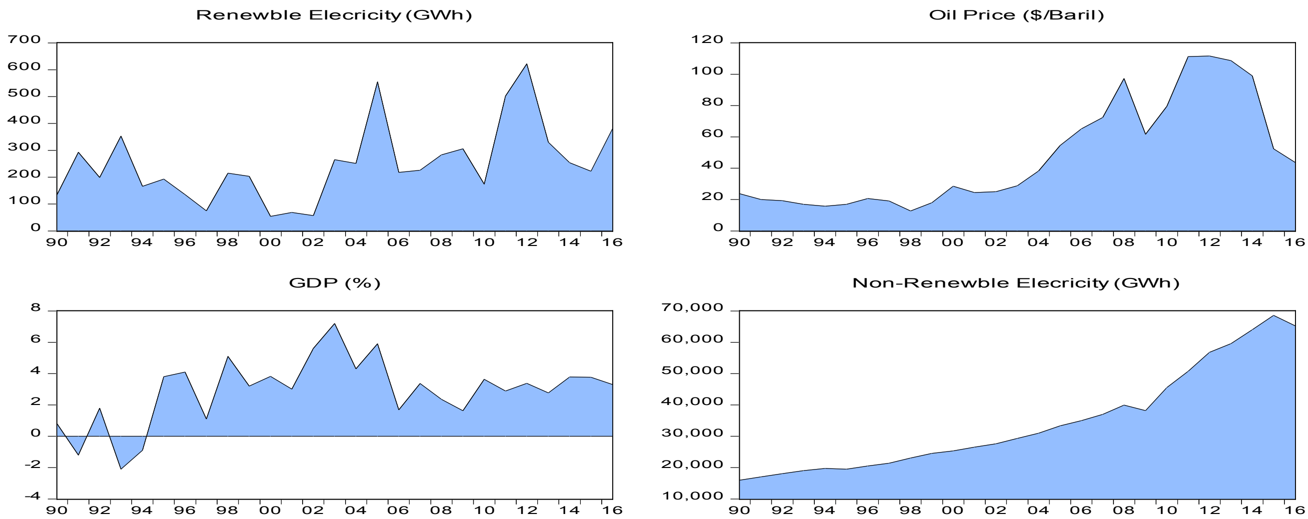
Source: CREG Commission de Régulation de l'Electricité et du Gaz, «Programme indicatif d'approvisionnement du marché national en gaz naturel 2019 - 2028,»

2.1 Data and Methods:

2.1.1. Data: The aim of this contribution is to estimate the impact of oil price and economic growth on the renewable electricity generation in Algeria. Using the cointegration tests and vector error correction model (VECM), we will examine simultaneously short run and long run impacts between the renewable electricity generation, oil price and economic growth.

The choice of the variables was not an easy task to model the impact of economic conditions upon the development of the renewable energy in Algerian case. Some data are quite incomplete and are only available at limited period. For this reason, we have limited our empirical study at a sample of 27 years, covering the period 1990 -2016. The considered variables are renewable electricity generation (RELEC), oil price (OILP), economic growth (GDP) and the non-renewable electricity generation (NRELEC). There are collected from World Development Indicators (WDI-2017) and BP Statistical Review of World Energy (2018).

Figure N°04 presents the general evolution of the economic growth (%), oil price ($/Baril), renewable and non-renewable electricity generation (GWh).



Source: Renewable and non-renewable electricity generation, oil price and economic growth, in Algeria (1990-2016)

2.1.2. MethodsM

- **Stationarity Test (Unit root tests):** Most macroeconomic time series are trended and therefore in most cases are non-stationary. Therefore, the standard ordinary least squares (OLS) regression procedures can easily lead to spurious regression. In some cases, the results of the OLS regression show a very large value of R2 and very large values of t-ratios, whereas the variables used in the analysis have no real interrelations (Granger, 1974,P111,120)Therefore, the stationarity test of the series is very important. If a series is stationary without any difference, it is designated I (0). On the other hand, a series that has stationary first differences is designated I (1), or integrated of order one. To test stationarity of our series, the Augmented Dickey-Fuller test has been used.

Augmented Dickey and Fuller tests (ADF) (1979, 1981) determine the presence of a unit root (the series can be considered as non-stationary) or not (the series is stationary) (Dickey, David A., and Wayne A. Fuller, 1979,p 427;431), (Dickey, 1981.p,1057-1072). Moreover, if the series (RELEC, NRELEC, OILP and GDP) present the same order of integration, we can conclude that there is a risk of cointegration between our variables.

- **Johansen's Test for Cointegration:** The Johansen's Test for cointegration uses two tests to determine the number of cointegration vectors: The Maximum Eigenvalue Test and the Trace Test. In some case, Maximum Eigenvalue and Trace test may yield different results, according to Alexander (2001); the results of Trace test should be preferred. (Alexander, 2001)

Knowing that, if we have more than two variables in the model, then there is a possibility of having more than one co-integrating vector (the variables in the model might form several equilibrium relationships). In general, for k-number of variables, we can have only up to k-1 co-integrating vectors. To find out how many cointegrating relationships exist among k variables requires the use of Johansen's methodology. (Johansen,s, 1988,p; 213,254)

After testing the order of integration of all variables, the Johansen's methodology require the selection of the optimum lags (p) of the vector autoregressive (VAR) models, which are determined with the Likelihood Ratio (LR), Final Prediction Error Criterion (FPE), Akaike Information Criterion (AIC), Schwarzinformation Criterion (SC) and Hannan-Quinn information criterion (HQ). Then, the lag length (p) was selected through the estimation of an unconditional VAR model. It is a crucial input for the cointegration test, which makes the estimation of long run relationships possible.

The identification of some long-run relationships between the studies variables (RELEC, NRELEC, OILP and GDP) leads to estimate a VECM by using the Johansen estimation techniques (Johansen S, 1991,p; 1551–1580,)

❖ **Vector Error Correction Model (VECM):** After finding a cointegration relationship between the examined variables, we can estimate a VECM.

VECMs are a category of multiple time series models to model simultaneously short run and long run impacts. The VECM separates the short-run and long-run relationship among the variables. It is recommending when the times series variables are cointegrated. (Engle, R.F., Granger, C.W.J, 1987;p; 277-304) Otherwise, VECM is no longer required and we directly precede to Granger causality tests to establish causal links between series. The estimation of our model is based on the following equations:

$$RELEC_t = \propto_0 + \sum_{i=1}^{p} \propto_{1i} OILP_{t-i} + \sum_{j=1}^{p} \propto_{2j} GDP_{t-j} + \sum_{n=1}^{p} \propto_{3n} NRELC_{t-n} + \sum_{m=1}^{p} \propto_{4m} RELC_{t-m} + \varepsilon_{1t} \quad \dots (1)$$

$$OILP = \beta_0 + \sum_{i=1}^{p} \beta_{1i} RELEC_{t-i} + \sum_{j=1}^{p} \beta_{2j} GDP_{t-j} + \sum_{n=1}^{p} \beta_{3n} NRELC_{t-n} + \sum_{m=1}^{p} \beta_{4m} OILP_{t-m} + \varepsilon_{2t} \quad \dots (2)$$

$$GDP_t = \gamma_0 + \sum_{i=1}^{p} \gamma_{1i} OILP_{t-i} + \sum_{j=1}^{p} \gamma_{2j} GDP_{t-j} + \sum_{n=1}^{p} \gamma_{3n} NRELC_{t-n} + \sum_{m=1}^{p} \gamma_{4m} NRELC_{t-m} + \varepsilon_{3t} \quad \dots (3)$$

$$NRELEC_t = \theta_0 + \sum_{i=1}^{p} \theta_{1i} OILP_{t-i} + \sum_{j=1}^{p} \theta_{2j} GDP_{t-j} + \sum_{n=1}^{p} \theta_{3n} RELC_{t-n} + \sum_{m=1}^{p} \theta_{4m} NRELC_{t-m} + \varepsilon_{4t} \quad \dots (4)$$

The VECM presents not only the long-run relationship of the variables, but it has an additional significant advantage: forecasting. (Anderson, R.G., Hoffman, D.L., Rasche, R.H., 2002,p;569;598)Thus, we apply dynamic forecasts to assess how far the estimated model has approximated the real-historical values and to see if long-term forecasts are close to the targets set in terms of renewable electricity production.

2.2 Results:

Table 2 indicates that the null hypothesis of no unit roots for the three series (RELEC, OILP and GDP) are rejected at their first differences, because the ADF statistical values are less than the critical values at a 5% significant level2. All variables become stationary after first difference. They are then integrated of order one I (1).

Table N°02 The Augmented Dickey Fuller (ADF) test results

Variable	t-statistic	
	At level	At 1st difference
RELEC	-1.1647	-6.9079*
NRELEC	1.7300	2.9907*
OILP	-0.5272	-4.4596*
GDP	-0.6767	-8.5440*

Lag lengths are selected automatically according to Akaike Info Criterion.
*: Test statistics are significant at 1 % level of significance.

To know the number of cointegration vectors by using Johansen approach, the length of VAR model must be determined by considering the different lag selection criterions (previously cited). Table 2 shows that the optimal lag order is one (p = 1) for three of information criterion.

Table N°03 Lag order selection criterion

Lags	Log L	LR	FPE	AIC	SC	HQ
0	-543.39	NA	5.52e+15	47.59	47.79	47.64
1	-477.36	103.35*	7.33e+13*	43.24	44.23*	43.49
2	-466.86	12.77	1.37e+14	43.72	45.50	44.17
3	-454.22	10.99	2.81e+14	44.01	46.58	44.66
4	-413.69	21.14	9.74e+13	41.88*	45.24	42.73*

* indicates lag order selected by the criterion

The results of Johansen's test for cointegration with a lag of order one are presented in table 3 (the model with constant, no trend is chosen). The Trace statistic indicates that RELEC, NRELEC, OILP and GDP are cointegrated. The null hypothesis of at most one cointegration relation is not rejected at 5% level (10.59 < 15.49). In other words, the number of cointegrated vectors with one lag is equal to one.

[2]The critical values of test statistics are tabulated in Fuller (1976) and MacKinnon (1996).

Table N°01 Results of Cointegration tests

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.59	48.21	47.85	0.046
At most 1	0.48	25.36	29.79	0.148
At most 2	0.24	8.78	15.49	0.385
At most 3	0.06	1.78	3.84	0.181

No intercept no trend Trace test indicates 1 cointegrating equation at the 5% level of significance.

* denotes rejection of the hypothesis at the 5% level.

**MacKinnon-Haug-Michelis (1999) p-values

❖ **Short and long-run relationships:** The presence of cointegration relationship between the variables requires the estimation of the VECM. The log run relationship between the RELEC, NRELEC, OILP and GDP for one cointegrating vector is given in the table 5

Table N°02 Long-run relationship

Dependant variable RELEC	Coefficient	Std Error	t-statistic
OILP	3.828	2.258	1.695
GDP	43.169	15.763	2.738
NRELC	-0.014	0.007	- 2.079
Constant	65.75	/	

In the long term, all the coefficients are significant at 5% of significance. Based on these results, we can say that the impact of OILP and GDP on RELEC are positive and significant. It implies that a higher oil price and more economic growth permit a more investment in the renewable energy. Besides, the impact of NRELEC is negative, due to a substitution effect between the shares of the two sources of generation electricity.

In the short run, table 6 indicates that only the variable oil price has a significant and positive effect at 5% level of significance. The effect of the economic growth on renewable electricity generation is statistically insignificant in the short term.

Table N°03 Short-run relationship

	Coefficient	Std. Error	t-Statistic	Prob.
ECT	-0.78	0.24	-3.17	0.004
D(RELEC-1)	0.09	0.22	0.41	0.685
D(OILP-1)	5.96	2.34	2.54	0.019
D(GDP-1)	14.69	12.01	1.22	0.236
D(NRELEC-1)	0.005	0.01	0.38	0.701
Constant	-17.07	39.30	-0.43	0.668
R-squared	0.46	F-statistic		3.29
Adjusted R-squared	0.32	Prob(F-statistic)		0.026
		Durbin-Watson stat		1.87

- **Parameter stability:** To test the parameter stability, we have use the cumulative sum of recursive residuals CUSUM and the cumulative sum of recursive residuals of squares CUSUM² tests. Figs 6 and 7 show that both diagrams are situated inside the critical bounds, which reflect the stability of model's parameters.

Figure N°05 Plot of cumulative sum of recursive residuals

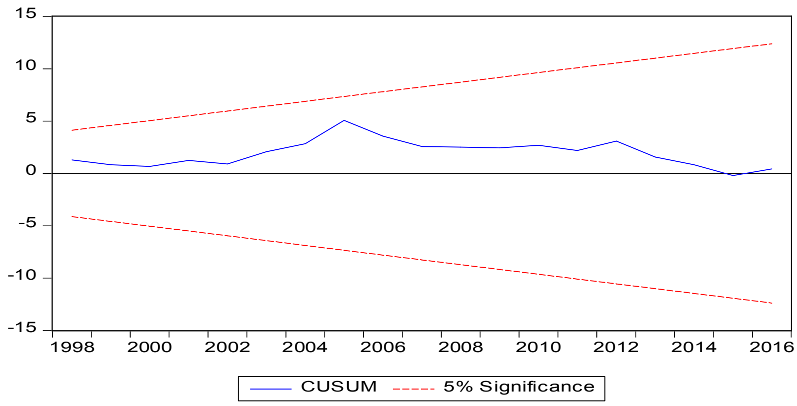
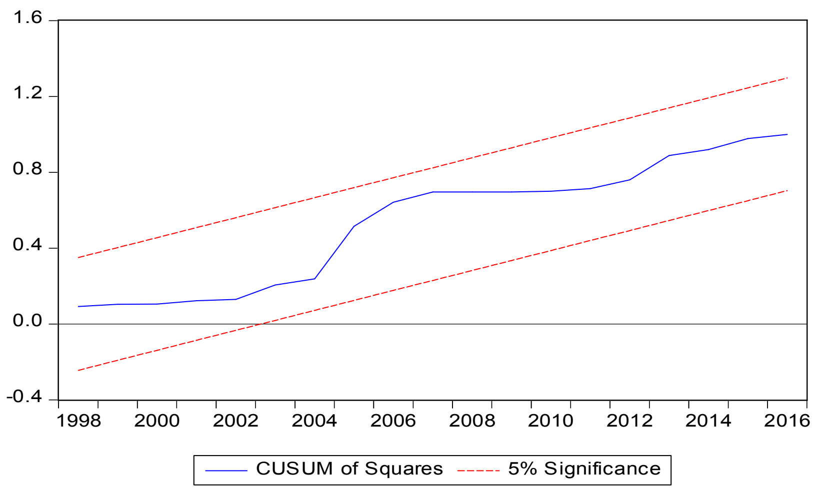


Figure N°06. Plot of cumulative sum of recursive residuals of squares



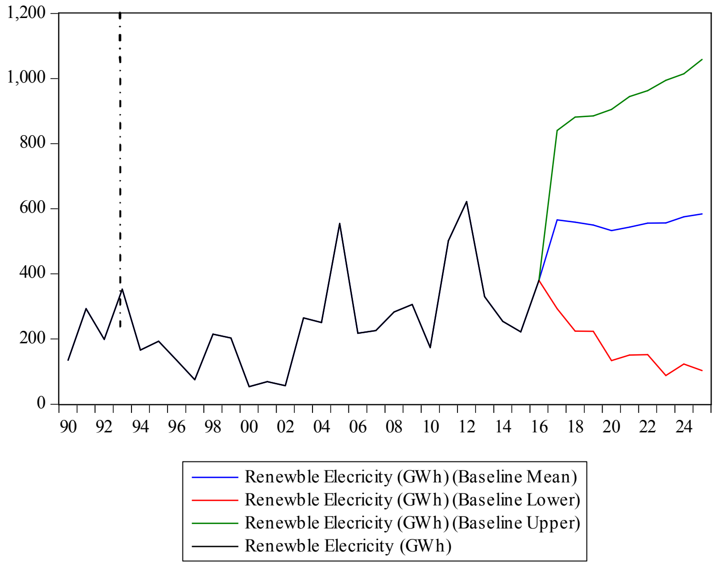
❖ **Forecasting using alternative scenarios:** According to the Annual Energy Outlook (2018), the price of Brent crude, in 2017 dollars, reaches $125 per barrel by 2020 and $170 per barrel by 2025, in the assumption of Higher Oil Price case, compared with $35 per barrel by 2020 and $40 per barrel by 2025 in the Low Oil Price case.

We use these projections of oil prices to determine the different scenarios for the renewable electricity generation in Algeria by 2025.

Fig.7 represents the forecasting output of our VECM model, which correspond to the three scenarios of oil price: In the Reference case3 (Base Line scenario), the renewable electricity generation will progress by 5% by 2025.

In the High Oil Price case, the Renewable electricity generation will almost tripled by 2025, where it will rise to 1058 GWh, reflecting good financial conditions. Finally, in the case of low oil prices, renewable electricity production is expected to decrease by 7% by 2025.

Figure N°02 Scenarios of Renewable Electricity Generation by 2025



[3] Notice that the Reference case projection assumes trend improvement in the actual conditions of the renewable electricity generation in Algeria.

3. Conclusion:

The goal of this paper was to set out the nexus between renewable electricity generation, economic growth and oil price in Algeria from 1990 to 2016. We reached this objective by using the cointegration approach and vector error correction model (VECM). The main results of the analysis show that the oil price influenced positively the renewable energy generation in Algeria (ceteris paribus) in the short and long term. It implies that higher oil price allows more investment in the renewable energy. In fact, in our forecast analysis, the high oil price case almost tripled renewable electricity generation. This result further confirms that public investment based on oil revenues has shown its limits especially in a context of low prices, and raises several questions about looking for new sources of financing to develop renewable energies and achieve the sustainable development. Currently, Algeria produces about 96% of its electricity from thermal technologies. However, considering the depletion of hydrocarbons with high greenhouse gas emissions, renewable electricity has become a major alternative to fossil fuels to cope with the runaway domestic demand and to honor the environmental commitments. In the regulatory framework, Algeria has ambitious quantitative targets to generate almost 40% electricity from RE by 2030, with financial incentives, but its implementation comes slowly.

So far, Algeria has relied on its hydrocarbon revenues to diversify its economy and deploy its renewable energy plan. This strategy has shown its limits given the volatility of oil prices.

The Algerian authorities have recently recognized the need to find new sources of financing for renewable energies and the public-private partnership seems to be a chosen option as a new scheme of financing. Indeed, on the inauguration of the 9th edition of the International Exhibition of Renewable Energies (ERA 2018), hold in Oran in October 2018, the Algerian Minister of Energy, launched messages to the national partner, public or private as well as the foreign partners to convince them to invest in Algeria where there is "good business, win-win partnerships". He also invited, during a press briefing, all present, foreign and national partners, to attend a meeting on 22 October 2018 in Algiers to discuss and prepare the tender notices of the renewable energy. The Minister explained: "We want to involve you in discussing the specifications, we changed the way we do things ... and now, we are open, and we want to welcome investors". This is a new era for the development of renewable energies in Algeria, which we hope will be more reactive and more efficient, to see green energy becomes a reality in Algeria.

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