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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Examining the Connection amongst Renewable Energy, Economic Growth and Carbon Dioxide Emissions in Algeria*

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Abstract

In this paper, we shall study the relationship between renewable energy, economic growth (GDP), carbon dioxide emissions and with control variable that are estimated into realized volatility and to verify if the EKC hypothesis is accepted or not. This study is focussed on the Algerian situation during the periods of 1995-2016 and we employed the VECM procedure and Granger causality to estimate the short and long-run coefficients. We found with VECM that an increase in carbon dioxide emissions, fossil energy consumption and production will raise the level of economic growth, while an increase in GDP, fossil energy consumption and production will upsurge the level of carbon dioxide emissions, but an increase in renewable energy consumption will reduce both GDP and carbon dioxide emissions. We concluded in the short-term that there's bidirectional causality between carbon dioxide emissions and GDP and there is unidirectional causality running from renewable energy consumption to carbon dioxide emissions.

Keywords

Environment • Renewable Energy • Economic Growth • Carbon Dioxide Emissions • EKC Hypothesis • VECM Model • Granger Causality

JEL Classifications

O13 • P18 • C32

* http://siteresources.worldbank.org/EXTMETAP/Resources/COED-AlgeriaCP.pdf.

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1. Introduction

In 1999, the cost of environment degradation has been estimated at 3.6% of the Algerian GDP and it is estimated at 97 billion Algerian Dinars annually (1.7 billion US dollars) which was lost due to ecological issues, and the damage cost to the global environment was approximately 1.2% of the GDP.

The impact of soil degradation was evaluated on the basis of losses in agricultural productivity resulting from water and wind erosion. Water erosion threatens 12 million hectares (ha) in northern and western Algeria. Wind erosion threatens more than 7 million ha of arid and semi-arid land.

The urban air pollution was caused by the transport sector in the large cities of Algiers, Oran and Constantine by burning municipal waste (Oued Smar in Algiers, Oran), and by the big industries in Annaba, Skikda, and Gazaouet. Such pollution has triggered on a yearly basis 353,000 cases of bronchitis, 544,000 asthma attacks and could be the cause of the 1,500 cases of lung cancer.

The lack of potable water and sanitation as well as poor water quality and hygienic practices causes mortality in children under the age of 5, because of acute diarrheal diseases. It is estimated that 205,500 DALYs (Disability Adjusted Life Years) to be lost per year. In addition to the health impacts, limited consideration was given to water resource degradation due to dam silting which is estimated at 0.09% of the GDP.

Coastal degradation is due primarily to coastal erosion affecting 250-300 kilometres of beaches, sand extraction of 10 million cubic meters over the last 10 years, dredging a volume of 20 million cubic meters of soil from 18 ports, and over-exploitation of fisheries by increasing catches from 91,000 tons to 113,000 tons over the last decade. Estimates of coastal degradation were made on the basis of the loss of tourism revenues.

Consequently, the country made new national programs for renewable energy and energy efficiency which focus on the reduction of the greenhouse gas emissions and environmental problems[1] by 7% to 22% in 2030, compared to a business as usual -BAU- scenario, conditional on external support in terms of finance, technology development and transfer, and capacity building.

In the light on this statement, we shall study the effect of renewable energy and economic growth on the carbon dioxide emissions in Algeria during the period of 1995-2016. The objective is to study the impact of renewable energy consumption and the development of economic growth on reduction of carbon dioxide emissions. This paper is divided into 5 titles, the introduction, a literature review, data and methodology, empirical results and the conclusion.

1 United Nations for Climate Change (UNFCCC), (September 3rd, 2015), « *Intended nationally determined contribution INDC-Algeria*».

2. Literature Review

The following table describes several studies in this domain:

Table 1
Literature review about the relationship between GDP, CO_2 emissions and renewable energy

Study	Period	Data	Methodology	Conclusion
Inglesi-Lotz and Dogan (2018)	1980 - 2011	10 biggest electricity generators in Sub-Saharan Africa countries	DOLS	The GDP and electricity production from renewable source had a negative and significant impact on carbon dioxide emissions, but the GDP squared and electricity production from non-renewable source had a positive and significant impact on carbon dioxide emissions.
Apergis et al. (2018)	1995 - 2011	42 sub-Saharan Africa countries	DOLS and FMOLS	The GDP had a positive and significant impact on (CO_2) emissions, while the renewable energy consumption had a negative and significant effect on (CO_2) emissions.
Mbarek et al. (2018)	1990 - 2015	Tunisia	VECM	An increase by 1% in (GDP) can raise renewable energy consumption, energy use and (CO_2) emissions by 1.33%, 0.36% and 1.12%, respectively. Also, they provided that a 1% increase in (CO_2) decreases (GDP) by 0.28%, but a 1% increase in renewable upsurge (GDP) by 0.16%.
Solarin et al. (2017)	1965 - 2013	India and China	ARDL	The GDP and urbanisation had a positive effect on CO_2 emissions, while real GDP squared and hydroelectricity consumption had a negative influence on CO_2 emissions
Shahbaz et al. (2017)	1960 - 2016	USA	ARDL and VECM	The biomass energy consumption has a negative impact on CO_2 emissions; GDP and GDP squared have a positive and negative effect, respectively on CO_2 emissions
Dogan and Aslan (2017)	1995 - 2011	25 European countries	LM bootstrap panel cointegration test	the elasticity of carbon emissions with respect to economic growth is negative and is reaching from −0.10% to −0.20%, so this can lead to lower level of emissions
Zoundi (2017)	1980 - 2012	25 countries	DOLS, GMM, dynamic fixed effect, mean group and pooled mean group.	An increase by 1% in the consumption of renewable energy reduces (CO_2) emissions by 0.13%, an increase by 1 % in primary energy consumption can lead to increase (CO_2) emissions by 0.85%, suggesting that the consumption of renewable energy along with primary energy reduces air quality by around 0.72% (0.85–0.13)
Attiaoui et al. (2017)	1990 - 2011	22 African countries	Panel regression and panel cointegration	a 1% increase in (GDP) increases (CO_2) emissions by 0.19 in the long-term and by 0.015% in short-term, while, an increase by 1% in non-renewable energy consumption increases (CO_2) emissions by 0.23% in the long-term and by 0.35% in the short-term. However, a 1% increase in renewable energy consumption decreases (CO_2) emissions by 0.22% in the long-term and by 0.07% in the short-term.

Paramati et al. (2017)	1990 - 2012	11 countries (Next 11)	Heterogeneous panel cointegration	The renewable energy consumption and income had a negative and significant impact on (CO_2) emissions
Chen et al. (2016)	1993 - 2010	188 countries	Panel cointegration and VECM	The energy consumption per capita has significant influences on (CO_2) emissions, a 1% increase in energy consumption per capita increase the emission of (CO_2) per capita by 7.6%, 26.1%, and 13.5% in developed countries, developing countries, and in the world, respectively. However, the real (GDP) per capita contributes positively to the energy consumption per capita for both countries. However, in the long-run, an increase in energy consumption will decrease the rate of (GDP) in the world.
Al-Mulali et al. (2016)	1980 - 2010	Seven selected regions	DOLS and VECM	The GDP and GDP squared had a positive and negative impact, respectively on CO_2 emissions except for the Sub Saharan Africa, and the renewable energy consumption had a negative influence on CO_2 emissions except for the Sub Saharan Africa,
Dogan and Seker (2016)	1985 - 2011	23 countries	Panel cointegration	the environmental effects of energy consumption by sources can allow an increases in renewable energy consumption by (1%) which will lead to mitigate the carbon emissions by (3% or 4%) and an increases in non-renewable energy consumption may rise the level of (CO_2) emissions by (20% or 24%).
Sulaiman et al. (2013)	1980 - 2009	Malaysia	ARDL	The elasticity of (CO_2) emissions with respect to electricity production from renewable sources was negative and statistically significant in both short and long-run.
Menyah and Rufael (2010)	1960 - 2007	USA	The generalized forecast error variance decomposition	The renewable energy consumption explains more than 19% of the forecast error variance of CO_2 emissions and GDP explains not more than 7% of the forecast error variance of CO_2 emissions.

Source: Done by the researchers

The 2nd table defines several causalities in some literature review:

Table 2
Causality amongst GDP, CO_2 emissions and renewable energy

Study	Method	EKC	Causal relationship
Inglesi-Lotz and Dogan (2018)	Emirmahmutoglu-Kose causality	No	GDP $\longleftrightarrow$ CO_2 CO_2 $\longrightarrow$ REP (renewable energy production)
Apergis et al. (2018)	Granger causality	N/A	RE $\longleftrightarrow$ CO_2 GDP $\longrightarrow$ CO_2
Mbarek et al. (2018)	Granger causality	N/A	CO_2 $\longleftrightarrow$ GDP GDP $\longrightarrow$ RE

Solarin et al. (2017)	Granger causality	Yes	GDP ↔ CO_2 GDP ↔ RE RE → CO_2
Shahbaz et al. (2017)	Granger causality	Yes	Biomass energy ↔ CO_2 GDP → BE GDP → CO_2
Dogan and Aslan (2017)	Emirmah mutoglu-Kose procedure causality	Yes	GDP ↔ CO_2
Paramati et al. (2017)	Homogenous causality of Dumistrescu-Hurlin (2012)	N/A	CO_2 → RE
Al-Mulali et al. (2016)	VECM Granger causality	Yes	Several causalities between GDP, CO_2 and RE.
Sulaiman et al. (2013)	Granger causality	N/A	GDP ↔ CO_2 REP ↔ CO_2
Menyah and Rufael (2010)	Toda-Yamamoto causality	N/A	GDP ↔ CO_2 GDP → RE CO_2 → RE

Source: Done by the researchers.
↔ : Bidirectional causality
→ : One-way causality

Therefore, these studies used different methodologies and variables to examine the link amongst renewable energy, economic growth and carbon dioxide emissions in several countries. The most variables used were trade openness, income (real GDP), GDP squared, CO_2 emissions, electricity production and consumption from renewable and non-renewable sources, renewable energy consumption (in all forms), gross fixed capital formation, and labour force.

Some investigations demonstrate that most African countries still do not mainly depend on renewable energy in their energy production **Attiaoui et al. (2017)**. However, according to World Bank[2] and IEA[3], the renewable energy will not only represent a decent addition to the total energy supply, but it will substitute the conventional fossil-fuelled energy as well. Also, the greener energy will allow meeting households' needs for energy and contribute to the improvement of air quality, but more efforts should be made to spread renewable energy policies across Africa and efforts should be made by households to switch to this new technology **Zoundi (2017)**.

2 https://www.worldbank.org/

3 International Energy Agency. https://www.iea.org/

3. Data and Methodology

The following table displays all variables used in this study over the period of 1995-2016 in Algeria:

Table 3
Variables description

Variables	Unites	Source of Data
FEC : Fossil energy consumption	Million tonne equivalent of petrol (Mtep)	Bp (British Petroleum) and International Energy Agency (IEA)
FEP: Fossil energy production	Mtep	Bp and IEA
REC: Renewable energy consumption	Mtep	Bp
REP: Renewable energy production	Mtep	OECD
CO_2 : Dioxide carbon emission	Million tonne carbon dioxide	Bp
GDP: Gross domestic product	Current US $	World Bank
GDP^2: Gross domestic product square	Current US $	Created with using World Bank
Kyoto: Kyoto protocol	Dummy variable	In 1997 and in 2005
Paris: Paris Agreement	Dummy variable	In 2015

Source: made by the researchers

The defined model is derivative from several literatures like **Inglesi-Lotz and Dogan (2018)**, **Apergis et al. (2018)** and **Mbarek et al. (2018)**…etc. We shall use the variables of per capita CO_2 emissions, per capita GDP and per capita REC in linear form, because it gives us consistent and efficient empirical results.

Also, the majority of the researchers and literatures in this domain follow a quadratic model with the inclusion of GDP^2 variable to verify the validity of the Environment Kuznets Curve hypothesis.

$$GDP_t = a_1 + \sum_{i=1}^{p} b_{1i}\, GDP_{t-1} + \sum_{i=1}^{p} c_{1i}\, CO2_{t-1} + \sum_{i=1}^{p} d_{1i}\, REC_{t-1} + e_1 RVGDP^2{}_t + f_1 RVREP_t + g_1 RVFEP_t + h_1 RVFEC_t + j_1 \text{Kyoto}_t + k_1 \text{Paris}_t + \varepsilon_{t1}$$

$$CO2_t = a_2 + \sum_{i=1}^{p} b_{2i}\, GDP_{t-1} + \sum_{i=1}^{p} c_{2i}\, CO2_{t-1} + \sum_{i=1}^{p} d_{2i}\, REC_{t-1} + e_2 RVGDP^2{}_t + f_2 RVREP_t + g_2 RVFEP_t + h_2 RVFEC_t + j_2 \text{Kyoto}_t + k_2 \text{Paris}_t + \varepsilon_{t2}$$

$$REC_t = a_3 + \sum_{i=1}^{p} b_{3i}\, GDP_{t-1} + \sum_{i=1}^{p} c_{3i}\, CO2_{t-1} + \sum_{i=1}^{p} d_{3i}\, REC_{t-1} + e_3 RVGDP^2{}_t + f_3 RVREP_t + g_3 RVFEP_t + h_3 RVFEC_t + j_3 \text{Kyoto}_t + k_3 \text{Paris}_t + \varepsilon_{t3}$$

GDP: represents the economic variable in Algeria that designs the economic growth or the economic factor of sustainable development because it takes into consideration the population over time (t).

CO_2: indicates the level of dioxide carbon emissions and it represents the factors of pollution which is emitted by from industrial sector and fossil fuel energy.

REC: designs the variable of renewable energy consumption in Algeria, especially the consumption of solar photovoltaic, hydropower and geothermal over time (t).

a_1, a_2 and a_3: are the intercept of each equation and they define the variables that are not included in the equation system like number of cars, fuel consumption and level of technology introduced which can have an influence on dioxide carbon…etc.

$RVGDP^2$: Is gross domestic production square or income square. This variable is used to show the difference in the partial effect of real production on carbon emission and to verify the validity of the Environment Kuznets Curve hypothesis.

RVREP and **RVFEP**: are the realized volatility of fossil energy production and the renewable energy production. Both variables have a close relationship with the increase or the decrease of the carbon emission

FEC: is the 1st control variable and it characterizes the realized volatility of fossil energy consumption in Algeria over time (t). There are many studies that stated that there is a close relationship between this variables and GDP, as it represents the main energy for the industrial development and technological advancement.

Kyoto and **Paris**: are the dummy variables that represent the Summit of Kyoto in 1997and in 2005, while the Paris climate conference was in 2015.

$^{\varepsilon}t1,\ ^{\varepsilon}t2$ and $^{\varepsilon}t3$: define the error term in the equation system and it represents also the innovation or the shock term that can be used to study the impulse responses.

The new evidence in such model is that we transformed the control variable into realized volatile series as they can be interpreted as variation change or rated coefficients. Then, in the time-series models, we usually employ the unit root procedure and cointegration test, to verify if such series can be estimated with Vector Autoregressive model (VAR), Vector Error Correction model (VECM), or Autoregressive Distributed Lags (ARDL) model…etc. And after, we select the perfect model.

Therefore, we tested the unit root with Phillips-Perron and Augmented Dickey-Fuller, so we make two hypotheses as following:

H_0 (null hypothesis): the series has a unit root;

H_1 (alternative hypothesis): the series has not a unit root;

Therefore, we make these two tests on 3 models: $^{\varepsilon}t1$, $^{\varepsilon}t2$ and $^{\varepsilon}t3$

$$\Delta x_t = \partial x_{t-1} - \sum_{j=2}^{p} \omega_j \, \Delta x_{t-j+1} + \varepsilon_t \text{.................. (1);}$$
$$\Delta x_t = \partial x_{t-1} - \sum_{j=2}^{p} \omega_j \, \Delta x_{t-j+1} + c + \varepsilon_t \text{.................. (2);}$$
$$\Delta x_t = \partial x_{t-1} - \sum_{j=2}^{p} \omega_j \, \Delta x_{t-j+1} + c + b * trend + \varepsilon_t \text{.................. (3);}$$

In this study, we selected four lag (p=4) for the Schwarz Info Criterion, Bartlett Kernel as the spectral estimation method and the Newey-West Bandwidth.

We found that the three variables were stationary at 1st difference, so they have the same order of integration I (1). Then, we need to check the optimal lag with lag length criteria with VAR estimation. Therefore, we concluded that the optimal model is with three lag (p=3), so we take (p=2) for Johansen cointegration test in Eviews 9.

Therefore, we concluded for the existence of VECM (2) model in 3 cointegration specifications (the model without interception, the model with interception in the long-run and the model with interception in the long and short-run). However, we selected the 2nd model with only interception in the long-run, because it has the less value of Akaike and Schwarz criteria. **Granger (1988)** posited that the VECM is more suitable to investigate the causality between series that are integrated at I (1), thus the model is based on the assumption that all the variables are not exogenous and also premised on the fact that the depend variables are explained by the past values of the independent variables and the past values of the dependent variables.

However, the sign of long-run relationship was accepted, but not for all coefficients, so we need to check the validity of the coefficient with exogeneity test and to make some restriction in VECM.

H_0: the restricted coefficients equal to 0;

H_1: the restricted coefficients are unequal to 0.

We struggled to find the perfect restriction for this VECM, but we selected the restriction A (2, 2) = 0, A (3, 1) = 0 and we accepted in this case the null hypothesis, so the 2nd coefficient of per capita GDP and the 1st coefficient of per capita REC have a low power of exogeneity in this model.

We shall also study the impulse response and the variance decomposition between the innovation and shock (residual series) of each variable and verify the Granger causality between variables, the existence of long-run relationship doesn't mean that there is a real causality between variables, so we need to check if there is a two-way causality or one-way causality or there is no causality.

4. Empirical Results and Discussion

4.1. The coefficient diagnostic

The system VECM equation have significant coefficients, the $DGDP_t$ model have the regression coefficient equal to 0.94, indicating that 94% of exogenous variables explain the endogenous variable and 6% were explicated by other factor that are not determining in the model, while the DCO_{2t} model have the regression coefficient equal to 0.99, indicating that 99% of exogenous variables explain the endogenous variable and 1% were explicated by other factor that are not defining in the model, and the $DREC_t$ have the regression coefficient equal to 0.892, indicating that 89.2% of exogenous variables explain the endogenous variable and 10.8% were explicated by other factor that are not determining in the model.

We can say also that the model was globally significant due to the high value of Fisher statistic.

4.2. The residual diagnostic

We initiated the investigations with the graph of the inverse roots of the characteristic AR polynomial (**Lütkepohl, 1991**). The autoregressive root graph showed that the model VAR is more or less stationary or stable.

We also tested with multivariate normality, if the residuals are normally distributed or not. Our outcomes showed that the VAR residuals are normally distributed and we concluded for the acceptation of the null hypothesis (normality distribution) and the rejection of alternative hypothesis.

4.3. Discussion

The model has 4 long-run coefficients, three of them have the negative sign and were statistically accepted, so we can accept the specification of VECM (2) restricted system equation.

In the 1st equation when per capita GDP was considered as endogenous variable. The signs of $DGDP_{t-1}$ and $DGDP_{t-2}$ were negative and significant at level of 5%, respectively, so an increase by 1% in $DGDP_{t-1}$ and $DGDP_{t-2}$ will decrease the economic growth by 1.392% and 0.756%, respectively, confirming the result of previous models (economic growth-renewable energy consumption model), so we can say that the industrial and the economic development of the country is lesser than what it was in the previous periods.

The sign of DCO_{2t-1} was positive and significant at level of 5%, and DCO_{2t-2} was negative and insignificant, demonstrating that a rise by 1% in carbon dioxide emission in 2015 had a positive impact on GDP by $5.27*10^{9}$%, so this result indicates that the country depends on a lot on goods and services that emitted the polluted air to develop its economic growth.

The coefficient of $DREC_{t-1}$ and $DREC_{t-2}$ were negative and insignificant, so this result is in line with the main hypothesis of Growth, indicating that Algeria did not depend on renewable energy to improve its socio-economic situation.

The variables of realized volatility of fossil energy production and consumption have a statistically accepted negative and positive coefficient, respectively, so an increase by 1 unit in RVFEP and RVFEP will decrease and increase the variation level of GDP by -305048.6 and by 754208.4, respectively. Therefore, we found an unexpected result, because Algeria is considered as one of the country that rely on fossil energy production, so this might reveal the existence of inefficiency in energy production and it may contribute negatively to the economic growth, while the sign of fossil energy consumption was good and have positive affect on per capita GDP.

The sign of RVREP, $RVGDP^2$ and Kyoto were both positive and insignificant, so they do not have any effect on GDP, while the coefficient of Paris was negative and statistically accepted, indicating that this conference had a negative effect on GDP of Algeria. in these circumstances when the country tries to change, systematically and rapidly its energy policy, it will impact negatively its economic growth (the change from fossil fuel dependence towards renewable energy dependence and then diminish the deforestation, loss of biodiversity, the carbon emissions and other sources of greenhouse gas were the aims of the Paris Summit).

In the 2nd equation when per capita CO_2 was considered as endogenous variable. The sign of $DGDP_{t-1}$ and $DGDP_{t-2}$ were positive, and significant at level of 1% and 5%, respectively, so an increase by 1% in $DGDP_{t-1}$ and $DGDP_{t-2}$ will upsurge the rate of carbon dioxide emissions by $2*10^{-10}$% and $4.05*10^{-11}$%, indicating that the industrial and the economic development of the country is depending a lot of polluted goods and services, so confirming again the relationship between GDP, CO_2 and fossil energy. This result is supported by the studies of **Mbarek et al. (2018)**, **Apergis et al. (2018)** and **Attiaoui et al. (2017)**.

The sign of DCO_{2t-1} was positive and insignificant, while the coefficient DCO_{2t-2} was statistically positive, demonstrating that a rise by 1% in carbon dioxide emission in 2014 had a positive impact on itself by 0.258%, approving the last result.

The coefficient of $DREC_{t-1}$ and $DREC_{t-2}$ were negative, insignificant and significant, respectively, so an increase by 1% in renewable energy consumption in 2014 would diminish the level of carbon dioxide emission by 18.50%. Consequently, the renewable energy can reduce the pollution factor that causes the warm climate. Also, Algeria is going to apply an energy policy that focuses on photovoltaic and wind energy, as they represent the alternative of hydropower and biomass energy which emit a lot of negative gas from their chemical product that contaminate the ocean and increase deforestation and the loss of biodiversity. This result is in line with the main literature of **Inglesi-Lotz and Dogan (2018)**, **Zoundi (2017)**, **Paramati et al. (2017)**, **Dogan and Seker (2016)** and **Sulaiman et al. (2013)**.

The variables of RVFEP and RVFEC have a positive and significant coefficient, respectively, so an increase by 1 unit in RVFEP and RVFEP will surge the variation level of carbon dioxide emissions by $3.35*10^{-5}$ and by $4.40*10^{-5}$, respectively. This outcome is in line with the hypothesis that the country is depending on fossil energy which represent the main source of energy that emits a lot of pollution in the atmosphere, carbon dioxide especially. This result indicates also that the country in this period was using unclean technology that used the waste and combustible energy which emits a high level of pollution in the ecosystem. Consequently, the energy policy of Algeria for now appears to be more focused on supporting the development of its economic growth than encouraging the decline of the air pollution. The same result found in studies of **Inglesi-Lotz and Dogan (2018)**, **Attiaoui et al. (2017)**, and **Chen et al. (2016)**.

For the rest of variables in this equation, they had an insignificant coefficient, meaning that Algeria was not concerned by the objectives of such conferences such as the protection of the fish stocks, the introduction of sustainable development term to the private sector and in global companies.

Also, we could not accept the Environment Kuznets Curves Hypothesis where the level of ecological pollution initially rise with income until it attains its equilibrium points, because the $RVGDP^2$ was not significant, so the EKC hypothesis is not valid, in this situation and we can say that the country is considered as a developing country that needs a lot of polluted manufactures and productions to keep its economic growth expansion and to develop its economic structure. This result is supported by studies of **Inglesi-Lotz and Dogan (2018)**, **Zoundi (2017)** and **Dogan and Ozturk (2017)**.

In the 3rd equation when per capita REC was considered as endogenous variable. All variables seem to be insignificant in every level, except the Kyoto variable, so an increase by 1 unit in the dummy variable of Kyoto will surge the elasticity of renewable energy consumption by $1.93*10^{-9}$, showing that the country is starting to more concerned with the environmental issues and Algeria is aware of the ratification of the Kyoto protocol and it will have a good consequence on the adoption of renewable sources.

After analyzing the impact of each coefficient on the VECM system, we shall display the impulse response to indicate the variation between the endogenous variables and their residual series. In the 1st period, a shock on per capita CO_2 does not have a contemporary effect on per capita GDP or on per capita REC, confirming the result of causality, while a shock on GDP has a contemporary effect on CO_2 only. The shock or innovation amplitude of GDP was 233.657 and will immediately be reflecting on CO_2 shock by $4.11*10^{-9}$, confirming the positive relationship between GDP and CO_2. Also, a shock on REC has a contemporary effect on CO_2 and GDP, by $6.69*10^{-10}$ and it will directly be reflecting on GDP innovation by 128.77 and on CO_2 shock by $1.39*10^{-8}$, confirming the positive link among REC and GDP, and a negative relationship between REC and CO2, suggesting that in the 1st period Algeria was using combustible renewables that release a lot of carbon dioxide in the air. In the 2nd period, a shock on CO_2 by $2.44*10^{-9}$ has contemporary effect on innovation of GDP by 7.979 and on innovation of REC by $3.86*10^{-12}$. A shock on GDP by -70.809 [9] has a current impact on shock of CO_2 by $3.86*10^{-8}$ and on the innovation of REC by $5.41*10^{-11}$, while an innovation on REC by $9.68*10^{-11}$ will influence the innovation of CO_2 by $3.38*10^{-8}$ and the shock of GDP by 214.073. From this outcome, we can say that Algeria is focusing on development of economic growth rather than reducing environmental issues, so the country is not concerned with the international conferences on climate change (the protocol Kyoto and the Summit of Paris).

The variance decomposition indicates in the 3rd period, that the forecast errors of per capita CO_2 is due 0.581% of its innovation, 29.069% of per capita GDP innovation, and 70.35% of per capita REC shock, while the forecast errors of GDP is due to 67.078% of its shock, 0.026% to per capita CO_2 innovation and 32.896% to per capita REC innovation. And, the forecast errors of REC is due to 99.062% to its shock, while 0.927% to CO_2 innovation and 0.011% of GDP innovation. Consequently, this result confirms the Granger causality test.

4.4. Granger causality

Table 4
VEC Granger causality/Block exogeneity between DGDP, DCO_2 and DREC

	DGDP	
Excluded	Chi-square	Probability
DCO_{2t}	9.302*	0.009
$DREC_t$	3.170	0.204
	DCO_2	
Excluded	Chi-square	Probability
$DGDP_t$	100.401*	0
$DREC_t$	12.705*	0.001
	DREC	
Excluded	Chi-square	Probability
$DGDP_t$	0.308	0.857
DCO_{2t}	0.031	0.984

Source: Done on EViews 9.

Table 5
Granger causality between per capita CO_2, GDP and REC with (p=2)

Null hypothesis	Fisher-statistic	Probability
CO_2 does not Granger cause GDP	1.180	0.334
GDP does not Granger cause CO_2	12.149*	0
REC does not Granger cause GDP	1.636	0.227
GDP does not Granger cause REC	1.525	0.249
CO_2 does not Granger cause REC	0.008	0.991
REC does not Granger cause CO_2	0.111	0.894

Source: Done on EViews 9.

The Granger causality in the short-run revealed that there is bidirectional causality between per capita DCO_2 and per capita DGDP at level of 1% and we also found that there is a unidirectional causality running from per capita DREC to per capita DCO_2 at level of 1%. Therefore, we can say that the carbon dioxide emissions and economic growth are interrelated to each other, so when there is a variation on GDP, it will impact directly the level of CO_2, and it is the same when there is a change in CO_2, it will influence the economic growth factor, confirming that Algeria depends a lot on combustible and fuel energy that emits a lot of polluted gas. The same result was found in the studies of **Inglesi-Lotz and Dogan (2018)**, **Mbarek et al. (2018)**, **Solarin et al. (2017)**, **Dogan and Aslan (2017)**, **Sulaiman et al. (2013)** and **Menyah and Wolde-Rufael (2010)**, while an impact on REC has a direct effect on CO2, we saw that the consumption of renewable energy, especially the photovoltaic and wind energy can decrease the level of carbon dioxide emissions, we can add that renewable energy is considered clean energy power since renewables induce far fewer pollutant gas emissions when they are compared to fossil energy sources, such as petrol, coal and natural gas. This result is supported by the main literature of **Solarin et al. (2017)** and **Al-Mulali et al. (2016)**. However, in the long-run there is a one-way causality running from per capita GDP to per capita CO_2 and it confirms the previous findings. This result is in line with the investigations of **Apergis et al. (2018)**, and **Shahbaz et al. (2017)**.

5. Conclusion

We established that the variable of economic growth will increase the level of carbon dioxide, indicating that Algeria still depends on combustible and fossil fuel that release a lot of carbon in the atmosphere and it approves the neutrality hypothesis between REC and GDP. However, we found that the use of renewable energy in Algeria can decrease the level of carbon dioxide emissions, and this result indicates the importance to include this source of energy in Algeria and its importance to mitigate issues related to the environment. We also found that there is no evidence for Environment Kuznets Curves hypothesis, because the country still depends on sources that emit a high quantity of pollution.

Consequently, this study reveals that a rise in the Algerian economic and industrial production will reduce the emission of carbon dioxide for a short-term, while if the country diminishes its economic growth, it will positively affect the emission of carbon dioxide, so in this case Algeria needs some controlling strategies that should be applied to fight against environmental pollution which is produced by several institutions, firms, factories, and electricity power companies. Therefore, they should be forced by regulations to meet some portion of their energy needs from renewable sources, and to gradually increase its portion in the future.

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Appendices

Appendix "A": Univariate study

Table 6
Long memory test on per capita exogenous variables

Variables	"D" parameter of Robinson and Henry	"D" parameter of Geweke and Porter-Hudak	Method
FEC	0.34*	0.47*	ARFIMA
FEP	0.35*	0.526	ARFIMA/ARMA
GDP^2	0.00007*	0.00006*	ARFIMA
REP	0.29*	0.40*	ARFIMA

Source: Done on the Ox-Metrics 6.0

*, indicate that we can reject the null hypothesis of short memory process rather we accept the alternative hypothesis of a long memory process, because the coefficient of *"d"*∈ (0,0.5). We verified these tests with OLS estimation on Eviews 9, if the sign of "d" was significant or not. However, we found that per capita GDP^2 cannot be performed with ARFIMA method, but with ARMA method.

Table 7
ARCH/GARCH or FIARCH/FIGARCH test

Variables	Model	Fisher statistic	LR test ($N*R^2$)
FEC	ARFIMA (2,d,2)	0.01	0.01
FEP	ARFIMA (0,d,0)	0.44	0.44
GDP^2	ARMA (0,0)	0.003	0.003
REP	ARFIMA (3,d,2)	0.01	0.01

Source: Done on the EViews 9

*, demonstrate that we accept the alternative hypothesis of existence of ARCH effect, but in this case we accepted the null hypothesis, so there's no ARCH effect on exogenous variables and we shall estimate the realized volatility with this formula:

$$\sigma = \sqrt{\frac{1}{T}\sum_{i=1}^{T} (r_i - \bar{r})^2}$$

σ is the realized volatility of series and r_i is the rated or yield series.

Table 8
Unit root test of per capita GDP

Per capita GDP						
	Phillips-Perron		**Augmented Dickey-Fuller**			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-0.984	-3.952**	Model 3	-0.984	-3.953**	I(1)
Model 2	-1.193	-3.909**	Model 2	-1.193	-3.907***	I(1)
Model 1	0.355	-3.872***	Model 1	0.355	-3.872***	I(1)

Source: made on EViews 9.

Table 9
Unit root test of per capita REC

per capita REC						
	Phillips-Perron		**Augmented Dickey-Fuller**			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-3.803**	-11.480***	Model 3	-3.803**	-6.474***	I(1)
Model 2	-3.597**	-11.233***	Model 2	-3.597**	-6.655***	I(1)
Model 1	-1.120	-10.725***	Model 1	-1.362***	-6.837***	I(1)

Source: made on EViews 9.

Table 10
Unit root test of per capita CO^2

per capita CO_2						
	Phillips-Perron		**Augmented Dickey-Fuller**			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-5.021***	-3.297*	Model 3	-2.854	-3.609*	I(1)
Model 2	1.149	-3.118**	Model 2	…	-3.201**	I(1)
Model 1	2.262	-2.590**	Model 1	…	-2.641**	I(1)

Source: made on EViews 9.

Table 11
Unit root test of RVFEC

RVFEC						
	Phillips-Perron		**Augmented Dickey-Fuller**			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-1.456	…	Model 3	-1.559	…	I(0)
Model 2	-2.031	…	Model 2	-2.014	…	I(0)
Model 1	-2.298**	…	Model 1	-2.755***	…	I(0)

Source: made on EViews 9.

Table 12
Unit root test of RVFEP

RVFEP						
Phillips-Perron			Augmented Dickey-Fuller			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-2.508	…	Model 3	-2.600	…	I(0)
Model 2	-2.748*	…	Model 2	-2.812*	…	I(0)
Model 1	-2.847***	…	Model 1	-2.882***	…	I(0)

Source: made on EViews 9.

Table 13
Unit root test of RVREP

RVREP						
Phillips-Perron			Augmented Dickey-Fuller			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-3.560*	…	Model 3	-3.697**	…	I(0)
Model 2	-3.645**	…	Model 2	-3.712**	…	I(0)
Model 1	-3.750***	…	Model 1	-3.810***	…	I(0)

Source: made on EViews 9.

Table 14
Unit root test of $RVGDP^2$

$RVGDP^2$						
Phillips-Perron			Augmented Dickey-Fuller			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-4.640***	…	Model 3	-4.628***	…	I(0)
Model 2	-4.588***	…	Model 2	-4.587***	…	I(0)
Model 1	-4.706***	…	Model 1	-4.706***	…	I(0)

Source: made on EViews 9.

(***), (**), (*) Show that the null hypothesis would be rejected respectively at 1%, 5% or 10%, so there's no existence of unit root. However, the variables of HDI and CO_2 have an insignificant trend, so we made the stationary series with differency stationary. But, the RVEU had a significant trend, so we avoided this deterministic trend and created RVEU without trend.

Table 15
The selection lag criterion

Lag	AIC	SC	HQ
0	-50.913	-49.869	-50.736
1	-55.018	-53.527	-54.765
2	-56.456	-54.517	-56.128
3	-62.232*	-59.846*	-61.829*

Source: made on EViews 9
*, indicate the optimal lag for the VAR model.

Table 16
Johansen cointegration test

1st model specification			
Unrestricted cointegration rank test (Trace)			
Eigenvalue	**λtrace statistic**	**5% critical value**	**Probability**
0.845	46.285*	24.275	0
0.433	10.825	12.320	0.087
0.001	0.023	4.129	0.900
Unrestricted cointegration rank test (Maximum Eigenvalue)			
Eigenvalue	**Max-Eigen statistic**	**5% critical value**	**Probability**
0.845	35.459*	17.797	0
0.433	10.802	11.224	0.059
0.001	0.023	4.129	0.900
2nd model specification			
Unrestricted cointegration rank test (Trace)			
Eigenvalue	**λtrace statistic**	**5% critical value**	**Probability**
0.996	142.769*	35.192	0
0.822	34.618*	20.261	0
0.088	1.755	9.164	0.825
Unrestricted cointegration rank test (Maximum Eigenvalue)			
Eigenvalue	**Max-Eigen statistic**	**5% critical value**	**Probability**
0.996	108.150*	22.299	0
0.822	32.862*	15.892	0
0.088	1.755	9.164	0.825
3rd model specification			
Unrestricted cointegration rank test (Trace)			
Eigenvalue	**λtrace statistic**	**5% critical value**	**Probability**
0.995	135.398*	29.797	0
0.822	33.554*	15.494	0
0.038	0.751	3.841	0.386
Unrestricted cointegration rank test (Maximum Eigenvalue)			
Eigenvalue	**Max-Eigen statistic**	**5% critical value**	**Probability**
0.995	101.843*	21.131	0
0.822	32.803*	14.264	0
0.038	0.751	3.84	0.386

Source: made on EViews 9.
*, indicate that we can't reject the alternative hypothesis.

Table 17
The VECM optimal

VECM Models	Akaike criterion	Schwarz criterion
1st model	-55.216	-55.128
2nd model	-61.930	-59.444
3rd model	-61.877	-59.342

Source: made on EViews 9.

Table 18
The VECM restricted

Cointegration restriction	Chi-square (2)	Probability
A(1,1)=0	$1.89*10^{-8}$	1
A(1,2)=0	$1.70*10^{-8}$	1
A(2,1)=0	$3.58*10^{-8}$	1
A(2,2)=0	$3.55*10^{-8}$	1
A(3,1)=0	$3.49*10^{-8}$	1
A(3,2)=0	12.095	0.007
A(1,1)=0, A(1,2)=0	17.144	0.008
A(1,1)=0, A(2,1)=0	15.392	0.001
A(1,1)=0, A(2,2)=0	$3.75*10^{-8}$	1
A(1,1)=0, A(3,1)=0	0.177	0.981
A(1,2)=0, A(2,1)=0	$1.64*10^{-6}$	1
A(1,2)=0, A(2,2)=0	15.392	0.001
A(1,2)=0, A(3,1)=0	0.037	0.998
A(2,1)=0, A(2,2)=0	32.264	0
A(2,1)=0, A(3,1)=0	11.459	0.021
A(2,2)=0, A(3,1)=0	$3.88*10^{-8}$	1
A(1,1)=0, A(1,2)=0, A(2,1)=0	17.144	0.016
A(1,1)=0, A(2,2)=0, A(3,1)=0	0.177	0.996
A(1,2)=0, A(2,1)=0, A(2,2)=0	32.264	0

Source: Done on EViews 9.

Table 19
VECM estimation

Cointegrating equation	C.E. 1	C.E. 2	
GDP_{t-1}	1	0	
CO_{2t-1}	0	1	
REC_{t-1}	$-4.22*10^{12}$***	-931.420***	
t-statistic	-5.938	-5.728	
C	2452.788**	$-1.29*10^{-6}$***	
t-statistic	2.466	-5.684	
Error correction	**$DGDP_t$**	**$DCO2_t$**	**$DREC_t$**
C.E. 1	0.007	$-5.83*10^{-11}$***	$-2.03*10^{-13}$
t-statistic	0.034	-4.736	-0.358
C.E. 2	$-6.37*10^{8}$	0.265***	0.002
t-statistic	-0.605	4.618	0.788
$DGDP_{t-1}$	-1.392***	$1.99*10^{-10}$***	$3.95*10^{-13}$
t-statistic	-3.702	9.674	0.418
$DGDP_{t-2}$	-0.756**	$4.05*10^{-11}$**	$-7.62*10^{-14}$
t-statistic	-2.629	2.582	-0.105
DCO_{2t-1}	$5.27*10^{9}$***	0.150	0.0001
t-statistic	3.010	1.579	0.036
DCO_{2t-2}	$-1.52*10^{9}$	0.258***	-0.0005
t-statistic	-1.133	3.534	-0.167

$DREC_{t-1}$	$-2.62*10^{10}$*	-5.321	0.140
t-statistic	-1.745	-0.650	0.373
$DREC_{t-2}$	$-1.63*10^{11}$	-18.500***	-0.018
t-statistic	-1.448	-3.004	-0.065
$RVFEP_t$	-305048.683**	$3.35*10^{-5}$***	$-2.003*10^{-7}$
t-statistic	-2.510	5.053	-0.657
$RVFEC_t$	754209.079***	$4.40*10^{-5}$***	$2.71*10^{-7}$
t-statistic	5.018	5.367	0.720
$RVREP_t$	10665.55	$3.46*10^{-7}$	$3.15*10^{-8}$
t-statistic	0.950	0.565	1.118
$RVGDP^2_t$	0.399	$-1.94*10^{-11}$	$6.77*10^{-13}$
t-statistic	1.683	-1.495	1.139
$Kyoto_t$	391.348	$-3.11*10^{-8}$	$1.93*10^{-9}$**
t-statistic	1.126	-1.639	2.215
$Paris_t$	-1249.706***	$3.63*10^{-8}$	$-1.65*10^{-9}$
t-statistic	-3.066	1.630	-1.610

Source: Done on EViews 9.

Table 20
VECM (r) estimation

Cointegrating equation	**C.E. 1**	**C.E. 2**	
GDP_{t-1}	0.003	-0.001	
CO_{2t-1}	-16830620.898	11069512.034	
REC_{t-1}	32970740.193	$-5.75*10^{9}$	
C	30.835	-16.952	
Error correction	**$DGDP_t$**	**$DCO2_t$**	**$DREC_t$**
C.E. 1	-26.271	$-1.58*10^{-8}$***	N/A
t-statistic	-0.487	-15.321	N/A
C.E. 2	-97.467***	N/A	$1.88*10^{-10}$***
t-statistic	-3.927	N/A	6.976
$DGDP_{t-1}$	-1.392***	$1.99*10^{-10}$***	$3.95*10^{-13}$
t-statistic	-3.702	9.674	0.418
$DGDP_{t-2}$	-0.756**	$4.05*10^{-11}$**	$-7.62*10^{-14}$
t-statistic	-2.629	2.582	-0.105
DCO_{2t-1}	$5.27*10^{9}$***	0.150	0.0001
t-statistic	3.010	1.579	0.036
DCO_{2t-2}	$-1.52*10^{9}$	0.258***	-0.0005
t-statistic	-1.133	3.534	-0.167
$DREC_{t-1}$	$-2.62*10^{10}$*	-5.321	0.140
t-statistic	-1.745	-0.650	0.373
$DREC_{t-2}$	$-1.63*10^{11}$	-18.500***	-0.018
t-statistic	-1.448	-3.004	-0.065
$RVFEP_t$	-305048.683**	$3.35*10^{-5}$***	$-2.003*10^{-7}$
t-statistic	-2.510	5.053	-0.657
$RVFEC_t$	754209.079***	$4.40*10^{-5}$***	$2.71*10^{-7}$
t-statistic	5.018	5.367	0.720

$RVREP_t$	10665.55	$3.46*10^{-7}$	$3.15*10^{-8}$
t-statistic	0.950	0.565	1.118
$RVGDP^2_t$	0.399	$-1.94*10^{-11}$	$6.77*10^{-13}$
t-statistic	1.683	-1.495	1.139
$Kyoto_t$	391.348	$-3.11*10^{-8}$	$1.93*10^{-9}$**
t-statistic	1.126	-1.639	2.215
$Paris_t$	-1249.706***	$3.63*10^{-8}$	$-1.65*10^{-9}$
t-statistic	-3.066	1.630	-1.610

Source: Done on EViews 9.
*,**,***, indicate that we can't reject the alternative hypothesis and the coefficients are significant at 10%, 5% or 1%.

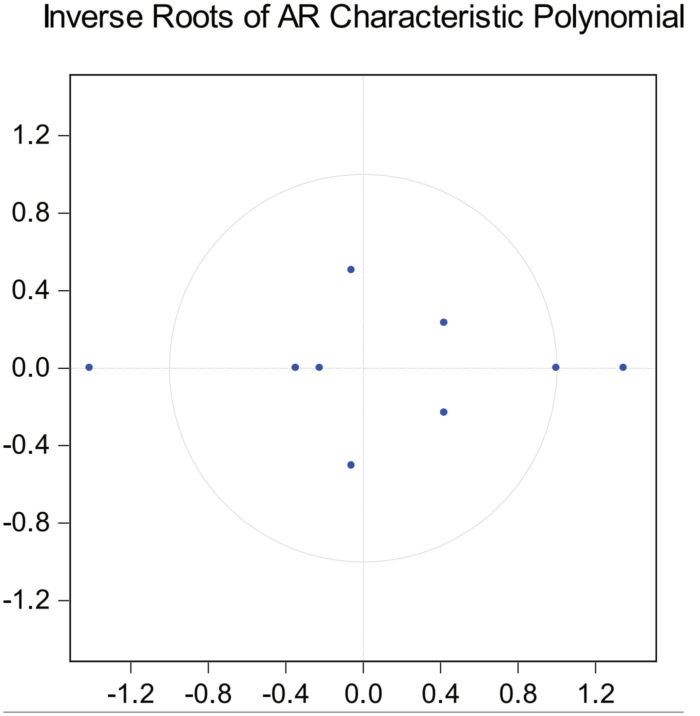

Figure 1. Autoregressive root graph

Source: done on EViews 9

Table 21:
Multivariate normality tests

Component	Jarque-Bera	Prob
1	6.467	0.039
2	0.689	0.708
3	2.660	0.264
Joint	9.817	0.132

Source: Done on EViews 9

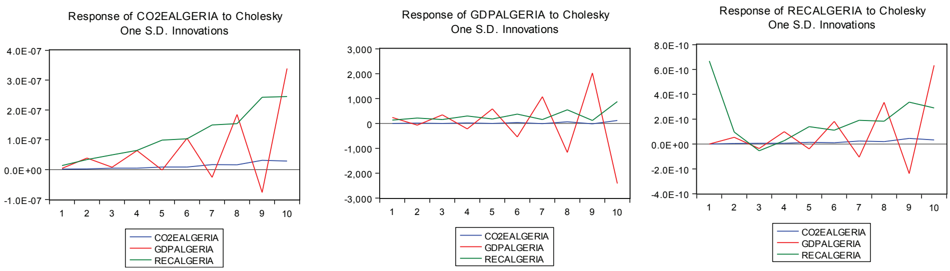

Figure 02. Impulse response with Cholesky decomposition

Source: Done on EViews 9.

Table 22
Impulse response to Cholesky of (CO_2)

Period	CO_2	GDP	REC
1	$1.72*10^{-9}$	$4.11*10^{-9}$	$1.39*10^{-8}$
2	$2.44*10^{-9}$	$3.86*10^{-8}$	$3.38*10^{-8}$
3	$4.74*10^{-9}$	$7.91*10^{-9}$	$4.96*10^{-8}$
4	$4.85*10^{-9}$	$6.36*10^{-8}$	$6.45*10^{-8}$
5	$9.02*10^{-9}$	$-1.04*10^{-9}$	$9.88*10^{-8}$

Source: Done on EViews 9

Table 23
Impulse response to Cholesky of (GDP)

Period	CO_2	GDP	REC
1	0	233.657	128.77
2	7.979	-70.809	214.073
3	-2.313	342.884	156.467
4	16.124	-225.012	297.622
5	-4.793	585.216	179.345

Source: Done on EViews 9

Table 24
Impulse response to Cholesky of (REC)

Period	CO_2	GDP	REC
1	0	0	$6.69*10^{-10}$
2	$3.86*10^{-12}$	$5.41*10^{-11}$	$9.68*10^{-11}$
3	$5.99*10^{-12}$	$-3.70*10^{-11}$	$-5.42*10^{-11}$
4	$5.35*10^{-12}$	$9.84*10^{-11}$	$2.71*10^{-11}$
5	$1.31*10^{-11}$	$-3.90*10^{-11}$	$1.40*10^{-10}$

Source: Done on EViews 9

Table 25
Variance decomposition (CO2)

Period	**GDP**	**CO_2**	**REC**
1	7.965	1.400	90.635
2	52.872	0.313	46.815
3	29.069	0.581	70.35
4	41.154	0.403	58.443
5	23.911	0.58	75.509

Source: Done on EViews 9

Table 26
Variance decomposition (GDP)

Period	**GDP**	**CO_2**	**REC**
1	76.703	0	23.297
2	48.827	0.052	51.121
3	67.078	0.026	32.896
4	56.443	0.082	43.475
5	73.276	0.045	26.679

Source: Done on EViews 9

Table 27
Variance decomposition (REC)

Period	**GDP**	**CO_2**	**REC**
1	0	0	100
2	0.638	0.004	99.358
3	0.927	0.011	99.062
4	2.948	0.017	97.035
5	3.129	0.051	96.820

Source: Done on EViews 9