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Renewable Energy, Pollutant Emissions and Economic Growth: Evidence from Tunisia

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Abstract: **In this study a cointegration analysis and vector error correction model are employed in order to study the relationship among Gross Domestic Product (GDP), Renewable Energy Consumption (REC), Carbon Dioxide Emissions (CO_2) and Energy Price (EP) in Tunisia during 1970 - 2009. The Granger causality test based on Error Correction Model (ECM) indicates the existence of a long-run cointegration between REC and the economic growth. Moreover the existence of a short-run unidirectional causality from REC to GDP. So the growth hypothesis is confirmed. The unidirectional causality from REC to GDP implies that increases in renewable energy consumption caused economic growth and energy which is an essential factor in production process. Hence, the economy dependents on renewable energy use. However, the causality isn't bidirectional, the fact that prove that Tunisian economy doesn't greatly depend on this form of energy.**

Keywords: **Renewable Energy Consumption, CO_2 emissions, Energy Price, Economic Growth, Error Correction Vector.**

I. INTRODUCTION

The successive oil shocks observed since the 1970s have shown the economic risks and geopolitical production of energy which was based on the exploitation of fossil resources. But, reserves of fossil combustibles are exhaustible and poorly distributed. The question about the energy security today occupies the forefront of political energy concerns. Thus, the rise of energy prices is explained by the decline of fossil fuels supply (oil, gas and coal) and the increase of their production costs. Meanwhile, the oil and gas reserves will come to an end. Also, Uranium, the fuel used by the nuclear industry, is also a limited resource. On the contrary, the accessible renewable energy reserves in the world are large and enough in order to provide a greater energy quantity. The Rise of oil prices should encourage households and businesses to reduce fossil fuels consumption, to purchase more efficient products and to switch to renewable energy sources.

Climate changes, Air pollution, global warming, nuclear risks and the limited resources made us aware that sustainable economic development is needed. Tunisia gave a great importance to the implementation of a comprehensive policy in terms of sustainable development and "green energies" that considers the economic development and the environment protection as additional factors in the development process of the country. The solution to the Tunisian future energy needs is based on the development of renewable energy in order to produce heat and electricity.

II. SITUATION of RENEWABLE ENERGIES in TUNISIA

A. Renewable Energies Consumption

Renewable energies consumption has grown slowly during the 70s and 80s. From the 1990, the REC has grown gradually. It has been assessed at almost 1300 (Metric Tons eq Oil) in 2009 compared to 600 (MT eq Oil) in 1990, by an annual average increase of 9% from 1990 to 2009 (Fig. 1). Recently, Tunisia has significantly accelerated its policies for the promotion of renewable energy. By this way, it provides comprehensive and sustainable solutions to environmental and to fossil fuels conservation problems challenges.

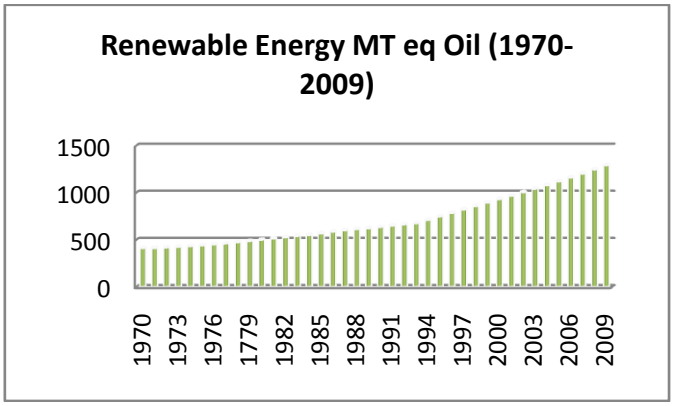

Fig.1: Renewable Energy Consumption in Tunisia (1970-2009)
Source: Author

B. Solar Energy

1) Solar Water Heating

Solar Water Heating (CES) is one of the most widespread uses in Tunisia. CES technology is now technically and commercially mature, therefore is ideal solution for the Tunisian consumer. These are primarily used by households in the residential sector. They allow savings in terms of 70% of the energy expenditure for the water heating.

We observed some growth was followed by a sharp decline. This may originate from a variety of reasons, including the important energy technology costs. The CES market was relaunched between 1997 and 2001, with the establishment of the subsidies granting to cover the additional costs funded by the Global Environment Facility: the GEF project (see fig. 2). The offer experienced the fastest growth rates, passing from 22000 m^2 installed in 2005 to 150000 m^2 in 2011.

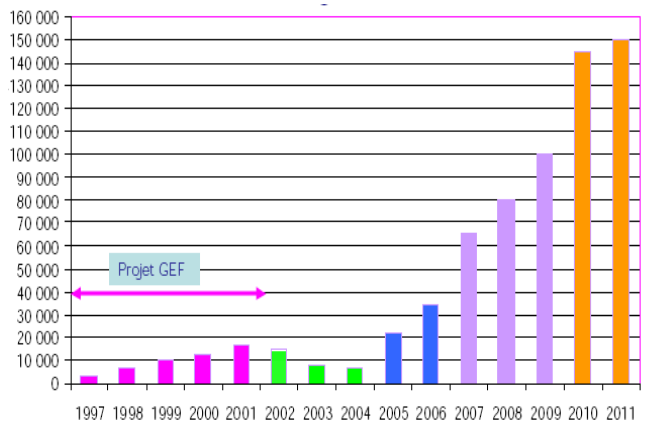

Fig. 2: Evolution of Solar Water Heating (m^2 installed)

Source : National Agency of Energy Conservation (2011)

The cumulative Offer of CES has evolved rapidly over the recent period. For instance, in 2010, it reaches 489551 m^2 installed compared to 73473 m^2 in 2000 and only 30745 m^2 installed in 1990 (National Agency of Energy Conservation **2011**). This evolution is due to subsidies to cover additional costs of CES and to privileges granted by the Government and the financial institutions.

2) PV Solar Energy

Electrified households amounted to 13162 in 2010 in comparison to 7657 in 2000 and only 200 households were electrified at the beginning of the 1990s (see Fig. 3). The PV solar is exploited in other uses such as the public lighting, pumping and the water desalination.

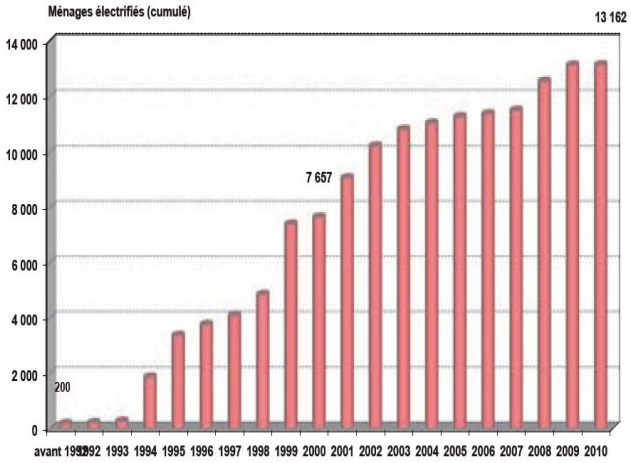

Fig. 3: Electrified households

Source: National Agency of Energy Conservation (2011)

III. LITERATURE REVIEW

Few studies have investigated the relationship between the economic growth and the RE consumption. For example the study of [1], who found that the positive effect of the installation of the RE on the Germany economy is accompanied by the negative effect of the increase of renewable energy production cost in the labour market. It was expected that 33000 new posts will be created in 2004, but due to the increase of production cost, the employment balance was slightly negative (6000 jobs) during 2004-2010 period. On the other hand, [2] provide that the impact of the RE integration had a positive impact on the employment in Germany; the number of jobs will reach 400,000 jobs by 2030 in the renewable energy industry. Moreover, in their study, [3] showed that during the construction phase, the profit generated from wind projects will be between $ 4.3-7 million annually in the following regions (Navago, Coconino, Arizona).

The relationship between the RE consumption and the economic growth was also discussed by **[**4**].** They concluded that the introduction of the RE in the production process will generate GDP growth in the European Union between 0.11 - 0.14% by 2020 and between 0.15 - 0.3% by 2030. In addition, [5] and [6], showed that in the G7 countries, the growth of the RE part relatively to the total energy quantity consumed significantly improves the technological efficiency (Canada, France, Germany, United Kingdom, Italy, Japan, USA). Reference [7] concluded that, in long term, a GDP growth causes an increase in RE consumption, 1% GDP growth generated RE consumption increase by 8.44%.

Later, researchers begin to examine the causal relationship between energy consumption - carbon emissions – economic growth in tri-variate framework, using the last techniques of time-series. Reference [8] examined the long-term relationship between these variables in the United States.

They demonstrate the existence of unidirectional causality from carbon emission to energy consumption in Turkey, the energy production (electricity), the mining sector (the source of 30% of gas emission) and manufacturer sector represent a main source of gas emission in Turkey. The relationship between GDP and the pollution level has been discussed also by [9], they claimed that CO_2 emissions and GDP are joined negatively in the low- income but joined positively in the high-income. In addition, the empiric results of [10] and [11] affirmed that the gas emissions are positively related to the income level.

IV. METHODOLOGY, DATA and RESULTS

A. Methodology

The structure of causality test is done in four steps:

Step 1: The test of the null hypothesis of non-stationary variables versus the alternative hypothesis of stationary variables using the Augmented Dickey–Fuller (ADF) and Phillips and Perron (PP) statistics (Dickey and Fuller, 1981; Phillips and Perron, 1988). We employed the Akaike information criteria (AIC) to select the lag length from the ADF test. If we decide to reject null hypothesis of non-stationarity, variables are introduced in level; otherwise differentiated variables are introduced. In the first case (variables are I (0)), step 3a is the following. For the second case (the non-stationarity assumption is accepted), the cointegration test is the following (step 2).

Step 2: The test of cointegration between variables through using the technique of Johnsen. The hypothesis of cointegration is accepted if Trace and Max-eigen statistics indicate the existence of cointegration at 5% level (less than the critical values). If the hypothesis of cointegration is rejected, Step 3a is the following otherwise step 3b.

Step 3a: the causality test between variables, using Granger test.

Step 3b: the LT relationship between variables exists; variables must be related at least in one direction. Therefore through using the Hsiao method to determine the order of lags in the Error Correction Model (ECM). If the estimated coefficients of Error Correction Terms (ECT) are positive o insignificant, the approach of cointegration is discarded then causality re-estimated as shown in Stage 3a.

B. Data

Our study uses yearly data from 1970 to 2009. For modeling, all variables are expressed in natural logarithms. Gross Domestic Product (GDP_t) is measured in US dollars and Renewable Energy Consumption (REC_t) is measured in kilotons of oil equivalency Ktep. Carbon Dioxide Emissions (CO_2) is measured in kilotons Kt. All data are obtained from the World Bank, World Development Indicators (2011).

C. RESULTS and DISCUTION

1) Unit root test

We test the null hypothesis of non-stationary variables versus the alternative hypothesis of stationary. Table I reports unit root test for RE, GDP, EP and CO_2 series. The unit root test indicates that GDP, RE, EP series are stationary while CO_2 at level contains a unit root (Table I).

TABLE I
UNIT ROOT TEST (AUGMENTED DICKEY-FULLER TEST STATISTICS)

Variables	Trend and constant(i)		Constant (ii)		without trend and constant
	t-stat(t)	ADF	t-stat(c)	ADF	ADF
RE	3.11	-4.23 (0.009)	2.63	-2.61 (0.098)	0.33 (0.776)
DRE(-1)	0.48	-7.89 (0.000)	0.43	-7.98 (0.000)	-8.06 (0.000)
GDP	3.01	-3.79 (0.027)	3.60	-3.29 (0.022)	4.06 (1.000)
DGDP(-1)	-2.77	-7.85 (0.000)	4.36	-6.75 (0.000)	-2.78 (0.006)
EP	3.01	-3.79 (0.027)	3.54	-3.29 (0.022)	5.98 (1.000)
DEP(-1)	-1.59	-4.35 (0.007)	2.62	-3.96 (0.004)	-2.78 (0.067)
CO_2	1.49	-2.43 (0.356)	2.86	-2.39 (0.150)	2.51 (0.996)
DCO_2(-1)	-1.39	-3.85 (0.024)	1.73	-3.63 (0.009)	-3.14 (0.002)

Notes: Critical values (i) 53, 2.79 et 2.38 (ii): 3.22, 2.54 et 2.17 respectively at the 1% 5% et 10% significance level, values between (..) represent error risk to reject H_0

For RE, the unit root test indicates no evidence of the presence of a unit root. The statistic t-stat=3.11 associated to the linear tendency is superior to the critical values at 5% significance level (A.1), therefore the hypothesis of the linear tendency presence is accepted. The ADF statistic = -4.23 less than critical values (A.2), H_0 of no stationarity is rejected therefore REC is stationary at level.

The unit root test indicates that GDP serie is stationary. The statistic t-stat=3.01 associated to the linear tendency is superior to the critical values at 5% significance level , therefore the hypothesis of the linear tendency presence is accepted. The ADF statistic = -3.79 less than critical values, H_0 of no stationarity is rejected therefore GDP is stationary at level.

For EP serie, the unit root test shows that EP is stationary at level. t-stat=3.01 associated to the linear tendency is superior to the critical values at 5% significance level , therefore the hypothesis of the linear tendency presence is accepted. The ADF statistic = -3.79 less than critical values,

H_0 of no stationarity is rejected therefore EP is stationary at level.

For CO_2 variable, The ADF test indicates the presence of a unit root. The statistic t-stat=1.49 associated to the linear tendency is less than critical values at 5% significance level, therefore the hypothesis of the linear tendency presence is rejected. We will examine in the second step a model with intercept, the statistic t-stat= 2.86 associated to the intercept is superior than the critical values at 5% significance level, therefore the hypothesis of intercept presence is accepted. We will examine in the following step a model without intercept and trend. The ADF statistic = 2.51 (p = 0.99), H_0 of no stationarity is accepted therefore CO_2 is no stationary at level.

The ADF test shows that ER, PE and GDP series are stationary but CO_2 is not stationary while all first differences of series are stationary. The hypothesis of stationarity of series at level isn't verified therefore the cointegration test is the following.

2) Cointegration test

We test the null hypothesis of no cointegration between variables versus the alternative hypothesis of presence of cointegration . In the model including trend, both tests indicate the absence of cointegration at the 5% significance level and a single cointegration vector at the 10% significance level. In the model without trend, trace statistics (trace stat.) shows a single cointregration vector at the 5% level while the Max eign stat. indicates the absence of cointegration (table II).

TABLE II
COINTEGRATION TEST, LAG=1

	Trend			Without trend		
H_0 : absence Of cointégration	Trace Stat.	CV (5%)	P-val.	Trace Stat.	CV (5%)	P-val.
r=0	38.85	47.85	0.26	40.74	40.17	0.04**
r≤ 1	18.97	29.79	0.49	21.18	24.27	0.11
r≤ 2	7.11	15.49	0.56	5.54	12.32	0.49
r≤ 3	2.90	3.84	0.08*	1.003	4.12	0.36
H_0 : absence Of cointégration	Max eign Stat.	CV (5%)	P-val.	Max eign Stat.	CV (5%)	P-val.
r=0	19.87	27.58	0.34	19.56	24.15	0.18
r≤ 1	11.86	21.13	0.56	15.64	17.79	0.10
r≤ 2	4.20	14.26	0.83	4.53	11.22	0.54
r≤ 3	2.90	3.84	0.08*	1.03	4.12	0.36

*, ** and *** indicate significance at 1%, 5% and 10% level respectively.
CV represents critical value at the 5% significance level.

In the presence of trend (lag = 2), both tests indicate a single cointegratin vector at the 5% significance level. In the case without trend, the trace test indicates three cointegration vectors while the eigen value test indicates two cointegration vector at the 5% significance level (table III).

TABLE III
COINTEGRATION TEST, LAG=2

	Trend			Without trend		
H_0 : absence Of cointégration	Trace Stat.	CV	P-val.	Trace Stat.	CV	P-val.
r=0	53.53	47.85	0.013**	62.65	40.17	0.0009**
r≤ 1	24.96	29.79	0.162	27.02	24.27	0.022**
r≤ 2	11.43	15.49	0.185	12.87	12.32	0.040**
r≤ 3	1.98	3.84	0.159	1.38	4.12	0.279
H_0 : absence Of cointégration	Max eign stat .	CV	P-val.	Max eign Stat.	CV	P-val.
r=0	28.56	27.58	0.037**	35.63	24.15	0.009**
r≤ 1	13.53	21.13	0.404	14.14	17.79	0.162
r≤ 2	9.45	14.26	0.250	11.48	11.22	0.044**
r≤ 3	1.98	3.84	0.159	1.38	4.12	0.279

*, ** and *** indicate significance at 1%, 5% and 10% level respectively.
CV represents critical value at the 5% significance level

3) Vector Error Correction Model

In the case of VECM with trend and constant, in equation of RE and GDP, the ECT is negative and significant at the 5% significance level which explains the existence of a long-term relationship between the two variables (GDP; RE) and the other explanatory variables (table IV). In the GDP equation, in short term, the variable GDP depends on lagged RE (RE_{t-1}, RE_{t-2}) with positive coefficients and statistically significant at the 1% significance level.

TABLE IV
VECTOR ERROR CORRECTION MODEL (TREND and CONSTANT)

Dep. Var.	Indep. Variables								
	Short term								Long term
	GDP_{t-1}	GDP_{t-2}	RE_{t-1}	RE_{t-2}	CO_{2t-1}	CO_{2t-2}	EP_{t-1}	EP_{t-2}	ECT
DGDP	-0.21	0.07	0.06***	0.04 **	0.04	-0.12	0.11	-0.08	-0.06***
	[-1.28]	[0.42]	[2.80]	[2.24]	[0.41]	[-1.09]	[1.00]	[-0.66]	[-2.72]
DRE	2.39	1.99	-0.04	-0.11	-1.81*	0.36	1.41	0.37 *	-0.47**
	[1.46]	[1.18]	[-0.19]	[-0.59]	[-1.75]	[0.33]	[1.31]	[1.89]	[-1.96]
DCO_2	0.02	0.28	-0.03	-0.23	0.19	-0.02	0.20	0.35	0.06
	[0.07]	[0.72]	[-0.02]	[-0.51]	[0.80]	[-0.08]	[0.83]	[1.26]	[1.18]
DEP	0.28	-0.21	-0.03	-0.06 *	-0.03	0.02	0.37*	-0.06	0.05
	[0.96]	[-0.69]	[-0.77]	[-1.71]	[-0.16]	[0.11]	[1.89]	[-0.30]	[1.27]

*, ** and *** indicate significance at 1%, 5% and 10% level respectively

The effect of GDP on CO_2 emissions is insignificant; imply that the pollutant emissions are not influenced by the level of economic growth. Namely the Tunisian economy doesn't still

reach the optimum income which encourages the improvement of environmental quality.

V. CONCLUSION

The first objective of this study was to evaluate the situation of renewable energy in Tunisia and to explore the causal relationship among the economic growth, renewable energy consumption, CO_2 emissions and total energy price during 1970-2009 period. The study showed, from the causality test in the context of the error correction model, the existence of a long-term relationship between the renewable energy consumption (REC) and the economic growth. Moreover, the evidence of a unidirectional causality running from REC to GDP in short term which implies that the introduction of the ER in the production process will generate economic growth. Indeed, the consumption of the RE offers a greater energy security to consumers while respecting the environment, realizing sustainable economic growth and reducing dependence via the exporting countries.

APPENDIX

A.1: Critical values for 1%, 5% and 10% levels, tests de Dickey-Fuller

	intercept			intercept			Trend		
T	1%	5%	10%	1%	5%	10%	1%	5%	10%
100	3.22	2.54	2.17	3.78	3.11	2.73	3.53	2.79	2.38
250	3.19	2.53	2.16	3.74	3.09	2.73	3.49	2.79	2.38
500	3.18	2.52	2.16	3.72	3.08	2.72	3.48	2.78	2.38
∞	3.18	2.52	2.16	3.71	3.08	2.72	3.46	2.78	2.38

A.2: Augmented Dickey-Fuller test statistic

Critical Values	intercept intercept+trend	
Seuil 1%	-3.610	-4.211
Seuil 5%	-2.938	-3.529
Seuil 10%	-2.607	-3.196

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