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Energy consumption, Economic Growth, Deterioration of Environmental Quality

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Abstract: **The main goal of this paper is to study the relation among Gross Domestic Product (GDP), Energy Consumption (EC) and Carbon Dioxide Emissions (CO_2) in Tunisia during the 1970 – 2009 period. For this purpose, we apply the variance decomposition analysis to evaluate how important is the causal impact of energy consumption on economic growth relatively to greenhouse gases emissions impact. The results of our Granger causality analysis give the evidence of causality running from energy consumption to an economic growth. However, the causality isn't bidirectional; subsequently this approved that Tunisian economy doesn't greatly depend on the energy. The findings also show that energy consumption explains the Carbon dioxide emissions; The EC represents the main origin of pollutant emissions. The use of energy is judged as inefficient because environmental pressures go with economic growth. In addition, the results of the orthogonalized impulse response results show that the pollutant emissions are influenced by the economic level of country.**

Keywords: Energy Consumption, Economic Growth, Carbon Dioxide Emissions, Causality, Generalized Variance Decomposition.

I.INTRODUCTION

Tunisia, as a developing country, has no commitment to reduce pollutant emissions vis a vis the Kyoto Protocol. However, studies have shown that the level of CO_2 emissions per capita has evolved over time. Later, Tunisia gave increasing importance to the implementation of an energy policy in sustainable development that considers the economic and social development and the protection of the environment as additional factors in the development process of the country. Tunisia signed the United Nations Convention on climate change in 1992 and ratified it in July 1993. In addition, Tunisia acceded to the Kyoto Protocol in June 2002.

The increasing attention given to global energy issues and the international policies needed to reduce the pollutant emissions level have given a renewed stimulus to research interest in the linkages between the energy sector and economic performance. Recently, this question has faced a renewed interest given the increasing debate about the world climate changes .The key objective of this paper is to estimate the Energy consumption and the pollutant emissions elasticities to income level in Tunisia.

This study is organized as follows; section two presented a brief literature review related to this topic. Section 3 illustrated the distinctive characteristics of the Tunisian energy sector. Section 4 presented the data used and the methodology adopted in this study. Section 5 reported the empirical results and discussion. Finally,Conclusions and perspectives.

II. LITERATURE REVIEW

Mc Connell (1997) used among others elasticity functions to study the interaction between income and environmental quality. He examined the role of the elasticity demand-income to interpret this in Environmental Kuznets Curve (EKC) models. He concluded that the pollution is positively related to energy consumption.

Later, researchers begin to examine the causal relationship among energy consumption - pollutant emissions – economic growth in tri-variate framework, using the last techniques of time-series. Reference [1] examined the long-term relationship between these variables in Turkey. 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 [2], they claimed that CO_2 emissions and GDP are joined negatively in the low-income economy but joined positively in the high-income economy. In addition, the empiric results of **[3]** and [4] affirmed that the gas emissions are positively related to the income level. Reference [5] studied the dynamic relation between the economic development, gas emission and the energy consumption in Malaysia, using a multivariate model; they found a bi-directional causality in LT between economic growth and energy consumption and uni-directional causality from CO_2 emissions to economic growth. It implies that the Malaysian economy depends on energy as an important factor of economic growth.

III. ENERGY SECTOR in TUNISIA

A. Energy, Economic Growth

Fig. 1 represents the evolution of Gross Domestic Production and the primary energy consumption in Tunisia during the period ranging from 1970 to 2010. We can observe a significant positive association between these two variables that show the importance of energy in production process, it"s important to incorporate energy as a contributing factor to output growth in addition to capital and labor. The positive relationship between these two variables has a tendency to decrease since the last decade; this situation explained by the decrease of the energy production in Tunisia and the decreasing role of energy in production process.

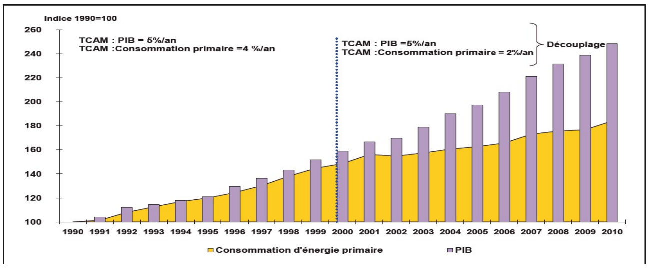

Fig.1: GDP Evolution and Primary Energy Consumption
Primary Energy Consumption GDP
TCAM: Average annual growth rate

B. Carbon emissions

Fig. 2 shows that the greenhouse gas emissions produced by the energy sector increased from 15415 Kté in 1990 to 28000 Kté in 2009 with annual growth more than 6%. The CO_2 emissions from energy sector represent 91.3% of total CO_2 emissions in 2003 and evolve with the same tendency during following period.

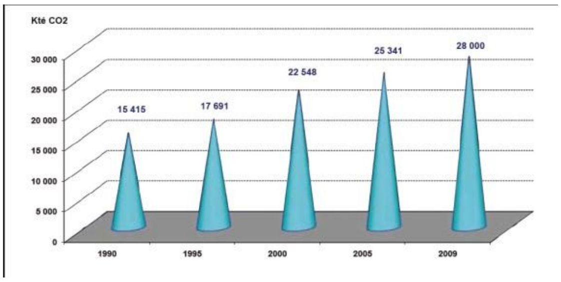

Fig.2: CO_2 emissions from energy sector

Source: National Agency of Energy Conservation (2011)

The transport sector represents the main source of these emissions (4.8 MMT in 2008 relatively to 1.75 MMT in 1980). Carbon emissions per capita increased from 1.89 téCO_2/capita to 2.86 téCO2 during the 1990-2009 period (National Agency of Energy Conservation (2011)).

IV. DATA and METHODOLOGY

A. Data

Our study uses annual data cover the period from 1970 to 2009. All variables used are in natural logarithms. For modeling the variables of interest are: Gross Domestic Product (GDP_t) is expressed in US dollars and Energy Consumption (EC_t) is expressed in kilotons of oil equivalency Ktep). Carbon Dioxide emissions (CO_2) is expressed in kilotons Kt. All data are obtained from the World Bank, World Development Indicators 2011.

B. Unit root tests

In order to have robust results, we conducted five different unit root tests, namely augmented Dickey–Fuller (ADF), Elliot–Rothenberg–Stock Dickey–Fuller GLS detrended (DF-GLS), Phillips–Perron (PP), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), and Ng–Perron MZα(NP). ADF and PP tests are often criticized due to their low power properties, but we included them in our analysis because most of the studies in the literature still use them. It is also well known that the unit root tests are also sensitive to different lag structures. In the literature, KPSS is sometimes used to verify the results of commonly used ADF and PP tests although it also suffers from the same low power problems [6].

Three models used in the Dickey-Fuller test are distinguished:

Model 1: model with intercept and trend

$$\Delta Y_t = \lambda + \delta t + \emptyset Y_{t-1} + \sum_{j=1}^{p} \emptyset_j \Delta Y_{t-j} + \varepsilon_t \quad (1)$$

Model 2: model with intercept

$$\Delta Y_t = \gamma + \emptyset Y_{t-1} + \sum_{j=1}^{p} \emptyset_j \Delta Y_{t-j} + \varepsilon_t \quad (2)$$

Model 3: model without intercept and trend

$$\Delta Y_t = \emptyset Y_{t-1} + \sum_{j=1}^{p} \emptyset_j \Delta Y_{t-j} + \varepsilon_t \quad (3)$$

Where p is the number of lags in the ADF regression and the error terms ε_t are assumed to be independently and normally distributed random variables for all t with zero means and finite variances ρ^2 . The null hypothesis is that each series contains a unit root ($\emptyset$ =1 for all t) whereas the alternative hypothesis is that at least one of the series is stationary ($\emptyset$ <1 for at least one t). The statistic test is normally distributed under H_0 and the critical values for given values of T are provided in [7]. We compare the student statistic to the ADF critical values. The null hypothesis is rejected if the calculated value is less than the critical values. The application of ADF test requires choosing the optimal number of lags to introduce.

We apply ADF test on one of the three models (model 1, 2 and 3). First, we test a model with intercept and trend (model 1).If trend is significant, then we apply the unit root test. If trend is not significant, the second stage is to test model with intercept (model 2). If intercept is significant we apply unit root test, if not we examine finally a model without trend and intercept (model 3).

C. Granger causality test

Granger causality test (**Granger, 1969**) is designed to detect causal direction between two time series. More precisely, Granger causality test detects a correlation between the current value of one variable and the past values of another variable. Based on Granger's definition of causality, **Sims (1980)** provided a variant. Consider a bivariate VAR model with two time series Y_t and X_t.

$$\Delta Y_t = \alpha_{12} + \sum_{i=1}^{T11}\beta_{11i}\,\Delta Y_{t-i} + \sum_{j=1}^{T12}\beta_{12j}\,\Delta X_{t-j} + v_{12t} \quad (4)$$
$$\Delta X_t = \alpha_{22} + \sum_{i=1}^{T21}\beta_{21i}\,\Delta X_{t-i} + \sum_{j=1}^{T22}\beta_{12j}\,\Delta Y_{t-j} + v_{22t} \quad (5)$$

Where Δ is the difference operator, T is the lag order, α and β are parameters for estimation, ν_t is an error term. To test whether the Granger causality runs from X to Y, the null (H_0) hypothesis is:

H_0. $\beta_{12j}=0$; j=1, 2… q

If H_0 is rejected, i.e. at least one of β_{12j} is not equal to zero.

D. Variance decomposition analysis

The Granger-causality test presented above indicates only the existence of causality between economic growth and three production factors. It does not provide any indication on how important is the causal impact that each production factor has on output growth see [8], [9], [10]. In order to assess how a shock to one variable affects another variable and how long the effect lasts, we use the forecast error variance decomposition and the impulse response functions (IRFs) used by [11] and [12].

E. The orthogonalized impulse responses

The impulse response functions are based on a moving average representation of the VAR model, and the dynamic responses of one variable to another are evaluated over horizons. The IRFs show the response of one variable to an orthogonal shock within another variable [13] and [14]. The generalized version gives an „optimal" measure of the amount of forecast error variance decomposition for each series (see [15] and [10]).

Representation of VAR (p) model is expressed as:

$$Y_t = A_0 + A_1Y_{t-1} + A_2Y_{t-2} + \cdots .. + A_PY_{1-p} + v_t \quad (6)$$

Representation of VMA (∞) as follows:

$$Y_t = \mu + v_t + M_1v_{t-1} + M_2v_{t-2} = \mu + \sum_{i=0}^{\infty} M_i v_{t-i} \quad (7)$$

Where $\mu = \mathrm{I} - A_1 - A_2 - \cdots - A_p$

Y_t are expressed in terms of the current and past values of the various types of shocks (v_t). The VMA representation (7) represents the reaction of the Y_t series in response to the various shocks (v_t).

V. EMPIRICAL RESULTS

A. Unit root tests

We test for unit roots in the natural logarithms of our variables. We test the null hypothesis of non-stationary variables versus the alternative hypothesis of stationary variables using the Augmented Dickey–Fuller (ADF) statistic. We employ the Akaike information criteria (AIC) to select the lag length from the ADF test. Following Tables report the results of unit root tests with and without a trend term.

For EC series, Unit root test indicates that Student statistic (t-stat=1.66) associated to the linear tendency is less than critical values mentioned in A.1, therefore the hypothesis of the linear tendency presence is rejected (Table I). We will examine in the second step a model with intercept. The student statistic (t-stat=4.4) associated to the intercept is superior to the critical values; therefore the hypothesis of intercept presence is accepted. The ADF statistic = -3.89 is less than critical values (A.2), H_0 of no stationary is rejected therefore EC is stationary at level.

TABLE I
STATIONARITY OF EC

Stat. Test / Variable	Trend and Constant		Constant	
	t-stat.	ADF	t-stat.	ADF
EC	1.6 (0.104)	-2.13 (0.508)	4.41 (0.0001)	-3.89 (0.004)

For GDP series, unit root test shows that GDP at level is stationary**.** The Student statistic (t-stat. = 3.019) associated to the linear trend is superior to the critical values, the hypothesis of linear trend presence is accepted (Table II). The ADF stat. = -3.79 is less than critical values, H_0 of no stationarity is rejected therefore GDP is stationary at level.

TABLE II
STATIONARITY OF GDP

Stat. Test / Variable	Trend and Constant		Constant	
	t-stat	ADF	t-stat	ADF
GDP	3.01 (0.004)	-3.79 (0.027)	3.54 (0.001)	-3.29 (0.022)

For CO_2 variable, ADF test indicates that t-stat=1.62 associated to the linear tendency is less than critical values (Table III), the hypothesis of the linear tendency presence is rejected.

TABLE III
STATIONARITY OF CO_2

Stat. Test / Variable	Trend and Constant		Constant	
	t-stat	ADF	t-stat	ADF
CO_2	1.62 (0.113)	-2.29 (0.425)	3.51 (0.001)	-3.19 (0.028)

In the next step, we will examine a model with intercept. The statistic t-stat = 3.51 associated to the intercept is superior to the critical values. Therefore the hypothesis of intercept presence is accepted. The ADF statistic = -3.19 is less than critical values, H_0 of no stationarity is rejected therefore CO_2 is stationary at level.

- All variables at level are stationary; the next step is Granger causality test.

B. Granger causality test

The Granger causality test (Table IV) reveals the existence of uni-directional causality running from energy consumption to economic growth. Still causality is not bidirectional. That approves that Tunisian economy is not greatly dependant on energy. Reducing energy consumption could lead to a fall in economic growth. Consequently, any energy conservation measures undertaken, don"t affect negatively economic growth. Causality test indicates also the existence of unidirectional causality from EC to CO_2 emissions, noticed that energy consumption is the main source of pollutant emissions. We can see the existence of unidirectional causality from GDP to CO_2 emissions; this explained that carbon emissions depend on economic level of countries.

TABLE IV
GRANGER CAUSALITY TEST

Null Hypothesis:	Obs	F-Stat	Prob.
EC does not Granger Cause GDP	38	3.34	0.04
GDP does not Granger Cause EC		0.51	0.60
CO_2 does not Granger Cause GDP	38	1.37	0.26
GDP does not Granger Cause CO_2		2.65	0.08
CO_2 does not Granger Cause EC	38	2.83	0.07
EC does not Granger Cause CO_2		3.38	0.04

C. Variance decomposition analysis

Results of the generalized variance decomposition analysis are presented in Tables (V, VI and VII). As we are more interested in the contribution of energy consumption to economic growth as compared to other factors, we only decompose the forecast-error variance of the income variable (GDP_t) in response to a one standard deviation innovation in energy consumption (EC_t) and Carbon dioxide emissions (CO_2).

TABLE V
VARIANCE DECOMPOSITION of EC

Period	S.E.	EC	GDP	CO_2
1	0.014	100.00	0.000	0.000
2	0.016	97.090	0.666	2.243
3	0.020	96.532	0.565	2.901
4	0.022	96.682	0.851	2.466
5	0.024	94.645	1.882	3.472
6	0.026	93.793	2.689	3.517
7	0.028	91.834	3.374	4.791
8	0.030	90.851	3.705	5.443
9	0.031	89.365	3.822	6.811
10	0.033	88.450	3.798	7.751

The result of the variance decomposition of EC within a ten period horizon indicates a least contribution of GDP to future change in energy consumption. The GDP accounts for just 3.79% of future changes in EC.

TABLE VI
VARIANCE DECOMPOSITION of GDP

Period	S.E.	EC	GDP	CO_2
1	0.030	26.852	73.147	0.000
2	0.045	24.995	74.070	0.934
3	0.056	30.151	68.859	0.989
4	0.062	33.365	65.326	1.308
5	0.066	36.911	59.817	3.271
6	0.069	39.214	55.884	4.901
7	0.072	41.038	51.824	7.137
8	0.074	42.285	48.993	8.720
9	0.076	43.343	46.378	10.277
10	0.077	44.225	44.436	11.338

The result of variance decomposition of GDP argues that the EC explains about 44.2% of variation in the GDP in tenth period. While there is a rather small impact of CO_2 on GDP about 11%.

Table VII
VARIANCE DECOMPOSITION of CO_2

Period	S.E.	EC	GDP	CO_2
1	0.019	29.981	2.171	67.847
2	0.023	44.500	1.933	53.566
3	0.025	45.879	1.610	52.510
4	0.028	51.780	2.942	45.276
5	0.029	53.779	4.973	41.246
6	0.032	56.676	7.266	36.056
7	0.033	58.405	8.780	32.813
8	0.035	60.193	9.603	30.202
9	0.036	61.531	9.883	28.585
10	0.037	62.624	9.786	27.588

The result of the variance decomposition of CO_2 shows that energy has the highest impact on future change in CO_2 emissions in Tunisia (62.6%). While GDP accounts for 7% of future changes in CO_2 emissions.

D. Orthogonalized impulse response function

Fig. 4 shows the IRFs with two standard error bands (two standard deviation confidence intervals) and a 10-year horizon. The error bands are obtained by using a Monte Carlo simulation procedure, and the years after the impulse shock are shown on the horizontal axis. The IRFs indicate that the GDP effect of total energy consumption shock is significant and positive and persists over the horizon. While, the response of energy consumption to GDP shock is insignificant during the three first years but it responds positively to GDP shock from the third year. We can also observe that the EC shock has a positive and significant impact on CO_2 emissions and lasts over the horizons.

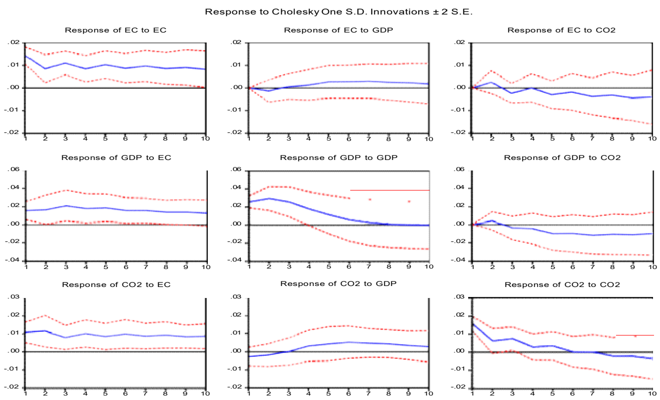

Fig. 4: Orthogonalized impulse response function GDP to EC and CO_2 from VAR model.
The thick solid lines show the mean impulse responses. The dotted lines are two-standard error bands. The horizon extends up to 10 years.

The GDP shock has a negative and significant impact on CO_2 emissions and enervates quickly (in 3 years). While, the response of GDP to CO_2 shock is insignificant. The impulse response function results confirmed the conclusions of Granger causality test.

VI. CONCLUSION

In this article, we examined the dynamic relation among GDP, energy consumption and CO_2 emissions in Tunisia during 1970-2009, using the VAR modeling. The results of our Granger causality test, the variance decomposition analysis and the impulse response function give evidence of a strong causality running from energy consumption to economic growth. But the causality is not bidirectional, which approves that the Tunisian economy is not greatly dependant on energy.

We also found the existence of unidirectional causality running from energy consumption to CO_2 emissions; imply that the Energy is the main source of pollutant emissions. This result explained by the important share of fossil fuels in total energy consumption in Tunisia and inefficient use of energy. The impulse response function results appear that the GDP shock has a negative and significant impact on CO_2 emissions but the response of GDP to CO_2 shock is insignificant; it implies that the pollutant emissions are influenced by the economic level of countries. This result argues that the Tunisian economy reaches the optimum income which encourages the improvement of environmental quality. To sum up the energy conservation policies and promotion of renewable energy in order to provide sustainable solutions to environmental challenges are necessary. Therefore, two questions remain to ask are: What‟s the situation of renewable energy in Tunisian? Does it promote the economic growth?

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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