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Causality relationship between CO_2 emissions, GDP and energy intensity in Tunisia

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Abstract This article analyzes the causality between the economic growth, the energy and the environment, measured by CO_2 emissions. Our empirical study is based on a series of annual data from 1980 to 2010 in Tunisia. Our study was conducted using the Granger causality test and variance decomposition. The empirical results confirm the presence of a positive effect between the energy consumption and the economic growth measured by gross domestic product (GDP). Thus, there is a unidirectional relationship between GDP and CO_2 emissions in the short term. This analysis shows, as is common to relatively fast-growing economies in Tunisia, that the biggest contributor to the rise is CO_2 emissions. Hence, in congruence with the result of variance decomposition, the GDP affects CO_2 emissions in the short and medium term at an almost constant level (10 %). The non-renewable energy intensity in Tunisian economy is responsible for a modest reduction in CO_2 emissions, which suggests the implementation of conservation policies aimed at energy efficiency and the orientation toward renewable energy.

Keywords CO_2 emissions · Energy consumption · Economic growth · Granger causality · Variance decomposition

1 Introduction

The human activities affect the environment by increasing concentrations of greenhouse gases (GHGs) in the atmosphere and the distribution of biogeochemical cycles and the

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depletion of natural resources (Spangenberg 2007). How the economic activities affect the environment is a question which became popular, although historical records showed that the man often has a share of responsibility for environmental disasters. Industrial growth led to the deterioration of the quality of the environment (Peng and Bao 2006). However, there are also studies have suggested that economic growth is beneficial for the environment, and both parties encouraged each other (Beckerman 1992). The relationship between economic growth and environmental quality has not yet reached a final conclusion, and it is still in need of further studies. Over the past 20 years, the average annual growth rate of gross domestic product (GDP) of Tunisia reached 5 %. However, extensive growth has exhausted the large amounts of resources and caused emissions. The recent study of ANME with the support of UNDP (ANME 2005) provided details on the development of local pollutants in Tunisia related to energy in the period 1900–2003; they are carbon monoxide (CO), monitoring of nitrogen oxide (MNOx), volatile organic compounds, but not méthaneux (NMVOCs) and sulfur dioxide (SO_2). Since several decades Tunisia contributes in the efforts of the international community to reduce the effects of human activities on the environment and the climate. For these reasons, Tunisia has signed the United Nations Framework Convention on Climate Change since its adoption in 1992 and ratified it in July 1993. In addition, Tunisia cooperates in a very active way with the United Nations Environment Programme (UNEP, Nairobi) and joined the Kyoto Protocol in June 2002 and met the conditions for eligibility of Clean Development Mechanism.

The aim of this paper is to investigate the causal links between economic growth, energy consumption and CO_2 emissions in Tunisia. To treat this problem, we use an econometric technique effective as the vector autoregressive model (VAR) Sims (1980).

The paper is organized as follows. Section 2 describes data and descriptive statistics, and Sect. 3 presents the model and empirical results, while Sect. 4 draws conclusion.

2 Literature review

In recent decades, many studies have tried to explain the direction of causality between energy consumption, economic growth (GDP) and emissions of CO_2. Studies in this area can be divided into three broad areas of research. The first axis focuses on the relationship between economic growth and energy consumption. Since the seminal study of Kraft and Kraft (1978), motivated by the oil price shock of 1973, the relationship between energy consumption and economic growth has been abundantly studied in the economic literature. The Granger causality test has been widely used to examine the sense of causality between energy consumption and economic growth. The type of relationship can be classified into four testable hypotheses. First, if a unidirectional relationship running from energy consumption to economic growth is found, then the economy is said to be an energy-dependent one, and any energy policy encouraging conservation might adversely affect economic growth. This is known as the growth hypothesis. Stern (1993), Yuan et al. (2008) and Binh (2011) Zeshan and Ahmed (2013) have also sought the causal relationship between energy consumption and economic growth in different countries. Other studies such as, Coondoo and Dinda (2002), De Vries et al. (2007), Zhang et al. (2013) and Tokimatsu et al. (2013) showed that energy is necessary for social and economic development, but energy use has imposed a potential that there may be significant environmental impacts. The second axis of research focuses on the interaction between the environment and economic growth. This relationship has been the subject of various approaches. For example, the approach of Kuznets curves (EKC), which analyzes the effects of economic growth on the various dimensions of the quality of the environment. Various studies in the literature have used different indicators, such as carbon dioxide, emissions of sulfur dioxide (SO_2) treated by (Grossman and Krueger (1991), air quality in urban areas (Esty and Porter 2005) and the contamination of heavy metals (Grossman and Krueger (1995). The empirical studies have tested the validity of the environmental Kuznets curve (EKC) and have drawn different conclusions. According to the study of Friedl and Getzner (2003), Kuznets curve takes the form of N (i.e., the appearance of the curve is increasing, decreasing and increasing for three successive intervals). The main result found by Agras and Chapman (1999) and Richmond and Kaufmann (2006) shows that there is no significant relationship between economic growth and environmental pollutants. The relationships between emissions, the energy consumption and economic growth are the third axis of research. The causal relationships between these three variables has been well studied in the work of Ang (2007), Akbostanci et al. (2009), Wang et al. (2011), Leukhardt and Allen (2013) and Zeshan and Ahmed (2013). Some previous studies have used with different econometric techniques. These studies have shown different results. The study of Apergis and Payne (2010) was done for 11 countries of Independent States during the period 1992–2004. They showed that the energy consumption has a positive and statistically significant impact on emissions of carbon dioxide in the long term. But in the short term, they revealed a unidirectional causality between energy consumption and real output, respectively, for emissions of carbon dioxide and bidirectional causality between energy consumption and real output. Wang et al. (2011) have used the co-integration technique and VECM model based on panel data for 28 cities in China during 1995–2007. They confirmed the existence of a relationship between the three variables. The main conclusion is that there is bidirectional causality between CO_2 emissions and energy consumption as well as between energy consumption and economic growth. The authors also noted that energy consumption and economic growth cause CO_2 emissions in the long term, and CO_2 emissions and economic growth cause energy consumption in the long term.

3 Data and methodology

3.1 Data and descriptive statistics

Table 1 summarizes the descriptive statistics associated with the three variables. The annual emissions of carbon dioxide CO_2 (kt), EU energy consumption (kt of oil equivalent), the GDP (Gross domestic product, constant prices) are downloaded from the World Development Indicators World Bank for the period 1980–2009. The empirical investigation is based on 30 annual observations. The country considered in this analysis is Tunisia. It is evident from the table that standard deviation (SD) of CO_2 is the highest and that of GDP is the lowest. All variables have negative value of skewness, indicating that the distribution is skewed to the left, with more observations on the right. The Jarque–Bera statistics shows that all variables used in the analysis have a normal distribution.

3.2 The model

The VAR model was used with great effectiveness in different works, where the object is to quantify the influence of energy variables on macroeconomic indicators. Yemane (2010) studied the correlation relationship between consumption coal and real GDP for the six

Table 1 Descriptive statistics

	CO_2	EU	GDP
Mean	16,975.13	6,159.744	23.96394
Median	16,501.50	5,804.323	18.72100
Maximum	25,878.02	9,673.822	63.38000
Minimum	9,490.196	3,267.939	3.887000
SD	5,081.812	2,050.560	17.41967
Skewness	0.187663	0.210381	0.765349
Kurtosis	1.778456	1.691094	2.476923
Jarque–Bera	2.109343	2.441605	3.379831
Probability	0.348307	0.294993	0.184535
Sum	526229.2	190952.1	742.8820
Sum Sq. Dev.	7.75E + 08	1.26E + 08	9,103.346
Observations	31	31	31

CO_2 dioxyde de carbone, *EU* energy use, *GDP* gross domestic product

largest countries. He used the VAR model for the period (1965–2005) and other such as: Belloumi (2009), Park et al. (2011), Tiago and João Tovar (2013) and Hassaballa (2014).

We use a VAR model to analyze the relationship between changes in CO_2 emissions, energy consumption and economic growth measured by GDP. VAR (*P*) is expressed by the model (1):

$$Y_t = c \sum_{i=1}^{p} \varphi_i Y_{t-1} + \mu_t \qquad (1)$$

where μ_t is a white noise process verifying $E\ (\mu_t) = 0$, Y_{t-1} is a vector autoregressive process of order (*P*) endogenous variables, and *c* is the $(n \times 1)$ intercept vector of the VAR model. It should be noted that before any econometric analysis of the relation (1), we determine the optimal P lag length of the model. To do this, several relations model (1) are estimated by considering sequential lag length. Each estimated model provides information criteria. Thus, the optimal lag length which is equal one ($P^* = 1$) is that which minimizes the information criteria, Akaike (AIC) and Schwarz (SC), defined by the Table (2).

4 The empirical results

4.1 Results of the unit root tests

The Dickey-Fuller (1979, ADF) and Phillips and Perron (1988, PP) are standard tests that lead to non-rejection of a unit root which could be considered suspect when the sample includes economic events that may cause changes in the regime. We conduct two different unit root tests, namely augmented Dickey-Fuller (ADF) and Phillips-Perron (PP). The ADF and PP tests suggest stationarity at least at the 5 % significance level. The results of the unit root tests are presented in Table (3). They show that the three series studied [the emission of CO_2 (CO_2), energy consumption (EU) and economic growth as measured by the (GDP)] are integrated with order one (I (1)) and so stationary in first difference.

Table 2 VAR lag order selection criteria of endogenous variables

Lag	Log *L*	LR	FPE	AIC	SC	HQ
0	−503.2185	NA	1.64e + 13	38.93988	39.08505	38.98169
1	−386.6012	197.3523*	4.19e + 09	29.83903*	31.24229*	30.82884
2	−381.2513	7.819082	5.73e + 09	30.57789	31.95856	31.23503
3	−375.1073	7.561838	7.77e + 09	30.66163	32.61375	31.58013
4	−358.5126	16.59473	5.14e + 09	30.94241	32.46504	31.12132
5	−339.9074	14.31166	3.37e + 09*	31.16210	32.16167	30.50787*

CO_2 dioxyde de carbone, *EU* energy use, *GDP* gross domestic product

4.2 Granger causality

The causality between two variables is usually studied in terms of improving the prediction characterization of Granger, or in terms of impulse analysis, according to the principles of Sims (1980). The basis of the definition of Granger is the dynamic relationship between the variables. As mentioned, it is stated in terms of improving the predictability of a variable. In Granger, temporal succession is central, and we can discuss causality without taking into consideration the time (Sekkat 1989). In the Granger sense, a series "cause" another series, if knowledge of the history of the first improves the prediction of a second. According to Sims (1980), a series can be recognized as causal for another series if the first innovations contribute to the forecast error variance of the second. Since the development of this statistical hypothesis test, some of the studies on the properties of the various test methods have been published, Jbir and Zouari (2009), Belloumi (2009), Mantalos and Shukur (2010), Mazbahul and Nazrul (2011) and Sung and Song (2013).

The equation of conventional Granger test could be written as

$$Y_t = \gamma + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \sum_{i=1}^{n} \beta_j X_{t-j} + \varepsilon_t \quad (2)$$

To detect the causal relationship between CO_2 and GDP is defined as follows

$$\begin{aligned} \mathrm{GDP}_t &= \gamma + \sum_{i=1}^{m} \alpha_i \mathrm{CO}_{2_{t-i}} + \sum_{i=1}^{n} \beta_j \mathrm{GDP}_{t-j} + \varepsilon_t \\ \mathrm{CO}_{2_t} &= \gamma + \sum_{i=1}^{m} \alpha_i \mathrm{CO2}_{t-i} + \sum_{i=1}^{n} \beta_j \mathrm{GDP}_{t-j} + \varepsilon_t \end{aligned} \quad (3)$$

From the aforementioned Granger causality representations, it seems that There is a unidirectional causality from CO_2 to GDP if

$$\sum_{i=1}^{m} \alpha_i \neq 0 \quad \text{and} \quad \sum_{j=1}^{n} \beta_j = 0 \quad (4)$$

Quite the reverse, a unidirectional causality from GDP to CO_2 will be found if

$$\sum_{i=1}^{m} \alpha_i = 0 \quad \text{and} \quad \sum_{j=1}^{n} \beta_j \neq 0 \quad (5)$$

There will be bi-directional causality or feedback between GDP and CO_2 if both the conditions

Table 3 Unit root test (ADF and PP)

Variables	Level			1st Difference		
	(i)	(ii)	(iii)	(i)	(ii)	(iii)
ADF test						
CO_2	5.216124	0.640526	−3.381379*	−5.239333***	−8.559563***	−8.572757***
EU	1.410336	1.040216	−3.039934*	−5.358393***	−9.668449***	−9.872674***
GDP	1.461469	1.292020	1.231250	−2.4405429**	4.435861***	4.587321***
Phillips–Perron test						
CO_2	1.602994	1.048541	−3.374112	−5.071565**	−8.782878***	−10.56974***
EU	10.05312	2.248645	−2.875999	−4.830954**	−9.633966**	−10.94636***
GDP	13.70628	4.24950	0.464304	−2.223298**	−4.334759**	−6.621343***

CO_2 dioxyde de carbone, *EU* energy use, *GDP* gross domestic product. (i): Without intercept, (ii) : with an intercept, and (iii) : with an intercept and trend

***, ** and *: Asterisks mean a *p* value less than 1, 5 and 10 %. Critical levels in the model: (i) −2.60 (1 %), −1.95 (5 %) and −1.61 (10 %).Critical levels in: (ii) −3.51, −2.89 and −2.58. Critical levels in: (iii) −4.04, −3.40 and −3.15

$$\sum_{i=1}^{m} \alpha_i \neq 0 \quad \text{and} \quad \sum_{j=1}^{n} \beta_j \neq 0 \tag{6}$$

Gross domestic product and CO_2 will be determined independently and not statistically significant if

$$\sum_{i=1}^{m} \alpha_i = 0 \quad \text{and} \quad \sum_{j=1}^{n} \beta_j = 0 \tag{7}$$

It is the absence of a causal relationship between the two variables.

The results of Granger causality tests are reported in Table 4. The results show that there is a bidirectional causality relationship between energy consumption and CO_2 emissions at a significance level of 5 %. This result is consistent with the findings of Pao and Tsai (2011), Kohler (2013) and Shafiei and Salim (2014). The economic growth causes the energy at a level of significance of 10 %. Therefore, we find that there is a unidirectional (indirect) causality from economic growth to CO_2 emissions through energy consumption. This implies that economic growth can be used as a leading indicator for future CO_2 emissions in Tunisia. Specifically, the results find that Tunisian's CO_2 emission levels increase in the presence of greater energy use within the economy. However, the high development that Tunisia has achieved in the last two decades leads to an increase in energy use and CO_2 emission. The study calls for more environment protection policy as environmental pollution may lead a negative externality to the economic power through affecting human health and reduce productivity. This problem can be resolved by the development of strategies for energy conservation.

4.3 Variance decomposition

The variance decomposition is a tool that can be used in our analysis. According to Sims (1980), this technique allows to determine the extent to which variables have an interaction

Table 4 VAR granger causality/block exogeneity wald tests

Dependent variables	Excluded variables: block exogeneity			
	CO_2	EU	GDP	All variables together
CO_2		13.88633** (0.0002)	0.0.105112 (0.7458)	17.00500** (0.0002)
EU	5.273467** (0.0217)		0.117087* (0.07322)	5.736644* (0.0568)
GDP	0.001373 (0.9704)	0.174379 (0.4733)		0.601885 (0.7401)

The values in each box represent chi-square (Wald) statistics for the joint significance of each other lagged endogenous variables in that equation. The statistics in the last column is the chi-square statistics for joint significance of all other lagged endogenous variables in the equation

**,* Significant at 5 and 10 %

Table 5 Variance decomposition, Cholesky ordering: CO_2, EU and GDP

Period	CO_2	EU	GDP
CO_2			
2	66.11881	23.87734	10.003854
5	56.99659	32.93781	10.065603
10	52.47330	37.04648	10.480227
EU			
2	41.11255	58.88321	0.004242
5	50.20757	49.72408	0.068356
10	53.21064	46.29815	0.491211
GDP			
2	9.034923	15.78075	75.18433
5	6.103740	12.06141	81.83485
10	2.629704	7.348658	90.02164

between them and by calculating the contribution of each of the innovations to the variance of the total error. Some studies have used the technique of variance decomposition among which are Soytas and Sari (2007) and Jbir and Zouari (2009). We will therefore be able to decompose the variance of forecast for each variable in our model.

In addition, Diebold and Yilmaz (2012) used the generalized VAR framework proposed by Pesaran and Shin (1998); he constructed a variance decomposition invariant to commanding. Let us denote the generalized forecast error variance decompositions by

$$\theta_{ij}^{g}(H) = \frac{\sigma_{ij}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \sum e_j^2 \right)}{\sum_{h=0}^{H-1} \left(e_i' A_h \sum A_h' e_i \right)} \quad (8)$$

where $\sum$ is the variance matrix for the error vector ε, σ_{ij} is the standard deviation of the error term for the jth equation, and e_i is the selection vector, with one as the ith element and zeros otherwise.

The Table 5 shows that for a time horizon of 2 years, almost 23.87 % of the variation CO_2 is explained by the energy consumption (EU). This variation increases more than 32.93 % at the fifth period and up 37.04 % in the tenth period (10 years).

It should be noted that the influence of the EU on CO_2 emissions reveals significant. The influence of the GDP is taken into account, while the direct effect of GDP on CO_2 emissions is almost stable during 10 years, 10 % of the effects on GDP in 2 years, and this cross until 10.48 % in 10 years. So these results show that GDP affects CO_2 emissions in the short and medium term at same level. Hence, CO_2 intensity remains at an almost constant level with economic growth. The results showed that energy consumption increases carbon emissions, and economic growth is among the contributors to CO_2 emissions. Our results imply that CO_2 emissions can be reduced to the detriment of economic growth or energy-saving technologies in the short and medium term. These results suggest that developing and implementing appropriate energy efficiency measures will result in a significant reduction in future CO_2 emissions in Tunisia.

5 Conclusion

This study aims to investigate the relationship between energy consumption, economic growth and carbon emissions in Tunisia during the period 1980–2009. Using the vector autoregressive analysis (VAR), the results of the study show a unidirectional causality running from GDP, passing through by energy use to CO_2 emissions. To support our result, the study of Fodha and Zaghdoud (2010), which investigated the relationship between economic growth and pollutant emissions of Tunisia, indicated a unidirectional causality from income to environmental changes. In addition, the increase in energy consumption, spurred by the growth of economic activity, will boost CO_2 emissions. Energy consumption is also positively correlated with economic growth and CO_2 emissions. Economic growth leads to a level of energy consumption which causes CO_2 emissions. After making the variance decomposition analysis, we observed that for a time horizon of 2 years, almost 23.87 % of the variation CO_2 is explained by the energy consumption (EU) and has creased over time that achieved 32.93 % after 10 years. CO_2 intensity remains at an almost constant level with economic growth (10 %). The close linkage between environmental pollution measured by CO_2 emissions and economic activities found in this study implies that the possible economic loss from CO_2 emissions mitigation is expected to be higher in fast-growing developing countries such as Tunisia where CO_2 emissions are also expected to be higher. This finding requires environmental policy which should mitigate CO_2 emissions while simultaneously having less impact on the economy. For example, policies which could substitute capital and job for energy power change the composition of energy by renewable energy sources for less polluting fuels and fossil fuels such as natural gas for more polluting fuels such as coal; improve emission efficiency as well as energy efficiency by technological development; and promote research and development investment in renewable energy technology. In addition, with regard to international negotiations fighting for a harmonious mitigation of global CO_2 emissions, this mutual causality can strengthen demands for developed countries to provide financial and technology supports to developing countries to offset possible adverse economic effects caused by the reduction in CO_2 emissions. Government of Tunisia has promoted strategies with higher emphasis placed on environmental issues that meet as global warming and climate change.

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