

Investigating linkages between economic growth, energy consumption and pollutant emissions in Tunisia

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Summary:

The aim of this study is to understand long and short-run linkages between economic growth, energy consumption and carbon emission using Tunisian data over the period 1971-2004.

Cointegration procedure is used to analyze the time series properties of the series and error-correction terms were considered to test for the direction of Granger causality.

Statistical findings indicate that economic growth, energy consumption and CO₂ emission are related in the long-run and provide some evidence of inefficient use of energy in Tunisia, since environmental pressure tends to rise faster than economic growth.

The short-run analysis, provide support for causality running from CO₂ emissions growth to output growth, both in the short-run and the long-run. The results provide also some support of mutual causal and feedback relationship in the long-run.

In addition, the results show strong evidence of causality running from output growth to energy consumption in the short-run and mutual causality in the long-run implying that Tunisia is an energy dependent economy.

From a policy perspective, policy makers in Tunisia should be mindful that a persistent decline in environmental quality may exert negative externalities to the economy.

Keywords: pollutant emissions, economic growth, cointegration, causality, Tunisia.

JEL codes: C32; O13; Q56

I. Introduction

The relationship between energy consumption and economic growth, as well as economic growth and environmental pollution, has been one of the most widely investigated questions in the economic literature during the three last decades. However, existing outcomes have varied considerably.

Whether energy consumption stimulates, retards or is neutral to economic activities has motivated curiosity and interest among economists and policy analysts to investigate the direction of causality between energy consumption and economic variables.

The pioneer study by (Kraft and Kraft 1978) found a uni-directional Granger causality running from output to energy consumption for the United States using data for the 1947–1974 time frame.

The empirical outcomes of the subsequent studies on this subject which differ in terms of time period, country, econometric techniques, and the proxy variables, have reported mixed results and are not conclusive to present policy recommendation that can be applied across countries. Depending upon the direction of causality; the policy implications can be considerable from energy conservation, emission reduction and economic performance viewpoints.

Most of the analyses on this topic have recently been conducted using Vector Autoregression (VAR) models. Earlier empirical works have used (Granger 1969) or (Sims 1972) tests to test whether energy use causes economic growth or whether energy use is determined by the level of output ((Akarca and Long 1980) and (Yu and Hwang 1984)). Their empirical findings are generally inconclusive. Where significant results were obtained they indicate that causality runs from output to energy use.

With advances in time series econometric techniques, more recent studies have focused on vector error correction model and the cointegration approach. (Masih and Masih 1996) used cointegration analysis to study this relationship in a group of six Asian countries and found that cointegration does exist between energy use and GDP in India, Pakistan, and Indonesia. No cointegration is found in the case of Malaysia, Singapore and the Philippines. The flow of causality is found to be running from energy to GDP in India and from GDP to energy in Pakistan and Indonesia.

Using trivariate approach based on demand functions, (Asafu-Adjaye 2000) tested the causal relationship between energy use and income in four Asian countries using cointegration and error-correction analysis. He found that causality runs from energy to income in India and Indonesia, and a bi-directional causality in Thailand and the Philippines. (Stern 2000) undertakes a cointegration analysis to conclude that energy is a limiting factor for growth, as a reduction in energy supply tends to reduce output. (Yang 2000) considers the causal relationship between different types of energy consumption and GDP in Taiwan for the period 1954–1997. Using different types of energy consumption he found a bi-directional causality between energy and GDP. This result contradicts with (Cheng and Lai 1997) who found that there is a uni-directional causal relationship from GDP to energy use in Taiwan.

(Soytas and Sari 2003) discovered bidirectional causality in Argentina, causality running from GDP to energy consumption in Italy and Korea, and from energy consumption to GDP in Turkey, France, Germany and Japan. (Wolde-Rufael 2005) investigates the long-

run and causal relationship between real. Using cointegration analysis, (Wietze and Van Montfort 2007) show that energy consumption and GDP are cointegrated in Turkey over the period 1970–2003 and found a unidirectional causality running from GDP to energy consumption indicating that energy saving would not harm economic growth in Turkey.

On the other hand, the relationship between output growth and pollution level has also been well discussed in the literature of Environmental Kuznets Curve (EKC).

The conclusions of (Hettige, Lucas and Wheeler 1992), (Cropper and Griffiths 1994), (Selden and Song 1994) and (Grossman and Krueger 1995) are consistent with the EKC hypothesis. (Martinez-Zarzoso and Bengochea-Moranco 2004) find evidence that CO₂ emissions and national income are negatively related at low income levels, but positively related at high-income levels. However, increased national income level does not necessarily warrant greater efforts to contain the emissions of pollutants. The empirical results of (Shafik 1994) and (Holtz-Eakin and Selden 1995) show that pollutant emissions are monotonically increasing with income levels.

The existing literature reveals that empirical finding studies differ substantially and are not conclusive to present policy recommendation that can be applied across countries. In addition, few studies focus to test the nexus of output-energy and output-environmental degradation under the same integrated framework. Given that energy consumption has a direct impact on the level of environmental pollution, the above discussion highlights the importance of linking these two strands of literatures together ((Ang 2007) and (Ang 2008)).

The aim of this country specific study is to understand long and short-run linkages between economic growth, energy consumption and pollutant emissions using Tunisian data. These linkages were largely under considered and unanswered for policy makers in Tunisia and this empirical research attempts to present some findings to better integrate the environment and emission reduction into economic development decisions.

Also, this study for the case of Tunisian economy attempts to overcome the shortcoming literature related with the causal linkages between GDP, energy consumption and CO₂ in developing economies. Tunisia appears to be an interesting case study given that it is one of the highest growth economies in Middle East and North Africa (MENA) region and energy supply in this country is insufficient to meet the increasing demand.

The rest of this country study is arranged as follows: Section 2 briefly describes the Tunisian economic and energy situations. Section 3 sets out the data used in this study and their stochastic characteristics. Long-run equilibrium relationships are analyzed in Section 4. Section 5 depicts the empirical findings from the short-run dynamics. Finally, some concluding remarks and some policy implications are outlined.

II. Tunisian economic and energy situations

With annual growth of Gross Domestic Product exceeding 5% since 1995, Tunisia is amongst the North African countries with a strong growth potential. The improvement of Tunisian major macroeconomic indicators is the result of the series of economic reforms and a prudent macroeconomic management (principally since the adoption and implementation of the Structural Adjustment Program).

The Tunisian economy has been diversified and is now less vulnerable than in the past to external shocks such as climate hazards. Agriculture accounted for 12% of GDP in 2006. The manufacturing sector accounted for more than 60% of industrial production, about 20% of the working population and 18.2% of GDP. The services sector represents about 40% of GDP and half of the working population. It has expanded significantly in the past few years and has driven Tunisian growth upwards.

At the sectoral level, growth in the last years was driven by strong domestic and European demand. It was primarily stimulated by services (telecommunications in particular), the machinery and electricity industries, and construction and civil engineering.

Over the years, the manufacturing and tourist sectors have gained a few percentage points of GDP to the detriment of the primary sector (agriculture, oil and phosphates).

In Tunisia, Demand for energy, notably electricity, is rising sharply during the last years. Household consumption is the main engine of growth; it represented 63.8% of GDP in 2006 (up 8.8% from 2005).

The increase of total primary energy consumption for 1990-2005 period was very strong. This is attributed to the fact that Tunisia has experienced rapid economic growth due to the expansion of the tourism and transportation activities, the increased industrial activity and the increase in the standard of living of the Tunisian population¹.

Based on the 2005 values, the consumption of primary energy exceeded 8.5 Mtoe (million tonnes oil equivalent) in Tunisia, covered prevalently by crude oil and petroleum products at 50%, while natural gas is today well represented, at 38%. Thanks to the switch of natural gas since the mid-1980s, the role of natural gas now is growing as the second largest source of fuel as well as being a main source for industrial and electricity sectors. Biomass is essentially used in rural areas and represents 13 % of primary energy consumption.

Lastly, the contribution of renewable energies (hydropower, wind and solar water heating) accounts for 46 ktoe (kilo tonnes of oil equivalent) and represents only 0.6% of the primary energy balance for 2005.

The energy consumption composition by sectors in Tunisia has not changed since 2000. The household is the leading sector (29%), followed by transportation (25%), industry sector (16%) and agriculture (4%).

Although crude oil is the leading export product in value, national production is far from covering the country's needs. In fact, Tunisia is a hydrocarbon importer in the absence of a significant discovery and has initiated a program to reduce the oil-deficiency². This objective was expressed by the national energy plan 'Energy 21' based on energy saving and the increased utilization of renewable energy sources³.

¹ With population growth slowing down, GDP per capita in 2007 was USD 9401 in purchasing power parity, which placed Tunisia just behind Romania and well ahead of Morocco.

² Since the end of the 1960s, Tunisia has benefited from relatively secure energy balance surplus; but the 1980s saw the advent of the era of energy dependency. In 1994 for the first time, Tunisia recorded a deficit in its energy balance. Following the extension of the gas pipeline between Algeria and Italy and the start-up of operations in the Miskar gas mine in 1996, surplus was restored, but as of 2001, deficits appeared again as a result of increasing demand and stagnating supply.

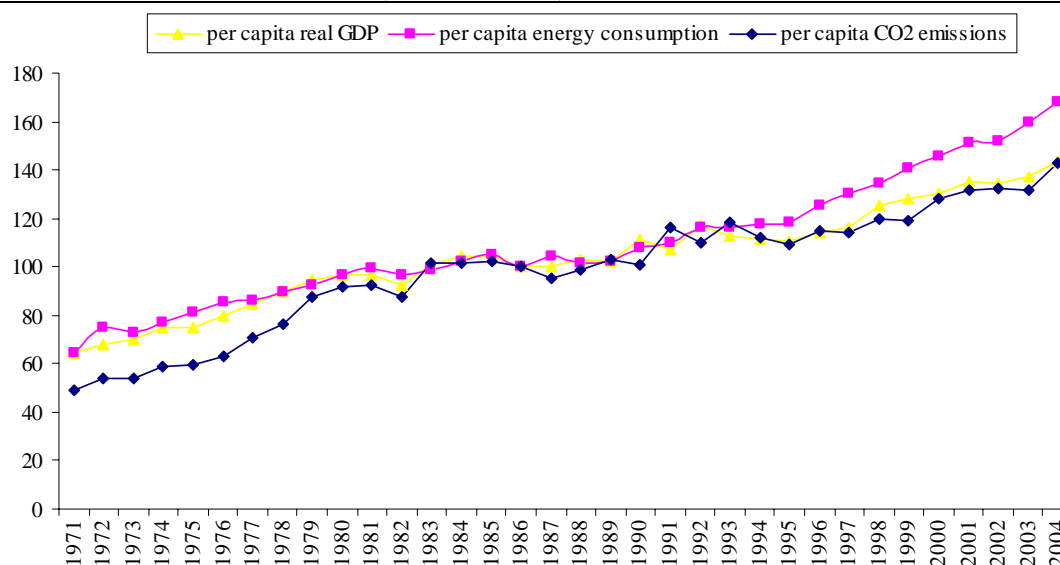
³ The 10th Tunisian Development Plan (2002-2006) contains specific provisions on sustainable development and is based on four pillars: (i) the integration of the environmental dimension in the process of development, (ii) the protection of natural resources and the fight against desertification, (iii) the fight against pollution and the improvement of living standards and (iv) the contribution of the environment to development.

III. Data and stationarity properties

In this empirical study, annual data for per capita real gross domestic product (PGDP), per capita of carbon dioxide emissions (PCO2) as proxy for the level of pollution and environmental degradation and per capita energy use (PENE) in Tunisia are collected from the World Development Indicators (World Bank, 2008). The sample period covers data from 1971 to 2004⁴, and series are transformed in logarithms so that they can be interpreted in growth terms after taking first difference.

Figure 1 suggests that the three selected variables tend to move together over time and a long-run or cointegrating relationship is likely to be present in this case⁵. In addition figure 1 reveals that per capita real GDP and per capita of CO2 emissions have a linear relationships so that a quadratic specification is not required.

Figure 1. Trends of the indexed series (basis 100=1986)



Source: World Development Indicators (World Bank, 2008).

The first step of this empirical work is to investigate the stationarity properties and establishing the order of integration of series (PGDP, PCO2 and PENE). When the number of observations is low, unit root tests have limited power (Blough 1992). For this reason we have examined the results from two different tests: the Augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979, ; Dickey and Fuller 1981), which tests the null of unit root, and KPSS (Kwiatkowski et al. 1992) , which tests the null of stationarity. The results of both tests for the individual time series and their first differences are shown in Table 1.

The ADF statistics suggests that all variables in levels are non-stationary and are I(1) (integrated of order one), but stationary in the first difference I(0) (integrated of order zero). The KPSS test rejects the null hypothesis of level and trend stationarity for both lag truncation parameters. The KPSS statistics does not reject the I(0) hypothesis for the first-differenced series at conventional levels of statistical significance.

⁴ Per capita CO₂ emissions value for 2004 is from the Carbon Dioxide Information Analysis Center (CDIAC).

⁵ The three variables in levels were indexed (basis 100 = 1986) in order to present the data series in the same scale.

Therefore, the combination of the unit root tests results (see Table 1) suggests that the series involved in the estimation procedure are integrated of order one (i.e., I(1)). This implies the possibility of cointegrating relationships.

Table 1. Results of the ADF and KPSS tests

Variables	Panel A: ADF test (null hypothesis is non-stationarity)											
	Level form				First difference							
	Intercept and time trend				Intercept, no time trend							
PGDP	-2.8166				-0.9818				-8.7645			
PCO2	-2.3636				-2.2248				-7.2017			
PENE	-2.8067				-1.7022				-6.7333			
	Critical values											
	intercept and time trend				intercept, no time trend							
1%	-3.96				-3.43							
5%	-3.41				-2.86							
10%	-3.13				-2.57							
	Panel B: KPSS test (the null hypothesis is stationarity)											
	Level form				First difference							
	l= 1		l = 3		l = 1		l = 3					
	η_{μ}	η_{τ}	η_{μ}	η_{τ}	η_{μ}	η_{τ}	η_{μ}	η_{τ}				
	PGDP	1.6399	0.2370	0.9337	0.1286	0.2145	0.2043	0.2091	0.1990			
PCO2	1.5039	0.2985	0.8627	0.1933	0.3604	0.1102	0.3160	0.1113				
PENE	1.5927	0.2030	0.9087	0.1498	0.2341	0.1228	0.2316	0.1302				
	Critical values											
	level stationarity				trend stationarity							
1%	0.739				0.216							
5%	0.463				0.146							
10%	0.347				0.119							

Note: The lag length for the ADF tests to ensure that the residuals were white noise has been chosen based on the Akaike Info Criterion. The KPSS statistics test for lag-truncation parameters one and three (l=1 and l=3) since it is unknown how many lagged residuals has been used to construct a consistent estimator of the residual variance.

IV. Long-run relationships study: a cointegration analysis

The next step is to investigate whether the series are cointegrated since the three variables were I(1). In this work, cointegration analysis has been conducted using the general technique developed by (Johansen 1988) and (Johansen and Juselius 1990). They provide a methodology that allows the researcher to distinguish between the short and the long-run.

These authors proposed a maximum likelihood estimation procedure which allows researchers to estimate simultaneously the system involving two or more variables to circumvent the problems associated with the traditional regression methods. Further, this procedure is independent of the choice of the endogenous variable and allows researchers to estimate and test for the presence of more than one long-run structural relationship(s) in the multivariate system and how variables in the system adjust to deviations from such long-run equilibrium relationship(s).

The base-line econometric specification for multivariate cointegration is a VAR(p) representation of a k-dimensional time series vector Y_t reparameterized as a Vector Error-correction Model (VECM):

$$\Delta Y_t = \mu D_t + \Gamma_1 \Delta Y_{t-1} + \dots + \Gamma_{p-1} \Delta Y_{t-p+1} - \Pi Y_{t-1} + e_t \quad (4.1)$$

where, Y_t is a $(k \times 1)$ column vector of endogenous variables; D_t is a vector of deterministic variables (intercepts, trend...); and μ is the matrix of parameters associated with D_t ; Γ_i are $(k \times k)$ matrices of short-run parameters ($i=1, \dots, p-1$), where p is the number of lags; Π is a $(k \times k)$ matrix of long-run parameters and e_t is the vector of disturbances $\text{niid}(0, \Sigma)$.

In the $I(1)$ system Y_t is said to be cointegrated if the following rank conditions are satisfied: $H_r: \Pi = \alpha\beta'$ of rank $0 < r < k$, where α and β are matrices of dimension $(k \times r)$. β is a matrix representing the cointegrating vectors which are commonly interpreted as meaningful long-run equilibrium relations between the Y_t variables, while α gives the weights of the cointegration relationships in the ECM equations.

This approach has been applied to the system including the three selected variables (PGDP; PCO_2 and PENE). However, in empirical applications, the choice of r is frequently sensitive to: i) the deterministic terms included in the system (such as a constant and/or a trend) and on the way in which such components interact with the error -correction term; and ii) the appropriate lag length to ensure that the residuals are Gaussian.

In the present work, model has been estimated including two lags and a constant term restricted to the cointegration space, implying that some equilibrium means are different from zero. In this work, although the underlying variables are trended, they move together, and it seems unlikely that there will be a trend in cointegrating relation between variables⁶.

Multivariate tests for autocorrelation (Godfrey 1988) and normality (Doornik and Hansen 1994) have been carried out to check for model statistical adequacy before applying the reduced rank tests. Results indicated that model could be considered correctly specified⁷.

Table 2 shows the results of Johansen's likelihood ratio tests for cointegration rank. As can be observed, for the 5 and 10% levels of significance, respectively, the trace statistics do not reject the null hypothesis that there are two cointegrating relation between the variables ($r=2$).

Table 2. Results of cointegration tests

H0: r	Ha: p-r	LR-Trace	Critical values		
			(90%)	(95%)	(99%)
0	3	52.24 ***	32.25	35.07	40.78
1	2	25.02 ***	17.98	20.16	24.69
2	1	6.62	7.60	9.14	12.53

Note: (*), (**) and (***) indicate 10%, 5% and 1% level of significance, respectively.

In all the following analysis we assume the presence of two stationary relations and one common stochastic trend in the system. The presence of two cointegrating vectors in our system suggests an inherent movement in the system to revert towards long-run equilibrium path of the Tunisian economy subsequent to a short-run shock.

The estimated β and α parameters are presented in Table 3 (Panel A), where β is presented in normalized form. The two cointegrating vectors have been normalized by PGDP

⁶ The lag length has been determined by the Akaike's information criterion. The maximum number of lags is set to be three given the reduced sample size.

⁷ The result from multivariate first-order autocorrelation test was 6.792, which was well below the critical value at the 5% level of significance ($\chi^2_9 = 16.919$). Also, the result from multivariate normality test was 7.264, which was well below the critical value at the 5% level of significance ($\chi^2_6 = 12.591$).

and PCO2, respectively. As can be observed, all the parameters of the long-run equilibrium relationships are statistically significant and have the expected signs.

Table 3. Normalized cointegration relations β and loading coefficients (α)

Panel A	
$\beta' = \begin{bmatrix} 1.000 & --- & -1.124 & 0.148 \\ --- & 1.000 & -1.352 & 8.154 \end{bmatrix} \times \begin{bmatrix} \text{PGDP} \\ \text{PCO}_2 \\ \text{PENE} \\ \text{Constante} \end{bmatrix}$ <p style="text-align: center;"> <small>(-16.413)*** (-18.872)***</small> </p>	$\alpha = \begin{bmatrix} 0.120 & -0.168 \\ -0.159 & -0.474 \\ 0.530 & 0.182 \end{bmatrix}$ <p style="text-align: center;"> <small>(0.852) (-1.337) (-0.603) (-2.017)*** (2.949)** (1.135)</small> </p>
Panel B	
<p>LR-test (H1: unrestricted model): $\chi^2_7 = 10.8742$ p-value = 0.1442</p>	$\alpha = \begin{bmatrix} --- & -0.238 \\ --- & -0.331 \\ 0.532 & 0.203 \end{bmatrix}$ <p style="text-align: center;"> <small>(-5.295)*** (-5.003)*** (7.790)*** (3.018)***</small> </p>

Note: (), (**) and (***) indicate 10%, 5% and 1% level of significance, respectively; and figures in the parentheses indicate t-ratio.*

The first cointegration vector reveals a positive linkage between PGDP and PENE. Interpreted as a long-run relation, a 1% rise in energy consumption will raise economic growth by 1.124%, in Tunisia. The second vector indicates that CO2 emission and energy consumption are positively related and a 1% increase in PENE will originate an increase in PCO2 by 1.352% in the long-run. These results may provide some evidence of “inefficient use” of energy in Tunisia since environmental pressure tends to rise faster than economic growth in the long-run.

On the other hand, in this type of analysis, it is also convenient to consider the estimated $\alpha_{i,j}$ (i indicates the row and j the column) parameters as they provide valuable information about the speed of adjustment of each variable towards the long-run equilibrium.

Following (Gil, BenKaabia and Chebbi 2009), we have restricted the loading coefficients which were non-significant to zero. The value of the statistic was 10.8742 which was under the critical value ($\chi^2_7 = 14.067$) at the 5% level of significance and this result indicate that it was not possible to reject the null (H_0 : restricted model). Table 3 (Panel B) shows the new loading coefficients for the reduced model.

In relation to the first cointegrating vector, the first comment is that parameters related with economic growth (α_{11}) and with PCO2 emission (α_{12}) are not significant and that any shock in the long-run relationship between GDP and ENE generates only a significant adjustment of energy consumption.

On the other hand, the α parameters corresponding to the second cointegrating relationship between PENE and PCO2 indicate that energy use react quicker than economic growth and CO2 emission ($\alpha_{32} > \alpha_{12} > \alpha_{22}$). This may indicate that energy policy in Tunisia seems to be more oriented to supporting economic growth than to encouraging the reduction of CO2 emission.

V. Causality study

The main purpose of this section is to complete the investigation of the both short and long-run linkage between economic growth, energy consumption and CO2 emissions with the application of the analysis of causality. Since cointegration is sufficient but not a necessary condition for Granger-causality, we next investigate the direction of causality by estimating vector error-correction model (VECM) derived from the long-run cointegrating relationship (Engle and Granger 1987) and (Granger 1988). The VECM contains the cointegration relation built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allows for short-run adjustment dynamics.

In this empirical work, the VECM can be written as follow:

$$\begin{aligned} \Delta \text{PGDP}_t = & \mu_1 + \alpha_{11} \text{ECT}_{1,t-1} + \alpha_{12} \text{ECT}_{2,t-1} \\ & + \sum_{i=1}^k \delta_{1i} \Delta \text{PGDP}_{t-i} + \sum_{i=1}^k \gamma_{1i} \Delta \text{PCO}_{2,t-i} + \sum_{i=1}^k \phi_{1i} \Delta \text{PENE}_{t-i} + \varepsilon_{1t} \end{aligned} \quad (5.1)$$

$$\begin{aligned} \Delta \text{PCO}_{2,t} = & \mu_2 + \alpha_{21} \text{ECT}_{1,t-1} + \alpha_{22} \text{ECT}_{2,t-1} \\ & + \sum_{i=1}^k \delta_{2i} \Delta \text{PGDP}_{t-i} + \sum_{i=1}^k \gamma_{2i} \Delta \text{PCO}_{2,t-i} + \sum_{i=1}^k \phi_{2i} \Delta \text{PENE}_{t-i} + \varepsilon_{2t} \end{aligned} \quad (5.2)$$

$$\begin{aligned} \Delta \text{PENE}_t = & \mu_3 + \alpha_{31} \text{ECT}_{1,t-1} + \alpha_{32} \text{ECT}_{2,t-1} \\ & + \sum_{i=1}^k \delta_{3i} \Delta \text{PGDP}_{t-i} + \sum_{i=1}^k \gamma_{3i} \Delta \text{PCO}_{2,t-i} + \sum_{i=1}^k \phi_{3i} \Delta \text{PENE}_{t-i} + \varepsilon_{3t} \end{aligned} \quad (5.3)$$

In addition to the variables defined above, $\text{ECT}_{1,t-1}$ and $\text{ECT}_{2,t-1}$ are the lagged error-correction terms derived from the long-run cointegrating vectors (see Table 3) and ε_{1t} , ε_{2t} and ε_{3t} are serially independent random errors with mean zero and finite covariance matrix.

There are two sources of causation, i.e., through the ECT, if $\alpha \neq 0$, or through the lagged dynamic terms.

The error-correction terms, $\text{ECT}_{1,t-1}$ and $\text{ECT}_{2,t-1}$, measure the long-run equilibrium relationships while the coefficients on lagged difference terms indicate the short-run dynamics.

The statistical significance of the coefficients associated with ECT provides evidence of an error-correction mechanism that drives the variables back to their long-run relationship.

Given the two separate sources of causation, three different causality tests can be performed, as mentioned in the econometric literature, i.e., short-run Granger non-causality, long-run weak exogeneity and overall strong exogeneity tests.

For example, in equation (5.1) to test ΔPCO_2 does not cause ΔPGDP in the short-run, we examine the statistical significance of the lagged dynamic terms by testing the null $H_0: \text{all } \gamma_{1i} = 0$ using the Wald test. Non rejection of the null implies ΔPCO_2 does not Granger-cause ΔPGDP in the short-run. Rejection of the null implies pollution growth Granger causes output growth in the short-run.

The long-run weak exogeneity test, which is a notion of long-run non-causality test, requires satisfying the null $H_0 : \alpha_{11} = \alpha_{12} = 0$ for non-causality from long-run equilibrium deviation to $\Delta PGDP$. It is based on a likelihood ratio test which follows a χ^2 distribution.

Finally, overall strong exogeneity which imposes stronger restrictions by testing the joint significance of both the lagged dynamic terms and error-correction terms, can be performed (Charemza and Deadman 1992). The overall strong exogeneity test does not distinguish between the short and the long-run causality, but it is a more restrictive test which indicates the overall causality in the system. This requires satisfying both short-run Granger non-causality and long-run weak exogeneity. In equation (5.1), ΔPCO_2 does not cause $\Delta PGDP$ requires satisfying the null $H_0 : \text{all } \gamma_{li} = \alpha_{11} = \alpha_{12} = 0$.

Statistical results presented in Table 4 provide support for causality running from CO2 emissions growth (degradation of the environment) to output growth, both in the short-run and the long-run. The results provide also some support of mutual causal and feedback relationship in the long-run⁸. This pattern of growth is consistent with the experiences of many developing countries.

Table 4. Results of non-causality tests

Hypothesis of non-causality	Short-run Granger non-causality	Long-run weak exogeneity	Overall strong exogeneity
$H_0 : PGDP \nrightarrow PENE$	4.8138 **	19.1665 ***	19.8034 ***
$H_0 : PENE \nrightarrow PGDP$	0.0043	22.1858 ***	22.8668 ***
$H_0 : PGDP \nrightarrow PCO_2$	1.1909	12.3698 ***	12.3707 ***
$H_0 : PCO_2 \nrightarrow PGDP$	6.1183 **	22.1858 ***	26.9372 ***

Note: (*), (**) and (***) indicate the rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively.

When examining the linkage between output and energy, the results show strong evidence of output growth causing energy use and do not support the view that energy and output are neutral with respect to each other in Tunisia⁹. This result is consistent with the argument that economic growth exerts a positive causal influence on energy consumption growth.

Support for reverse causality is also found in the long-run¹⁰. Indeed, the finding of a bi-directional causality between output growth and growth in energy consumption in the long-

⁸ This result differ from J. B. Ang, "Economic Development, Pollutant Emissions and Energy Consumption in Malaysia," *Journal of Policy Modeling* 30 (2008). who found long-run causality running from the CO₂ emissions growth to the economic growth, but was not able to identify a feedback relationship.

⁹ This result is consistent with the findings of W. Oh and K. Lee, "Energy Consumption and Economic Growth in Korea: Testing the Causality Relation," *Journal of Policy Modeling* 26 (2004). for the Korean data and Ang, "Economic Development, Pollutant Emissions and Energy Consumption in Malaysia." for the Malaysia data.

¹⁰ This finding is in line with A. M. M. Masih and R. Masih, "Energy Consumption, Real Income and Temporal Causality: Results from a Multicountry Study Based on Cointegration and Error-Correction Modeling Techniques," *Energy Economics* 18 (1996)., Y. U. Glasure and A. R. Lee, "Cointegration, Error-Correction, and the Relationship between GDP and Energy: The Case of South Korea and Singapore," *Resource and Energy Economics* 20 (1997)., H. Y. Yang, "A Note on the Causal Relationship between Energy and GDP in Taiwan," *Energy Economics* 22 (2000)., Y. Wolde-Rufael, "Energy Demand and Economic Growth: The African Experience," *Journal of Policy Modeling* 27 (2005). and Ang, "Economic Development, Pollutant Emissions and Energy Consumption in Malaysia.".

run implies that Tunisia is an energy dependent economy. The Tunisian economy may be vulnerable to energy shocks in which an energy shortage may adversely affect output growth.

VI. Summary and some policy implications

The aim of this country specific study is to understand long and short-run linkages between economic growth, energy consumption and carbon emission using Tunisian data over the period 1971-2004.

These linkages were largely under considered and unanswered for policy makers in Tunisia and this empirical research attempts to present some findings to better integrate the environment into economic development decisions.

Results of the cointegration study detect the presence of two cointegrating vectors. The first vector reveals a positive linkage between output and energy use and the second indicates that CO₂ emission and energy consumption are positively related in the long-run. In addition, results of the long-run relationships provide some evidence of “inefficient use” of energy in Tunisia, since environmental degradation tends to rise more rapidly than economic growth.

In the short run, empirical results provide support for causality running from CO₂ emissions growth to output growth, both in the short-run and the long-run. The results provide also some support of mutual causal and feedback relationship in the long-run. This pattern of development is consistent with the experiences of many developing countries.

These results have important implications for policy makers in Tunisia who should be mindful that a persistent decline in environmental quality may exert negative externalities to the economy through depressing the tourism sector and through affecting human health and thereby reduce productivity and growth in the future.

Since statistical results confirm that an increase in pollution level induces economic expansion and in order not to adversely affect economic growth, more efforts must be made to encourage Tunisian industry to adopt technology that minimizes pollution, as a serious environmental policy, although Tunisia has no commitment to reduce Greenhouse Gas (GHG) emissions.

In Tunisia, the potential exists for the development of other renewable energies (solar, wind, biogas and geothermic) and further efforts would require additional financing by policy makers.

In addition, the results of causality analysis do not support the view that energy and output are neutral with respect to each other in Tunisia and the finding of a bi-directional causality between output growth and growth in energy consumption in the long-run implies that Tunisia is an energy dependent economy.

The Tunisian economy may be vulnerable to energy shocks in which an energy shortage may adversely affect output growth. For this reason, it seems possible that energy conservation policies in Tunisia could be achieved through the rationalization of consumer and household demand and the reduction of the transportation sector consumption.

VII. References

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