CO_2 emissions, energy consumption and economic growth in Tunisia

Chebbi H. E. [1] and Boujelbene Y. [2]

[1] Institut Supérieur d'Administration des Affaires (ISAAS) / University of Sfax, Sfax, Tunisia
[2] Faculté de Sciences Economiques et de Gestion (FSEGS) / University of Sfax, Tunisia

Abstract — **The aim of this country specific study is to understand long and short-run linkages between economic growth, energy consumption and CO_2 emission using Tunisian data over the period 1971-2004. Statistical findings indicate that economic growth, energy consumption and CO_2 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. In the short run, results support the argument that economic growth exerts a positive "causal" influence on energy consumption growth. In addition, results from impulse response do not confirm the hypothesis that an increase in pollution level induces economic expansion. Although Tunisia has no commitment to reduce Greenhouse Gas emissions, energy efficiency investments and emission reduction policies will not hurt economic activities and can be a feasible policy tool for Tunisia.**

Keywords — **CO_2 emissions, Energy Consumption, Economic Growth, Tunisia.**

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 in the economic literature in 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 period 1947–1974. The empirical outcomes of the subsequent studies on this subject which differ in terms of the time period covered, country chosen, econometric techniques employed, and the proxy variables used in the estimation, have reported mixed results and supports and is not conclusive to present policy recommendation that can be applied across countries. Depend upon the direction of causality; the policy implications can be considerable from the point of view of energy conservation, emission reduction and economic performance.

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 tended to focus on vector error-correction model (ECM) and the cointegration approach. Masih and Masih (1996) used cointegration analysis to study this relationship in a group of six Asian countries and found cointegration 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 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. Paul and Bhattacharya (2004) found bidirectional causality between energy consumption and economic growth in India. 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 co-integrated 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.

The relationship between output and pollution level has also been well discussed in the literature of Environmental Kuznets Curve (EKC) where environmental degradation initially increases with the level of per capita income, reaches a turning point, and then declines with further increases in per capita income (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992). The conclusions of Hettige et al. (1992), Cropper and Griffiths (1994), Selden and Song (1994) and Grossman and Krueger (1995) are consistent with the EKC hypothesis. Martinez-Zarzoso and Bengochea-Morancho (2004) find evidence that CO_2 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 2008). Consequently, to avoid problems of misspecification, these two hypotheses must be tested under the same framework.

This study for the case of Tunisian economy tries overcoming the shortcoming literature related with the linkage between economic growth, energy consumption and pollutant emissions under the same integrated framework, following the idea of Ang (2007 and 2008). Tunisia appears to be an interesting case study given that it is one of the highest growth economies in Middle East and North Africa region and energy supply in this country is insufficient to meet the increasing demand. Also, this empirical country study may be useful to formulate policy recommendation from the point of view of energy conservation, emission reduction and economic performance.

II. DATA AND STATIONARITY PROPERTIES

In this empirical study, annual data for per capita real gross domestic product (PGDP), per capita of carbon dioxide emissions (PCO_2) as proxy for the level of pollution and environmental degradation and per capita energy use (PENE) in Tunisia are collected from the World Bank, World Development Indicators. The sample period covers data from 1971 to 2004, and series are transformed in logarithms so that they can be interpreted in growth terms after taking first difference.

The first step of this empirical work is to investigate the stationarity properties and establishing the order of -integration of each series (PGDP, PCO_2 and PENE) since only variables -integrated of the same order can be co-integrated. The combination of the unit root tests results suggests that the series involved in the estimation procedure are integrated of order one. This implies the possibility of cointegrating relationships.

III. LONG-RUN RELATIONSHIPS STUDY: A CO-INTEGRATION ANALYSIS

The next step is to investigate whether the series are co-integrated since the three variables were I(1). In this work, cointegration analysis has been conducted using the general technique developed by Johansen (1988, 1991 and 1992) and Johansen and Juselius (1990, 1992 and 1994). This approach has been applied to the system including the three selected variables (PGDP; PCO_2 and PENE).

After applying some tests to check for the correct specification of the model (lag order and deterministic components), cointegration tests indicated the existence of two cointegration vectors.

The estimated β and α parameters are presented in Table 1 (Panel A), where β is presented in normalized form. The two co-integrating vectors have been normalised by PGDP and PCO_2, respectively. As can be observed, all the parameters of the long-run equilibrium relationships are statistically significant and have the expected signs.

Table 1 Normalized cointegration relations β and loading coefficients α

Panel A

$$\beta' = \begin{bmatrix} 1.000 & --- & \underset{(-16.413)^{***}}{-1.124} & 0.148 \\ --- & 1.000 & \underset{(-18.872)^{***}}{-1.352} & 8.154 \end{bmatrix} \times \begin{bmatrix} PGDP \\ PCO_2 \\ PENE \\ Constante \end{bmatrix}$$

$$\alpha = \begin{bmatrix} \underset{(0.852)}{0.120} & \underset{(-1.337)}{-0.168} \\ \underset{(-0.603)}{-0.159} & \underset{(-2.017)^{***}}{-0.474} \\ \underset{(2.949)^{**}}{0.530} & \underset{(1.135)}{0.182} \end{bmatrix}$$

Panel B

$$\alpha = \begin{bmatrix} --- & \underset{(-5.295)^{***}}{-0.238} \\ --- & \underset{(-5.003)^{***}}{-0.331} \\ \underset{(7.790)^{***}}{0.532} & \underset{(3.018)^{***}}{0.203} \end{bmatrix}$$

LR-test (H_1: unrestricted model): $\chi^2_7 = 10.8742$

p-value = 0.1442

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 CO_2 emission and energy consumption are positively related and a 1% increase in PENE will originate an increase in PCO_2 by 1.352% in the long-run.

Based on the EKC hypothesis, these results provide some evidence of inefficient use of energy in Tunisia. In fact, environmental pressure tends to rise faster than economic growth) and the delinking economic growth from environmental degradation has not yet arisen (Stagl, 1999).

On the other hand, 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.

Moreover, in this empirical study, we have applied a sequential elimination strategy test to delete those regressors in the VECM (all the loading coefficients and Γ_i parameters) with the smallest absolute values of t-ratios until all t-ratios (in absolute value) are greater than some specified threshold value (Brüggemann and Lütkepohl, 2001). 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 1 (Panel B) shows the new loading coefficients for the reduced model.

In relation to the first co-integrating vector, the first comment is that parameters related with economic growth (α_{11}) and with PCO_2 emission (α_{21}) 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 co-integrating relationship between PENE and PCO_2 indicate that energy use react quicker than economic growth and CO_2 emission ($\alpha_{32}>\alpha_{21}>\alpha_{22}$). This result supports the idea of dissociation between energy use policy and pollution reduction policy in Tunisia.

IV. SHORT-RUN DYNAMICS

Once the VECM has been estimated, following Gil et al. 2007, short-run dynamics can be examined by considering the impulse response functions (IRF). These functions show the response of each variable in the system to a shock in any of the other variables.

The IRF are calculated from the Moving Average Representation of the VECM (Lütkepohl, 1993 and Pesaran and Shin, 1998): $Y_t = \sum_{i=0}^{\infty} B_i \varepsilon_t$ where matrices B_i (i=2,…,n) are recursively calculated using the following expression:

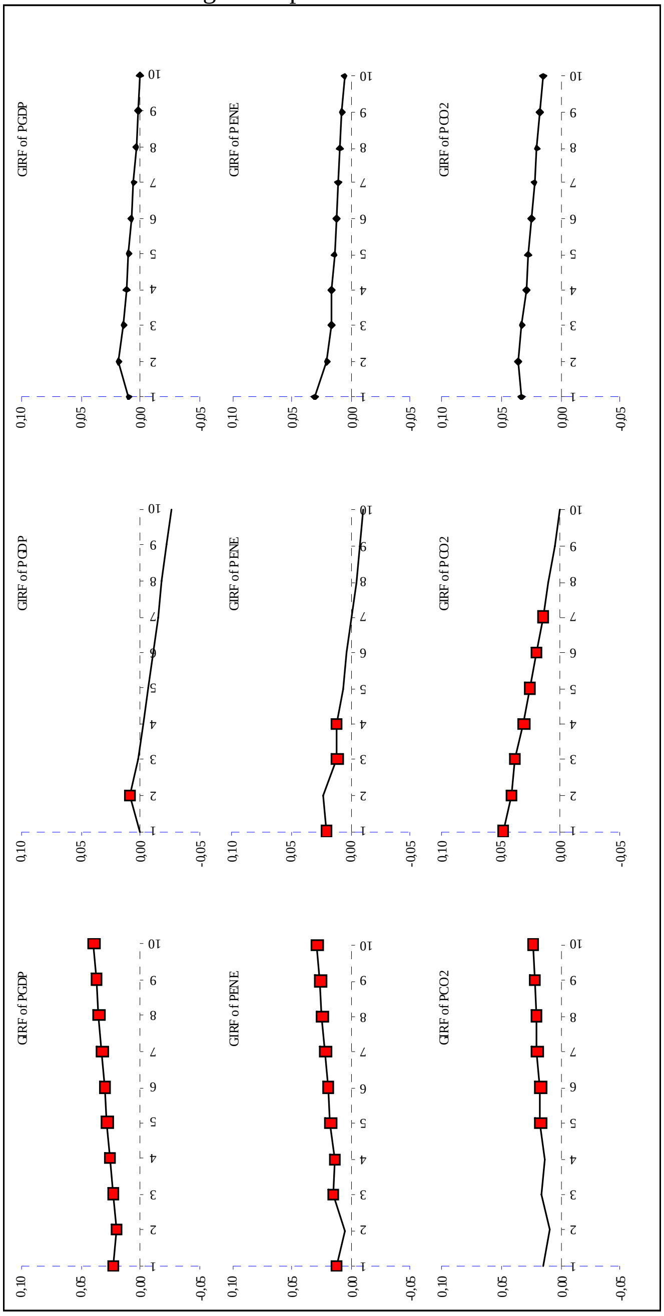
$$B_n = \Phi_1 B_{n-1} + \Phi_2 B_{n-2} + ... + \Phi_k B_{n-p}; \quad B_0=I_p; \quad B_n=0$$

for n<0; $\Phi_1 = I + \Pi + \Gamma_1$; and $\Phi_i = \Gamma_i - \Gamma_{i-1}$ (i=2,…,p).

Following Pesaran and Shin (1998) the scaled Generalized Impulse Response Functions (GIRF) of variable Y_i with respect to a standard error shock in the j^{th} equation can be defined as: $GIRF(Y_{it}, Y_{jt}, h) = \frac{e_i' B_h \Sigma e_j}{\sqrt{\sigma_{jj}}}$; $h = 0, \dots, n$ where e_{ls}(s=i, j) is the s^{th} column of the identity matrix.

The GIRF are unique and do not require the prior orthogonalisation of the shocks (the reordering of the variables in the system). On the other hand, the GIRF and the orthogonalised IRF (Cholesky) coincide if the covariance matrix, Σ, is diagonal and j=1. Standard deviations of impulse responses are obtained following Pesaran and Shin (1998). To analyse the short-run dynamics, we have considered the restrictions on the long-run parameters shown in the Table 1 and we have restricted the loading coefficients (2 restrictions) and Γ_i parameters (5 restrictions) which were non-significant to zero. Generalised impulse-response functions are plotted out in Figure 1.

Fig. 1 Responses of variables



Note: Responses marked with a square indicate 5% level of significance.

The results indicate that the initial impact of an output growth is positive and significant for PGDP and PENE, but insignificant for PCO_2.
In addition, the responses of PENE appear to be slightly larger than those of PCO2 and the significant output growth appears to have some permanent pressure on energy use and CO2 emissions providing some support that economic growth in Tunisia takes precedence over energy consumption in the short-run. These results are inline with the argument that economic growth exerts a positive causal influence on energy consumption growth.
Note also that the response of carbon emissions is only significant five horizons after the initial shock, indicating that higher growth in Tunisia may lead to pollution as consequence of emissions occurring during the production process.
On the other hand, the initial impact of a positive shock in PCO_2 is positive and significant for PENE and PCO_2, but insignificant for PGDP. Moreover, the response of output is only positive and significant two years after the initial shock in CO_2 emission.
Finally, the results show that the initial impact of a positive shock in energy consumption (PENE) is positive but statistically insignificant for PGDP, PENE and PCO_2.
In the short-run, the effect of an expansion in energy consumption on GDP and, as consequence, on CO_2 is non significant indicating that energy does not appear to be a stimulus factor for growth in Tunisia. On the other hand, the relevant emission reduction policy variable is energy use and reducing energy use will decrease carbon emissions. Since there does not appear to be an immediate and statistically significant impact of energy use on output, Tunisia may consider reducing energy consumption as a serious environmental policy that does not harm growth prospects.

V. SUMMARY AND CONCLUDING REMARKS

The aim of this country specific study is to understand long and short-run linkages between economic growth, energy consumption including CO_2 emission using Tunisian data over the period 1971-2004.
Results of the cointegration study reveal the presence of two cointegrating vectors in our system. The first cointegration vector reveals a positive linkage between output and energy use and second vector indicates that

CO_2 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, results support the argument that economic growth exerts a positive "causal" influence on energy consumption growth. For this reason, it seems possible that energy conservation policies could be achieved through the rationalization and reduction of consumer demand with a little impact on economic expansion.
In addition, results from impulse response do not confirm the hypothesis that an increase in pollution level induces economic expansion.
Although Tunisia has no commitment to reduce Greenhouse Gas (GHG) emissions, energy efficiency investments and emission reduction policies will not hurt economic activities and can be a feasible policy tool for Tunisia.
To conclude, it has to be said that the results presented in this paper depend on the variables and sample period chosen. Further analysis, including other variables and an extended sample period, could be conducted in the future.

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Corresponding author: Houssem Eddine CHEBBI
(chebbihe@planet.tn)