

Agricultural and non-agricultural outputs and energy consumption in Tunisia: empirical evidences from cointegration and causality

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Abstract — This short paper investigates the cointegration and causality link between energy consumption and agricultural, non-agricultural outputs (manufacturing sector and services sector) and overall gross domestic product in Tunisia for 1971-2003 period.

Empirical results suggest that there is only unidirectional causality running from agricultural and non-agricultural sectors to energy consumption as well as from overall GDP growth to energy consumption. This unidirectional causality signifies a less energy dependent economy and suggests that it is sectoral growth that drives the energy consumption in Tunisia and not vice versa.

Empirical results suggest also that Tunisian agricultural sector growth does not depend on energy, and high consumption of energy do not implies more productivity in the short run for this sector.

Keywords — energy consumption, output growth, causality, cointegration, Tunisia.

I. INTRODUCTION AND OBJECTIVE

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 during the three last decades. However, existing outcomes have varied considerably. Whether energy consumption stimulates, delays or is neutral to economic activities has motivated curiosity and interest among economists and policy analysts to find out 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 covered time period, chosen country, employed econometric techniques, 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.

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 output¹. Their empirical findings are generally inconclusive. Where significant results were obtained they indicate that causality runs from output to energy use.

Erol and Yu (1987) tested the data of six industrialized countries and found some indications of a causal relationship between energy and output in a number of industrialized countries with the most significant relationship being for Japanese data between 1950 and 1982. However, when the sample was restricted to 1950-1973, the relationship was no longer significant. Yu and Choi (1985) also found a causal relationship running from energy to GDP in the Philippines economy, but causality is reversed in the case of South Korea. Ebohon (1996) examines the causal directions between energy consumption and economic growth for two African economies (Nigeria and Tanzania). The results show a simultaneous causal relationship between energy and economic growth for both countries.

With advances in time series econometric techniques, more recent studies have tended to focus on vector error correction model (ECM) and the co-integration approach.

Masih and Masih (1996) used co-integration analysis to study this relationship in a group of six Asian countries and found co-integration between energy use and GDP in India, Pakistan, and Indonesia. No co-integration 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-

¹ See for example, Yu and Hwang (1984).

Adjaye (2000) tested the causal relationship between energy use and income in four Asian countries using co-integration 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 co-integration 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. Paul and Bhattacharya (2004) found bidirectional causality between energy consumption and economic growth in India. The empirical results by Oh and Lee (2004) for the case of Korea suggested the existence of a long-run bidirectional causal relationship between energy and GDP, and short-run unidirectional causality running from energy to GDP using vector error correction model (VECM). Based on a production function approach, Ghali and El-Sakka (2004), develops a vector error-correction (VEC) model to test the existence and direction of causality between output growth and energy use in Canada. Their empirical findings indicate that the long-run movements of output, labour, capital and energy use in Canada are related by two co-integrating vectors and the short-run dynamics of the variables indicate that Granger-causality is running in both directions between output growth and energy use.

Wolde-Rufael (2005) investigated the long run and causal relationship between real GDP per capita and energy use per capita for 19 African countries for the period 1971–2001. This work provides evidence of a long run relationship between energy consumption and economic growth for only eight of the 19 countries and a causal relationship for only 10 countries. Using co-integration analysis, Wietze and Van Montfort (2007) showed 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 have a negative impact on economic growth in Turkey.

The plethora of previous works have reported mixed results and supports and is not conclusive to present policy recommendation that can be applied across countries and for all economic sectors. 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.

This study tries overcoming the shortcoming literature related with understanding long-term energy transitions and growth trajectories for the North African economies and attempt to investigate the causal link between output growth and energy consumption between i) total primary energy (ENER) and ii) overall economic activities (GDP); iii) agricultural (AGR); iv) industrial (IND) and v) services value added (SER) using vector correction model for the case of Tunisia within 1971–2003.

Also, in this empirical paper, with the consideration of the main sectors of the Tunisian economy, time series data, cointegration and causality analysis can draw some specific answers for the Tunisian case, on whether energy consumption affect sectoral output, whether sectoral output cause energy consumption, or whether a two-way causal relationship exists.

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 economic indicators is the result of the series of macroeconomic reforms principally since the adoption and implementation of the structural adjustment programme in 1986.

Tunisia appears to be an interesting case study given that it is one of the highest growth economies in Africa and energy supply in this country is insufficient to meet the increasing demand. This empirical country study may be useful to formulate policy recommendation for energy efficiency and conservation in the move towards sustainable development for African economies. In fact, having a better view on link between energy consumption and GDP in Tunisia can help untangle the question to which extent economic growth can be sustained under various energy availability scenarios.

Conclusions for Tunisia may be relevant for a number of countries, which have to go through a

similar development path, increasing the pressure of the already scarce energy resources.

The rest of paper is organized as follows. Section 2 briefly describes the Tunisian energy context. Section 3 sets out the data used in this study and their stochastic characteristics. Section 4 presents the empirical findings from cointegration and causality tests. Finally, some concluding remarks and some policy implications are outlined.

II . TUNISIAN ENERGY SITUATION

The increase of total primary energy consumption for 1990-2005 period is around 100%. This is attributed to the fact that Tunisia has experienced rapid economic growth during the last years 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 population. The evolution of annual energy consumption and resources in Tunisia during the period 1990-2005 is showed in Table 1.

Table 1 Energy resources and consumption in Tunisia

	1990	1995	2000	2005
Petroleum (Thousand Barrels per Day)				
Total Oil Production	97.7	90.1	80.5	76.9
Crude Oil Production	93.0	89.2	78.7	75.0
Consumption	63.2	70.0	84.5	90.0
Net Exports / Imports	34.5	20.0	- 4.0	- 13.1
Natural Gas (Billion Cubic Feet)				
Production	12.0	11.7	66.4	88.3
Consumption	54.0	57.6	108.8	151.9
Net Exports / imports	- 42.0	- 45.9	- 42.4	- 63.6
Electricity (Billion Kilowatt-hours)				
Net Generation	5.2	6.9	10.0	12.8
Net Consumption	4.6	6.2	8.8	11.2
Total Primary Energy (Quadrillion Btu)				
Production	0.2	0.2	0.2	0.3
Consumption	0.2	0.2	0.3	0.4

Sources: Energy Information Administration (EIA).

Based on the 2005 values, the consumption of primary energy exceeded 8.5 Mtoe 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 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%).

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 sources.

III . DATA AND STATIONARITY PROPERTIES

In this empirical study, we use total energy consumption (ENER), value added for agricultural sector (AGR); value added of manufacturing sector (MAN); value added for services sector (SER) and overall gross domestic product (GDP) to investigate cointegration and causality. Annual data from 1971 to 2003 are collected from the World Bank, World Development Indicators (WDI). All variables are indexed (basis 100=2000) and transformed in logarithms.

The first stage of this empirical work involves investigating the stationarity properties and establishing the order of integration of each of the time series (AGR, MAN, SER, GDP and ENER) since only variables integrated of the same order can be cointegrated and the causality tests are valid if the variables have the same order of integration.

When the number of observations is low, unit root tests have little power. For this reason we have examined the results from two different tests: the Augmented Dickey-Fuller (ADF) (Dickey and Fuller,

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.

1979, 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.

Table 2 Results of the ADF and KPSS tests

Panel A: ADF test (null hypothesis is non-stationarity)										
Variables	Level form				First differences					
	Intercept and time trend	Lags	Intercept, no time trend	Lags	Intercept and time trend	Lags	Intercept, no time trend	Lags		
	AGR	-2,78	0	-1,30	1	-7,56	0	-7,51	0	
MAN	0,13	1	-4,18	1	-9,19	0	-2,26	1		
SER	-0,73	0	-5,09	0	-6,02	0	-3,78	0		
GDP	-1,26	0	-4,36	0	-6,44	0	-4,51	0		
ENER	-2,01	1	-2,54	1	-7,45	0	-6,69	0		
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)										
Variables	Level form				First differences					
	l = 1		l = 3		l = 1		l = 3			
	η_μ	η_τ	η_μ	η_τ	η_μ	η_τ	η_μ	η_τ		
AGR	1,72	0,28	0,92	0,20	0,17	0,03	0,63	0,05		
MAN	1,70	0,42	0,91	0,24	1,03	0,04	0,76	0,06		
SER	1,71	0,40	0,92	0,23	1,11	0,05	0,72	0,06		
GDP	1,70	0,40	0,92	0,23	1,00	0,05	0,68	0,06		
ENER	1,68	0,34	0,91	0,20	0,46	0,07	0,42	0,08		
Critical values										
level stationarity					trend stationarity					
1%	0,74					0,22				
5%	0,46					0,15				
10%	0,35					0,12				

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.

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 (1 and 3). The KPSS statistics does not reject the I(0) hypothesis for the first-differenced series at conventional levels of statistical significance. Therefore, the combined

results of ADF and KPSS tests suggest that all series involved in the estimation procedure appear to be I(1).

IV . TESTING FOR COINTEGRATION AND CAUSALITY

The next step is to investigate whether the series are cointegrated. Cointegration is explored with Johansen' likelihood ratio trace test (Johansen, 1988 and Johansen and Juselius, 1990). These tests check the number the cointegration relations in a VAR framework and use the full information in all time series involved. Since only two I(1) variables are considered simultaneously, the only null hypothesis of interest is no cointegration relation between them. If that hypothesis is rejected, we can conclude that there is a cointegration relation.

This stationary linear combination of the two variables converges to a long-run equilibrium over time. Also, if a pair of series (that is, {ENER and AGR}; {ENER and MAN}; {ENER and SER} and {ENER and overall GDP}) are cointegrated, the bivariate cointegrated system must have a causal ordering in at least one direction (Engle and Granger, 1987).

In the present work, the cointegration tests are based on a model with restricted constant in the cointegration space. Despite the fact that the underlying variables are trended, they move together, and it seems unlikely that there will be a trend in cointegrating relation between variables³.

The results of cointegration are given in Table 3 and they suggest a cointegration relation between {ENER and AGR}; {ENER and MAN}; {ENER and SER} and {ENER and overall GDP}.

Table 3 Results of Johansen Trace tests for cointegration

		$H_0 : r=0$	$H_0 : r=1$
	Critical Value (95%)	19.26	9.24
Agricultural output	{ENER & AGR}	30.54	5.34
Non-agricultural outputs	{ENER & MAN}	39.10	2.99
	{ENER & SER}	35.45	7.90
Overall GDP	{ENER & GDP}	34.52	6.47

³ Since the cointegration test results are sensitive to the number of lags included in the underlying VAR model, optimal number of lags for cointegration test is determined on the basis of the residual misspecification tests of the VAR model. For a lag length of 2, the VAR model residuals have been found to be statistically white noise.

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 (Granger, 1988).

The VECM contains the cointegration relation built into the specification so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegrating relationships while allows for short-run adjustment dynamics.

Engle and Granger (1987) showed that if two series are cointegrated, the VECM can be written as follow:

$$\Delta Z_t = \alpha_Z + \sum_{i=1}^k \beta_i \Delta Z_{t-i} + \sum_{i=1}^k \gamma_i \Delta \text{ENER}_{t-i} + \lambda \text{ECT}_{t-1} + \varepsilon_{Zt} \quad (1)$$

$$\Delta \text{ENER}_t = \alpha_{\text{ENER}} + \sum_{i=1}^k \beta_i \Delta \text{ENER}_{t-i} + \sum_{i=1}^k \gamma_i \Delta Z_{t-i} + \lambda \text{ECT}_{t-1} + \varepsilon_{\text{ENER}t} \quad (2)$$

where $Z = \{\text{AGR}; \text{MAN}; \text{SER} \text{ and } \text{GDP}\}$, ECT_{t-1} refers to the error correction term and ε_t are Gaussian residuals.

In this work, we explore overall strong exogeneity that imposes stronger restrictions by testing the joint significance of both the lagged dynamic terms and error-correction terms.

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.

Statistical results presented in Table 3, suggest that there is unidirectional causality running from AGR to ENER; from MAN to ENER; from SER to ENER and from overall GDP to ENER and as Wolde-Rufael (2006) says, past values of economic growth and past values of value added for agricultural sector, manufacturing sector and services sector, have a predictive ability in determining the present values of energy consumption.

The reverse causalities, i.e. ENER do not Granger-cause AGR, MAN, SER and GDP growth are accepted at the usual confidence level.

The unidirectional causality running from overall GDP and from the three sectors considered in this study imply that Tunisian economic development seems to have taken precedence over energy consumption and that economic growth caused greater

demand for energy consumption in agricultural and non-agricultural sectors.

Table 4 Results of non-causality tests

	Overall strong exogeneity	Test	P-value
Agricultural output	H_0 : ENER do not cause AGR	0.005	0.999
	H_0 : AGR do not cause ENER	14.170	0.003
Non-agricultural outputs	H_0 : ENER do not cause MAN	0.348	0.951
	H_0 : MAN do not cause ENER	32.860	0.000
	H_0 : ENER do not cause SER	1.524	0.677
Overall GDP	H_0 : SER do not cause ENER	19.052	0.001
	H_0 : ENER do not cause GDP	0.818	0.845
	H_0 : GDP do not cause ENER	21.329	0.000

V . SUMMARY AND SOME POLICY IMPLICATIONS

This country specific study check for cointegration and causality between energy consumption (ENER), and respectively, output for agricultural sector (AGR); output of manufacturing sector (MAN); output for services sector (SER) and overall gross domestic product (GDP) using Tunisian data.

The empirical results show that ENER is bi-cointegrated with the mains sectors of Tunisian economy (AGR, SER and MAN) and also with the overall GDP for 1971-2003 period.

The error correction model approach reveal one-way causality running from overall GDP to ENER and from agricultural and non agricultural sectors (AGR, SER and MAN) to ENER.

This statistically suggests that it is sectoral growth that drives the energy consumption in Tunisia and not vice versa.

This unidirectional causality running from GDP to energy consumption signifies a less energy dependent economy and suggests that Tunisian agricultural sector growth does not depend on energy, and high consumption of energy do not implies more productivity in the short run for this sector.

Given that energy supply in Tunisia is insufficient to meet the increasing demand and the Tunisian government still subsidizes a percentage of the fuel price, energy conservation measures and regulatory reforms may be implemented with little or no adverse effect on economic growth.

In the other hand, although Tunisia has no commitment to reduce Greenhouse Gas (GHG)

emissions, by the Kyoto Protocol, energy efficiency investments and emission reduction policies will not hurt economic activities and agricultural productivity and can be a feasible policy tool for Tunisia.

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