

Energy Consumption-Economic Growth Nexus: Does the Level of Aggregation Matter?

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ABSTRACT: This study investigates the causal relationship between energy consumption and economic performance for the total economy as well as for industry, transport, and residential sectors for Tunisia during the period 1980-2007. The application of Vector error correction model (VECM) for non-stationary and cointegrated series suggests that causality directions at aggregated and disaggregated levels are mixed. However, the findings have important policy implications. While at the level of the total economy, energy plays an important role in development of Tunisian economy, it seems not to have an impact on economic performance at sectoral level. We conclude that results appear to be dependent on the level of aggregation and therefore policy advices should be given with caution.

Keywords: Energy sector; Economic growth; Granger causality; Vector Error Correction Models; Tunisia.

JEL Classifications: C01; C32; Q43

1. Introduction

The growing concerns over energy scarcity and the sharp increase in its prices in recent years have renewed interests in the implementation of appropriate energy policies. Although, the effect of energy consumption on economic growth at the level of the total economy has been the subject of many empirical studies, little attention has been paid to examine such a relationship at sectoral level. It has been discussed that conflicting results about the direction of causality relationship may arise due to the country or group of countries considered, econometric techniques, variables incorporated and time series included in the study. According Gross (2012), another, even more important reason for why the evidence is so weak is the level of aggregation. The author has recommended the use of the appropriate level of aggregation when studying the energy-growth nexus. The author has argued that an absence of causality at the aggregate total economy does not indicate an absence of causality at disaggregate level¹. Therefore, policy implications could be misleading and affect individual sectors in both short and long run.

The causal relationship between energy consumption and economic growth at aggregate and/or disaggregate level has been recently studied by Jobert and Kranfil (2007), Zachariadis (2007), Bowden and Payne (2009), Costantini and Martini (2010), Tsani (2010), Cheng-Lang et al. (2011)². The case of total energy consumption and energy used in industrial sector in Turkey was analyzed by Jobert and Kranfil (2007). The authors found an instantaneous causality between energy consumption

¹ "If evidence for Granger causality cannot be found at the level of the total economy, the implication that no causality exists at all is myopic (Simpson's Paradox)", (Gross, 2012).

² A detailed survey of literature on energy consumption-economic growth nexus can be found in the study of Ozturk (2010) and Binh (2011).

and income, while at the long-run a neutral relationship was proved. Zachariadis (2007) used data for G7 countries from 1949 to 2004. The results indicate no evidence for causality at the level of the total economy, but for services as well as transport sectors, GDP Granger causes energy consumption. The author concluded that one should be cautious when drawing policy implications with the aid of bivariate causality tests on small samples. Bowden and Payne (2009) used USA time series from 1949 to 2006 to analyze primary energy consumption-GDP nexus using aggregate and sectoral measures. The authors found different results but they concluded that one should be prudent when using energy use by sector and total GDP as a pair of variables. Costantini and Martini (2010) used data for OECD and non-OECD countries to check the causality between economic growth and energy consumption for different sectors. For industrial sector, the two groups of countries show similar trends at the short-run, while they behave differently toward energy consumption at the long-run. For transport sector, different results were obtained for the two sub-samples, but similar conclusions were derived from residential sector indicating no causality relationships in both developed and developing countries. Tsani (2010) studied the case of Greece from 1960 to 2006 and found different results at aggregated and by sectors (industrial, residential, and transport). Hence, different policy implications were driven for different sectors. Cheng-Lang et al. (2011) investigated the causal relationship between real GDP and electricity use in industrial and residential sectors using quarterly data from 1982 to 2008 in Taiwan. The authors used two types of causality, linear and non-linear. Different results for different sectors were obtained according the econometric methodology used.

In a recent paper, Belloumi (2009) investigated the causal relationship between energy consumption and economic growth for the total economy in Tunisia during the period 1971-2004. The author concluded that energy can be considered as a limiting factor to GDP growth. Does this conclusion still valid when investigating the causality for the different sectors? The present attempt aims to give a response to this question by explaining the causality between energy and economic performance in the most energy-intensive sectors in Tunisia (industrial, transport, and residential).

The rest of the paper is organized as follows. Section 2 reviews the evolution of energy use in Tunisia focusing on main intensive-energy sectors. Section 3 describes the methodology and data used. Section 4 provides the analysis of empirical results. Section 5 concludes the paper.

2. Energy Sector in Tunisia

From historical point of view, the energy sector in Tunisia has known some ups and downs. Until the end of 90s, Tunisia had been an exporting country and during the 80s, the oil exportations had assured more than 50% of currencies takings. Whereas from the beginning of the last decade the country has become a net importer of hydrocarbons. This takes the Tunisian intensive-energy sectors in very sensitive situation especially with the sharp increase in energy prices in recent years.

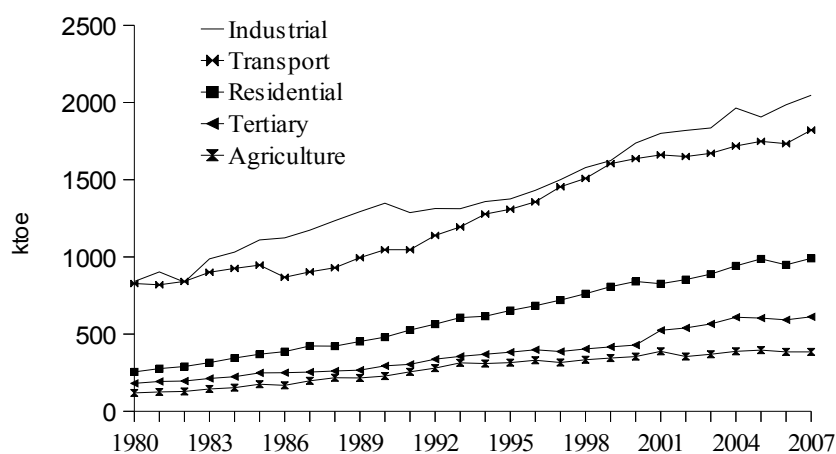


Figure I. Total energy consumption by end-use sector
source: own compilation

The industrial, transport and residential sectors have the most share of energy consumption in Tunisia. For example, in 2007, they represent about 83% of total energy consumption, while the tertiary and the agriculture sectors represent only 17%. Figure I display the evolution of energy consumption by end-use sector in Tunisia from 1980 to 2007.

Given the dominance of industrial, transport and residential sectors in ultimate energy use, our descriptive as well as econometrical analyses will focus only on these three sectors. Moreover, we will consider that energy consumption depends only on the three basic components: oil, electricity, and natural gas because the other energy categories represent very small proportions and/or their consumption statistics are integrated in those of basic components.

2.1 Industrial sector

The industrial sector occupies the first place in total energy consumption of the country with a share of 35% in 2007. This sector consumes about 2047 kilo tonnes oil equivalent (ktoe) which has increased about 3.1% within last year. The most energy component in this sector is oil with a total consumption of 960 ktoe. The next two important components are natural gas and electricity with 687 ktoe and 400 ktoe respectively. Figure II illustrates the shares of each component in total energy consumption for industrial sector from 1980 to 2007.

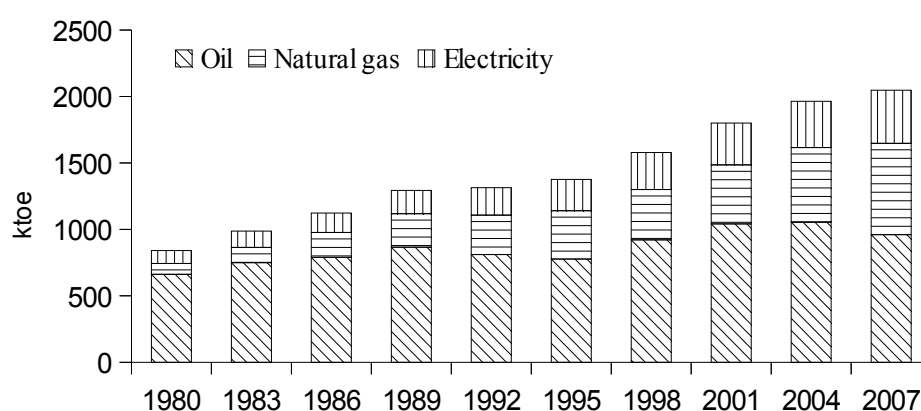


Figure II. Evolution of industrial energy consumption by component

source: own compilation

The industrial sector plays a significant role in the Tunisian economy. It contributes significantly to the Gross Domestic Product, employment, gross fixed capital formation, merchandise exports, and the use of advanced technologies. Accordingly, it has been called upon to play a key role in the transformation and development of the Tunisian economy since the launching of market oriented reforms. The industrial value added has expanded rapidly from less than 8% in 1960 to 26% in 2007. During the period 1980-2007, the average annual growth rate in value added of industrial sector has been above 10%. The increase in performance of this sector has been accompanied by an average yearly growth rate in energy consumption of about 8.70%.

2.2 Transport sector

The transport sector by about 31% of ultimate energy consumption has the second place after the industry sector, but it stills the first consumer of oil component by nearly 47% of total oil consumption in the country. The energy consumption in the transport sector is essentially based on oil component with more than 99% and electricity which represents only 0.5% in 2007. This intensive dependency on oil consumption makes this sector as an important transmitter of greenhouse gas with a share above 25%. During the period 1980-2007, the average yearly growth rate in energy consumption in transport sector is about 7.85% which is very close to the average annual growth rate in industrial sector.

The transport sector plays an important role in the development of Tunisian economy. It employs 120000 persons (107000 in the public sector and 13000 in the private one), and generates about 14% of total investment in the country. However, the sharp increase in price of petroleum in recent years lets this sector (which is oil dependent) in sensitive situation which would influence economic growth of Tunisia. Hence, the government should adopt some policies of energy conservation such as encouragement of public transport, periodic control on vehicles.

2.3 Residential sector

The residential sector by about 17% of ultimate energy consumption occupies the third place behind the industrial and transport sectors. Total energy consumption in residential sector in 2007 reached to 990.5 ktoe which has increased by about 4.37% within last year. During the period 1980-2007, the average yearly growth rate in energy use in this sector is nearly 13.86% which is the highest rate among all other sectors. The most used carrier in the residential sector is oil with a total consumption of 492 ktoe in 2007, but its consumption has known a gradual decrease in 2007 and 2006 in comparison with its values in last years (see Figure III). The decrease in oil consumption is accompanied by an increase in consumption of electricity and natural gas which have an average yearly growth rate about 28.71% and 89.73% respectively from 1980 to 2007. The decrease in oil consumption and the increase in electricity and natural gas consumption imply that there is a tendency to use more clean energy. Figure III illustrates the trend of total energy consumption for residential sector by carrier from 1980 to 2007.

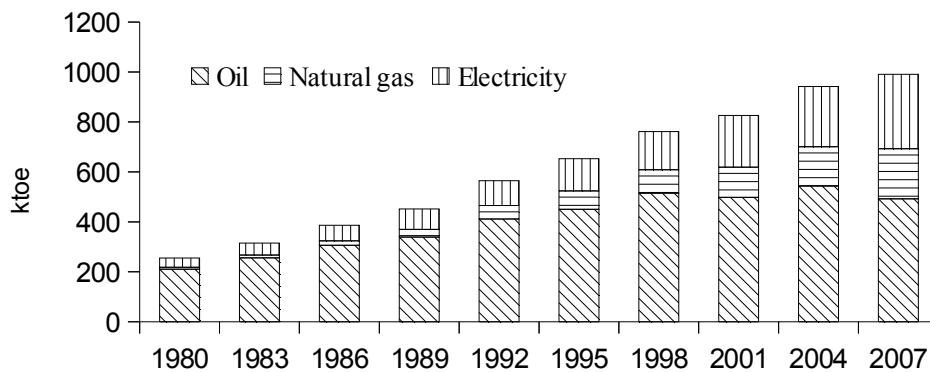


Figure III. Evolution of residential energy consumption by component

source: own compilation

Energy use in the residential sector includes energy for heating, cooking, cleaning, washing, drying, lighting, cooling, and for entertainment. However, in Tunisia, energy saving in this sector creates a win-win scenario. Households frugal with energy reduce the amount of their power bills and they help lessen the budget allocations by the state to subsidize the consumption. Thus, it is wise to invest in programs and actions to eliminate waste and streamline consumption.

3. Methodology and Data

To test the direction of causality between aggregated and disaggregated energy consumption and economic growth in Tunisia, we follow the now widely used Engle-Granger methodology. We first search for the order of integration of the different time series using the Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) and Phillips-Perron (PP) tests (Phillips and Perron, 1988). Once, the series are integrated of the same order a long-run relationship (cointegration vector) could be exist. To test the presence of cointegration of the variables in this study, Johansen's approach (Johansen, 1988; Johansen and Juselius, 1990) is employed. If the presence of cointegration is confirmed, then Engle and Granger (1987) error correction specification can be used to test for Granger causality and show its direction. According Engle and Granger (1987), the vector error correction model (VECM) for the per capita variables can be written as follows:

$$\Delta y_t = \beta_{10} + \sum_{i=1}^{k11} \beta_{11i} \Delta y_{t-i} + \sum_{j=1}^{k12} \beta_{12j} \Delta x_{t-j} + \beta_{13} ECT_{t-1} + \mu_{1t} \quad (1)$$

$$\Delta x_t = \beta_{20} + \sum_{i=1}^{k21} \beta_{21i} \Delta x_{t-i} + \sum_{j=1}^{k22} \beta_{22j} \Delta y_{t-j} + \beta_{23} ECT_{t-1} + \mu_{2t} \quad (2)$$

Where Δ is the difference operator, y_t presents economic performance and x_t is the energy consumption for the total and by sector; μ_{1t} and μ_{2t} are white noise error terms; ECT_{t-1} gives the lagged error

correction term derived from the long-run effect. The existence of short-run causality meaning that the dependent variable responds only to short-term shocks can be determined by testing the null hypothesis of $\beta_{12} = 0$ in the equation (1) and $\beta_{22} = 0$ in the equation (2). To determine whether economic growth causes energy consumption or vice versa in the long-run, we look at the coefficients of the ECT's in equations (1) and (2) by testing the null hypothesis of $\beta_{13} = 0$ in equation (1) and $\beta_{23} = 0$ in equation (2) based on the t-statistics. These two coefficients measure the speed of adjustment. We can also check whether these two sources of causality are jointly significant by testing the joint hypothesis of $\beta_{12} = \beta_{13} = 0$ in equation (1) and $\beta_{22} = \beta_{23} = 0$ in equation (2). The rejection of the joint hypothesis indicates that after a shock to the system, both these sources of causality are responsible for the re-establishment of long-run equilibrium.

Annual time series data for Tunisia from 1980 to 2007 are used in the present study. Bivariate relationship at aggregate level includes total energy use for the whole economy (EC) and GDP. Whereas, bivariate relationships at disaggregate level consider data on energy use (IEC) and value added (IVA) for the industrial sector, energy use (TEC) and GDP for the transport sector, and energy use (REC) and the household final consumption expenditures (HFE) for the residential sector. For this last sector, we have used the GDP to represent the economic dimension, which is a common choice in literature (Zachariadis, 2007; Costantini and Martini, 2010)³. Data on economic performance are obtained from World Bank World Development Indicators (WDI, 2010) and are expressed in constant 2000 US\$. Energy data are sourced from official source, National Agency for Energy Conservation (NAEC) and are expressed in terms of kg oil equivalent. All series are taken in terms of per capita and defined in natural logarithms.

4. Empirical Results

As mentioned in the methodology section, the analysis begins by testing the order of integration of the series in hand. Table 1 reports the results for both ADF and PP unit root tests. As shown in table I, all series are not stationary in levels but stationary in first difference. Hence, they are integrated of order one (I(1)).

Table 1. Results of ADF and PP unit root tests

Variables	ADF test		PP test	
	Level	First difference	Level	First difference
GDP	2.228(0)	-4.996(0)*	4.549(6)	-4.997(1)*
IVA	0.855(0)	-4.866(0)*	1.082(3)	-4.873(1)*
HFE	1.374(2)	-5.352(11)*	2.754(1)	-4.183(3)*
EC	-0.017(1)	-8.077(0)*	-0.049(1)	-8.074(1)*
IEC	-0.919(0)	-7.389(0)*	-0.919(0)	-7.389(0)*
TEC	-0.012(0)	-4.618(0)*	-0.063(1)	-4.616(1)*
REC	-1.959(0)	-5.499(0)*	-1.294(1)	-5.499(0)*

* denotes the rejection of null hypothesis of non-stationarity of the variable at 1% level of significance. For the ADF and the PP tests the values in parentheses indicate the optimum number of lags and bandwidth chosen based on Schwarz Bayesian Criterion (SBC) and Newey-West Bartlett kernel, respectively. The critical values for the ADF and PP tests t-statistics are based on MacKinnon (1996). Note that only intercept is included in the tests.

Once the series are found to be integrated of the same order, an investigation of potential cointegration relationship is carried out using both the Johansen maximum eigenvalue (λ -max) and trace statistics to test the null hypothesis of no cointegration. The results reported in table 2 show that

³ Gross (2012) has suggested that the use of total GDP instead of value added of transport is not appropriate choice especially when the share of value added of the transport sector in total GDP is negligible.

the values of the calculated tests statistics are greater than the critical values which imply the rejection of the null hypothesis. Then, long-run relationships exist between the pairs of considered series.

Table 2. Johansen test for the number of cointegration relationships

Models	Eigenvalue	$H_0: r^a$	Trace	λ -max	Critical values at 5%	
					Trace	λ -max
(GDP, EC)	0.561	0	26.452	21.407	20.261	15.892
	0.176	1	5.044	5.044	9.164	9.164
(IVA, IEC)	0.641	0	32.997	23.607	20.261	15.892
	0.335	1	9.389	9.389	9.164	9.164
(GDP, TEC)	0.529	0	23.095	19.586	20.261	15.892
	0.126	1	3.508	3.508	9.164	9.164
(HFE, REC)	0.502	0	25.063	16.746	20.261	15.892
	0.292	1	8.317	8.317	9.164	9.164

^a r indicates the number of cointegration relationships. The critical values for maximum eigenvalue and trace test statistics are given by Johansen and Juselius (1990). We assume here that the level data have no deterministic trends and the cointegrating equations have intercepts.

Cointegration between series indicates a confirmed relationship in long-run but it fails to give the direction of causality. Hence, to shed light on the causal relationship, a VECM is used to test the short-run as well as long-run Granger causality, and the results are reported in table 3. The analysis of the Granger causality will be conducted according each energy sector.

Full economy

It can be seen that The χ^2 -Wald statistics on the lagged explanatory variables of the VECM design the absence of short-run causal effects in either direction. This implies that Tunisian economic growth does not rely on energy use and energy sector is not a limiting factor to growth. The conclusion drawn from short-run context is not valid in the long-run context since the t-statistics on the coefficients of the ECT indicate the significance of the long-run causal effects. The ECT coefficients in the GDP and energy consumption equations are -0.10 and -0.059 respectively. This implies that the adjustment coefficients are 10% and 5.9% in the two equations.

Industry

We find a uni-directional short-run Granger causality running from industrial value added to energy consumption. These findings indicate that the knowledge of past values of industrial production influences the prediction of energy consumption. This is expected consequence as industry sector is the biggest consumer of energy. However, in the long-run the coefficient of the ECT in energy equation is significant but not negative which does not imply a presence of causality.

Transport

The results of non-causality hypothesis test indicate absence of Granger causality between energy consumption in transport sector and GDP in either direction and in either run. This neutrality suggests that any public conservation policies in energy sector do not harm transport sector amelioration. On the other hand, any change in the performance of transport sector would not have an impact on energy consumption.

Residential

The estimations of residential energy sector suggest that a feedback relationship exists in the short-run between household final consumption expenditures (proxy of income) and energy consumption, showing that household energy use level is positively influenced by the household income which is a fundamental hypothesis of demand modeling. This finding is also confirmed in long-run as the coefficient of ECT in energy equation is negative and statistically significant. On other hand, an increase in energy consumption would affect household income in short-run.

Table 3. Granger causality tests

Causality direction	Short-run causality		Long-run causality	
	Wald chi-sq statistics	p-value	$\beta_{13}; \beta_{23}$	t-statistics
Full economy				
$\Delta GDP \rightarrow \Delta EC$	0.034	0.852	-0.059	-1.66***
$\Delta EC \rightarrow \Delta GDP$	0.201	0.653	-0.100	-4.823*
Industry				
$\Delta IVA \rightarrow \Delta IEC$	18.348	0.0011**	0.485	4.398*
$\Delta IEC \rightarrow \Delta IVA$	5.466	0.242	0.147	0.775
Transport				
$\Delta GDP \rightarrow \Delta TEC$	1.840	0.174	0.01	1.950***
$\Delta TEC \rightarrow \Delta GDP$	0.228	0.632	0.033	4.971*
Residential				
$\Delta HFE \rightarrow \Delta REC$	13.418	0.003*	-0.127	-3.796*
$\Delta REC \rightarrow \Delta HFE$	15.525	0.0014**	-0.003	-0.147

*, ** and *** denote significance level at 1%, 5% and 10% respectively.

Comparing our findings with results of earlier studies, we argue that at aggregate level, our results are in line with those of Belloumi (2009) who found an existence of a feedback relationship between total energy consumption and economic growth in the case of Tunisia. This bidirectional relationship was also found by Ozturk and Acaravci (2010) in the case of four Eastern European countries (Albania, Bulgaria, Hungary and Romania) and Belke et al., (2011) for the OECD countries. At disaggregated level, our findings are similar to those found by Tsani (2010) who estimated a bidirectional causal relationship between energy consumption and economic growth in the case of residential sector and absence of causality in the case of transport sector. In the case of industrial sector, our estimation results which indicate a unidirectional relationship running from industrial value added to energy consumption are supported by Costantini and Martini (2010) when using data of OECD and non-OECD countries.

5. Conclusion

We examined the Granger causality approach to investigate the relationship between energy consumption and economic growth in Tunisia during 1980-2007 for the total economy as well as for the industry sector, transport sector, and residential sector. While a substantial body of literature has been related to the analysis of causality between energy consumption and growth at aggregated level (total economy), a little attention has been paid to the investigation of such a relationship at disaggregated level (by different sectors). The adoption of disaggregated analysis has the main advantage that it allows distinguishing between trends and patterns of different sectors towards energy consumption and therefore helping to implement appropriate policies.

The results of estimations are mixed. At aggregate level, the estimated bidirectional causal relationship between energy consumption and growth in long-run suggests that energy could be considered as limiting factor to Tunisian economic growth and economic growth stimulates further energy consumption. In contrast, an absence of causal relationship is found in the short-run. The disaggregated analysis gives different directions of causality for different sectors. Results in the case of industry sector indicate a unidirectional causality running from industrial value added to energy consumption in the short-run but the neutrality hypothesis is found in the long-run. This implies that energy demand is strongly dependent from the economic performance of industry sector, while adopting some policies of energy conservation would not harm industrial production. This last conclusion remains valid in the case of transport in both short and long-run sector as energy consumption does not Granger cause the performance of transport sector and vice versa. Finally, estimation results suggest bidirectional causality between energy use in residential sector and

household income in the short-run, but a unidirectional causality running from household income to energy consumption in the long-run. The increase in household income will be followed by improvement in living standards which leads to higher demand for energy. Whereas, in long-run, no matter what measures are implemented in the residential sector the private household income will remain unaffected.

In summary, the current study on the energy consumption-economic growth nexus proves the fundamental role of energy resources in increasing performance of total economy. However, at sectoral level, energy consumption seems to not be a limiting factor for industry, transport and residential sectors.

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