Energy consumption in Tunisia over 1990–~~-~~2008: A decomposition analysis using Logarithmic Mean Divisia Index technique

Sana Essaber-Jouini *

ISCAE, University of Manouba, Tunisia; Laboratoire d'Economie et de Gestion Industrielle (LEGI), Ecole Polytechnique de Tunisie

Abstract

~~By~~ We apply ~~ing~~ the logarithmic mean Divisia index to a dataset of ~~4~~ four economic-energy-using sectors (manufacturing, agriculture, transport and tertiary) and the residential sector, ~~we~~ and examine ~~study~~ the ~~underlying forces~~ factors contributing to ~~driving the growing~~ increase in ~~total~~ energy consumption and changes in patterns of use ~~the contributing factors of the changes of~~ in Tunisia. ~~n's energy use in these sectors and~~. ~~w~~ ~~e find that for economic sectors, e~~Energy consumption in commercial sectors is mostly influenced by activity ~~change~~ and intensity changes ~~but for~~ and in residential sector, ~~there are~~ income ~~change~~ and population changes ~~who~~ contribute the most to the change in final energy use.

1. Introduction

~~During~~ Over the past decades, energy analysts and policy makers have shown increasing concern over ~~about~~ the adverse effects of energy use. Two major ~~reasons~~ factors are behind this interest ~~, the~~ increasing energy demand and ~~the acceleration of~~ continuous environmental degradation. ~~The aim of e~~ Energy and environmental policy is aimed at ~~to~~ reducing ~~e~~ pollution ~~ant~~ emissions into the atmosphere, in particular those related to energy use. Energy is considered ~~as~~ the principal source of pollutant emissions, in particular CO_2 emissions. Several methodologies have been developed to surround temporal variations in energy and environmental factors for a single country or a ~~panel~~ group of countries. Decomposition Analysis (DA) methodologies, i.e. Index Decompostion Analysis (IDA) and Structural Decomposition Analysis (SDA), were ~~as~~ developed to identify the ~~specified~~ factors responsible for ~~which contribute to~~ energy demand and related CO_2 emissions (Ang, 2004b, 1999). Reviews of IDA can be found in Ang (2004b, 1995) and Ang and Zhang (2000). IDA methods ~~constitute~~ are a widely accepted analytical tool ~~for~~ in policy making ~~s~~ to evaluate energy conservation programs ~~as in the works of~~ (Ang and Liu (2007) and Reddy and Ray (2010)) or to analyze the scenario of future evolution (Ang, 2004a). ~~But~~ However, there is no consensus among researchers on ~~about which is~~ the 'best' decomposition method. ~~Two~~ Both the main methods, ~~are used, those based on~~ the Laspeyres index and ~~those based on~~ the Divisia index, are used. ~~.~~

* Tel.: (00216) 98404054 , Fax : (00216) 71434389.
E-mail address: jouinisana@gnet.tn

Boyd et al. (1988) proposed the Divisia index approach as an alternative to the Laspeyres index approach in energy decomposition analysis. Extensions ~~of methods linked~~ to the Divisia index have been made since the early 1990s. Relevant studies include Boyd et al. (1988), Ang (1995), Ang and Choi (1997), Ang et al. (1998), Ang and Liu (2001), Ang (2005) and Reddy and Ray (2010). Other studies ~~have made~~ compare ~~risons between different~~ decomposition approaches or methods such as Howarth et al. (1991), Greening et al. (1997), Ang and Zhang (2000) and Zhang and Ang (2001). A range of techniques have been established, among which the log-mean Divisia index (LMDI) technique has been identified as the preferred approach by Ang (2004b) and Ang and Zhang (2000) due to its mathematical properties: perfect decomposition, consistency in aggregation and ability to handle zero values. The LMDI approach has both additive and multiplicative forms. The basic mathematical formulae ~~for~~ of LMDI has been reported in detail in a number of studies (Ang and Zhang, 2000; Ang and Liu, 2007; Ang et al., 2009; Ang, 2005 and 2004b).

Since ~~From~~ the ~~beginning of the~~ early-80s ~~Eighties~~, Tunisia has in place ~~set up~~ a long-term policy of energy management which ~~wa~~ is based on four instruments: institutions~~al~~, law~~ful~~, finance ~~ial~~ and tax. ~~The implementation of this policy is based on s~~ Several initiatives have been made such as the creation in 1986 of the Agency of Energy Management (ANME today) which ~~role~~ is to develop a mechanism for the rational use of energy as well as the promotion of renewable energies. ~~The role of the~~ STEG (Tunisian Company of Electricity and Gas) ~~is also~~ was established ~~important in~~ to ~~the~~ develop~~ment of~~ renewable energies, in particular, through the development of wind parks (54 MW installed and 190 MW in progress), the promotion of ~~the~~ photovoltaic solar roofs and the diffusion of solar-fired heater PROSOL. Likewise, ~~In the same way~~, an Indicated(?) National Authority (AND) was established ~~installed~~ in ~~since~~ December 2004 ~~for the approval of~~ to consider MDP projects (Mechanism for a Clean Development) in ~~the~~ sectors that have~~ing~~ a potential of reducing GES such as energy ~~sectors~~ and industry. This mechanism makes it possible to sell Units of Certified Reduction of Emissions (URCE) and the revenue earned ~~of this sale represents~~ is used~~an~~ ~~additional source to~~ for ~~the national~~ investment~~s~~ and ~~to~~ transfer of clean technology. ~~transfer.~~

This paper ~~is an application of~~ applies DA to the data ~~for~~ of the Tunisian economy which has not been examined ~~up to~~ until now. ~~And a~~Among the various decomposition techniques, we cho~~o~~se the LMDI decomposition method ~~for our study~~. The rest~~mainder~~ of the paper ~~aim to~~ presents (ii) ~~present~~ the energy consumption and carbon dioxide emission of ~~5~~ five energy-end-use sectors, namely, manufacturing, agriculture, transport, tertiary and residential sectors in Tunisia, (iii) identify the factors that contribute to the change of energy demand in these ~~5~~ five energy-end-use sectors over the period 1990–2008 by using the LMDI approach, and (iv) ~~to conclude~~ conclusion.

2. Tunisian energy context:

2.1 Energy balance in Tunisia

The major energy resources in Tunisia ~~n energy resources~~ are ~~essentially composed by~~ oil and natural gas. In ~~Since~~ 2001, Tunisia ~~passes from the status of an active balance to the status of~~ became a net importer of energy~~. That is explained by the~~ due to stagnation ~~of the~~ in ~~national~~ production, but ~~while energy~~ consumption ~~doesn't stop~~ kept rising. ~~growing up.~~

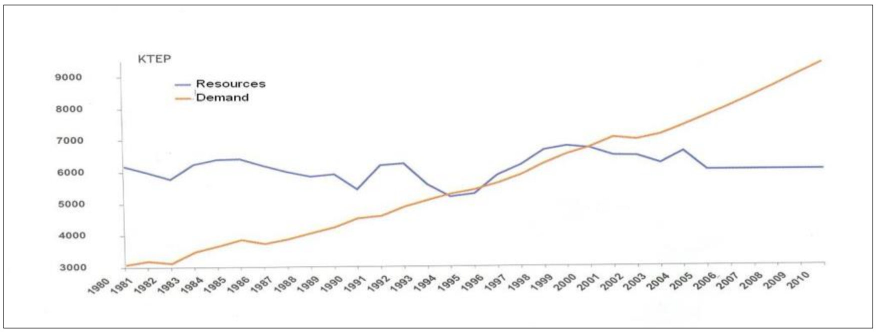


Figure 2. *Energy balance in Tunisia during 1980–~~-~~2010.*

2.2 Economic growth trends

During ~~the~~ 1990–~~-~~2010 ~~period~~, the GDP ~~knew~~ grew at an annual average ~~growth~~ rate of 4.82% ~~passing~~ from 10,815.8 TMD in 1990 (at constant prices 1990) to 28,~~-~~523.4 TMD in 2010 (Fig. 2). The GDP structure has changed, especially since 2000, with ~~a~~ the share ~~-~~of services ~~in the~~ ~~GDP~~ growing; ~~in favor of the services and~~ the industrial sector as a whole remained ~~ing~~ almost stagnant. ~~for the industrial sector as a whole~~.

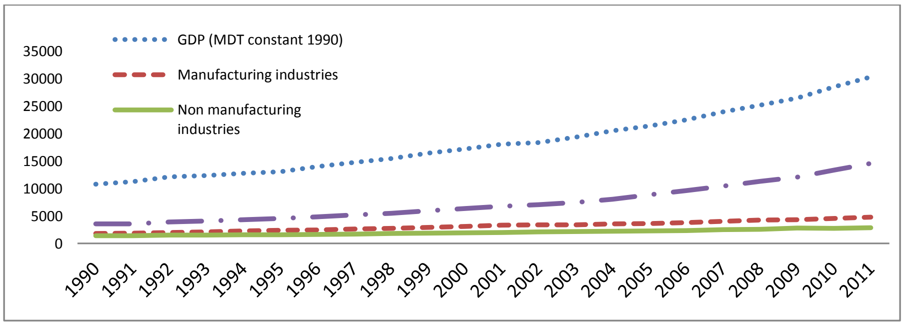


Figure 2. *Value addition for each ~~- added per~~ sector in Tunisia and growth of GDP ~~evolutions~~ at constant prices as of 1990 ~~in Tunisia,~~*

(1990–~~-~~2008)

2.3 Energy consumption

~~Since 1985,~~ ~~t~~ Primary ~~he~~ ~~Tunisian~~ energy primary consumption in Tunisia ~~passed~~ grew from 3889 ktep in 1985 to 7897 ktep in 2008, with an annual average rate of 3.12% during this period.

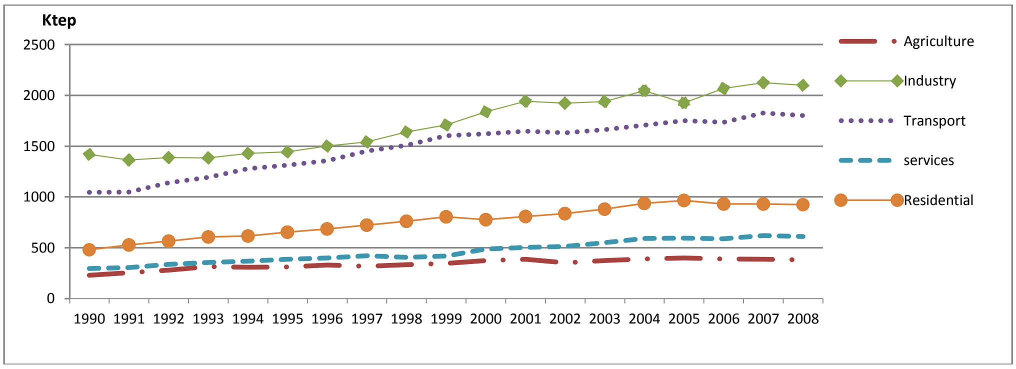


Figure 3. *Sector-wise ~~Final~~ final energy consumption in Tunisia ~~by sector:~~ during 1990–~~-~~2008*

~~As have regard to the initial weight of each sector in the final fuel consumption, there are m~~ Manufacturing industry ~~ies~~ followed by transport and ~~the~~ residential sectors ~~which~~ contributed the most to the rise ~~of~~ in the final energy consumption in Tunisia. ~~in the country~~. ~~The~~ While oil products are widely ~~remain the more consumed~~ used ~~fuel~~ in Tunisia, with 63% of the total, ~~but the~~ the share of natural gas and electricity has ~~ve also~~ ~~seen their shares~~ increased ~~ing~~ ~~passing~~ respectively to 21% and 17% in 2008 compared with only 10% and 9% in 1985.

2.4 GHG emissions

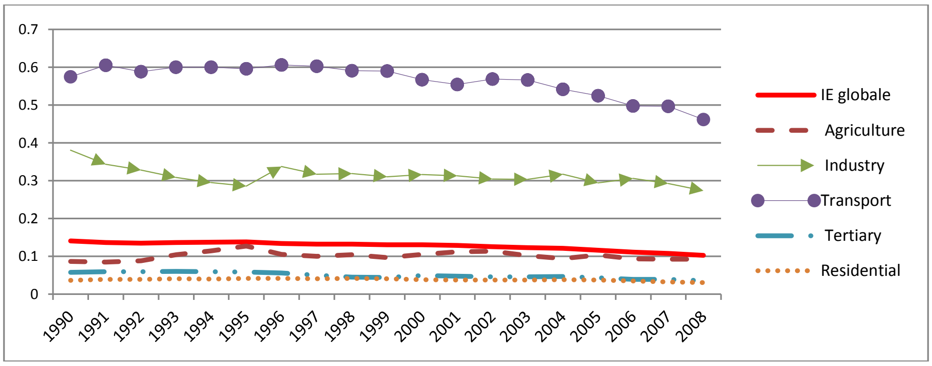
The GHG emissions due to energy ~~did not cease increas~~increase increased to ~~ing to reach~~ 2.65 téCO_2 ~~/habitant~~ person in 2008 against 1.~~,~~91 téCO_2/person ~~habitant~~ in 1985, with an annual increase of 1.~~,~~4%. These emissions ~~remain weak~~ are relatively subdued in relation ~~compared~~ to ~~the~~ industrialized countries. The ~~urban~~ population in urban areas in 2008 ~~represents a growing share~~ accounted ~~ting~~ for 65% of the total population, while ~~against 35% allowed to~~ the rural ~~population~~ population represented the rest ~~in 2008~~ (NSI, 2008). The GHG emissions due to energy ~~come~~ emanate from two sources: energy combustion and fugitive emissions. ~~The f~~ Fugitive emissions emanate from ~~are related to the~~ production activities, ~~,~~ transport and hydrocarbons distribution. These emissions ~~kn~~ grew at ~~n increase of~~ 2.6% per annum between 1985 and 2008~~, attributed to entry in production, since 1996, of~~ because of the natural gas layer (?) and the development in 1996 of the ~~transport capacity of the~~ Trans-Mediterranean gas pipeline. The GHG emissions ~~due to~~ from energy combustion ~~come~~ emanate from six sectors: energy processing industry (electricity production and refining) and five final energy consumption sectors: manufacturing industry, transport, residential, tertiary(?) and agriculture ~~sectors~~. In Tunisia, ~~the typology of GHG emissions due to combustion by type of gas shows that the~~ carbon dioxide emissions (CO_2) ~~represents the~~ dominates ~~dominating share of total emissions~~ with almost 98.3% share. The remainder is distributed between methane (CH_4) and nitrous oxide (N_2O) which respectively account for 1.1% and 0.6% of the whole emissions due to combustion (Fig. 9).

Formatted: Subscript

Formatted: Subscript

2.5 Energy intensity

During ~~the eighteens~~ 80s, both primary and final energy intensities recorded a rise due to accelerated growth ~~rate~~ of industrial sectors in highly intensive ~~in~~ energy-use areas such as the IMCCV (construction materials, ceramic and glass industries) and ~~the~~ mines. ~~But since~~ Between 1985~~, they remained rather stable~~ and until the end of the ~~nineties~~ 90s they remained rather stable~~.~~ ~~Since, these two intensities,~~ and ~~started to~~ decreased thereafter. This fall is due to ~~a consequence of~~ two ~~main~~ reasons: ~~,~~ i) the energy management policy followed by the country since 1986 (creation of National Energy Management Agency: ANME) ,and ii) the structural change brought ~~of the~~ in production in the Tunisian economy in favor of lower~~-less~~ energy-~~-~~intensive industries and ~~of the~~ services. ~~In f~~Figure 4~~, we~~ represents the ~~results~~ data of final energy intensity ~~calculated by~~ of different sectors ~~in Tunisia from~~ between 1990 ~~to~~ and 2008.~~.~~ ~~We find~~ It shows that ~~that~~ the transport sector has ~~s~~ the highest ~~energy~~ intensity ~~relative to other sectors of Tunisian economy during all the 1990-2008 period,~~ followed by manufacturing industry and agriculture sectors.



Source: ~~a~~ Author calculations

Figure 4. *Energy intensity for Tunisia by sector, 1990–~~-~~2008*

3. Decomposition of total energy consumption in Tunisia: data and application

~~In this study, w~~ We apply LMDI formulae to ~~for decompo~~ decompose ~~sing~~ changes in industrial energy consumption in a time-~~-~~series analysis as presented in Ang (2005, 2004a) ~~in order~~ to separate ~~all~~ the three effects ~~cited above~~ mentioned earlier. ~~In detail, t~~ The methodology focuses on the analysis of the following driving forces~~ effects~~:

- Activity effect, which gauges the effect of total output change on the assessed indicator.
- Structural effect, which measures the effect of a variation in the production share~~s~~ of economic sectors.
- Intensity effect, a technological effect which measures the energy use per unit of constant monetary value of output. This indicator is preferred ~~in this analysis~~ here as ~~because~~ it allows a comparison across end-energy-use sectors, in contrast to physical energy intensity, i.e. energy use per unit of physical output, ~~that~~ as it is ~~better~~ suitable for the analysis of energy efficiency, and permits ~~international~~ comparison ~~s~~ of a certain manufacturing subsector on a global scale (Reddy and Ray, 2010, Ang and Zhang, 2000).

~~The d~~ Decomposition analysis was done ~~conducted~~ using data for ~~om~~ the period 1990-–2008. However, ~~T~~ the major challenge ~~of~~ for the estimation is that ~~there are~~ no ~~consistent~~ reliable final energy use and CO_2 emission ~~s~~ data sources are available in Tunisia ~~for the~~ classifying ~~ication~~ ~~of~~ the different economic sectors ~~in Tunisia~~. Owing to ~~the~~ time and data constraints, the economy was ~~structured~~ divided into five ~~sectors~~ categories: agriculture, manufacturing, transport, tertiary and residential ~~sectors~~. The residential sector ~~doesn't present~~ is not a value-added one; its energy intensity is calculated as the ratio between final energy use and total private consumption expenditure ~~during the period~~. We'll analyse ~~do the decomposition of~~ its energy use ~~and present its results~~ separately.

This ~~paper~~ work has made use of various data sources. These data comprise yearly observations over the years 1980–~~-~~2008, namely:

- Gross domestic product in million Tunisian dinars (MDT) in 2005 constant prices,
- Value-added per sector in study in MDT in 2005 constant prices,
- Total and per sector final energy consumption in thousand tons of oil equivalent (ktoe),
- Total and per sector energy intensity in tep/1000 DT.
- Total population

Energy data are collected f~~o~~rom the National Energy Efficiency Agency (ANME). The GDP and the data are collected ~~value added per sector are taken~~ category-wise from the National Accounts, International Financial Statistics and the ~~from~~ National Institute of Statistics ~~in~~ with 1990 ~~constant~~ prices as the base; ~~and we do transformations on these~~ data ~~to let them~~ are recalculated at ~~be in~~ 2005 constant prices. Population ~~is~~ data are taken from the National Institute of Statistics.

3.1 Industry energy use decomposition for Tunisia, 1990–2008:

We have examined the contribution of the activity effect (ΔE_{act}), the structure effect (ΔE_{str}) and the energy intensity effect (ΔE_{int}) of ~~4~~ four sectors: manufacturing industries, agriculture, transport and tertiary??? by decomposing the aggregate energy consumption ~~are expressed~~ as ~~follows~~:

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

$$E_t = \sum_{i=1}^{4} \frac{E_{it}}{VA_{it}} \frac{VA_{it}}{\sum_{i=1}^{4} VA_{it}} \sum_{i=1}^{4} VA_{it} \qquad (1)$$

$$E_t = \sum_{i=1}^{4} I_{it} * S_{it} * Y_t \qquad (2)$$

~~W~~where

E_{it} = energy consumption of sector i at time t

VA_{it} = value-~~-~~added of sector i at time t

$Y_t = \sum VA_{it}$ = total value of output at time t

$I_{it} = \frac{E_{it}}{VA_{it}}$ = energy intensity of sector i at time t

$S_{it} = \frac{VA_{it}}{\sum_{i=1}^{4} VA_{it}}$ = share of value of output of sector i at time t

Applying LMDI in its additive form, the change in total energy consumption between any two years (t and t-1), ΔE_{tot}, is decomposed as follows:

$$\Delta E_{total} = \Delta E_{activity} + \Delta E_{structure} + \Delta E_{intensity} \qquad (3)$$

~~W~~ where:

$$\Delta E_{act} = \sum_i \frac{E_i^t - E_i^{t-1}}{\ln E_i^t - \ln E_i^{t-1}} \ln\left(\frac{Y_t}{Y_{t-1}}\right) \qquad (4)$$

$$\Delta E_{str} = \sum_i \frac{E_i^t - E_i^{t-1}}{\ln E_i^t - \ln E_i^{t-1}} \ln\left(\frac{S_t}{S_{t-1}}\right) \qquad (5)$$

$$\Delta E_{\text{int}} = \sum_i \frac{E_i^t - E_i^{t-1}}{\ln E_i^t - \ln E_i^{t-1}} \ln\left(\frac{I_t}{I_{t-1}}\right) \qquad (6)$$

Then

$$\Delta E = E_t - E_{t-1} = \sum_i \frac{E_i^t - E_i^{t-1}}{\ln E_i^t - \ln E_i^{t-1}} \left[\ln\left(\frac{Y_t}{Y_{t-1}}\right) + \ln\left(\frac{S_t}{S_{t-1}}\right) + \ln\left(\frac{I_t}{I_{t-1}}\right)\right] \qquad (7)$$

The results of energy consumption decomposition analysis are presented ~~below~~ in ~~t~~ Table 3.

Table 2. *~~Results of i~~ Industry energy use decomposition for Tunisia, 1990–2008: LMDI additive decomposition*

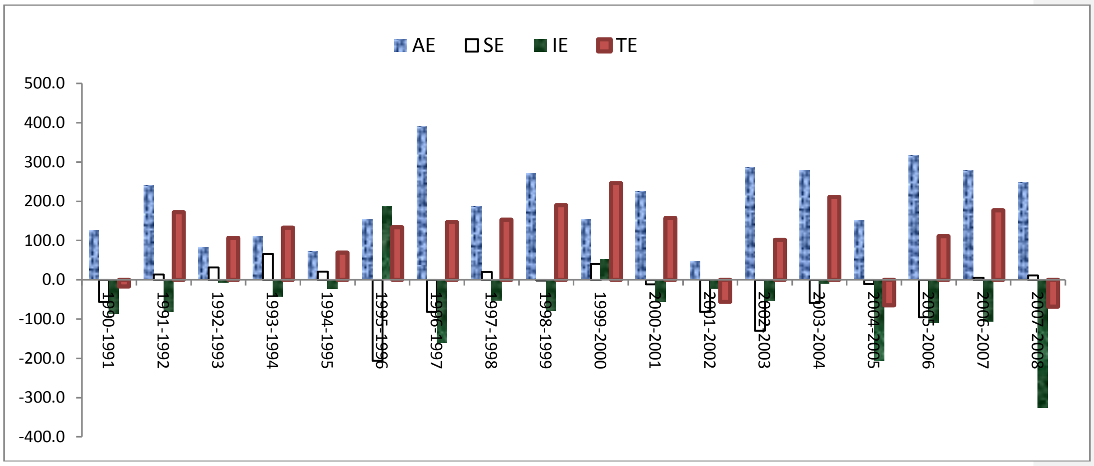
Actual value			Economy				Shares in total effect (%)		
Year	Total Energy Consumption	Differences	ΔE_{act}	ΔE_{str}	ΔE_{int}	Model Difference	ΔE_{act}	ΔE_{str}	ΔE_{int}
1990	2988								
1991	2971	-17	127	-57	-87	-17	-747.2	333.0	514.3
1992	3143	172	240	14	-82	172	139.4	8.1	-47.5
1993	3250	107	83	32	-8	107	77.4	29.6	-7.1
1994	3383	133	111	65	-43	133	83.3	49.2	-32.4
1995	3452	69	73	21	-24	69	105.2	29.7	-34.9
1996	3586	134	154	-207	187	134	115.0	-154.2	139.3
1997	3733	147	390	-81	-161	147	265.0	-55.3	-109.6
1998	3886	153	186	20	-53	153	121.6	12.9	-34.5
1999	4076	190	272	-2	-80	190	143.3	-1.2	-42.1
2000	4322	246	154	40	52	246	62.6	16.4	21.0
2001	4479	157	225	-12	-56	157	143.4	-7.4	-36.0
2002	4423	-56	48	-82	-22	-56	-84.9	146.3	38.6
2003	4525	102	286	-130	-54	102	280.5	-127.4	-53.1
2004	4736	211	279	-59	-9	211	132.3	-27.9	-4.4
2005	4671	-65	152	-11	-206	-65	-235.3	17.0	318.3
2006	4782	111	317	-95	-111	111	285.4	-85.7	-99.6
2007	4959	177	278	5	-106	177	157.1	3.0	-60.1
2008	4891	-68	247	11	-327	-68	-363.6	-16.9	480.5
Total			3621	-527	-1191	1903	190.3	-27.7	-62.6

Notes:
ΔE_{act}: changes in energy due to activity effect; ΔE_{str}: changes in energy due to structure effect; and ΔE_{int}: changes in energy due to intensity effect.
Energy consumption in kilo tonnes of oil equivalent (ktep); industrial production in million Tunisian dinars (MDT) in 2005 constant prices and energy intensity in tep/1000 DT.

Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript
Formatted: Subscript

We note that LMDI gives perfect decomposition, i.e. the results do not contain an unexplained residual term. The total change~~s~~ in energy consumption share~~s~~ which results from activity, structure and energy intensity effect, respectively, are: 190.3%, -27.7% and -62.6%. The output effect is positive when more output can be produced with the same energy use (Reddy and Ray, 2010). If this effect is positive, it implies an improvement in energy use. The structural effect shows the changes in product mix in the economy, which was induced by changes in the composition of GDP. This effect is negative~~, it~~ implying a shift ~~ies a movement~~ to ~~wards~~ less~~-~~energy-intensive industries: thus, ~~and then we'll find~~ energy intensity decreased~~ing~~ during ~~the period in study (~~1990–2008~~)~~. Finally, intensity effect measures improvements in energy efficiency, changes in technology, efficient energy management practice or any other factor which is not related to the volume of output or composition. In Tunisian case, this effect is negative. There is a decrease in total energy use per unit of GDP which implies improvement~~s~~ in energy use.

Figure 5 shows the annual trends in energy consumption at the macroeconomic level in chaining and decomposition between two consecutive years.



Note: AE= activity effect, SE= structural effect, IE= energy intensity effect and TE= total effect

Figure 5: *Decomposition of change in total energy consumption (1990–2008)*

The analysis shows that energy consumption is mostly influenced by activity ~~change~~ and intensity changes. Activity effect (AE) has positive impact and intensity effect (IE) ~~has~~ negative impact. The negative impact of structural effect (SE) is also clear in the figure.

As shown in Figure 5, AE is the ~~main~~ significant ~~explaining~~ factor for ~~the~~ increase ~~of~~ in total energy use in the Tunisian economy. It accounts for ~~(~~+190.3%~~)~~ of change in energy use over the period 1990–2008. ~~The~~ IE has ~~more~~ greater impact ~~than the structural effect~~ (approximately twice) than the structural effect on change in total energy consumption and both are negative~~. This means~~ implying ~~that there was~~ a significant improvement in energy efficiency. Thus, ~~and that~~ the ~~composition of~~ Tunisian economy has become somewhat less energy intensive over time. Hence, the overall effect on energy consumption was ~~is always~~ positive during the period of study, but ~~although~~ it turned negative ~~doesn't~~

~~improve~~, during the la~~s~~ter period of study ~~years,~~ ~~due to~~ as the negative signs of both intensity and structural effect offset ~~ting~~ the positive impact~~s~~ of AE.

Table 3. *Results of decomposition of change in energy consumption in Tunisia: 1990–~~-~~2008*

	Activity Level Impact					Structure Level Impact					Intensity Level Impact				
	Agr	*Manuf Indust*	*Trans*	*Tertiar*	*Econ*	*Agr*	*Manuf. Indust*	*Trans*	*Tertiar*	*Econ*	*Agr*	*Manuf. Indust*	*Transp*	*Tertiar*	*Econ*
1991	10.3	59.3	44.6	12.8	127.0	21.2	28.9	-97.3	-9.4	-56.6	-5.5	-142.2	53.7	6.6	-87.4
1992	20.9	108.0	85.7	25.2	239.9	-6.8	-20.1	36.2	4.6	13.9	9.8	-63.9	-29.9	2.2	-81.8
1993	7.7	36.0	30.2	9.0	82.8	-23.0	47.0	2.4	5.3	31.7	50.4	-85.0	22.3	4.7	-7.6
1994	10.4	47.0	41.2	12.1	110.7	-43.1	59.3	41.5	7.7	65.4	27.7	-63.3	0.2	-7.8	-43.1
1995	6.6	30.5	27.5	8.0	72.6	-38.9	30.1	18.2	11.1	20.5	33.3	-46.6	-8.7	-2.1	-24.1
1996	14.0	64.4	58.5	17.1	154.1	68.8	-253.0	-38.8	16.2	-206.7	-61.8	245.5	23.3	-20.4	186.6
1997	34.5	161.9	149.5	43.6	389.5	-33.9	-27.6	-45.8	25.8	-81.4	-14.6	-93.3	-7.7	-45.5	-161.1
1998	15.9	77.6	72.3	20.2	186.0	-11.4	14.8	14.4	2.0	19.8	12.5	5.5	-30.7	-40.1	-52.8
1999	23.2	114.5	106.4	28.1	272.2	12.2	-1.4	-8.4	-4.6	-2.3	-24.4	-42.1	-3.0	-10.5	-80.0
2000	13.2	65.1	59.2	16.6	154.0	-14.6	33.9	21.0	0.0	40.3	30.4	31.0	-63.2	53.5	51.7
2001	19.5	96.7	83.6	25.3	225.1	-29.3	26.5	-19.5	10.7	-11.6	22.9	-21.3	-37.1	-21.0	-56.5
2002	4.0	20.7	17.5	5.4	47.6	-42.8	13.1	-74.3	22.0	-82.0	4.8	-51.8	41.7	-16.4	-21.6
2003	23.2	123.5	105.4	34.0	286.1	36.9	-102.8	-69.5	5.4	-130.0	-39.1	-5.8	-6.9	-2.4	-54.1
2004	23.0	120.1	101.5	34.4	279.0	25.4	-101.7	15.6	1.8	-58.8	-31.5	89.5	-73.1	5.8	-9.3
2005	12.8	64.4	56.1	19.2	152.5	-44.9	-34.0	46.3	21.5	-11.0	39.1	-150.2	-56.4	-38.7	-206.3
2006	26.3	133.9	116.9	39.6	316.8	3.6	-70.0	-40.2	11.4	-95.2	-40.0	79.1	-91.8	-58.0	-110.6
2007	22.1	119.7	101.7	34.5	278.0	-18.9	29.1	-9.7	4.9	5.4	-4.2	-93.8	-3.0	-5.4	-106.4
2008	19.3	106.0	91.1	30.9	247.3	-22.9	10.7	17.1	6.5	11.5	-2.4	-142.7	-133.2	-48.4	-326.7

The activity effect

Of the three effects, ~~T~~the activity effect had the largest cumulative impact ~~of the three effects~~ and it ~~was also the~~ best explains ~~er of~~ the cumulative change in energy consumption. Over the entire analysis period, the activity effect had a positive effect but it did not show a constant growth rate. Large activity effects between 1996 and 1997 (389.5) were closely tied to the expansion of GDP growth rate during this time (11% in 1997) ~~as shown in f~~ (Figure 6). The ~~–~~ leading ~~main~~ contributors ~~or sectors~~ to the total activity ~~a~~ effect are manufacturing industries and transport, followed by tertiary and agriculture sectors.

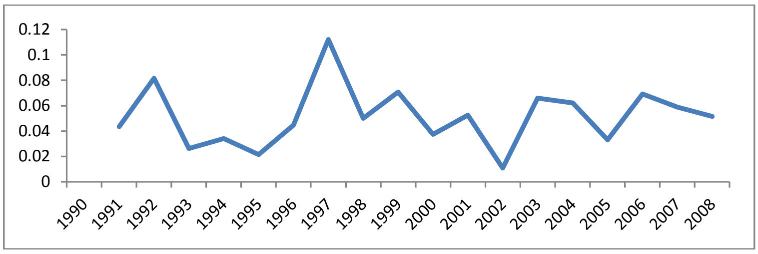


Figure 6: *Growth rate of GDP (%) in Tunisia (1990–2008)*

~~The i~~Intensity effect

The intensity effect was the second largest effect~~. It~~ and is the~~ main~~ significant factor operating in the opposite direction with ~~its~~ negative effect. In certain years, ~~the~~ its direction ~~river of intensity effect~~ was clear, in particular during the last year of the study period (2008).

Aggregate intensity changes are affected by intensity changes in the underlying sectors (agriculture, manufacturing, transport and tertiary sectors) as well as by changes in the composition (product mix). ~~We note that t~~ The share of the intensity effect becaome more evident when the share of the manufacturing industries increased as in 1996, 1997, 2005 and 2008.

~~The s~~ Structure effect

~~The c~~ Compositional changes defined as the structure effect is a component of energy consumption. The positive structure effect shows that the sector has been more energy-intensive during the study period (Zhao et al., 2012). The structure effect embodies two effects: (i~~1~~) the structural shift in sectoral consumption between energy-–intensive activities and those that do not directly use energy in final consumption, and (~~2~~ii) the energy efficiency changes in energy-using products. We notice that the total structure effect is always negative during the study period~~ in study~~. The negative result shows that energy efficiency gain has over compensated that of the structural shift towards more energy-using activities on economic structure.

3.2 Residential sector decomposition

We use the LMDI approach in its additive form to explore the driving factors behind the growth of residential energy consumption.

The steady growth in residential energy consumption is caused by a combination of factors, such as steady growth in population (population effect: ΔE_{pop}), and continual rise in per capita income (income effect: ΔE_{inc}).~~, t~~ These two aggregate changes are defined as scale effects, share of private consumption on total revenue (structure effect: ΔE_{str}) and the share of household~~s~~ expenditure in energy use relative to total private consumption (intensity effect: ΔE_{int}). The total annual residential energy consumption is factored in the following expression:

$$E_{rest} = \frac{E_{rest}}{C_t} \frac{C_t}{Y_t} \frac{Y_t}{Po_t} Po_t$$

$E_{rest} = I_t * S_t * R_t * Po_t$

~~W~~ where

E_{rest} = residential energy consumption at time t

Ct = total private consumption at time t

Yt = total output (GDP) at time t

Pt = total population at time t

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

$I_t = \frac{E_{rest}}{Ct}$ = Energy intensity of residential sector in year t measured by the ratio between energy consumption in the residential sector and total private consumption used to calculate Intensity effect (ΔE_{int}).

$S_t = \frac{C_t}{Y_t}$ = The share of total private consumption on total employees of total output (GDP) used to calculate Structure effect (ΔE_{str})..

$R_t = \frac{Y_t}{Po_t}$ = Total output per capita at time t used to define Income effect (ΔE_{inc}).

Po_t = Total population at time t used to calculate Population effect (ΔE_{po}).

Applying LMDI in its additive form, the change in residential energy consumption between any two years (t and t-1), ΔE_{res}, is decomposed as follows:

$$\Delta E_{res} = Eres_t - Eres_{t-1} = \Delta E_{intensity} + \Delta E_{structure} + \Delta E_{income} + \Delta E_{population}$$

Wwhere

$$\Delta E_{int} = \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln\left(\frac{I_t}{I_{t-1}}\right)$$

$$\Delta E_{act} = \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln\left(\frac{S_t}{S_{t-1}}\right)$$

$$\Delta E_{inc} = \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln\left(\frac{R_t}{R_{t-1}}\right)$$

$$\Delta E_{po} = \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln\left(\frac{Po_t}{Po_{t-1}}\right)$$

Then,

$$\Delta E_{res} = E_{res\,t} - E_{res\,t-1} = \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \left[\ln\left(\frac{I_t}{I_{t-1}}\right) + \ln\left(\frac{S_t}{S_{t-1}}\right) + \ln\left(\frac{R_t}{R_{t-1}}\right) + \ln\left(\frac{Po_t}{Po_{t-1}}\right)\right]$$

The results of residential energy consumption decomposition analysis are presented below inT table 5 (not Table 4?).

Formatted: Space Before: 12 pt

Table 4. Results of residential energy use decomposition for Tunisia, 1990––2008: LMDI additive decomposition

Year	Residential Energy Consumption	Diffrences	ΔE due to intensity	ΔE due to Structure	ΔE due to Income	ΔE due to population	Model Differences
1990	480						
1991	527	47	41	-13	9	10	47
1992	565	38	2	-5	30	11	38
1993	607	42	23	6	1	11	42
1994	616	9	-9	-1	8	11	9
1995	653	37	18	4	5	10	37
1996	684	31	2	-17	36	10	31
1997	724	40	-7	10	28	10	40

1998	762	38	1	3	25	9	38
1999	806	44	-0.1	-2	36	10	44
2000	777	-29	-63	-3	27	9	-29
2001	809	32	-14	7	32	7	32
2002	836	27	-1	14	6	8	27
2003	880	44	4	-6	38	8	44
2004	938	58	12	-7	45	9	58
2005	964	26	-19	7	28	9	26
2006	931	-33	-74	-8	40	9	-33
2007	931	-	-50	-7	48	9	0
2008	925	-6	-50	1	33	9	-6
Total			-185	-17	476	170	445

LMDI gives perfect decomposition and the results do not contain any unexplained residual term when dealing with residential sector. The total changes in the share of energy consumption ~~shares which result~~ from intensity, structure, income and population effects ~~are~~ is, respectively: -41.5%, -3.76%, 106.95% and 38.30% (Table 4). The income effect (ΔE_{inc}) and the population effect (ΔE_{po}) are both scale effects indicating the positive impacts of rising income levels and population. ~~In fact, o~~ On one hand, the income effect dominates positive contribution to the overall residential energy consumption growth and it is very robust, ~~.~~ but, ~~O~~ on the other ~~hand~~, growing population and rapid urbanization have ~~also~~ significantly contributed to the increased residential energy consumption in cities. The structural effect shows the changes in private consumption contribution to total output functions in the economy. ~~This effect~~ It ~~on energy use~~ is negative on energy use. Finally, intensity effect measures improvements in energy efficiency and in Tunisian case, ~~this effect~~ it is negative. This implies a decrease in total energy use per unit of private consumption expenditure.

4. Conclusion~~:~~

In this paper, we have studied the underlying forces driving the growing total energy consumption in Tunisia. By applying the logarithmic mean Divisia index to a dataset of ~~4~~ four economic end-energy-use sectors (manufacturing, agriculture, transport and tertiary) and the residential sector compiled from a wide range of sources, we are able to ~~detail~~ identify the contributing factors of the changes of Tunisian's energy use in these sectors. The analysis shows that ~~for economic sectors,~~ energy consumption is mostly influenced by activity ~~change~~ and intensity changes. But ~~for~~ in the case of residential sector, ~~there are~~ income ~~change~~ and population changes, ~~who~~ contribute the most to the change in final energy use besides ~~the~~ intensity change.

~~In terms of further work, d~~ Decomposition analysis presents ~~much~~ great opportunities ~~y~~ for …. although it depends to a great extent on data availability. Our objective is to ~~realize~~ present ~~a~~ decomposition analysis, ~~to~~ determine the contributing factors of polluting ~~ant~~ emissions and ~~with more~~ investigate ~~ion into~~ the impact of renewable energy in reducing CO_2 emissions in Tunisia.

Acknowledgments

I wish to thank Prof. Sudhakara Reddy and Dr Binay Ray for their valuable contribution and insights into this article.

Formatted: Subscript

Formatted: Subscript

References

1- Ang, B.W., H.C. Huang and A.R. Mu, 2009. Properties and linkages of some index decomposition analysis methods. Energy Policy, 37, pp 4624–~~-~~4632.
2- Ang, B.W., and Liu Na~~.~~, 2007. Energy decomposition analysis: IEA model versus other methods. Energy Policy, 35(3), pp 1426–1432.
3- Ang, B.W., 2005. The LMDI approach to decomposition analysis: a practical guide. Energy Policy, 33, pp 867–~~-~~871.
4- Ang, B.W., 2004a. Decomposition analysis for policymaking in energy: which is the preferred method?~~.~~ Energy Policy, 32. pp. 1131–1139.
5- Ang, B.W., 2004b. Decomposition analysis applied to energy. Encyclopedia of energy. ~~i~~In Cleveland, C.J.~~,~~ (editor) Amsterdam, Elsevier.
6- Ang, B.W., 1999. Decomposition methodology in energy demand and environmental analysis. In: van den Bergh, J.C.J.M., (editor), Handbook of environmental and resource economics, Cheltenham, Edward Elgar.
7- Ang, B.W., 1995. Decomposition methodology in industrial energy demand analysis. Energy, 20(11), pp 1081–1095.
8- Ang, B.W., and Choi, K.H., 1997. Decomposition of aggregate energy and gas emission intensities for industry: a refined Divisia index method. The Energy Journal, 18 (3), pp. 59–73.
9- Ang, B.W., and Liu, F.L., 2001. A new energy decomposition method: perfect in decomposition and consistent in aggregation. Energy, 26, pp 537–548.
10- Ang, B.W., and Zhang, F.Q., 2000. A survey of index decomposition analysis in energy and environmental studies. Energy, 25, pp 1149– 1176.
11- Ang, B.W., Zhang, F.Q., and Choi, K.H., 1998. Factorizing changes in energy and environmental indicators through decomposition. Energy, 23, pp 489–495.
12- Boyd, G.A., Hanson D.A., and Sterner T., 1988. Decomposition of changes in energy intensity: a comparison of the Divisia and other methods. Energy Economics, 10(4), pp 309-312.
13- Greening L.A., Davis W.B., Schipper L., and Khrushch M., 1997. Comparison of six decomposition methods: application to aggregate energy intensity for manufacturing in 10 OECD countries. Energy Economics, 19(3), pp 375–390.
14- Howarth, R.B., Schipper, L., Duerr, P.A., and Strom, S., 1991. Manufacturing energy use in eight OECD Countries. Energy Economics, 13, pp 135–~~-~~142.
15- National Institute of Statistic of Tunisia, See: http://www.ins.nat.tn/indexfr.php/
16- Reddy, B.S. and B.K. Ray, 2010. Decomposition of energy consumption and energy intensity in Indian manufacturing industries. Energy for Sustainable Development, 14, pp 35–~~-~~47.
17- Zhang, F.Q. and Ang, B.W., 2001. Methodological issues in cross-country/region decomposition of energy and environment indicators. Energy Economics, 23(2), pp179–190.