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LMDI decomposition analysis of change in energy consumption in the non-energy industrial sector: The Algerian case

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Abstract

The reduction of energy consumption is an important key not only to improving the performance of the Algerian economy but also to contributing to the effective mitigation of greenhouse gas emissions. This study provides a decomposition analysis of a set of sub-sectors belonging to the non-energy industry in terms of energy use. The Logarithmic Mean Divisia Index (LMDI) is used to identify the factors affecting the change in energy consumption between 2002 and 2015. It is estimated that the energy consumption of Algeria's non-energy industries has increased from 4904 ktoe in 2002 to 8818 ktoe in 2015. The findings reveal that the increase in energy consumption in Algeria's non-energy industry was due to the activity effect, whereas the structure and intensity effects contributed to the decrease. The increase in energy consumption due to the activity effect is largest in the construction materials industry. The intensity effect has a significant impact on energy consumption in the iron and steel, mechanical, electronic, and electrical equipment industries. Furthermore, the construction materials industry had a large share of the total change in energy consumption for the entire non-energy industry during 2002–2015, accounting for 136%.

Keywords:

Non-energy industry, energy consumption, decomposition analysis, Logarithmic Mean Divisia Index, Algeria.

1. Introduction

Many studies have been conducted to reduce energy consumption in the industrial sector with various strategies, such as energy-saving plants and waste treatment targets. On the one hand, energy-saving plants include energy management, as well as the implementation of technologies and policies [1-4]. Waste treatment, on the other hand, includes energy waste and the valorization of building materials [5]. The first step toward reducing industrial energy consumption without making large investments is to measure and monitor the energy of the activity. Ang et al. [6, 7] have proposed several approaches to decomposing the total energy into activity, structural, and intensity effects. This decomposition is important for measuring the actual effect of energy efficiency policies and for controlling the sub-sectors that should be emphasized.

The approaches can be classified into two categories: those related to the Divisia index, and those related to the Laspeyres Index. In order to measure the change in the value of a group of items between a given base year and a subsequent year. The Laspeyres index calculates the weight according to values that were present in the base year. In contrast, a Divisia index, which is a weighted sum of logarithmic growth rates, can be described as a weighted sum of growth shares, where the weights are growth percentages [7]. A residual term is produced when the Laspeyres index decomposition formula is used. The logarithm mean divisia index is widely used because of its perfect decomposition, which eliminates the need for a residual term, simple interpretation of the results, multi-level aggregation, and numerous other advantages it has over other methods [6-9]. In this paper, the analysis and discussions will use the LMDI (Logarithmic Mean Divisia Index) method for decomposition, which has the benefit of leaving no unexplained residuals. The results could help policymakers determine which sub-sectors should reduce energy consumption the most.

Algeria, as a developing country, has intensified efforts to diversify resources and achieve environmental sustainability through economic policies and energy management strategies [10-13].

Previous studies have estimated Algeria’s energy consumption and CO_2 emissions from the industrial energy sector [14, 15]. However, no research has been done to investigate the non-energy sector, which raises an urgent need for such a study. This paper aims to remedy this problem by introducing a detailed analysis of energy consumption in non-energetic industries in Algeria.

The main objectives of this work are twofold. First, it assesses the overall energy consumption and identifies the factors affecting the change in energy consumption in the non-energy industry and its subsectors. We investigate the trends in energy consumption in the non-energy industrial sub-sectors. Such an investigation aims to propose strategies to decrease energy consumption on the one hand and improve productivity on the other. Second, it analyzes the factors influencing changes in energy consumption in the Algerian non-energy industrial sector.

This paper looks at an analysis of energy consumption in the non-energy industry from 2002 to 2015 using the logarithmic mean divisia index (LMDI) method as well as the focal points of the factors that affect energy consumption by subsector, which have never been analyzed in previous studies.

The remaining sections of the paper are structured as follows: Section 2 presents how the decomposition method can be used to analyze changes in energy consumption and the data source. The results of the energy consumption analysis and its driving factors are shown in Section 3. Section 4 concludes the discussion by summarizing and interpreting the study's findings.

2. Methodology and data source

The logarithmic mean divisia index (LMDI) was found to be the most effective decomposition analysis method in this study. It contains an easy and efficient method of solving for differential expressions that removes the effects of any residuals. It has the ability to manage scenarios where the data set contains zero values and is most useful for expressions of larger intensities.

In recent years, many studies have been conducted in different ways to improve energy performance in the industrial sector [9, 16-19]. Ang and Lee have introduced a simple procedure for the multilevel decomposition method to study the factors behind changes in energy intensity [7, 8, 20, 21]. Ramirez et al. have suggested using LMDI to separate structural, production, and intensity effects for the non-energy intensive industry in the Netherlands [22]. Seck et al. used an index decomposition analysis to demonstrate that structural change is the most important factor in improving energy performance in France's non-energy intensive industries [23]. Other studies adopted decomposition methods for both energy and CO_2 emissions [24-26]. In this paper, the Logarithmic Mean Divisia Index decomposition method (LMDI) in multiplicative form is used to quantify the change in total energy consumption in the Algerian non-energy industry for the period 2002–2015.

The data for this study was collected from two sources: 1) The data on energy consumption was compiled from several Ministry of Energy reports [27], and 2) the value-added was provided to the previous data from the National Office of Statistics [28, 29].

The LMDI approach identifies three main effects (structural effect, energy intensity effect, and activity effect) driving the change in total energy consumption in different sub-sectors. Ang has divided an aggregate V to n factors and i sub-sector:

$$V = \sum_i V_i = \sum_i X_{1,i} X_{2,i} X_{3,i} \dots X_{n,i} \quad (1)$$

From year 0 to year t, the multiplicative form is used to calculate the aggregate contribution of n factors.

$$D_{tot} = V_t/V_0 = D_{X1} D_{X2} D_{X3} \dots D_{Xn} \quad (2)$$

The basic equation of LMDI can be expressed in the following form:

$$D_{ij} = exp(\sum_i \frac{L(V_i^t, V_i^0)}{L(V_t, V_0)} ln\left(\frac{X_{j,i}^t}{X_{j,i}^0}\right) \quad (3)$$

Where

$$L(\alpha, \beta) = (\alpha - \beta)/\ln(\alpha/\beta) \quad (4)$$

The multiplicative decomposition can be expressed in the following equations:

$$D_{int} \times D_{srt} \times D_{int} = E_t/E_0 \quad (5)$$

$$D_{act} = exp \sum_i^n \left[\frac{L[w_{i.t} . w_{i.0}]}{\sum_i^n L[w_{i.t} . w_{i.0}]} \; ln \frac{Q_t}{Q_0}\right] \quad (6)$$

$$D_{srt} = exp \sum_i^n \left[\frac{L[w_{i.t} . w_{i.0}]}{\sum_i^n L[w_{i.t} . w_{i.0}]} \; ln \frac{S_{i.t}}{S_{i.0}}\right] \quad (7)$$

$$S_i = Q_i/Q \quad (8)$$

$$I = E/Q \quad (9)$$

$$D_{int} = \; exp \sum_i^n \left[\frac{L[w_{i.t} . w_{i.0}]}{\sum_i^n L[w_{i.t} . w_{i.0}]} \; ln \frac{I_{i.t}}{I_{i.0}}\right] \quad (10)$$

$$L[w_{i.t} . w_{i.0}] = [w_{i.0} - w_{i.t}]/ln[w_{i.0}/w_{i.t}] \quad (11)$$

$$w_{i.t} = E_{i.t}/E_t \quad (12)$$

Table 1.- The change in energy consumption of non-energy industries by sub-sector and by sub-period.

Unit : %

non-energy industry sub-sector	Code	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2002-2015
Construction materials	CE	6.97	6.51	7.38	11.92	6.95	4.00	3.64	14.24	3.25	-3.05	5.46	1.52	6.15	54.33
Iron and steel, mechanical, electronic and electric equipment	IS	-5.46	-5.78	19.35	25.90	-15.22	-24.34	-16.89	35.67	-34.90	-0.44	-2.08	0.45	1.78	-19.83
Chemistry	CI	-3.00	-3.09	-3.59	7.63	-1.15	-4.25	11.11	19.83	1.97	12.99	-16.42	-0.29	-5.59	16.82

Food products, beverages and tobacco	AF	19.45	19.28	10.84	18.93	7.17	5.99	-8.80	-3.29	31.64	7.64	7.67	14.23	-3.50	75.91
Textile, clothing and leather	ITCL	4.94	5.81	5.49	31.58	-9.77	-2.50	-2.56	-9.65	3.74	5.31	-3.54	4.39	-0.88	31.86
Construction and public works	BTP	4.83	5.91	5.44	-42.69	16.84	31.97	22.22	-12.87	-18.06	-42.22	-7.73	14.36	12.17	-28.48
Other industries	OI	6.55	12.22	-7.34	14.30	10.38	17.98	-1.09	-6.07	1.85	13.90	5.76	-9.89	13.00	53.84

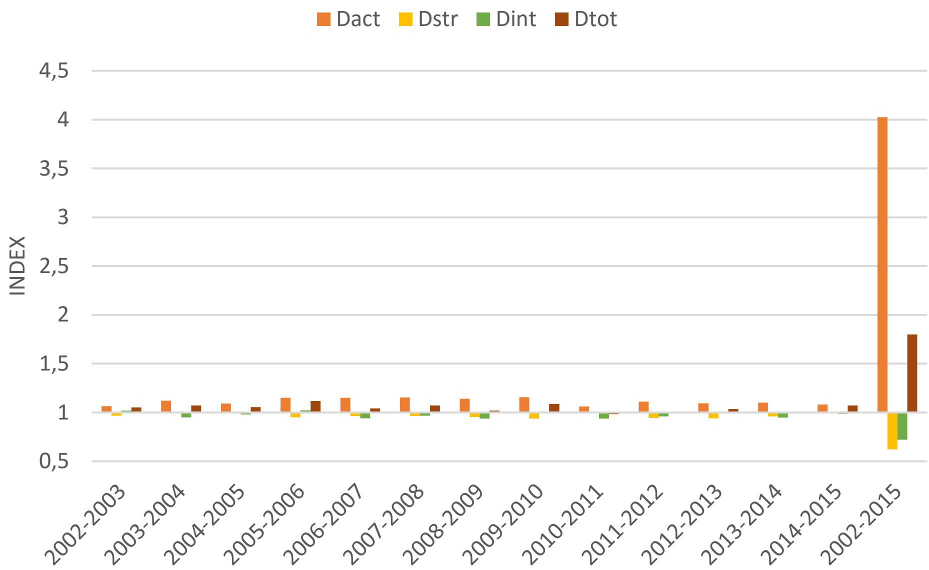

Fig. 1.Energy intensity decomposition of non-energy industries.

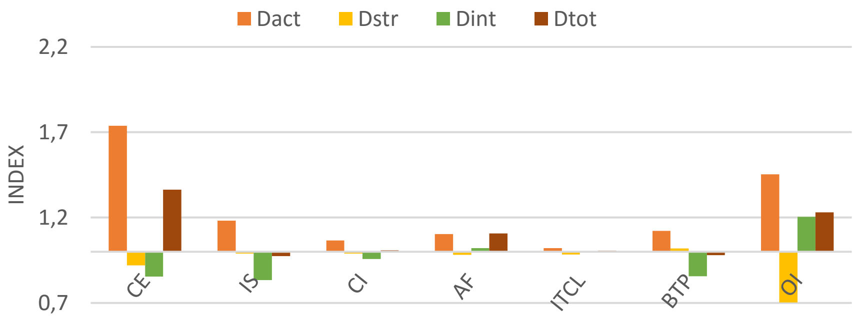

Fig. 2.Sub-sectoral decomposition analysis for the period (2002-2015**).**

3. Results and discussion

This section analyzes the energy consumption of Algeria's non-energy industry. The analysis, which involves the use of graphical tools, aims to quantify the influence of activity, structure, and intensity factors on total energy consumption from 2002 to 2015. Figure 1 shows that energy consumption in Algeria's non-energy industries increased by 180% over a 13-year period. The activity change effect was responsible for a significant increase in non-energy sector energy consumption.

The evolution of energy consumption in the Algerian industry depends on the behavior of individual sub-sectors. Table 1 illustrates the total change in energy consumption in Algeria's non-energy industry subsectors. During this period, food, beverages, and tobacco, as well as construction materials, textiles, clothing, and leather, all ranked as the top three energy consumers. The construction and public works, iron and steel, mechanical, electronic, and electric subsectors saw the biggest percentage reductions in energy use, by 28% and 19%, respectively.

According to the findings, the ITCL industry contributed the least to total energy consumption across all time periods analyzed.

3.1 Decomposition of construction materials sub-sector

The cement industry is one of the top energy consumers in the non-energy sector in Algeria. As a result of significant investments made in recent years, the cement industry has been able to meet the entirety of Algeria's demand for this construction material. The energy consumption of the construction materials industry has increased from 1729 ktoe to 3786 ktoe from 2002 to 2015. When separating the analysis by sub-period, it is evident that the increase in energy consumption of the construction materials sub-sector is due largely to the activity effect. By contrast, the structural and intensity effects play a role in reducing energy consumption. Figure 2 indicates that construction materials accounted for 136% of the total change in energy consumption for the whole non-energy industry from 2002 to 2015.

3.2 Decomposition of the iron and steel, mechanical, electronic, and electric equipment sub-sector

After the cement industry, the iron and steel industry consumes the most energy. Algeria is a major primary metal producer, with a total share of 16% of African production (iron and steel) after Egypt. In 2015, the iron and steel, machinery equipment, electronic, and electrical equipment subsector represented about 35% of annual turnover. According to the results, the intensity effect led to a change in energy consumption in the IS industry across all sub-periods.

3.3 Decomposition of the chemistry sub-sector

The chemical industry produces a vast range of items such as petrochemicals, paints, cosmetics, rubber, plastic, and pharmaceutical products. For the most part, chemicals are sold to other industries as raw materials or as intermediates in their production. The energy consumption has increased from 219 to 909 ktoe between 2002 and 2015. The contribution of the chemistry industry to aggregate energy consumption was weak because of contracting effects during the period 2002–2015.

3.4 Decomposition of food products, beverages, and tobacco sub-sector

The food products, beverages, and tobacco industries make up 27% of the total turnover in the national industry, with over 140,000 employees and 17,000 industrial firms. From 2002 to 2003 and from 2009 to 2011, the food products, beverages, and tobacco industries were liable to the intensity change effect, but the activity effect increased the energy consumption in the remaining sub-periods.

3.5 Decomposition of the textiles sub-sector

The textile industry consists of three (03) industrial divisions: basic textiles, clothing, and leather and shoes. In 2015, it produced more than 53.822 million Algerian dinars in gross output. According to the results, the ITCL industry had the weakest contribution to aggregate energy consumption during the period 2002–2015.

3.6 Decomposition of Construction and public works

According to the ONS, the BTP appears to be stabilizing following a decade of rapid growth fueled by substantial state investment. The BTP value addition has increased from 369.9 billion DA in 2002 to 1859.8 billion DA in 2015 at constant 1989 prices, representing an annual growth of 14.2%. Figure 2 shows that the BTP had a positive activity effect on energy consumption.

3.7 Decomposition of other industries in the sub-sector

All the remaining unspecified non-energy industries are referred to as "other industries." As compared to 2002, the energy consumption of other industries in 2015 increased by 23%, of which 45% increased due to the activity effect, 30% increased due to the structural effect, and 23% due to the intensity effect. Energy consumption declined from 2004 to 2006 and from 2009 to 2010 due to both negative intensity and structural effects.

The study's findings can be used to integrate industrial change policies to improve the energy efficiency of each non-energy sub-sector and achieve balanced, sustainable economic development. Improved energy efficiency in non-energy industries is easier to understand when the decomposition framework is used.

4. Conclusion

In this study, we computed the energy consumption of Algeria's non-energy industry from 2002 to 2015. Using decomposition analysis, we can separate the net effects of each specific component on aggregate energy consumption over a period of thirteen (13) years. The source analysis of changes in energy consumption is carried out by dividing the analysis into different sub-periods and monitoring the performance. The results show that energy consumption has increased from 4904 ktoe in 2002 to 8818 ktoe in 2015. The construction materials industry is the most intensive non-energy industry, followed by the food products, beverages, and tobacco industries, as well as the iron and steel, mechanical, and electronic, and electric equipment industries. The factor analysis reveals an 80% increase in total energy consumption from 2002 to 2015 due to a 300% activity change effect. Based on the research results, this study makes two fundamental recommendations. The first is that restructuring industries and implementing energy-saving strategies targeted at non-energy industries can reduce industrial energy consumption (such as energy saving certificates or the taxation of CO_2 emissions). The second suggestion is to integrate new energy-saving plants or processing techniques for improving energy efficiency.

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Nomenclature		I	energy intensity (Ktoe/billion AD)
LMDI	logarithmic Mean Divisia Index	E	energy consumption (Ktoe)
D_{tot}	total change index between years t and 0	Q	value added of non-energy industry output at 1989 constant prices (billion AD)
D_{int}	intensity effect of individual subsectors	S_i	production share of the sub-sector and is equal to the ratio of the sub-sector output to the total output
D_{act}	activity effect	D_{str}	structural effect