

LMDI Decomposition of Energy Intensity: Application To Ukraine



Halyna Pudycheva

Abstract: *In the world today, energy efficiency plays a key role in economic development of the countries. Over the period of 2013-2017 the energy intensity of economic entities in Ukraine decreased by 64.9 % or 0.0174 kgoe/UAH. However, its level is one of the highest in the world. The objective of this article is to reveal the main factors, which affect this tendency. In order to do this the decomposition analysis is used through the application of the Logarithmic Mean Divisia Index (LMDI-I) method. This paper uses both additive and multiplicative models to identify the impact degree, which the structure and energy intensity of economic sectors (namely industry, transport, service sector, agriculture and others) have on the overall energy intensity of economic entities. The results indicate that in the period under review the sectoral energy intensity factor has the greatest influence on the total energy intensity, whereas the impact of the economic structure is insignificant.*

Keywords : *decomposition, driving factors, energy intensity, energy sector analysis, LMDI method, Ukraine.*

I. INTRODUCTION

Ukrainian energy system is one of the least efficient in Europe and the whole world. In terms of the significant interest to the problems of energy sustainability, it is crucial to understand which factors have the main influence on the energy intensity level, in order to provide effective measures in energy policy.

Fig. 1 shows that the total energy intensity (primary energy consumption/GDP) in Ukraine exceeded European and world level during the period from 2008 to 2017. In 2013, when the above-mentioned indicator in Ukraine had the lowest level, it exceeds the world level by 462.42 kilogram oil equivalent/thousand USD (kgoe/thousand USD) (by 278.4 %) and the level of EU countries by 534.39 kgoe/thousand USD (by 772.0 %). In 2017, Ukrainian energy intensity was by 562.73 kgoe/thousand USD (by 337.2 %) higher than in the world and by 623.39 kgoe/thousand USD (by 650.2 %) higher than in the EU.

This paper attempts to use the LMDI method to analyze the impact degree that the economic structure has on energy

intensity. This study will be of great theoretical and practical importance on the achieving the goals of “The Energy Strategy of Ukraine until 2035” (2017) [1]. It also will be useful to prioritize the economic sectors, which ought to be modernized to improve the energy efficiency.

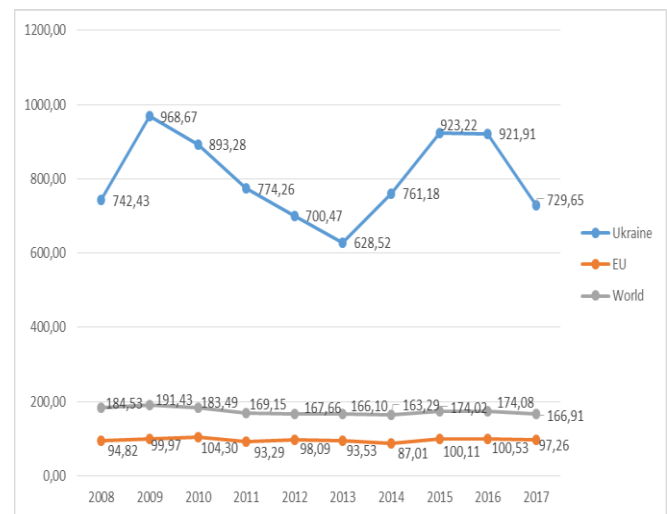


Fig. 1. Energy intensity level in Ukraine in comparison to EU and world level, 2008-2017, kgoe/thousand USD.

Source: Author’s calculation based on [2] and [3]

II. LITERATURE REVIEW

The Logarithmic Mean Divisia Index (LMDI-I) was first proposed by Ang & Choi [4], who modified the often used Divisia index decomposition method developed by Divisia [5] by replacing the arithmetic mean weight function by a logarithmic one. This gave perfect decomposition with no residual. Later this method was discussed in numerous studies [6-11].

A significant number of recent publications are devoted to the application of LMDI decomposition analysis based on statistical data of different countries. Baležentis, Baležentis, and Streimikiene [12] decompose energy use changes in Lithuania in 1995-2009 by applying both multiplicative and additive models of LMDI. Wang, Liu, Zhang, and Song [13] used LMDI method in order to analyze China’s energy consumption over the period 1991-2011. González, Landajo, and Preño [14] analyzing changes in carbon dioxide emissions of the European Union, apply LMDI methodology to decompose changes in Co2 emissions. Kim [15]

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uses LMDI decomposition analysis to identify the driving factors of energy consumption in the Korean manufacturing sector in 1991-2011. Chen, Liu, Song, and Valdmanis [16] combine LMDI analysis with LSTM (long short – term memory) to predict changes in solar energy consumption in the United States.

De Oliveira-De Jesus [17] has applied LMDI method to identify the drivers of aggregate carbon intensity of Latin America and Caribbean power sector.

However, there are no studies, which used LMDI decomposition analysis for the investigation of the driver factors of energy consumption and energy intensity in Ukraine.

III. RESEARCH METHODOLOGY

A. Data sources

The production volume of goods and services and energy data, which is used for this analysis, are from the main statistical database of Ukraine formed by the State Statistics Service of Ukraine [18]. For the calculation of the factor decomposition of energy intensity, a data set contains annual data from economic entities in Ukraine for the period from 2013 to 2017. This study does not include data of households and economic entities, which use energy for non-energetic purpose. The analyzed sectors include industry, transportation, service sector, agriculture, forestry and fisheries (the latter three sectors are analyzed as one) and other economic entities, which are not included in the previous sectors. The total energy consumption of economic entities was calculated in thousand tonnes oil equivalent, the volume of production of goods and services – in million UAH.

B. LMDI decomposition method

The decomposition analysis of energy intensity was conducted through the application of the Logarithmic Mean Divisia Index (LMDI-I) method.

To decompose aggregate energy intensity change, we begin with the IDA identity:

$$V = \frac{E}{Q} = \sum_i \frac{Q_i}{Q} \frac{E_i}{Q_i} = \sum_i S_i I_i, \quad (1)$$

where V is the total energy intensity of economic entities level, E is the total energy consumption of economic entities, Q is the total industrial activity level (the volume of

production of goods and services), $S_i (= \frac{Q_i}{Q})$ is the share of production volume of sector *i* in the total production volume

of economic entities in Ukraine, $I_i (= \frac{E_i}{Q_i})$ is energy intensity of sector *i*.

LMDI method can be applied to the additive and multiplicative decomposition analysis problem. Both cases are shown in this paper.

For the additive decomposition analysis, the following formula is used:

$$\Delta V_{tot} = V^T - V^0 = \Delta V_{str} + \Delta V_{int}. \quad (2)$$

For the multiplicative decomposition analysis, the following formula is used:

$$U_{tot} = V^T / V^0 = U_{str} U_{int}. \quad (3)$$

The *tot* represents the total effect associated with overall energy intensity of economic entities; *str* and *int* represent structural effect and sectoral energy intensity effect, respectively.

The Eq. (4) provides the link between the additive and multiplicative models of LMDI decomposition.

$$\frac{\Delta V_{tot}}{\ln U_{tot}} = \frac{\Delta V_{str}}{\ln U_{str}} = \frac{\Delta V_{int}}{\ln U_{int}} \quad (4)$$

The formulae for calculating the effects in Eqs. (2), (3) and (4) according to LMDI method are following. For the additive model:

$$\Delta V_{str} = \sum_i \frac{\frac{E_i^T}{Q^T} - \frac{E_i^0}{Q^0}}{\ln \left(\frac{E_i^T}{Q^T} \right) - \ln \left(\frac{E_i^0}{Q^0} \right)} \ln \left(\frac{Q_i^T Q^0}{Q^T Q_i^0} \right). \quad (5)$$

$$\Delta V_{int} = \sum_i \frac{\frac{E_i^T}{Q^T} - \frac{E_i^0}{Q^0}}{\ln \left(\frac{E_i^T}{Q^T} \right) - \ln \left(\frac{E_i^0}{Q^0} \right)} \ln \left(\frac{E_i^T Q_i^0}{Q_i^T E_i^0} \right). \quad (6)$$

For the multiplicative model:

$$U_{str} = \exp \left(\sum_w \frac{\left(\frac{E_i^T}{Q^T} - \frac{E_i^0}{Q^0} \right)}{\left(\ln \left(\frac{E_i^T}{Q^T} \right) - \ln \left(\frac{E_i^0}{Q^0} \right) \right)} \frac{\left(\ln \left(\frac{E_i^T}{Q^T} \right) - \ln \left(\frac{E_i^0}{Q^0} \right) \right)}{\left(\frac{E_i^T}{Q^T} - \frac{E_i^0}{Q^0} \right)} \ln \left(\frac{Q_i^T Q^0}{Q^T Q_i^0} \right) \right). \quad (7)$$

$$U_{int} = \exp \left(\sum_w \frac{\left(\frac{E_i^T}{Q^T} - \frac{E_i^0}{Q^0} \right)}{\left(\ln \left(\frac{E_i^T}{Q^T} \right) - \ln \left(\frac{E_i^0}{Q^0} \right) \right)} \frac{\left(\ln \left(\frac{E_i^T}{Q^T} \right) - \ln \left(\frac{E_i^0}{Q^0} \right) \right)}{\left(\frac{E_i^T}{Q^T} - \frac{E_i^0}{Q^0} \right)} \ln \left(\frac{E_i^T Q_i^0}{Q_i^T E_i^0} \right) \right). \quad (8)$$

IV. RESULTS AND DISCUSSION

Over the 2013-2017 period, the energy intensity of economic entities in Ukraine declined by 0.0174 kgoe/UAH, or 64.9 %, from 0.0268 kgoe/UAH to 0.0094 kgoe/UAH (Fig. 2). It should be mentioned that the trend of this indicator does not match the trend of total energy intensity in Ukraine. This is due to the fact that the large portion of the total energy consumption relates to the residential sector, where energy ensures household needs and does not affect the creation of added value. Moreover,

Fig. 2 demonstrates the positive tendency to constant decline of the energy intensity indicator. For the five aggregate sectors for this analysis, sectoral energy intensity in 2013 varied from a low 0.0114 kgoe/UAH in agriculture, forestry and fisheries to 0.0531 kgoe/UAH for the transport sector. In 2017 this indicator varied from a low 0.0036 kgoe/UAH in agriculture, forestry and fisheries to 0.0022 kgoe/UAH for the transport sector (Fig.3).

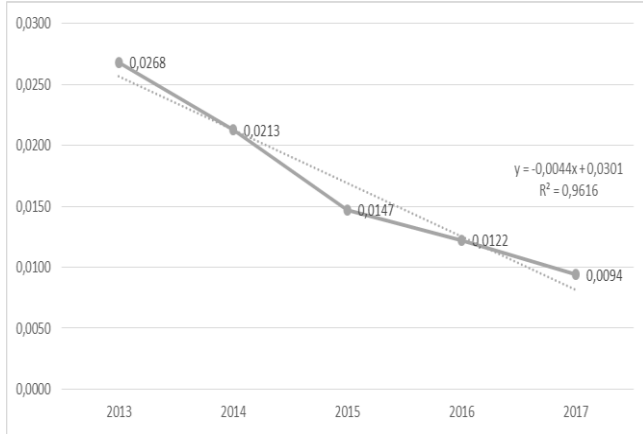


Fig. 2. Energy intensity of economic entities (V) in Ukraine, 2013-2017, kgoe/UAH.

Source: Author’s calculation based on [18].

Table I illustrates the changes in the proportion of each economic activity in total production of goods and services and energy intensity of the main economic sectors in Ukraine for the period from 2013 to 2017.

Over the 2013-2017 period, the share of transport, service sector and agriculture have increased by 1.89 %, 4.1 % and 29.88 %, respectively, whereas the share of industrial sector and other economic activity in total production of goods and services showed a decline of 5.22 % and 1.92 %, respectively. During this period the energy intensity of each sector on the average annually of 16.24 %, with total decline of 64.96 %.

To understand the factors leading to this change, the LMDI decomposition analysis was applied.

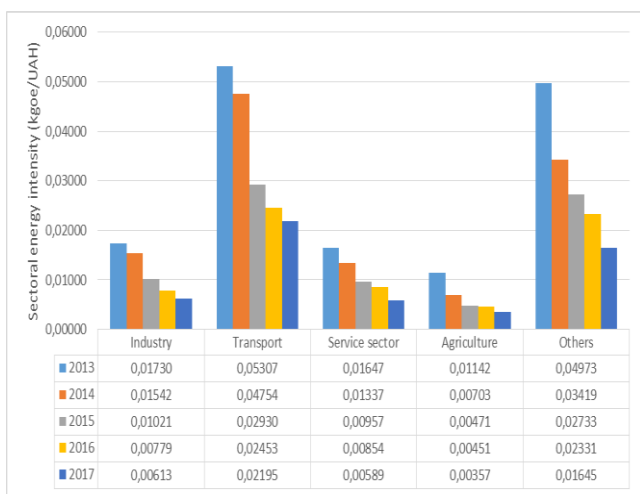


Fig. 3. Energy intensity of economy sectors (Qi) in Ukraine, 2013-2017, kgoe/UAH.

Source: Author’s calculation based on [18].

Table-I. The change in structure and energy intensity of economic entities of Ukraine (2013-2017), %.

	Share of economic activity in total production of goods and services		Energy intensity	
	Total Change Rate	Annual Average Change Rate	Total Change Rate	Annual Average Change Rate
Industry	-5.22	-1.31	-64.53	-16.13
Transport	1.89	0.47	-58.64	-14.66
Service sector	4.10	1.02	-64.23	-16.06
Agriculture	29.88	7.47	-68.75	-17.19
Others	-1.92	-0.48	-66.93	-16.73
Total	-	-	-64.96	-16.24

A. Additive model

According to additive decomposition model, LMDI analysis showed that the sectoral structure of the economic entities and sectoral energy intensity had multidimensional effect on energy intensity (Fig. 4).

The additive LMDI decomposition results show that:

- In 2014, the structural change made energy intensity increase by 0.00016 kgoe/UAH, whereas the factor of sectoral energy intensity made the total energy intensity decrease by 0.00568 kgoe/UAH. In general, the total energy intensity of economic entities in Ukraine in 2014 compared to 2013 decreased by 0.00552 kgoe/UAH.
- In 2015, the structural factor and sectoral energy intensity both lead to the decrease in total energy intensity by 0.00043 kgoe/UAH and 0.00614 kgoe/UAH, respectively. The total decrease of energy intensity in 2015 in comparison to 2014 was 0.00657 kgoe/UAH.
- In 2016 compared to 2015, as well as in 2017 compared to 2016, the structural factor had a negligible positive impact on the total energy intensity of economic entities. The factor of sectoral energy intensity lead to the decline in total energy intensity by 0.00252 kgoe/UAH and 0.00290 kgoe/UAH, respectively. The total energy decline of energy intensity was 0.00249 kgoe/UAH and 0.00285 kgoe/UAH, respectively.
- In general, in 2017 compared to 2013, the total energy intensity of economic entities decreased by 0.01742 kgoe/UAH. According to the additive LMDI decomposition model this is a result of the structural factor (by 0.00014 kgoe/UAH) and the sectoral energy intensity factor (by 0.01728 kgoe/UAH).

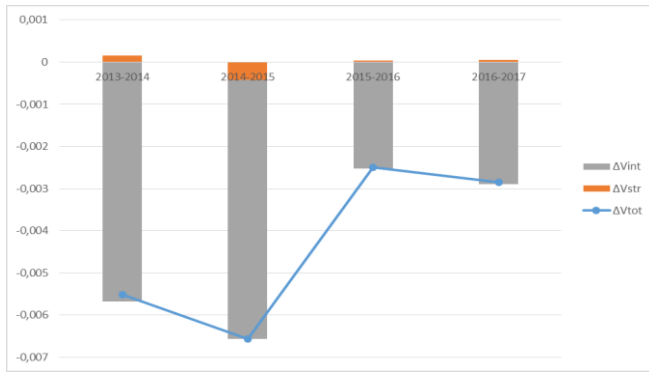


Fig. 4. LMDI decomposition results (additive) of energy intensity of economic entities in Ukraine, 2013-2017, kgoe/UAH.

Source: Author's calculation

B. Multiplicative model

The multiplicative LMDI decomposition results of energy intensity of economic entities in Ukraine are presented in Fig. 5.

The results of multiplicative LMDI decomposition analysis are the following:

- In 2014, the structural change made energy intensity increase by 0.67 %, while the change in sectoral energy intensity made the total energy intensity decrease by 21.12 %. In general, the total energy intensity of economic entities in Ukraine in 2014 compared to 2013 decreased by 20.59.
- In 2015, the structural factor and sectoral energy intensity both had negative effect on the total energy intensity by 2.37 % and 29.19, respectively. The total decrease of energy intensity in 2015 in comparison to 2014 was 30.82 %.
- In 2016 compared to 2015, as well as in 2017 compared to 2016, the structural factor had a positive effect on the total energy intensity. This factor lead to the increase of energy intensity by 0.30 % and 0.50 %, respectively. The factor of sectoral energy intensity lead to the decline in total energy intensity 17.14 % and 23.63 %, respectively. The total energy decline of energy intensity was 16.89 % and 23.25 %, respectively.
- In general, in 2017 compared to 2013, the total energy intensity of economic entities decreased by 64.96 %. According to the multiplicative LMDI decomposition model this is a result of the structural factor (by 0.85 %) and the sectoral energy intensity factor (by 64.66 %).

V. CONCLUSION

Although the energy intensity of economic entities in Ukraine is continuously declining, it is still has a relatively high level in comparison with other countries. It leads to higher prices for the domestic goods and services and lower competitiveness of manufactured exports. That is why the identification of factors, which have a direct impact on the energy intensity level, can contribute to the understanding of priority objectives in improving energy efficiency by the government and the enterprises' management. The following conclusions could be made from this study:

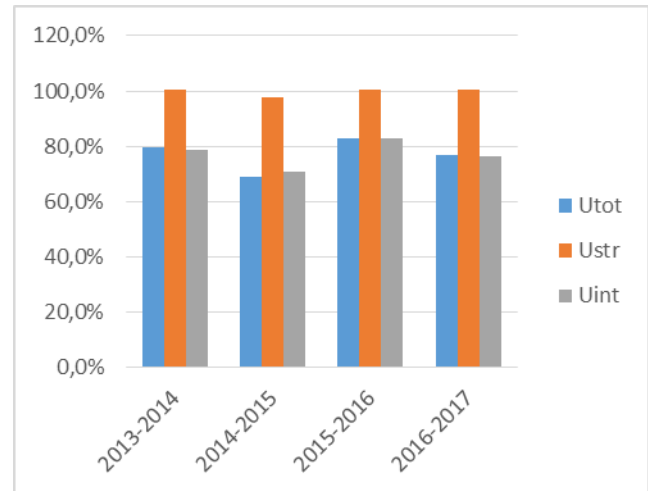


Fig. 5. LMDI decomposition results (multiplicative) of energy intensity of economic entities in Ukraine, 2013-2017, %

Source: Author's calculation

- 1) As the most affecting factor on energy intensity of economic entities in Ukraine is sectoral intensity, the priority actions should be made in the sectors, where the energy intensity has the highest level. Namely, transportation and other sectors of economy, except for industry, service sector, agriculture, forestry and fisheries. This can be made by using latest energy efficient and energy saving technologies, as well as by implementation of renewables, which are widely available in Ukraine.
- 2) The structural factor, despite its negligible impact, may also lead to the decline of the energy intensity of economic entities. The increase in the production volumes of the most energy efficient sectors, for example, industrial and service sectors, agriculture, forestry and fisheries, in the long term will entail the reduction of overall energy intensity.
- 3) The utilization of the modern technologies and renewables will help to reduce the CO₂ emission associated with the fossil fuels and thus will foster the transition to the more sustainable development of Ukrainian energy sector.

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