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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

DECOMPOSITION OF INDUSTRIAL ENERGY CONSUMPTION IN TURKEY

TÜRKİYE SANAYİ ENERJİ TÜKETİMİNİN AYRIŞTIRILMASI

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Abstract

Energy efficiency means reducing amount of energy required to produce goods and services. Improving energy efficiency is an important issue concerning reduction of energy dependency, energy security, competitiveness and sustainable growth, as well as environmental concerns and climate change. In the literature, changes in aggregate energy intensity are decomposed into real energy intensity effect and structural change effect with the help of Logarithmic Mean Divisia Index (LMDI) method. In this study, the energy efficiency of agriculture, industry and services and the effectiveness of the policies followed are revealed for the period 2003-2017. In addition, the energy efficiency of the sub-sectors is examined to determine the importance of the energy intensive sectors.

Keywords: Energy Efficiency, Energy Intensity, Decomposition Analysis, Divisia Index.

JEL Classifications: Q40, Q43, C43.

Öz

Enerji verimliliği, mal ve hizmet üretmek için gereken enerji miktarını azaltmak anlamına gelir. Enerji verimliliğinin arttırılması, enerji bağımlılığının azaltılması, enerji güvenliği, rekabet edebilirlik ve sürdürülebilir büyümenin yanı sıra çevresel kaygılar ve iklim değişikliğiyle ilgili önemli bir konudur. Literatürde, toplam enerji yoğunluğundaki değişimler, Logaritmik Ortalama Divisia Endeksi (LMDI) metodu yardımıyla reel enerji yoğunluğu etkisine ve yapısal değişim etkisine ayrıştırılmaktadır. Bu çalışmada, 2003-2017 döneminde tarım, sanayi ve hizmetlerin enerji verimliliği ve izlenen politikaların etkinliği ortaya koyulmaktadır. Ayrıca alt sektörlerin enerji verimliliği de enerji yoğun sektörlerin önemini belirlemek amacıyla incelenmektedir.

Anahtar Kelimeler: Enerji Verimliliği, Enerji Yoğunluğu, Ayrışma Analizi, Divisia Endeksi.

JEL Sınıflandırması: Q40, Q43, C43.

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1. Introduction

Countries try to use energy more efficiently due to increasing international competitiveness, improving public awareness for environmental sustainability, increasing energy costs and volatility of energy supply. Most importantly, energy efficiency is seen as a cost-effective way of decreasing greenhouse gas emissions. Providing affordable and clean energy for everyone and taking actions for avoiding climate change are two of the UN Sustainable Development Goals.

After the first oil crisis of 1973, energy security problem emerged as a prominent issue for mostly developed countries. But, afterwards, because of the ongoing volatility of energy supply due to political turmoils and wars with the increase in energy consumption and supply groups and internationalization of world energy industry, energy security became a more globalized issue. Besides, environmental concerns started 30 years ago due to various factors such as severe drought and heat and vast fires in some regions of the world putting forward the greenhouse effect to atmosphere. Kyoto Protocol which entered into force in February 2005 was the first commitment of countries for setting emission reduction targets. The Paris Climate Change Agreement which came into force in November 2016 and ratified by 169 countries aimed first-ever universal target of global temperature rise of below two degrees Celsius above pre-industrial levels and to make efforts to limit the temperature increase further to 1.5 degrees Celsius.

Energy efficiency is an important source for energy and CO_2 emission reductions. It has multiple effects on energy security, climate change and environment, job creation, competitiveness, energy prices, new innovations related to energy efficiency and health. Most of the countries set targets and implement laws, regulations, give financial and fiscal incentives in order to decrease energy intensity to target levels.

In energy efficiency studies energy intensity levels are decomposed into real energy intensity and sectoral shares/structural change effects by using decomposition methods. Ang (1994) implemented one of the first approaches to energy intensity which decomposes the change in aggregate energy intensity into real energy intensity effect and structural change effect. Ang and Choi (1997) introduced the Logarithmic Mean Divisia Index (LMDI) methodology to decomposition. An extension to LMDI methodology introduced by Choi and Ang (2012) to compute the contribution of each sector to total percent change of indices after obtaining real energy intensity index and structural change index. LMDI has two types: Montgomery-Vartia index (LMDI-I) and Sato-Vartia index (LMDI-II). This study uses LMDI-II approximation. Because, extended LMDI analysis starts with geometric mean, and Montgomery-Vartia index (LMDI-I) is not a suitable geometric mean, as sum of the weights is not unity although close to unity for most of the time. Gonzalez and Presno (2013) investigated real energy efficiency and contributions of agriculture, industry, services and transport sectors on the real energy efficiency indices in the 20 European countries from 1995 to 2000. They suggested that promotion and adaptation of more efficient techniques, innovation, better use of technologies, higher quality energies and R&D are particularly important. Gonzalez (2015) examined sectoral composition effect and contributions of agriculture, industry, services and transport sectors on the structural change indices in several EU economies between 1995-2010. He found that intensity factor is more important than structural factor and there is a positive effect of structural change in ex-communist countries and a negative contribution of industrial sector especially in the Western countries.

In Turkey, Ediger and Huvaz (2006), examined sectoral energy use in Turkish economy for the 1980-2000 period in agriculture, industry and services using additive version of the LMDI method. They found that significant variations in the sectoral energy use during 1982, 1988-1989, 1994 and 1998-2000 period are related to the economic policies. They concluded that Turkish economy had gone through a transformation from agricultural to industrial and urbanization, however industrialization hasn't completed yet therefore energy demand should be increasing much faster in this period. Şahin (2017), applied a decomposition methodology on a firm-level manufacturing data set. She found a significant decrease in energy intensity between 2005-2012, and that structural change across manufacturing sectors and firms had positive but limited effects on change in energy efficiency. Selçuk (2018) with the same decomposition methods of LMDI and extended LMDI examined the energy efficiency in the Turkish industry, and contribution of sub-sectors to change in industry energy intensity between 2003-2011. İpek-Tunç et al. (2009), examined the factors that contribute to changes in CO_2 emissions by using LMDI method in agriculture, industry and services sectors and by four energy sources of solid fuels, petroleum, natural gas and electricity between 1970-2006. They found that CO_2 emissions are mostly determined by level of the economic activity, structure effect is not a significant factor but intensity effect is a significant factor for CO_2 emissions.

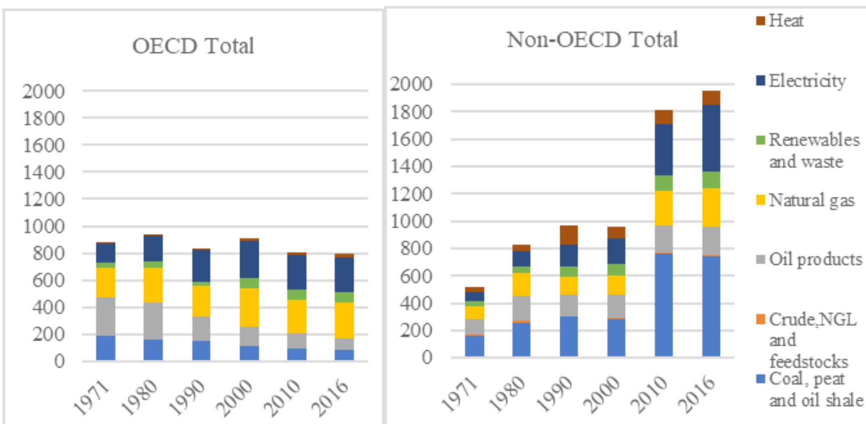
In the second section some facts about energy consumption and energy intensity levels in world and Turkey are given. In the third section energy efficiency policies in the world and in Turkey are explained briefly. Fourth section presents the LMDI methodology. Fifth section gives information about dataset and sixth section demonstrates the results and makes interpretation for these results. Seventh section concludes.

2. Facts

With increasing population and income, energy demand is increasing gradually. According to IEA statistics, world total primary energy supply (TPES) increased from 5519 Mtoe to 13972 Mtoe, by more than 2.5 times between 1971-2017, and it increased by 1.9% only between 2016-2017. Energy demand changed differently across regions between 1971-2017. OECD's share of TPES fell from 61% to 38%, while share of non-OECD Asia including China increased from 13% to 36%. Energy demand grew sevenfold in non-OECD Asia, multiplied by more than four in Africa, and it also increased strikingly in Middle East and non-OECD Americas. Top five energy consumers, China, US, India, Russia and Japan consume more than half of the total world energy (52% in 2017) (IEA, 2019a, pp. 5–6).

In terms of the share of energy use of sectors, industry is the largest energy consuming sector, while transport and residential sectors are the second and third largest energy consuming sectors, and shares of these sectors in world total final consumption were 37%, 29% and 21% respectively, in 2017 (IEA, 2019a, p. 8). Figure 1 shows industry energy consumption in OECD and non-OECD countries between 1971-2016. According to IEA energy statistics, between 1990-2016, world industrial energy consumption increased by 53%, which originates from the increase in industrial energy consumption in non-OECD countries by 102%. Share of OECD in industrial energy consumption fell from 46% to 29% (IEA, 2019b). This shows a change in global economic structure as well as a shift in more energy-intensive processes to emerging economies.

Figure 1: Industry energy consumption by source in OECD and non-OECD countries between 1971-2016

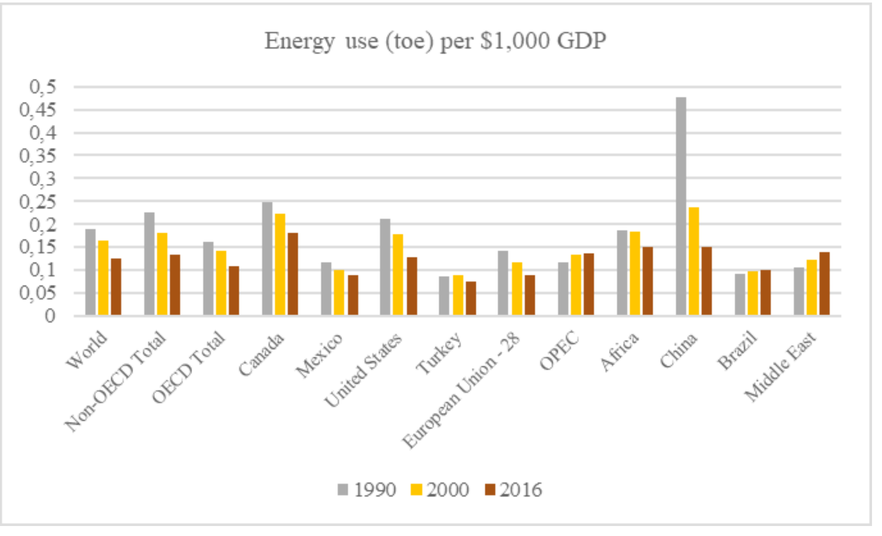


Source: IEA. (2019b). World Energy Balances, IEA Headline Energy Data

In the IEA countries, among manufacturing sub-sectors largest energy consuming sectors are ferrous metals, chemicals, paper and printing and food and tobacco, and, shares of these sectors in world total final consumption were 21%, 21%, 13% and 10% respectively, in 2016. However, sectors with the largest value added are machinery, transport equipment and chemicals, and, shares of these sectors were 37%, 15% and 14% respectively, in 2016. In terms of the intensities of manufacturing sub-sectors and services (energy consumption per value added), basic metals (ferrous and non-ferrous metals), paper and printing and non-metallic minerals are most energy intensive sectors, while machinery is the least energy intensive and services energy intensity is lower than all of the manufacturing sub-sectors (IEA, 2018b, p. 4).

According to Figure 2, in the world, energy intensity has been gradually decreasing since the 1990s. Energy consumption required to generate $1000 GDP (constant 2010 PPP) decreased from 0.190 toe (tons of oil equivalent) in 1990 to 0.163 toe in 2000 and further decreased to 0.126 toe in 2016. OECD countries decreased their energy consumption required to produce $1000 GDP from 0.160 toe to 0.108 toe between 1990-2016. China, especially has been very successful in decreasing its energy intensity, however it is still above the world average. Energy required to produce $1000 GDP, in China, decreased from 0.477 toe to 0.150 toe between 1990-2016. However, in some of the countries, energy intensity rose in this period. These are OPEC countries in average, Middle East countries such as Syria, Iran, Oman, Saudi Arabia, Kuwait, United Arab Emirates, Lebanon, and some of the non-OECD Americas such as Brazil. Low energy intensity of an economy may indicate either less-energy intensive economic structure and/or a more efficient use of energy. Therefore, different economic and sectoral structures cause different energy intensities for countries (IEA, 2018c, p. III.140-142).

Figure 2: Energy use (tons of oil equivalent) per $1,000 GDP (constant 2010 PPP) by countries between1990-2016



Source: World Energy Balances 2018. (2018c). TPES/GDP PPP (toe per thousand 2010 USD)

In comparison, Turkey has a low energy consumption compared to the developed countries but also has a strong growth potential for energy demand. In Turkey in 2016, per capita energy consumption was 1.7 toe, which was less than half of OECD average per capita energy consumption (4.1 toe per capita) and very close to world average (1.9 toe per capita) (IEA, 2018c, p. III.143-145). Energy consumption required to generate $1000 value-added (constant 2010 PPP) slightly decreased from 0.086 toe to 0.074 toe between 1990-2016. This was lower than OECD average of 0.108 and world average of 0.126. However, as indicated before, low energy intensity of an economy may indicate either less energy intensive economic structure or/and a more efficient use of energy. Therefore, examining sectoral structure and its effect on energy intensity changes is important for calculating Turkey's real energy efficiency (IEA, 2018c, p. III.140).

Despite being an energy corridor for Europe and Russia, Middle East and the Caspian Sea, energy dependence is quite high in Turkey. Energy dependence is defined by the share of energy need of a country provided by imports (calculated by net imports divided by gross available energy). According to Eurostat data (2019), in Turkey, total energy import dependency increased from 65.4% to 77.1% between 2000-2017, and it is higher than EU (28) countries. Energy import dependency for solid fossil fuels increased from 39.1% to 61.7%, for oil and petroleum products it increased from 93.4% to 95.7% and for natural gas it increased from 95.4% to 101.7%.

Despite the decrease in world energy intensity, CO_2 emissions from fuel consumption continue to increase, due to the predominant use of fossil fuels and the emerging economies relying on and increasing demand for those. Energy intensity index according to Kaya decomposition method decreased by 34%, however CO_2 emissions index increased by 57% between 1990-2016 (IEA, 2018a, p. 25). World fossil share of TPES was 81% in 2016 and it remained stable since the 1990s. Use of oil and gas increase; use of coal decreases, however, it is still the largest source of energy globally. Coal and oil represented 60% of TPES and nearly 80% of CO_2 emissions. Gas represented 22% of TPES and 20% of CO_2 emissions. Coal was the second source of energy (27%) but largest source of emissions (44%) in 2016 due to its high carbon intensity. [1] And emissions from coal are driven mostly from emerging economies like China. And, non-emitting resources still represented 19% of TPES in 2016 (IEA, 2018a, p. 11). In comparison, Turkey's contribution to CO_2 emissions is low. In 2016, CO_2 emissions was 4.33 tons per capita, which was less than half of OECD average (9.02 tons) and very close to world average (4.35 tons). But, it increased by 85.3% between 1990-2016 (IEA, 2018a, p. 116). Electricity, natural gas and coal, peat and oil shale shares in total energy consumption were 34.2%, 32.2% and 25.9% respectively in 2016, and these are three important sources for energy consumption. Oil products were most important source for energy consumption until 1985, while it decreased from 56.2% to 3.1% between 1971-2016. In terms of non-emitting resources, in 2016 heat consumption increased to 3.5% since 2000, and renewables and waste consumption increased to 1.1% since 1988 (IEA, 2019b).

3. Energy Efficiency Policy in the World and Turkey

As stated before, energy security problem emerged as a prominent issue for mostly developed countries after the first oil crisis of 1973 and with the increase in energy consumption and supply groups and internationalization of world energy industry, energy security became a more globalized issue. Besides, environmental concerns started 30 years ago due to various factors such as severe drought and heat and vast fires in some regions of the world putting forward the greenhouse effect to atmosphere which ended up with the establishment of The Intergovernmental Panel on Climate Change (IPCC) in 1988 (Revkin, 2018). Kyoto Protocol which entered into force in February 2005 was the first commitment of countries for setting emission reduction targets, and 192 parties have signed the protocol until today. Kyoto protocol has a principle of

1 According to *2006 IPCC Guidelines* estimated carbon emission factors are 15.3 tC/TJ for gas, 15.7 to 26.6 tC/TJ for oil products, 25.8 to 29.1 tC/TJ for primary coals.

"common but differentiated responsibilities", so it puts more pressure to developed countries due to their higher responsibility for high levels of GHG emissions in the atmosphere with their more than one and a half century industrial activities (UNFCCC, 2019). Turkey became a party of the protocol in February 2009. Afterwards, COP 21 or the Paris Climate Conference led to an agreement which came into force in November 2016 and ratified by 169 countries aimed first-ever universal target of global temperature rise of below two degrees Celsius above pre-industrial levels and to make efforts to limit the temperature increase further to 1.5 degrees Celsius.

Energy efficiency is seen as an important source for energy and CO_2 emission reductions. It has multiple benefits for supply security, climate change, job creation, deforestation, competitiveness and productivity of industry and services, energy prices, income, access to energy and electricity, energy poverty, new innovations related to energy efficiency and health (World Energy Council, 2016, pp. 124–131). Most of the countries set targets and implement laws, regulations, give financial and fiscal incentives in order to decrease energy intensity to target levels. According to WEC energy efficiency 2016 survey, more than 50% of World Energy Council (WEC) countries implemented energy efficiency laws and 90% of 54 countries participated in survey set quantitative objectives in 2015. EU countries set stricter objectives for energy consumption reduction, while other regions targeted energy intensity reduction more common. 75% of targets consisted of total energy consumption (primary or final), second common targets were end-use sector targets and a low percentage of targets were for energy suppliers. In world most of the targets were set for residential sector, share of targets related to industry and transport were close to each other and much lower share of targets were related to services in 2015. Asia put more pressure to targets related to industrial sector (World Energy Council, 2016, pp. 48–51). Countries applied measures such as regulations, financial incentives, fiscal incentives and others. Regulations were more important to improve energy efficiency in the residential and service sectors. While, financial incentives were used widely in industry and transport sectors to avoid the detriment of regulations to competitiveness (World Energy Council, 2016, p. 57).

In Turkey, energy efficiency is an important issue for governments and consumers due to scarce resources causing energy dependency and energy security problems, increasing costs and taxes and increasing CO_2 emissions. Regulatory instruments, economic instruments, voluntary approaches and information and education centers are carried out for industry policies and measures. Energy Management Regulations which is a national policy in force since 1995 enforce establishment of energy management units and employment of energy managers for enterprises with energy consumption higher than certain level. Energy Conservation Centre was established as a part of General Directorate of Renewable Energy (GDRE)/ Ministry of Energy and Natural Resources (MENR). The center provides energy management training programs which targets 10% energy efficiency increase in Turkish industry. Energy Efficiency Law enforced in 2007 is the most important step in energy policy. This law enforces preparation of energy efficiency plans and programs at the national level, evaluate their effectiveness, and implementation of new measures where necessary. Monitoring Energy Efficiency Sectors is a regulatory instrument in force since 2007 consists monitoring energy efficiency according to the energy efficiency law obliged to establishments including industrial enterprises consuming more than 1000 toe, power plants with minimum 100 MW installed capacity, commercial or service buildings with minimum 20,000 m^2 construction area or 500 toe energy consumption in a year and public buildings with minimum 10,000 m^2 construction area or 250 toe energy consumption in a year. 2008 was announced as an Energy Efficiency Year. A Support Scheme for Energy Efficiency in Industry was organized in 2008 also. 5th Region Incentives which was put in force in 2014 consists of encouraging energy efficiency investments for manufacturing industrial plants for over 1 million TL. These economic instruments include many incentives from VAT and custom duty exemption and social security premium to interest support and land allocation (IEA, 2019c).

4. Methodology

This section follows the energy intensity approach introduced by Ang (1994) which decomposes the change in aggregate energy intensity into real energy intensity effect and structural change effect. To decompose the change in aggregate energy intensity this study uses the Logarithmic Mean Divisia Index (LMDI) methodology introduced by Ang and Choi (1997). After obtaining real energy intensity index and structural change index the contribution of each sector to total percent change of each indices will be calculated according to extended LMDI methodology introduced by Choi and Ang (2012). Changes in the energy intensity and effects will be calculated for single-period and multi-period. Depending on the weights used in the index, LMDI has two types: Montgomery-Vartia index (LMDI-I) and Sato-Vartia index (LMDI-II). This study uses LMDI-II approximation. Extended LMDI analysis starts with geometric mean, and Montgomery-Vartia index (LMDI-I) is not a suitable geometric mean, as sum of the weights is not unity although close to unity for most of the time. This section shows briefly some expressions in order to apply decomposition analysis.

Energy intensity is defined as the ratio of total energy consumption to total production. Change in aggregate energy intensity depends on two effects:

a) technical changes and use of higher quality energy inputs (real energy intensity effect)

b) changes in the sectoral production shares (structural change effect)

Table 1: Notations and abbreviations used in the decomposition analysis

Notations/ abbreviations	Meaning
E	Aggregate energy consumption
Y	Aggregate production
I	Aggregate energy intensity (E/Y)
R	Real energy intensity effect
S	Structural change effect (Sectoral shares effect)

Table 1 shows notations and abbreviations used in the energy decomposition analysis. E is the aggregate energy consumption and Y is the aggregate production of a country. If there are N sectors E_i and Y_i are respectively the energy consumption and the production of sector i. Therefore, we can define the energy intensity $I_i=E_i/Y_i$ and the production share $S_i=Y_i/Y$ for ith sector. The aggregate energy intensity (I=E/Y) is written as follows:

$$I=\sum_{i=1}^{N}\frac{E_i}{Y_i}\frac{Y_i}{Y}=\sum_{i=1}^{N}I_iS_i \quad (1)$$

Divisia decomposition is carried out with the change in the aggregate energy intensity. Change in the aggregate energy intensity are computed for single period and multiple periods. For single-period change is for the aggregate energy intensity between year 0 and year T. Year 0 and year T are respectively the beginning and ending years of a time period which can be two consecutive years. Single period change in the aggregate energy intensity of year T to year 0 is formulated as following where R_T/R_0 is the real energy intensity effect and S_T/S_0 is the structure (sectoral production share) effect:

$$\frac{I_T}{I_0}=\frac{R_T}{R_0}\frac{S_T}{S_0} \quad (2)$$

Real energy intensity effect and structural change effect in the right-hand side of Eq. (2) can be calculated using sectoral data as follows:

$$\frac{R_T}{R_0}=exp\left(\sum_{i=1}^{N}\frac{L\left(E_{i,T}/E_T,E_{i,0}/E_0\right)}{\sum_{i=1}^{N}\left(E_{i,T}/E_T,E_{i,0}/E_0\right)}ln\frac{I_{i,T}}{I_{i,0}}\right) \quad (3)$$

$$\frac{S_T}{S_0}=exp\left(\sum_{i=1}^{N}\frac{L\left(E_{i,T}/E_T,E_{i,0}/E_0\right)}{\sum_{i=1}^{N}\left(E_{i,T}/E_T,E_{i,0}/E_0\right)}ln\frac{S_{i,T}}{S_{i,0}}\right) \quad (4)$$

Multi-period aggregate real energy intensity and structural change indices are the cumulative product of single-period indices:

$$\frac{R_T}{R_0}=\prod_{t=1}^{T}\frac{R_t}{R_{t-1}}\ and\ \frac{S_T}{S_0}=\prod_{t=1}^{T}\frac{S_t}{S_{t-1}} \quad (5)$$

According to extended LMDI decomposition approach, after obtaining real energy intensity and structural change effects for the aggregate the contribution of each sector to total percent change of these effects for single-period can be decomposed as follows:

$$\frac{R_T}{R_0}-1=\sum_{i=1}^{N}s_i\left(\frac{I_{i,T}}{I_{i,0}}-1\right)\ where\ s_i=\frac{\pi_iI_{i,0}}{\sum_{k=1}^{N}\pi_kI_{k,0}}=\frac{\frac{w_i}{L(I_{i,T},I_{i,0}R_T/R_0)}I_{i,0}}{\sum_{k=1}^{N}\frac{w_i}{L(I_{k,T},I_{k,0}R_T/R_0)}I_{k,0}} \quad (6)$$

$$\frac{S_T}{S_0} - 1 = \sum_{i=1}^{N} s_i \left(\frac{S_{i,T}}{S_{i,0}} - 1 \right) \text{ where } s_i = \frac{\pi_i S_{i,0}}{\sum_{k=1}^{N} \pi_k S_{k,0}} = \frac{\frac{w_i}{L(S_{i,T}, S_{i,0} S_T / S_0)} S_{i,0}}{\sum_{k=1}^{N} \frac{w_i}{L(S_{k,T}, S_{k,0} S_T / S_0)} S_{k,0}} \quad (7)$$

Multi-period indices will be calculated as chain indices in a way similar to LMDI analysis. Multi-period percent change of real intensity is the cumulative sum of single-period percent changes multiplied by R_{t-1}/R_0. Multi-period percent change of structural effect is the cumulative sum of single-period percent changes multiplied by S_{t-1}/S_0.

$$\frac{R_T}{R_0} - 1 = \sum_{t=1}^{T} \frac{R_{t-1}}{R_0} \left(\frac{R_t}{R_{t-1}} - 1 \right) = \sum_{i=1}^{N} \sum_{t=1}^{T} \frac{R_{t-1}}{R_0} s_{i,t-1,t} \left(\frac{I_{i,t}}{I_{i,t-1}} - 1 \right)$$

$$\text{where } s_i = \frac{\frac{w_{i,t-1,t}}{L(I_{i,t}, I_{i,t-1} R_t / R_{t-1})} I_{i,t-1}}{\sum_{k=1}^{N} \frac{w_{k,t-1,t}}{L(I_{k,t}, I_{k,t-1} R_t / R_{t-1})} I_{k,t-1}} \quad (8)$$

$$\frac{S_T}{S_0} - 1 = \sum_{t=1}^{T} \frac{S_{t-1}}{S_0} \left(\frac{S_t}{S_{t-1}} - 1 \right) = \sum_{i=1}^{N} \sum_{t=1}^{T} \frac{S_{t-1}}{S_0} s_{i,t-1,t} \left(\frac{S_{i,t}}{S_{i,t-1}} - 1 \right)$$

$$\text{where } s_i = \frac{\frac{w_{i,t-1,t}}{L(S_{i,t}, S_{i,t-1} S_t / S_{t-1})} S_{i,t-1}}{\sum_{k=1}^{N} \frac{w_{k,t-1,t}}{L(S_{k,t}, S_{k,t-1} S_t / S_{t-1})} S_{k,t-1}} \quad (9)$$

5. Dataset

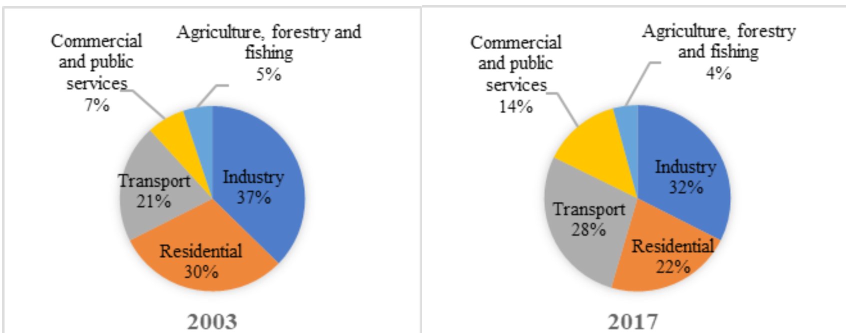
Turkish agriculture, industry, services sectors and industry sub-sectors energy consumption data between 1960-2017 are collected from International Energy Agency (IEA), World Energy Balances database. Energy consumption values are expressed in thousand tons of oil equivalent (ktoe). Agriculture, industry, services GDP data between 2003-2009 are collected from TurkStat website. Sub-sectors value-added data are collected from TurkStat website from Annual Industry and Service Statistics database. GDP and value added at factor costs are deflated based on Consumer Price Index (CPI) (2003=100).

The sub-sectors in IEA database are classified according to ISIC Rev. 4 classification system, and TurkStat GDP and Annual Industry and Service Statistics use NACE Rev. 2 classification system. After the correspondence of classifications industrial sub-sectors are defined as follows: Basic metals (iron and steel with non-ferrous metals); chemicals and pharmaceuticals; other non-metallic mineral products; transport equipment; machinery and equipment; mining and quarrying; food, beverages and tobacco; paper, paper products and printing; wood and products of wood; construction; textile and leather; other industry (rubber and plastic products, furniture and other manufacturing).

6. Results

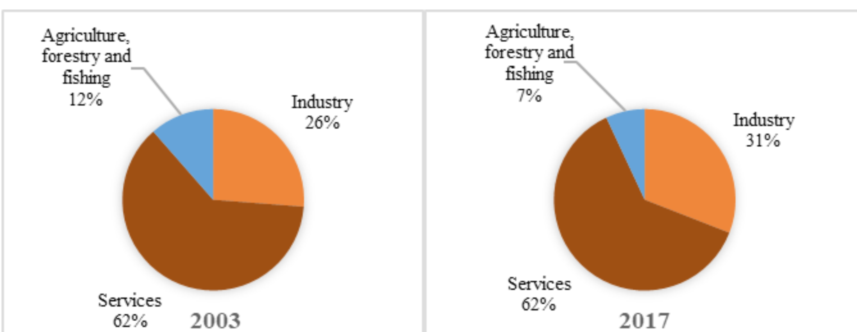
Before giving the results, some descriptive statistics are presented. Figure 3 and Figure 4 show energy consumption and GDP shares of agriculture, industry and services. Commercial and public services, transport and residential sectors are aggregated in the services sector. According to the figures, agriculture share in energy consumption decreased from 5% to 4% despite relatively higher decrease in the GDP share from 12% to 7%. Industry share in energy consumption decreased despite the increase in GDP share. Services share in energy consumption increased from 58% to 64%.

Figure 3: Energy consumption shares by sectors for 2003 and 2017



Source: IEA Data Services (2019).

Figure 4: GDP shares by sectors for 2003 and 2017



Source: Turkish Statistical Institute (TurkStat) (2019a).

Table 2: LMDI decomposition of aggregate energy intensity change, between 2003-2017

	Single-period analysis (base year is previous year)			Multi-period analysis (base year is 2003)		
	Aggregate	Real	Structure	Aggregate	Real	Structure
2003	1	1	1	1	1	1
2004	0.910	0.905	1.005	0.910	0.905	1.005
2005	0.960	0.958	1.002	0.874	0.867	1.008
2006	1.025	1.016	1.009	0.895	0.881	1.016
2007	1.019	1.016	1.003	0.912	0.895	1.019
2008	0.943	0.944	1.000	0.861	0.845	1.019
2009	1.043	1.045	0.998	0.897	0.883	1.016
2010	1.001	1.003	0.999	0.899	0.885	1.015
2011	0.943	0.935	1.009	0.848	0.827	1.024
2012	1.002	1.001	1.001	0.849	0.828	1.025
2013	0.933	0.929	1.005	0.793	0.769	1.030
2014	0.979	0.978	1.001	0.776	0.753	1.031
2015	1.016	1.018	0.999	0.788	0.766	1.030
2016	1.002	0.998	1.004	0.790	0.765	1.034
2017	1.031	1.031	1.001	0.815	0.788	1.034

According to Table 2, the results show that energy efficiency improved between 2003-2017. Single period results show that energy efficiency did not improve regularly. Real energy intensity and structural effects indices based on previous years did not decrease regularly. According to multi-period results energy efficiency increased by 18.5% in 2017 compared to 2003. Real energy intensity decreased significantly by 21.2%, although, structural effect deteriorated energy efficiency by 3.4%. Therefore, in Turkey, increase in energy efficiency resulted from real energy intensity effect, however sectoral composition had negative effect on energy efficiency.

In Table 3, total contribution of each sector to change in real energy intensities are given. According to single-period results real energy intensities decreased in the years 2004, 2005, 2008, 2011, 2013, 2014 and 2016, and increased in the others. According to multi-period results, highest contributions to overall decrease in the real energy intensity were the industry and the services sectors, however, agriculture had an insignificant increasing effect on real energy intensity.

In Table 4, sectoral contributions to changes in the structural effect index are given. According to single-period results structural effect indices decreased in the years 2008, 2009, 2010 and 2015 and increased in the others. According to multi-period results, shift to agriculture and services sectors affected structural effect positively and there was a negative contribution of industrial sector.

Table 3: Extended LMDI decomposition results of real energy intensity change by sectors, between 2004-2017 (percentage changes)

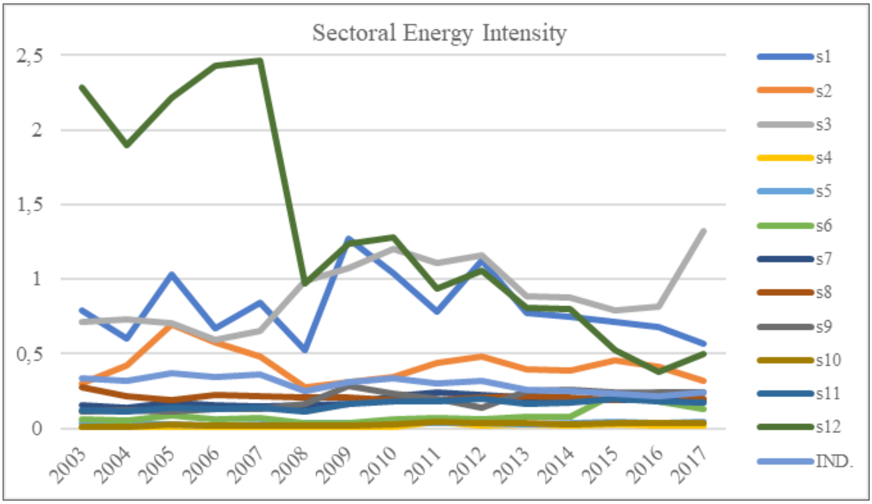
	Single-period analysis, base year=previous year				Multi-period analysis, base year=2003			
	Total	Agr.	Ind.	Ser.	Total	Agr.	Ind.	Ser.
2004	-9.49	0.16	-4.98	-4.68	-9.49	0.16	-4.98	-4.68
2005	-4.19	-0.24	-3.48	-0.47	-13.29	-0.05	-8.13	-5.10
2006	1.60	0.68	0.58	0.33	-11.90	0.54	-7.63	-4.81
2007	1.61	0.82	-1.00	1.79	-10.48	1.26	-8.51	-3.23
2008	-5.64	1.48	-8.65	1.52	-15.53	2.59	-16.25	-1.87
2009	4.54	-0.63	6.32	-1.14	-11.70	2.05	-10.91	-2.84
2010	0.27	-0.89	2.44	-1.29	-11.46	1.27	-8.76	-3.98
2011	-6.55	0.37	-3.98	-2.94	-17.26	1.59	-12.28	-6.58
2012	0.11	-0.89	0.46	0.54	-17.16	0.85	-11.89	-6.13
2013	-7.13	0.04	-5.53	-1.64	-23.07	0.89	-16.47	-7.49
2014	-2.18	0.21	-0.44	-1.95	-24.75	1.05	-16.81	-8.99
2015	1.76	-1.31	-0.62	3.69	-23.43	0.06	-17.27	-6.22
2016	-0.15	0.22	-0.99	0.61	-23.54	0.23	-18.03	-5.75
2017	3.06	0.28	2.93	-0.14	-21.20	0.44	-15.79	-5.85

Table 4: Extended LMDI decomposition results of structural effect change by sectors, between 2004-2017 (percentage changes)

	Single-period analysis, base year=previous year				Multi-period analysis, base year=2003			
	Total	Agr.	Ind.	Ser.	Total	Agr.	Ind.	Ser.
2004	0.55	-0.25	0.92	-0.12	0.55	-0.25	0.92	-0.12
2005	0.21	-0.09	0.45	-0.14	0.75	-0.35	1.36	-0.26
2006	0.86	-0.69	1.23	0.31	1.62	-1.04	2.60	0.06
2007	0.29	-0.51	-0.06	0.86	1.91	-1.56	2.55	0.92
2008	-0.03	-0.05	-0.57	0.59	1.88	-1.61	1.97	1.52
2009	-0.25	0.59	-2.78	1.95	1.63	-1.01	-0.87	3.51
2010	-0.12	0.84	1.02	-1.97	1.51	-0.16	0.17	1.50
2011	0.91	-0.67	3.35	-1.77	2.44	-0.84	3.57	-0.29
2012	0.07	-0.40	-0.52	0.99	2.51	-1.25	3.03	0.73
2013	0.51	-0.75	1.45	-0.18	3.04	-2.02	4.52	0.54
2014	0.08	-0.17	0.27	-0.02	3.12	-2.19	4.79	0.52
2015	-0.15	0.25	-0.11	-0.28	2.97	-1.94	4.68	0.23
2016	0.38	-0.48	0.35	0.51	3.36	-2.43	5.03	0.75
2017	0.05	-0.10	1.03	-0.88	3.41	-2.53	6.10	-0.15

Between 2003-2017, industry energy consumption increased by 53% and industry real value added increased by 114%. Industry energy intensity decreased by 28%.

Figure 5: Sectoral energy intensities (Ei/Yi) for industry, between 2003-2017



Note: NACE Rev. 2 codes and sector names: Sector 1: 24 (Basic Metals), Sector 2: 20+21 (Chemicals and Pharmaceuticals), Sector 3: 23 (Other Non-Metallic Mineral Products), Sector 4: 29+30 (Transport Equipment), Sector 5: 25+26+27+28 (Machinery and Equipment), Sector 6: 07+08+099 (Mining and Quarrying), Sector 7: 10+11+12 (Food, Beverages and Tobacco), Sector 8: 17+18 (Paper, Paper Products and Printing), Sector 9: 16 (Wood and Products of Wood), Sector 10: 41+42+43 (Construction), Sector 11: 13+14+15 (Textile and Leather) and Sector 12: 22+31+32 (Other Industry).

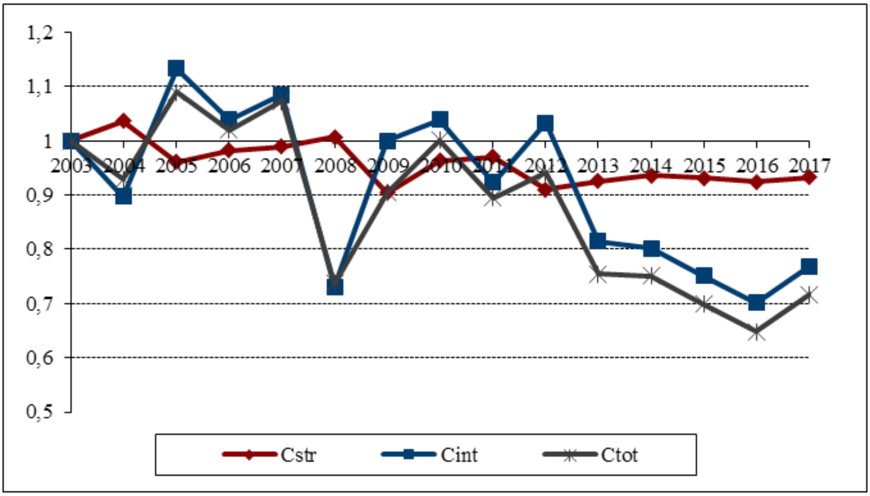
In Figure 5, industry energy intensity decreased until 2008 with the help of economic policies aimed at increasing energy efficiency. Despite the increase in the crisis year of 2009, energy intensity decreased further to 0.24 in 2017. Other industry includes larger classes of sectors which are rubber and plastic products, furniture and other manufacturing sectors. These sector use energy more intensively, however energy intensity decreased rapidly between 2003-2017. Basic metals, chemicals and pharmaceuticals and other non-metallic mineral products consume energy more intensively than industrial average. Other sectors' energy intensity levels are below the industrial average. Mining and quarrying, food, beverages and tobacco, paper, paper products and printing, wood and products of wood and textile and leather sectors can be categorized as middle level energy consuming sectors with respect to Turkish industry average. Low energy consuming sectors are transport equipment, machinery and equipment and construction sectors. The construction sector grew in this period but energy intensity levels do not indicate this growth because recent dataset from IEA World Energy Balances seems it has higher total energy consumption for non-metallic minerals sector than construction sector, despite other studies showing the opposite. There is a shift of classification of energy consumptions due to data revisions performed by the countries to past years' data which does not go beyond 1990s.

Table 5: LMDI decomposition of Turkish industry aggregate energy intensity change, between 2003-2017

	Single-period analysis (base year is previous year)			Multi-period analysis (base year is 2003)		
	Aggregate	Real	Structure	Aggregate	Real	Structure
2003	1	1	1	1	1	1
2004	0.930	0.897	1.037	0.930	0.897	1.037
2005	1.172	1.263	0.928	1.089	1.133	0.962
2006	0.937	0.917	1.021	1.020	1.039	0.982
2007	1.052	1.044	1.007	1.073	1.085	0.989
2008	0.687	0.674	1.019	0.737	0.731	1.007
2009	1.228	1.368	0.898	0.904	1.000	0.904
2010	1.107	1.039	1.065	1.001	1.039	0.963
2011	0.895	0.888	1.007	0.895	0.923	0.970
2012	1.051	1.120	0.938	0.941	1.033	0.910
2013	0.802	0.789	1.017	0.754	0.815	0.926
2014	0.995	0.984	1.012	0.751	0.802	0.936
2015	0.932	0.937	0.994	0.699	0.751	0.931
2016	0.927	0.934	0.992	0.649	0.702	0.924
2017	1.104	1.094	1.009	0.716	0.768	0.932

Table 5 shows the single-period and multi-period decomposition results. A decrease in energy intensity index indicates an increase in energy efficiency. Figure 6 shows multi-period or cumulative decomposition results. According to both of these demonstrations, the results, similar to previous studies, show that energy efficiency continued to improve between 2003-2017. During 2008 after the enactment of Energy Efficiency Law energy efficiency increased effectively (by 31%) in the whole industry compared to the previous year. In the 2009 crisis year, energy efficiency decreased by 23% compared to the previous year. However, with the help of governmental regulations and financial incentives given to the enterprises, energy efficiency level increased regularly starting from 2013 until 2016. 2017 was a year with high growth rates in industry and energy sectors in the whole world. In line with the world trend of growth, and increasing production levels of fuels and decreasing costs, in 2017, energy efficiency decreased compared to previous year. However, according to the multi-period analysis energy efficiency increased by 28% in 2017 compared to 2003. Real energy intensity decreased significantly by 23%, sectoral composition changes led to an improve in energy efficiency by 7%. Therefore, in Turkey, increase in energy efficiency resulted from real energy intensity effect, however structural effect was less significant. Although structural and real energy intensity effects were opposite to each other until 2012, they continued a decreasing trend starting from the year 2013.

Figure 6: Aggregate industry cumulative changes of total energy intensity, real energy intensity and structural effects, between 2003-2017



In Table 6, total contribution of each sub-sector to change in real energy intensities in industry are given. According to single-period results industrial real energy intensities decreased in the years 2004, 2006, 2008, 2011 and for the years between 2013-2016, and increased in the others. The sectors that made the highest contributions to both decreases and increases in the real energy intensity of the industrial sector were the basic metals and the other manufacturing sectors which are energy intensive sectors. According to multi-period results, likewise highest contributions to overall decrease in the real energy intensity of the industrial sector were the basic metals and the other manufacturing sectors, however, chemicals and pharmaceuticals, other non-metallic mineral products and textile and leather sectors had an increasing effect on industry real energy intensity.

In Table 7, sectoral contributions to changes in the structural effect index are given. According to single-period results industrial structural effect indices decreased in the years 2005, 2009, 2012, 2015 and 2016, and increased in the others. According to multi-period results, chemicals and pharmaceuticals, other non-metallic mineral products, transport equipment, food, beverages and tobacco, textile and leather contributed energy efficiency positively. While, basic metals, machinery and equipment, mining and quarrying, paper, paper products and printing, wood and products of wood, construction and other industry contributed negatively.

Table 6: Extended LMDI decomposition results of real energy intensity change by sub-sectors, between 2004-2017 (percentage changes)

	IND.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Single-period analysis, base year=previous year												
2004	-10.31	-3.92	2.82	0.27	0.09	-0.27	-0.02	-0.44	-0.44	0.02	-0.06	-0.57	-7.78
2005	26.30	9.91	6.28	-0.49	0.08	0.12	0.15	1.22	-0.24	-0.01	0.50	1.61	7.18
2006	-8.29	-6.74	-1.86	-2.30	-0.09	-0.17	-0.14	-0.50	0.25	0.05	-0.19	-0.39	3.78
2007	4.42	3.76	-1.58	1.33	-0.04	0.14	0.09	-0.09	-0.05	0.00	-0.08	0.40	0.54
2008	-32.59	-7.33	-3.11	6.41	0.04	0.55	-0.23	0.05	-0.06	0.11	-0.14	-0.95	-27.93
2009	36.80	21.22	0.88	2.38	0.15	-0.20	0.00	0.64	-0.02	0.58	0.00	2.82	8.35
2010	3.87	-3.96	0.80	2.72	-0.07	0.42	0.24	1.93	-0.15	-0.18	0.68	0.48	0.95
2011	-11.19	-5.25	1.73	-1.85	0.71	-0.31	0.09	0.68	0.01	-0.15	0.65	0.14	-7.64
2012	11.98	7.47	0.94	1.00	-0.44	-0.02	-0.07	-0.57	0.14	-0.29	-0.22	0.71	3.32
2013	-21.14	-6.50	-1.58	-5.23	0.01	-0.35	0.20	-0.62	0.09	0.49	-0.24	-1.45	-5.95
2014	-1.61	-0.61	-0.11	-0.29	-0.09	0.16	-0.02	-0.39	-0.11	0.04	-0.41	0.48	-0.27
2015	-6.31	-0.88	1.45	-2.08	0.11	0.46	1.66	-0.07	-0.18	-0.09	0.42	1.25	-8.37
2016	-6.56	-0.82	-0.99	0.62	-0.08	-0.31	-0.59	0.24	0.57	0.03	0.22	-0.90	-4.55
2017	9.44	-3.51	-2.51	12.91	-0.18	0.41	-0.57	-0.33	-0.54	0.01	0.08	-0.50	4.18
	Multi-period analysis, base year=2003												
	IND.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2004	-10.31	-3.92	2.82	0.27	0.09	-0.27	-0.02	-0.44	-0.44	0.02	-0.06	-0.57	-7.78
2005	13.28	4.97	8.45	-0.17	0.15	-0.17	0.11	0.66	-0.66	0.01	0.39	0.87	-1.34
2006	3.89	-2.66	6.34	-2.77	0.05	-0.36	-0.05	0.09	-0.37	0.06	0.17	0.42	2.95
2007	8.48	1.24	4.70	-1.39	0.01	-0.22	0.05	0.00	-0.42	0.07	0.09	0.84	3.51
2008	-26.88	-6.71	1.33	5.56	0.06	0.38	-0.21	0.06	-0.48	0.19	-0.06	-0.18	-26.80
2009	0.03	8.80	1.97	7.31	0.17	0.23	-0.21	0.52	-0.49	0.61	-0.06	1.88	-20.69
2010	3.90	4.84	2.77	10.03	0.10	0.66	0.04	2.45	-0.64	0.43	0.63	2.36	-19.74
2011	-7.72	-0.62	4.56	8.11	0.83	0.34	0.13	3.16	-0.64	0.27	1.30	2.50	-27.67
2012	3.33	6.28	5.43	9.04	0.43	0.32	0.06	2.63	-0.51	0.00	1.10	3.16	-24.61
2013	-18.51	-0.44	3.79	3.63	0.44	-0.05	0.27	1.99	-0.41	0.50	0.85	1.66	-30.76
2014	-19.83	-0.93	3.70	3.40	0.36	0.08	0.25	1.68	-0.51	0.53	0.52	2.06	-30.98
2015	-24.89	-1.63	4.86	1.73	0.45	0.44	1.58	1.63	-0.65	0.46	0.86	3.06	-37.69
2016	-29.81	-2.25	4.12	2.20	0.39	0.21	1.14	1.81	-0.23	0.48	1.02	2.39	-41.10
2017	-23.19	-4.71	2.36	11.26	0.27	0.50	0.74	1.58	-0.60	0.49	1.08	2.04	-38.17

Note: NACE Rev. 2 codes and sector names: Sector 1: 24 (Basic Metals), Sector 2: 20+21 (Chemicals and Pharmaceuticals), Sector 3: 23 (Other Non-Metallic Mineral Products), Sector 4: 29+30 (Transport Equipment), Sector 5: 25+26+27+28 (Machinery and Equipment), Sector 6: 07+08+099 (Mining and Quarrying), Sector 7: 10+11+12 (Food, Beverages and Tobacco), Sector 8: 17+18 (Paper, Paper Products and Printing), Sector 9: 16 (Wood and Products of Wood), Sector 10: 41+42+43 (Construction), Sector 11: 13+14+15 (Textile and Leather) and Sector 12: 22+31+32 (Other Industry).

Table 7: Extended LMDI decomposition results of structural effect change by sub-sectors, between 2004-2017 (percentage changes)

	Single-period analysis, base year=previous year												
	IND.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2004	3.67	3.30	-0.84	2.16	0.03	0.07	0.03	-0.62	-0.05	0.01	-0.02	-0.78	0.38
2005	-7.24	-4.77	-3.02	2.09	-0.01	0.11	0.00	0.13	0.38	0.14	0.16	-0.77	-1.68
2006	2.12	4.73	-0.54	0.82	-0.03	0.00	0.16	-0.73	-0.28	-0.10	0.14	-0.60	-1.46
2007	0.71	-1.34	-0.38	0.27	0.01	0.00	0.00	0.29	0.03	0.14	-0.02	-0.37	2.07
2008	1.86	5.80	0.24	-4.03	-0.01	0.05	-0.02	-0.17	-0.21	-0.10	0.06	-0.78	1.04
2009	-10.25	-14.59	0.75	-1.26	-0.01	0.11	0.01	1.01	0.30	0.03	0.05	0.08	3.26
2010	6.53	6.02	0.50	1.91	-0.02	-0.05	0.11	-0.81	0.04	0.11	-0.08	0.26	-1.47
2011	0.75	3.98	-0.92	-2.05	0.00	0.05	0.10	-0.69	-0.07	-0.04	-0.02	0.11	0.28
2012	-6.17	-6.80	-0.30	-0.30	-0.05	0.03	0.02	0.43	0.06	0.13	0.21	-0.06	0.46
2013	1.68	3.20	-0.70	0.70	-0.03	0.02	-0.05	-0.60	-0.15	-0.16	0.09	0.27	-0.91
2014	1.16	-0.24	0.19	0.48	0.02	0.00	-0.18	0.25	0.15	0.06	-0.09	0.12	0.41
2015	-0.58	-0.26	0.49	-0.40	0.01	0.05	-0.27	-0.14	-0.07	-0.10	0.05	-0.17	0.22
2016	-0.75	1.05	-0.01	-1.30	0.03	-0.06	-0.13	0.18	-0.25	-0.01	0.11	-0.31	-0.05
2017	0.91	3.53	0.59	-2.64	0.04	0.01	0.27	-0.60	0.19	-0.10	-0.21	-0.13	-0.06
	Multi-period analysis, base year=2003												
	IND.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2004	3.67	3.30	-0.84	2.16	0.03	0.07	0.03	-0.62	-0.05	0.01	-0.02	-0.78	0.38
2005	-3.85	-1.64	-3.97	4.33	0.01	0.18	0.03	-0.48	0.35	0.15	0.15	-1.58	-1.36
2006	-1.81	2.90	-4.49	5.12	-0.01	0.18	0.18	-1.18	0.08	0.05	0.28	-2.16	-2.76
2007	-1.11	1.59	-4.86	5.39	0.00	0.18	0.18	-0.90	0.11	0.19	0.26	-2.52	-0.73
2008	0.73	7.32	-4.63	1.40	-0.01	0.23	0.17	-1.07	-0.10	0.10	0.32	-3.29	0.30
2009	-9.60	-7.38	-3.88	0.13	-0.02	0.34	0.18	-0.05	0.20	0.13	0.37	-3.21	3.59
2010	-3.70	-1.93	-3.42	1.86	-0.04	0.30	0.28	-0.78	0.24	0.22	0.30	-2.97	2.26
2011	-2.98	1.91	-4.30	-0.12	-0.04	0.35	0.37	-1.44	0.17	0.18	0.28	-2.87	2.53
2012	-8.96	-4.69	-4.59	-0.40	-0.08	0.37	0.39	-1.03	0.23	0.31	0.49	-2.93	2.98
2013	-7.43	-1.78	-5.23	0.24	-0.11	0.39	0.35	-1.58	0.10	0.16	0.57	-2.69	2.15
2014	-6.36	-2.01	-5.05	0.68	-0.09	0.39	0.18	-1.35	0.23	0.21	0.49	-2.58	2.53
2015	-6.90	-2.25	-4.60	0.31	-0.08	0.45	-0.07	-1.48	0.17	0.12	0.54	-2.74	2.73
2016	-7.60	-1.27	-4.60	-0.91	-0.05	0.39	-0.19	-1.32	-0.06	0.12	0.64	-3.03	2.69
2017	-6.75	1.99	-4.06	-3.34	-0.01	0.40	0.06	-1.87	0.12	0.03	0.45	-3.15	2.63

Note: NACE Rev. 2 codes and sector names: Sector 1: 24 (Basic Metals), Sector 2: 20+21 (Chemicals and Pharmaceuticals), Sector 3: 23 (Other Non-Metallic Mineral Products), Sector 4: 29+30 (Transport Equipment), Sector 5: 25+26+27+28 (Machinery and Equipment), Sector 6: 07+08+099 (Mining and Quarrying), Sector 7: 10+11+12 (Food, Beverages and Tobacco), Sector 8: 17+18 (Paper, Paper Products and Printing), Sector 9: 16 (Wood and Products of Wood), Sector 10: 41+42+43 (Construction), Sector 11: 13+14+15 (Textile and Leather) and Sector 12: 22+31+32 (Other Industry).

7. Conclusion

In Turkey, energy efficiency continues to improve since 2003. Increase in energy efficiency results from real energy intensity effect, however, changes in the sectoral composition decreases energy efficiency. Highest contributions to overall decrease in the real energy intensity are made by the industry and the services sectors, however, agriculture has an increasing effect on real energy intensity. Shifts to agriculture and services sectors have a positive contribution. While, shift to industry has a negative contribution to energy efficiency. Regulations and promotion of more efficient use of energy are more important for Turkey. Intensity factor is more important than structural factor, although there is a negative contribution of industrial sector.

When we examine the industrial sector in detail, between 2003-2017, industry energy consumption increased, but industry real value added increased much more, as a result, industry energy intensity decreased. Similar to previous studies, energy efficiency in industry continues to improve. The enactment of Energy Efficiency Law lead to an increase in energy efficiency in the whole industry. Increase in energy efficiency results from real energy intensity effect, however structural effect is positive but less significant.

References

Ang, B. (1994). Decomposition of industrial energy consumption: The energy intensity approach. *Energy Economics*, *16*(3), 163–174. https://doi.org/10.1016/0140-9883(94)90030-2

Ang, B. W., & Choi, K.-H. (1997). Decomposition of Aggregate Energy and Gas Emission Intensities for Industry: A Refined Divisia Index Method. *The Energy Journal*, *18*(3), 59–73. Retrieved from JSTOR.

Choi, K.-H., & Ang, B. W. (2012). Attribution of changes in Divisia real energy intensity index—An extension to index decomposition analysis. *Energy Economics*, *34*(1), 171–176. https://doi.org/10.1016/j.eneco.2011.04.011

Ediger, V. Ş., & Huvaz, O. (2006). Examining the sectoral energy use in Turkish economy (1980–2000) with the help of decomposition analysis. *Energy Conversion and Management*, *47*(6), 732–745. https://doi.org/10.1016/j.enconman.2005.05.022

Eurostat. (2019). Energy Import Dependency by Products. Retrieved September 5, 2019, from https://ec.europa.eu/eurostat/data/database

Fernández González, P. (2015). Exploring energy efficiency in several European countries. An attribution analysis of the Divisia structural change index. *Applied Energy*, *137*, 364–374. https://doi.org/10.1016/j.apenergy.2014.10.020

Fernández González, P., Landajo, M., & Presno, M. J. (2013). The Divisia real energy intensity indices: Evolution and attribution of percent changes in 20 European countries from 1995 to 2010. *Energy*, *58*, 340–349. https://doi.org/10.1016/j.energy.2013.06.013

IEA. (2018a). *CO2 Emissions from Fuel Combustion 2018 Highlights*. Paris: OECD/IEA.

IEA. (2018b). *Energy Efficiency Indicators 2018: Highlights*. Paris: OECD/IEA.

IEA. (2018c). *World Energy Balances 2018*. Paris: OECD/IEA.

IEA. (2019a). *World Energy Balances 2019 Overview*. Paris: OECD/IEA.

IEA. (2019b). World Energy Balances, IEA Headline Energy Data. Retrieved September 5, 2019, from https://www.iea.org/statistics/balances/

IEA. (2019c). Energy Efficiency Policies: Industry. Retrieved September 27, 2019, from https://www.iea.org/topics/energyefficiency/policies/industry/

IEA Data Services. (2019). Energy Balances of OECD Countries: Beyond 2020 Documentation. Retrieved September 2, 2019, from http://data.iea.org/

İpek Tunç, G., Türüt-Aşık, S., & Akbostancı, E. (2009). A decomposition analysis of CO2 emissions from energy use: Turkish case. *Energy Policy*, *37*(11), 4689–4699. https://doi.org/10.1016/j.enpol.2009.06.019

Revkin, A. (2018, June 21). Climate Change First Became News 30 Years Ago. Why Haven't We Fixed It? Retrieved September 25, 2019, from National Geographic website: https://www.nationalgeographic.com/magazine/2018/07/embark-essay-climate-change-pollution-revkin/

Sahin, S. (2017). Firm-Level Decomposition of Energy Consumption in Turkish Manufacturing Industry. *World Bank Policy Research Working Paper*, *WPS8211*.

Selçuk, I. Ş. (2018). Türkiye Sanayi Sektörü Enerji Verimliliği: Genişletilmiş Logaritmik Ortalama Divisia Endeks Ayrıştırma Yöntemi Uygulaması. *Sosyoekonomi*, *26*(37), 127–145. https://doi.org/10.17233/sosyoekonomi.2018.03.07

The World Bank. (2019). World Development Indicators | DataBank. Retrieved September 8, 2019, from https://databank.worldbank.org/source/world-development-indicators

Turkish Statistical Institute (TurkStat). (2019a). Annual Gross Domestic Product by Production Approach. Retrieved October 9, 2019, from http://www.turkstat.gov.tr/PreTablo.do?alt_id=1108

Turkish Statistical Institute (TurkStat). (2019b). Annual Industry and Service Statistics. Retrieved September 2, 2019, from http://www.turkstat.gov.tr/PreTablo.do?alt_id=1035

UNFCCC. (2019). What is the Kyoto Protocol? Retrieved September 25, 2019, from https://unfccc.int/kyoto_protocol

World Energy Council. (2016). *Energy Efficiency: A straight path towards energy sustainability*. London: WEC.