Közgazdász Fórum
Forum on Economics and Business
16 (6), 149–170.
2013/6

Eight methods for decomposing the aggregate energy intensity with special regard to the industrial sector[1]

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The energy intensity of East-Central Europe strongly improved in the last two decades and it has two main reasons. The first one is that after the change of regime the heavy industry collapsed, and there was a shift from agriculture towards the service sector. The second is the technological development of the economy, which increased the energy efficiency of the economic sectors. The subject of this paper is to give a comprehensive analysis and decompose both the energy intensity of the industrial sector and the aggregate energy intensity of the economy in East-Central Europe (Czech Republic, Slovakia, Slovenia, Poland and Hungary) between 1990 and 2010. We study how the aggregate energy intensity is influenced by the structural and the intensity effects.

Keywords: energy consumption, energy intensity, East-Central Europe, change of regime, industry sector.

JEL classification codes: P28, Q43.

Introduction

There are serious differences in the size of the energy intensity of economic sectors. The energy intensity of an economy is affected by two factors. On one hand it is affected by the role of the given economic sector (such as the value added in percentage of GDP) and on the other hand by its energy intensity.

Our analysis can be divided into two main parts. In the first part we aim to examine these two factors, we analyze the transformation process of the East-Central European region after the change of regime, with

[1] The article presents the results of a research carried out as part of the TÁMOP 4.2.1.B-10/2/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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Published: Hungarian Economists' Society from Romania and Department of Economics and Business Administration in Hungarian Language at Babeș–Bolyai University
ISSN: 1582-1986 www.econ.ubbcluj.ro/kozgazdaszforum

special regard to the shifts among the economic sectors and the changes of the sectoral energy intensity. In our database we used the final energy consumption of economic structures (primary, secondary, tertiary sectors, 1000 toe) and the value added of these sectors (constant 2000 US$; % of GDP). "Final energy consumption covers energy supplied to the final consumer for all energy uses. It is calculated as the sum of final energy consumption of all sectors. These are disaggregated to cover industry, transport, households, services and agriculture." (IEA, 2005) The examined countries and time spans: Hungary (1990-2010), Poland (1993-2010), Czech Republic (1990-2010), Slovakia (1993-2010) and Slovenia (1990-2010). We used the Eurostat and the Worldbank database, which enable the results to be comparable.

In the second part we examine the changes of the industry sector, because in the last two decades the improvements of the energy intensity in the economy stemmed from the development of energy efficiency of the industry sector. For our analysis we also use the final energy consumption (Mtoe) and the added value (constant 2000 €) of the industrial subsectors (chemical industry; primary metals; non metallic minerals; wood industry; paper, pulp and printing industry; food industry; textile and leather industry; machinery; transport equipment; other industries; mining; construction). We apply the Odyssee database and the division of the industry sector is based on the UN ISIC (International Standard Industrial Classification of All Economic Activities).

We use the following abbreviations: D_{tot} means the changes of the aggregate energy intensity (energy intensity of the primary, secondary and tertiary sectors), D_{int} is the intensity effect and D_{str} is the structural effect.

Theoretical background

The effects of economic activities on energy intensity have become a central research topic of the energy and environmental economy after the first oil price shock (Boyd and Roop 2004.). The Index Decomposition Analysis (IDA) is a widespread method: it is used for the analysis of energy consumption and emission both in the energy and environmental economy; furthermore in the last years it appeared as a toolbar of human resource economy (Achao and Schaeffer 2009) and it gives new additives for the examination of income inequalities. It can be easily interpreted and nowadays it is a frequently used tool for the decision-makers (Ang 1995, 2000; Hoekstra et al. 2003; Zhao et al. 2010; Liu and Ang 2003; Unander 2007).

Table 1 contains relevant publications regarding this reviewed topic, which includes not only methodology surveys, but empirical results as well. It is somewhat odd – with some exceptions – that they use only one method and they do not aim to compare their results with others. The analyzed area is quite wide: Achao and Schaeffer (2009) try to explain Brazil's income inequalities, Mairet and Decellas (2009) decompose the energy intensity of the French service sector and Ang (2005) studies the emission in the Canadian industry sector. The examined number of subsectors fluctuates heavily: the minimum is 3, the maximum is 28 in the reviewed publications, but Ang (2000) mentioned as well that an analysis ranging between 2 and 400 subsectors is not rare.

The index decomposition method has many similar characteristics with the shift-share analysis which is presented by Nemes Nagy (1995). The latter is an additive approach; the former one can be additive and multiplicative as well. The target of both analyses is the decomposition of an aggregate data into components. While the shift-share analysis can be mainly observed in the regional studies, the index decomposition analysis is the result of increasing energy interests caused by the 1973 oil crisis. At this time the general target of the governments was to restrain energy consumption and enhance energy efficiency. The first step was to determine factors which have influence on the energy consumption and to work out the exact methodology, with special regard to the index decomposition analysis.

The essential of the IDA is that it can explain the changes of an indicator at sectoral level, and another advantage is the low data request (Hoekstra 2003). The starting point is the final intensity in the economic structure (aggregate energy intensity) which is essentially affected by two factors: changes in energy intensity of economic sectors (intensity effect) and the shift in the mix of products or activities (structural effect) (Liu and Ang 2003). The method disaggregates the economy into sectors and then weights the sectoral energy intensity by their output shares. In our paper the final intensity in the economic structure reveals the ratio of the final energy use of primary, secondary and tertiary sectors to the added value they produce.

Table 1. Summary of the reviewed publications

Publication	Examined country	Time period	Method	Type of method	Subsector number
Zhao et al. 2010.	China	1998-2006	LMDI	Additive	15
Mairet and Decellas 2009.	France	1995-2006	LMDI	Additive	7
Achao and Schaeffer 2009.	Brazil	1980-2007	LMDI	Additive	4
Hatzigeorgiou et al. 2008.	Greece	1990-2002	AMDI LMDI	Additive	3
Mercados-EMI et al. 2007.	Cyprus, Estonia, Hungary, Lithuania, Latvia, Poland, Czech Republic, Slovakia, Slovenia	1995-2004	Divisia	Additive	10
Unander 2007.	Australia, Denmark, Finland, France, Italy, Japan, Norway, Sweden, Great-Britain, USA	1973-1998	Laspeyres	-	7
Ang 2005.	Canada	1990-2000	LMDI	Multiplicative	23
Boyd and Roop 2004.	USA	1983-1998	AMDI Fisher Ideal	Multiplicative	19
Farla and Blok 2000.	Netherlands	1980-1995	simple average parametric Divisia method 2. (AVE-PDM2)	Additive	5 and 21
Ang 1995.	Singapore	1982-1990	general parametric Divisia 1	Additive	28

Source: own compilation

The index decomposition analysis is a really wide research topic. We used the most popular methods: the Laspeyres-, Paasche-, Marshall Edgeworth-, Walsh-, Fisher Ideal, Drobish, LMDI and the AMDI-methodology. The Laspeyres-index shows the changes in the examined time span and it uses the weights based on values in base year. In contrast, the Paasche-index uses values of the current year as weight. The Marshall-Edgeworth index calculates the arithmetic average of basic and target years, the Walsh-index uses the geometric means. The Fisher Ideal-index is the geometric mean of the results of the Laspeyres and Paasche methods, while the Drobish-index argues for their arithmetic average (Liu and Ang 2003). According to Boyd and Roop (2004), the perfect index decomposition method is the Fisher Ideal index, because it is fit for all of the strict requirements and the value of residual term is one of them. Both the AMDI and LMDI are integral index numbers and they have many advantages such as “path independency, ability to handle zero values and consistency in aggregation” (Zhao et al. 2010. 1382).

Let V be an energy-related aggregate. We assume that it is affected by n variables, x_1, x_2,… x_n. The aggregate can be divided into *i* subsector, where the changes happen (the structural and the intensity changes). The connection among the subsectors can be described as following:

$$V = \sum_i V_i = x_{1,i} x_{2,i} \ldots x_{n,i}$$

By using the multiplicative method we decompose the relative changes (Ang 2005. 867):

$$D_{tot} = \frac{V^T}{V^0} = D_{x1} D_{x2} \ldots D_{xn}$$

where:

$$V^0 = \sum_i V_i = x_{1,i}^0 x_{2,i}^0 \ldots x_{n,i}^0 \qquad V^T = \sum_i V_i = x_{1,i}^T x_{2,i}^T \ldots x_{n,i}^T$$

By using the additive method we decompose the absolute changes:

$$\Delta V_{tot} = V^T - V^0 = \Delta V_{x1} + \Delta V_{x2} + \ldots + \Delta V_{xn}$$

where:

$$V^0 = \sum_i V_i = x_{1,i}^0 x_{2,i}^0 \ldots x_{n,i}^0 \qquad V^T = \sum_i V_i = x_{1,i}^T x_{2,i}^T \ldots x_{n,i}^T$$

Hereafter we present the methodology of index decomposition analysis with the Laspeyres-index. We chose this one, because this is the most frequently used method (Ang 2000, Mairet and Decellas 2009), and the methodology is easily realized.

Table 2. Multiplicative methods of index decomposition analysis

Method	Formula
Laspeyres	$D_{x_1} = I_L = \frac{\sum_i x_{1i}^T * x_{2i}^0 \dots x_{ni}^0}{\sum_i x_{1i}^0 * x_{2i}^0 \dots x_{ni}^0}$
Paasche	$D_{x_1} = I_P = \frac{\sum_i x_{1i}^T * x_{2i}^T \dots x_{ni}^T}{\sum_i x_{1i}^0 * x_{2i}^T \dots x_{ni}^T}$
Marshall Edgeworth	$D_{x_1} = I_{ME} = \frac{\sum_i x_{1i}^T * (x_{2i}^0 + x_{2i}^T) * (x_{3i}^0 + x_{3i}^T) \dots (x_{ni}^0 + x_{ni}^T)}{\sum_i x_{1i}^0 * (x_{2i}^0 + x_{2i}^T) * (x_{3i}^0 + x_{3i}^T) \dots (x_{ni}^0 + x_{ni}^T)}$
Walsh	$D_{x_1} = I_W = \frac{\sum_i x_{1i}^T * \sqrt{x_{2i}^0 * x_{2i}^T} * \sqrt{x_{3i}^0 * x_{3i}^T} \dots \sqrt{x_{ni}^0 * x_{ni}^T}}{\sum_i x_{1i}^0 * \sqrt{x_{2i}^0 * x_{2i}^T} * \sqrt{x_{3i}^0 * x_{3i}^T} \dots \sqrt{x_{ni}^0 * x_{ni}^T}}$
Fisher 1(Fisher Ideal)	$D_{x_1} = I_F = \sqrt{I_L * I_P}$
Drobish	$D_{x_1} = I_D = \frac{I_L + I_P}{2}$
AMDI (Arithmetic Mean Divisia Index)	$D_{x_1} = \exp\left(\sum_i \frac{\frac{V_i^0}{V^0} + \frac{V_i^T}{V^T}}{2} * \ln\left(\frac{x_{1i}^T}{x_{1i}^0}\right)\right)$ $L(a,b) = \frac{a-b}{\ln(a) - \ln(b)}$, $a \neq b$
LMDI 1 (Log Mean Divisia Index 1)	$D_{x_1} = \exp\left(\sum_i \frac{L(V_i^0, V_i^T)}{L(V^0, V^T)} * \ln\left(\frac{x_{1i}^T}{x_{1i}^0}\right)\right)$ $L(a,b) = \frac{a-b}{\ln(a) - \ln(b)}$, $a \neq b$

where: t=0 (year 0); t=T (year T); i: economic sector

Source: own compilation by Granel 2003. 35

Excluding the Laspeyres-index, the other methods can also be easily conducted (Ang and Zhang 2000. 1157). In every case the multiplicative type was supported, because it is insensible for the units (in contrast with the additive type which can lead to serious differences) and the results can be perfectly illustrated. Ang et al. (2003) also suggest this method in every case when the researchers analyze long time series (Ang et al. 2003. 1564). Every method has three main parts:

$$D_{tot} = D_{int} * D_{str} * D_{res} = \frac{I_t}{I_0}$$

where: *Et:* total energy consumption; *Ei,$_{t:}$* energy consumption of sector *i; Yt: G*DP; *Yi,t:* GDP of sector *i; Si,$_{t:}$* share of sector $(=Y_{i,t}/Y_t)$; I_t: energy intensity of the economy, $(=E_t/Y_t)$; $I_{i,t:}$ energy intensity of sector *i* $(=E_{i,t}/Y_{i,t})$.

The first part shows (D_{tot}) the changes of energy intensity in the economy within two years.

$$D_{str} = \frac{\Sigma_i S_{i,T} I_{i,0}}{\Sigma_i S_{i,0} I_{i,0}}$$

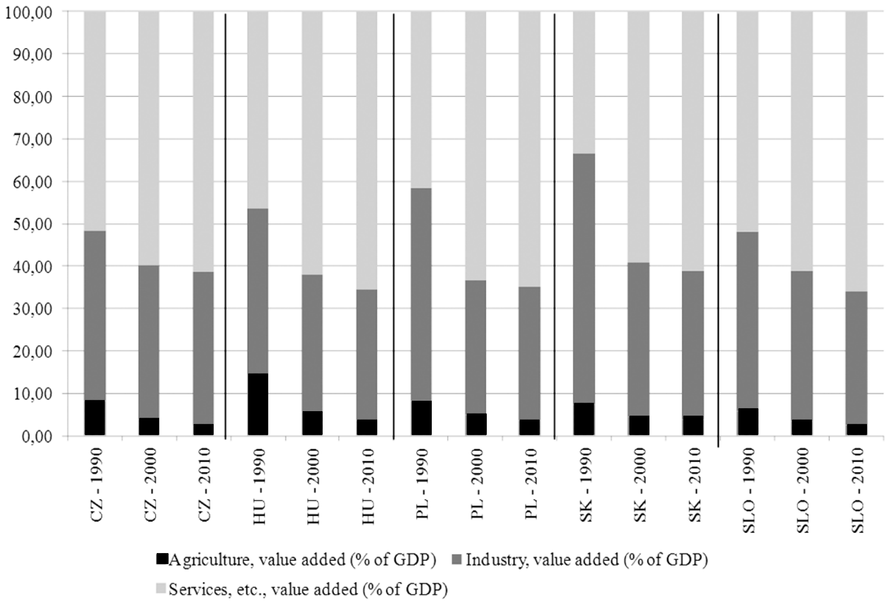
The next two indicators ($D_{str,}$ D_{int}) are the difference of final intensity in the economic structure belonging to the year *0* and year *t*. The difference between them is the factor that is unchanged (base year) in the counter. The D_{str} leaves the energy intensity of subsectors unchanged so it shows the structural effect, which means the size of the effect in the final intensity (in the economic structure) caused by the shift in the economic structure (from agriculture and industry sector towards the service sector).

$$D_{int} = \frac{\Sigma_i S_{i,0} I_{i,T}}{\Sigma_i S_{i,0} I_{i,0}}$$

The D_{int} leaves the share of subsectors unchanged and it presents the effect of energy intensity changes (intensity effect), which reveals how the changes of the subsectors' energy intensity affect the final intensity in the economic structure. The closer D_{str}, D_{int} are to the value 1, the less the effect is. The equation includes a residual term for every method, which shows all the effects that are not explained by the model. The value of the residual term is ideal if it is close to 1 (in multiplicative method).

Results

By change of economic structure we mean the changes of the share of the primary, secondary and tertiary sectors. As a starting point we examine the changes of the share within the economic sectors with regard to its value added (% of GDP). Similar processes can be observed in the examined region. The share of agriculture and industry sectors declined in comparison with the development of the service sector. "The main reason is that the ratio of the capital and labor and so the productivity grows faster in the manufacturing than in the service sector so the free labor is integrated by the tertiary sector." (Szalavetz 2008. 503-504)



Source: Worldbank database

Figure 1. Changes of the shares of the main economic sectors with regard to the GDP, 1990-2010 (%)

Both the industry sector and the industrial subsectors underwent significant changes: the value added increased (in contrast with the energy consumption) which denotes a serious technological development and it is an evidence of a reindustrialization process (Barta et al. 2008). At the same time the share of the subsectors in industry changed, which shows the altering conformation for the industry restructuring. In the economic development the subsectors producing higher value added displace the others. So the automobile, the pharmaceutical and the electronics industry have become more and more important in the developed industrial structure…” (Barta et al. 2008. 3). The energy-intensive heavy industry had a central role in the socialist industrial policy, but after the change of regime the magnitude of these subsectors decreased, gave space for more developed and less energy intensive branches. The effects of reindustrialization can be found in the energy consumption as well: the decrease of its value is significant, which is caused by the development of energy efficiency, the technological and production changes. The energy consumption of the secondary sector, with special regard to the heavy industry decreased significantly in the Czech Republic, Poland and Hungary and slightly in Slovakia (Figure 1).

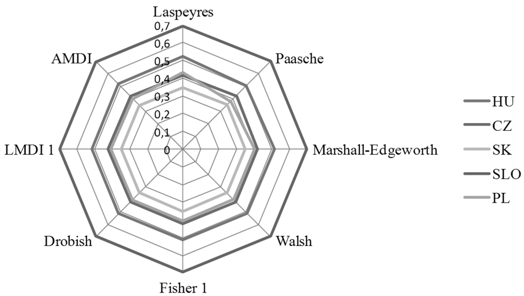


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Figure 2. Index decomposition analysis results for aggregate energy intensity of the economic structure (D_{int}, 1990-2010)

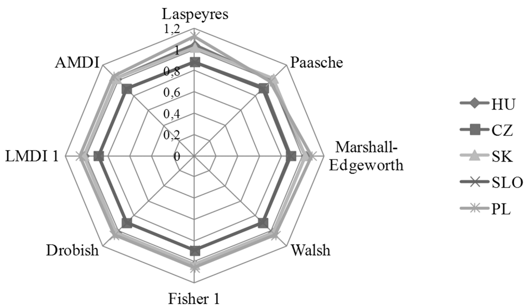

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Figure 3. Index decomposition analysis results for aggregate energy intensity of the economic structure (D_{str}, 1990-2010)

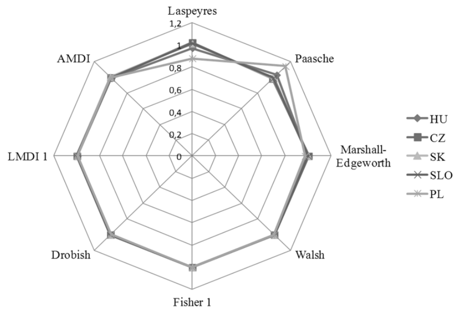

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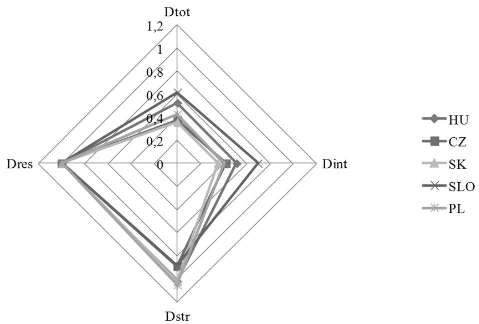
Figure 4. Index decomposition analysis results for aggregate energy intensity of the economic structure (D_{res}, 1990-2010)



Source: own compilation

Figure 5. Index decomposition analysis results for aggregate energy intensity of the economic structure (Fisher I, 1990-2010)

Barta et al. (2008) divided the countries of the world into three main groups by the changes of their industrial sector: the first group is characterized by the process of deindustrialization and delocalization. To the second group belong the dynamic developing economies, such as China and these countries are under the process of industrialization. The third group contains those countries (the East-Central-Europe also belongs to this group), where the reindustrialization is determining: “new industrial subsectors come into the life, mainly caused by the foreign direct investments” (Barta et al. 2008. 4).

The objective of this paper is to determine the sources of the energy efficiency and to quantify their roles and measures. The method of Laspeyres-, Paasche-, Marshall-Edgeworth, Walsh-, Fisher 1, Drobish-, LMDI-, and the AMDI- index are applied. The deviation of the results is really small and this highly confirms the reliability of the analysis and facilitates the interpretation.

The results of the index decomposition analysis with regard to the aggregate energy intensity

The results of the decomposition analysis presented in this paper show that between 1990 and 2010, mainly in East-Central Europe, the intensity changes have significantly affected the energy use in the industrial sector and the whole economy as well (Figures 2, 3, 4 and 5). These results confirm Ang and Zhang's conclusion that "… for the industrialized countries, declining sectoral energy intensity has generally been found to be the main contributor to decreases in the aggregate energy intensity … The impact of structural change is smaller in comparison." (Ang and Zhang 2000. 1162). The publication of Mercados-EMI (2007) gives similar results and it is also supported by Kuttor's statement, that "it is important to state and emphasize that in spite of the vigorous tertiarisation of the economies, the industry has maintained its significance in the economies of the region [Visegrád countries], both in terms of the employment of workers and of the production of added value." (Kuttor 2011. 51).

The impact of the structural change would have increased the energy use in Hungary, Slovakia and Poland (in these countries, the mix of industrial output moved away towards energy intensive sectors), but the intensity effect was so strong that in the end the final energy intensity in the economic structure improved everywhere.

Results of the 5 years period are presented in Table 3.

Leamer and Uliha (2011) suggests the extreme bounds analysis (EBA) as an appropriate method: „EBA addresses the issue of specification uncertainty by computing the maximum and minimum values on a large set of model specifications. The highest and lowest estimates are called the upper and lower bounds." (Uliha 2011. 237). At

Table 3. The results of the index decomposition analysis with regard to the aggregate energy intensity

Country		1990-1995		1995-2000		2000-2005		2005-2010		1990-2010	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
HU	D_{int}	0.842	0.848	0.788	0.803	0.840	0.847	0.913	0.916	0.505	0.520
	D_{str}	0.976	0.983	1.022	1.042	0.996	1.004	1.000	1.003	1.008	1.039
	D_{res}	0.993	1.007	0.981	1.019	0.992	1.008	0.997	1.003	0.970	1.031
CZ	D_{int}	0.866	0.887	0.778	0.780	0.796	0.796	0.772	0.777	0.415	0.423
	D_{str}	0.867	0.888	1.022	1.025	1.002	1.003	0.985	0.991	0.884	0.901
	D_{res}	0.976	1.025	0.997	1.003	1.000	1.000	0.994	1.006	0.981	1.020
PL	D_{int}	0.868	0.875	0.702	0.712	0.832	0.833	0.781	0.796	0.379	0.432
	D_{str}	1.041	1.049	0.983	0.998	0.997	0.998	1.012	1.031	0.987	1.125
	D_{res}	0.992	1.008	0.985	1.015	0.999	1.001	0.981	1.019	0.877	1.140
SK	D_{int}	0.809	0.810	0.774	0.775	0.686	0.688	0.802	0.805	0.348	0.351
	D_{str}	0.993	0.993	0.988	0.990	1.087	1.090	0.966	0.969	1.019	1.030
	D_{res}	1.000	1.000	0.998	1.002	0.997	1.003	0.997	1.003	0.989	1.011
SLO	D_{int}	0.984	0.997	0.979	0.980	0.887	0.887	0.808	0.809	0.692	0.699
	D_{str}	0.894	0.905	1.018	1.019	1.006	1.007	0.960	0.962	0.882	0.891
	D_{res}	0.987	1.013	0.999	1.001	1.000	1.000	0.998	1.002	0.990	1.010

Source: own compilation

the end this interval is the result. In Table 3 this method is applied, and the maximum and minimum values are presented here.

In the first time span (1990/1993-1995) the aggregate energy intensity in East-Central-Europe decreased, but its measurement was different. In Hungary, Slovakia, Poland and Slovenia the decline was caused mainly by the changes of energy intensity of the economic sectors (the Fisher Ideal index's results are the following, sequentially: 0.844; 0.81; 0.87; 0.89), not by the shift of the sectors (the Fisher Ideal index's results are the following, sequentially: 0.98; 0.99; 1.04; 0.98). In the Czech Republic the strength of these two effects was nearly equal (according to the Fisher Ideal index the results are 0.88 for both of these effects). For example, in Hungary these values reveal that as a result of the intensity effect the aggregate energy intensity in 1995 would have been 0.84 times of the value in 1990 and as a result of the structural effect in 1990 it would have been 0.98 times of the value in 1990, so finally the aggregate energy intensity changed by 0.83 times at the end of the period.

Between 1995 and 2000, excluding Slovakia, the intensity effect became stronger, the value of the Fisher Ideal index dispersed around 0.78 (Hungary – 0.795, Slovakia – 0.774, Czech Republic – 0.779, Poland – 0.707). The value of the structural effect is close to 1 which means the aggregate energy intensity was not significantly affected in this period. In Slovenia this tendency is the opposite, the aggregate energy intensity did not change, because the two effects exactly offset each other (the Fisher Ideal index with regard to the structural effect was 1.02 and the intensity effect was 0.98).

These trends were the same in the next intervals of time (2000-2010) but it is interesting that the structural effect in Slovakia exceeded the value of 1 (the Fisher Ideal index is 1.08) which probably was the consequence of the automobile industry development.

Analyzing the entire period of time, in Hungary the aggregate energy intensity is 0.524 times in 2010 compared to 1990, which is mainly caused by the intensity effect (the Fisher Ideal index of it is 0.513), not by the structural effect (the Fisher Ideal index of it is 1.02). Elek (2009), who examined the Hungarian energy intensity (1992-2007) – using the additive approach –, concludes that the intensity effect is more significant than the structural effect.

The same tendencies can be observed in the other countries (strong intensity and weak structural effect); except Poland and Slovakia, the structural effect is close to 1. In Poland and Slovakia the structural effect would have worsened the energy intensity (the Fisher Ideal index is 1.05 and 1.02), but it was offset by the intensity effect.

The results of the index decomposition analysis with regard to the energy intensity of the industrial sector

In the last two decades the increasing energy efficiency has been mainly caused by the industry sector, because not only in the macro level, but also in the sectoral level the structural changes can be observed. With regard to this process two controversial opinions were developed: "one group believes these tendencies are the expression of the deindustrialization, (...), while the others think the structural changes are the consequences of the natural evolution of the developed production processes." (Kiss 2010. 11).

Next, our objective is to determine and measure the main sources of the developing energy efficiency. We suppose that the value of the intensity and the structural effect can significantly differ from the former results.

The value added of industrial subsectors underwent significant growth (contrary to energy consumption). It is a mark of the developing energy efficiency and an evidence for a reindustrialization process (Barta et al. 2008.). In parallel the share of the subsectors has also changed, which indicates the industrial structural changes. "During the development the higher value added subsectors displace the lower ones. So the automotive, the pharmaceutical, the electronic etc. industry sectors have increasing weight in the developed industrial structure..." (Barta et al. 2008. 3). In the socialist industrial policy the energy intensive heavy industry had a central role, but after the change of regime these subsectors have become less important and more efficient and modern branches gained space.

Reindustrialization can be observed in the field of the energy consumption: the indicator has significantly decreased, which is mainly caused by the developing energy efficiency and changes of the product structure and technology. The energy consumption of the sector (mainly the heavy industry) dramatically decreased in the Czech Republic, Poland and Hungary, and slightly in Slovakia and Slovenia.

Barta et al. (2008) divided into three main parts the world's countries based on the processes taking place in the industrial sector. The first group can be characterized by deindustrialization and delocalization. The dynamic developing economies (such as China) belong to the second group, where the industrialization processes represent the main characteristic feature. In the third group the reindustrialization and delocalization determine the economic growth: "new industrial branches emerged, thanks to the growth of the FDI" (Barta et al. 2008. 4).

With regard to the industrial sector, between 1995 and 2010 in every country the intensity effect was the strongest, but regarding the value of the intensity one can observe huge differences (Figures 6, 7, 8 and 9). While in Poland the magnitude of the intensity effect is more than twice as the structural one, in Slovenia the structural effect is insignificant (The Fisher Ideal index is 1.02). In Hungary the difference between the effects is relatively small (by the intensity effect the Fisher Ideal index is 0.62, by the structural effect it is 0.68). In the Czech Republic and Slovakia – similar to Poland – the difference is significant: for both these countries the intensity effect is close to 0.3, the structural effect is 0.9 for the Czech Republic and 1.43 for Slovakia. The publication of the Mercados-EMI (2007) has similar results: they assess the intensity effect more significant than the structural effect in East-Central Europe.

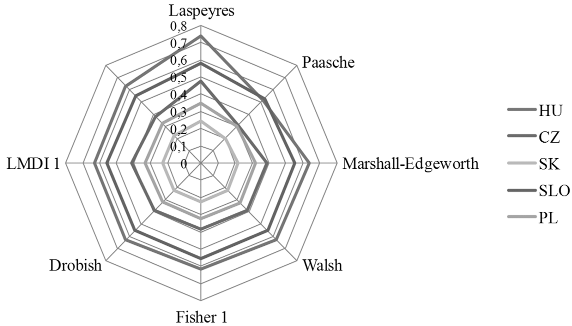


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Figure 6. Index decomposition analysis results for the industrial sector (D_{int}, 1995-2009)

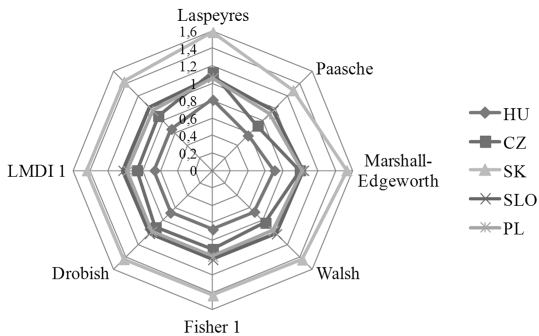

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Figure 7. Index decomposition analysis results for the industrial sector (D_{str}, 1995-2009)

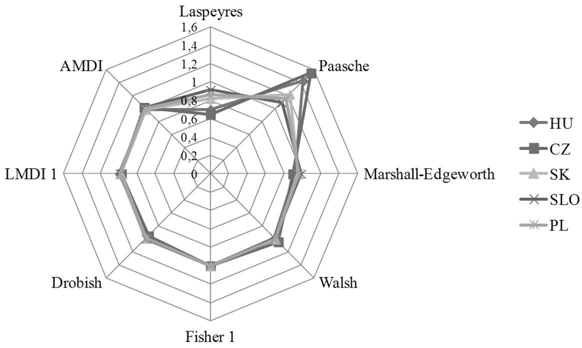

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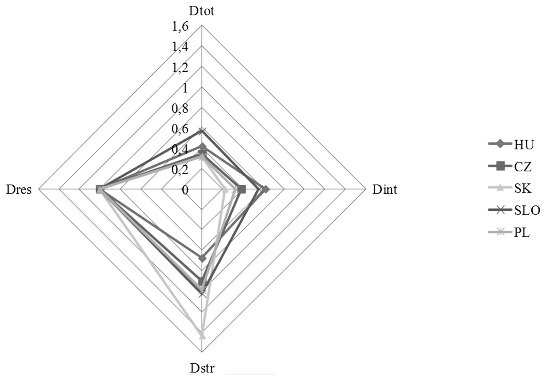
Figure 8. Index decomposition analysis results for the industrial sector (D_{res}, 1995-2009)



Source: own compilation

Figure 9: Index decomposition analysis results for the industrial sector (Fisher I, 1995-2009)

Our results contradict the former analysis (such as Unander 2007) made in Western-Europe and in the USA, which emphasizes the relevance of the structural effect. These different results are given by the dramatic industrial structural changes after the change of regime and the technological changes.

As before, table 4 shows the maximum and minimum results, but the Laspeyres and Paasche indexes are omitted, because their residuum is higher than 1.1. In our evaluation their results are unreliable so we do not present them.

Table 4. The results of the index decomposition analysis with regard the energy intensity of the industrial sector

Country		1995-2000		2000-2005		2005-2010		1995-2010	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
HU	D_{int}	0.853	0.860	0.846	0.848	0.882	0.883	0.618	0.640
	D_{str}	0.794	0.802	0.879	0.881	0.937	0.937	0.666	0.705
	D_{res}	0.985	1.000	0.996	1.000	0.999	1.000	0.926	1.000
CZ	D_{int}	0.707	0.716	0.856	0.867	0.683	0.684	0.382	0.410
	D_{str}	0.965	0.993	0.873	0.881	0.962	0.965	0.851	0.995
	D_{res}	0.981	1.010	0.994	1.009	0.997	1.000	0.897	1.045
PL	D_{int}	0.616	0.618	0.839	0.847	0.667	0.687	0.321	0.329
	D_{str}	0.986	0.997	0.875	0.880	1.028	1.086	0.971	1.025
	D_{res}	0.990	1.001	0.990	1.002	0.974	1.005	0.962	1.003
SK	D_{int}	0.784	0.790	0.741	0.749	0.394	0.396	0.219	0.228
	D_{str}	1.034	1.041	1.019	1.034	1.299	1.321	1.433	1.527
	D_{res}	0.995	1.002	0.995	1.000	0.988	1.000	0.955	1.000
SLO	D_{int}	0.848	0.852	0.824	0.829	0.785	0.787	0.550	0.559
	D_{str}	1.036	1.038	1.039	1.040	0.950	0.953	1.018	1.036
	D_{res}	0.995	1.000	0.998	1.004	0.998	1.000	0.986	1.011

Source: own compilation

Between 1995 and 2000, with the exception of Hungary, the intensity effect was more significant and the value of the structural effect was close to 1. In Hungary the structural effect is more relevant and its value is far from 1 (the Fisher Ideal index is 0.8). In the following five year period the intensity effect became stronger in all countries, but in Hungary, Czech Republic and Poland the size of the two effects is nearly the same (close to 0.85), while in Slovakia and Slovenia the structural effect is really small (the Fisher Ideal index close to 1).

Between 2005 and 2010 the structural effect magnified (by contrast in the whole economy it ceased) which reveals the shift between the economical sectors. In Slovakia and in Poland its value is higher than 1.

In the Czech Republic, Hungary and Slovenia the intensity effect is stronger, but the structural effect is also present.

Our conclusions are similar to the analysis of the Odyssee project (2009) which concluded that both the structural and intensity effects influenced the development of the energy intensity in the industrial sector. Taylor et al. (2010) examined the member states of the IEA. He concluded that more than half of the energy intensity development in the industrial sector is given by the structural effect.

Conclusions

The main difference between the neoclassical and energy economy is the different opinion regarding the role of energy in the economic development. According to the former one the energy is just an intermediary input among other production factors (land, capital and workers), which determines directly or indirectly the economic development. For the energy economists (Cleveland C. J., Herring H. and Stern D. I.) the energy significantly affects the income and the economy depends on the changes in energy consumption. The relationship between economic development and energy use was a core topic for many centuries.

In this paper we study how the aggregate energy intensity is influenced by the shift in the mix of products or activities (structural effect) and the changes in energy intensity of economic sectors (intensity effect). The starting hypothesis was that both these effects were significant. We carried out the examination with the index decomposition analysis and we used eight methods. Significant differences between the results did not appear, therefore the size of the residual term was treatable.

In East-Central Europe the aggregate energy intensity includes the primary, secondary and tertiary sectors which underwent significant development in the last two decades. It is mainly caused firstly by the intensity effect and secondly by the structural effect. By using the 8 methods of the Index Decomposition Analysis we divided the changes of the aggregate energy intensity into their components. We quantified the intensity and the structural effect for the whole time span (1990-2010) and for a 5 year-period as well. In our analysis, between 1990 and 1995, the intensity effect was more significant than the structural one in all countries, except Slovakia.

In the second section we examined the industrial sector, because the development of the aggregate energy intensity mainly stems from the secondary sector and it is also interesting whether the processes are the same in the whole economy and at sectoral level. There was only one situation in the industrial sector (Hungary, 1995-2000) when the structural effect was more significant, so generally the processes in the secondary sectors are similar to the processes within the whole economy. So, we drafted the following conclusions:

1. In East-Central Europe (Czech Republic, Poland, Hungary, Slovakia, Slovenia) between 1990 and 2009 the intensity effect contributed more to the improvement of final intensity in the economic structure than the structural effect.

2. The magnitude of structural effect is smaller than the intensity effect from the energy intensity perspective.

3. The development of the energy intensity in the industrial sector of the Czech Republic, Slovakia, Hungary and Poland is mainly caused by the intensity and structural effect, but the intensity effect is more significant.

4. In Slovenia the development of the energy intensity in the industrial sector is mainly caused by the intensity effect, the structural effect is insignificant.

5. The processes developing the aggregate energy intensity of an economy can be different at the level of the economy and the sectors.

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