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Investigation of Driving Forces of Energy Consumption in European Union 28 Countries

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ABSTRACT

This paper aims to analyze drivers of energy consumption in European Union (EU) in recent period and identify the role of energy efficiency in it. We analyzed energy consumption using logarithmic mean Divisia index decomposition technique on three different levels of data aggregation for EU 28 countries in pre-crisis period (2004-2008) and crisis period (2008-2012). Our paper challenged the view that recent decline in energy consumption is caused by economic slowdown as improvements in energy intensity EU countries seems to be slowing down. We conclude that intensity effect was the major factor influencing energy consumption, while the contribution of activity effect representing the performance of economy was of less importance. The impact of structural effect was only of minor magnitude but interestingly has larger influence during the period of oil prices surge than in period of high oil prices. Our evidence also suggests that structural changes of economies towards service sector will likely lead to lower improvements in energy efficiencies.

Keywords: Energy Efficiency, Energy Consumption, European Union, Energy Intensity
JEL Classifications: O13, Q2, Q3, Q4

1. INTRODUCTION

Energy efficiency dubbed by International Energy Agency (IEA) as the world's first fuel is getting on the forefront of energy policy activities. Such attitude has its ratio as non-consumed energy is obviously most environmentally friendly, accessible and secure - Therefore actions in this field fulfill all the fundamental requirements of any sensible energy policy. Even more, the benefits are far wider as conclude IEA (2014) estimating that the uptake of economically viable energy efficiency investments has the potential to boost cumulative economic output through 2035 by USD 18 trillion (IEA, 2014). The importance of measures aimed at increasing energy efficiency cannot be overstated in case of European Union (EU) especially in the wake of recent geopolitical development on its eastern borders. Energy efficiency (together with investments into renewable energy) could according the study by ECOFYS (2014) cut EU's natural gas imports in half, with carbon reductions of 49% or more (below the 1990) by 2030, enhancing so energy security of EU.

A number of actions have already been put into operation by EU in this field as Europe has had increasingly more ambitious energy efficiency policies already since the oil crises of the 1970s (Obadi et al., 2013). The pace of change has picked up particularly after 2000s as the priority for energy efficiency gained ground. The most significant indication of the policy direction in the EU has been through the energy efficiency plans action plans for energy efficiency 2000-2006, 2007-2013 (including measures to reduce energy consumption and improve energy efficiency) and energy efficiency plan in 2011 (which should have lowered the household energy bills, increase competitiveness of EU industry and create new jobs) González et al. (2014). Those were supplemented by number of directives and policy frameworks aimed at final customer such as Energy Efficiency Directive, the Energy Performance of Buildings Directive, the Ecodesign of Energy-Using Products Directive (regulating minimum energy performance of products), the Energy Labeling of Domestic

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Appliances Directive and various directives aimed at efficiency in transportation sectors and others[1].

The most famously, energy efficiency target is one of the three energy headline targets within the Europe 2020 policy frame. After accession of Croatia, this commitment stipulates the EU energy efficiency target as the "union's 2020 energy consumption of no more than 1 483 Mtoe of primary energy or no more than 1 086 Mtoe of final energy." As it is better known, this target aims at reducing energy consumption by 20% till 2020 (compared to energy consumption forecasts for that year). Even though it remains unclear whether this former goal is going to be reached target for energy efficiency is also going to be among main pillars of energy policy in extending time frame reaching till 2030. Although the controversy aroused around the target when 30% energy consumption reduction finally suggested by EC is below 35% which was previously said to be economically optimal level and far below 40% demands by some NGOs. Obvious reason for that is effort to reach at least some agreement when despite the clear benefits related costs are not appealing to economically stressed economies of EU. The reluctance of member states to finance upfront costs are highlighted by fact that such move is rejected even if it might considerably alleviate the costs of energy dependence – EC pointed out that every extra 1% of energy savings should cut EU gas imports by 2.6% (van Rensen, 2014). The final agreement - 27% non-binding target agreed by European leaders which was said to not to get translated into binding national plans only stresses our point above. Needless to say, that even if this plan does not look that ambitious, we must realize such sensation is incorrect when comparing with the national targets of other developed nations. And more importantly, the goal that really matters - 40% CO_2 emissions reduction was agreed on.

Energy efficiency and renewable energy sources (RES) need be recognized in their roles of enablers of GHG emissions cutters but their role should not be untouchable. During recent period it was repeatedly announced that various RES are still getting closer to cost parity with conventional generation sources. Therefore with costs neutrality and CO_2 reduction target, RES can likely count on government support even without additionally set goals. On the other hand, improvements in energy efficiency implicitly hold the risk of rebound effect. Its range may vary from few percent to more than 100%, the point however is that policies in this field might lead to unclear results. Such idea needs to be considered especially with respect to less developed, growing economies where rebound effect is believed to be stronger. In case of EU such group of countries is represented particularly by the later joining members with worse indicators of energy intensity (EI). Energy efficiency policies in these countries are more likely to backfire and resources spent on energy efficiency measures in these countries is more likely to have less than expected effect on reducing energy consumption itself. As putted by Nordhaus and Schellenberger (2014) "*if we are to be serious about reducing greenhouse gas emissions, we need to remain focused on the main event the transition to cleaner forms of energy.*"

To sum it up, energy consumption is targeted by different set of policies while being dependent on the state of economy at the same time, which hinders direct evaluation of intended effects. In order to find out what were the drivers of energy consumption in EU in recent period and what the role of energy efficiency in it was, we analyzed energy consumption using decomposition technique.

2. LITERATURE REVIEW

As we already stated, energy consumption of any country is driven by several factors – economic activity, sector composition of economy and energy efficiency. In most of discussion all those factors are usually hidden behind one variable expressed as energy consumed in creation of one unit of gross domestic product (GDP) – so called EI of economy. The loss of information in this aggregation might be useful in describing the overall situation to general public. It should however, not serve as a foundation for policy decisions. Logarithmic mean divisia index (LMDI) decomposition index which we applied in this study provide equally understandable information which unlike the traditional EI indicator is more profound. Such approach has been tested on several of countries [Hammamia et al. (2014); Ocaña et al. (2009); Baležentis et al. (2011) and others]. In the comparative study examining energy consumption patterns of EU15 and Spain, Ocaña et al. (2009) found out that during the period 1995-2006 the main driver that caused different development of Spain's energy consumption is its structure of economy, which was characterized by increased importance of energy demanding sectors such as construction, transportation and tourist related services as well as increased demand from residential sector reflecting improvements in standards of living. Such results were possible to obtain thanks to inclusion of transport a residential sector into detail sector analysis. However, this approach leads to inconsistencies in sectors definition which may cause large errors despite the use of the most precise index-number procedure, and possibly misleading conclusions as Marrero and Ramos-Real (2013) warned. Their research on EI of EU 15 countries between years 1991 and 2005 came to conclusion that changes in structure of the economy are predominant drivers of EI of the economy. However the situation in individual countries followed various paths and not even environmental commitments (such as Kyoto protocol) were able to set general direction of EI evolution. Their research further suggested that restructuring of the economy towards services would likely not lead to improvement in energy efficiency component due to its heterogeneity and lacking international competition in this segment. González et al. (2013) in similar vein reported that structural effect together with activity effect (even if the former significantly lesser than the latter) were able to offset positive intensity effect altogether leading to aggregate energy consumption growth of 2.245% between 2001 and 2008 in EU 27[2]. This was also the first paper such methodology was applied

1 González et al. (2014) in this respect noted that most of the measures taken by the European Union are oriented to improving energy intensity via energy efficiency. However, at the same time, a large proportion of these actions – such as funding renewable or some taxation – involves changes in the market that lead to readjustment in agent decisions. Thereof, this intervention is likely to affect the production structure that way also energy consumption.

2 It needs to be noted their results might be biased by variable selection as their paper stated that GDP at current (not constant) prices fixed for PPP was used as proxy variable for economic activity.

on full set of EU 27 countries. González et al. (2014) in their other paper based on more detail data on sector activity of selected 20 economies of EU refined their conclusion and marked the industry sector as the prime mover of energy efficiency improvement giving special credit to energy efficiency improvement in post-communist-countries. Baležentis et al. (2011) studied development of energy consumption in Lithuania between years 1995 and 2009 and stressed the need for energy policy measures in sectors of services and households as those are less elastic compared to industry or transport which confirmed after the wake of great recession when largest decline in energy consumption was recorded in latter two sectors. They also pose question whether the period 2009-2010 does not mean (for Lithuania) the outset of new economic-energetic cycle, given the fact that in 2009 energy consumption in Lithuania reached its lowest value during the period of 1995-2009.

Our paper contributes to previous research in several ways. Firstly we used the data up to 2012 that enabled us analyze reasonably long development in crisis period and compare it to pre-crisis development therefore it enabled us to test whether we are actually witnessing some kind of new economic-energetic cycle and what patterns (if any) of energy consumption has been altered. Secondly, unlike the previous research (González et al., 2014) we applied the LMDI methodology on the set of EU countries with data reflecting the real output (in PPP) that enabled us the unbiased detection of main factors influencing the energy consumption for the whole EU 28. Thirdly, we investigated the development of energy consumption in industry sector for majority of EU (21) countries on detailed disaggregated industrial data in order to answer the question what are the driving forces of its energy consumption flexibility and whether it changed during the course of observed period.

3. METHODOLOGY AND DATA

Decomposition analysis has been widely used to study the driving forces of changes of an aggregate indicator over time. Two popular decomposition techniques are the index decomposition analysis (IDA) and the structural decomposition analysis (SDA).

The original purpose of IDA in the late 1970s was to study changes in industrial energy consumption, or more specifically electricity consumption in industry. In contrast, SDA has been used to study other aspects of economic issues before it was used to study energy consumption and emissions in the 1970s and early 1980s. Hence the development of IDA was driven primarily by energy and emission studies while those of SDA were originally confined to other subjects. SDA has been used primarily by researchers who are familiar with input–output (I-O) analysis and wish to extend it to study changes in energy consumption or emissions in the economy. Since I-O tables are developed for the whole economy of a country, the scope of SDA studies tends to be for the whole economy. In contrast, IDA studies are normally for a sector of energy consumption, such as transportation, industry or household or its energy-related emissions. It is obvious that fundamental differences between the two techniques originated from the scope of required data i.e. SDA relies on the I-O model framework while IDA does not. On the one hand this enables SDA to account for the indirect effect while IDA can only deal with direct effect. On the other however, such requirements represent major challenge in terms of data availability, especially when examining the most recent trends as I–O tables are not assembled on yearly basis. It was also pointed out that while only absolute indicator and additive decomposition form is often used in SDA literature (Ang-Bin, 2012), IDA has preferable properties in two indicator forms (absolute and intensity) and two decomposition forms (additive and multiplicative).

A desirable index decomposition method should comply with following criteria theoretical foundation, adaptability, ease of use, and ease of result interpretation. Out of IDA methods that may be divided into two groups depending on their construction – one is based on the concept of the divisia index method the arithmetic mean divisia index method, LMDI and the other one on Laspeyres index method (Marshall-Edgeworth method, Shapley/Sun method and the conventional and modified Fisher ideal index methods) – Ang (2004) recommends LMDI as the one with most desirable properties. Logarithmic mean weight function that leads to a refined divisia method so called LMDI was proposed by Ang and Choi (1997). Comprehensive reviews of its usage and application can be found in Ang (2004); Ang (2005); Ang et al. (2010); Ang-Choi (2005). According to Ang (2005) LMDI has several advantages it gives perfect decomposition, i.e. the results do not contain an unexplained residual term; it can be applied to more than two factors; there is a simple relationship between multiplicative and additive decomposition; it is consistent in the aggregation and the estimates of an effect at the subgroup level can be aggregated to give the corresponding effect at the group level, a property useful for our analysis that contains sub-groups of industry activities. Another useful feature of this methodology is that it is capable to handle zero values by replacing all the zeros in the data set may by small positive constant, e.g. between 10^{-10} and 10^{-20}, while the computation proceeds as usual.

With respect to our intention of analysing the recent trends of energy consumption development we have therefore selected the LMDI out of above listed methods for decomposing the changes in energy consumption. LMDI framework recognizes three possible factors determining energy consumption, namely overall industrial activity (activity effect - E_{act}), activity mix (structure effect - E_{str}), and sector EI (intensity effect - E_{int}). Such idea can be expressed by following formulae

$$E = \sum_i E_i = \sum_i Q\frac{Q_i E_i}{QQ_i} = \sum_i QS_i I_i$$

Where E denotes the total energy consumption in the economy, $Q=\Sigma Q_i$ represents total economic activity, $S_i=Q_i/Q$ is share of activity of individual sectors in total economy and $I_i=E_i/Q_i$ represents the EI of sector i.

In case of additive decomposition the change of energy consumption between periods T and 0 gains following form

$$\Delta E_{tot}=E^T-E^0 = \Delta E_{act} + \Delta E_{int} + \Delta E_{str}$$

And formulas of individual parts of total energy consumption are computed as follows

$$\Delta E_{act} = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln\left(\frac{Q^T}{Q^0}\right)$$

$$\Delta E_{str} = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln\left(\frac{S_i^T}{S_i^0}\right)$$

$$\Delta E_{int} = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln\left(\frac{I_i^T}{I_i^0}\right)$$

In similar manner the multiplicative decomposition of the change of energy consumption can be obtained according following rule

$$D_{tot}=E^T/E^0 = D_{act}\, D_{int}\, D_{str}$$

While individual components are computed using formulas below:

$$D_{act} = exp\left(\sum \frac{\left(E_i^T - E_i^0\right)/\left(\ln E_i^T - \ln E_i^0\right)}{\left(E^T - E^{T0}\right)/\left(\ln E^T - \ln E^0\right)} \ln\left(\frac{Q^T}{Q^0}\right)\right)$$

$$D_{str} = exp\left(\sum \frac{\left(E_i^T - E_i^0\right)/\left(\ln E_i^T - \ln E_i^0\right)}{\left(E^T - E^{T0}\right)/\left(\ln E^T - \ln E^0\right)} \ln\left(\frac{S_i^T}{S_i^0}\right)\right)$$

$$D_{int} = exp\left(\sum \frac{\left(E_i^T - E_i^0\right)/\left(\ln E_i^T - \ln E_i^0\right)}{\left(E^T - E^{T0}\right)/\left(\ln E^T - \ln E^0\right)} \ln\left(\frac{I_i^T}{I_i^0}\right)\right)$$

The source of data we used was statistical database of EC - EUROSTAT. EUROSTAT energy data follows the rules of the IEA. According to these rules, all final energies are considered oil derivatives, natural gas, electricity, including the so-called free fuels (biomass, wood, thermal solar, among others in the category of renewable energy commodities) etc. Energy consumption is measured in tons of oil equivalent (toe) and is further broken down according its specific purposes and corresponding sectors, although the disaggregation does not strictly follow NACE classification which created some obstacles and need for approximation in our paper.

Data on economic activity on aggregated level were represented by GDP expressed in PPP (in 2005 €) which were deflated in order to provide comparable real GDP and other derived variables. Such procedure however cannot be replicated on lower levels of aggregation and comparison of absolute values not corrected for PPP might lead to spurious conclusions, therefore only development trend can be subject of spatial comparison in such cases. In cases of analysis on level of four sectors (agriculture, industry, construction and services) and individual industry segments, gross value added in 2005 constant prices (not fixed for PPP) was used as the proxy variable for economic activity. We followed the classification of economic activities used by the European Community and EUROSTAT (NACE) and used table *nama_nace10_k* which provides GVA for 10 branches, namely agriculture and fishing, construction, industry and seven other economic activities[3] which we aggregated under service sector. Those four sectors where selected despite the fact they cover only slightly over 40% of final energy consumption. The reason for that was limitation of this procedure and selected variable - GVA, since as Marrero and Ramos-Real (2013) stated GVA is the best way to measure the level of activity in productive sectors, but it is not a good proxy to measure activity in other sectors such as the transport or the residential. Therefore it is also worth noted that energy consumption in service sector does not consider energy consumed in transportation as this is not sector specific (i.e. the energy reported to be consumed in transportation is linked to activities in all sectors) and neither energy consumption of households as those could lead to significant distortions of results. Such incorrectly selected variables are however, not rare and were previously used e.g. by Ocaña et al. (2009); González et al. (2013); Baležentis et al. (2011) and calculation of transport intensity as its energy consumption in transport divided by GVA of transport sector was even used by EC (2013). Due to lack of data our analysis omitted Malta and to our surprise only two segments were possible to analyze in case of Germany (which did not report data on energy consumption in construction and agricultural sector since 2003).

The availability of data was even scarcer in our individual industrial sectors' analysis. Here EUROSTAT provided sufficient data only for 21 countries and EU 28 as a group. Our analysis was done for 11 industrial sectors reported in energy database of EUROSTAT ferrous and non-ferrous metals[4], food and beverages and tobacco, chemical and petrochemical, machinery, mining, non-metallic minerals, non-specified industry, paper pulp and printing, Textile and leather, transport, equipment, wood and wood products. GVA data in constant prices 2005 that served as the information on economic activity level in individual sectors was retrieved from EUROSTAT table *nama_nace64_k* and matched and approximated with above mentioned industry sectors by following instructions of EUROSTAT (2013).

In each of our partial analyses we compared three periods - years 2004-2012 to get general overview of energy consumption driving forces and consequently we compared periods 2004-2008 (pre-crisis period) with 2008-2012 (crisis period) in order to challenge the general knowledge that lower consumption of energy after to 2008 was driven by decrease in economic activity.

4. ANALYSIS OF DEVELOPMENT OF STANDARD EI INDICATOR

The 2012 became the year when size of economies of first several individual EU countries[5] outreached its pre-crisis level

3 Namely: Wholesale and retail trade, transport, accommodation and food service activities, information and communication, financial and insurance activities, real estate activities, professional, scientific and technical activities; administrative and support service activities, public administration, defense, education, human health and social work activities, arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies.

4 We had to merge energy consumption in segment iron and steel and non-ferrous metals as GVA database on NACE64 level does not provide sufficiently compliant data to analyse these sectors separately.

5 Belgium, Germany, Austria, Ireland, Poland.

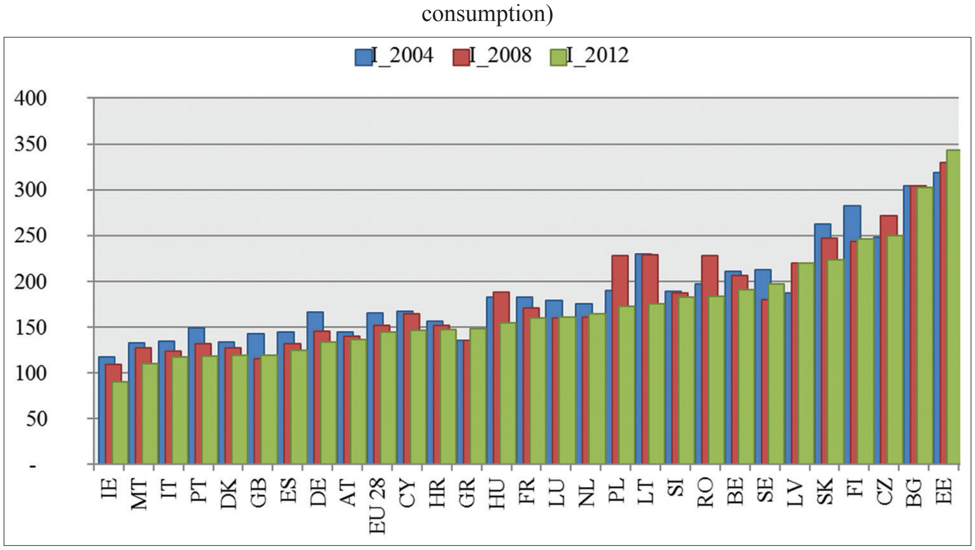
(in PPP terms, 2005 constant prices). Compared to 2004 the aggregated economy of EU 28 grew by 8% which meant that aggregated output of community was still slightly below 2008 level underlining so the fragility of the ongoing recovery. While the V-shaped trajectory of development could be observed in case of economic performance, development of energy consumption in majority of the EU countries underwent various alternations of W-shaped trajectory in the same period. The energy consumption peaked before the outbreak of crisis in 23 countries with EU 28 as entity peaking energy consumption in 2006. Countries that already exceeded their pre-crisis energy consumptions level are AT, BE, EE, NL and PL. It is also worth noting that BE, AT and PL were also economies that outperformed their pre-crisis level of output denting so the beliefs of energy-economics decoupling. Fact that Ireland's and Germany's energy consumption (two other countries that economies are bigger than before 2008) on the other hand reached its maximum in 2006 and 2007 only shows the heterogeneity of input requirements and substitution capacity of individual economies and its influence on energy consumption. As we already mentioned, the traditional indicator of energy requirements of economy is EI expressed as the share of energy consumption on economic output. As the Graph 1 depicts when we focused on our key years 2004, 2008, 2012 we could observed several trends

1. EI of EU countries declined by 13% in 2004-2012 from 166 to 144 toe/M€ of output
2. EI remains extremely heterogeneous (EI in Estonia is almost 4 times higher than in Ireland) and no obvious trend of EI convergence was detected during the observed period. Quite the opposite, the half of the EU countries which has the lower EI in 2004 improved this indicator in average by 12% while the other group of EU countries only by 6%
3. GR, LV, CZ and EE even worsened their EI indicator by 9%, 17%, 1% and 8% respectively
4. In addition, Graph 2 revealed that pre-crisis period was characterized by more significant improvements of EI indicator. That can be indeed consequence of exploiting benefits of low hanging fruit, but as higher correlation between stronger growth and improvements in EI suggests it was not the only reason. Apparently companies were willing to allocate bigger dedicated budgets into energy efficiency measures in good times. This might also indicate that companies do not see investments into EI measures as optimal allocation of scarce resources. Intuitively, EI investments should lead to savings of costs; therefore their implementation should not have been affected on such level by economic downturn unless they become too expensive. In such case, only proper incentives and favorable economic conditions can trigger further investments into EI which seems to be not the case in EU currently.

4.1. Energy Consumption Decomposition

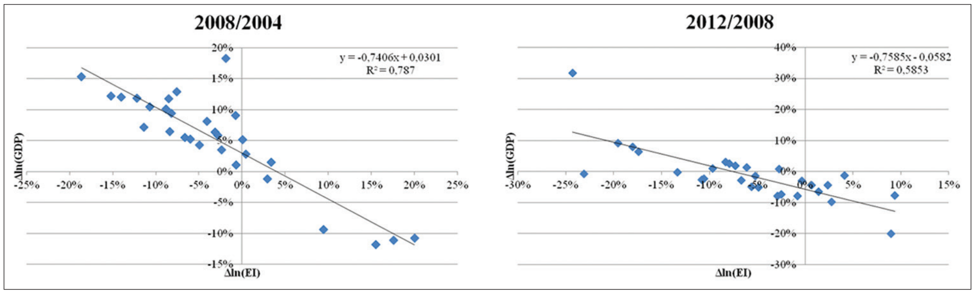
During 2004-2012 energy consumption of EU 28 decreased by 134 Mtoe (7%, from 1 818 to 1 683 Mtoe). However, if no energy efficiency would came to play energy consumption would grow by 6% as countries kept their shares on EU aggregate consumption (no structural effect on this level of aggregation played a role) and economic growth would have raised energy consumption by 108 Mtoe. The reason of aforementioned energy consumption decline was obviously the growth in the energy efficiency which increased by 13% virtually saving so 242 Mtoe of energy which represents roughly 60% of yearly natural gas consumption in the whole EU, or more than the double the volume supplied by Russia illustrating so its importance for energy security. Most of the 134 Mtoe of savings - 116 Mtoe was realized in the second observed period (2008-2012). During the first observed period 2004-2008 EI improvements almost evened out with growing demand for energy due to soaring economic activity. The important factor in the first observed period therefore was structural effect which helped to keep energy consumption on downward path. Structural effect in this form of presented index basically means that economies of countries with less demanding energy profile grew more rapidly compared to countries with the higher one. Such result is perfectly plausible considering the rapid growth of oil and energy prices in given period that penalized countries with higher energy consumption profile. Such intuition is confirmed

Graph 1: Energy intensity of European Union 28 economies (based on gross domestic product in PPP, 2005 c.p. and gross inland energy consumption)



Source Authors' calculations

Graph 2: Energy intensity and gross domestic product development dependence



Source Authors' calculations

by the development in period 2008-2012, when energy prices avoided that dramatic fluctuations and more energy consuming countries slightly increased their share on total EU output. During this period structural component was the only factor leading to notional growth of energy consumption. The forces pulling the energy consumption against it were both lower economic activity and improved energy efficiency. The improvement of energy efficiency in this period was slightly lower (than in first period) representing savings of 108 Mtoe which, however, in combination with remaining factors meant energy savings roughly equaled to above mentioned 116 Mtoe between 2008 and 2012 (yearly energy consumption of Poland).

In terms of individual countries, highest energy savings came from largest EU economies UK, DE, FR, IT, ES. Poland, the 6th largest economy of EU, on the other hand, recorded single biggest growth of energy consumption – 6.3 Mtoe. Other five countries that increased their energy consumption by aggregated 1 Mtoe were EE, AT, NE, CY, and LV. Results of all examined countries shown in Table 1. With some minor exceptions, it can be concluded that in pre-crisis period, countries' energy consumption related to economic growth in most cases roughly equaled to their improved energy savings originating from higher energy efficiencies. The majority of unrealized energy consumption however occurred in latter period when smaller gains in energy efficiencies grouped with lower economic growth resulted in markedly lower energy consumption. Presented data so clearly pinpointed the importance of energy efficiency. In further section we therefore further decompose the energy consumption in order to find out whether countries on the aggregated level use less energy due to their increased efficiency or changing economic structure towards less intensive sectors.

4.2. Decomposition of Sector Energy Consumption using LMDI Technique

In this section we continue with our analysis considering four sectors - Agriculture, industry, services, construction. Those four sectors account for 40% of final energy consumption (for details see the part dedicated to data description). Our goal in this section is to find out how significant was structural effect for enhancing the total indicator of EI.

During 2004-2012 we observed minor shift in economy structure on the EU 28 level – share of agriculture remained at 2%, construction decreased its share from 7% to 5%, industry from 20% to 19% and services increased by 3 p.p. to 74%. This shift happened gradually and we did not observe any changes of patterns due to crisis period. Such shift in economy structure obviously supports lower energy consumption and therefore 48 Mtoe (9%) consumption decrease comes not as a surprise. Our analysis also revealed that that structural component on EU 28 level played less important part as it led only to energy consumption reduction of 13.5 Mtoe (3%) compared to EI component that offset as much as 75 Mtoe (14%), activity effect would have on the other hand increase the consumption by 44 Mtoe (9%).

With respect to individual countries the general decrease of importance of agriculture was visible in almost each EU country (zero change or minor increase was observed only in case of EE, FI, DE and NE). Largest decrease, roughly 5 p.p. occurred in BG and RO where however agriculture sector in 2012 still significantly overreached EU average with 5% respectively 7%. EI of agriculture of those countries is three respectively 2 times higher than EU 28 therefore further decrease in importance of this sector can partially ameliorate EI indicator in these countries. Trend of decreasing importance in economy structure was also valid for construction sector. The fall was especially harsh in IE, GR, ES and CY as construction sector of those countries have been heavily impacted by economic crisis, property bubble and consequences of austerity measures taken by local governments in their struggle against crisis. Their share on economic output decreased by 6 p.p., 5 p.p., 4 p.p. and 4 p.p. respectively, to 4%, 3%, 9% and 6%. On the other side stood PL, RO and EE where construction slightly increased its weight in countries' economic profile. Sector of industry followed similar path, when its importance in majority of EU economies decreased by 1-3 p.p. Against this, the importance of this sector raised in CEE countries, most remarkably in CZ, PL, SK, EE and HU that benefited from relocation activities of industrial corporations during that period and became targets for influx of many FDIs. This set of countries (except for HU) also happened to be the only one where the weight of service sector in economy decreased[6]. Aforementioned development obviously supported energy consumption decline in majority of EU countries. The exceptions of this were economies of GR, PL and especially SK, AT, EE and CZ but combined structural effect in these countries would have only caused negligible energy consumption growth of 2 Mtoe. On the other hand the structural effect played

6 It also needs to be noted that absolute value of output produced in service sector in given years rose and the decrease of weight in economic sector mix was only caused by lagging growth in service sector compared to others.

Table 1: EU 28 Energy consumption (in Ktoe) decomposition via LMDI

	2004-2012			2004-2008			2008-2012		
	Activity	**Intensity**	**Total**	**Activity**	**Intensity**	**Total**	**Activity**	**Intensity**	**Total**
Germany	47 399	-71 897	-24 498	38 083	-44 262	-6 179	10 261	-28 579	-18 319
	(115%)	(81%)	(93%)	(112%)	(88%)	(98%)	(103%)	(92%)	(95%)
United Kingdom	8 668	-38 829	-30 160	32 022	-46 366	-14 344	-21 483	5 666	-15 817
	(104%)	(84%)	(87%)	(115%)	(81%)	(94%)	(90%)	(103%)	(93%)
France	17 921	-35 037	-17 116	14 623	-18 640	-4 017	3 626	-16 725	-13 099
	(107%)	(88%)	(94%)	(105%)	(93%)	(99%)	(101%)	(94%)	(95%)
Italy	1 952	-23 871	-21 919	11 386	-15 959	-4 573	-8 768	-8 578	-17 346
	(101%)	(87%)	(88%)	(106%)	(92%)	(98%)	(95%)	(95%)	(90%)
Spain	6 182	-20 065	-13 883	13 609	-13 007	601	-6 733	-7 751	-14 484
	(105%)	(86%)	(90%)	(110%)	(91%)	(100%)	(95%)	(94%)	(90%)
Netherlands	5 512	-5 383	129	9 176	-7 342	1 834	-3 609	1 904	-1 705
	(107%)	(94%)	(100%)	(112%)	(91%)	(102%)	(96%)	(102%)	(98%)
Poland	15 384	-9 083	6 302	-10 800	17 334	6 534	27 083	-27 315	-232
	(118%)	(91%)	(107%)	(89%)	(120%)	(107%)	(132%)	(76%)	(100%)
Belgium	3 087	-5 774	-2 687	2 012	-1 419	593	1 137	-4 417	-3 280
	(106%)	(90%)	(95%)	(103%)	(98%)	(101%)	(102%)	(93%)	(94%)
Sweden	1 766	-3 832	-2 066	5 787	-8 339	-2 552	-3 948	4 434	486
	(104%)	(93%)	(96%)	(112%)	(85%)	(95%)	(92%)	(109%)	(101%)
Austria	2 338	-1 972	366	2 082	-1 052	1 030	280	-944	-664
	(107%)	(94%)	(101%)	(106%)	(97%)	(103%)	(101%)	(97%)	(98%)
Greece	-5 747	2 649	-3 098	852	143	994	-6 649	2 557	-4 092
	(82%)	(109%)	(90%)	(103%)	(100%)	(103%)	(80%)	(109%)	(87%)
Portugal	1 093	-5 666	-4 573	1 784	-3 143	-1 359	-561	-2 653	-3 214
	(105%)	(79%)	(83%)	(107%)	(89%)	(95%)	(98%)	(89%)	(87%)
Czech Republic	-3 209	364	-2 845	-4 488	4 127	-361	1 151	-3 635	-2 484
	(93%)	(101%)	(94%)	(91%)	(110%)	(99%)	(103%)	(92%)	(95%)
Denmark	235	-2 290	-2 055	833	-1 018	-185	-556	-1 315	-1 871
	(101%)	(89%)	(90%)	(104%)	(95%)	(99%)	(97%)	(93%)	(91%)
Finland	1 684	-4 875	-3 190	4 141	-5 502	-1 361	-2 307	477	-1 829
	(105%)	(87%)	(91%)	(112%)	(86%)	(96%)	(94%)	(101%)	(95%)
Romania	-1 430	-2 729	-4 159	-5 027	5 774	747	3 315	-8 221	-4 906
	(96%)	(93%)	(89%)	(88%)	(116%)	(102%)	(109%)	(80%)	(88%)
Hungary	1 590	-4 214	-2 624	-319	773	454	1 907	-4 985	-3 078
	(107%)	(84%)	(90%)	(99%)	(103%)	(102%)	(108%)	(82%)	(88%)
Ireland	2 642	-3 899	-1 256	1 864	-1 205	659	914	-2 830	-1 916
	(120%)	(76%)	(92%)	(113%)	(92%)	(104%)	(106%)	(83%)	(88%)
Slovakia	1 077	-2 878	-1 801	941	-1 138	-197	177	-1 780	-1 604
	(106%)	(85%)	(90%)	(105%)	(94%)	(99%)	(101%)	(90%)	(91%)
Bulgaria	-572	-135	-707	971	15	986	-1 540	-153	-1 693
	(97%)	(99%)	(96%)	(105%)	(100%)	(105%)	(92%)	(99%)	(92%)
Croatia	-209	-485	-693	502	-251	251	-693	-251	-944
	(98%)	(94%)	(92%)	(106%)	(97%)	(103%)	(92%)	(97%)	(90%)
Slovenia	73	-228	-156	646	-53	594	-564	-186	-749
	(101%)	(97%)	(98%)	(109%)	(99%)	(108%)	(93%)	(98%)	(90%)
Lithuania	34	-2 182	-2 147	99	-58	41	-53	-2 136	-2 188
	(100%)	(76%)	(77%)	(101%)	(99%)	(100%)	(99%)	(77%)	(76%)
Luxembourg	250	-485	-235	462	-525	-63	-202	30	-172
	(106%)	(90%)	(95%)	(110%)	(89%)	(99%)	(96%)	(101%)	(96%)
Latvia	-668	718	49	-540	746	206	-141	-16	-157
	(86%)	(117%)	(101%)	(89%)	(118%)	(105%)	(97%)	(100%)	(97%)
Estonia	18	437	455	86	197	283	-71	243	172
	(100%)	(108%)	(108%)	(102%)	(103%)	(105%)	(99%)	(104%)	(103%)
Cyprus	352	-332	20	450	-50	400	-72	-308	-380
	(115%)	(88%)	(101%)	(118%)	(98%)	(116%)	(97%)	(89%)	(87%)
Malta	67	-164	-97	74	-39	34	-2	-129	-131
	(108%)	(83%)	(90%)	(108%)	(96%)	(104%)	(100%)	(87%)	(86%)
	Activity	**Structural**	**Intensity**	**Activity**	**Structural**	**Intensity**	**Activity**	**Structural**	**Intensity**
EU 28	108 683	-1 192	-242 136	135 482	-14 170	-140 260	-22 267	14 164	-107 594
	(106%)	(100%)	(87%)	(108%)	(99%)	(93%)	(99%)	(101%)	(94%)
	Total for period			**Total for period**			**Total**		
	-134 645			-18 948			-115 697		
	(93%)			(99%)			(94%)		

Source: Authors' calculations

more significant role in case of ES, IT, CY, FR, CR, IE, FI, GB and especially DK, BE and LU where structural effect topped EI effect in terms of energy savings. In the remaining countries, intensity effect played the most substantial role in driving energy consumption down.

The most salient decrease in EI was recorded by sector of industry where EI declined by 19% (therefore the next part of our paper analyze the development in industry sector itself). That was followed by service and agriculture sector with average EI decline of 6% and lastly construction sector, where EI increased by 17%. With respect to individual countries, the countries where on average[7] across sector EI improved mostly were SK, EE, CZ, PL, and HU. Although it needs to be noted that EI indicators of these countries are still on average significantly above EU average.

Energy consumption of EU in observed sectors during period 2004-2008 decreased by 12 Mtoe (−2%) and this decrease in subsequent period tripled to savings of 36 Mtoe (−7%). Our comparison of pre-crisis versus crisis period signals that slowdown of economic performance played important role, shifts in economy structure happened gradually and even if overall EI of the economy decreased especially in pre-crisis period as Graph 3 indicates we could assume it served as a prime mover in both periods with respect to its volume.

While in pre-crisis period, the activity effect in EU 28 would have caused energy consumption increase of 47 Mtoe (10%), economic slowdown after the year 2008 meant energy consumption decrease by 5 Mtoe (−1%). EI was of no less importance since improvement of this indicator before 2008 prevented some 50 Mtoe (−10%) of energy consumption and subsequently, savings due to EI improvement roughly halved to 26 Mtoe (−5%). Indisputably EI was the most salient determining factor of energy consumption path. Structural effect on the other hand proved to be relatively stable but only modestly important when in both observed periods diversion from higher EI sectors lead to savings of 8,7 Mtoe (2%), respectively 5 Mtoe (1%).

As can be seen on Graph 4, the pattern of evolution of energy consumption determinants was similar on level of individual EU countries. In pre-crisis period, apart from DK, IE, LU and GR where structural effect played the crucial role in moderating energy consumption, were other countries dependant on improvements in their EI in order to avoid increases in their consumption as their economies grew. Relation between EI and activity effects was obviously more complicated due to well recognized impacts of rebound effect however such analysis is outside the scope of current paper. Development after 2008 was characterized by stagnant economic growth with activity effect being prime determinant of movements in energy consumption in GR, SI, CR, DK, LT and LV. BE, FI, and LU were only three countries which energy consumption was mainly driven by the shifts in their economic structure, while the rest of the countries benefited from their lowering energy intensities. Generally, the period after 2008 with more stable oil prices and stagnant economy was reflected in more moderate changes in determinants of energy consumption.

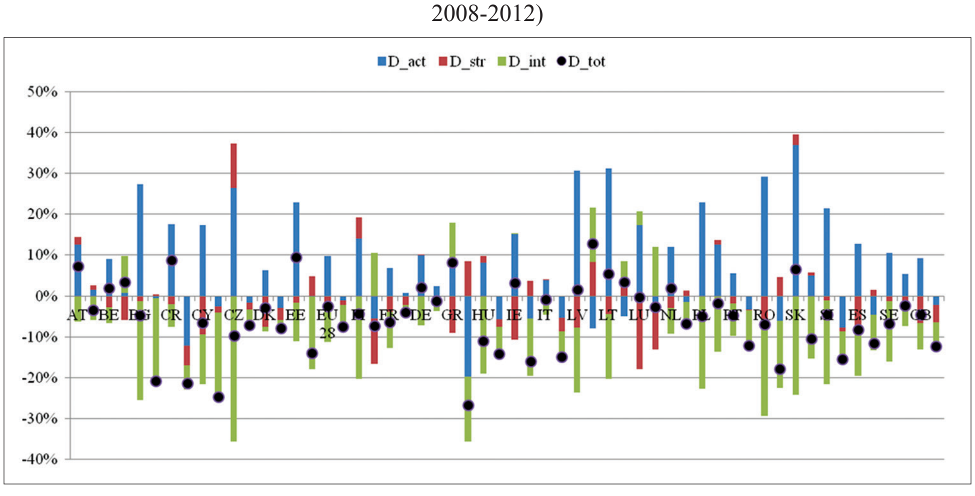
4.3. Drivers of Energy Consumption in Industrial Sector

Industrial sector was historically most capable to reflect on energy price spikes. Fact that growing energy costs before crisis period did not have more disturbing effects on industry and ability to decrease its EI in order to adapt to changing environment from that period only confirmed this.

Final energy consumption of EU 28 industry represents 17 % of gross inland energy consumption. Since 2004 it has declined by 45 Mtoe (14%), while the sector output reached some 2178 billions (GVA measured in 2005 c.p.) in 2011 which meant increase of 6% since 2004. The energy consumption of industry declined in both observed periods, despite differing trajectory of output development. In the pre-crisis period, energy consumption decreased by 18 Mtoe (6%) despite 8% increase of output. In

7 We simply ranked EI improvements in each segment in each EU country and averaged the obtained rankings.

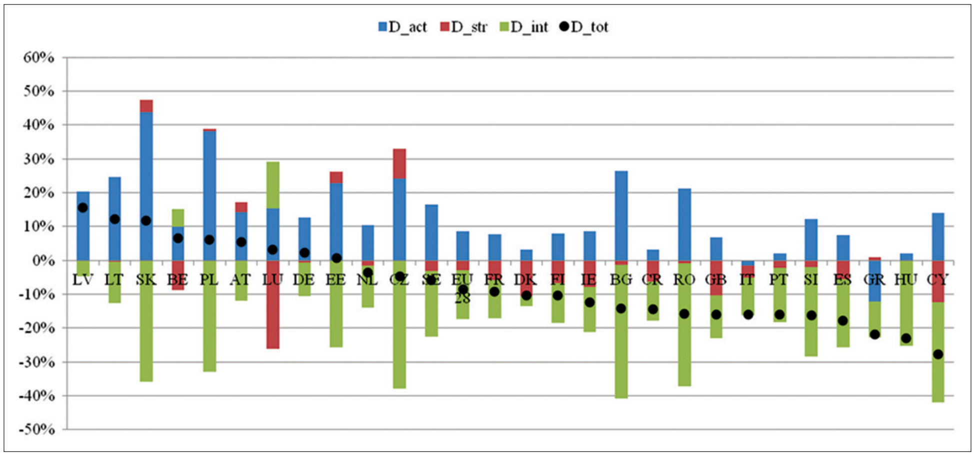
Graph 3: European Union 28 energy consumption decomposition via logarithmic mean divisia index (four sectors during 2004-2008 and 2008-2012)



**First line of graph for given country represents period 2004-2008, second one is for 2008-2012*

Source Authors' calculations

Graph 4: European Union 28 energy consumption decomposition via logarithmic mean divisia index (four sectors 2004-2012)



Source Authors' calculations

subsequent period, output decreased by 2% with accompanying decline of energy consumption of 28 Mtoe (9%).

As of individual countries, the most significant industrial output growth recorded SK, which almost doubled its industry production and was followed by CZ (79%), PL (63%), and EE (45%). On the other side of the scale stood GR (−28%), FI (−15%), DK (−12%), UK (−12%) and smaller negative growth recorded also BG, IT and FR. Economic recession was undoubtedly cardinal driver of such development as industrial output was in milder decline only in DK, UK and GR prior 2008. The growth of the output however took place without direct visible effect towards energy consumption. That overall increased only in AT, BE, DE and LT between years 2008 and 2012. And even in high economic growth period, before 2008, only 5 countries mildly increased their energy consumption (NL, DE, GR, EE, AT). After 2008 the single country that significantly increased its energy consumption was Belgium (14%), especially due to its strong and still growing chemical industry.

Energy consumption of industry in EU 28 between years 2004 and 2011 was primarily determined by intensity effect which saved 45 Mtoe (14%), therefore basically counting for the whole energy consumption savings in observed period as 17 Mtoe of savings resulting from structural effect evened out with the similar sized (inversed) impact of activity effect. As documents Table 2, pre-crisis period was typical by more significant improvements in intensity factor, while activity and structural components followed opposite trajectories with former being stronger, altogether resulting in 18 Mtoe (6%) of energy savings. As of 2008, all three components pushed energy consumption into decline with intensity factor still being dominant one, even if to a lesser extent, together aggregating into 27 Mtoe (9%) savings of energy consumption.

We now focus on analyzing the individual countries, with again paying exclusive attention to outlier-countries. EU member states that decreased their energy consumption in industry mostly are BG, RO, IT and HU. The contributions of individual factors were quite differing though. BG and RO recorded outstanding improvement in intensity factor which in former case decreased consumption by 53% and latter by 39%. Unlike BG that did not experience change in structure of industrial production, RO consumption benefited also from decrease caused by structural effect (−16%). Industrial output of both countries rose; therefore activity effect would have caused energy consumption increase by 24% (RO) respectively 35% (BG). Combined, these effects led to 37% decrease energy consumption in both countries. The other two countries, IT and HU followed different paths towards their energy consumption decrease by 26% respectively 24%. In case of IT, activity and structural effect slightly diminished energy consumption complementing so major influence of intensity effect. On the other hand, intensity effect played no part in energy consumption development of HU, and energy consumption growth pulled by increased sector activity was more than vanished by implications of structural change of industry on energy consumption. When comparing data for 2004 to latest available data, it can be seen that only two countries increased their energy consumption in industrial sector significantly - BE (9%) and AT (12%). While BE case is explained by growing EI (25%) with both activity and structural effect lowering energy consumption by 7% each, in AT 2% positive intensity effect together with 19% activity effect overweighed 7% decline resulting from structural effect.

Comparison of pre-crisis and crisis period suggests that sector of industry underwent changes that disrupted previous trends. We did not find any significant correlation in industrial energy consumption of EU countries in those periods, in other words, on average countries that were able to decrease their energy consumption in period of high economic growth were not able to do so in later years. As we already stated, development of observed factors in crisis period saved approximately 10 Mtoe more energy compared to pre-2008 period. It is indisputable, that lower energy consumption of industry is good for economy and environment. But from the broader point of view equally important is the way it was achieved. The effects of energy savings captured under intensity effect are unlike those of activity effect more of a long-run nature. Modern technologies, optimization of production processes and other factors affecting EI will not diminish after the industry will start running again, and lower improvement in EI during recent years suggests those actions aimed at decreasing EI were postponed or canceled and instead of enhancements on company levels, optimization was focused on sector levels, as decreasing energy consumption related to structure effect indicates. Since industrial output is growing again, the need for those postponed

Table 2: European Union energy consumption (in Ktoe) decomposition in industry via loga-rithmic mean divisia index

	2004-2012				2004-2008				2008-2012			
	Activity	Structural	Intensity	Total	Activity	Structural	Intensity	Total	Activity	Structural	Intensity	Total
Austria	1 415 (119%)	-578 (93%)	156 (102%)	993 (113%)	1 401 (119%)	-530 (94%)	86 (101%)	957 (113%)	13 (100%)	-86 (99%)	109 (101%)	36 (100%)
Belgium*	-909 (93%)	-957 (93%)	2 932 (125%)	1 067 (109%)	334 (103%)	-886 (93%)	-93 (99%)	-645 (95%)	-1 238 (91%)	-170 (99%)	3 119 (128%)	1 711 (114%)
Bulgaria	949 (135%)	18 (101%)	-2 425 (47%)	-1 459 (63%)	1 107 (134%)	134 (104%)	-1 678 (64%)	-436 (89%)	27 (101%)	-37 (99%)	-1 012 (71%)	-1 022 (71%)
Czech Republic	4 285 (163%)	-2 712 (73%)	-3 360 (68%)	-1 788 (82%)	4 253 (159%)	-2 753 (74%)	-2 488 (76%)	-987 (90%)	218 (103%)	-293 (97%)	-725 (92%)	-801 (91%)
Denmark*	-312 (88%)	-19 (99%)	-137 (95%)	-468 (83%)	-98 (96%)	33 (101%)	-143 (95%)	-208 (92%)	-211 (91%)	-49 (98%)	(100%)	-260 (90%)
Estonia	213 (144%)	-127 (80%)	-207 (70%)	-121 (81%)	152 (125%)	-79 (89%)	-3 (100%)	70 (111%)	90 (116%)	-88 (87%)	-192 (73%)	-190 (73%)
EU 28*	17 171 (106%)	-17 562 (94%)	-45 356 (86%)	-45 747 (86%)	24 214 (108%)	-12 755 (96%)	-29 602 (91%)	-18 142 (94%)	-5 785 (98%)	-5 172 (98%)	-16 647 (95%)	-27 605 (91%)
Finland	-1 847 (85%)	-1 201 (90%)	1 015 (109%)	-2 034 (84%)	2 962 (128%)	-4 115 (71%)	383 (103%)	-769 (94%)	-4 632 (66%)	2 691 (127%)	677 (106%)	-1 264 (89%)
France	-1 299 (96%)	-756 (98%)	-5 405 (85%)	-7 459 (79%)	220 (101%)	-986 (97%)	-2 701 (92%)	-3 468 (90%)	-1 434 (95%)	356 (101%)	-2 913 (91%)	-3 991 (88%)
Germany*	10 666 (119%)	-7 265 (89%)	-1 827 (97%)	1 574 (103%)	8 154 (114%)	-3 189 (95%)	-2 811 (95%)	2 154 (104%)	2 602 (104%)	-4 042 (94%)	860 (101%)	-580 (99%)
Greece*	-1 160 (72%)	-28 (99%)	511 (115%)	-677 (83%)	-436 (90%)	433 (111%)	152 (104%)	149 (104%)	-800 (80%)	-489 (87%)	463 (114%)	-826 (80%)
Hungary	451 (117%)	-1 345 (63%)	115 (104%)	-778 (76%)	557 (118%)	-129 (96%)	-452 (87%)	-25 (99%)	-37 (99%)	-1 168 (67%)	452 (117%)	-753 (77%)
Italy*	-1 580 (96%)	-832 (98%)	-7 980 (79%)	-10 391 (74%)	1 721 (105%)	-587 (98%)	-4 937 (88%)	-3 803 (91%)	-2 983 (91%)	-374 (99%)	-3 232 (91%)	-6 588 (82%)
Lithuania*	247 (132%)	71 (108%)	-303 (71%)	16 (102%)	234 (130%)	80 (109%)	-311 (70%)	3 (100%)	13 (102%)	-18 (98%)	17 (102%)	13 (101%)
Netherlands	474 (103%)	245 (102%)	-2 165 (86%)	-1 447 (90%)	700 (105%)	150 (101%)	-736 (95%)	114 (101%)	-189 (99%)	119 (101%)	-1 490 (90%)	-1 560 (90%)
Poland*	9 406 (178%)	-1 515 (91%)	-10 913 (51%)	-3 023 (83%)	6 813 (150%)	-1 681 (91%)	-6 943 (66%)	-1 811 (90%)	2 741 (120%)	7 (100%)	-3 960 (77%)	-1 212 (92%)
Portugal*	48 (101%)	-216 (96%)	-150 (97%)	-318 (94%)	25 (100%)	-106 (98%)	-78 (99%)	-158 (97%)	23 (100%)	-102 (98%)	-81 (98%)	-160 (97%)
Romania	1 713 (124%)	-1 436 (84%)	-3 967 (61%)	-3 690 (63%)	1 827 (122%)	-1 134 (88%)	-2 276 (78%)	-1 583 (84%)	115 (102%)	-472 (94%)	-1 749 (79%)	-2 107 (75%)
Slovakia	3 015 (197%)	-3 401 (46%)	118 (103%)	-268 (94%)	2 057 (157%)	-1 443 (73%)	-693 (86%)	-79 (98%)	996 (125%)	-1 833 (66%)	648 (116%)	-189 (96%)
Slovenia	114 (109%)	-76 (94%)	-356 (76%)	-318 (79%)	288 (122%)	-74 (95%)	-280 (83%)	-66 (96%)	-144 (89%)	-17 (99%)	-92 (93%)	-252 (82%)
Sweden*	1 674 (115%)	-2 353 (83%)	-402 (97%)	-1 081 (92%)	1 047 (109%)	-1 413 (89%)	-377 (97%)	-744 (94%)	627 (105%)	-920 (93%)	-45 (100%)	-337 (97%)
United Kingdom*	-3 669 (88%)	782 (103%)	-4 556 (86%)	-7 443 (78%)	-1 444 (96%)	991 (103%)	-1 807 (95%)	-2 261 (93%)	-2 263 (92%)	-132 (100%)	-2 787 (91%)	-5 182 (83%)

*Last known data available for 2011

Source: Authors' calculations

actions will reemerge and current inactivity therefore basically represents lost years. We do not intend to doubt the decision of industry sector to use the slower years to do the clean-up of their activities, only stressing the point that lower energy consumption of industry attributed to great recession should not be perceived as positive aspect of economic crisis.

5. CONCLUSION

Improvements in energy efficiency got to the forefront of energy policy agenda of EU in aftermath of recent geopolitical turmoil between Russia and Ukraine. Therefore the current target of 20% growth of energy efficiency that has been aimed for in 2020 package is going to be followed by at least 27% target till 2030. As improvements in energy efficiency seems to be slowing down and recent decline in energy consumption is generally believed to be caused by economic slowdown, we aimed to analyze the drivers of recent development of energy consumption and find out the roles of individual factors.

EU energy efficiency measured by standard EI indicator improved from 166 in 2004 to 152 in 2008 and 144 toe/M€ in 2012.

Seemingly so, improvements in EI slowed down after the wake of crisis and decline in energy consumption was mainly driven by slowdown of economic activity. Our analysis using LMDI technique however revealed quite the contrary. Intensity effect was the major factor influencing energy consumption on the level of whole EU economy, while activity effect representing the performance of economy pulled the energy consumption up in pre-crisis period and even during the crisis its contribution to lowering energy consumption was of less importance (compared to intensity effect). As the analysis also revealed the impact of structural effect reached bigger magnitude during the period of oil prices surge than in period of high oil prices which indicates that not the price *per se* but rapid fluctuations are the primal drivers of changes in structure of economies. Such interpretation looks even more plausible when considering that economies of countries which consumed energy more efficiently grew more rapidly compared to countries with higher EI till 2008. Another important observation relates to structural factor and emphasizes that structural changes of economies towards service sector would likely lead to lower improvements in energy efficiencies in future years, as service sector is not exposed to such level of international competition and knowledge transfer as in case of industry. This statement was most visible in case of CEE countries which were both able to improve their energy efficiency the most among all the EU members and the only group of countries whose share of industry in economy structure grew.

Our findings emphasized the role of energy efficiency as the first energy source and revealed the need for creation of more favorable conditions for implementing further actions and investments in this field, as under current economic conditions those will naturally progress only at lower speed. Cost-benefit analysis must obviously precede to any such program, but it must be understood by policymakers that public investment into energy efficiency needs to be evaluated equally with any other programs aimed at enhancing energy security such as renewable subsidies, or guaranteed prices for new nuclear power plants.

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