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EU Energy Security - Multidimensional Analysis of 2005-2014 Development[1]

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ABSTRACT

Concept of energy security has been subject to multiple attempts for its conceptualization. Nowadays generally accepted approach is based on multiple dimensions and incorporates factors of energy availability, energy affordability, energy efficiency and environmental stewardship. This paper used z-scored standardization methodology in order to empirically examine the development of overall energy security via synthesizing the contributions of individual dimensions. We took into account eleven distinct variables which describes the each dimension. We found out, that most important common denominator that distinguishes the most secured countries from its peers within EU is their ability to generate energy indigenously due to its natural endowments. Our analysis further revealed that dimensions that are covered under common energy policies (energy efficiency and environmental stewardship) show signs growing cohesion across countries. However countries which improved their overall energy security relied primarily on their affordability dimension. We need to add that each dimension contributed its significant share to the total energy security index development.

Keywords: Energy Security, European Union, Energy Security Index, Z-score Standardization
JEL Classifications: Q2, Q3, Q4

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1. INTRODUCTION

Concept of energy security underwent the extensive historical development and was subject of multiple disciplines and approaches of which ones none can be considered obsolete (Obadi and Korcek, 2014). Complexity and persisting relevancy of the issue has led to several attempts to conceptualize the category of energy security (Sovacool and Brown, 2010; Cherp et al., 2011; Kruyt et al., 2009; Winzer, 2012), and dimensions, individual experts have considered to be crucial for energy security are in many cases almost equivalent.

Those are:
- Physical accessibility - geological, technological and geopolitical factors;
- Economic availability - energy efficiency, affordability, price fluctuations;
- Environmental acceptability - environmental impacts and social acceptability.

The various attempts to establish a theoretical platform for empirical analysis differs only marginally depending on the exact definitions of dimensions.

The origins of individual categories are clearly recognizable in the historical perspectives of above mentioned approaches and novelty and added value of this conceptualized theory is in its aggregation, which creates holistic approach to this issue. According to study by Sovacool and Brown (2010), physical accessibility was identified as an important factor of energy security in 80% of the research studies on this topic between 2003 and 2008. The classical approach to energy security put emphasis on diversifying the sources and it aims to ensure sufficient uninterrupted energy supply while minimizing dependence on foreign resources. Diversification involves the diversification of energy sources (coal, oil, gas, renewables), logistic chain (transport routes and means) and suppliers at the level of companies and states. The experts asserting this dimension of energy security include: Scheepers et al., Nuttall - Manz, Wright. According to the same study Sovacool and Brown (2010) economic availability in terms of affordable price was indicated as a factor of energy security in 50% of studies (in terms of economic efficiency, which is in this study defined as a separate dimension of security it was cited as a factor of energy security in one third of the examined scientific articles). Economic availability can be understood on several levels. The first of these is the actual price level of energy, which determines the economic options of using energy resources by final consumers. Since the outbreak of the first oil crisis, the high price of energy commodities (especially of oil) was seen as a channel of wealth transfer between oil exporting and oil-importing countries. However, from a historical perspective it is clear that Western countries importing crude oil were able to offset the impact of higher prices through productivity growth and high oil prices did not constitute an unsolvable problem for their energy security[1]. Another important factor within the dimension of economic availability apart from price level of energy is price stability. The sharp fluctuations in prices of energy carriers negatively affect consumers and producers and are able to significantly disrupt economic development of countries involved in oil trading. Increases of energy prices in the importing countries force economic actors to optimize their allocation of resources, which has negative impact on economic growth at least in the short term[2].

Economic, respectively energy efficiency can be considered to be another factor of economic availability. The growth of energy efficiency means reduction of energy intensity and overall importance of energy as such in the national accounts of the economy. Increases in energy efficiency, have historically taken place as a result of price increases. In terms of energy security it means the improvement of the situation, as the country is less exposed to the shocks caused by the potential fluctuations in price of energy. On the other hand, countries with administrative measures maintaining low prices generally waste more energy (natural gas in Russia, crude oil in the US). To complete the picture economic aspects of increases of energy efficiency cannot be taken for granted. Capital investments which such process necessary requires can be evaluated as economically ineffective in case of price fluctuations. The most important factor in terms of this dimension of energy security is therefore stability of prices, which would ensure an economically affordable growth of energy efficiency, and thus improving the position of the economy in terms of energy security. Economic availability is a core definition of energy security according to Grubb et al., Joode et al., Bohi et al.

Social acceptability and environmental protection in the twenty-first century become an integral part of energy security issue. According to cited study Sovacool and Brown (2010) this dimension of energy security appeared in one quarter of the examined articles, but considering the events in the recent years it is likely that this percentage will increase. In the sixties and seventies the main subject of discussion on environmental security was depletion of mineral and fossil resources. These concerns were highlighted by several studies - limits to growth (Meadows et al., 1972), the population bomb (Ehrlich, 1971), the tragedy of commons (Hardin, 1968), which in Malthusian spirit pointed to the unsustainability of the growth of population and the carrying capacity of ecosystems. These concerns became gradually pushed out from the core of the debate by implications of resources use. And a great paradox of the early 21st century is that instead of the scarcity of fossil resources it is the implication of abundance of its usage that is being the principle concern for the environment. The emergence of anthropogenic climate change due to a large scale use of energy represents the fundamental threat for the humankind. However it is not the only link to energy security. According to Sovacool (2014) there are four environmental dimensions of energy security (in Asia Pacific region) - climate change, air pollution, water availability and quality and land-use change. As our research takes into consideration only EU countries (for the purpose of this paper) we take into consideration only former two. The importance of environmental dimension of energy security is apparent also in the definition of energy security by the IEA (2007), Deutch and Schlesinger (2007).

2. MEASURING ENERGY SECURITY

With respect to all the aspects that affects and enters into concept of energy security, it should be clear that its measurement is not straightforward. The simplest definition of energy security (adequate supply of energy at a reasonable cost) illustrates how complex any attempt of measurement would be: From the assessment of the "adequate" level of supply to the "reasonable" price level of the energy mix (Labandeira and Manzano, 2012). One approach towards measuring energy security is to focus on the geopolitical analysis (Keppler, 2007), Baláž and Londarev, 2006) which expose the conclusions to subjective judgments resulting from contextual nature of this type of analysis. In order to make conclusions more objective, multiple researchers used various indicators of security of supply. Kruyt et al. (2009) state that there is no ideal indicator and therefore, it is needed the application of several indicators for a broader assessment and understanding of energy security. Scheepers et al. (2007) proposed two quantitative indicators that can be used to in EU security of supply: The supply/demand index based on objective information contained in energy balances and the crisis capability index, which measures the ability of countries to manage short-term supply interruptions, however some of the inputs entering the calculation are of more subjective nature. Studies covering subject of energy security usually focus on natural gas and oil. It is arguably logical approach considering past experience, uneven dislocation and importance of these sources in energy

1 Since the main focus of this paper is on EU countries which represent the importers we tend to emphasize their view. We are however aware that given scenario impacts also governments of exporting countries which are usually forced to increase transfers of revenue from the energy sector to its population in order to keep their favor, which can result in a lack of investment within the energy sector itself. In case of monoculture oriented economy a fall in prices of main commodity supporting the economy can therefore result into social unrest and threats to supplies of oil or gas on a global scale (the events of the Arab Spring).

2 On the other hand in case of oil exporting countries, price fluctuations mean uncertainty of return on investment and the potential for wrong assessment of future demand. In other words, low prices could lead to underestimation production capacities needed for the future. From a longer-run perspective, price volatility may automatically trigger a condition when supply side will not be capable to meet the growing demand.

mix. Measurements of energy security in such cases starts with quantifying the diversification of sources as a proxy variable for supply security. In order to that multiple studies Lefevre (2010); Le Coq and Paltseva (2008, 2009); Gupta (2008); Loschel et al. (2010) use the Herfindahl-Hirschmann index (HHI). This index is equal to the sum of the squares of each supplier's market share. Thus the more concentrated the market, the higher is the value of the index; the maximum value of the index is achieved when there is only one supplier. Other approach was used by Neumann (2004; 2007) who used a Shannon-Weiner concentration index, which is calculated by multiplying the market share for each participant by the log of the market share and summing up the absolute values of the products over all the suppliers. This index gives greater weight to the impact of the smaller participants in contrast to HHI. This initial assessment of diversification as a basis for energy security is consequently extended by incorporating political risks, transportation risks and others (Cohen et al., 2011).

Roupas et al. (2009) compare the security of oil supply of the 27 countries of the European Union by measuring past episodes of oil vulnerability. The methodology uses principal-component analysis to set up a synthetic index that intends to reflect the core of vulnerability and security of supply. From a different perspective, but also employing an index-based methodology, Marín-Quemada and Muñoz-Delgado (2011) explore the relationship between the EU and other countries in terms of competition (rivalry) or complementarities (affinity) regarding energy import and export flows. The authors propose an Energy Affinity Index to analyse the EU-27's energy relations with third countries.

Apart from that, International Energy Agency has very recently developed a model of short-term energy security (MOSES) to evaluate short-term security of energy supply in IEA countries (IEA, 2011). The model is based on a set of quantitative indicators that measures both the risk of disruptions in energy supply and the ability of the energy system to deal with those eventual disruptions. MOSES however focuses only on short-term physical disruptions of energy supply.

However none of these approaches does not take into account dynamic changes in energy market development with respect to other dimensions of energy security - such as importance of decarburization and push towards greener shifts in energy mix or overall influence and potential of energy and economic efficiency measures and energy costs. Such extended indicator is provided by World Energy Council (WEC's) energy trilema index, which covers s three core dimensions: Energy security, energy equity, and environmental sustainability and is being issued for last 6 years. It takes into account 35 indicators devised in above mentioned categories and provides the overall ranking enabling to identify the issues individual countries need to focus on. Similarly as Brown et al. (2014) who calculated energy security index for OECD countries during period 40 years period of 1970-2010, WEC used z-score standardization as basis methodology for their calculation (Tables 1 and 2). This methodology allows to consider and compare various aspects of energy security and so synthesize a single numerical indicator which enables identifying the strengths and weaknesses of energy security of given country.

In our paper we applied this methodology for the group of EU countries for the decade after its big enlargement in 2004 in order to examine their performance and changes in the context of the policies which EU taken and shifts that happened in the energy realm during the observed period.

3. DATA AND METHODOLOGY

Our examination of energy security is based on methodology developed by Brown et al. (2014). We collected the data on 11 indicators of energy security of the country and divided them into four groups with respect current theoretical understanding of multidimensional approach towards energy security discussed in previous section. Four dimensions taken into account in this article are energy and economic efficiency - EEE (with variables energy intensity, emission intensity of new cars, electricity consumption per capita), affordability - AF (gasoline price, natural gas prices for households and enterprises)[3], physical availability - AV (oil and natural gas import dependency, share of RES in transportation) and environmental stewardship - ES (GHG emissions per capita, GHG of energy consumption). The main source of our data was Eurostat, the only exception was gasoline prices where we obtained data from World bank database. Since such data are collected only for odd years, instead of 2005 we used 2004 in our calculation for that variable. Our calculation covers 26 country of EU for which we have available data - Malta and Cyprus are omitted. We compare data in 2005 and 2014 in order to asses development of energy security for those countries during the period of steep oil prices rise, infrastructure building, shale revolution happening in US and implication of financial crisis and crush of oil prices.

Z-scores evaluate the relative magnitudes of change in indicators, they identify divergences of individual countries from underlying trends. The z-scores represent the normalized distances from the data points to the means in terms of standard deviation z-scores are "dimensionless" quantities that indicate how many standard deviations a country is above or below the mean of our group of EU countries. We calculated z-scores for each of the 11 indicators in 2005 and 2014 by subtracting the mean value for each data point and dividing it by the indicator's standard deviation.

$$\text{z-score}_{d,y} = \frac{\text{absolute value}_{d,y} - \text{mean}_{d,y}}{\text{standard deviation}_{d,y}}$$

By imposing a z-score normalization, we are able to distinguish between "common cause" variation (when all countries experience similar shifts) and "special cause" variation (when a country's actions and situations result in a distinct change in energy security. The z-scores are then summed for 2005 and 2014, giving equal weight to each indicator and providing a total energy security score for each country in both years. We then multiply all the variables

3 We fixed these data to reflect purchasing power in individual countries by dividing them with price level indices to reflect actual costs which are comparable. If we did not include this fix, lower prices for energy in lower income countries would artificially inflate the score of affordability dimension for them - i.e., 5EUR/GJ means something different for consumers in Romania and Germany.

Table 1: Energy security index - 2005

Indicator/ country	Energy and economic efficiency			Affordability			Availability			Environmental stewardship	
	Energy intensity	Emissions new car	Electricity Cons/p.c.	Gasoline price/USD	NG price (industry)	NG price (household)	Oil import dependence	Share of RES in transprot	Natural gas import dependence	GHG emissions/ p.c.	SO2 emissions/ p.c.
Denmark	1.17	0.18	−0.06	1.30	1.43	−2.06	3.05	0.43	2.32	−0.27	0.64
United Kingdom	0.76	−0.29	0.05	0.51	0.95	1.61	3.05	−0.85	2.11	−0.12	0.32
Austria	0.81	0.30	−0.30	0.91	0.63	0.03	−0.21	2.78	−0.28	−0.02	0.68
France	0.64	1.06	−0.22	0.81	0.71	0.81	−0.48	−0.25	−0.62	0.48	0.52
Croatia	−0.03	0.97	0.76	−0.92	−1.81	0.02	0.23	1.13	1.62	0.86	0.30
Romania	−1.16	−0.17	1.21	−1.13	−0.51	0.66	1.68	0.69	1.43	0.93	−0.56
Italy	0.87	1.28	0.22	0.32	0.58	−0.54	−0.21	−0.09	−0.19	0.27	0.52
Belgium	0.39	0.84	−0.50	0.53	1.13	0.61	−0.53	0.95	−0.66	−0.56	0.45
Ireland	1.06	−0.07	0.03	1.37	1.20	1.16	−0.51	−0.65	−0.25	−1.28	0.15
Netherlands	0.65	−0.31	−0.13	0.23	0.53	−0.38	−0.37	−0.71	2.32	−0.48	0.59
Spain	0.67	0.83	0.11	0.71	1.00	−0.08	−0.55	0.09	−0.67	0.21	−0.50
Latvia	−0.28	−1.65	1.00	−0.55	0.12	1.03	−0.58	1.57	−0.80	1.28	0.68
Portugal	0.52	1.64	0.45	−0.22	−0.25	−0.61	−0.59	0.62	−0.75	0.58	0.11
Hungary	−0.50	0.75	0.80	−1.27	−1.37	1.17	0.16	−0.83	−0.08	0.79	0.64
Slovenia	−0.01	0.68	−0.12	0.18	−0.03	−0.37	−0.55	0.68	−0.63	0.24	−0.10
Germany	0.66	−0.58	−0.11	0.49	−0.32	−0.10	−0.40	−0.45	−0.04	−0.17	0.57
Sweden	0.59	−2.17	−2.49	0.90	0.13	−1.47	−0.65	2.06	−0.49	0.78	0.67
Lithuania	−0.93	−1.58	1.04	−1.02	−0.05	0.57	−0.22	−0.87	−0.66	0.97	0.38
Greece	0.70	−0.11	0.39	0.68	−0.61	−0.34	−0.42	−0.59	−0.61	−0.23	−1.26
Estonia	−1.31	−1.38	0.44	0.09	1.30	1.30	0.53	−1.03	−0.64	−0.43	−1.63
Poland	−0.86	0.84	0.93	−1.44	−1.48	−0.23	−0.42	−0.93	0.26	0.21	−0.44
Luxembourg	0.70	−0.21	−2.15	1.43	0.46	1.45	−0.48	−0.90	−0.64	−4.01	0.72
Slovakia	−1.16	0.67	0.50	−1.57	−1.51	−0.70	−0.09	−0.13	−0.57	0.38	0.16
Czech Republic	−0.90	0.83	0.16	−0.72	−1.11	−0.09	−0.42	−0.87	−0.57	−0.65	−0.02
Finland	0.23	−1.05	−2.76	0.73	0.79	−1.97	−0.45	0.57	−0.64	−0.42	0.42
Bulgaria	−3.30	−1.29	0.76	−2.34	−1.90	−1.47	−0.58	−0.52	−0.28	0.66	−4.04

Source: Authors' calculations based on Eurostat and World Banka database, 2016

except for share of RES in transportation by −1 and that way, positive z-scores in 2005 and 2014 would indicate higher energy security relative to other EU countries. Furthermore, we subtracted individual z-scores for year 2014 from year 2005 and that way we are able to evaluate whether the energy security (expressed by our index) improved or worsened during the period of our observation. If the result is positive value, it can be concluded that country's energy security got better and negative values represent worsened situation. Analysis of variations of individual dimension can on top reveal the main area of variation of country energy security position.

4. RESULTS

We first start our analysis with the overview of initial state of energy security as defined by our variables in year 2005. We will focus our analysis on top (under) performers and we will analyze individual dimensions which led to calculated result.

The group of countries with most outstanding performance in relative to the rest of the EU27 have several common traits. Top three countries on the list are DK, UK and AT. All these countries benefited from good performance with respect to AV dimension resulting from their natural endowments. In case of UK and DK this is obviously implication of indigenous sources of oil and gas and in case of AT significant electricity production using RES - mainly hydropower. The second strong dimension for UK and AT is AV (which reflects purchasing power of country), followed by EEF. The orders of these dimension is reversed for DK. Each of these countries shows also slightly above averaged results in ES dimension. Unlike the group of the top three countries, the other two showed little bit more heterogeneous results. Fourth place in 2005 belonged to FR. Unlike the previous countries it did not built on AV dimension as its import dependence on oil and gas reached almost 100% in 2005 and domestic power production from RES was below EU average. France's edge comes predominantly from the AV dimension, closely followed by above averaged efficiency and low level of pollution and emissions due to high share of nuclear power in electricity generation. The next country on the list is HR, like DK an UK its position reflecting its relative energy security is a consequence of domestic resources of oil and especially natural gas. It also gained positive values dimensions of EEF - mainly as a result of new cars' emissions and lower electricity consumption, and ES. The significant factor with negative effect on overall score is AF primarily due to high natural gas prices for industrial consumers.

On the other side of this list are BG, FI, CZ, SK and LU. BG scored significantly below average in all dimension of energy security with total score reaching almost −16. It performed worse

Table 2: Energy security index - 2004

Indicator/ country	Energy and economic efficiency			Affordability			Availability			Environmental stewardship	
	Energy intensity	Emissions new car	Electricity cons/p.c.	Gasoline price/USD	NG price (industry)	NG price (household)	Oil import dependence	Share of RES in transport	Natural gas import dependence	GHG emissions/ p.c.	SO2 emissions/ p.c.
Denmark	1.18	1.48	0.10	1.15	1.64	0.51	3.69	1.13	2.40	−0.07	0.63
United Kingdom	0.87	0.02	0.36	0.86	0.94	1.50	1.88	−0.64	1.06	0.18	0.32
Netherlands	0.61	1.77	−0.13	0.27	1.18	0.16	−0.28	−1.09	2.40	−0.67	0.56
Austria	0.76	−0.38	−0.48	1.18	0.89	0.42	−0.26	2.37	−0.48	0.03	0.70
Romania	−0.69	−0.35	1.27	−1.98	0.10	0.84	1.40	0.74	2.25	1.05	−0.40
Croatia	−0.18	0.91	0.78	−0.95	−1.43	0.12	0.51	0.95	1.55	0.96	0.31
Italy	0.84	0.67	0.39	−0.02	0.68	−0.23	−0.12	0.26	−0.27	0.63	0.60
France	0.60	1.08	−0.18	0.90	0.71	0.74	−0.54	−0.61	−0.68	0.58	0.59
Ireland	1.11	0.78	0.13	0.72	0.71	0.90	−0.51	−0.36	−0.47	−1.06	0.44
Spain	0.68	0.63	0.30	0.54	0.21	−0.53	−0.68	0.51	−0.68	0.54	0.20
Latvia	−0.46	−1.57	0.85	−0.14	−0.35	0.24	−0.28	1.28	0.26	0.97	0.69
Sweden	0.57	−0.62	−2.41	1.35	0.90	−0.89	−0.68	1.98	−0.55	0.95	0.62
Belgium	0.36	0.36	−0.51	0.72	1.15	1.00	−0.66	−0.89	−0.61	−0.33	0.59
Germany	0.67	−0.77	−0.21	0.71	0.35	0.66	−0.40	−0.04	−0.27	−0.59	0.29
Portugal	0.48	1.62	0.49	−0.57	−0.65	−2.76	−0.46	1.34	−0.57	0.78	0.62
Slovenia	−0.12	0.36	−0.11	−0.20	−0.25	−0.49	−0.51	0.29	−0.56	0.34	0.36
Greece	0.47	1.68	0.42	−0.56	−0.62	−0.80	−0.60	−0.40	−0.55	−0.06	−0.89
Luxembourg	0.86	−0.51	−1.94	1.56	0.62	1.94	−0.63	−1.32	−0.56	−3.47	0.73
Finland	−0.13	−0.26	−3.05	1.09	1.03	−0.21	−0.38	0.15	−0.57	−0.52	0.01
Hungary	−0.51	−0.83	0.74	−1.23	−1.61	0.69	−0.09	−1.24	−0.51	0.96	0.56
Slovakia	−0.53	−0.70	0.45	−1.03	−0.66	−0.07	−0.22	−0.34	−0.72	0.49	−0.18
Lithuania	−0.33	−1.11	0.91	−0.90	−1.67	−1.07	−0.30	−0.87	−0.69	0.77	0.23
Poland	−0.67	−0.80	0.85	−0.65	−1.38	−0.59	−0.31	−0.95	0.26	−0.20	−1.03
Czech Republic	−0.92	−0.70	0.14	−0.95	−0.26	−0.68	−0.51	−0.86	−0.46	−0.76	−0.58
Estonia	−2.43	−1.62	0.17	0.19	−0.17	0.49	1.48	−0.82	−0.57	−1.87	−3.56
Bulgaria	−3.08	−1.13	0.67	−2.04	−2.04	−1.90	−0.52	−0.57	−0.40	0.37	−2.42

Source: Authors' calculations based on Eurostat and World Banka database, 2016

with respect to AF which can at least partially explained by relatively low purchasing power. The low score in this dimension was joined by negative scores from EEE, ES and AV. BG so became the only state that underperformed in all dimension. BG is quite surprisingly followed by FI with significantly better score of −4.56. To a large extent it was influenced by low ranking in EEE dimension - mainly as a result of high electricity consumption. Reasons for this are industries with high energy consumption (half of energy is consumed by industry), high standards of living, cold climate (25% of consumption is used in heating) and long distances (16% of consumption is used in transport). Other than that, other dimensions did not show more remarkable deviation from the EU average. Next two countries are CZ and SK. Both scored relatively well with respect EEE, however affordability of energy is big issues in both countries - bigger in SK where energy related cost for consumers represented over 14 of household expenditures (measured by COICOP) compared to average 5% for EU 28. Negative score of AF dimension and positive one of ES dimension almost evened out. CZ on the other hand got equally bad scores both from AF and AV and with respect to its coal industry, negative score of ES is not a surprise. The 5th country in this group is LU. LU scores extremely good with respect to AF, reflecting its economic strength. However the size of the country and steel industry mean, negative score in EEE and ES, while negative AV score results from virtually no indigenous resources and almost non-existing RES participation in power generation.

The decade between 2005 and 2014 brought some moderate changes to our ranking. The first five countries scoring the highest are DK, UK, NL, AT and RO while HR moved to the sixth place and FR fell to eighth. In 2014 DK energy security as defined by our variables was even more outstanding compared to the rest of EU. DK basically doubled its share of power generated from RES, while on average this indicator improved for "only" 63%. This, combined with self-sufficiency in oil and gas, which the rest of EU become more import dependent on, translated into better performance even in dimension where DK was already extremely strong before. Moreover, DK significantly improved in EEE, and AF dimension, recording improvement in each and every indicator. Although, changes in ES were only minor and did not have significant impact on its overall situation. UK kept its second position, but its situation slightly deteriorated (score went from 8.09 to 7.37). AF, EEE and ES dimensions recorded only minor shifts all in positive direction and were able at least partially offset implications of diminishing indigenous resources of oil and gas which make UK over 40% dependent on imports of these commodities from virtually zero in 2005. The third place in 2014 belongs to NL, which recorded improvements in EEE and AF dimension, especially with respect to car emissions intensity and prices for natural gas that increased much less compared to EU average. Other than that it basically held its position in AV and ES dimension. AT lost one position in our ranking as a result of smaller deteriorations in EEE, AV and ES position an opposite movement in AF dimension with total loss of 0.6 point which basically means stable position. Energy security of RO is based on strong AV dimension, where this country got the second highest score after DK and actually improved its score due to lowering natural gas import dependence and strengthening the position of RES in power generation. The changes in other dimension were of a lesser importance with improvements with respect to EEE and ES and lower score in AF dimension.

The weakest energy security was recorded for BG, EE, CZ, PL and LT. Compared to 2005 SK, FI and LU dropped from this group moving to sixth, eighth and ninth position respectively, counting from the end. BG stayed on the very last place in our ranking, even though its total score improved by 1 point mainly as a result of improvements in ES dimension resulting from air pollution lowering by 80%. Estonia's drop was consequence of several counter-acting forces. Its improvements in AV dimension were not able to offset lower score in AV dimension resulting from energy cost growth. Slight increase in energy intensity during the period when average intensity of EU countries declined from 220 kgoe/kEUR to 174 kgoe/kEUR meant worsening of performance in EEE dimension and even bigger regress in ES dimension was similarly caused by EE lag in improvements it the air quality expressed by the SO_2 emissions indicator. The position of CZ remained unchanged, although its overall score worsened as result of changes in EEE and ES since improvements in emissions of new car and SO_2 emissions lagged behind the trend in the rest of countries. Poland ranking worsened by one position, due to similar reasons as was the case of CZ, which were not compensated by improvements in AF. LT's fall to fifth position was almost single-handedly caused by lower score in its AF dimension, as prices for gasoline, and natural gas prices for households (fixed for price level indices) and consumers grew by 50%, 155% and 124% in respective order.

As we indicated in previous text, values obtained by subtracting 2005 from 2014 score can clearly present us shifts in energy security development of individual countries. As can be seen on the Figure 1 the majority of countries did not undergo more significant changes and shifts stayed within the limit of two standard deviations.

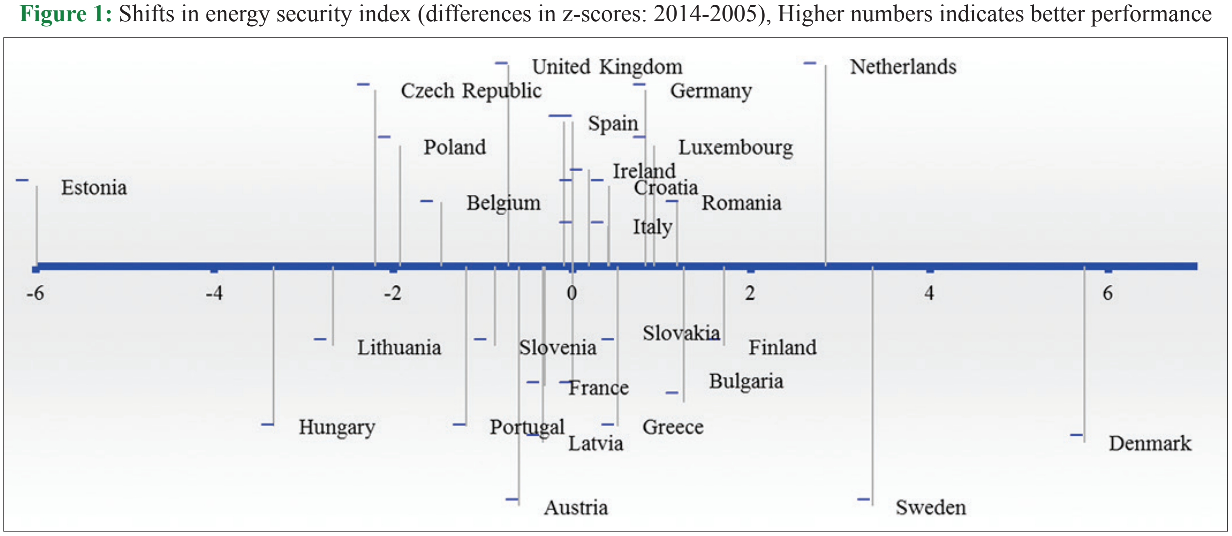
The "winners" in this comparison are DK, SE, NL and on the other end stand EE, HU, CZ and LT. We start with SE and NL (DK's results have already been discussed in previous section), which improved their index score by 3.4 respect 2.8 points. Both countries benefited from improvements in EEE and AF dimension, without any bigger changes in the other two dimensions. Improvement of performance of both countries stemmed from radical cut of emissions of new cars and smaller than average price increase of natural gas.

On the other side, the only country that significantly worsened its energy security situation that we did not discuss in previous text is HU, which despite second largest decrease in score (by 3.3 point) fell on seventh position from the end. Worse result comes from 3 dimensions - EEE, AF and AV. EEE, as was the case in other countries, was mostly influenced by slower than average improvements with respect to car efficiency. Deterioration in AF dimension was mostly influenced by spike in natural gas prices for households, which however still stayed below the EU average, even after counting for price indices. AV dimension was affected by combination of increasing import dependence slow and deployment of RES.

Our results have shown that countries that gained higher scores in our energy security index benefited especially from their indigenous energy resources as they scored above average in AF dimension. None other dimension was of such an importance. Analyzing the development between selected years, we observed several facts.

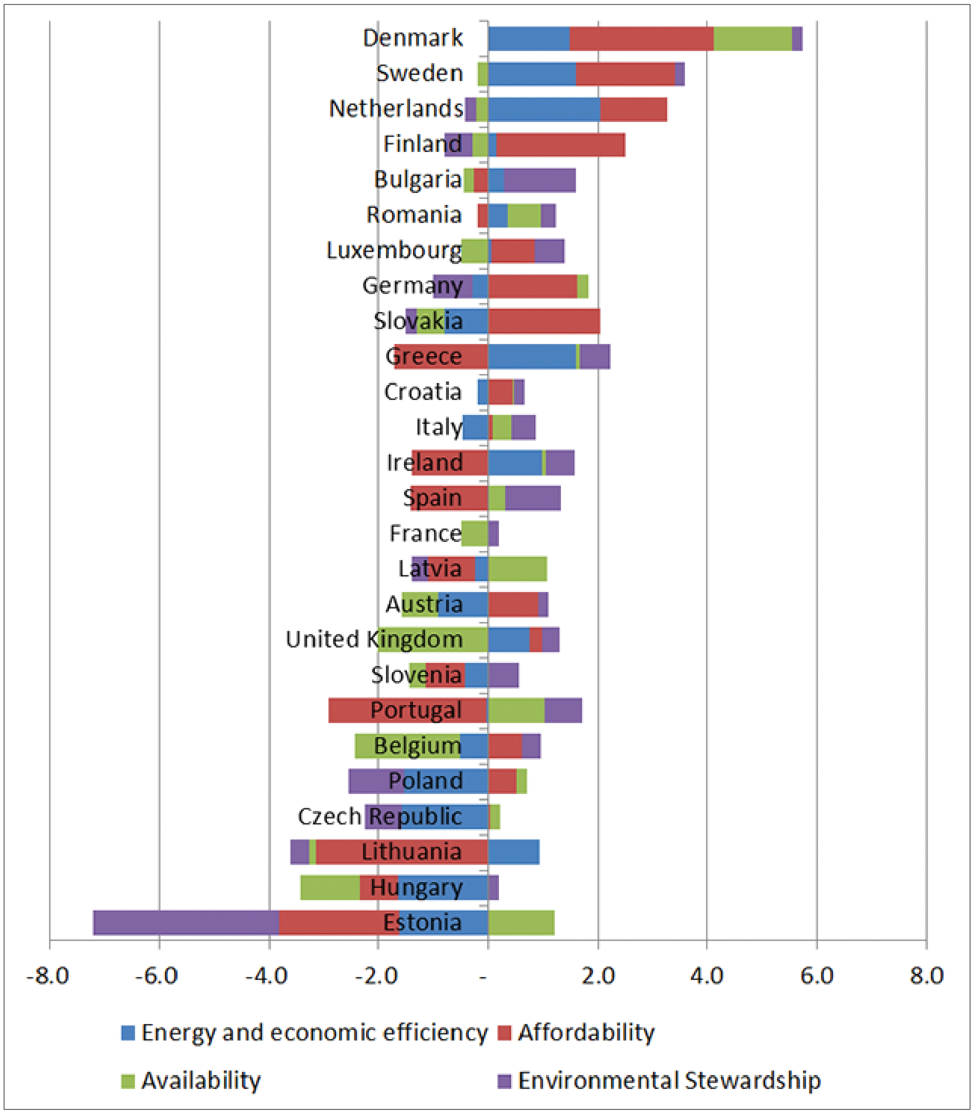
Firstly, we did not find any significant correlation between individual dimensions, meaning absence of coherent strategy of holistic strategy towards energy security, which is not surprising considering that most of competencies in this area stayed in the hands of national states. At the same time, we need to add, that

Figure 1: Shifts in energy security index (differences in z-scores: 2014-2005), Higher numbers indicates better performance



Source: Authors' calculations

Figure 2: Structure of changes in energy security dimensions (differences in z-scores: 2014-2005)



Source: Authors' calculations based on Eurostat and World Banka database, 2016

directions of correlations among individual dimensions are in line with theoretical understandings. Therefore supports the construction of our index (for instance, EEE is positively correlated with all the other dimensions, which means improvement in energy efficiency come along with increased availability, affordability and environmental sustainability, but the correlation between AF and AV is negative, meaning increased availability requires investments which translates to higher costs). Secondly, when we compared standard deviations of individual variables in years 2005 and 2014, we can see signs of lowering the interstates differences especially with respect to EEE and ES dimension - areas that are covered under EU 2020 policy oriented on increasing energy efficiency and lowering emissions and pollution. Slight increase in standard deviation with respect to electricity produced from RES suggests various speeds countries have chosen to pursuit in this area. Similarly, development of energy costs show diverging trend among the individual states (Figure 2).

Thirdly, the contributions of individual dimension to overall score varied hugely. However, on average, none of the dimension played negligible role. EEE, AF, AV and ES were responsible for 25%, 35%, 20% and 20% of overall development of index. In case of countries which improved their energy security index against the ones that do not, we can see that EEE and ES played approximately same role in both groups of countries. What is different is the importance of AF dimension, which determined as much as 41% in the first group compared to 29 % for the second one. In case of AV dimension it is basically reversed 14% versus 28%. This conclusion is also quite intuitive, since changes in affordability dimension of energy security can be executed more swiftly compare those in availability (just consider the time of implementation of price subvention vs. installation of new RES). Therefore, its impact on energy security is more visible in short to medium run, even if other strategy might be preferable in the longer run.

5. CONCLUSION

The important factor when implementing the strategy aimed at enhancing the energy security is being able to evaluate actual results of taken measures and their impact. Energy security requires a complex approach, which accounts for all the differing aspects of the wider goals. In this paper, we applied z-score standardization methodology in order to evaluate and compare performance of EU countries' energy security. Countries, which we identified as most secure among the whole group - DK, UK, NL and AT, benefited from their natural endowments, either in terms of fossil fuel resources or capability to efficiently generate renewable energy. The other side of our ranking is mostly populated with latter joining members of EU and generally countries which are poor in terms of indigenous energy sources and overall less affluent, which affects their performance in AF dimension, while their ES and EEE dimensions are influenced by increasingly important contribution of industry sector negatively affecting overall energy efficiency and emissions indicators. That is more or less valid for both 2005 and 2014 despite some changes that happened during the observed period.

Our analysis further revealed that differences in areas under EEE and ES dimensions are diminishing and since these two areas are covered under common energy policy, this development can be seen as the consequence of common energy policies. This notion is also supported by fact that results in AF dimension became more diverge since that area is conducted by national states without the coordination at EU level. At the same time AF dimension was on average most salient dimension for all the countries which improved their overall energy security dimension in our observed period, clearly so suggesting the perception of energy security by national policymakers. At the same time, we need to add that our calculations suggest each dimension contributed its significant share to the total energy security index development, which confirms the general acceptance of multidimensional perception of energy security.

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