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Quantifying the Energy Security of Selected EU Countries

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ABSTRACT

This paper examines the energy security of a selected group of EU countries. The study covers period 2006-2017 and is done for selected group of countries - Germany, France, Italy, Poland, Netherladns, United Kingdom and Slovakia. The primary used methodology is the Z-score standardization. In order to obtain an index of greater complexity, we extended this methodology by incorporating Herfindahl-Hirschmann index values for natural gas imports. Our findings suggest, that, among the largest energy consuming countries in the EU, Italy came as the country with the highest level of energy security index (ESI) as it benefitted from improved security of supply. France ESI slightly decreased due to worsening indicator of economic availability. Poland and Slovakia both suffered from low advancements in the are of environmental acceptability. The complexity of the solved problem caueses undesired consequences, as development of ESI index deteriorated after German nulear phase-out. The paper clearly ducuments there there is not a single way how to approach enhancing a country's energy security.

Keywords: Energy Security, EU, Z-score Standardization, Herfindahl-Hirschmann Index, Natural Gas
JEL Classifications: Q40, Q42

1. INTRODUCTION

The 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 Korček, 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 being crucial for energy security are in many cases almost equivalent.

These 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 the above mentioned approaches, novelty and added value of this conceptualized theory are in its aggregation, which creates a holistic approach to this issue. The classical approach to energy security places 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. 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 the final consumers. Another important factor within the dimension of economic availability apart from the price level of energy is price stability. The sharp fluctuations in the prices of energy carriers negatively affect consumers and producers and are able to significantly disrupt the economic development of countries involved in oil trading. In terms of economics, the respective energy efficiency can be considered to be another factor of economic availability. The growth of energy efficiency means a reduction of energy intensity and the overall importance of energy as such in the national accounts of the economy. 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 the price of energy. Social acceptability and environmental protection in the 21st century has become an integral part of the energy security issue. In the sixties and seventies, the main subject of discussion on environmental security was depletion of mineral and fossil resources. 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 abundance of its usage that is of principal concern to the environment. The emergence of anthropogenic climate change due to large scale use of energy represents the fundamental threat to the human race.

The main objective of this paper is an assessment of the energy security by calculation of energy security index (ESI) and an analysis of development pattern of its components in selected EU Member states, namely DE, FR, IT, NL, UK, PL and SK. For this purpose, we used the z-score standardization methodology, which is frequently used in literature (Lobova et al., 2019; Sovacol and Brown, 2010; Winzer, 2012). The contribution of this paper to the mentioned methodology is incorporating Herfindahl-Hirschmann index (HHI) values for natural gas imports in order to obtain an index of greater complexity.

Our paper is divided into 5 sections. The literature review is discussed in Section 2. The Z-score standardisation, data and indicators are presented in Section 3. Section 4 contains the detailed results of ESI. Section 5 is the concluding part.

2. LITERATURE REVIEW

In respect to all the aspects that affect and enters into the 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) which expose the conclusions to subjective judgments resulting from the contextual nature of this type of analysis. In order to make conclusions more objective, multiple researchers used various indicators of security of supply (SoS). Kruyt et al. (2009), stated that there is no ideal indicator and therefore, the application of several indicators for a broader assessment and understanding of energy security is needed. Studies, covering the subject of energy security usually focus on natural gas and oil. It is arguably a logical approach considering past experience, uneven dislocation and the importance of these sources in the energy mix. Measurements of energy security in such cases start with quantifying the diversification of sources as a proxy variable for supply security. Other previous multiple studies, Lefevre (2010); Coq and Paltseva (2009); Gupta (2008) used the 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. Another approach was used by Neumann (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), compared 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 SoS. From a different perspective, but also employing an index-based methodology, Marín-Quemada and Muñoz-Delgado (2011), explored the relationship between the EU and other countries in terms of competition (rivalry) or complementarities (affinity) regarding energy import and export flows. The authors proposed an Energy Affinity Index to analyse the EU-27's energy relations with third countries. Apart from that, the International Energy Agency had 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 take into account dynamic changes in energy market development with respect to other dimensions of energy security such as the importance of decarbonisation and push towards greener shifts in energy mix or overall influence, the potential of energy and economic efficiency measures and energy costs. Such extended indicator is provided by World Energy Council (WEC's) energy trilema index (World Energy Council, 2018), which covers three core dimensions: Energy security, energy equity, and environmental sustainability and is being issued since 2008. It takes into account 35 indicators divided into the 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 ESI for OECD countries during a 40 years period from 1970 to 2010, WEC used the Z-score standardization as a basis methodology for their calculation. This methodology allows the consideration and comparison of various aspects of energy security and so synthesize a single numerical indicator which enables identifying the strengths and weaknesses of energy security of a given country.

In our paper, we extended this methodology by incorporating HHI values reflecting their natural gas imports. That way we were able to obtain an index of greater complexity. We are not aware this approach was used before. We examined developments in specifically selected EU countries which count for the largest share of energy consumption in the EU and Slovakia. The group of selected countries, employs various approaches towards their energy mix and security, therefore, we attempted to find if there is any clear optimum strategy.

3. DATA AND METHODOLOGY

Our examination of energy security is extending the methodology developed by Brown et al. (2014). We collected the data on 10 indicators (Eurostat, 2018) of energy security of the country and divided them into three groups in respect to the current theoretical understanding of the multidimensional approach towards energy security discussed in the previous section. Dimensions taken into account in this article are SoS (with variables HHI of natural gas imports which we calculated, share of renewable energy sources [RES] and energy savings), economic availability – EA (electricity price, natural gas prices for end customers and energy productivity), and environmental stewardship - ES (GHG emissions per capita, GHG of energy consumption and GHG emissions in sectors of transportation). The main source of our data was Eurostat. Our calculation covers 6 countries of the EU which are namely Netherlands, France, Germany, United Kingdom, Poland and Slovakia. We compared the development during the last 10 years which we have available data for 2007-2016.

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 (SD) Z-scores are "dimensionless" quantities that indicate how many SD a country is above or below the mean of our group of EU countries. We calculated Z-scores for each of the 10 indicators in between 2007 and 2016 by subtracting the mean value for each data point and dividing it by the indicator's SD.

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

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 individual years, giving equal weight to each indicator and providing a total energy security score for each country in each year. We arrange all the variables in such a way that higher values indicate higher energy security. Analysis of variations detected the changes in the relative development of energy security while analysis of changes in individual dimensions can reveal the main area of variation of the country's energy security position.

4. RESULTS

This article investigates the energy security of countries with diametrically differing energy sectors and approaches towards providing energy security to its citizens. In this part of our article, we investigated countries' energy mixes and analyze several indicators describing their standings in the energy area.

4.1. Energy Security Development Over 2006-2017

In this part we analyse energy profiles of examined countries. The discussed data are sourced from Eurostat and can be found in Table 1.

Germany is the largest energy consumer in the European Union using 314 Mtoe of energy annually. After the Fukushima disaster, Germany decided to stop the use of nuclear energy in 2022. This decision is crucial for understanding the current state of affairs in the energy realm. Germany aims to replace nuclear with RES, however, the remaining capacity of 10 GW nuclear power plants still provided 8% of energy in 2015 compared to 12% of energy produced from RES.

The RES is subject to heavy subsidies which led to a rapid rise in German power prices. These politics received a lot of criticism, as the main goal to replace nuclear with carbon free energy has failed so far. The main beneficiary of the German nuclear phase-out is coal, which covers 25% of the country's energy needs. And the intermittency of RES inevitably favours the usage of natural gas, which now covers 21% of energy needs. Oil is the main source of energy with 34%. The rise in natural gas usage and plans for further import projects means greater dependence on foreign energy resources, mainly Russia, which even violates the EU energy security rules (Bros, 2018). The expected phase-out of nuclear energy combined with cutting back on electricity produced from coal power plants is the reason the commercial aspect of new natural gas pipeline Nord Stream II that will eventually double the Russian export capacity to Germany. However, the political aspect of this project is irrefutable as 99% of natural gas consumption in Germany comes from third countries. As a typical energy import-dependent economy, Germany is quite efficient with energy usage. It has an energy intensity of 112 toe/million Euro of output. However, the energy mix is heavily dependent on coal being not environmentally friendly as each consumed ton of energy releases 2579 kg of CO_2.

The second largest energy consuming country in the EU is France with 256.8 Mtoe. Unlike Germany, France embraces nuclear energy, having the largest share of this energy source in power energy mix worldwide. France is however not immune to current anti-nuclear sentiment caused by skyrocketing construction costs of new power plants and rising outages in the aging fleet of existing power plants. France has decided to cut the share of nuclear power in electricity generation from the current 75% to 50% in 2030 to 2035, but as at now, nuclear power generation is responsible for 44% of energy consumption in France. It is followed by oil and gas which both covers 14% of energy needs and coal covers just 3%. This stark difference in usage of fossil fuels is due to a combination of milder climate in the main energy consuming areas of France compared to Germany and usage of electricity (not natural gas) as a major source in space heating which together maximize the positive impact of nuclear energy. The RES keep increasing covering 8% of the energy mix in 2015. As carbon free energy sources represent 52% of the energy mix in France, half carbon intensity (1392 kg CO_2/toe) compared to Germany is not surprising. France is also heavily dependent on gas imports (90%). Countries import routes are more diversified. France has developed several

Table 1: Energy profiles of selected countries

Indicator/Country	France	Germany	Netherlands	United Kingdom	Poland	Italy	Slovakia
Energy consumption (Mtoe)							
Total	256.8	314.1	76.0	187.9	94.9	151.0	16.0
Energy mix (%)							
Coal	3	25	14	13	51	8	20
Oil	30	34	41	37	25	38	21
Gas	14	21	38	33	15	37	24
Nuclear	44	8	1	10	0	0	25
RES	8	12	5	8	9	17	10
Gas import dependency (%)	90.1	98.7	−32.1	41.8	72.2	90.4	95.1
Energy intensity - toe/M€	120.5	112.6	118.3	94.3	227.3	100.4	215.2
Renewables in gross final energy (%)	15.2	14.6	5.8	8.2	11.8	17.5	12.9
Carbon intensity - kg CO_2/toe	1 392.0	2 578.6	1 966.3	2 309.9	3 268.2	2 321.0	2 067.5

Source: Authors, based on Eurostat data. RES: Renewable energy sources

liquefied natural gas (LNG) import terminals and has pipeline connections to surrounding countries and Norway, which supports the resiliency of natural gas supplies. The country however, lacks better internal infrastructure which effectively limits the positive impact of extensive import options. The energy intensity of France reaches 120.5 toe/Moe, which is the EU average level.

UK is the third largest energy consuming country in the EU with 2015's consumption of almost 188 Mtoe. The largest energy source with 37% share in the energy mix is oil, followed closely by natural gas with 33%. Natural gas in the UK has a natural advantage in energy mix thanks to the policy setting a minimum price for emission allowances of 18 GBP/ton. This led to coal being pushed totally out of the power generation mix several times during 2017. The UK is the second largest natural gas producer in the EU following the Netherlands, but its endogenous production is rapidly declining. Yet in 2003, the UK was producing 92.6 Mtoe of natural gas being a net exporter. By 2015, the UK production shrunk by 62% to 35.7 Mtoe and the UK now imports 39% of its natural gas consumption. The UK's gas security was not severely threatened by this development as it has several import options. Namely three LNG import terminals that benefit from the UK having one of the most liquid natural gas exchange. This makes it attractive for imports worldwide while the UK is also connected to Norway export infrastructure and is also connected to the continental natural gas system via pipelines to Belgium (Interconnector) and Netherlands (Balgzand Bacton Line). The third largest energy source in the UK is coal with 13 % in the energy mix. Its importance started to dwindle especially after the introduction of carbon tax, while in 2013, 130 TWh of electricity was produced using coal, in 2015 this number fell to 75 TWh. Coal was mainly replaced by renewables, especially wind and biomass as their production increased by 53% in just 3 years. The overall share of renewable energy in the UK energy mix reached 8% just below 10% supplied by nuclear energy. The UK is the most energy efficient country in our sample with just 94.3 toe/mil.€. The high share of carbon-based fuels makes it more carbon intensive - 2309 kg CO_2/toe compared to France where nuclear energy plays a more significant role.

The other large energy consumer is Italy with 151 Mtoe. Its energy mix is also dominated by oil followed by gas with 38% resp. 37%. Italian gas import dependency reached above 90% as domestic production provides only some 5.5 Mtoe of natural gas. Similar to the UK, Italy has relatively diversified importing routes. It can import natural gas from Germany and France via Switzerland which enables it to benefit from most liquid natural gas markets in North-western Europe. At the same time, it has long term contracts with Gazprom which uses its Brotherhood pipeline primarily for serving this market. Italy is at the same time connected to the African market importing large quantities from Libya and Algeria. Apart from pipeline options Italy also benefits from its LNG importing infrastructure and favourable position closer to large exporting LNG countries located in the Middle East. Moreover, construction of Trans Adriatic pipeline which would connect Italy to Caucasian natural gas should be completed in the near future. Unlike in the previously mentioned countries, Italy does not rely on nuclear power. Although it has a larger share with a RES contribution to energy mix reaching 17%. This is the plain truth, especially due to strong hydropower, however, the contribution of wind and recently solar and biomass has risen significantly. Coal covers the remaining 8% of Italian energy consumption. A similar share of carbon free sources and fossil-based sources put Italian carbon intensity close to UK's at 2321 kg CO_2/toe. Energy use in Italy is also relatively efficient with 100 toe/M€ of output, which is well below the European average of 120 toe/M€.

Energy-wise Poland is the other largest energy consumer in Europe. As much as 91% of Poland's 95 Mtoe of energy consumption is carbon-based. Coal is with 51% is the largest contributor. The primary reason for this is the endogenous coal production in Poland which is largest among EU countries. Its main use is power generation as coal accounts for 80% of the total electricity production. With this in mind carbon intensity of 3268 kg CO_2/toe which is 50% above the EU average comes as no surprise. Oil with 24% is the second largest share in the energy mix distinctly followed by natural gas with 13.8%. Poland's reliance on coal limits the natural gas, which was until the end of 2015 almost exclusively supplied by Russia since domestic production covers just 25%. As international relations between these two countries have been historically tense, Poland launched its LNG import terminal in Swinoujscie in order to be able to better diversify its import needs. Poland has since closed several long term deals which suppliers from Qatar and USA, even under less financially beneficial terms, which makes Poland just one of the few countries (along with Baltic states) which are ready to pay a premium for energy security. This development is not yet visible in our data as LNG imports have risen only in the last 2 years. The rest of the energy needs of Poland are covered by RES, mainly quickly growing wind production (2800% growth in installed capacity in 10 years running to 2015) and biomass. Poland has currently no operational nuclear power plant but the government has for many years nurtured the idea of developing nuclear energy. Current plans expect the first power plant to come into operation in 2033, the expectation is nuclear power capacity will reach 6-9 GW by 2043, which will account for around 10% of power generation (Reuters, 2018).

The Netherlands is the only country in EU with the status of a net natural gas exporter. This guarantees a special position in respect to energy security. However, the Netherlands has a special place in European gas having the most liquid trading hub in Europe in virtual trading hub title transfer facility, which guarantees fair market pricing. It is also being connected to Norwegian's export pipeline system, to the UK via Interconnector pipeline and at the same time connected to Germany, which ensures the access to Russian gas, not to forget operational 12 bcm/p.a. LNG import terminal which ensures truly diverse importing options for this country. The energy mix of this country is in major part (96%) covered by fossil fuels, oil 41%, natural gas 38% and 14% by coal. The remaining share is almost entirely covered by RES as nuclear energy covers just 1%.

Slovakia is the next country examined with consumption of 16 Mtoe, it belongs to the smaller energy consumers within the EU. Unlike other previously mentioned countries, Slovakia has a well diversified and balanced energy mix. The primary suppliers are two nuclear power plants with a capacity of 2 GW, responsible for 25% of energy consumption. There are two more reactors currently under construction which should increase the capacity for another 1 GW in the future. The second most important energy source in Slovakia is natural gas with approximately 24%. Slovakia after the Netherlands has the second most extensive natural gas network within the EU. 94% of Slovakian residents have access to the distribution network, which makes natural gas to be the primary source of space heating in Slovakia. Until the recent gas crises, Slovakia has been 100% dependant on Russian imports. After the incident which led to rationing of natural gas supplies to selected industrial customers in Slovakia for 10 days as Russia stopped supplies via Ukraine, Slovakia invested into reverse flows, which enables supplies to Slovakia from Austria and the Czech Republic. A Pipeline connecting Slovakia to Polish natural gas network, which will further enhance energy security is currently being constructed. Another pipeline called Eastring which would guarantee Slovakia access to natural gas from the Black sea area is under feasibility study right now. The main concern for Slovakia energy security with respect to natural gas remains the natural gas transit contract between Ukraine and Russia which is expiring in 2020. Slovakia currently financially benefits from transporting Russian gas further to Western Europe and possibly significant downsizing of transported natural gas would greatly hit the position of natural gas within Slovak energy mix. Both coal and oil cover some 20% of energy consumption. Some 82% of coal used in Slovakia is being produced domestically. The coal mining in Slovakia is heavily subsidised by the government as it is concentrated in regions with lesser economic opportunities. However, recently announced strategy aims at closing coal mines until 2027. This will most likely lead to the diminishing importance of coal in the Slovak energy mix. As is the case for all countries examined, the usage of oil is concentrated in the transport sector. The remaining share of the energy needs in Slovakia is covered by RES. According to IEA report (2018), the Slovakian has close to the median share of renewables in TPES among the IEA member countires. The potential of renewable energy still exists, however there are several obstacles as the main principle that guides the use of renewable energy in the Slovak Republic is cost-effectiveness. Potential of biomass is limited by perceived overlogging, solar by absence of financial support, wind energy is lacking suitable sites. The additional potential is in are area of hydro and geothermal power. Therefore more significant contributions in this area can be expected to be more of a gradual character.

4.2. Natural Gas Import Index

We will start discussing the results of our analysis with presenting the development of HHI. The average across the countries observed in the concentration of natural gas imports have risen by 10% comparing 2016-2007 as can be seen on Graph 1. Development across individual countries, however varies significantly. Natural gas import concentration as measured by the HHI of Germany increased by 33% (we cannot, however, exclude the possibility of inaccurate data since the year before the increase was just 2%). The trajectory of development, however, is plausible as Germany become more dependent on Russian Gas transported via the Nord Stream at the expense of Dutch gas. As natural gas in the Netherlands is rapidly declining and other import options are constrained by physical or commercial factors, the trajectory of rising import dependency on Russian gas is the most likely. HHI of France increased by 27% to 2508, and is significantly below the German level. The majority of French imports come from three countries which are namely Norway, Netherlands and Russia. During the recent 5 years, 93-95% of gas was supplied by those countries. Their share increased as more flexible LNG imports coming from Algeria which is the fourth largest exporter got redirected to more profitable markets in Asia. This clearly depicts possible setbacks of the growing globalization of the natural gas market. In respect to more recent developments which are not visible in our data, during the next 2 years, price signals attracted considerably more flexible LNG to the French market. The other two countries where market concentration on the natural gas market increased are Poland and Italy. In the case of Poland, natural gas imports increased by 44% which was accompanied by 13% growth in HHI. The index reached its maximum in 2009, afterwards it started to recede as Poland started progressively pursuing alternative import options - backhaul of Russian Gas from Germany and launch of LNG import terminal. Qatar became the first large scale LNG supplier to Poland, but long term deals were already signed with US LNG exporters. Unlike in Poland, imports of natural gas to Italy decreased during observed decade by 12%. HHI on the other hand increased by 14% as Russia's share on imports increased from 30% to 41%. This happens on account of Norway, Netherland and North African exporters. Imports via LNG on other hand were on upward trajectory.

Imports of natural gas to Netherland rose by 75%. Despite this fact HHI went down by 16% to 3036. This happened as Norway imports declined and Netherlands increased imports from Russia, UK and in 2018 after more limits being imposed on endogenous production even LNG started to play more important role in natural gas import mix.

HHI values in case of Slovakia and UK remained basically unchanged. UK imports increased by 56% but UK was able to diversify its importers base as can be seen on graph below, as it was primary target for Qatar exports of LNG to Europe. Since Qatar was able to find more attractive outlets for its LNG lately, HHI started increasing as Norway became the main source of incremental imports. Similarly as was said above, competitive nature and global nature of LNG market led to increased supplies from various sources after price of natural gas on European hubs increased during last 2 years (2017-2018). Its impact on HHI is yet no visible in our data.

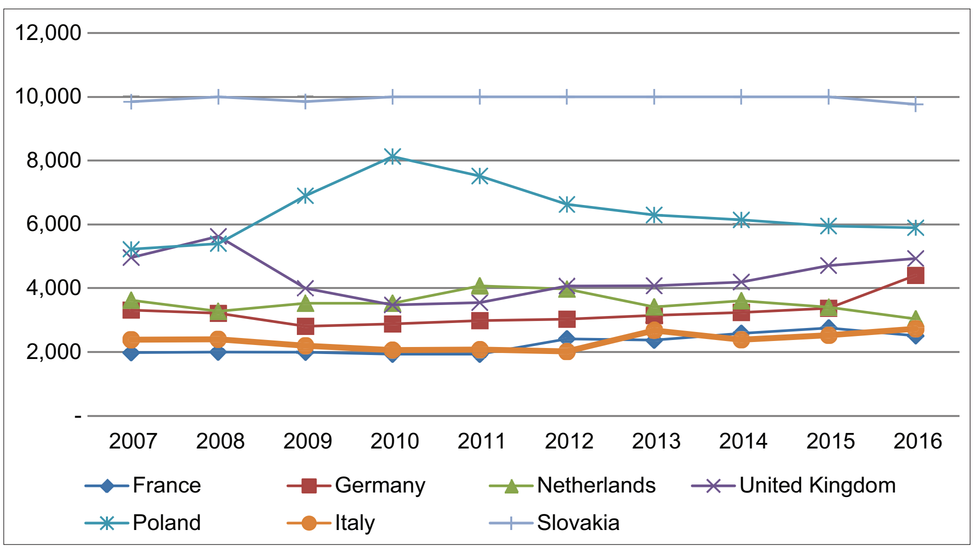
HHI of Slovak natural gas imports is still around 10,000 meaning we are talking about absolute monopoly. This remained the case, despite a 30% fall of natural gas imports. Russia is the single supplier of natural gas to Slovakia even if reverse flow options from the Czech Republic and Austria exist. The fact is these other import options are still dependant on Russian gas as both markets are primarily supplied by Russia. Increased security is coming from transport routes diversifications primarily. But commercial incentives for using described options are lacking since Russia keeps its supplies to Slovakia competitive compared to European wholesale gas prices.

The above analysis of HHI development revealed that increasing import dependency does not have to come at the expense of lower energy security. On the other hand, lowering consumption of natural gas does not automatically imply lower HHI as major suppliers try to keep export volumes and lower offtake can very easily lead to growing concentration on the supply side.

4.3. ESI and its Components

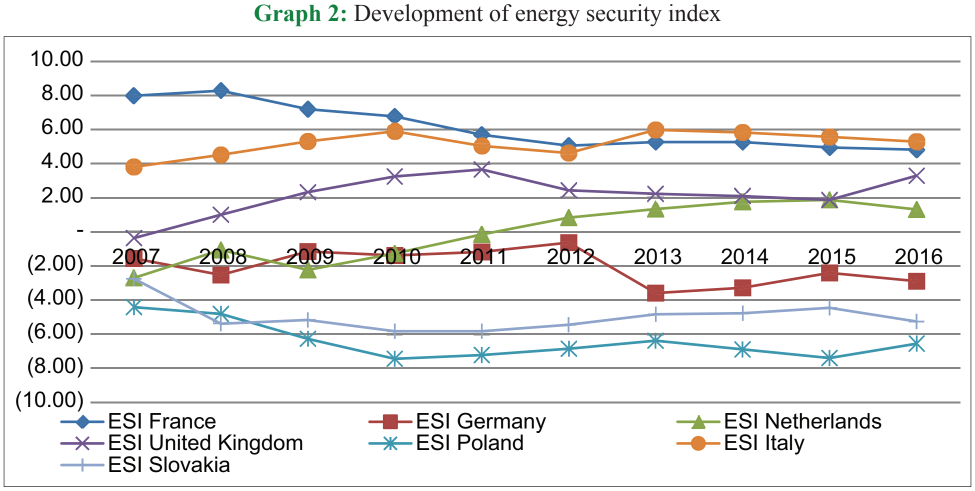
We will now proceed with the evaluation of our ESI depicted on Graphs 2 and 3. At the beginning of our observed period, the country with the best relative energy security as measured by

Graph 1: Herfindahl-Hirshman index



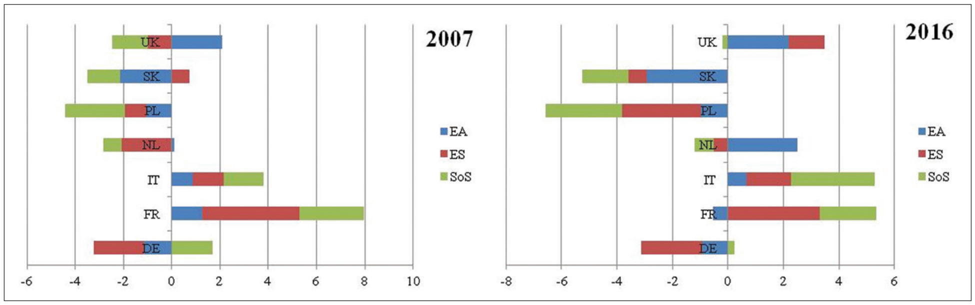
Source: Authors' calculation based on Eurostat data

Graph 2: Development of energy security index



Source: Authors' calculation based on Eurostat data

Graph 3: Development of individual dimensions of ESI



Source: Authors calculation based on Eurostat data

our index is France. Its position results, especially from a strong position in the realm of ES, which is primarily being caused by the share of nuclear power generation in energy mix and electrification of transportation. The second area where France shows significantly above average results is the SoS, not only due to diversified portfolio of import options but also due to the share of RES in the energy mix. As of economic availability, France showed slightly above average mainly due to competitive electricity prices. We attribute it to the fact that a large part of the French nuclear fleet of power plants was built in 1970s and 1980s of the twentieth century and is now to a large extent depreciated. The ESI for France was on downward trajectory during the observed period, declining from being eight SD above the group results in 2007 to 4.82 SD in 2016. The main source of decline is worsening indicator of economic availability. It was driven especially by a minor increase in natural gas prices (natural gas prices in other countries declined), growth of electricity prices that grew by 63% compared to an average of 13% in the remaining countries and lagging improvement in energy productivity which increased by 22% compared to an average of 31%. Developments of these variables explained 57% of index deterioration. Both SoS and ES did not manage to improve as much as in other countries, which lead to fall in our rankings. The main contributor was a worse indicator of carbon productivity, which improved by 35% compared to an average of 48% for other countries. Despite France being the most carbon efficient country in our list. However, this cannot be said about energy productivity, where France lags behind. As we already mentioned, France imports of natural gas became more concentrated between 2007 and 2016 which further deteriorated its energy security.

Italy moved in our rankings to become the most energy secure country. The fact that just in 2017 after an explosion in Baumgarten, which cut Russian exports via Austria to Italy and led to the declaration of a state of emergency shows the difficulty and vagueness of any attempt to strictly define energy security. However, we believe, based on our calculations that apart from unforeseeable circumstances, Italian energy mix to ensures the country's significant level of energy security. Italy moved from being 3.8 SD above average to 5.3 SD above average in terms of our index. In 2007, Italy benefited from a strong position in SoS dimension, driven primarily by the strong place of RES in the energy mix and relatively diversified energy imports. The effect of strong RES spilled over in ES dimension with lower levels of carbon emissions. As in the EA area, relatively high electricity prices were more than compensated by the above average level of energy productivity. The trajectory of ESI development suggests continuous improvements that were mostly due to improvements in SoS dimension, especially energy savings. Improvements in relative position in ES dimension were mostly cancelled out by worsening indicator of EA. Diversified and robust supply options, therefore, became Italy's main strength in the realm of energy security.

United Kingdom remained third in our ranking while it improved its score by 3.7 SD. This improvement came as a result of stronger performance in the area of SoS, mainly due to deeper penetration of RES and growth in energy savings, and ES as a result of improved carbon intensity (73% compared to 42% average for the rest of the group), while emissions per capita decreased by 32% compared to the 13% average for the remaining countries. The area of EA saw little changes and basically followed the general trends we were able to observe in other countries. Therefore, in the case of UK, we can conclude that developments in the area of developing green endogenous resources and increased efficiency of energy usage became the main sources of comparative improvements in the realm of energy security.

The only other country that significantly enhanced its ESI is the Netherlands. Its ESI values went up by 4 SD. Furthermore, it is interesting the way the Netherlands was able to achieve this. Improvements came especially in the area of EA namely price of electricity that decreased by 21% compared to a 27% increase in the rest of the countries. Similarly, the price of natural gas declined by 27% in the Netherlands, while the remaining countries experienced a more modest decline of 4%. The other significant improvement for the Netherlands was lowering of carbon intensity in transportation. Changes within areas belonging under the framework of SoS was cancelled out without any significant impact on the overall score.

The energy security of Germany slightly deteriorated as its ESI went down by 1.3 SD during the observed period. The primary reason was the development in the field of SoS, especially energy consumption that grew compared to the remaining countries. EA values reflecting relatively higher energy prices and ES impacted by the importance of coal and lignite in the German energy mix both negatively affected the overall result. Despite Germany is at the forefront of multiple green energy-related policy initiatives, hard data showed that positive developments in Germany's energy realm are not able to offset its increasing energy consumption of carbon intense fuel as new RES increase costs for consumers.

Slovakia recorded the second largest drop in ESI, falling by 2.51 SD. The worsening happened in all three observed areas. SoS was affected by the inability to develop indigenous RES fast enough, while import diversification and energy savings developed alongside the other examined countries. EA score declined by 0.8 SD mainly due to the relative increase of natural gas prices in Slovakia, with electricity prices and energy productivity being able only to partially offset that. Similarly, single source negatively impacting the overall score could be identified in the ES dimension which went down by 1.39 SD, as emissions in transportation worsened by 1.44 SD. Slovakia's energy policies were not able to improve the country's energy security despite diversified energy mix and relatively good opportunity in the availability of finances for energy import diversification activities (to be fair, activities in this field are still in progress and can materialize in the future).

Poland situation compared to our selected group of countries worsened by 2.14 SD which put Poland 6.5 SD below the mean range. We realize Poland's approach towards securing energy availability for her citizens lies in using domestic coal resources, and this effect is not reflected in our analysis, however, we made this decision deliberately as EU climate goal implies the need to abandon unabated coal as an energy source (Climate Analytics, 2017). Poland's performance is below the mean range in every single category. The developments in individual areas, however, show that situation in SOS and EA dimension developed in a similar way as in other countries and the worse score is due to performance in ES dimension since CO_2 emissions per capita and those in transportation declined more slowly compared to the other countries.

5. CONCLUSION

In our paper, we aimed to examine factors determining energy security in a selected group of countries. Relative performance that is measured by this type of index showed great dynamic determining development in this area. There is no single way to enhance energy security and various countries employ differing strategies based on their legacy in the energy realm. France lost its position of most "energy secure" country. Its superiority declined due to convergence in areas of natural gas price, electricity price, carbon intensity and rising concentration of natural gas imports.

Italy, on the other hand, recorded significant improvements in energy supplies, one of the less developed areas at the beginning of the observed period. Its focus on a relatively weaker area makes perfect economic sense as Italy was able to capture benefits of low hanging fruit. A similar trajectory can be observed in the case of the UK, where greater penetration of RES helped address issues related to energy availability and lower carbon intensity, while Netherland's energy security benefited from improvements in relative prices of both natural gas and electricity. On the other hand, our index shows that German push to nuclear phase-out did not enhance its energy security relative to other countries, quite contrary its position deteriorated. The largest drop in the ESI was recorded in Slovakia and Poland. The main reason for that was not an outright worsening of observed indicators but the inability to keep up with the pace of developments in other countries.

The above overview shows there is not a single way on how to approach the enhancement of energy security. Option to focus on countries strengths can be an equally good solution to address the biggest weakness in the countries energy realm. The complexity of the problem needs to be kept in mind as a sudden decision can have undesired consequences as is currently the case of Germany.

Our paper outlined preliminary results of the more approachable way into examining energy security as even the complexity of diversification of import routes are included in a single variable describing also the environmental and economic aspects of energy security. This area demands further research, the inclusion of more energy variables and deeper analysis of national energy policies can add further insights on this topic.

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