Some aspects of energy security in the EU member countries in the period 2000-2010

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Abstract

The aim of the paper is to analyse selected aspects of energy security in the EU member countries. During the first stage of the analysis the countries were divided into clusters according to certain variables describing energy security and then the quality of clustering was evaluated. During the second stage energy security level in the EU member countries in the years 2000 and 2010 was assessed. Taking into consideration a multidimensional aspect of energy security, its level was assessed with a reduced number of variables by using the sPCA method and identifying 4 variables of energy security. The comparison of energy security levels in the EU member countries in the years 2000 and 2010 within new coordinates indicates the lack of explicit progress.

Keywords: *energy security indicator, PAM, sPCA, energy policy in the EU*

***JEL Classification*:** O43, Q50

***AMS Classification*:** 62M99

1. Introduction

Energy production in the EU is still based on such fossil fuels as coal, oil and gas. While the world coal market is highly diversified, as coal is easy to handle and store, the main oil and gas deposits can be found in several regions only, most of which are politically unstable. The major gas providers for the EU are Russia and Norway, and the major oil providers are the Near East and Russia. Taking into consideration supply stability, it is important to take into consideration the fact that gas is imported by pipelines, thus potential problems occurring in transit countries may cause supply disturbances. Such a situation took place in 2007 and 2009 when Russia stopped sending the supplies to Ukraine, which blocked the supplies the Western European countries.

The continuity of energy supply is the priority of the EU policy. The construction of a single energy market, declared in the *Treaty on European Union*, has become the most important step in assuring energy security. However, energy security does not denote only the continuity of energy supply. A lot of countries and international organizations such as EU, WEF, OECD, NATO or G8 have incorporated energy security policies into their developmental strategies. The concept of energy security, however, is not clear-cut. According

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to the International Energy Agency, energy security refers to the uninterrupted availability of energy sources at an affordable price[2]. Kruyt et al. [2] analysed the four dimensions of energy security. The most obvious dimension (in accordance with its traditional meaning) was the availability of energy to the economy, and the other ones were the accessibility (due to the large spatial discrepancy between the consumption and the production of resources), the costs of acquiring energy sources and the environmental aspects. Sovacool and Mukherjee [6] suggested that energy security ought to encompass five dimensions related to availability, affordability, technology development, sustainability, and regulation. Various energy security dimensions can be described by different variables and indicators. The Delphi method offers more than 150 indicators which thoroughly describe energy security. However, such a broad approach poses certain problems and challenges. First of all, particular dimensions of energy security are not independent. Some measures describe more then one energy security dimensions at the same time. Presenting the situation of particular countries with regard to given dimensions of energy security requires appropriate tools of multidimensional analysis. The problem with data supply should also be mentioned. Some measures suggested by Sovacool and Mukherjee [6] have not been applied to all the countries, so it is not possible to conduct a full analysis of energy security.

The aim of the paper is to analyse energy security in the EU member countries in the period 2000 - 2010. The aim will be achieved by applying the procedure of clustering objects in order to obtain homogeneous clusters of countries with similar values of variables referring to energy security. The quality of clustering will also be evaluated. Another aim is to reduce the number of variables in order to describe energy security with new aggregated variables, smaller in number than initially. Interpreting the coordinates will allow the author to put the countries in order according to new categories. Both parts of the analysis will be based on the data from 2000, while the data from 2010 will be used to investigate the changes in the EU member countries according to previously identified new categories of energy security. Clustering will be conducted using the partitioning among medoids (PAM) procedure proposed by Kaufman and Rousseeuw [1]. The average silhouette width will be used to evaluate the quality of clustering. The reduction will be conducted with the use of sPCA method, which is a modification of a classical Principal Component Analysis procedure and facilitates the interpretation of the results.

[2] Problem of relations between fossil fuel prices was considered in Papież and Śmiech [5], Śmiech and Papież [7].

2. Methodology

Taking into account a great variety of objects analysed with regard to the indicators describing energy security, which results in high volatility and the occurrence of outliers, partitioning among medoids (PAM) procedure developed by Kaufman and Rousseeuw [1] was used. Similarly to a traditional k-means method, it assumes partitioning *n* observations into *k* clusters. PAM operates on the dissimilarity matrix, is less sensitive to outliers because it is based on the most centrally located object in a cluster (i.e. medoids), provides the silhouette which allows to determine which objects lie well within their clusters and which do not, and also shows how good the quality of the clustering obtained is. Kaufman and Roussew [1] suggested that silhouettes, i.e. the average silhouette width, can be used for the selection of the best number of clusters in PAM (or in k-means methods). However, the PAM algorithm is time consuming and works well only for small data sets.

In the second part of the analysis the Author focused on the interpretations of the differences between the countries and clusters of countries. The classical principal components (PC) analysis is the most popular extraction and dimension reduction tool. It seeks the linear combinations of the original variables which capture maximal variance. Each PC is a linear combination of all variables and the loadings are usually non zero, which makes the interpretation difficult. Rotation techniques are commonly used in interpreting principal components. Then it is assumed ad hoc that the loadings with absolute values smaller than a threshold set to zero. Zou et al. [8] proposed a new method called a sparse principal component analysis (sPCA). They used the lasso (elastic net) to generate a modified principal component with sparse loadings. The idea is to formulate PCA as a regression-type optimization problem and obtain sparse loadings by imposing the lasso constraint on the regression coefficients.

3. Data

The objects analysed comprise the EU member countries with the same regulations and aims regarding energy security. The comparison of their situation in 2000 and 2010 will allow to assess the progress of particular countries with regard to various aspects of energy security.

The data taken from Eurostat and IAE bases were used in the analysis. The variables constituted a subset of indicators suggested by Martchamadol and Kumar [3] forming an index. The list of variables included: X1 Net Energy Import Dependency, X2 Net import per TPES, X3 Net import per GDP, X4 Net import per capita, X5 Shannon–Weiner index (SW) - Concentration of energy supply, X6 Total primary energy intensity, X7 Loss in

Transformation, X8 Total primary energy per capita, X9 Thermal efficiency of power stations (%), X10 Value of energy imports per GDP, X11 Value of energy imports per capita, X12 CO 2 emission per capita, X13 CO 2 emission per GDP, X14 CO 2 emission per TPES, X15 Share of Renewable energy per TPES.

It should be emphasised that an effective procedure of reducing the number of variables requires a good approximation of covariance matrix. In this paper the evaluation of the coefficients of covariance matrix was obtained on the basis of information regarding 25 countries. Such a low sample size limits the number of variables. The number of variables analysed was a result of a compromise between obtaining a broad picture of energy security and limiting the number of variables necessary to assess the elements of covariance matrix correctly.

4. Empirical results

The division methods require stating the number of target groups at the beginning. If a target number of groups is not set a priori, Kaufman and Roussew [1] suggest using average silhouette width. In such a case, several groupings should be carried out and the one with the greatest average silhouette width should be selected.

In this study grouping was carried out with the assumption that the number of groups is between 2 and 18. The procedure of clustering was conducted for {2,3, …, 18} number of groups. The maximum value of average silhouette width 0.27 was obtained for 8 clusters (Fig. 1), and further analyses were conducted for this number of groups.

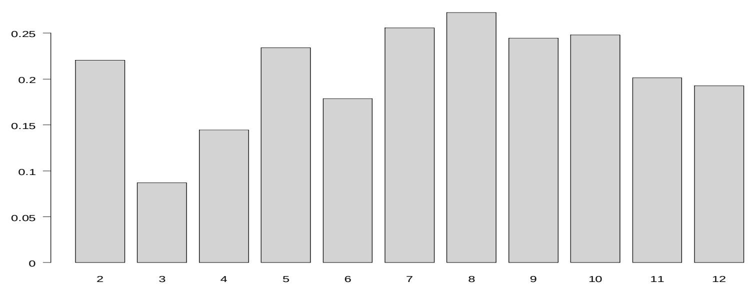

Fig. 1. Average silhouette width for different cluster.

Average silhouette width equalling 0.27 achieved for 8 clusters prove that the structure is weak and could be artificial. Kaufman and Roussew [1] argue that a reasonable structure has been found if average silhouette width exceeds 0.50. The following results were obtained: two groups consisting of one component (Cyprus, Latvia), three groups consisting of two components, and one group consisting of three, five and ten elements (Fig. 2a).

The countries with the greatest similarities with regard to energy security were found in group 6 (namely Denmark and the United Kingdom) and 7 (Finland and Sweden). The least homogeneous group was a group comprising Bulgaria, Lithuania and Slovakia.

The clustering plot confirms the lack of a clear structure; it shows that two best components explain 53.7% of the total point variability (Fig. 2b). Despite the lack of an explicit structure, the groups of countries obtained were used in further analysis.

The reduction of dimensions was carried out using the sPCA method. The factor loadings have been shown in table 1.

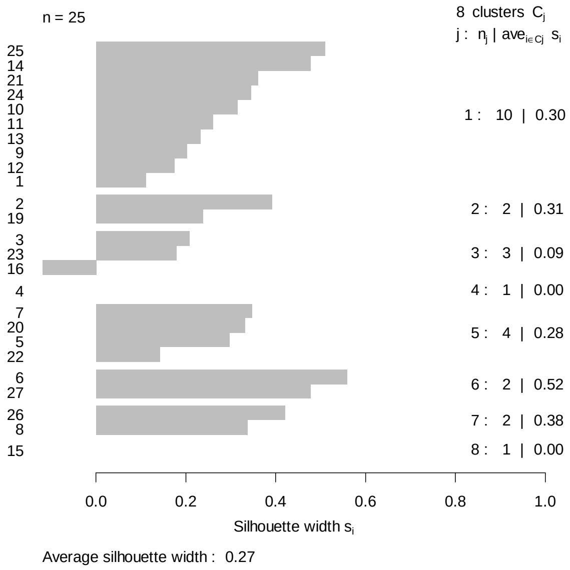

Fig. 2a. The silhouette plot for 8 clusters.

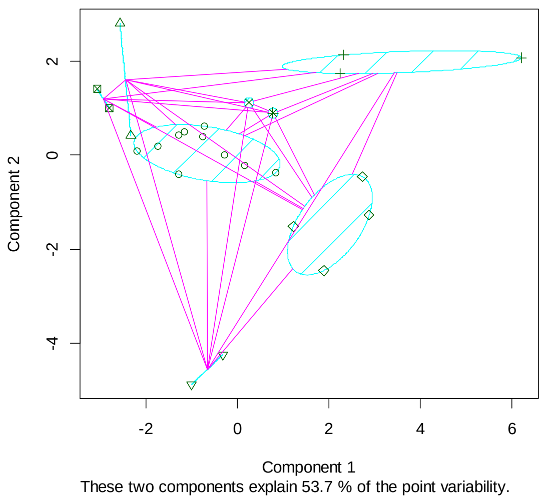

Fig. 2b. The results of clustering in 2 dimensions.

The application of sPCA indicated four main components of energy security, which explained 78% of total variance. The components were named according to their economic interpretation. Colors of countries names correspond to the groups received from clustering process. The first sPCA component represents **energy efficiency of the economy**. The higher its value, the worse the economic situation of a given country with regard to energy efficiency. The highest energy efficiency in 2000 was found in Denmark and the United Kingdom, and the lowest in Bulgaria. It can be noticed that 'old' EU countries are characterised by higher energy efficiency and 'new' ones - by lower energy efficiency.

	1 sPCA	2 sPCA	3 sPCA	4 sPCA
X1	0.00	0.51	0.00	0.06
X2	0.00	0.52	0.00	0.21
X3	0.39	0.05	0.00	0.02
X4	0.00	0.60	0.00	0.00
X5	0.00	0.00	-0.26	-0.18
X6	0.60	0.00	0.00	0.00
X7	0.14	0.00	0.03	0.00
X8	0.00	0.11	0.00	-0.65
X9	0.00	0.00	-0.59	0.00
X10	0.49	0.00	0.00	0.00
X11	0.00	0.31	0.00	-0.39
X12	0.00	0.00	0.17	-0.59
X13	0.47	0.00	0.00	0.00
X14	0.00	0.00	0.55	0.00
X15	0.00	0.00	-0.50	0.00

Table 1 The loadings of the first 4 sPCA components.

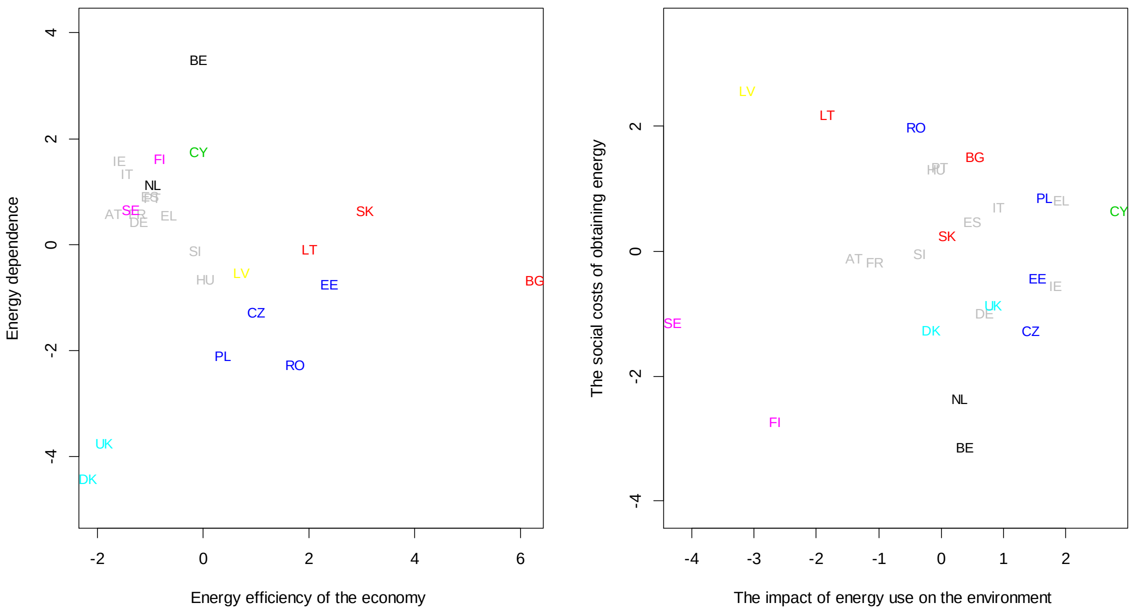

Fig. 3. The situation in EU countries with respect to the new dimensions of energy security.

The second sPCA component represents **energy dependence**, i.e. dependence on energy source and type. The higher the component is, the more energy dependent a country is. In 2000 Belgium was the country with the highest dependence, and Denmark and the United Kingdom were the countries with the lowest energy dependence.

The third sPCA component represents **the impact of energy use on the environment.** The higher the component is, the more negative impact of energy use on the environment in a given country can be noticed. The lowest negative impact was observed in 2000 in Sweden, Finland, Lithuania and Latvia, and the highest in Cyprus.

The fourth sPCA component represents **the social costs of obtaining energy**. The higher the component is, the less it costs a society of a given country to obtain energy. The lowest value of this component in 2000 was noticed in Belgium, Finland and the Netherlands and the highest in Lithuania, Latvia and Romania.

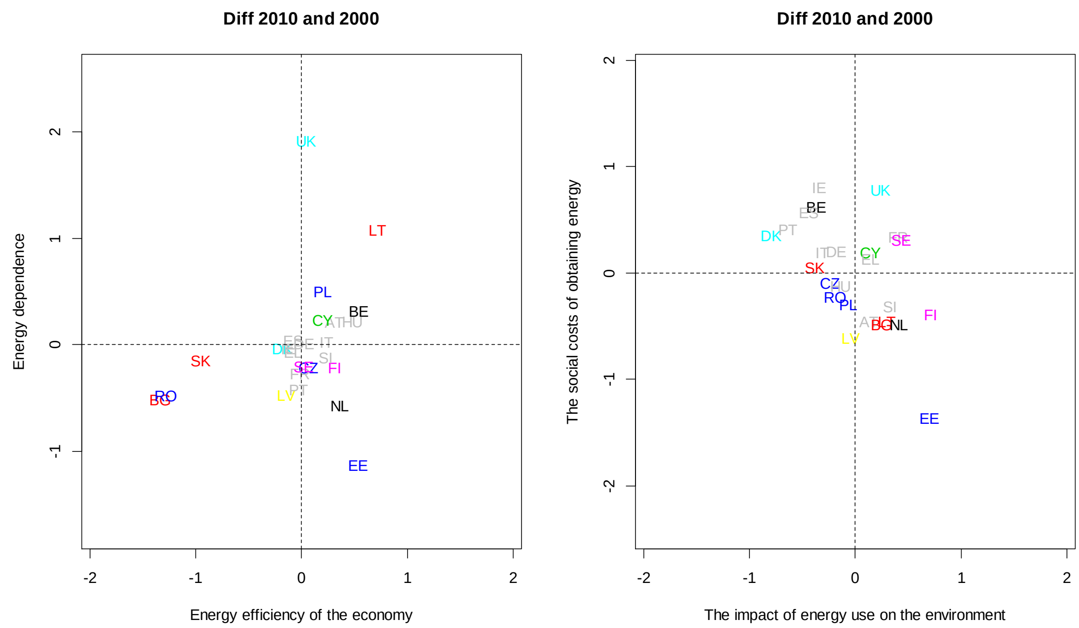

Fig. 4. Changing the position of the EU energy security.

The second stage of the analysis focused on assessing the changes in the levels of energy security in 2010 in comparison to 2000 (fig. 2). The results obtained indicate that the greatest improvement of energy efficiency took place in Romania, Bulgaria and Slovakia, and deterioration was observed in Lithuania, Belgium and Estonia. The highest increase of energy dependency was noted in the United Kingdom and Lithuania, and the greatest decrease of energy dependency in Estonia. The negative impact of energy use on the environment decreased in Denmark and Portugal, and increased in Finland and Estonia. The social costs of obtaining energy decreased most in the United Kingdom and Ireland, and increased in Estonia.

5. Conclusions

The results of clustering of the EU member countries indicate that their structure is weak. The poor quality of clustering may result from geographic, political and economic factors significantly differentiating those countries. The lack of similarities between them makes it more difficult to adopt a common energy security policy, as it is hard to find common needs, problems and interests. The comparison of the situation in the countries divided into 4 dimensions of national security in the period 2000-2010 does not yield clear-cut results. No matter which area of energy security is taken into consideration, both the countries where the situation improved and deteriorated can be found. Four countries (DK, IE, PT, SK) improved their energy security in all dimensions, while two countries (AT, LT) worsened. Despite the convergence of energy security level described in [4], progress of the EU with regard to energy security within ten years cannot be described as unquestionably positive, partially because of the crisis, which lowered the economy of EU member countries (GDP indicators were less favourable) and weakened the efforts to achieve broadly understood energy security.

Acknowledgement

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