MULTIVARIATE ANALYSIS OF HEALTHCARE SYSTEMS IN SELECTED EUROPEAN UNION COUNTRIES. CLUSTER ANALYSIS

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Abstract: The European Union as a whole tends to be a highly diversified entity. Therefore it should not be surprising that the main goal of EU authorities is the limitation of inequalities among member countries. The aim of this study is to identify some groups of countries from the EU that show similar characteristics concerning the functioning of healthcare sectors. The selected countries will be analysed through the prism of characteristics connected with the financial and organizational issues. The study will be backed up by a chosen multivariate statistical analysis — cluster analysis.

Keywords: multivariate statistical analysis, cluster analysis, EU healthcare systems

INTRODUCTION

The European Union is undoubtedly an extremely diversified entity. Its countries differ in many ways such as language, culture and organization. Each country's economy is organized in a slightly different way. Therefore, it should not be surprising that the main goal of the EU authorities is the reduction of inequalities among member countries. However, identification of possible directions of changes can be done only with a prior recognition of those inequalities. The matter of health care has been a subject of research in many research centres all over Europe [Willan and Kowgier 2008; Journard et al. 2010; Hass-Symotiuk 2011; Nojszewska 2011; Knapp et al. 2012; Vanberkel et al. 2012; Jena and Philipson 2013]. The problem of the organization of healthcare systems in European countries is of crucial importance. Despite the fact that all the healthcare systems derive from four basic models, they slightly differ from country to country. The aim of this study is to identify some groups of the EU countries from the EU

that behave similarly or show similar characteristics concerning the performance of healthcare sectors. Selected countries will be analysed through the prism of characteristics connected with the financial and organizational issues. The study in question will be backed up by a multivariate statistical analysis - cluster analysis, which finds similarities of objects (in this study – countries) described as data and puts them into groups. This method has been widely used in the field of healthcare services in many different research centres in the world [Chan et al. 2006; Roy et al. 2009; Liu and Liu 2011]. This analysis will lead to the possibility of creating a classification of the EU countries based on healthcare issues which may constitute valuable information for all managers of healthcare units, not to mention the countries' authorities.

MULTIVARIATE STATISTICAL INFERENCE METHODS – CLUSTER ANALYSIS

Introduction to the method

Numerical techniques for deriving classifications originated largely in natural sciences such as biology in an effort to rid taxonomy of its traditionally subjective nature. Their aim was to provide stable and objective classifications; *objective* in a sense that the analysis of the same set of organisms by the same sequence of numerical methods produces the same classification, *stable* in a sense that the classification remains the same under a wide variety of additions of organisms or of new characteristics describing them. Those numerical methods have been named in many different names depending on the area of application. In that sense numerical taxonomy is generally used in biology; Q analysis is applied in psychology; unsupervised pattern recognition in the artificial intelligence literature; and segmentation in market research. However, nowadays cluster analysis is the most commonly used term of procedures which seek to uncover groups in data. Cluster analysis tends to be the most familiar of all approaches to exploratory multivariate analysis, although it is not always thought of as a multivariate technique parallel to, for example, a principal components analysis. Cluster analysis mimics one of the human mind's fundamental ways of dealing with complicated variability: categorizing, or putting things into groups [Drennan 2010].

Clustering is a statistical tool for those who need to arrange large quantities of multivariate data into natural groups. Methods for clustering items (either observations or variables) depend upon how similar or dissimilar they are to each other. Similar items are treated as a homogeneous group, whereas dissimilar items form additional groups. The great majority of the output of this analysis is visual. The results are displayed as scatterplots, trees, dendrograms, silhouette plots, and heat maps [Izenman 2008].

Cluster analysis is not a statistical test, but a collection of different algorithms that group the objects in focus. Cluster analysis methods are used when there are not any a priori hypotheses, but the research is in exploratory phase [Stanisz 2007].

What is a cluster? Unfortunately there is no universally accepted definition. A cluster is a group of items in which each item is "close" (in some appropriate sense) to a central item of a cluster and that members of different clusters are "far away" from each other [Izenman 2008].

The clustering methods

The clustering solutions are found by applying an algorithm which determines the rules by which observations are aggregated. Algorithms can be classified into two basic groups: hierarchical methods and nonhierarchical methods.

Hierarchical algorithms are the most common methods of cluster analysis. In such algorithms, observations are added to each other one by one in a treelike fashion. As a result of these methods of aggregation the dendrogram is created. These methods do not require a prior application of the number of clusters. [Gatignon 2010]

Hierarchical clustering techniques may be subdivided into agglomerative methods, which proceed by a series of successive fusions of the "n" individuals into groups, and divisive methods, which separate the "n" individuals successively into finer groupings. [Everitt et al. 2011]

The group of hierarchical methods includes e.g. [Everitt et al. 2011]:

- single linkage method - also known as the nearest-neighbour technique; the distance between groups is defined as that of the closest pair of individuals, where only pairs consisting of one individual from each group are considered,

- complete linkage method - also known as furthest neighbour is opposite to single linkage, in a sense that distance between groups is now defined as that of the most distant pair of individuals,

- unweighted pair-group method using arithmetic averages (UPGMA) - the distance between two clusters is the average of the distance between all pairs of individuals that are made up of one individual from each group,

- ward method - the fusion of two clusters is based on the size of an error sum-of-squares criterion. The objective at each stage is to minimize the increase in the total within-cluster error sum of squares, E, given by [Everitt et al. 2011]:

$$E = \sum_{m=1}^{g} E_m \tag{1}$$

where,

$$E_m = \sum_{l=1}^{n_m} \sum_{k=1}^{p_k} \left(x_{ml,k} - \bar{x}_{m.k}\right)^2 \tag{2}$$

$\bar{x}_{m.k} = \left(\frac{1}{n_m}\right) \sum_{l=1}^{n_m} x_{ml,k}$ (the mean of the m_{th} cluster for the k_{th} variable),

$x_{ml,k}$ - being the score on the k_{th} variable (k= 1,…, p) for the l_{th} object (l=1,…,nm) in the m_{th} cluster (m=1,…,g)

Nonhierarchical methods are fast but require providing a prior number of clusters. The choice of number of clusters has a large impact on the quality of the resulting segmentation. Application of too many clusters can cause the situation in which the clusters will be internally homogeneous, however their interpretation will be difficult. On the other hand, the smaller the number of clusters is, the less uniform is the concentration. [Everitt et al. 2011]

Basic steps in cluster analysis

Cluster analysis should begin with the standardization of selected variables. The standardization is carried out using the following formula:

$$\bar{z}_{l,k} = \frac{x_{lk} - \bar{x}_{lk}}{s_k}$$
(3)

where,

l –   object,
k –   variable,
$\bar{x}_{lk}$ –arithmetic average,
S_k – the standard deviation of the variable sample.

Standardization is made to make an objective assessment of similarity, apart from a given scale, in which the individual variables are expressed [Adamowicz and Janulewicz 2012].

The next step of cluster analysis is similarity measurement. Since similarity is fundamental to the definition of a cluster, a measure of the similarity between two patterns drawn from the same feature space is essential to most clustering procedures. Because of the variety of feature types and scales, the distance measure (or measures) must be chosen carefully. It is most common to calculate the dissimilarity between two patterns using a distance measure defined on the feature space [Abonyi and Feil 2007].

The most common metric for continuous features is the Euclidean distance shown in the formula below:

$$d(x,y) = \sqrt{\sum_{i=1}^{p}(x_i - y_i)^2}$$
(4)

where,

x = $(x_1,…,x_p)$
y = $(y_1,…,y_p)$

The last step to be made, in order to conduct cluster analysis, is the choice of hierarchical or nonhierarchical classification methods presented earlier in the paper.

RESULTS OF THE RESERACH

Empirical data

The conducted research was based on the data from two main resources: the Organisation for Economic Co-operation and Development database and Eurostat database. Due to poor availability of data, the empirical data used in the study apply to the healthcare system in the year 2010. The main objects of the study are countries. In order to carry out this study the cluster analysis method was chosen because it allowed to classify the countries in question according to the chosen criteria.

In order to examine the similarities of the selected countries, and thus to create clusters, there were chosen 21 European Union member countries. At the beginning there was made an assumption to conduct the research on all EU countries, however due to scarcity of data, the sample was limited.

The countries were analysed according to three groups of data: finance, resources and health status. Into those three groups six different variables were assigned. The group gathering data connected with financial issues of countries in question consists of two variables:

- Total health expenditure per capita [in purchasing power parity in US $] – defined as the sum of expenditure on activities that – through application of medical, paramedical, and nursing knowledge and technology – have the goals of e.g.: - promoting health and preventing disease, treatment and reducing premature mortality, providing and administering public health [OECD 2012a]

- Public health expenditure as a percentage of total health expenditure – public health expenditures are health expenditures incurred by public funds. Public funds are state, regional and local government bodies and social security schemes. [OECD 2012a]

To the group of data connected with health care resources there were assigned the following variables:

- Total hospital beds [per 1000 inhabitants] - all hospital beds which are regularly maintained and staffed and immediately available for the care of admitted patients [OECD 2012b]

- Practising physicians [per 1000 inhabitants] – physicians who provide services directly to patients, including e.g.: people who have completed studies in medicine at university level and who are licensed to practice; interns and resident physicians; foreign physicians licensed to practice and actively practising in the country. From this group the following are excluded, e.g.: students who have not yet graduated; dentists and dental surgeons; physicians working in administration, research and in other posts that exclude direct contact with patients [Eurostat 2013]

The last group of data consists of:

- Perceived health status - percentage of the population, aged 15 years old and over who report their health to be 'good' or 'better'. Perceived health status reflects people's overall perception of their health, including both physical and psychological dimensions [OECD 2011]
- Life expectancy at birth - the average number of years that a person at that age can be expected to live, assuming that age-specific mortality levels remain constant. [OECD 2012c]

In order to conduct the analysis Statistica PL package was used.

Results

The main goal of the study was to identify some groups of countries from the EU that behave similarly or show similar characteristics concerning the performance of healthcare sectors. The study was conducted by one of agglomeration method of creating clusters – Ward method. However, in order to check the correctness of reasoning and compare the results obtained by different methods, the results of Ward's method were compared with three other agglomeration methods: single linkage, complete linkage and unweighted pair-group method using arithmetic averages (UPGMA). The research was carried out with an assumption of Euclidean distance, as a method of distance calculation.

At first there was applied a single linkage method. As a result there was received a dendrogram presented by Figure 1. This method showed a clear division between countries of eastern and western Europe. There is no clear distinction for many clusters. The first cluster is created by Hungary, Poland and Slovenia and the second one by Austria, Belgium, Finland, France, Spain, Sweden, UK, Luxembourg, the Netherlands and Ireland.

Figure 1. Dendrogram: single linkage method, Euclidean distance
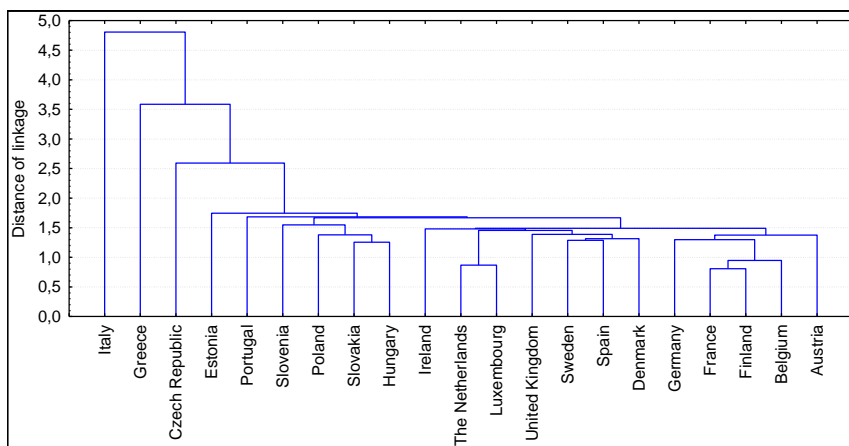
Source: own application in Statistica PL

According to the results of complete linkage method and UPGMA method (unweighted pair-group method using arithmetic averages) the composition of their clusters tends to be similar. In the complete linkage method three clusters were created, however those groups were not fairly homogenous. Poland remained in a group with Slovenia, Slovakia and Hungary. UPGMA method brought more specified results of four clusters. Contrary to the previous method, Austria and Germany created there a separate group. Similarly to the complete linkage method, Poland remained in the same cluster. In both methods Italy, Greece and Czech Republic constituted single-element clusters.

According to the research conducted by Ward's method three clusters can be easily seen. This method gave the most obvious results (see Figure 2), what is justified because this method is considered to be the most effective. The first cluster consists of Austria, Germany, Belgium, France, Finland, and optionally Czech Republic. The second group is created by Denmark, UK, the Netherlands, Sweden, Ireland, Spain and Luxembourg. The last group consists of Poland Estonia, Portugal, Slovenia, Hungary and Slovakia. In this type of segmentation method there is also observed a division into middle - eastern and western Europe countries. Only Portugal makes an exception.

Figure 2. Dendrogram: Ward's method, Euclidean distance
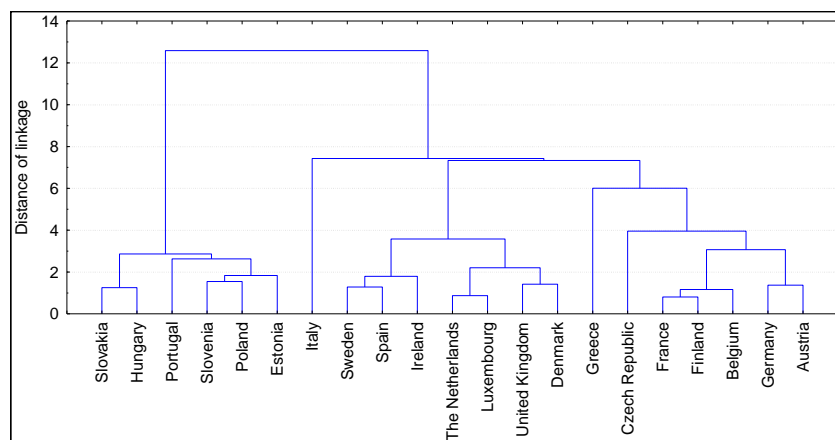
Source: own application in Statistica PL

SUMMARY

Hierarchical methods form the backbone of cluster analysis in practice. They are widely available in software packages and easy to use, although clustering large data sets is time-consuming. Choices that the investigator needs to make refer to the measure of proximity, the clustering method and, often, the number of clusters. The main problem in practice is that no particular clustering method

can be recommended, since methods with favourable mathematical properties (such as single linkage) often do not seem to produce empirically interpretable results. Furthermore, application of the results involves choosing a partition, but hardly do we know the best way of doing that. When a particular partition is required and there is no underlying hierarchy, the nonhierarchical algorithms may be more appropriate [Everitt 2011].

According to the study in question it should be marked that all the clustering methods chosen produced similar but not identical solutions. All the methods applied presented a clear division into countries of eastern/middle-east and western Europe, which is justified from the economic point of view. Italy, Greece and Czech Republic were identified as detached items, creating at the same time, single-itemed clusters. Those three countries were mostly included into the clusters at the last moment, which proved their dissimilarity. In all the cases there is a clear division into groups of eastern / middle-east and western European countries. This shows some still existing differences in healthcare systems in the countries in question. There is still a gap in finance, resources and health status among the EU countries. Poland is always placed in a group with Estonia, Slovenia, Hungary and Slovakia. This fact should be treated as a sign that despite all conducted reforms there is still a substantial gap between Poland and other western countries.

To sum up, it should be said that the greatest limitation of research results was poor availability of data in question. That is why this analysis should be considered as a starting point for further, more detailed analysis.

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