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Assessment of EU Competitiveness Factors by Multivariate Methods

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***Abstract*—**Measurement of competitiveness between countries or regions is an important topic of many economic analysis and scientific papers. In European Union (EU), there is no mainstream approach of competitiveness evaluation and measuring. There are many opinions and methods of measurement and evaluation of competitiveness between states or regions at national and European level. The methods differ in structure of using the indicators of competitiveness and ways of their processing. The aim of the paper is to analyze main sources of competitive potential of the EU Member States with the help of Factor analysis (FA) and to classify the EU Member States to homogeneous units (clusters) according to the similarity of selected indicators of competitiveness factors by Cluster analysis (CA) in reference years 2000 and 2011. The theoretical part of the paper is devoted to the fundamental bases of competitiveness and the methodology of FA and CA methods. The empirical part of the paper deals with the evaluation of competitiveness factors in the EU Member States and cluster comparison of evaluated countries by cluster analysis.

***Keywords*—**Competitiveness, cluster analysis, EU, factor analysis, multivariate methods.

I. Introduction

EUROPEAN Union (EU) is a heterogeneous unit with significant disparities between its Member States and their regions and with unbalanced territorial allocation of economic activities resulting in different living standard. This has a negative impact on balanced development across EU. The support of cohesion and balanced regional development together with increasing level of EU competitiveness belong to the *EU key development objectives*. Strengthening of cohesion in order to support balanced development of EU countries and regions is being carried out by the *EU Cohesion Policy* purposing to reduce disparities in disparities and competitiveness. The EU Cohesion Policy has an important role in enhancing of competitiveness and prosperity. From the long-term perspectives, competitiveness requires paying attention not only to economic but also to social and environmental factors, in recent years especially to territorial characteristics of areas – *cohesion* and *competitiveness* are thus *partly complementary goals* [7].

Competitiveness measurement and evaluation at any level of territorial development is associated with the lack of integrated approaches and methodologies in the EU. More sophisticated methods that can contribute to competitiveness measurement and evaluation represent *multivariate methods*. Within this paper, the application of multivariate methods (factor analysis and cluster analysis) is introduced in the topic of competitiveness in the EU Member States.

The aim of the paper is to calculate the main factors that determine competitiveness level of evaluated countries by FA. Factor analysis is suitable for assessment of internal relations between competitiveness indicators and for reduction of their high number to a smaller number of variables. Factor analysis allows to use a structure of common factors of all variables and create factors including the most important and convenient indicators for national competitiveness. Results of factor analysis are used for classifying of the EU Member States to the optimal number of the homogeneous clusters according to the similarity of the selected indicators of competitiveness factors in reference years 2000 and 2011. For this purpose, *the hypothesis of the paper* is based on the generally accepted concept of Willem Molle [9] that countries with lower level of national/regional disparities (old EU Member States (EU15)) achieve higher level of competitiveness in the territory than new EU Member States (EU12), and vice versa; see e.g. [11].

II. Theoretical Background of Competitiveness

Competitiveness in the level of performance is a major obstacle to the balanced and harmonious development of the regions, but also of the territory. Analysis of competitiveness brings the important information about the key problematic issues in region (and thus in country) on the one side and its development and competitive potential on the other side.

A. Concept of Competitiveness

The topics about measuring and evaluating of competitiveness acquire economic interest. The definition of competitiveness is difficult because of the *lack of mainstream view* for understanding this term. Competitiveness can be understood in different ways and levels despite widespread acceptance of its importance. The concept of competitiveness is distinguished at three basic levels - *microeconomic, macroeconomic and regional*. Anyway, there are some differences between these approaches; see e.g. [3], [6].

Although there is no uniform definition and understanding of this concept, competitiveness remains one of the *fundamental criteria of economic performance evaluation* and it is also seen as a reflection of success of area (country/region) in a wider (international/interregional) comparison. Competitiveness is monitored characteristic of

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national economies which is increasingly appearing in evaluating their prosperity, welfare and living standards. The need for a theoretical *definition of competitiveness* at macroeconomic level emerged with the development of globalization process in the world economy as a result of increased competition between countries. Despite that, growth competitiveness of the territory belongs to the main priorities of countries' economic policy; there is not a standardized definition and understanding of national competitiveness. The concept of competitiveness in the EU is specific regarding the inclusion of *elements of European integration* that goes beyond the purely economic parameters such as social standards, living standards, environmental factors etc.

B. Evaluation of Competitiveness

Competitiveness evaluation is also a main issue of economic research, which also lacks a mainstream approach, so there is space for alternative approaches. Evaluation of competitiveness in terms of differences between countries and regions should be measured through complex of economic, social and environmental criteria that can identify imbalance areas that cause main disparities. Currently not only quantitative but also qualitative development at the national level, and especially at the regional level, increase socio-economic attraction and create new opportunities that are fundamentals for subsequent overcoming disparities and increasing the competitiveness of the territory.

Competitiveness is most commonly evaluated by *decomposition of aggregate macroeconomic indicators*. Competitiveness of countries is monitored by many institutions. To compare a level of competitiveness of countries it can be used the databases performed by *Institute for Management Development* (IMD) and *World Economic Forum* (WEF). Competitiveness of the European Union (EU) can be measured also by indicators of *EU' growth strategies* (Lisbon strategy – Structural indicators, Strategy Europe 2020 – Indicators of Europe 2020) or by *macro-econometric modeling* with creation of an econometric panel data model; see e.g. [5], [10]. Furthermore there is continuity between the approach of EU and WEF in *EU Country/Regional Competitiveness Index*. Another approach is evaluation by the *Data Envelopment Analysis* (DEA) method, which measures national efficiency and subsequent competitive potential; see e.g. [8].

III. Multivariate Methods to Competitiveness Measurement

Competitiveness and its evaluation have a significant position in EU and all over the world. The most common quantitative methods convenient for a high number of multivariate measured variables can be identified as *multivariate statistical methods*. Multivariate analysis is an ever-expanding set of techniques for data analysis that encompasses a wide range of possible research situation [4]. Between collections of multivariate statistical methods it can be include e.g. *Method of main components, Factor analysis* or *Cluster analysis*, which are used in the paper. Measuring the competitiveness factors of the EU Member States is based on procedure in Table I.

TABLE I
Procedure of Competitiveness Factors Analysis

Pre-processing phase – Input data analysis
Collection of indicators » Data analysis of indicators » Groups of indicators for input and output
Factor analysis
Z-Score matrix » Correlation » Method of main components » Input factors » Output factors » Set of new composite indicators » Factor description
Cluster analysis
Hierarchical cluster analysis » Ward's method » Cluster description

Source: Own elaboration, 2013

A. Fundamental Background of Factor Analysis

Factor analysis is a collection of methods used to examine how underlying constructs influence the responses on a number of measured variables. Factor analysis is a method for investigating whether a number of variables of interest Y_1, $Y_2, \ldots Y_n$, are *linearly related* to a smaller number of unobservable factors F_1, $F_2, \ldots F_k$. If we suggest that one measured variable Y_1, is function of two underlying factors, F_1 and F_2, then it is assumed that Y variable is linearly related to the two factors F, as follows in (1):

$$Y_1 = \beta_{10} + \beta_{11}F_1 + \beta_{12}F_2 + e_1. \quad (1)$$

The error terms e_1, serves to indicate that the hypothesized relationships are not exact. In the special vocabulary of factor analysis, the parameters $\beta_{i,j}$ are referred to as *loadings*. For example, β_{12} is called the loading of variable Y_1 on factor F_2. There are basically *two types of factor analysis*: exploratory and confirmatory [12]. *Exploratory factor analysis* (EFA), which is applied in this paper, attempts to discover the nature of the constructs influencing a set of responses. *Confirmatory factor analysis* (CFA) tests whether a specified set of constructs is influencing responses in a predicted way.

The main *applications* of factor analytic techniques are (1) to *reduce* the number of variables and (2) to *detect structure* in the relationships between variables that is to *classify variables*. Therefore, factor analysis is applied as a *data reduction* or *structure detection method* [4]. Factor analyses are performed by examining the pattern of *correlations* between the observed measures. Measures that are highly correlated (either positively or negatively) are likely influenced by the same factors, while those that are relatively uncorrelated are likely influenced by different factors. The primary objectives of an *EFA* are to determine (1) The number of common factors influencing a set of measures and (2) The strength of the relationship between each factor and each observed measure. There are *seven usual basic steps* to performing *EFA*, used in the empirical analysis of the paper: (1) Collection of measurement variables; (2) Obtain the correlation matrix between each of variables; (3) Selection of the number of factors for inclusion; (4) Extraction of initial set of factors; (5)

Rotation of factors to a final solution; (6) Interpretation of factor structure; (7) Construction of factor scores for further analysis.

B. Fundamental Background of Cluster Analysis

Cluster analysis is a group of multivariate method whose primary purpose is to group objects based on the characteristics they possess. Cluster analysis classifies objects that are very similar to others in the cluster based on a set of selected characteristics. The resulting cluster of objects should exhibit high internal (within-cluster) homogeneity and high external (between-cluster) heterogeneity [4]. The most popular clustering procedures represent the *hierarchical methods* and *non-hierarchical methods*. Each of procedures follows a different approach to grouping the most similar objects into a cluster and to determining each object's cluster membership.

The hierarchical cluster analysis (agglomerative or divisive) is one of the most obvious methods. It uses the dissimilarities such as distances between objects when forming the clusters. The distance is mostly defined as *Euclidean distances* or the *Squared Euclidean distance* suitable for categorical variables, but there are my other specialized measures, e.g. for binary variables. After the determination of the distance measure, the clustering algorithm has to be selected. There are many methods available, the criteria used differ and hence different classification may be obtained for the same data [2]. The most frequently used methods are: nearest neighbor (single linkage), furthest neighbor (complete linkage), average linkage with (between) groups, Ward´s method, centroid method, median method. The last step of the cluster analysis is interpretation of the results. The most important is to select the cluster solution that the best represent the data sample. To define the characteristics of the cluster, it is appropriate to analyze the profile of cluster´s variables.

C. Basic Characteristics of Empirical Analysis

The empirical analysis, based on FA and CA, starts from building database of indicators that are part of a common approach of WEF and EU in the form of *Country Competitiveness Index* (CCI). Eleven pillars of CCI are grouped according to the different dimensions (*input versus output aspects*) of national competitiveness they describe, as show Fig. 1 [1]. The terms '*inputs*' and '*outputs*' are meant to classify pillars into those which describe driving forces of competitiveness, also in terms of long-term potentiality, and those which are direct or indirect outcomes of a competitive society and economy.

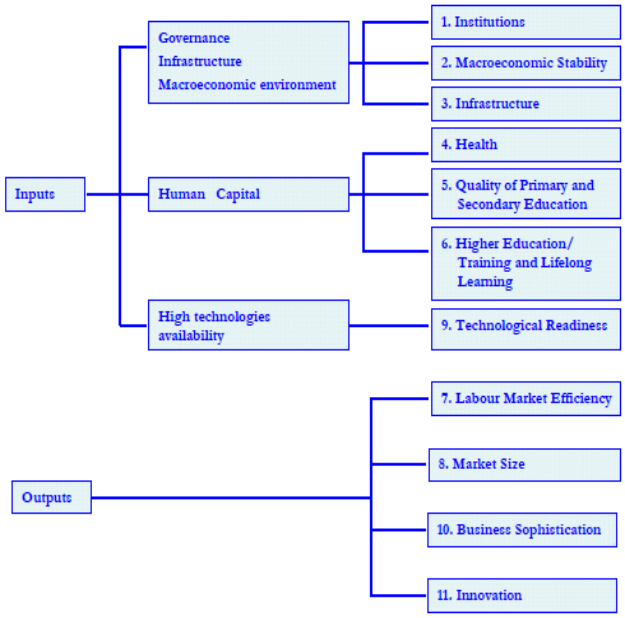

Fig. 1 Interpretation of the pillars included in framework for CCI
Source: [1, p. 30]

Set of CCI data file consists of *66 CCI indicators* – 38 of them are inputs and 28 outputs. In this paper, all CCI indicators are not used because all indicators were not available for the whole period for each country, but for some indicators were found comparable indicators. In this paper, only 62 indicators are used – 37 for inputs and 25 for outputs (see Table II), but some indicators were excluded due to correlation (cross out in Table III), *33 indicators relevant to FA and CA* are listed bold in Table III.

TABLE II
INDICATORS RELEVANT TO FA AND CA AFTER CORRELATION

Number of indicators	
Inputs	Outputs
37 » 19	25 » 14

Source: Own calculation and elaboration, 2013

The reference years 2000 and 2011 are thus determined by selection of all indicators and their data availability in territorial unit NUTS 0 (national level) in database of *the European Statistical Office*, the *World Bank*, *Euro barometer*, *the Organization for Economic Co-operation and Development* and *the European Cluster Observatory*.

For elaboration of the practical part of this paper, the software *IBM SPSS Statistics 20* and the table processor *Microsoft Office Excel 2010* has been used.

TABLE III
INDICATORS OF INPUTS AND OUTPUTS RELEVANT TO FA AND CA

Dimension	Pillar	Indicators*
Inputs	*Institution*	Political Stability~~, Voice and Accountability, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption~~
	Macroeconomic Stability	~~Harmonized Index of Consumer Prices~~, Gross Fixed Capital Formation; ~~Income, Saving and Net Lending/Net Borrowing,~~ Total Intramural Research & Development Expenditure, ~~Labour Productivity per Person Employed~~
	Infrastructure	~~Railway transport - Length of Tracks~~, ~~Air Transport of Passengers, Volume of Passenger Transport, Volume of Freight Transport;~~ ~~Motorway Transport - Length of Motorways~~, ~~Air Transport of Freight~~
	Health	Healthy Life Expectancy, ~~Infant Mortality Rate~~, ~~Cancer Disease Death Rate~~, Heart Disease Death Rate, Suicide Death Rate; Hospital Beds, Road Fatalities
	Primary, Secondary and Tertiary Education; Training and Lifelong Learning	Mathematics-Science-Technology Enrolments and Graduates, Pupils to Teachers Ratio, Financial Aid to Students, Total Public Expenditure at Primary Level of Education, Total Public Expenditure at Secondary Level of Education, Total Public Expenditure at Tertiary Level of Education, Participants in Early Education, Participation in Higher Education, Early Leavers from Education and Training, ~~Accessibility to Universities~~; Lifelong Learning
	Indicators for Technological Readiness	Level of Internet Access; ~~E-government Availability~~
Dimension	**Pillar**	**Indicators***
Outputs	*Labour Market Efficiency*	~~Labour productivity~~, ~~Male employment~~, Female employment, ~~Male unemployment~~, ~~Female unemployment~~, Public expenditure on Labour Market Policies; ~~Employment rate~~, ~~Long-term unemployment~~, ~~Unemployment rate~~
	Market Size	Gross Domestic Product; Compensation of employees, Disposable income
	Business Sophistication	Gross Value Added in sophisticated sectors, ~~Employment in sophisticated sectors~~
	Innovation	Human resources in Science and Technology, Total patent applications, Employment in technology and knowledge-intensive sectors, Employment in technology and knowledge-intensive sectors-by gender, Employment in technology and knowledge-intensive sectors-by type of occupation, ~~Human resources in Science and Technology – Core~~, ~~Patent applications to the EPO~~, Total intramural R&D expenditure, High-tech patent applications to the EPO, ~~ICT patent applications to the EPO~~, Biotechnology patent applications to the EPO

Note: * Number of indicators for inputs was decreased after correlation from 37 to 19; Number of indicators for outputs was decreased after correlation from 25 to 14
Source: Own elaboration, 2013

IV. APPLICATION OF FACTOR AND CLUSTER ANALYSIS IN THE CASE OF SELECTED COMPETITIVENESS INDICATORS IN THE EU MEMBER STATES

The *initial hypothesis* was confirmed through analysis by Factor analysis and Cluster analysis, as it is illustrated in following evaluation. Apparently the best results are traditionally achieved by economically powerful countries, i.e. in old EU Member States (EU15) than in new EU Member States (EU12).

A. Results of Competitiveness Factors by Factor Analysis

In this paper, *six dominating factors for inputs* explained *77,412 % of total variability in 2000 and 80,448 % in 2011*, which can be considered as very satisfactory result. In the case of *outputs, three dominating factors explained 87,530 % of total variability in 2000 and 83,393 % in 2011*, which can be considered also as very satisfactory results.

The optimal number of factors is already known, their interpretation still proceeds not. Jurisdiction of inputs and outputs to relevant factors is illustrated by grey color in Tables IV and V. In the case of inputs, optimal number of factors is six (Table IV). *Factor I* is created by indicators of Total Public Expenditure at Tertiary Level of Education, Lifelong Learning - Participation in Education and Training, Financial Aid to Students, Level of Internet Access and Total Public Expenditure at Primary Level of Education – indicators having positive impact on level of education in society. *Factor II* is constructed through indicators as Suicide Death Rate, Early Leavers from Education and Training, Participants in Early Education, Road Fatalities, Hospital Beds and Participation in Higher Education. Factor II thus indicates negative aspects of the educational system in connection with the civilization health aspects. Parts of *Factor III* are indicators Pupils to Teachers Ratio, Gross Fixed Capital Formation and Total Intramural R&D Expenditure; this factor describes financial aspects of education and research system. *Factor IV* is created by indicators of Political Stability and Healthy Life Expectancy. Factor IV indicates connection between stability of political situation in countries and satisfaction of quality life and healthy expectancy. Indicators as Heart Disease Death Rate and Total Public Expenditure at Secondary Level of Education are part of *Factor V* and describe connection between the most common level of education and the most common lifestyle diseases. *Factor VI* is created by only one indicator – Mathematics, Science and Technology Enrolments and Graduates.

TABLE IV
ROTATED COMPONENT MATRIX FOR INPUT FACTORS

Indicators	Component					
	1	*2*	*3*	*4*	*5*	*6*
TPETLE	,885	,064	-,005	,108	,170	,144
LLPET	,764	-,158	,319	-,093	-,025	,034
FAS	,762	,052	-,116	,000	,200	-,091
LIA	,679	-,249	,564	,006	-,030	-,138
TPEPLE	,603	,114	-,089	-,060	-,386	-,404
SDR	,005	,805	-,167	,139	,347	-,140
ELET	-,311	-,716	-,359	-,131	,035	-,176
PEE	-,004	-,666	,295	,318	,253	-,231
RF	-,324	,660	-,443	,065	-,078	-,207
HP	-,429	,609	,182	-,034	,397	,132
PHE	-,008	,513	-,485	-,003	-,222	,437
PTR	-,127	,095	,862	-,216	,092	,043
GFCF	,227	-,345	,643	,374	-,139	,031
GERD	,615	-,121	,623	,143	,080	,261
PS	-,175	,048	-,095	-,804	,023	,042
HLE	-,348	,144	-,187	,765	,091	-,083
HDDR	-,078	,012	-,094	,105	-,775	-,008
TPESLE	,273	,187	-,111	,451	,724	-,022
MSTEG	-,003	,064	,074	-,112	,017	,924

Source: Own calculation and elaboration, 2013

In the case of outputs, optimal number of factors is three (Table V). *Factor I* is created by indicators of Employment in technology and knowledge-intensive sectors, by level of education, Employment in technology and knowledge-intensive sectors, by type of occupation, Employment in technology and knowledge-intensive sectors, by gender, Compensation of employees and Total patent applications. These are indicators having direct impact on the labor market and social situation on the labor market. Indicators as High-tech patent applications to the EPO, Total intramural R&D expenditure, Biotechnology patent applications to the EPO, Female employment and Public expenditure on Labour Market Policies are part of *Factor II*. This factor describes connection between quality level of research and development and financial situation in this sector on the one side and employment situation on the second side. *Factor III* is constructed through indicators Gross Value Added in sophisticated sectors, Gross Domestic Product, Disposable income and Human resources in Science and Technology. Factor III largely reflects the economic strength of the country.

TABLE V
ROTATED COMPONENT MATRIX FOR OUTPUT FACTORS

	Component		
	1	2	3
ETKIedu	,981	,035	,012
ETKIocc	,980	,034	,010
ETKIgen	,978	,026	,009
CoE	,897	,192	,078
TPAp	,879	,247	,072
HTI	,168	,898	,197
GERD	,108	,848	,184
BioT	,092	,846	,151
FE	,026	,822	,100
PEoLMP	,151	,596	,300
GVA	,045	-,034	,972
GDP	,030	,341	,918
DI	,075	,522	,813
HRST	-,007	,503	,681

Source: Own calculation and elaboration, 2013

B. Country Cluster Profile by Cluster Analysis

Based on results of correlation and factor analysis, it could proceed to cluster analysis. For the final matrix to cluster analysis, it was chosen selected *33 indicators* (19 for inputs and 14 for outputs) that represent the most frequently factors related to competitiveness in CCI. *CA is used for defining clusters of countries based on the value of the individual factors*. In this paper, the best interpretation of data ensures *five-cluster solution for inputs* in year 2000, as well as in 2011. The best interpretation of data ensures also *five-cluster solution for outputs* in year 2000, as well as in 2011. *The number of inputs/outputs clusters* has been set, based on previous analysis, thus at *5*, as shown in Figs. 2 and 3.

In the case of inputs indicators, *Cluster I* is created by economic powerful countries such as Germany, Austria, Ireland, Luxembourg, Finland, Czech Republic, Slovakia, France, Belgium, Netherlands and United Kingdom. Cluster I is characterized by *higher economic efficiency and performance* than all other cluster achieve (except Cluster I). *Cluster II* is characterized by countries as Denmark as Sweden having very good economic prosperity, the greatest level of competitiveness indicators and thus *the highest economic efficiency and performance* of all countries. *Cluster III* represents Latvia, Lithuania, Estonia, Hungary and Cyprus. These countries are characterized with lower level of macroeconomic indicators and lower level of performance. *Cluster IV* is created by countries as Spain, Italy, Portugal and Malta having also not very good economic prosperity and level of performance. *Cluster V* represents Bulgaria, Greece, Poland, Slovenia and Romania, which are characterized with the lowest level of macroeconomic indicators and the lowest level of performance. Between Cluster III, IV and V are visible differences, but there are not so high.

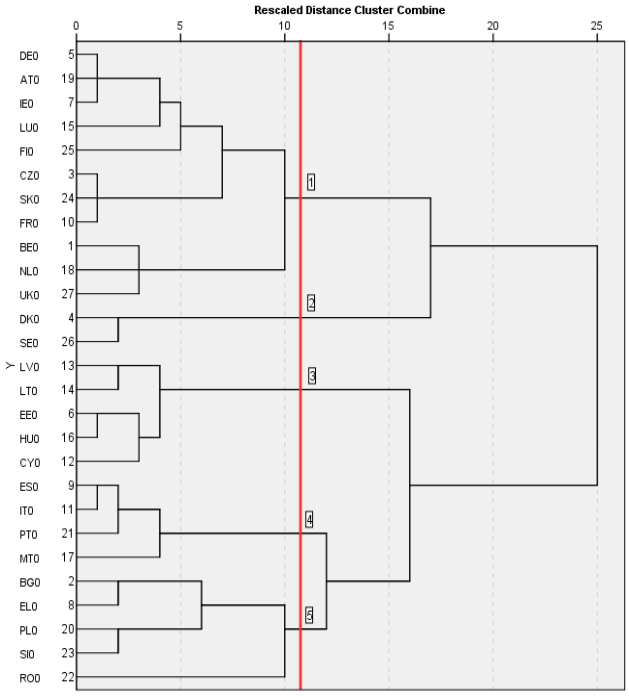

Fig. 2 Dendogram of inputs clusters using Ward linkage
Source: Own calculation and elaboration, 2013

In the case of outputs indicators, *Cluster I* is represented by countries such as Bulgaria, Latvia, Slovakia, Hungary, Lithuania, Greece, Portugal, Poland, Romania, Estonia, Slovenia, Czech Republic, Malta and Cyprus. These countries have the worst economic prosperity and level of performance, are characterized with the lowest level of macroeconomic indicators. *Cluster II* is created by Spain, Italy, France and United Kingdom having higher economic performance and better economic efficiency than Cluster I. *Cluster III* represents then only one country – Germany, which is characterized by *the highest economic efficiency and performance* of all countries. Identical result having Luxembourg created *Cluster V*, which is distinguished by the *high level of efficiency and performance trend*. *Cluster IV* is represented by countries such as Belgium, Ireland, Finland, Sweden, Netherlands, Austria, and Denmark with *higher economic efficiency and performance* than countries in Cluster I and II other cluster achieve (except Cluster I). Between Cluster I and II on the one side, and Cluster III, IV and V on the other side are visible and important differences.

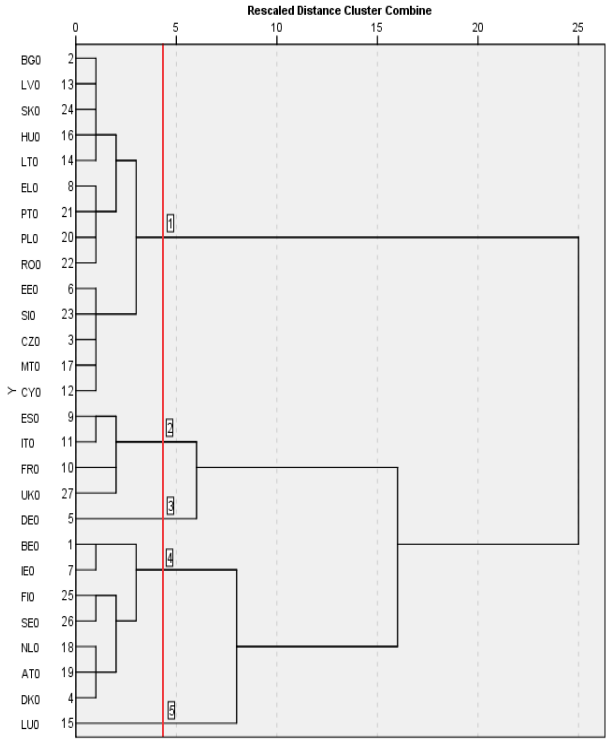

Fig. 3 Dendogram of outputs clusters using Ward linkage
Source: Own calculation and elaboration, 2013

V. Conclusion

Competitiveness and cohesion are complementary objectives, which determine the long-term development of countries. These are also concepts that cannot be avoided in economic theory and practice. Evaluation of competitiveness can be performed only if it is used existing concept of this term or selected mainstream. Because of the fact that there is no mainstream in competitiveness evaluation, there is space for alternative approach in this area. Based on factor analysis and cluster analysis was *confirmed the initial hypotheses* that countries with better results in FA and CA are EU15 countries and having higher level of competitiveness in the territory than EU12 countries. Therefore, these countries have tended to be naturally grouped into homogeneous clusters that have separated from the other clusters. The significant differences in composition of competitiveness factors were noticed between old EU Member States on the one side and new EU Member States on the other side. Despite of, the significant disparities have persisted between EU15 and EU12 countries, and also within these groups of countries.

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