THE APPLICATION OF CLUSTER ANALYSIS IN MEASUREMENT OF HUMAN DEVELOPMENT

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Abstract. *Many methods of measurement were designed for comparison of human development, the most popular being the Human Development Index (HDI), which has been used since 1990. This index measures the level of human development by not only GDP per capita but also trough the indicators of education and healthy life. The differences in the level of human development are observed not only at the national level, they are also measured at the regional level of countries. The aim of this article is, with the quantification of regional human development, to describe the potential for human development using cluster analysis at the regional level. The regions of the Visegrad Group Plus countries (the countries of Visegrad Group - Czech Republic, Poland, Hungary, Slovakia, and the countries of Regional Partnership Agreement, Austria, and Slovenia) at NUTS II level were selected for this purpose. There are 46 regions on the NUTS II level – eight in the Czech Republic, seven in Hungary, sixteen in Poland, nine in Austria, four in Slovakia and two in Slovenia. The research was made in the period from 2004 to 2013. In the selection of indicators, the same approaches as by the HDI were adopted; however, the components of each dimension were modified. Life expectancy at birth (dimension of health), tertiary educated people and lifelong learning (dimension of education) and GDP per capita in PPS (dimension of living standards) have been chosen as indicators of human development. These components were then used in a hierarchy cluster analysis in the Ward method. Three clusters were created with different levels of development potential (from below-average potential to above average one). Initially, a research hypothesis that there was a dynamization of human development processes in most regions has been set. Namely, it was assumed that more than half of monitored regions in the lower group of potential to human development would shift to the higher group. This hypothesis was not confirmed and it was found that a vast majority of the regions have not changed their positions in the cluster in the monitored period.*

Keywords: *cluster analysis; GDP per capita; human development; life expectancy at birth; lifelong education; NUTS II regions; tertiary education; Visegrad Group Plus.*

Introduction

The most widely used indicator for measuring the state of the economy is the GDP (Stiglitz, Sen & Fitoussi, 2009; Van den Bergh, 2009), although it does not include social, political, cultural and environmental aspects of development. Many alternatives can be applied for measurement of socio-economic development, the best known and most often used is an index called the Human Development Index (HDI) as Todaro and Smith (2011) demonstrated. The index that has been used by the United Nations since 1990 brings a different perspective on development issues. It should be better able to emphasize the effect of other than just monetary (economic) factors of the economy of a country. The basis of the HDI index is a greater explanatory power, which is to follow economic development or sustainable development in general. The measurement of human development through the HDI is an alternative to the GDP/GNI per capita as a measure of human well-being.

Basu and Basu (2005) consider HDIs as primarily nation level indicators, estimated for the country as a whole. The constructions of the HDI do not express the differences in regions of countries. However, the regional disparities exist and influence the regional development. Based on it, we decided to analyze the issue of human development for a group of countries of the Visegrad Group Plus (hereafter V4+) at the NUTS II level. This group includes the Visegrad Group countries (Czech Republic, Hungary, Poland and Slovakia), Slovenia and Austria, which were included in this group on the ground of the Regional Partnership Agreement from 2001. There are 46 regions on the NUTS II level – eight in the Czech Republic, seven in Hungary, sixteen in Poland, nine in Austria, four in Slovakia and two in Slovenia. The research was made in the period from 2004 (the beginning of membership of most countries V4+) to 2013 (last available data). In the selection of indicators, the same approach as by the HDI was adopted; however, the components of each dimension were modified. Life expectancy at birth (dimension of health), tertiary educated people and lifelong learning (dimension of education) and GDP per capita in PPS (dimension of living standards) have been chosen as indicators of human development at regional level. These components were then used in a hierarchy cluster analysis in the Ward method.

Three created clusters include a plurality of regions based on their inner similarities that would not otherwise be apparent at first glance. These clusters include the regions with different levels of development potential – first cluster with above-average potential for human development, second cluster with average potential for human development and third cluster with under-average potential for human development. Initially, a research hypothesis that there was a dynamization of human development processes in most regions has been set. Namely, it was assumed that more than half of monitored regions in the lower group of potential to human development would shift to the higher group. This hypothesis was not confirmed and it was found that the vast majority of the regions have not changed their positions in the cluster in the monitored period.

Modified Human Development Index

The beginning of the Human Development Index dates back to 1990 when the UN Development Programme (UNDP) published the first report on human development (Human Development Report) which established the need for human development measurement. Human development has two forms, which should be in balance, the formation of human capabilities in terms of improving health, increasing knowledge and skills to meet human need and their own skills and competencies, free time, job security, cultural, social and political events. Basically, human development is clearly and directly dependent on income. It is, therefore, necessary to examine other variables that point out the potential of a country much better as well as the options currently appear in human development (Majerova, 2012).

Data of Human Development Index

The Human Development Index (HDI) is a summary measure of achievements in key dimensions of human development: a long and healthy life, an access to knowledge and a decent standard of living as has been shown in UNDP (2015).

These three dimensions have four parts - health and standard of living have one part each and education has two parts:
- health dimension – life expectancy at birth (interval 20-85 years)
- education dimension – expected year of schooling (0-18 years) and mean years of schooling (0-15 years)
- the standard of living dimension – GNI per capita in USD/PPP (100-75.000).

Because of the need to improve their explanatory power, the calculation method of two of three dimensions (health indicator index is the only one that has remained unchanged) has changed over time; last change was made in 2010. The literacy rate of population has been replaced by an indicator of expected years of schooling, the combined gross enrolment by the mean number of years of education (knowledge dimension). The dimensions of living standards are now measured by GNI per capita in purchasing power parity to the USD. "The main change was to switch from the original additive aggregation function (the arithmetic mean of the three components) to a multiplicative function (their geometric mean)" (Ravallion, 2012, p.208) as shown in Equation (1).

$$HDI = \sqrt[3]{I^n_{LE} \cdot I^n_E \cdot I^n_{GDP}} \tag{1}$$

HDI index calculation required the values in the range from zero (the lowest level of human development) to one (the highest human development), and therefore they were determined for each dimension of the minimum and maximum values (Anand & Sen, 1994) based on historical evidence.

NUTS Human Development Index

For the purpose of the paper, we adopted the same principle of HDI creating at the national level – the health dimension, knowledge dimension and dimension of a living standard. Components of each dimension, however, had to be modified because of the lack of data at the regional level (NUTS II level).

Data were used from a regional database of Eurostat and converted to the number of inhabitants representing the given group.

The construction of the HDI of V4 regions (NHDI) was as follows:
- Health with the value of life expectancy at birth that represents, according to Eurostat, the mean number of years that a newborn child can expect to live if subjected throughout his life, to the current mortality conditions (age-specific probabilities of dying).
- Knowledge, which includes two components:
1. Tertiary educated people in the age of 25-64, where the indicator is defined as a percentage of the population aged 25-64 who have successfully completed tertiary studies (e.g. university, higher technical institution, etc.). This educational attainment refers to ISCED (International Standard Classification of Education) 1997 level 5-6, that includes the first stage of tertiary education (bachelor and master or equivalent) and second stage of tertiary education (doctoral or equivalent).
2. Lifelong learning in the form of the participation rate in education and training covers participation in formal and non-formal education and training. The reference period for the participation in education and training is at least four weeks. Participation rates in education and training for the age group of 25-64 are presented. The data are calculated as annual averages of quarterly EU Labour Force Survey data (EU-LFS).
- Standard of living, measured by GDP per capita in PPS – Purchasing Power Standards (PPS), is a common currency that eliminates the differences in price levels between countries and regions allowing meaningful volume comparisons of GDP between them.

These indicators were chosen for their greatest explanatory power in relation to human development. The life expectancy at birth reflects the level of health and quality of life and measures the qualitative aspects of living a healthy life. It correlates positively with human development – the higher the healthy life expectancy of the region, the more developed it is.

The share of tertiary educated people in productive age on the population in this age group is connected with the ability of people to reflect the needs of knowledge of the economy and to contribute to it and human development. Lifelong learning, in the form of participation in education and training, encompasses all learning activities undertaken throughout life (after the end of initial education) with the aim of improving knowledge, skills and competences, within personal, civic, social or employment-related perspectives as Eurostat (2015) demonstrates. Due to lifelong learning people extend their possibilities for increasing their incomes. As a dimension of health, both indicators of education are positively correlated with human development.

The last but not least dimension is the GDP per capita. The implementation of this indicator was influenced by the opinion of Sen (1999) who considered the income (product) as a primarily mean to achieve human development. The GDP per capita reflects the economic level better than its absolute value. The indicator is measured by an artificial European currency unit, the purchasing power standard (PPS).

The values of the index and its sub-indexes in every NUTS II region of V4+ are shown as an example of the year 2013 in Table 1.

Table 1. Components of index NHDI and the values of NHDI in 2013

Stat. name	Region	LEB	TE	LL	GDP/c	NHDI
CZ01	Praha	80.1	38.4	8.7	46,000	**0.630**
CZ02	Střední Cechy	78.2	19.9	9.1	19,500	**0.357**
CZ03	Jihozápad	78.4	18.0	10.5	19,400	**0.361**
CZ04	Severozápad	76.4	12.5	8.0	16,500	**0.224**
CZ05	Severovýchod	78.6	16.8	13.2	18,000	**0.370**
CZ06	Jihovýchod	79.1	22.6	9.2	20,600	**0.407**
CZ07	Střední Morava	78.1	16.2	7.8	17,700	**0.305**
CZ08	Moravskoslezsko	77.1	17.6	10.7	18,400	**0.313**
HU10	Közép-Magyarország	77	33.2	4.2	28,700	**0.397**
HU21	Közép-Dunántúl	75.5	19.0	2.0	15,600	**0.178**
HU22	Nyugat-Dunántúl	76.1	17.8	1.8	17,900	**0.200**
HU23	Dél-Dunántúl	75.2	18.3	2.6	11,900	**0.140**
HU31	Észak-Magyarország	74.2	16.7	2.1	10,500	**0.051**
HU32	Észak-Alföld	75.4	17.8	3.4	11,300	**0.144**
HU33	Dél-Alföld	75.6	18.2	2.5	11,900	**0.154**
PL11	Lódzkie	75.4	23.5	3.1	16,700	**0.211**
PL12	Mazowieckie	77.7	35.4	6.7	28,500	**0.453**
PL21	Malopolskie	78.5	26.6	4.7	15,800	**0.342**
PL22	Slaskie	76.3	24.4	4.5	18,600	**0.278**
PL31	Lubelskie	77.1	25.5	4.9	12,600	**0.261**
PL32	Podkarpackie	78.6	23.1	2.6	12,700	**0.270**
PL33	Swietokrzyskie	77.1	26.0	3.1	13,100	**0.259**
PL34	Podlaskie	77.1	26.1	3.7	13,000	**0.279**
PL41	Wielkopolskie	77.2	23.4	3.7	19,300	**0.303**
PL42	Zachodniopomorskie	76.7	23.9	3.2	15,100	**0.257**
PL43	Lubuskie	76.3	20.6	2.8	15,000	**0.221**
PL51	Dolnoslaskie	76.9	25.1	4.1	20,100	**0.311**
PL52	Opolskie	77.2	20.9	3.1	14,500	**0.248**
PL61	Kujawsko-Pomorskie	76.9	20.7	3.9	14,800	**0.247**

PL62	Warminsko-Mazurskie	76.3	20.7	2.8	12,900	**0.203**
PL63	Pomorskie	77.9	26.7	5.8	17,300	**0.347**
AT11	Burgenland (AT)	81.1	15.8	10.1	23,300	**0.428**
AT12	Niederösterreich	81	17.6	12.0	27,900	**0.484**
AT13	Wien	80.1	30.6	19.0	42,300	**0.648**
AT21	Kärnten	81.7	17.3	13.0	28,400	**0.510**
AT22	Steiermark	81.8	17.5	13.1	30,700	**0.525**
AT31	Oberösterreich	81.4	17.2	12.7	34,500	**0.524**
AT32	Salzburg	82.2	21.8	13.0	40,200	**0.601**
AT33	Tirol	82.4	19.1	13.4	35,800	**0.575**
AT34	Vorarlberg	82.3	19.0	14.5	35,600	**0.582**
SK01	Bratislavský kraj	78.1	37.5	7.1	49,000	**0.541**
SK02	Západné Slovensko	76.8	16.6	2.6	18,800	**0.224**
SK03	Stredné Slovensko	76.2	18.8	2.5	15,900	**0.208**
SK04	Východné Slovensko	76.2	17.5	1.9	13,800	**0.179**
SI01	Vzhodna Slovenija	79.5	23.5	10.9	18,100	**0.333**
SI02	Zahodna Slovenija	81.7	32.9	14.0	25,900	**0.551**

Note: LE in the years, TE and LL in the thousands of inhabitants, GDP/c in PPS

As mentioned, we accepted the values of the HDI that range in the interval of 0-1 and formed the categories of NHDI as follows:
- very high human development, with the value of 0.800 and above
- high human development, in the interval of 0.700–0.799
- medium human development, in the interval of 0.550–0.699
- low human development, below 0.550.

The results of the level of human development are interesting. If we analyze the NHDI in terms of categorization, the regions reached low levels of the NHDI (below 0.550), with some exceptions related to the regions with capitals (except Poland and Hungary) and certain regions in Austria. The medium human development amounted regions, in which the capital city is situated, and some Austrian regions such as Salzburg, Tyrol, and Voralberg mainly due to the high value of the GDP index.

If we focus on the evolution of the NHDI in individual economies, we find out that the value of this index is similar in all regions of Austria - between the best and the worst value of the indices there is a difference of 34%, while in Hungary the difference between the best and the worst result is 87 percent! It is caused by a very low value of the NHDI in the Észek-Magyarország region (0.051) where the life expectation at birth component is approaching the minimum values.

Methodology of cluster analysis

Cluster analysis is primarily focused on the search for similarities or differences between examined objects. „Cluster analysis provides one, empirically based, means for explicitly classifying objects" (Punj & Stewart, 1983, p.134). If the research object is the region, as in our case, it is clear that only by applications of cluster analysis, we can confirm our assumption about the most or the least developed regions in the area of human development and its modifications.

Blashfield and Aldenderfer (1988, p.447) consider that „cluster analysis method has a long history – the earliest known procedures were suggested by anthropologists, later this ideas were picked up in psychology". Clustering analysis became one of the qualifying methods in the 20th century, the usefulness of which immediately had an impact on practically all fields of science. Tryon (1939) created the first comprehensive work dealing with cluster analysis in 1939. The main motivation for the use of clustering is uncovering of hidden similarities or differences. For this reason, a cluster analysis is now widely used by all scientific disciplines (for us is most interesting use in the field of economy, see e.g. Halásková & Halásková, 2015).

If we want to formulate the principle of cluster analysis mathematically, it can be stated that it is the decomposition of set $S^{(k)}$ by the objects to k certain groups of clusters C, see Equation (2):

$$S^{(k)} = \{C_1, C_2, C_3, ..., C_k\} \tag{2}$$

where $C_i \neq 0$.

The basis of cluster analysis is sorting (for details see Meloun, 1994), of which we appoint two basic approaches. The first is called hierarchy cluster method and is most widely used by the software. It is based on the use of once formed clusters. Thus, formed clusters are then used to create other clusters from the rest of the data file. This manner is then preceded until all elements of the data file are a part of the cluster. This procedure has been chosen for our analysis of the regional level of human development in the V4+ countries.

The second method is a non-hierarchy cluster approach, which is based on cluster search on the principle of the smallest difference from the average. The procedure, however, is advantageous only if the number of clusters we want to achieve, is determined beforehand. However, this may become a significant limitation in a further research, because only such a number of clusters are finally formed, which we determined beforehand and for example, some extreme values may merge with average ones (K-means).

The selection of cluster methods is necessary after determining the clustering process. There are seven methods (Caliński & Harabasza, 1974). The first two methods are based on the Between Groups Linkage or Within Groups Linkage. Their use depends on good knowledge of the data file and information about the number of clusters that we want to achieve. In the case of ignorance of the total number of clusters we want to achieve, both methods are limitations in further research. The third method, Nearest

Neighbour is based on the shortest distance between clusters. The fourth method, Furthest Neighbour method, searches the values in the data file that are furthest apart. The fifth method, Centroid Clustering method, may look at first glance like the most ideal. It is based on the Euclidean distance between the centroids of clusters. The closest are those clusters that have the smallest distance between the centroids. However, it does not solve the differences that may occur due to different weights for equally large clusters. The sixth method - Median clustering - solves the problem of weights variance that the previous method gives to differently large clusters.

The last method, the Ward method, focuses on the allocation of profiles to groups equally. This method can be represented graphically, similarly to the previous methods, see Figure 1. The principle of the method is not optimization, but minimization of heterogeneity. The purpose is to find the greatest similarity. In measuring the human development and its modifications, it is necessary to look for similarities among the 46 regions using this method.

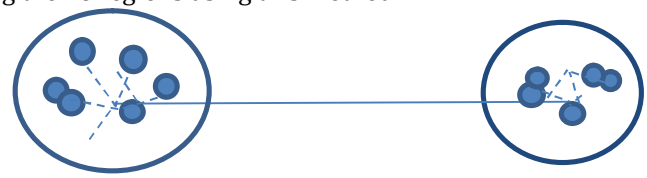

Figure 1. Ward Method in Cluster Analysis

Since the values of each variable were in different units (years, population, monetary unit), it was necessary to standardize data. This standardization was carried out in two steps:

1. firstly, the medium value $\bar{z}_k$ and standard deviation s_k were calculated according to Equation (3) and (4)

$$\bar{z}_k = \frac{1}{n}\sum_{k=1}^{n} z_{jk} \tag{3}$$

$$s_k = \left[\frac{1}{n}\sum_{k=1}^{n}\left(z_{jk} - \bar{z}_k\right)^2\right]^{1/2} \tag{4}$$

2. afterwards the standardization through normalization of each object in the z-score was made (the standardization z-function) by the following Equation (5)

$$x_{ik} = \frac{z_{jk} - \bar{z}_k}{s_k} \tag{5}$$

One of the fundamental problems of clustering analysis is the concept of mutual similarity of objects and quantitative expression of this similarity. One of the most

common ways of expressing relationships among objects is the metrics. The metric squared Euclidean distance (SED) was used for Ward's method (6):

$$d_e^2(x_i, x_j) = \sum_{k=1}^{n} (x_{ik} - x_{jk})^2 \tag{6}$$

where d^2 is SED, x_{ik} is the value of k-symbol for the *i* observation of the variable and *n* is the total number of objects.

Application of cluster analysis in NUTS II Regions of V4+

Based on the methodology described in the previous section of this paper, cluster analysis will now be practically applied to the regions at NUTS II level of the Visegrad Group Plus countries. The V4+ regions will be divided according to their development potential in terms of human development.

As already mentioned, the hierarchy cluster approach by means of Ward's method was used for the classification of regions, and all performed calculations were performed by using SPSS software. Ward's method not based on the optimization of distances between clusters, but on optimization of the clusters´ homogeneity according to some criterion, which is the minimizing of increase in the error sums of squares of deviations from the points of the cluster centroid. The sum of squares is calculated for each possible pair of connection aggregates at each stage of this analysis. Then those clusters are combined where there is a minimal increase in the error sum of squares.

The advantage of using this method and also our motivation of its use is the tendency to remove small clusters, thus forming clusters of about the same size, which is often welcome feature. This is because this method requires expression of objects´ distance by the squared Euclidean distance. Since the Ward's method leads to minimization of intra-cluster dispersion, causing research that is more accurate examined objects, its choice was for our purposes the best option.

The subjects of cluster analysis are 46 NUTS II regions that have been evaluated by following metrics:
- cluster 1 is the group of regions with above-average potential for development in terms of human development and its input parameters;
- cluster 2 indicates the group of regions with average development potential in terms of human development and its input parameters;
- cluster 3 indicates the group of regions with below-average development potential in terms of human development indicators and its input.

Table 2 shows how various inputs influencing the final value of human development during the reporting period have changed. Some of the clusters remained unchanged throughout the monitored period, on the contrary, some of them evolved over time. From this table, we derive whether developments in the regions when analyzing the input variables are rather constant or whether the processes lead to dynamization in regions.

Table 2. Created and changed clusters of V4 + regions taking into account the four inputs between the years 2004-2013

NUTS 2	Cluster (period)	NUTS 2	Cluster (period)
SK01	cluster 1	PL51	cluster 3
SK02	cluster 2	PL52	cluster 2
SK03	cluster 2	PL61	cluster 2
SK04	cluster 2	PL62	cluster 2
CZ01	cluster 1	PL63	2004 – 2009 cluster 2 2010 – 2013 cluster 3
CZ02	2004-2010 cluster 2 2011-2013 cluster 1	HU10	cluster 1
CZ03	2004-2010 cluster 2 2011-2013 cluster 1	HU21	cluster 2
CZ04	cluster 2	HU22	cluster 2
CZ05	2004-2010 cluster 2 2011-2013 cluster 1	HU23	cluster 2
CZ06	2004-2007 cluster 2 2008-2013 cluster 1	HU31	cluster 2
CZ07	cluster 2	HU32	cluster 2
CZ08	cluster 2	HU33	cluster 2
PL11	cluster 3	AT11	cluster 1
PL12	cluster 1	AT12	cluster 1
PL21	cluster 3	AT13	cluster 1
PL22	cluster 3	AT21	cluster 1
PL31	cluster 3	AT22	cluster 1
PL32	cluster 2	AT31	cluster 1
PL33	cluster 2	AT32	cluster 1
PL34	cluster 2	AT33	cluster 1
PL41	cluster 1	AT34	cluster 1
PL42	cluster 2	SI01	2004-2007 cluster 2 2008-2013 cluster 1
PL43	cluster 2	SI02	cluster 1

Note: The change in the development of the region in the years 2004-2013 is indicated.

Conclusions

The Human Development Index is one of the indicators, which can measure the socioeconomic development. This indicator has been used since 1990, it measures the abovementioned development at the national level and it is used to compare differences between economies. However, there are not only disparities between economies but also within them. For this reason, we decided to construct the modified Human Development Index (NHDI) and for this purpose, countries of the Visegrad Group Plus at the NUTS II level have been selected. This group includes the Visegrad Group countries (Czech Republic, Hungary, Poland and Slovakia), Slovenia and Austria and there are the 46 NUTS II regions. For our purpose, the data had to be modified, but the methodology of the NHDI was the same as for the HDI. We used three components - the health dimension (life expectancy at birth), the knowledge dimension (tertiary educated people and participation rate in education and training) and the dimension of living standard (GDP per capita).

These components were then used in hierarchy cluster analysis in the Ward´s method in the period from 2004 to 2013. The three clusters were created. These clusters included a plurality of regions based on their inner similarities that would not otherwise be apparent at first glance. At the beginning of the monitored period, the situation in various regions was as follows: Regions of Austria were very homogeneous and placed in a group with above-average potential for development (group 1). Hungarian regions (except a region in which the capital is) were in the second group – with average development potential. Czech regions were placed in the first two groups (1 and 2) and Polish regions exhibited the lowest homogeneity and were placed in all groups (most in group 2). There was initially set the research hypothesis that more than half of monitored regions in the lower group of potential to human development will shift to the higher group (1 or 2).

Finally, it is also necessary to note that in some regions the time offset between the individual clusters is quite obvious. Generally, it was a situation where regions have shifted from average to above-average potential towards of development, i.e. from cluster 2 to cluster 1. It was the case of regions in the Czech Republic – Střední Čechy (CZ02), Jihozápad (CZ03), Severovýchod (CZ05), Jihovýchod (CZ06) and Slovenia – Vzhodna Slovenia (SI01). There was, however, the reverse process, which led to some slowdown in the development potential of the region. The shift from the group of average to below average happened only in one region, the region of Poland – Pomorskie (PL63). However, the vast majority (exactly forty of forty-six) of the examined regions did not change their position in the cluster during the reporting period. Our hypothesis about dynamization of most regions was not confirmed.

It should be emphasized that the resulting allocation of regions into individual clusters was dependent on the number of input variables. If we reduced the number of input variables or added more input variables correlating with a modified human development, the resulting allocations of regions would change, the question remains whether significantly or only slightly.

In our future research, we would like to create the modified Human Development Index (from the variables of human development used in this paper) at the regional level and focus on the comparison of cluster analysis´ results with the results of this index in the monitored period.

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