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A Mathematical Model for Comparing the Financing Policy in Health Systems of European Union Countries

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Abstract

This paper presents a comparative analysis of the health systems financing strategies of the 27 European Union (EU) member states, based on seven significant financial indicators, in order to point out the evolution of the health financing policies of the analyzed countries between years 2000-2010.

In order to process the information contained in a matrix with the size of 27 (EU member states) x 7 (significant indicators), difficult to visualize, the Principal Component Analysis and the Cluster Analysis were used.

Key Words: *health systems, principal component analysis, cluster analysis.*

Jel Classification: *H75, I18*

Introduction

The organizational structure and the financing of National Health Systems have a direct impact on the population's health. In order to define the Romanian health financing policy, considering also the integration in the European Union, it is necessary to apply a comparative analysis of the funding policies of the EU member states. These are characterized by a large number of indicators/variables, with different values from one country to another.

The aim of the paper is to compare the funding policies of the health systems of European Union countries performing a Principal Component Analysis (PCA) in order to reduce the number of variables that characterize the health systems and to group the EU countries in clusters using a grouping procedure.

Selection of Health System Indicators/Variables

For the 27 countries of European Union 7 variables describing the features of the financing policy in the health sector were selected[1]:

- I1 – General government expenditure on health as a % of total expenditure on health
- I2 - General government expenditure on health as a % of total government expenditure
- I3 – Out-of –pocket expenditure as a % of private expenditure on health
- I4 – per capita government expenditure on health
- I5 – Per-capita total expenditure on health
- I6 – Private expenditure on health as a % of total expenditure on health
- I7 – Total expenditure on health as a % of Gross Domestic Product.

The 7 health system variables corresponding to each European country for the year 2000 are presented in Table 1, and in Table 2 for 2010.

Table 1. Values of the 7 health system variables for EU countries, for the year 2000

	I1	I2	I3	I4	I5	I6	I7
Sweden (S)	84.9	12.6	91.1	1938	2283	15.1	8.2
Poland (PL)	70	9.4	93.2	408	583	30	5.5
Austria (A)	76.8	14.7	66.1	2169	2824	23.2	9.9
Bulgaria (BG)	59.6	8.5	100	222	372	40.4	6.1
Czech Rep. (CZ)	90.3	14.1	100	885	980	9.7	6.5
Denmark (DK)	82.4	12.6	91	1960	2378	17.6	8.3
France (F)	79.4	15.5	34.4	2076	2615	20.6	10.1
Germany (D)	79.7	18.2	55.1	2128	2671	20.3	10.3
Italy (I)	72.5	12.7	89.1	1488	2052	27.5	8.1
Netherlands (NL)	63.1	11.4	24.3	1474	2337	36.9	8
UK (GB)	79.3	14.3	64.8	1454	1833	20.7	7
Estonia (EST)	77.5	11.3	88.5	404	521	22.5	5.3
Romania (RO)	67.7	9.2	100	202	298	32.3	5.2
Slovakia (SK)	85	10.7	76.4	612	720	15	6.6
Finland (FIN)	71.1	10.6	77	1317	1853	28.9	7.2
Hungary (H)	70.7	10.6	89.8	602	852	29.3	7
Ireland (IRL)	73.5	14.7	41.2	1326	1805	26.5	6.3
Belgium (B)	71.8	13.3	84.7	1807	2518	28.2	9.1
Cyprus (CY)	41.7	6.5	95.7	787	1889	58.3	5.7
Lithuania (LT)	54.4	8.8	96.8	260	479	45.6	6
Latvia (LV)	69.7	11.6	86.2	390	559	30.3	6.5
Luxembourg (L)	89.3	13.9	65.2	2800	3137	10.7	5.8

[1] World Health Organization, *Global Health Expenditure Database,* available at http://apps.who.int/nha/database/PreDataExplorer.aspx?d=1, [accessed on 01.20.2012]

Table 1 (cont.)

Malta (M)	72.5	12	96.9	2104	2903	27.5	6.8
Portugal (P)	72.5	14.9	80.8	1095	1509	27.5	8.8
Spain (S)	71.6	13.2	83.1	1100	1536	28.4	7.2
Slovenia (SLO)	74	13.1	44.1	1070	1447	26	8.3
Greece (GR)	60	10.1	94.5	870	1449	40	7.9

Source : *World Health Organization, Global Health Expenditure Database, http://apps.who.int/nha/database/PreDataExplorer.aspx?d=1*

The data set represents a (m x n) matrix, where m=27 is the number of countries and n=7 is the number of corresponding variables. Each country is represented by a line (a 7 dimensional vector) and each variable by a column (a 27 dimensional vector). From a geometrical point of view, the data appear as a cloud of m points in the n dimensional space[2]. When n is large (greater than 3), the graphical representation is not available. Therefore, in order to analyze the differences in medical expenditures in European countries, a data reduction procedure is necessary. The Principal Component Analysis is such a procedure: it helps us to reduce the large number of initial variables to a smaller set of variables, called principal components.

Table 2. Values of the 7 health system variables for EU countries, for the year 2010

	I1	I2	I3	I4	I5	I6	I7
Sweden (S)	81	15	90	3047	3757	19	10
Poland (PL)	73	12	81	1072	1476	27	7
Austria (A)	78	16	65	3401	4388	22	11
Bulgaria (BG)	54	10	97	516	947	46	7
Czech Rep. (CZ)	84	15	90	1716	2051	16	8
Denmark (DK)	85	17	88	3861	4537	15	11
France (F)	78	16	33	3130	4021	22	12
Germany (D)	77	19	57	3339	4332	23	12
Italy (I)	78	15	88	2345	3022	22	10
Netherlands (NL)	79	18	38	3991	5038	14	12
UK (GB)	84	16	62	2919	3480	16	10
Estonia (EST)	79	12	92	965	1226	21	6
Romania (RO)	78	11	98	633	811	22	6
Slovakia (SK)	66	14	89	1357	2060	34	9
Finland (FIN)	75	12	75	2462	3281	25	9
Hungary (H)	69	10	78	1019	1469	31	7
Ireland (IRL)	69	10	49	2562	3704	31	9
Belgium (B)	75	15	80	3009	4025	25	11
Cyprus (CY)	42	5	83	764	1842	58	6
Lithuania (LT)	61	9	97	668	1093	39	7

[2] Härdle, W., Simar, L., *Applied Multivariate Statistical Analysis,* Springer-Verlag, Berlin, Heidelberg 2003, 2007.

Table 2 (cont.)

Latvia (LV)	73	13	97	955	1299	27	7
Luxembourg (L)	84	15	73	5692	6743	16	8
Malta (M)	65	13	93	1481	2261	35	9
Portugal (P)	68	15	78	1921	2818	32	11
Spain (S)	73	15	76	2204	3027	27	10
Slovenia (SLO)	74	14	48	1879	2552	26	9
Greece (GR)	59	12	95	1695	2853	41	10

Source : World Health Organization, Global Health Expenditure Database, http://apps.who.int/nha/database/PreDataExplorer.aspx?d=1

Applying Principal Component Analysis

Principal Component Analysis is a technique for reducing a complex data set of correlated variables to a considerably smaller data set of uncorrelated variables, named principal components. In order to apply the PCA, we obtained some preliminary information about the mean, minimum, maximum and the standard deviation values of the sample of original variables. The information is presented in Table 3, for the year 2000 and in Table 4, for the year 2010.

Table 3. Mean, minimum, maximum and standard deviation of the sample of variables for year 2000

VARIABLES	I1	I2	I3	I4	I5	I6	I7
MEAN	72.6	12.2	78.1	1220.3	1644.6	27.4	7.3
MINIMUM	41.7	6.5	24.3	202	298	9.7	5.2
MAXIMUM	90.3	18.2	100	2800	3137	58.3	10.3
STANDARD DEVIATION	10.61	2.55	21.6	721.9	879.4	10.61	1.47

Source : made by the authors

Table 4. Mean, minimum, maximum and standard deviation of the sample of variables for year 2010

VARIABLES	I1	I2	I3	I4	I5	I6	I7
MEAN	72.6	13.5	77.4	2170.5	2893.1	27.1	9.0
MINIMUM	42.0	5.0	33.0	516.0	811.0	14.0	6.0
MAXIMUM	85.0	19.0	98.0	5692.0	6743.0	58.0	12.0
STANDARD DEVIATION	10.0	3.1	18.7	1258.7	1450.0	10.3	1.9

Source : made by the authors

We observe there are big differences between standard deviation of the variables, therefore it is necessary their standardization. Each standardized variable has a mean of 0 and a variance (standard deviation squared) equal to 1.

The matrix of correlation coefficients calculated and presented in Table 5 for year 2000 and Table 6 for year 2010, shows that some variables are strongly correlated, thus permitting the application of PCA in order to reduce the number of variables.

Table 5. Matrix of correlation coefficients for year 2000

	I1	I2	I3	I4	I5	I6	I7
I1	1.0000	0.6930	-0.2115	0.4949	0.2894	-1.0000	0.2561
I2	0.6930	1.0000	0.5473	0.6744	0.5710	-0.6930	0.6778
I3	-0.2115	-0.5473	1.0000	-0.4460	-0.4549	0.2115	-0.4647
I4	0.4949	0.6744	-0.4460	1.0000	0.9675	-0.4949	0.6090
I5	0.2894	0.5710	-0.4549	0.9675	1.0000	-0.2894	0.6207
I6	-1.0000	-0.6930	0.2115	-0.4949	-0.2894	1.0000	-0.2561
I7	0.2561	0.6778	-0.4647	0.6090	0.6207	-0.2561	1.0000

Source : made by the authors

Table 6. Matrix of correlation coefficients for year 2010

	I1	I2	I3	I4	I5	I6	I7
I1	1.0000	0.7568	-0.2806	-0.6084	0.4945	-0.9915	0.3814
I2	0.7568	1.0000	-0.4160	0.7014	0.6507	-0.7765	-0.7986
I3	-0.2806	-0.4160	1.0000	-0.5434	-0.5736	0.3288	-0.5774
I4	0.6084	0.7014	-0.5434	1.0000	0.9868	-0.6310	0.6780
I5	0.4945	0.6507	-0.5736	0.9868	1.0000	-0.5208	0.7136
I6	-0.9915	-0.7765	0.3288	-0.6310	-0.5208	1.0000	-0.4121
I7	-0.3814	0.7986	-0.5774	0.6780	0.7136	-0.4121	1.0000

Source : made by the authors

A very nice property in a PCA is the following[3]: the variances of the principal components PC_i are the eigenvalues[4] λ_i of the correlation matrix. The values of these variances (calculated in Matlab[5] for the year 2000, respectively 2010) arranged in descending order, are presented in Table 7. The first principal component has the largest variance, followed by the second principal component and so on; the last principal component has the lowest variance[6]. Note that the total variance of the cloud of the points (i.e the sum of the variances of the variables) remains constant after this transformation. Thus, in our case, the sum of the variances of the principal components is 7, because the original 7 variables have been standardized (for each variable the mean is equal to 0 and the variance equal to 1).

Table 7. The variances of the principal components

Year	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7
2000	4.1815	1.4582	0.7130	0.4926	0.1476	0.0070	0.0000
2010	4,7126	1,1819	0.5240	0.5088	0.0636	0.0070	0.0021

Source : made by the authors

[3] H ä r d l e , W., S i m a r , L., *Applied Multivariate Statistical Analysis,* Springer-Verlag, Berlin, Heidelberg 2003, 2007

[4] D e m i d o v i c h , B.P., M a r o n I.A., *Computational Mathematics,* Mir Publishers, 1981.

[5] *** Matlab 7.7.0 (R2008b), MathWorks, Natick, Massachusetts, U.S.A

[6] S p i r c u , L., *Analiza Datelor: Aplicații Economice,* ASE Publishing House, Bucharest, 2006. available at http://www.biblioteca-digitala.ase.ro/biblioteca/carte2.asp?id=489&idb= [accessed on 02.21.2012].

The proportion of variance accounted for by each principal component can be calculated by the following formula:

$$proportion = \lambda_i \Big/ \sum_{i=1}^{n} \lambda_i \qquad (1)$$

The first two principal components combined, account for 80.57% of the total variance for the year 2000 and 84.21% for the year 2010. Therefore, it is possible to reduce the number of variables to the first two principal components, without much loss of initial information.

The correlations between the two principal components (noted FPC, respectively SPC) and the initial variables, as well as the sum of squared correlation coefficients are presented in Table 8 for the year 2000, respectively in Table 9 for the year 2010. The sum of squared correlation coefficients is very close to 1, for the variables I1, I2, I4, I5, I6, in both cases. Therefore, these variables are very well explained by the first two principal components.

Table 8. Correlation coefficients between principal components and initial variables for the year 2000

	corr(Ii, FPC)	**corr(Ii, SPC)**	**Sum of squared correlation coefficients**
I1	-0.7353	0.6711	0.9910
I2	-0.9056	0.0930	0.8287
I3	0.5957	0.3576	0.4828
I4	-0.8828	-0.2419	0.8379
I5	-0.7907	-0.4476	0.8256
I6	0.7353	-0.6711	0.9910
I7	-0.7215	-0.4028	0.6829

Source: made by the authors

Table 9. Correlation coefficients between principal components and initial variables for the year 2010

	corr(Ii, FPC)	**corr(Ii, SPC)**	**Sum of squared correlation coefficients**
I1	-0.7954	0.5841	0.9738
I2	-0.8984	0.1504	0.8297
I3	0.6242	0.4966	0.6362
I4	-0.9071	-0.1795	0.8550
I5	-0.8689	-0.3186	0.8565
I6	0.8200	-0.5458	0.9702
I7	-0.7957	0.3740	0.7731

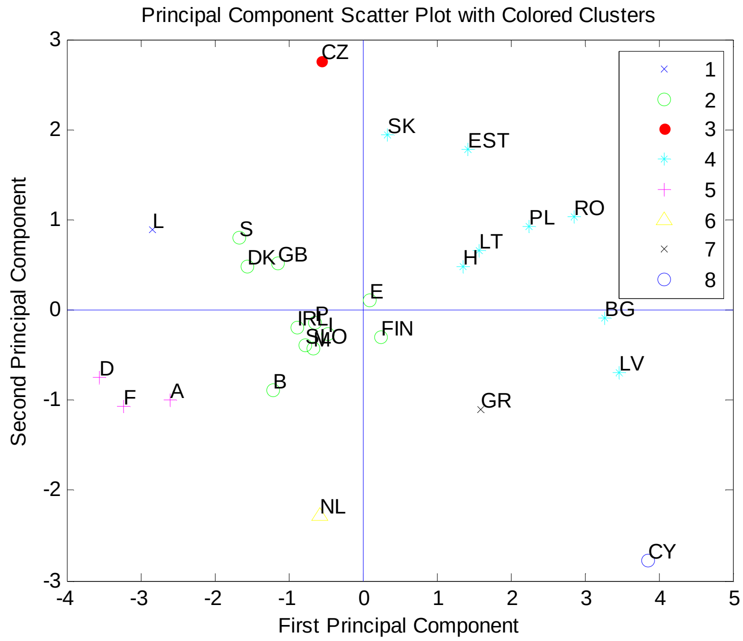
Source: made by the authors

Results and Discussion

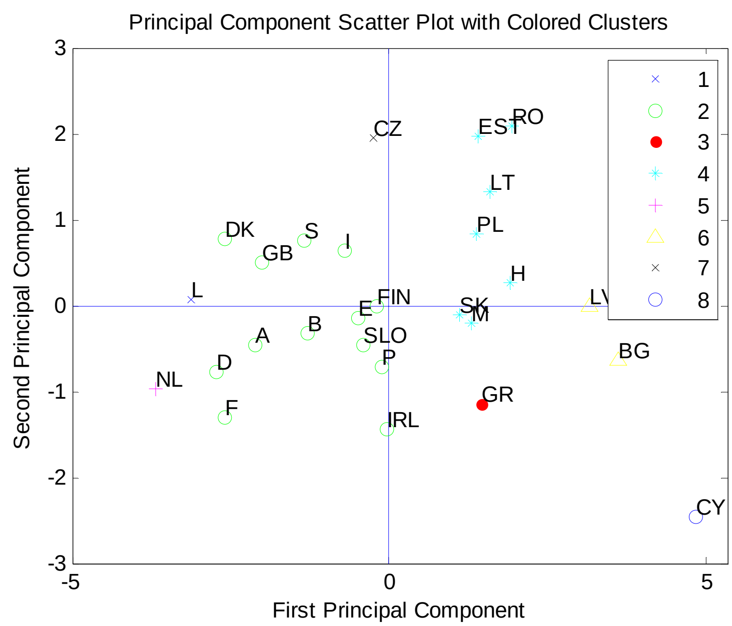
As a result of applying the PCA technique, each European country can be represented as a point in the Cartesian coordinate system determined by the first two principal components axis. When the data are standardized (our case), the origin of the coordinate system coincides with the centroid (the mean of the standardized dataset). The two principal components scatter plots obtained by using the Matlab's functions[7] (Figure 1a and Figure 1b) show the position of each

[7] . Matlab 7.7.0 (R2008b), MathWorks, Natick, Massachusetts, U.S.A.

country in this coordinate system. At the same time, groups of EU countries with similar health policy, called clusters[8], were also identified.



a)



b)

Fig. 1. Principal component scatter plot with colored clusters for the years 2000 (a) and 2010**(**b**)**

Source : made by the authors

[8] . Härdle, W., Simar, L., *Applied Multivariate Statistical Analysis,* Springer-Verlag, Berlin, Heidelberg 2003, 2007

There are three main clusters, for the year 2000: cluster 2, cluster 4 and cluster 5.

Cluster 2, consisting of Sweden, Denmark, United Kingdom, Belgium, Spain, Finland, Ireland, Portugal, Malta, Italy and Slovenia, groups countries having the health expenditure per capita closer to the European average.

Cluster 4, consisting of ex-socialist countries, except for Slovenia and Czech Republic, groups countries having the health expenditure per capita lower than the European average. The main part of the health expenditure of these countries consists of out-of-pocket expenditures.

Cluster 5, consisting of France, Germany and Austria, has the biggest health expenditure per capita.

In 2010 (Figure 1b), new countries were added to Cluster 2: Germany, France, Austria, Netherlands and Slovakia.

Romania occupies the former position of the Czech Republic, having the lowest percent of private expenditures in the total health expenditures.

Cluster 6, consisting of Bulgaria and Latvia, are spending even less money for health than the countries in cluster 4.

Comparing the position of each country between the years 2000-2010, the clusters dynamic presented in Figure 2 is obtained.

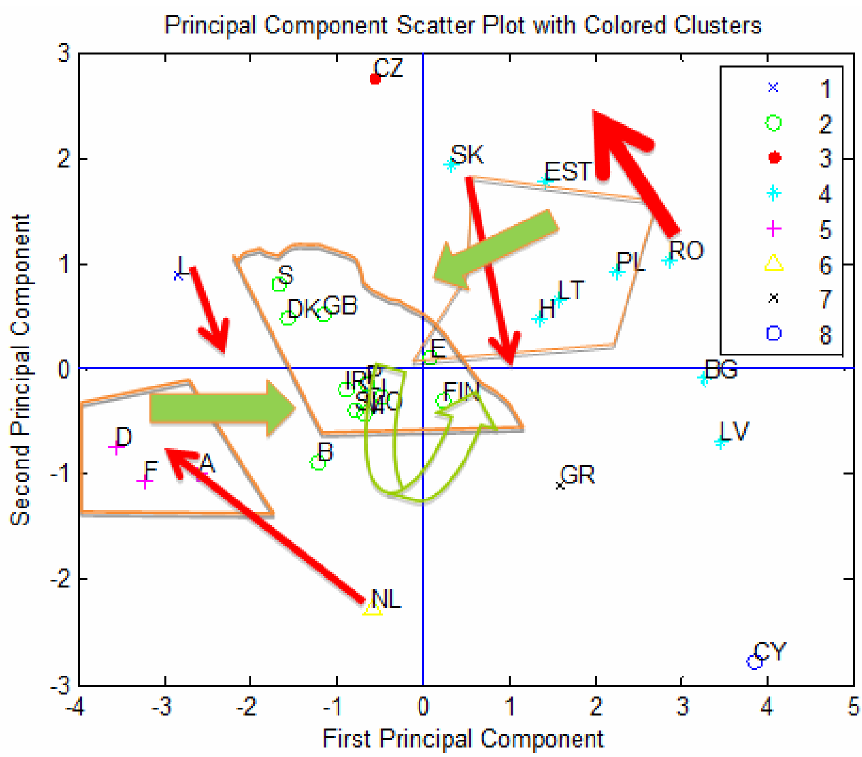


Fig. 2. Clusters dynamics between years 2000-2010

Source: made by the authors

- There is a trend of the most developed EU countries to evolve towards the center of the axes. Among them we can mention : Austria, Germany, France, Belgium, Italy and Denmark;
- There are also some different and specific evolutions, like the health systems of Netherlands, Ireland, and Slovakia. Slovakia has been presenting a spectacular evolution

over the past 10 years, leaving the cluster of the transitional countries and reaching the proximity of the most developped countries cluster, close to the center of the axes. Netherlands and Ireland followed a different trend compared to the other developped countries.

- There are also some countries, like Greece, Estonie and Cyprus, that kept almost the same positions in the clusters.
- Romania follows the trend of the ex-comunist countries cluster, but towards an opposite direction, compared to the other cluster members.Instead of approaching the area of the most developped EU countries, Romania takes a different trend, proving that the political reforms made in the past ten years didn't reach the real issues of the system.
- Bulgaria and Lithuania present the same situation as Romania, following an opposite trend compared to the developped EU countries.

Conclusions

The application of Principal Component Analysis proved as a useful technique for solving the problem of reducing the number of variables that describe the health expenditures in the health systems. The smaller number (only 2) of artificial variables accounts for most of the variance in the initial data set.

Cluster Analysis assigned the countries into groups with similar medical expenditure policies, offering the possibility to compare the different clusters.

A proper strategy is needed in order to integrate Romania in the cluster group of the most developed European countries.

References

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Model matematic de analiză a performanțelor financiare ale sistemelor de sănătate din țările membre ale Uniunii Europene

Rezumat

Articolul realizează o analiză comparativă a strategiilor de finanțare a sistemelor de sănătate din cele 27 de țări membre ale Uniunii Europene, pe baza unui număr de şapte indicatori economico-financiari semnificativi, cu scopul evidențierii modului în care au evoluat politicile de finanțare a sistemelor de sănătate din țările analizate în perioada 2000-2010.

Pentru prelucrarea informațiilor conținute într-o matrice de date cu dimensiunea 27 (țări membre UE) x 7 (indicatori reprezentativi), greu de vizualizat, se aplică Analiza Componentelor Principale şi Analiza Cluster.