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Convergence between the Romanian and the EU RD&I Systems

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CONVERGENCE BETWEEN THE ROMANIAN AND THE EU RD&I SYSTEMS*

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The globalisation of economy and communications, quick technological progress and its social implications led to the creation of the European Research Area, an important objective for the convergence of national RD&I systems.

The monitoring of convergence process is achieved, since 2000, through a system of indicators, developed and refined every year, in order to make them consistent with new trends and requirements for relevant and systemic expression of the progress made in the RD&I field, in relation to both inputs and outputs and RD&I contribution as a determinant factor of improving national and European competitiveness.

This paper analyses the progress made in the last six years in achieving the convergence of European RD&I systems, the factors that have accelerated or slowed down the process, laying the stress on Romania's position in closing the gaps that separate it from European average and from the leaders in this area. For this purpose, we tested a model for estimating the degree of convergence of the Romanian RD&I system with the EU27 system by the clustering method.

Keywords: *European Research Area (ERA), convergence of RD&I systems, innovation gaps, clustering.*
JEL: *F15; O32; O47*

1. The European Research Area – An important step towards the convergence of the European Research Systems

The *European Research Area* was based on a new vision concerning the research activity and the related policies on the European level, focused on eliminating the weaknesses and fragmentation of the European RD&I system, improving performance, coordinating EU member states policies and developing the inter-European and international scientific cooperation, in order to ensure the convergence of the national RD&I systems.

Based on the analysis of the gap between Europe, on the one hand, and the USA and Japan, on the other hand, the European Commission proposed, in January 2000, the creation of the European Research Area[1]. The heads of state and government

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[1] Commission of the European Communities, Communication: "Towards a European Research Area", COM (2000), 18th January, 2000; Communication from the Commission to the Council, the

fully accepted the project at the European Council in Lisbon (23-24th March, 2000), as a basic element for the development, by 2010, of the European competitive knowledge-based society, able to create new jobs and social cohesion.

The idea to create and consolidate a "European Research Area" (ERA), although not a new one, found a favourable political and academic environment in 2000. Gradually, the ERA changed from a concept, as a result of a political wish to overcome the weakness and fragmentation of European RD&I, into a coherent and effective policy and a many-sided practical approach.

Guided by several strategic documents of the European Commission issued between 2000-2007[2], the ERA underwent several development stages, having specific objectives and instruments, such as: Framework Programme VI, ERA-NET, ESFRI (European Strategy Forum for Research Infrastructure), Marie Curie Programme and European Charter for Researchers, OMP (Open Method of Coordination), European Innovation Scoreboard, etc.

In compliance with the ERA, national RD&I policies should be correlated and implemented coherently, as parts of the European RD&I system.

The action taken to build the ERA resulted in a certain degree of similarity and convergence between the objectives of national RD&I policies, especially due to the coordination at the EU level both by Commission Communications, Open Method of Coordination and interactions and exchange of good practices between member states and acceding countries, on the one hand, and by imitation of priorities set within RD&I Framework Programmes,on the other hand.

There are other common priorities, such as research of excellence or increasing competitiveness by innovation, resulted from increasing globalisation.

The progress made in building ERA differs from one country to another and from one field to another. Issues concerning the creation of European labour market for researchers or increasing private investment in the RD&I field require further efforts to attain ERA objectives.

Box 1
Guidelines to achieve the ERA in the period 2000-2007, determinant for RD&I system convergence

I. Use of public instruments and resources
- Creation of networks of Centres of Excellence (CoEs) and Integrated Projects (IPs)
- Integrated Infrastructure in FP6.
- European Strategy Forum for Research Infrastructures Roadmap for Europe (ESFRI), 2006
- Communication Network Development, in FP6, which resulted in e-infrastructures for European Scientific Community: GEANT, EGEE, DEISA.
- ERA-NET

European Parliament, the Economic and Social Committee and the Committee of the Regions: "Making a reality of the European Research Area: Guidelines for EU research activities (2002-2006)".

[2] EC Communications: "Towards a European research Area" (2000); "The ERA Providing New Momentum" (2002); "Building the ERA of Knowledge for Growth" (2005), and the recent "Green Paper: The European Research Area. New Perspectives" (2007).

- Technological Platforms

II. Stimulation of private investment
- Regulation of State Aid to RD&I through New Community Framework for RD&I State Aid (2006)
- Fiscal incentives of RD&I through Commission Communication 2006: "Towards a More Effective Use of Tax Incentives in Favour of RD&I"

III. Protection of Intellectual Property
- WIPO Standard Committee on Law of Patent, 2003
- EU Patent Strategy, to be issued

IV. Stimulation of risk capital to invest in RD&I
- Guidelines on State Aid for Risk Capital, 2001, revised in 2006
- Adoption of Competitiveness and Innovation Programme (CIP), supported by European Investment Fund

V. A common system of reference for RD&I strategies
- Creation of SINAPSE Web Communication Platform

VI. Stimulation of human resource mobility
- European charter for Researchers and Code of Conducts for their Recruitment
- One Directive and two Recommendations for permission and residence for researchers in third countries, October 2005
- Pan-European Researchers Mobility Portal
- European Network of Mobility Centres (ERA MORE)

VII. Women's and youth's involvement in RD&I
- Gender Action Plan

VIII. Increasing the role of regions in European RD&I
- European Regional Development Fund in support of RD&I in less developed areas

XI. Development of academic research
- European Research Council
- Mobility within Marie Curie Programme
- More EU funding for academic research from 50% to 75% of all eligible costs

Source: Processed by the author, based on data from: Commission Staff Working Document Accompanying the Green Paper: " The European Research Area: New Perspectives", Brussels, 4/4, 2007, pp. 20-31.

Some of the principles on which the European Research Area is based are the following: research for improving competitiveness and meeting the people's expectations; promotion of excellence; balanced and coherent development of technology in all Europe[3]; complementarity's between the EU and the member states' research.

[3] http://europa.eu.int/comm/research/area.html.

To make a Romanian Research Area, several EU priority measures[4] were guided the policy-makers, as follows:

1. The optimisation of the material resource stock and facilities on the European level by: creating networks of centres of excellence; developing a European approach to research incentives; developing electronic networks and encouraging their use by European researchers.

2. The coherent utilisation of public resources and tools by: their decentralisation, as well as by a closer national and European coordination of the research programmes and a closer cooperation among the European institutions of science and technology.

3. The stimulation of the investment in the private sector by: concerted use of the tools for direct research support; higher protection of the intellectual property; new ways to stimulate emerging companies and risk capital.

4. The creation of a common reference system in the science and technology field so that the research activity respond, to a greater extent, to the citizens' and decision-makers' needs.

5. The rise of the amount and mobility of the human resources by a higher mobility of the researchers from one country to another and between the academic community and the industry, more support for the research career, better positions and jobs for female researchers, making the RD&I more attractive to the youth.

6. The improvement of the European research environment to become more dynamic, open and attractive to the researchers and investors by assigning a more active role to the regions, integrating the Western and Eastern European scientific communities and stimulating foreign (non-EU) researchers to join the European research.

7. The creation of an Area of European values by finding common and convergent answers to the question concerning the relation between science and society and improving the coordination between national mechanisms.

Romania's position regarding the integration into the ERA was based on official documents concerning the acceptance of the Community acquis on science and research and the strategically targets, such as:

1. Increasing legislative, financial and organisational support for the participation in the EU Framework Programmes.

2. Preparing the RD&I field for the accession and integration into the European Research Area.

3. Correlating the national research programmes, creating networks of excellence and drawing-up large targeted research projects.

Romania undertakes to correlate the national RD&I programmes with the EU programmes, pursues to attain the ERA objectives and takes corresponding measures. The priorities for scientific research and technological development, as formulated in the position papers on the integration into the ERA, bear the specific national mark and result from the urgent need to restructure and remodel some more inert structural components of the RD&I system, in accordance with the present needs and future prospects of the country. In accordance with the EU's

[4] Commission for the European Communities, Communication: "The European Research Area: New perspectives". Green Paper, COM (2007), 161 final, SEC (2007), 412.

objective of the RD&I expenditures in GDP, one of the specific objectives of the Romanian RD&I Strategy 2007-2013 is to increase private expenditures on RD&I to 1.5% of the GDP by 2013. Among the means to attain this objective, the Strategy includes fiscal incentives for the private investment in RD&I and adequate accounting of these expenditures[5]. Structural funds devoted to innovation and development of human resources will complement public investment in RD&I. According to National Strategy for Research, Development and Innovation, between 2007-2013 Romanian RD&I basic indicators will catch up with European average.

The progress made by Romania in the process of integration into the ERA is monitored by the National Authority for Scientific Research (NASR). According to a recent report of this institution[6], the efforts have been oriented "towards restructuring and consolidating a Romanian Area of Research (ARC), which may properly respond to the highly demanding needs of compatibility, necessary for the integration into the European Research Area (ERA)".

The Romanian scientific community's integration into the ERA is supported by the NASR's measures taken to improve the quantitative and qualitative structures, as well as the performance of the RD&I system. Directing the research programmes towards hi-tech fields, consolidating the poles of excellence in these fields, increasing the capability of the national RD&I system to meet the ERA specific requirements, increasing the international visibility of Romanian researchers and their involvement in finding solutions to the economic and social problems, allotting additional funds for the RD&I, especially private ones, for the fulfilment of the 3% target, are priority objectives of the NASR.

2. The convergence of the EU countries' RD&I systems

The 2006 European Innovation Scoreboard, (Figure 1), shows that six years after the initiation of the ERA Project there still are differences among the European countries in their innovative performance, measured by the Summary Innovation Index, the major component of which is scientific research. Only a few countries may compete with Japan or the USA, so that reducing the performance gap is still a real challenge. Sweden, Finland, Denmark and Germany continue to be "the European leaders in innovation".

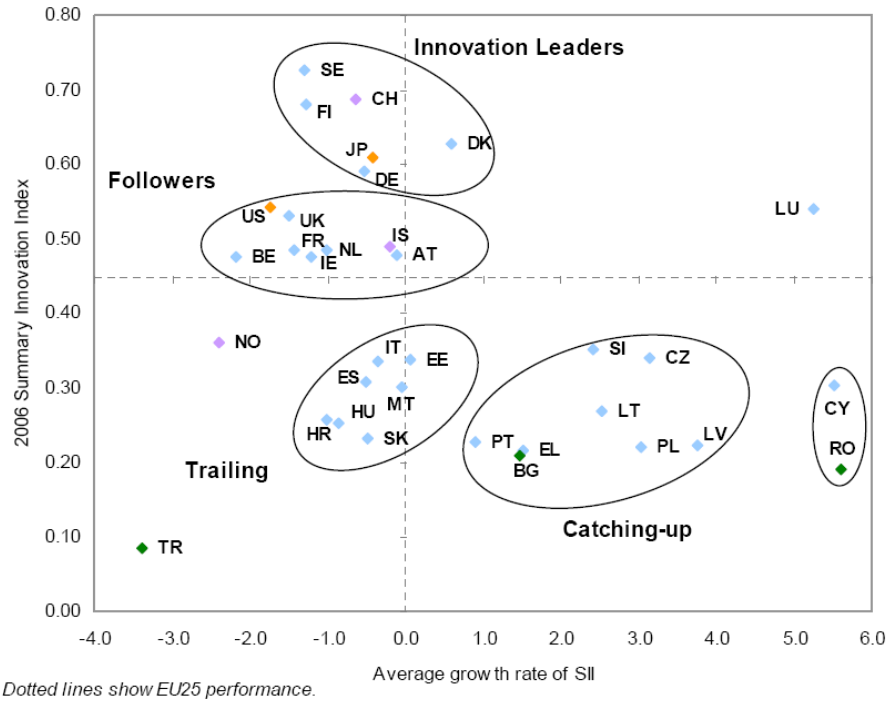
The gap between the leaders and the second group of countries (including the United Kingdom, Ireland, France, the Netherlands, Belgium, Austria and Iceland) considered "innovation followers" still mist. However, another cluster, including the "catching-up" countries (Slovenia, the Czech Republic, Lithuania, Portugal, Poland, Latvia, Greece and Bulgaria), have partially closed the gap by rates above the average, although their innovative performance is below the EU-25 average and

[5] The Government Decision 217/2007 concerning the approval of the National Strategy for Research, Development and Innovation between 2007-2013, published in the Official Monitor, No. 214 of March 2007.

[6] National Authority for Scientific Research, "Government Policies in the Field of RD&I and Innovation in Romania", 2006 Report, Bucharest, December 2006.

the average of the second cluster mentioned above. The fourth cluster contains the "trailing countries", with a performance below that of the first two groups and a growth rate close to or below the EU-25 average.

The European experts[7] consider that "the results from this year's Innovation Scoreboard suggest that there is a process of convergence in the innovation performance of European countries. That is, the catching-up countries are closing the gap with the EU-25 and both the innovation leaders and followers".



Source: 2006 European Innovation Scoreboard, p. 4.

Figure 1. Country classification by the size and growth rate of the SII in 2006.

While the 2005 European Innovation Scoreboard included Romania in the country group estimated to close the gap with the European average in 50 years, the 2006 scoreboard includes Romania and Cyprus in the group of "fast growing, catching up countries"; however this group is less consolidated. In Romania, the share of the RD&I expenditures in the GDP, although on the rise in 2005, accounts for about one-fifth of the EU-15 average level.

[7] European Commission, DG Enterprise and Industry: "European Innovation, a work in progress", in: European Innovation, March 2007, p. 22.

An important indicator of the RD&I dispersion within the EU countries is the total RD&I expenditure in the GDP in correlation with their dynamics, since there are major divergences between European countries.

According to the most recent Report – on Key RD&I indicators[8] the gap between the countries with highest RD&I intensity (Sweden, Finland) and the lowest RD&I intensity (Cyprus, Romania) is of 9:1. The high innovative performance of the Northern countries is ensured, among others, by the high RD&I intensity. Sweden and Finland allotted the largest share of the GDP to RD&I in 2005 (3.86% and 3.45%, respectively) and achieved a high growth rate between 2000-2005, in comparison with Romania and Bulgaria, for example, as they allotted a lower share of the GDP for RD&I expenditures (0.41% and 0.50%) and achieved negative growth rates (-3.98% and -2.59%) in 2004.

A positive trend is the considerable effort made in the last year by the recent EU members, including Romania, to close the gap with the EU average. In Romania, the share of the public expenditure on RD&I in the GDP has reached 56% in 2007, which is supposed to help our country reduce the gap with the EU average. In 2005, the share of the RD&I expenditure in the GDP increased to 41%, according to the 2006 Romanian Statistical Yearbook.

Table 1

Private sector contribution to RD&I funding in 2005 - percent -

EU 27	54.5	Cyprus	18.9
Luxembourg	80.4	Romania	37.2
Switzerland	69.7	Spain	48
Finland	69.3	Italy	43
Germany	66.8	Austria	45
Estonia	36.5	Iceland	43.9
Greece	28.2	United Kingdom	44
Poland	30.3	Croatia	42
Bulgaria	28.2	Turkey	41

Source: Key Figures 2007, p. 56. For Romania, Statistical Yearbook, 2006.

Table 1 shows significant differences in private sector contribution to RD&I. There are three main groups of countries:

1. Countries with a private sector contribution over 65% (Germany, Finland, Switzerland, Luxembourg);
2. Countries with a private sector contribution between 40-50%;
3. Countries with a low private sector contribution, most of them new member countries.

[8] Key Figures 2007 on Science, Technology and Innovation. Towards a European Knowledge Area. 11 June 2007, pp. 2-3.

The mobilisation of the business sector, by specific policies, to increase its financial contribution to the RD&I is an important factor for further increasing the RD&I intensity and for closing the structural and intensity gap among the EU countries.

The contribution of the Romanian business sector to the RD&I expenditures diminished to 45.4% in 2003, 43.9% in 2004, and 37.2% in 2005.

Closing the gap in the sectoral distribution of the RD&I funds provided by the private sector among the high-tech (HT), the medium high-tech (MHT), medium low-tech (MLT) and low-tech (LT) sectors, represents another dimension of the convergence of the European RD&I systems.

According to Key Indicator 2007 there are countries that allocate considerable amounts to the high-tech sector (Slovenia – 70.3%, Finland – 66.4%, Ireland and United Kingdom – 62%, Sweden – 58.5%, Denmark – 57.9%), countries where the private contribution prevails in the MT sectors (Czech Republic, Germany and Lithuania) and countries where funding is balanced between the HT sector and the MT sector (France, Spain, Italy, Poland). Very few countries support the LT sectors (Malta, Lithuania, Croatia, Cyprus)[9].

The development of the RD&I activity, especially the transfer of the research outcome to the users, depends heavily on the SMEs' place in the allocation of funds. Considering the fact that over 95% of the European companies are SMEs and that they employ over 75% of the available labour force in the EU, it is obvious that successful innovation depends on the involvement of this sector in the RD&I activity by specific financing instruments, like venture capital. The involvement of the venture capital in the innovative SMEs in Romania is recent and the access to financial resources is hindered by institutional and legislative barriers.

The specific features of the venture capital in the Romanian market are the following:

- The main fields of interest for venture capital funding are: information technology, mass media, automation and control of industrial processes, agriculture, pharmaceutical industry, tourism, financial services, sanitation.
- The investment value varies between 500 thou. USD and 20 bill. USD and it may be also ensured by syndicates that could cover the funding when the maximum limit of one fund is exceeded.
- The focus is on the companies with a high development potential and a managerial team familiar with the business to be financed.
- The profitability rate is at least 30%, in USD.
- The investment decision is based on the business plan reflecting the competitive advantage for attaining the objective; also, the profitability should be

[9] According to Key Figures 2007, p. 56.

proportional to the risk. Other documents taken into account are the account books of the last three years and the CVs of the executive staff.

- The funds are not aimed at holding the majority share, but they are rather focused on selecting and supporting managerial teams able to get acquainted with the business and the company.

- The funds do not leave the companies in which they were invested at the expiration time, but when the share price is the highest. To get higher share price, the funds request the company listing at the stock exchange or quotation on the over-the-counter market.

The workforce involved in the RD&I activity is another indicator when analysing the efforts made to create the ERA, considering the considerable gap both between the EU and the international competitors, and among the EU countries themselves in the number of researchers per one thousand employed people.

One may notice the direct relation between the research intensity and the size of this particular indicator. It is not surprising that Finland and Sweden, with the highest RD&I intensity, have the largest number of researchers per 1000 employed people, in comparison with the new member countries or South-European countries. By ranking the countries by the above indicator and analysing its growth rate a wide gap can easily be pointed out. The countries facing problems are those with a high growth rate but with still low research intensity (Spain, Greece, Hungary, Portugal), or with a negative or very low growth rate but with a small number of researchers (Slovakia, Lithuania, Estonia, Poland, Italy).

The official data on Romania, expressed in number of researchers per 1000 employed people, show an upward trend since 2000, from 2.69 to 3.53 (2005), as against the negative growth rate of – 8.2% between 1996-2000. Out of about 41035 employees in 2005 (as against 40725 in 2004), 29608 were researchers (as against 27253 in 2004), and over 50% of them worked in engineering sciences. The number of recognized researchers was 10339 in 2005, as against 9318 in 2004, and the number of doctors in sciences was 8746 in 2005, as against 8954 in 2004. According to the CREST experts[10], the low level of the wages of the RD&I personnel and improper equipment caused the intensification of the external migration of the young researchers, especially to the USA, which further caused a higher age average of the RD&I personnel in Romania.

The analysis of the dynamics and distribution of the researchers by sectors (public sector, private sector and higher education sector), also proves the existence of differences within several groups of European countries:

[10] Policy Mix Peer Reviews: The Report of the CREST Policy Mix Working Group, Second Cycle of the Open Method of Coordination for the Implementation of the 3% Action Plan in Romania, prepared by Ken Guy, Wise Guys Ltd., March, 2006.

- Countries with a higher proportion of private sector researchers (Luxembourg, Austria, Ireland, France, the Netherlands and Sweden).

- Countries with a balanced distribution of the researchers (Hungary, Czech R., Slovenia).

- Countries with a higher proportion of researchers employed in the higher education system (Portugal, Estonia, Lithuania, Poland).

The data prove that there is a great difference among the EU countries in the researchers' distribution by sector. According to *Key Figures 2005*, the private sector share varies from 66.8% (Ireland) to 6.7% (Lithuania), the government sector share, from 4.1% (Austria) to 32% (Slovenia) and the higher education share, from 67.8% (Lithuania) to 27.2% (Germany). In 2005, the Romanians employed in business sector research activities represented 56% of the total. Out of the total number of RD&I employees, 25% worked in the government sector, 33.86% in the higher education sector and only 0.58% in the non-profit private sector.

There are even greater disparities between the EU countries in regard to their RD&I output. Most patents recognized simultaneously by the three most important institutions – the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) – are concentrated in a few countries (Germany, France, United Kingdom, Netherlands, Sweden and Italy).

Switzerland, Germany, Finland, Sweden and the Netherlands are ranked on top according to the number of patents recognized by both the EPO and the USPTO.

Also, the high-tech goods export share in total exports – which shows the level of involvement in the world division of labour and the competitiveness of the products resulted from the RD&I activity – is different within the EU. There are countries with a high rate of high-tech exports (Malta, Ireland, Luxembourg or Hungary), beyond that of the USA or Japan, and countries with an insignificant rate of high-tech exports in total exports (Lithuania, Slovakia, Latvia or Poland).

The country with the most dynamic export in 2003 was the Czech Republic (an impressive rate of 31.4%), followed by smaller countries (Belgium, Luxembourg, Greece, Hungary, Austria and Ireland). It is worth mentioning that there were some large countries (France or the United Kingdom) with a negative rate of the indicator.

Although small in amount, if compared to other economic sectors, Romania's software and ITC service exports are characterized by a high growth rate. In the last eight years Romania's exports in accordance with NACE 72 have increased 24 times, *i.e.*, from 10 million USD in 1997 to 240 million in 2004.

Table 2

Romania's software and IT service exports, 1997-2004

	1997	2000	2002	2003	2004
Exports, mill. USD	10	68	130	175	245
Growth rate		134%	33%	35%	40%

Share in NACE 72 production	16%	40%	41%	37%	34%
Share in NACE 722 production		69%	68%	57%	56%

Source: INSSE, 2005.

3. Assessment of the convergence of Romania's and EU's RD&I systems by the clustering method

Special methods and "distance indicators" are needed for testing the proximity to and remoteness from a group of countries or from their average.

The clustering enables us to group some countries according to their common features and find out how the countries move from one group to another in time. The grouping of the countries is based on the geometrical distance among them and on a set of parameters. In practice, four clustering methods are used:

- k-means clustering;
- hierarchical clustering;
- fuzzy C-means clustering;
- Gaussian clustering.

Our study is based on two frequently used methods for testing the integration or the belonging to a group with common features:

- The *individual clustering model,* for testing the belonging to a group by means of a set of relevant indicators (hierarchical clustering, mean-based clustering).

- The *distance computation model*, a simpler model which entails the measurement of (Euclidean, Minkovski and Cebishev type, etc.) distances in relation to the mean of a group of countries or to a country considered as representative.

In order to test the convergence between Romania and the EU countries we have used the first two methods.

3.1. k-means clustering method

This is a model suggested by MacQueen (1967)[11], considered as the simplest clustering algorithm. The procedure is easy when applied to a definite number of clusters (equal to k). It requires to initially (and carefully) set a number of k centroids in accordance with the number of identified centroids.

The centroids should be placed as far from each other as possible. The next step is to place every country or group of countries as close to the centroid as possible. After this preliminary grouping, we compute the centroid again and re-position the k-clusters set during the previous process, and then we re-position the

[11] J.B. MacQeen (1967), "Some Methods for Classification and Analysis of Multivariate Observations", Proceedings of the 5th Berkeley Symposium on Mathematical Statistics and Probability, Berkeley, University of California Press, 1:281-297.

countries in relation to the new centroids. This way, we get a country loop. Later, the centroids change position step by step until no move is possible and they reach a fixed position on the chart. The methodology implies the maximisation of an objective function for a square function of the errors, as follows:

$$J = \sum_{j-1}^{k} \sum_{i-1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \quad (1)$$

where: $\left\| x_i^{(j)} - c_j \right\|^2$ is a distance measured between each country $\mathbf{x^j_i}$ and the centroid of each cluster c_j.

This clustering method is very easy and quite common to the economic analyses and convergence tests based on the distance between various individuals. The more complex fuzzy-C means clustering was developed based on the k-means clustering method.

3.2. Hierarchical clustering method

The hierarchical clustering was developed by S.C. Johnson (1967)[12] and further by R. D'andrade (1978)[13]. Countries are also grouped by their common features. Considering the N countries, we get a matrix of the distances (or similarities) consisting of NxN distances.

To cluster the European countries, the following steps were considered:

1. Each country was associated with a cluster, so N clusters were generated for N countries; each cluster contained one country. In this case, the distances (similarities) between clusters are equal to the distances (similarities) between countries.

2. We selected the closest pair of clusters and included them in a single cluster, so we got N-1 clusters; one of them consisted of two countries.

3. We determined the distances in relation to the new cluster and the initial clusters.

4. We repeated steps 2 and 3 until all countries were included in a cluster of N size.

The hierarchical clustering includes several clustering schemes:

- *The single linkage clustering*. According to this scheme, the distance between one cluster and another one is equal to the shortest distance between one individual and a cluster and the shortest distance between other individual and other cluster.

- *The complete linkage clustering*. It implies that the distance between one cluster and another one is equal to the longest distance between one member and one cluster and any other member of another cluster.

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[12] S.C. Johnson (1967), "Hierarchical Clustering Schemes", *Psychometrika*, 2:241-254.

[13] R. D'Andrade (1978) "U-Statistic Hierarchical Clustering", *Psychometrika*, 4:58-67.

- *The average linkage clustering*. According to this scheme, the distance between one cluster and another cluster is equal to the average distance between any member of a cluster and any member of another cluster.

The hierarchical clustering scheme based on a single linkage is the following:

1. First, we select an N number of countries;

2. We build the NxN matrix of countries by means of an indicator relevant to our analysis;

3. The first insertion requiers finding the minimum distance between two countries, N_i and N_j, from the set of N countries in relation to the minimum distance between the two clusters:

$$d[(N_i),(N_j)] = min\ d[(i),(j)] \quad (2)$$

4. We build a cluster of N_i and N_j, with the above minimum distance.

5. Further, we determine a new minimum distance between countries of the N-1 set of countries.

6. We repeat the above operations and get several country linkage trees.

These trees allow the qualitative analysis of the linkages between the countries by means of a set of indicators relevant to our analysis.

3.3. The set of indicators and data included in the model

To identify the similarity among the EU countries and to find what country is closest to Romania we used the 1999-2005 data for a set of relevant indicators:

1. *General expenditure on RD&I (GERD, %) – share in GDP*

This indicator is computed as percentage of the GDP and expresses the overall resources allocated for acquiring the knowledge necessary to develop projects to the benefit of the society.

2. *Expenditure on RD&I made by industry (GERDI)*

3. *General expenditure on the RD&I from abroad (GERDA, %)*

This indicator measures the expenditure on the RD&I made by foreign companies. It is quite relevant for small countries, as major importers of foreign capital. Foreign investment is decisive.

4. *Graduates from the technology and science areas (ABS, number of graduates)* per 1000 people aged between 20-29. These graduates come from state and private higher education institutions and are presently undergoing post-academic training. The field of education and the level of training correspond to the International Standard of Classification in Education and Training (1999).

5. *EPO patents (PATEPO, number of patents)*

This indicator quantifies the number of applications to the European Patent Office (EPO) per one million people. The patents are counted in the year of application to the EPO.

6. *Youth education level (PREG, %)*

This indicator is linked to the human factor, which is essential for the research activity. It is measured as percentage in the population aged between 20-24, which completed at least their secondary education.

7. *Exports of high-tech products (HITECHX, %)*

This is an important indicator of the research outcome and is computed as percentage in total exports. The high-tech products included in this indicator are the following: aeronautical products, pharmaceutical instruments, electric equipment and weapons. The EU's total exports do not include the intra-EU trade.

In our opinion, this set of indicators is quite relevant, since it includes both the input and the output.

3.4. Outcome of the k-means and hierarchical clustering exercise

The conclusions based on data obtained by hierarchical clustering in the period between 1999-2005 are the following:

- During the analysed period no significant changes occurred in the grouping of the countries, based on similarity.
- Considering the distance between clusters, the highest convergence to the EU-25 and EU-27 averages took place in Belgium, France, Austria and the United Kingdom.
- Initially (in 1999), Ireland was included in the cluster with the EU-25 and EU-27 average, but later it departed from this cluster, but stayed close to it and turned into a new cluster to which Slovenia came closer (see Tables 7.3 and 7.4 for the distance between the cluster centroids).
- Romania is included in the largest group of countries together with Spain, Slovenia, Hungary, Czech R., Portugal, Greece, Cyprus and Poland.
- There is only one significant change in the group to which Romania belongs. It occurred in 1999-2000, when this cluster included a larger number of countries.

An important aspect concerning the estimation of the convergence between the EU countries' RD&I systems is connected with the evolution of the distance between the centroids of the clusters (similar groups of countries).

Table 3

The evolution of the country groups and their convergence in comparison with EU-27 and EU-25

1999	2000	2001	2002	2003	2004	2005
Czech R.	EU-27	EU-27	EU 27	EU 27	EU 27	EU 27
Spain	EU-25	EU-25	EU 25	EU 25	EU 25	EU 25
Hungary	Belgium	Belgium	Belgium	Belgium	Belgium	Belgium
Poland	France	France	France	France	France	France
Romania	Austria	Austria	UK	UK	UK	UK
Slovenia	UK	UK	Denmark	Denmark	Denmark	Denmark
Slovakia	Denmark	Denmark	Netherlands	Netherlands	Netherlands	Netherlands
Denmark	Netherlands	Germany	Austria	Austria	Austria	Austria
Netherlands	Germany	Netherlands	Germany	Germany	Germany	Germany
Germany	Finland	Finland	Finland	Finland	Finland	Finland
Finland	Sweden	Sweden	Sweden	Sweden	Sweden	Sweden
Sweden	Bulgaria	Bulgaria	Bulgaria	Bulgaria	Bulgaria	Bulgaria
Bulgaria	Czech R.	Czech R.	Czech R.	Czech R.	Czech R.	Czech R.
Estonia	Estonia	Estonia	Estonia	Estonia	Estonia	Estonia
Greece	Greece	Greece	Greece	Greece	Greece	Greece
Cyprus	Spain	Spain	Spain	Spain	Spain	Spain
Latvia	Cyprus	Cyprus	Cyprus	Cyprus	Cyprus	Cyprus
Lithuania	Latvia	Latvia	Latvia	Latvia	Latvia	Latvia
Portugal	Lithuania	Lithuania	Lithuania	Lithuania	Lithuania	Lithuania
EU-27	Hungary	Hungary	Hungary	Hungary	Hungary	Hungary
EU -25	Poland	Poland	Poland	Poland	Poland	Poland
Belgium	Portugal	Portugal	Portugal	Portugal	Portugal	Portugal
Ireland	Romania	Romania	Romania	Romania	Romania	Romania
France	Slovenia	Slovenia	Slovakia	Slovakia	Slovakia	Slovakia
Austria	Slovakia	Slovakia	Ireland	Ireland	Ireland	Ireland
UK	Ireland	Ireland	Slovenia	Slovenia	Slovenia	Slovenia

Note: The shades of grey indicate the cluster to which the countries belong.

Source: Own computation.

The tables below present the matrix of the final distance between the cluster centroids determined by the k-means method in 1999 and 2005 (in 1999, the EU-25 and EU-27 averages were placed in cluster 5 and Romania in cluster 1, and in 2005, the EU-25 and EU-27 averages were included in cluster 1 and Romania in cluster 4).

Table 4

The final distance between the cluster centroids determined by the k-means scheme (1999)

Cluster	1	2	3	4	5
1		192.341	310.531	28.124	116.906
2	192.341		119.415	200.783	76.999
3	310.531	119.415		319.537	195.087
4	28.124	200.783	319.537		127.056
5	116.906	76.999	195.087	127.056	

Table 5

The final distance between the cluster centroids determined by the k-means scheme (2005)

Cluster	1	2	3	4	5
1		89.444	165.694	126.438	73.161
2	89.444		77.716	214.772	161.988
3	165.694	77.716		291.562	237.090
4	126.438	214.772	291.562		61.053
5	73.16	161.988	237.090	61.0553	

We reached the following conclusions:

- The distance between the centroids of the two clusters in 1999 was 116.906 (the square of the Euclidean distance between cluster 1 that included Romania and cluster 5 that included EU-25 and EU-27).

- The distance between the two clusters in 2005 was 126.438 (the square of the Euclidean distance between cluster 4 that included Romania and cluster 1 that included EU-25 and EU-27).

- The distance between Romania and its centroid increased from 14.209 in 1999 to 15.345 in 2005.

- Therefore, we may consider that the Romanian RD&I system was divergent both within its own group and within the whole group that departed from the EU-25 and EU-27 averages.

The table below shows the evolution of the distances between the centroid of the group that included Romania and the centroid of the group that included the EU-25 and EU-27 averages as well as the evolution of the distances (square of the Euclidean distances) of the main countries pertaining to Romania's group between 1999-2005.

Table 6

The evolution of the distances between the centroids of the two clusters that include Romania and the EU-25 and EU-27 averages

Distances	1999	2000	2001	2002	2003	2004	2005
Distances between centroids	116.906	133.049	131.457	125.764	126.679	126.523	126.438

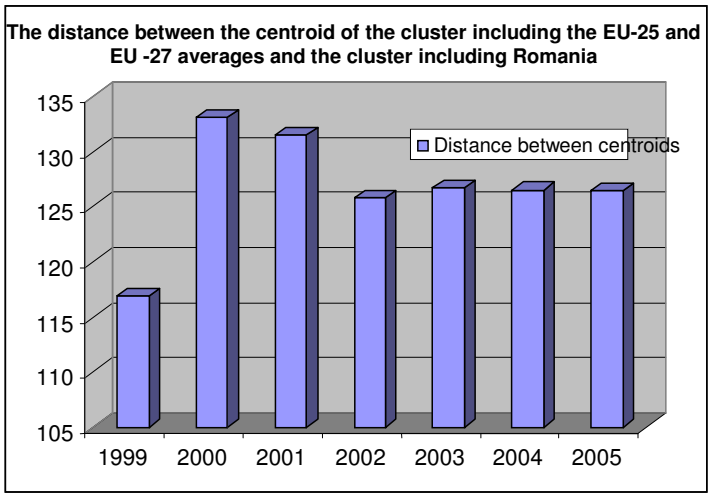

Figure 2

We may draw the following conclusions:

- The distance between the group including Romania and the group including the EU-25 and EU-27 averages increased slowly between 1999 and 2000, that is, a slight divergence occurred between the two groups.
- The 2000-2002 convergence in relation of the EU average was on the rise.
- After 2002, the group including Romania was relatively stable as compared against the group including the EU-25 and EU-27 averages (one may notice a slight divergence in relation to the cluster including the European average).

An interesting fact is the evolution of the convergence within the group of countries similar to Romania. Initially, in 1999, this group included a smaller number of countries than in the period 2000-2005. By means of the clustering and the Euclidean distances determined in relation to the centroid of this group, we may define the convergence level of each country included in this group with features similar to those of Romania in relation to the RD&I system.

Table 7

The evolution of the distances in relation to the centroid of the group of countries including Romania with similar RD&I systems

Country	1999	2000	2001	2002	2003	2004	2005
Bulgaria	na	16.03626	13.73001	12.62431	11.52735	11.9592	11.997
Cyprus	na	19.83472	25.82931	18.21531	16.26796	18.2835	19.225
Czech R.	9.62791	20.78177	21.01431	25.96159	23.9866	24.1555	24.625
Estonia	na	21.39843	11.56827	7.6205	7.64088	9.36699	9.301
Greece	na	19.91908	10.16123	8.38402	13.19997	14.2042	14.257
Hungary	16.68126	18.99349	16.6358	19.55078	18.69871	18.7655	17.604
Latvia	na	22.32593	30.94127	28.63458	12.75049	18.5439	11.348
Lithuania	na	12.69119	12.46507	12.38806	20.79606	19.4253	19.518
Poland	17.06185	16.81919	17.89014	15.6934	16.37719	17.0619	15.529
Portugal	na	37.06607	35.66579	35.42642	31.64553	42.7908	31.447
Romania	**14.20987**	**17.39989**	**14.78834**	**12.23837**	**16.78501**	**15.112**	**15.345**
Slovenia	12.44116	32.17491	27.32999	26.79018	20.79856	17.456	13.564
Spain	21.20186	24.6894	24.93416	30.90511	30.08657	29.1029	29.993

Source: Own computation.

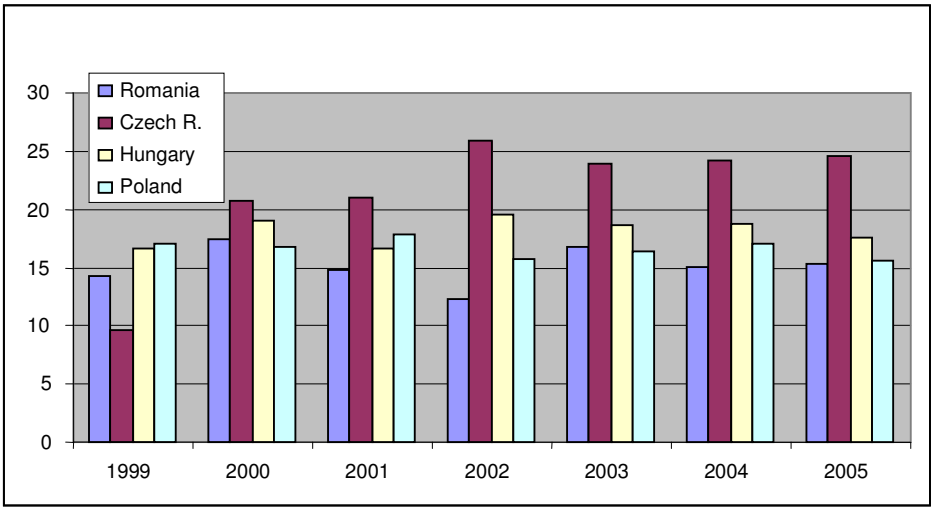

Figure 3. The evolution of the convergence of the countries of the cluster including Romania.

Romania's convergence within the group oscillated: on the rise between 1999 and 2000 and on a slow decrease from 2000 to 2002. Between 2002 and 2003 there was again a slight increase and then a slight decrease. Poland and Hungary evolved similarly. The Czech Republic, Slovakia, Spain and Portugal were characterized by the continuous convergence rise within the group.

The results obtained by the k-means clustering method were confirmed by the hierarchical clustering, as the related dendograms indicated the similar belonging to the groups of countries, as well as a similar evolution.

3.5. Convergence estimation based on the Minkovski distance

Another simplified method for measuring the countries' convergence is the clustering based on the Minkovski distance. This distance is very common for the measurement of the convergence (based on dissimilarities) of several individuals (countries, in our case)[14].

The formula for measuring the distance between countries:

$$d_p\left(x_i, x_j\right) = \left(\sum_{k-1}^{d} \left|x_{ik} - x_{jk}\right|^p\right)^{\frac{1}{p}} \tag{3}$$

where: d is the number of dimensions given by the number of parameters considered: p = 2 for Euclidean distances and p = 1 for the Manhattan metric distance system.

Theoretical and empirical developments of the Minkovski distance were provided by A. Ricci (1973), Barr (1981)[15], Hanson (1988)[16] and Akelman (1996)[17], who created several operators and functions based on the Minkovski inequality, applied mainly to economy and finance.

To estimate the convergence by this type of distance, we maintained the same set of indicators characteristic of the European RD&I system.

Using the above indicators, we could determine the distance between the countries (including Romania) and the EU-25 and EU-27 averages and the evolution of that distance. The interpretation of this indicator is very simple: the longer the distance, the lower the degree of convergence with the EU average and vice versa.

The conclusions drawn from the convergence analysis based on the Minkovski distance are the following:

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[14] See A. Ricci, „A Constructive Geometry for Computer Graphics", *The Computer Journal*, vol. 16, No. 2, pp. 157-160, May 1973, concerning the introduction of the p value in the Minkovski inequality and the development of the Ricci operators.

[15] A.H. Barr, "Superquadrics", *IEEE Computer Graphics and Applications*, vol. 1, No. 1, 1981, pp. 11-23.

[16] A. Hanson, "Hyperquadrics: Smoothly Deformable Shapes with Convex Polyhedral Bounds", *Computer Vision, Graphics and Image Processing*, vol. 44, No. 1, 1988, pp. 191-210.

[17] E. Akleman, "Interactive Construction of Smoothly Blended Star Solids", *Proceedings of Graphical Interface 96*, May 1996 and E. Akleman, "Ray-Quadrics", Proceedings of Implicit Surfaces '96, Oct. 1996, pp. 89-98.

- While in 1999 there were considerable discrepancies among the countries as regards the convergence with the EU average, in 2005 the discrepancies decreased, and the countries were closer to each other.
- The distance between Romania and the EU increased between 1999 and 2005 from 117.5 to 134.11, meaning that divergence of the Romanian RD&I system occured as against the EU-27 average, in relation to the RD&I.
- The Minkovski distance shows that the Romanian RD&I system was closer, in 1999, to that of Portugal, Finland or Slovenia. In 2005, the situation was very different, as the Romanian RD&I system was closer to that of Austria, Slovakia, Hungary or Portugal.

Table 8

The synthesis of the Minkovski distance from the EU-27, between 1999-2005

Country	1999	2000	2001	2002	2003	2004	2005
Belgium	20.71	24.04	**18.40**	22.26	21.70	21.60	16.81
Bulgaria	17.91	52.07	18.79	**18.91**	23.75	23.61	**16.07**
Czech R.	**7.81**	52.18	52.59	21.62	**21.03**	17.61	21.36
Denmark	14.55	**16.90**	20.43	94.81	108.15	108.13	99.98
Germany	30.35	97.95	97.10	121.86	116.55	116.57	108.41
Estonia	185.51	119.71	177.55	64.35	69.25	69.08	61.10
Ireland	202.38	180.44	153.29	176.01	**184.38**	**184.34**	170.39
Greece	278.85	224.70	**221.26**	**185.58**	178.75	178.61	**176.29**
Spain	**329.33**	**242.48**	199.28	170.11	157.71	157.69	149.61
France	326.29	129.65	128.23	124.94	127.62	127.48	135.31
Cyprus	35.32	119.61	112.33	122.91	118.04	118.46	125.30
Latvia	30.29	118.42	117.42	114.07	113.45	113.42	121.20
Lithuania	37.86	120.92	118.96	120.11	115.09	114.76	122.62
Hungary	37.30	126.29	121.73	117.83	120.92	121.13	129.05
Netherlands	40.45	108.75	111.61	108.84	112.17	111.12	118.68
Austria	27.04	126.60	131.60	127.51	125.39	124.17	133.06
Poland	60.89	128.25	127.56	125.97	129.04	128.29	135.90
Portugal	109.85	128.70	129.05	125.26	128.41	128.56	135.68
Romania	*117.50*	*130.03*	*128.87*	*126.88*	*126.41*	*128.09*	*134.11*
Slovenia	136.18	127.11	126.85	124.74	127.94	123.22	136.12
Slovakia	81.92	122.66	125.49	119.51	122.50	99.45	130.71
Finland	126.19	93.03	99.61	95.88	99.40	53.85	107.56
Sweden	147.28	102.45	100.64	49.75	54.36	79.88	61.56
UK	118.36	57.72	46.43	75.46	79.79	**12.60**	88.32

Source: Own computation.

4. Conclusions

The European Research Area meant a new vision for the European scientific and technical activity and related policies in order to ensure the correlation between the policies and the research activity, between science and society, for the convergence of the national RD&I systems.

Although there are many similarities in the contents of the national RD&I policies regarding the directives and priorities, still there is a divergence in the private funding of the innovation, in the share of the RD&I expenditure in the GDP, as well as in the outcome of the RD&I activity.

The greatest difference is among the new EU members and EU-15, especially in the venture capital, the fund allocation and researchers' distribution to the public and private sectors, and the research output.

The small countries and the new member states make obvious endeavours to close the gap with the EU-15.

Empirical studies confirmed the existence of both similarities and differences between Romania and the EU in the RD&I system. The distance between Romania and the EU average is slightly increasing, which means a slowed pace of the Romanian Research Area integration into the ERA between 2000 and 2005.

The models used in this study help us to estimate not only the evolution of the convergence degree as against the European average, but also the number of years necessary for Romania to reach the EU average or the growth rate necessary for the Romanian RD&I sector to reach the EU average in a certain number of years, on the basis of the comparative dynamics of the sectors in Romania and the EU.

European experts have appreciated[18] the progress made in the construction of the ERA and in attaining the objectives (some of them on the 2020 horizon):

- Eliminating the fragmentation of the public RD&I base.
- Eliminating the legislative or any other barriers against researchers' mobility.
- Gradually eliminating the problems concerning the cooperation and the partnership between the research institutes and industry.
- Improving the coordination of the national and regional funding through adequate programmes and infrastructure and preventing the financial resources dispersion and excessive duplication, which might cause a diminution in the expected multiplication.
- Taking into consideration the European integration when implementing reforms in the national RD&I sector.
- The European research does not yet meet the social and sustainable development requirements, which might be achieved by the priority research in fields such as: health, energy, climate changes.
- Finding a balance between competition and partnership within the European institutions.
- Taking advantage of the specific features and diversity of the enlarged EU.

[18] Commission for the European Communities: The European Research Area – New perspectives", Green Paper 412/2007.

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