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REGIONAL R&D&i PRODUCTIVITY IN EUROPE. IDENTIFYING REGIONAL TYPOLOGIES AND POLICY RECOMMENDATIONS

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REGIONAL R&D&i PRODUCTIVITY IN EUROPE. IDENTIFYING REGIONAL TYPOLOGIES AND POLICY RECOMMENDATIONS

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Abstract:

Research, development and innovation activities have become key sources of competitive advantage, which is one of the main factors behind the wellbeing of citizens living in a given territory. Being aware of this fact, public administrations at different administrative levels have encouraged the production of innovations through different public policies. On the other hand, firms that invest in research, development and innovation usually obtain in the long and medium terms innovative products and services that allow them to compete in favorable conditions in the local and international markets. If we focus in Europe, regional disparities in the amount of innovation inputs on one side and in the amount of innovation outputs on the other side are very high.

In this paper the authors will measure the productivity of research, development and innovation activities performed by all regions in the EU. In order to do so, the authors will take into account some indicators to measure innovation inputs and outputs (related to science, technology and also to collaboration among agents in innovation activities and wealth creation) at the regional level. Using the Data Envelopment Analysis (DEA) we will measure regional productivity in the field of R&D and innovation and we will compare this productivity outcome between regions in the EU. After explaining this first DEA model, we will use the main components analysis and then cluster analysis to achieve a typology of regions regarding their productivity in R&D and innovation

activities. Once the typology of regions has been described and analyzed, the paper will end with some policy recommendations for each type of region, taking into account the regional innovation systems approach to innovation understanding and innovation policy. It may be possible to establish learning processes between different types of regions, taking into account the singularity and the unique mix of assets of each region.

1. INTRODUCTION

R&D investment has become one of the main variables to achieve competitive advantages. These competitive advantages, in the long run, will create higher levels of prosperity in a given region. This idea has been accepted by economic theory since Adam Smith, but it has been in recent times when economic theory has focused in R&D and its connection with policy makers and society in general (Dodgson and Rothwell, 1994; Porter, 1998; Porter et al., 2000).

Once we have highlighted the importance of R&D as a basic tool to achieve higher levels of prosperity in a given society, it would be obvious that the public administration would support R&D activities through a proper public policy. Additionally, the different schools of economic thought are in favor of this kind of behavior (Velasco, 1996). The neoclassical literature accepts that the competitive market underinvests in R&D activities (Mani, 2002). Hence, the level of R&D investment that maximizes profit for firms is smaller than the level of R&D that maximizes social prosperity (Arrow, 1962; Beije, 1998).

On the other hand, the evolutionary school, linked with the concept of national/regional innovation system (NIS/RIS), proposes the public intervention to strengthen the different economic agents inside a NIS/RIS, and also to increase the interaction among these actors (Lundvall, 1992).

A consequence of the positive economic results that governments and firms link with R&D investment has been a non-stop increasing in the public and private funding devoted to R&D in almost all developed economies. (Martínez and Aguado, 2009)

Although the volume of private and public expenditure in R&D activities has been growing for the last decades both at the national and regional levels, there are few studies about the efficiency of this kind of expenditure, specially at the regional level.

In this work we are going to present a comparative study of all regions in the European Union (27 countries). In this paper we will analyze the efficiency of R&D expenditures taking into account EU27 regions, in order to build a common taxonomy, discovering similarities and disparities between regions.

Some attempts to measure the efficiency of RIS at the European level have been done by different authors in recent times (Navarro, Gibaja, Aguado and Bilbao-Osorio, 2009) (Buesa and Heijs, 2007) (Martínez Pellitero, 2007) (Brioschi, Cassia and Colombelli 2006). In these studies the conceptual framework of RIS has been used to select a range of variables linked with inputs and outputs of R&D activities. In all these cases, the methodology and statistical use of data has been similar: principal component analysis to highlight the main dimensions that explain regional behavior in R&D activities and then a cluster analysis to gather regions in groups with common features measured in the axes defined previously in the principal component analysis.

This kind of econometric analysis is used to group regions with similar levels of economic development, R&D inputs and R&D outputs. Moreover, it helps in finding the strong and weak points of each group of regions in comparison to the rest of groups.

However, this kind of analysis do not link directly the amount of output achieved with the amount of inputs devoted to R&D. A region (region Y) using a great quantity of R&D inputs and achieving exactly the same output as other region (region Z) that uses a smaller amount of R&D inputs would appear in a higher position in the ranking of innovative regions. In reality, region Z is using its resources in a more efficient way than region Y, so region Z should be highlighted as more efficient and rank in a higher position.

Different authors have tried to measure the efficiency of RIS in certain national economies (Buesa and Heijs, 2007) (Miceli, 2010). In these analysis the number of patent applications in the national patent office or in the European Patent Office (EPO) has been used as one of the main or even unique R&D output indicator.

The number of patent applications has been a widely used indicator in the economic literature (Kamien and Schwartz, 1975) (Mani, 2002), and allows quick comparisons between regions and nations. However, the use of this indicator as the only variable to measure the R&D output does not allow to take into consideration the whole result achieved by a region in this field (Álvarez, Aguado and Martínez, 2008). In some

economic sectors, the propensity to patent may be very low. In other cases, firms may develop products or processes which are new to the firm, but not to the sector at the global level. In this case, a patent is not possible, although that company has achieved an R&D output. Due to the aforementioned facts, it may be sensible to complement the number of patent applications with other variables in order to have a better measure of the R&D output of regions in Spain and Italy.

The objective of this work is to measure the efficiency (productivity) of EU27 regions in R&D activities, building a regional taxonomy according to those efficiency levels. In order to fulfill this task we will use the statistical tool Data Envelopment Analysis.

The paper is developed as follows. In section 2 the evolution of the R&D expenditure will be analyzed, in the context of the EU. In section 3 the Data Envelopment Analysis tool will be explained in detail and also its relation with measuring the efficiency (productivity) of R&D activities. In section 4 the methodology followed in this paper will be described and in section 5 the results of the DEA analysis will be presented. The paper ends with a conclusions section.

2. EVOLUTION OF R&D EXPENDITURES IN THE CONTEXT OF THE EU

As mentioned in the introduction, the relevance of the productivity of investment in R&D in the long-term growth of the economy is a topic widely accepted in economic literature (Cameron, 1998). Recent articles (Balmaseda and Melguizo, 2007; Escribá and Murgui, 2007; Miceli, 2010, Brioschi, Cassia and Colombelli, 2006) have been working on the relationship between investment in R&D and production showing its importance. In this section we will make a brief overview on the status of R&D in EU27 countries¹.

As seen in Table 1, Spain's position is low in terms of total investment in R&D relative to GDP, from 0.91% in 2000 to 1.06% in 2004. In the Italian case the evolution is similar: from 1.05% to 1.10%. The development is positive but of insufficient entity to reach the leading countries, like Sweden and Finland, which by far exceed 3%. Both countries are below the average for the EU27 and the EU15. The countries with low rates on business investment in R&D (such as Greece, Portugal, Italy and Spain) show a

¹ A similar work but focusing in the countries of the EU-15 has been carried out by Romero et al., 2007.

growth rate above average. This would indicate the existence of a certain process of convergence in business expenditure on R&D between those countries and the EU-27

	2000				2004			
	All	Business	PPAA	University Education	All	Business	PPAA	University Education
UE 27	1,85	1,20	0,25	0,38	1,82	1,16	0,24	0,40
UE 15	1,91	1,24	0,26	0,39	1,89	1,21	0,25	0,42
Belgium	1,97	1,43	0,12	0,40	1,87	1,29	0,14	0,41
Bulgaria	0,52	0,11	0,36	0,05	0,50	0,12	0,33	0,05
Czech Rep.	1,21	0,73	0,31	0,17	1,25	0,79	0,26	0,18
Denmark	2,24	1,50	0,28	0,44	2,48	1,69	0,17	0,61
Germany	2,45	1,73	0,33	0,40	2,49	1,74	0,34	0,41
Estonia	0,61	0,14	0,14	0,32	0,86	0,33	0,11	0,39
Ireland	1,12	0,80	0,09	0,23	1,24	0,81	0,09	0,33
Greece	..	0,15	..	..	0,55	0,17	0,11	0,26
Spain	0,91	0,49	0,14	0,27	1,06	0,58	0,17	0,31
France	2,15	1,34	0,37	0,40	2,15	1,36	0,37	0,40
Italy	1,05	0,52	0,20	0,32	1,10	0,52	0,20	0,36
Cyprus	0,24	0,05	0,11	0,06	0,37	0,08	0,13	0,13
Latvia	0,44	0,18	0,10	0,17	0,42	0,19	0,08	0,15
Lithuania	0,59	0,13	0,25	0,22	0,75	0,16	0,19	0,41
Luxemburg	1,65	1,53	0,12	0,00	1,63	1,43	0,18	0,02
Hungary	0,78	0,35	0,20	0,19	0,88	0,36	0,26	0,22
Malt	..	..	..	..	0,53	0,35	0,01	0,17
Netherlands	1,82	1,07	0,23	0,51	1,78	1,03	0,26	0,49
Austria	1,94	..	..	..	2,26	1,53	0,12	0,60
Poland	0,64	0,23	0,21	0,20	0,56	0,16	0,22	0,18
Portugal	0,76	0,21	0,18	0,28	0,77	0,28	0,12	0,28
Rumania	0,37	0,26	0,07	0,04	0,39	0,21	0,13	0,04
Slovenia	1,39	0,78	0,36	0,23	1,40	0,94	0,28	0,18
Slovakia	0,65	0,43	0,16	0,06	0,51	0,25	0,16	0,10
Finland	3,34	2,37	0,35	0,60	3,45	2,42	0,33	0,68
Sweden	..	..	..	..	3,62	2,67	0,11	0,83
United Kingdom	1,81	1,18	0,23	0,37	1,69	1,06	0,18	0,42
Croatia	..	..	..	..	1,13	0,47	0,24	0,42
Turkey	0,48	0,16	0,03	0,29	0,52	0,13	0,04	0,35
Iceland	2,67	1,50	0,68	0,43	..	..	..	..
Norway	..	..	..	..	1,59	0,87	0,25	0,47
Switzerland	2,53	1,87	0,03	0,58	2,90	2,14	0,03	0,66

average.

Table 1. R&D expenditure by performance sectors, in % of GDP, 2000-04

Source: Eurostat and own elaboration

3. ASSESING R&D EFFECTIVENESS AND PRODUCTIVITY USING DATA ENVELOPMENT ANALYSIS

In many economic studies performance/productivity is defined or measured as the quantity of resource (*inputs*) needed to obtain some quantity of product (*outputs*).

This performance analysis leads us to the study of efficiency: how to obtain the best mix of resources for obtaining those results.

In general terms, the modelling approach to measuring comparative performance could be summarized in two groups:

- Parametric methods, like the Stochastic Frontier Analysis (SFA), which uses multivariate techniques to analyze the variation in the production rate or cost rate among different organizations running the same activity (i.e. financial services, hospitals, ...)
- Non parametric methods, like Data Envelopment Analysis (DEA), that tries to measure the efficiency of those homogeneous entities estimating the optimum level of product as function of the type and quantity of available resources (Smith and Street, 2005).

In this paper DEA² is being used as it was coined by Charnes et al (1978) in their seminal paper on DEA, based on a previous work by Farell, 1957. DEA is for measuring relative efficiency, so an organization that consumes fewer resources for getting the same quantity of product can be considered as more efficient.

With such premise, this methodology starts from the definition of Decision Making Unit (DMU) as the unit of assessment or entity whose efficiency would be relatively measured. And the efficiency ratio defined as a weighted sum of outputs to a weighted sum of inputs.

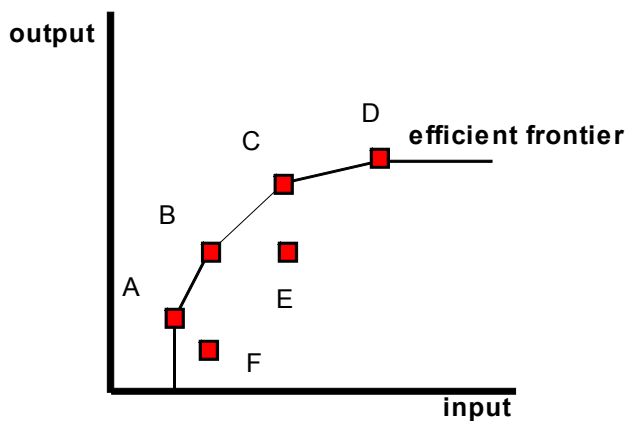
How to obtain the weight factors? A linear programming is, then, used to get those numbers where the objective function is the efficiency ratio of a DMU and the

² A thorough study of this methodology can be found in Cooper et al., 2004, Thanassoulis, 2001 and Coelli et al., 1998.

constraint set is defined by the fact that the efficiency ratio of the rest of DMUs cannot be upper than 1 (or 100%).

Repeating the analysis for each DMU allow us to build up an efficiency frontier where more efficient DMUs are located (those which minimize inputs levels for given outputs levels or alternatively, maximize the output for given inputs levels). All those efficient DMUs have an efficiency score equal to 1 while the rest will get a lower value.

Figure 1. Efficient Frontier



In this figure, A, B, C, D are efficient DMU .
On the contrary, E and F are relatively inefficient units.
It can be observed that Unit C achieves greater output level with the same input level and alternatively unit B achieve the same level of output with smaller level of input.

DEA models could be classified regarding two criteria:

- The Pareto Definition: Two definition are given:
 - the one labelled “*output oriented*”- when outputs are controllable (i.e. hospitals and resources such as doctors), so inputs are minimized for given output levels and
 - the one labelled “*input oriented*” – when inputs are controllable (i.e. schools and students’ attainments) and, therefore, outputs are maximized given inputs levels
- The focus on the technical efficiency, that is
 - Constant Returns to Scale (CRS) models (Charnes et al., 1978)
 - Variable Returns to Scale (VRS) models (Banker et al., 1984).

As R&D investment is mainly focused in the obtaining of results (output maximization) and following, for example, Graves and Langowitz, 1996 who studies the behaviour of R&D expenditure, an output oriented CRS model has been selected.

Following, Lee and Park, 2005, let us assume that we have n DMUs ($k = 1, 2, \dots, n$) using r inputs to secure s outputs.

Let x_{jk} ($j = 1, 2, \dots, r$), be the input levels used by DMU k and y_{ik} the levels of output i ($i = 1, 2, \dots, s$) secured by DMU k . Let u_j the weight factor assigned to input j and v_i the weight factor assigned to output i .

The following linear programming model can be stated:

$$\begin{aligned}
 & \min \sum_{j=1}^r u_j x_{jk} \\
 & s.a. \sum_{i=1}^s v_i y_{ik} = 1, \\
 & \sum_{i=1}^s v_i y_{il} - \sum_{j=1}^r u_j x_{jl} \leq 0, \quad l = 1, 2, \dots, n \\
 & u_j \geq \varepsilon > 0, \quad j = 1, 2, \dots, r \\
 & v_i \geq \varepsilon > 0, \quad i = 1, 2, \dots, s
 \end{aligned} \tag{1}$$

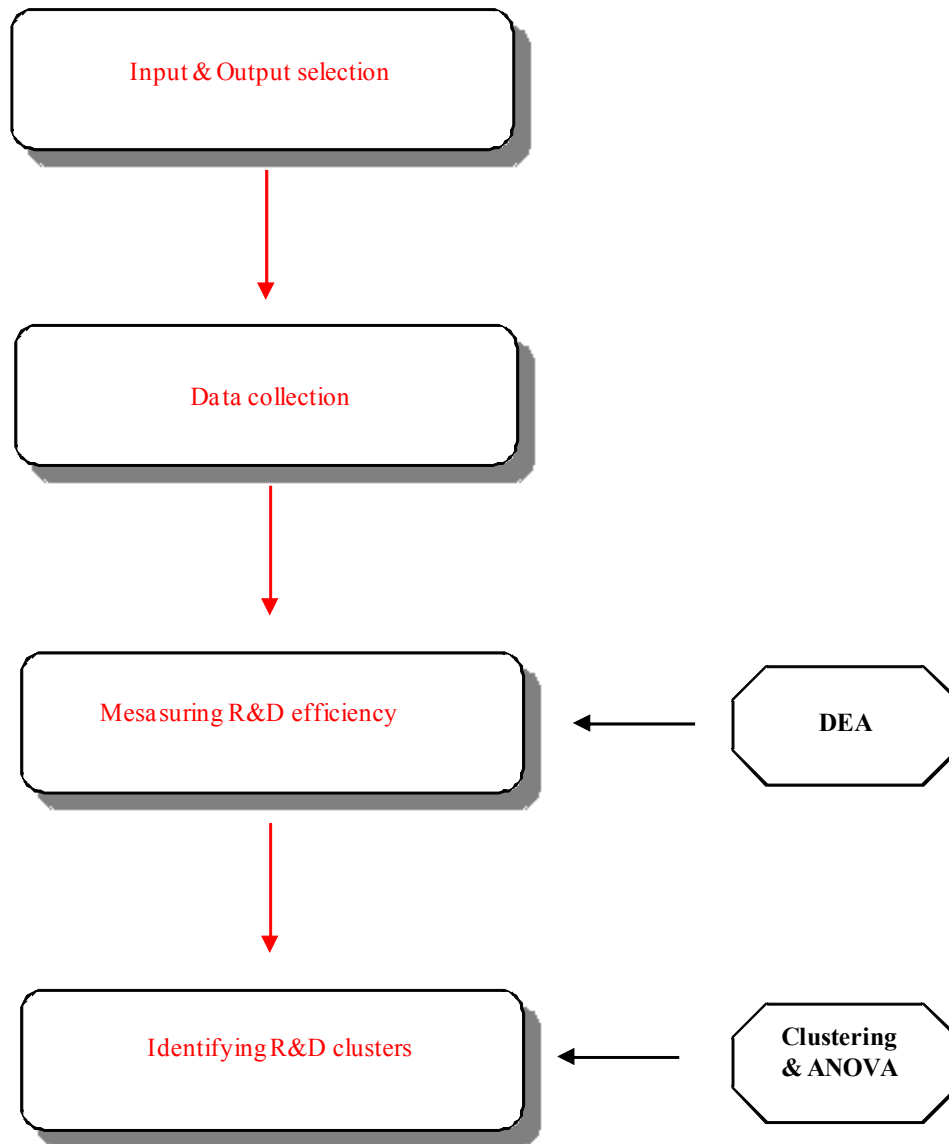
where ε is a very small positive number to avoid null weight factors.

4. Methodology

The methodology used in this paper is very straightforward and it is depicted in Figure 2.

- Firstly, the input-output variables have been selected following recommendations found in previous studies that analyze the RIS efficiency.
- Secondly, data from all EU27 regions has been collected.
- Next, R&D activities' efficiency have been measured based on DEA.
- Finally, an exercise of clustering the analyzed regions has been made according to the previous findings and results.

Figure 2. A four- step methodology



Source: own elaboration based upon Lee y Park, 2005

On building the efficiency models 3 inputs and three outputs have been considered. Table 2 summarizes their key characteristics.

Table 2. Input and Output Variables

Variable	Description	Unit of Measurement	Source	Variable as Used on DEA
INPUT PERD	Expenditure in R&D made by Public Administrations	% GDP	Eurostat	Average 1998-2001
INPUT BERD	Expenditure in R&D made by Company	% GDP	Eurostat	Average 1998-2001
INPUT UERD	Expenditure in R&D made by High Education Institutions	% GDP	Eurostat	Average 1998-2001
OUTPUT GDPpc	GDP per cápita	€/million pers.	Eurostat	2004
OUTPUT Patents	Ordered Patents EPO per cápita	patents/million pers.	Eurostat	2003
OUTPUT Employment	Knowledge intensive services and High & mid tech manufacturing employment	%	Eurostat	2003

Source: own elaboration based on Eurostat data

For measuring R&D outputs three variables have been selected: GDP per capita, knowledge intensive services and high & mid tech manufacturing employment and the number of patents applied for in the European Patent Organization. Several examples to measure R&D outputs can be found in the recent literature. Some authors (Buesa et al., 2007; Navarro, Gibaja, Aguado and Bilbao-Osorio, 2009) have used the number of patents, while others (Martínez-Pellitero, 2002 and 2007; Buesa and Heijs, 2007) have used GDP per capita and knowledge intensive services and high & mid tech manufacturing employment as output variables.

On selecting the time period covered by input and output data, a lag has been used, as R&D inputs are not turned into outputs instantaneously. Some studies (i.e. Lee and Park, 2005) state that there is a three to five years lag since R&D inputs is reverted into outputs. In this paper, inputs are being measured as the average of the values obtained in the period 1998 – 2001 while all output data has been gathered from 2003 data, with the exemption of GDP per capita, whose data derived from 2003.

The whole dataset have been obtained from Eurostat. In the EU27 there are 187 regions. We have eliminated from the analysis regions with at least one of the following characteristics:

- Number of patents < 0.1 per million of inhabitants
- R&D expenditure performed by Public Administration < 0.0001 over GDP
- R&D expenditure performed by businesses < 0.0001 over GDP
- R&D expenditure performed by universities < 0.0001 over GDP

These filters are necessary in order to obtain valid results, not distorted by regions without significant R&D expenditures. After applying the filters we have excluded 31 regions. This means that 155 regions remains as valid units for the final analysis.

5. RESULTS

This section shows the results of measuring the efficiency of R&D investment of the 155 regions using data envelopment analysis (DEA). First, we made the analysis of efficiency using the basic model (which includes all inputs and outputs). Then we have proceeded to the execution of partial models that combine a a single output with all inputs. In this way, it is possible to measure the efficiency in R&D for each selected output.

For example, the DEA model that includes all inputs and that incorporates patents as output can be understood as the model that measures the efficiency oriented to the achievement of patents. Additionally, we have estimated other additional model apart from the basic model (which includes all inputs and outputs) and the patent-oriented model: the employment efficiency-oriented model. Table 3 shows inputs and outputs included in each of the seven DEA models that have been calculated

Table 3. Inputs and Outputs considered in the DEA models

DEA MODEL	Input			Output		
	PERD	BERD	UERD	GDPpc	Patents	Employment
Basic Model	○	○	○	○	○	○
Patent-oriented efficiency	○	○	○		○	
Employment-oriented efficiency	○	○	○			○

Source: Own elaboration

Table 4 shows the results of the efficiency of R&D for the 155 regions in the three DEA models. Regions from different countries are able to achieve maximum efficiency in the basic model. On the other hand, the most inefficient regions (less than 40% efficiency) are also widespread at the European level. The rest are in an intermediate position between these two extremes. It is noteworthy that some of the regions 100% efficient in the basic model show a small level of R&D investment over GDP compared to others, such as capital regions (Madrid, London, Lazio, Berlin,...) that have higher levels of use of inputs. The results of efficiency of each region vary significantly from model to model. For example, Noord-Brabant achieves 100% efficiency in the patent-oriented model, but only 31% in the employment-oriented model. It seems clear, then, that Noord-Brabant has a strong point in productivity measured by patents, showing a clear weakness in the employment-oriented model. These specific data would have remained undeveloped in case of estimating only the basic model.

These results differ markedly from those obtained by Buesa and Heijs (2007) using a DEA model based on patent application as the only output for R&D investment. For Buesa and Heijs, the more efficient regions tend to coincide with that showing the highest R&D expenditure per capita and in absolute terms. However, in this study, those regions are in an intermediate position. In contrast, some regions with a reduced R&D, both in absolute and relative terms, are capable of reaching the highest level of efficiency.

Table 4. Results of the three DEA models for the EU27 regions, in percentage.

Region	Basic Model	Patent-oriented efficiency	Employment-oriented efficiency
Niederösterreich	1,0000	1,0000	0,9994
Wien	0,2685	0,2505	0,0265
Kärnten	0,4966	0,3748	0,2240
Steiermark	0,3318	0,3156	0,0867
Oberösterreich	0,6981	0,5256	0,3764
Salzburg	1,0000	1,0000	0,1530
Tirol	0,4344	0,3910	0,0875
Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest	0,7300	0,3216	0,0232
Vlaams Gewest	0,3156	0,2617	0,1376

Région Wallonne	0,3019	0,2495	0,2112
Praha	0,1527	0,0960	0,0555
Jihozápad	0,5211	0,0629	0,5196
Severozápad	1,0000	0,0660	1,0000
Severovýchod	1,0000	0,0724	1,0000
Jihovýchod	0,3324	0,1121	0,3073
Střední Morava	0,7414	0,0401	0,7408
Moravskoslezsko	0,8738	0,0676	0,8666
Baden-Württemberg	0,6521	0,6420	0,1052
Bayern	0,6321	0,6215	0,1289
Berlin	0,2520	0,2520	0,0273
Brandenburg	0,3589	0,3182	0,1188
Bremen	0,2961	0,2403	0,0635
Hamburg	0,5942	0,5341	0,0596
Hessen	0,5144	0,4832	0,1368
Mecklenburg-Vorpommern	0,4354	0,3885	0,0970
Niedersachsen	0,3892	0,3739	0,0992
Nordrhein-Westfalen	0,6393	0,6393	0,1148
Rheinland-Pfalz	0,5171	0,5022	0,1643
Saarland	0,6709	0,6709	0,1562
Sachsen	0,2000	0,1872	0,0775
Sachsen-Anhalt	0,2307	0,2178	0,1119
Schleswig-Holstein	0,7122	0,7122	0,1270
Thüringen	0,3074	0,2979	0,1179
Denmark	0,4147	0,3792	0,0718
Estonia	0,3156	0,0800	0,2936
Galicia	0,3912	0,0332	0,2614
Principado de Asturias	0,3825	0,0634	0,2040
Cantabria	0,4403	0,1020	0,2617
Pais Vasco	0,6240	0,1157	0,4352
Comunidad Foral de Navarra	0,7137	0,3508	0,6806
La Rioja	0,8391	0,3301	0,5056
Aragón	0,4576	0,1794	0,2708
Comunidad de Madrid	0,2231	0,0967	0,0794
Castilla y León	0,5186	0,1212	0,1989
Castilla-la Mancha	0,6512	0,0823	0,3633
Extremadura	0,3472	0,0956	0,2160
Cataluña	0,4614	0,2326	0,2596
Comunidad Valenciana	0,5288	0,1818	0,2563
Illes Balears	1,0000	0,4308	0,4075
Andalucía	0,2972	0,1018	0,1428
Región de Murcia	0,3699	0,0809	0,2384
Canarias (ES)	0,3880	0,1507	0,1146
Itä-Suomi	0,2410	0,1955	0,1011
Etelä-Suomi	0,3986	0,3911	0,0531
Länsi-Suomi	0,3546	0,3502	0,1083
Pohjois-Suomi	0,2200	0,2107	0,0622
Île de France	0,3989	0,3710	0,0322
Champagne-Ardenne	1,0000	0,7222	0,9496
Picardie	0,8665	0,2611	0,6399
Haute-Normandie	0,8664	0,3417	0,6059

Centre	0,3585	0,2966	0,1658
Basse-Normandie	0,4842	0,2947	0,2092
Bourgogne	0,4917	0,3241	0,2671
Nord - Pas-de-Calais	0,5804	0,2769	0,2797
Lorraine	0,3998	0,2619	0,2053
Alsace	0,6631	0,6116	0,1855
Franche-Comté	1,0000	0,4551	1,0000
Pays de la Loire	0,4703	0,2370	0,2543
Bretagne	0,3891	0,3579	0,0961
Poitou-Charentes	0,5381	0,3627	0,2347
Aquitaine	0,3477	0,1140	0,1051
Midi-Pyrénées	0,1916	0,1674	0,0387
Rhône-Alpes	0,3990	0,3928	0,0896
Auvergne	0,2404	0,1705	0,1376
Languedoc-Roussillon	0,1692	0,1546	0,0373
Provence-Alpes-Côte d'Azur	0,2976	0,2610	0,0489
Corse	0,5918	0,2360	0,0426
Kentriki Makedonia	0,4653	0,1273	0,3806
Dytiki Makedonia	1,0000	0,5994	1,0000
Ipeiros	0,8766	0,3098	0,5903
Dytiki Ellada	0,2866	0,0861	0,1761
Attiki	0,2746	0,1190	0,1376
Kriti	0,5220	0,2939	0,1779
Közép-Magyarország	0,2468	0,1755	0,1469
Közép-Dunántúl	0,8673	0,0439	0,8673
Nyugat-Dunántúl	1,0000	0,1506	0,9717
Dél-Dunántúl	0,9887	0,2548	0,9343
Észak-Magyarország	1,0000	0,0908	1,0000
Észak-Alföld	0,3810	0,0606	0,3656
Dél-Alföld	0,3977	0,0682	0,3977
Ireland	0,6506	0,2233	0,1692
Piemonte	0,4720	0,3482	0,2812
Liguria	0,2973	0,2530	0,1044
Lombardia	0,6829	0,6089	0,3113
Provincia Autonoma Trento	0,8140	0,7769	0,2110
Veneto	1,0000	1,0000	0,4735
Friuli-Venezia Giulia	0,3782	0,3335	0,1760
Emilia-Romagna	0,7611	0,7611	0,2278
Toscana	0,4665	0,4526	0,1729
Umbria	0,5522	0,3617	0,3727
Marche	1,0000	1,0000	0,6213
Lazio	0,2491	0,1625	0,0594
Abruzzo	0,3731	0,1938	0,2003
Campania	0,2027	0,0518	0,0983
Puglia	0,4015	0,1569	0,2782
Basilicata	0,3166	0,1711	0,2190
Sicilia	0,2969	0,1216	0,1159
Sardegna	0,5043	0,1914	0,2436
Lithuania	0,3297	0,0840	0,3297
Latvia	0,3397	0,0643	0,3397
Malta	0,6896	0,3243	0,5706

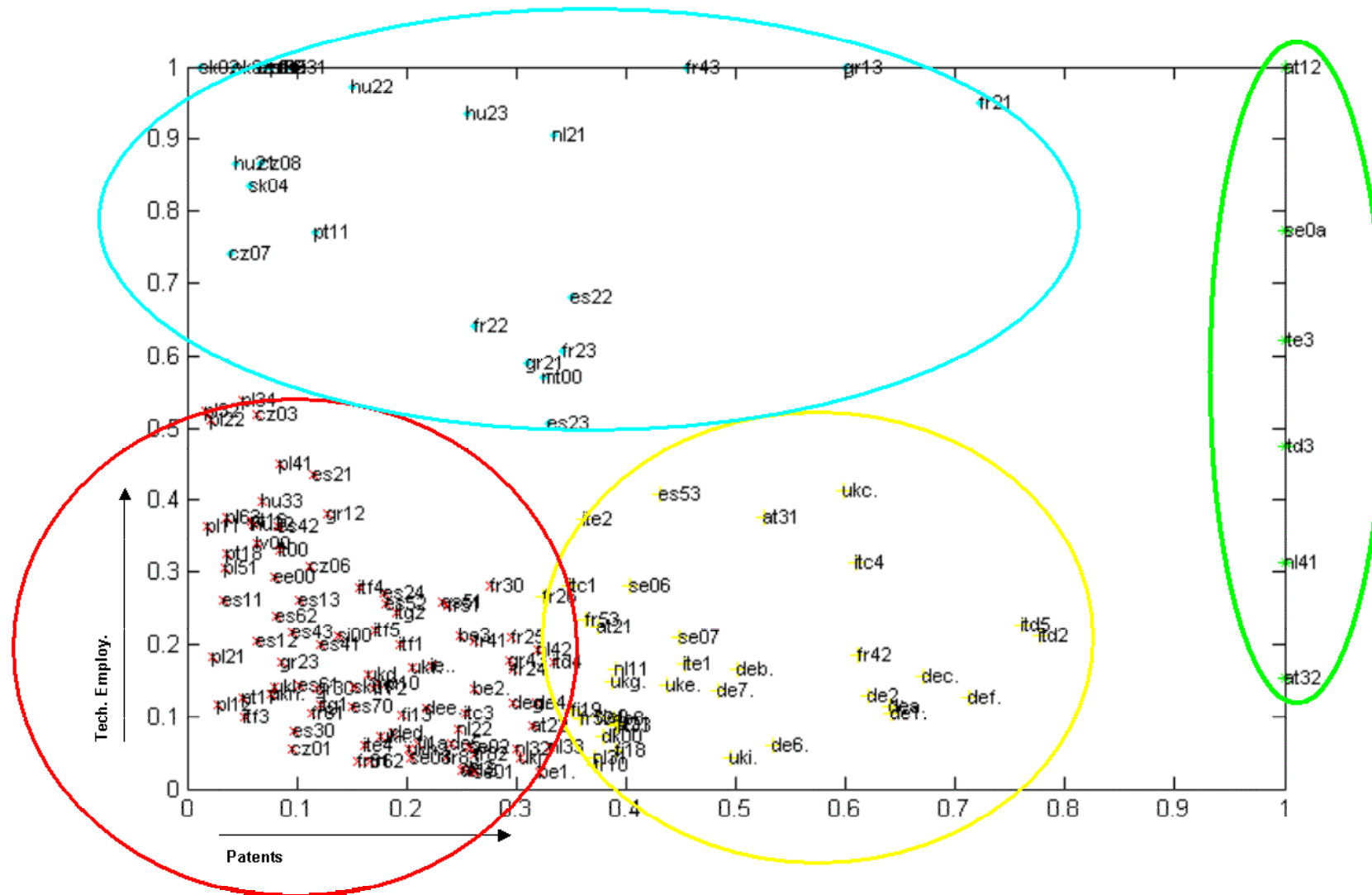
Groningen	0,7773	0,3910	0,1655
Overijssel	1,0000	0,3336	0,9064
Gelderland	0,2552	0,2464	0,0812
Utrecht	0,3767	0,3717	0,0420
Noord-Holland	0,3467	0,3000	0,0555
Zuid-Holland	0,3459	0,3310	0,0574
Noord-Brabant	1,0000	1,0000	0,3136
Limburg (NL)	0,3966	0,3203	0,1914
Lódzkie	0,3634	0,0188	0,3634
Mazowieckie	0,1186	0,0278	0,1169
Malopolskie	0,1875	0,0228	0,1831
Slaskie	0,5099	0,0210	0,5099
Podkarpackie	0,5224	0,0166	0,5224
Podlaskie	0,5391	0,0500	0,5373
Wielkopolskie	0,4490	0,0852	0,4490
Dolnoslaskie	0,3178	0,0344	0,3045
Warminsko-Mazurskie	1,0000	0,0769	1,0000
Pomorskie	0,3773	0,0360	0,3773
Norte	0,8809	0,1170	0,7716
Centro (PT)	0,5877	0,0580	0,3722
Lisboa	0,1973	0,0512	0,1264
Alentejo	0,3880	0,0356	0,3239
Stockholm	0,2902	0,2624	0,0223
Östra Mellansverige	0,2592	0,2568	0,0570
Norra Mellansverige	0,5475	0,4033	0,2798
Mellersta Norrland	0,7405	0,4491	0,2093
Övre Norrland	0,2496	0,2034	0,0441
Västsverige	1,0000	1,0000	0,7725
Slovenia	0,2798	0,1377	0,2119
Bratislavský kraj	0,2360	0,1527	0,1419
Západné Slovensko	1,0000	0,0127	1,0000
Stredné Slovensko	1,0000	0,0432	1,0000
Východné Slovensko	0,8351	0,0572	0,8351
North East	0,7506	0,5977	0,4134
North West (including Merseyside)	0,3855	0,1658	0,1581
Yorkshire and The Humber	0,5613	0,4371	0,1428
East Midlands	0,3481	0,2059	0,1689
West Midlands	0,4446	0,3880	0,1473
Eastern	0,2275	0,2024	0,0550
London	0,6738	0,4957	0,0429
South East	0,3355	0,3034	0,0429
South West	0,2568	0,1768	0,0732
Wales	0,3330	0,0796	0,1418
Northern Ireland	0,4540	0,0769	0,1301

Source: Own elaboration

Considering the output variables used to estimate the DEA models (patents and employment in knowledge intensive services and in high & mid high tech

manufacturing) we have conducted a cluster analysis of the 35 regions included in the models. The results of this analysis are shown in Figure 3.

Figure 3. Cluster analysis of the EU27 regions using the two output variables



We can distinguish 4 groups of regions:

- Group 1: 100% efficient regions in patents, with different results in terms of efficiency in job creation in knowledge intensive services and high & mid high tech manufacturing (6 regions)
- Group 2: high efficiency regions in patents, with low results in the efficiency of job creation in knowledge intensive services and high & mid high tech manufacturing (37 regions)
- Group 3: low efficiency regions in both variables (89 regions)
- Group 4: high efficiency regions in job creation in knowledge intensive services and high & mid high tech manufacturing, with different results regarding to efficiency in patents (23 regions)

In the following pages we represent the regions of each group.

Table 5. Groups of regions resulting from cluster analysis

Cod.	Region	Cluster	N. of Reg.
at12	Niederösterreich	1	
at32	Salzburg	1	
itd3	Veneto	1	
ite3	Marche	1	
nl41	Noord-Brabant	1	
se0a	Västsverige	1	6
at21	Kärnten	2	
at31	Oberösterreich	2	
at33	Tirol	2	
de1	Baden-Württemberg	2	
de2	Bayern	2	
de6	Hamburg	2	
de7	Hessen	2	
de8	Mecklenburg-Vorpommern	2	
de9	Niedersachsen	2	
dea	Nordrhein-Westfalen	2	
deb	Rheinland-Pfalz	2	
dec	Saarland	2	
def	Schleswig-Holstein	2	
dk00	Denmark	2	
es53	Illes Balears	2	
fi18	Etelä-Suomi	2	
fi19	Länsi-Suomi	2	
fr10	Île de France	2	
fr26	Bourgogne	2	
fr42	Alsace	2	
fr52	Bretagne	2	

fr53	Poitou-Charentes	2	37
fr71	Rhône-Alpes	2	
itc1	Piemonte	2	
itc4	Lombardia	2	
itd2	Provincia Autonoma Trento	2	
itd5	Emilia-Romagna	2	
ite1	Toscana	2	
ite2	Umbria	2	
nl11	Groningen	2	
nl31	Utrecht	2	
se06	Norra Mellansverige	2	
se07	Mellersta Norrland	2	
ukc	North East	2	
uke	Yorkshire and The Humber	2	
ukg	West Midlands	2	
uki	London	2	
at13	Wien	3	
at22	Steiermark	3	
be1	Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest	3	
be2	Vlaams Gewest	3	
be3	Région Wallonne	3	
cz01	Praha	3	
cz03	Jihozápad	3	
cz06	Jihovýchod	3	
de3	Berlin	3	
de4	Brandenburg	3	
de5	Bremen	3	
ded	Sachsen	3	
dee	Sachsen-Anhalt	3	
deg	Thüringen	3	
ee00	Estonia	3	
es11	Galicia	3	
es12	Principado de Asturias	3	
es13	Cantabria	3	
es21	Pais Vasco	3	
es24	Aragón	3	
es30	Comunidad de Madrid	3	
es41	Castilla y León	3	
es42	Castilla-la Mancha	3	
es43	Extremadura	3	
es51	Cataluña	3	
es52	Comunidad Valenciana	3	
es61	Andalucía	3	
es62	Región de Murcia	3	
es70	Canarias (ES)	3	
fi13	Itä-Suomi	3	
fi1a	Pohjois-Suomi	3	
fr24	Centre	3	
fr25	Basse-Normandie	3	
fr30	Nord - Pas-de-Calais	3	
fr41	Lorraine	3	
fr51	Pays de la Loire	3	

fr61	Aquitaine	3
fr62	Midi-Pyrénées	3
fr72	Auvergne	3
fr81	Languedoc-Roussillon	3
fr82	Provence-Alpes-Côte d'Azur	3
fr83	Corse	3
gr12	Kentriki Makedonia	3
gr23	Dytiki Ellada	3
gr30	Attiki	3
gr43	Kriti	3
hu10	Közép-Magyarország	3
hu32	Észak-Alföld	3
hu33	Dél-Alföld	3
ie	Ireland	3
itc3	Liguria	3
itd4	Friuli-Venezia Giulia	3
ite4	Lazio	3
itf1	Abruzzo	3
itf3	Campania	3
itf4	Puglia	3
itf5	Basilicata	3
itg1	Sicilia	3
itg2	Sardegna	3
lt00	Lithuania	3
lv00	Latvia	3
nl22	Gelderland	3
nl32	Noord-Holland	3
nl33	Zuid-Holland	3
nl42	Limburg (NL)	3
pl11	Lódzkie	3
pl12	Mazowieckie	3
pl21	Malopolskie	3
pl22	Slaskie	3
pl32	Podkarpackie	3
pl34	Podlaskie	3
pl41	Wielkopolskie	3
pl51	Dolnoslaskie	3
pl63	Pomorskie	3
pt16	Centro (PT)	3
pt17	Lisboa	3
pt18	Alentejo	3
se01	Stockholm	3
se02	Östra Mellansverige	3
se08	Övre Norrland	3
si00	Slovenia	3
sk01	Bratislavský kraj	3
ukd	North West (including Merseyside)	3
ukf	East Midlands	3
ukh	Eastern	3
ukj	South East	3
ukk	South West	3
ukl	Wales	3

ukn	Northern Ireland	3	89
cz04	Severozápad	4	
cz05	Severovýchod	4	
cz07	Střední Morava	4	
cz08	Moravskoslezsko	4	
es22	Comunidad Foral de Navarra	4	
es23	La Rioja	4	
fr21	Champagne-Ardenne	4	
fr22	Picardie	4	
fr23	Haute-Normandie	4	
fr43	Franche-Comté	4	
gr13	Dytiki Makedonia	4	
gr21	Ipeiros	4	
hu21	Közép-Dunántúl	4	
hu22	Nyugat-Dunántúl	4	
hu23	Dél-Dunántúl	4	
hu31	Észak-Magyarország	4	
mt00	Malta	4	
nl21	Overijssel	4	
pl62	Warminsko-Mazurskie	4	
pt11	Norte	4	
sk02	Západné Slovensko	4	
sk03	Stredné Slovensko	4	
sk04	Východné Slovensko	4	23

Each group presents averages in the two variables under study that are different with statistical significance (table 6):

Table 6. Averages of the 4 groups of regions in the two considered variables

Group	Patents	Employment	number of regions
1	1,0000	0,5556	6
2	0,4777	0,1741	37
3	0,1640	0,1922	89
4	0,2227	0,8451	23
General average	0,2799	0,2988	155

Source: Own elaboration

In figure 3 we can observe the geographic concentration of the leading regions in efficiency (groups 1 and 4), regions with a high level of efficiency regarding to employment in knowledge and technology intensive sectors (group 4) and regions with a low efficiency level (groups 2 and 3). The largest group of regions is the one with the lowest level of efficiency (group 3). The two leading groups of regions (1 and 4) gather 29 regions, in contrast with the 126 regions of the low efficiency groups.

We can conclude from this analysis that there is a strong polarization among the leading regions and the low efficiency regions. The number of low efficiency regions is extremely high in comparison with the number of the leading regions in efficiency. This shows the necessity of improving the use of R&D inputs at the regional level in Europe and the convenience of establishing learning processes between regions so that low efficiency regions could adapt policies and know-how from the leading regions.

6. CONCLUSIONS

The aim of this study has been to measure the efficiency of R&D activities performed at the regional level in the EU27 using the data envelopment analysis (DEA). In addition to the basic model (that model includes 3 inputs and 3 outputs) we have built 2 models in order to measure the efficiency of each output. After analyzing the three DEA models we have grouped all regions in 4 different categories, according to the efficiency levels achieved in the DEA models.

The results of this study could be used to assess the regional R&D policy in the EU27 at the regional level. The final objective of DEA is to give each region a tool to ameliorate the efficiency of regional expenditures in R&D and also to offer a context to compare the results of each region with the results of other regions located in the same economic and cultural environment. With this tool non-efficient regions could calculate the increase in output needed to become 100% efficient. Regional policy makers could benefit from this tool and take into account the efficiency level of their region in order to design policies to improve it. Policy makers in low efficiency regions should consider this low level of efficiency in their territories and analyze its causes. These causes may differ from region to region. Noord-Brabant and Veneto, for example, obtain satisfactory results in general terms, but they show a clear weakness in terms of efficiency in employment. If these regions improve their situation in that field, they could achieve higher levels of efficiency.

The limitations of this study are twofold. On one hand, the DEA models we have estimated have been built using constant returns to scale, following the vast majority of authors presenting this kind of analysis. On the other hand, the number of input and output indicators used in this work is very limited. A wider range of the indicators taken into consideration in this study could be beneficial in order to strengthen the final outcome.

A qualitative analysis of the regional innovation systems (RIS) taken into consideration in this study could clarify the reasons why some regions are more efficient than others. Using the concept of regional innovation system, it could be possible to conclude whether the lack of interaction between RIS agents, the lack of investment and/or the lack of an institutional framework at the regional level are lowering the efficiency of regional R&D activities.

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