

REGIONAL PATTERNS OF EFFICIENCY IN R&D EXPENDITURE IN SOUTHERN EUROPE

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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 Italy and Spain, 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. Differences between regions in the same country may be bigger than differences between regions in the two selected countries. An efficient use of the funding available for research, development and innovation activities is of the highest importance because of different reasons. In the first place, in most regions in Spain and Italy the amount of funding for this kind of activity is very limited (under EU standards), so an efficient use of this funding is crucial in order to get tangible results. Secondly, many regions in the selected countries are in the process of increasing the amount of money invested in R&D and innovation activities (to achieve the recommended levels of the Lisbon strategy), without addressing previously the

efficiency of their regional innovation systems. And in the third place, many regional governments in Spain and Italy are taking into account only input indicators to measure the evolution and correctness of their regional innovation policies, assuming that more expenditure is always better. It may be the case that this fresh money could be expended in highly inefficient innovation systems, without any impact in the regional productive systems.

In this paper the authors will measure the productivity of research, development and innovation activities performed by all regions in Italy and Spain. 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 Spain and Italy, and also mixing regions of the two countries. 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 regional innovation system (RIS), proposes the public intervention to strengthen the different economic agents inside a 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. Spain and Italy have followed this path, although disparities between regions in Spain and Italy are quite big (Martínez and Aguado, 2009) (Miceli, 2010).

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 Spain and Italy. These two countries share important similarities: cultural features, level of expenditure in R&D, level of economic development, regional disparities, and also some differences, such as the level of political decentralization (much higher in Spain). In this paper we will analyze the efficiency of R&D expenditures taking into account Italian and Spanish regions, in order to build a common taxonomy, discover similarities and disparities between the two countries and contextualize the results achieved by regions in each country.

Some attempts to measure the efficiency of RIS at the Italian, Spanish and European level have been done by different authors in recent times (Navarro, Gibaja, Aguado y Bilbao-Osorio, 2009) (Buesa y 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 Italy and Spain (Buesa and Heijjs, 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. In addition to these limitations, in the case of Spain and Italy, the number of patent applications is very low in comparison with other developed economies (EU average, Japan, USA) (EC, 2009). Due to the aforementioned facts, it may 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 Italian and Spanish 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-DEA.

The paper is developed as follows. In section 2 the evolution of the R&D expenditure in Italian and Spanish regions 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 SPANISH AND ITALIAN REGIONS 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). Recently, two articles (Balmaseda and Melguizo, 2007 and Escribá and Murgui, 2007) have been working on the relationship between investment in R&D and production in Spain showing its importance. In Italy, this relationship has also been addressed in recent publications (Miceli, 2010, Brioschi, Cassia and Colombelli, 2006). In this section we will make a brief overview on the status of R & D in EU countries, focusing on Italian and Spanish regions¹.

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 (Greece, Portugal, Italy and Spain) show a growth rate above average. This would indicate the existence of a certain process of convergence in business expenditure on R&D between countries and the EU-15 average.

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

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

	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 Republic	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

Source: Eurostat and own elaboration

Table 2 shows the same analysis at the regional level, only for regions in Spain and Italy.

Table 2. R&D expenditures by sectors of performance, in % of GDP. Years 2000 and 2004. Regions of Italy and Spain.

Cod.	Región	2000			2004		
		Business	AAPP	University Education	Business	AAPP	University Education
es11	Galicia	0,21	0,11	0,32	0,32	0,14	0,40
es12	Principado de Asturias	0,41	0,11	0,29	0,28	0,11	0,26
es13	Cantabria	0,12	0,10	0,21	0,17	0,10	0,17
es21	Pais Vasco	0,90	0,03	0,21	1,20	0,06	0,26
es22	Com. F. Navarra	0,56	0,02	0,28	1,17	0,09	0,54
es23	La Rioja	0,35	0,04	0,18	0,43	0,08	0,15
es24	Aragón	0,39	0,11	0,19	0,40	0,14	0,16
es3	Madrid	0,86	0,43	0,27	0,93	0,43	0,28
es41	Castilla y León	0,26	0,05	0,32	0,50	0,08	0,35
es42	Castilla-la Mancha	0,36	0,05	0,15	0,18	0,06	0,17
es43	Extremadura	0,14	0,13	0,27	0,13	0,11	0,17
es51	Cataluña	0,71	0,08	0,26	0,88	0,12	0,32
es52	Com. Valenciana	0,30	0,06	0,34	0,31	0,10	0,48
es53	Illes Balears	0,03	0,05	0,14	0,05	0,05	0,15
es61	Andalucia	0,21	0,12	0,31	0,27	0,16	0,34
es62	Región de Murcia	0,30	0,11	0,28	0,25	0,13	0,28
es7	Canarias (ES)	0,10	0,11	0,26	0,13	0,14	0,31
itc1	Piemonte	1,38	0,09	0,21	1,27	0,06	0,29
itc2	V. d'Aosta/d'Aoste	0,72	0,03	0,00	0,28	0,05	0,03
itc3	Liguria	0,51	0,19	0,43	0,66	0,18	0,36
itc4	Lombardia	0,83	0,11	0,18	0,79	0,07	0,28
itd1	Bolzano-Bozen	0,25	0,00	0,02	0,26	0,01	0,04
itd2	P. A. Trento	0,19	0,27	0,24	0,19	0,45	0,39
itd3	Veneto	0,24	0,06	0,21	0,31	0,06	0,30
itd4	Friuli-Venezia Giulia	0,54	0,16	0,45	0,50	0,13	0,53
itd5	Emilia-Romagna	0,48	0,13	0,32	0,74	0,09	0,42
ite1	Toscana	0,30	0,17	0,54	0,37	0,14	0,62
ite2	Umbria	0,16	0,11	0,67	0,20	0,07	0,60
ite3	Marche	0,13	0,05	0,32	0,29	0,03	0,35
ite4	Lazio	0,58	0,93	0,35	0,47	0,78	0,42
itf1	Abruzzo	0,42	0,12	0,36	0,55	0,13	0,46
itf2	Molise	0,11	0,02	0,29	0,04	0,05	0,31
itf3	Campania	0,35	0,15	0,51	0,38	0,15	0,55
itf4	Puglia	0,13	0,09	0,39	0,15	0,09	0,36
itf5	Basilicata	0,17	0,29	0,33	0,20	0,09	0,21
itf6	Calabria	0,01	0,05	0,22	0,02	0,05	0,34
itg1	Sicilia	0,21	0,10	0,55	0,19	0,10	0,54
itg2	Sardegna	0,06	0,13	0,48	0,06	0,12	0,54

Source: Eurostat, INE and own elaboration

In the case of Spain only Madrid, Navarra, Basque Country and Catalonia overcome 1% of total investment in R&D on GDP in 2004. By sector of performance, the public administration in Madrid is very significant. This situation is due in part to the concentration of the main public research organizations (PROs) in the capital. By contrast, in Navarra and the Basque Country companies show the highest investment rate. In the case of the Basque Country we must consider that its powerful network of Technology Centers is included in the corporate sector for statistical purposes (Aguado, 2007). In the Italian case ten regions are exceeding 1% of expenditure on R&D, being the ones with higher percentages Piemonte, Liguria, Emilia-Romagna and Lazio, all of them with levels above 1.2%. While the weight of the university is high in regions such as Toscana and Umbria, businesses play a key role in Piemonte and Emilia Romagna. The weight of the public sector is prominent in Lazio, for similar reasons to what happens to Madrid in Spain: the Italian public administration focuses its PROs in the capital, Rome.

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).

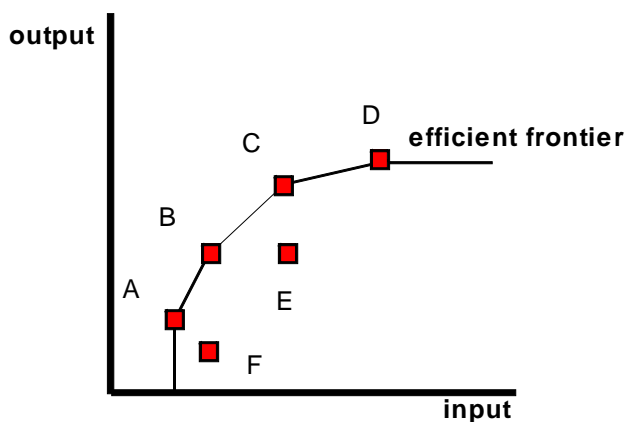
In this paper DEA² is being used as it was coined by Charnes et al (1978) in their seminal paper on DEA, based on a previous work by Farrell, 1957. DEA is for measuring relative efficiency, so an organization that consumes fewer resources for getting the same quantity of product can be considered as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

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

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:

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

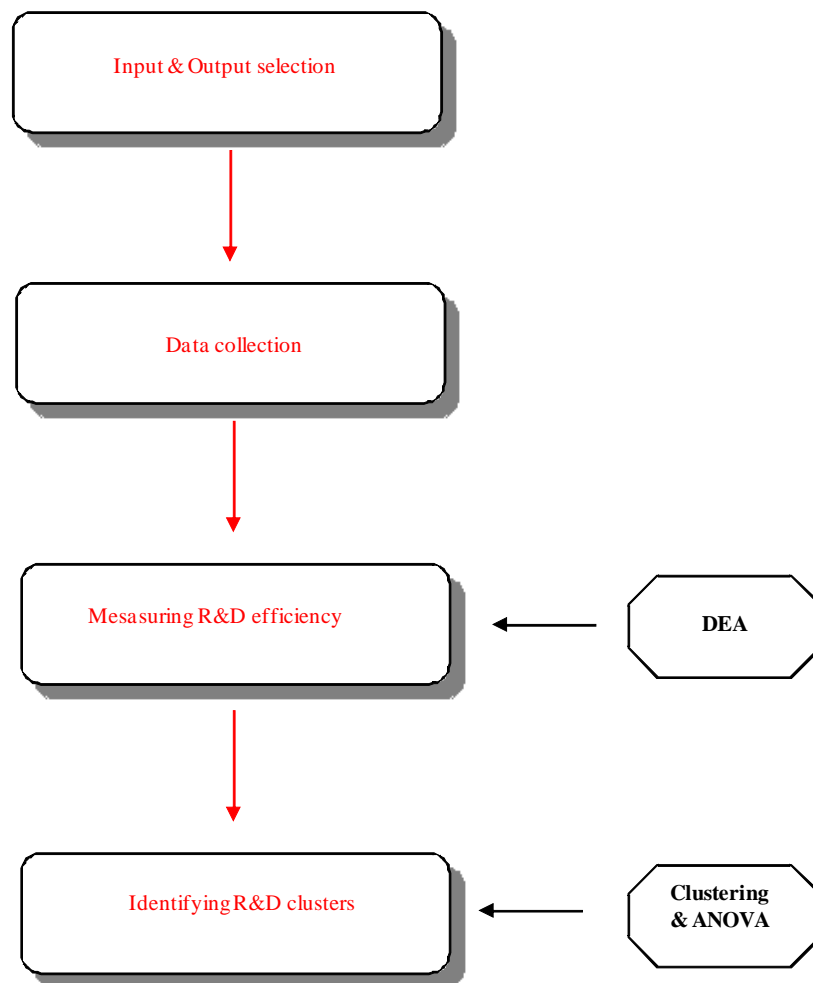
where ε is a very small positive number to avoid null weight factors.

4. Methodology

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

- Firstly, the input-output variables have been selected following recommendations found in previous studies that analyze the RIS efficiency.
- Secondly, data from 38 regions (17 Spanish regions and 18 Italian regions) have 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 3 summarizes their key characteristics.

Table 3. 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	2004

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 can be found. For example, Buesa et al., 2007, Navarro, Gibaja, Aguado y Bilbao- Osorio, 2009 used the number of patents, while Martínez-Pellitero, 2002 y 2007, Buesa y Heijs, 2007 used GBP 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 2004 data, but patents, whose data derived from 2003.

The whole dataset have been obtained from Eurostat. Three Italian regions have been excluded (Valle de Acosta, Bolzano – Bolzen and Calabria) as their level of expenditure in R&D were lower than 0,01% over GDP produced by companies, Administration and/or Universities and final results could have been distorted.

5. RESULTS

This section shows the results of measuring the efficiency of R&D investment of the 35 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 single input with all outputs or a single output with all inputs. In this way, it is possible to measure the efficiency in R&D for each selected input and output.

For example, the DEA model that incorporates all outputs and includes the sole input “R&D made by public administration” can be considered as the model that measures the efficiency of the public administration. Similarly, 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 six additional models apart from the basic model (which includes all inputs and outputs): the model of public administration efficiency, the model of business efficiency, the model of efficiency in universities, the production efficiency-oriented model, the patent efficiency-oriented model and the employment efficiency-oriented model. Table 4 shows inputs and outputs included in each of the seven DEA models that have been calculated

Table 4. Inputs and Outputs considered in the DEA models

DEA MODEL	Input			Output		
	PERD	BERD	UERD	GDPpc	Patents	Employment
Basic Model	○	○	○	○	○	○
Efficiency Model GI+DAAPP	○			○	○	○
Efficiency Model GI+DEMP		○		○	○	○
Efficiency Model GI+DES			○	○	○	○
Efficiency-oriented production	○	○	○	○		
Patent-oriented efficiency	○	○	○		○	
Efficiency-oriented employment	○	○	○			○

Source: Own elaboration

Table 5 shows the results of the efficiency of R&D for the 35 regions in the seven DEA models. Eight regions achieve maximum efficiency in the basic model: Basque Country, Navarra, La Rioja and the Balearic Islands in Spain and Veneto, Marche, Molise and Lombardia in Italy. In contrast, the most inefficient regions (less than 40% efficiency) are Extremadura and Andalusia in Spain and Sicilia, Puglia and Campania in Italy. The rest are in an intermediate position between these two extremes. It is noteworthy that one of the regions 100% efficient in the basic model shows a small level of R&D investment over GDP compared to others, such as Madrid, Cataluña, Lazio and Emilia-Romagna that have higher levels of use of inputs (see section 2). The results of efficiency of each region vary significantly from model to model. For example, the Basque Country achieves 100% efficiency in the production-oriented model (GDP per capita), but only 40% in the patent-oriented model. It seems clear, then, that the Basque Country has a strong point in productivity measured by GDP per capita, showing a clear weakness in patenting. These specific data would have remained undeveloped in the case have estimated only the basic model.

These results differ markedly from those obtained by Buesa and Heijs (2007) for Spanish regions 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 (Cataluña, Madrid, Valencia, Basque Country, Andalusia). 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 (see Section 2), are capable of reaching the highest level of efficiency. To reach this level of efficiency, regions such as Madrid and Cataluña should get better results in the output variables.

Tabla 5. Results of the seven DEA models for the Spanish and Italian regions in percentage.

Cod.	Region	Basic Model	Efficiency Model PERD	Efficiency Model BERD	Efficiency Model UERD	Efficiency-oriented production	Patent-oriented efficiency	Efficiency-oriented high technology empl.
es11	Galicia	43,7851	10,7919	18,8854	36,4027	33,7468	3,3206	43,7851
es12	Asturias	45,4223	11,0142	11,4549	40,8485	43,0586	6,4734	45,4223
es13	Cantabria	65,2952	10,8819	16,4084	56,7992	59,8015	10,5940	65,2952
es21	Pais Vasco	100,0000	51,9675	7,9550	79,7284	100,0000	40,2105	100,0000
es22	C.Foral de Navarra	100,0000	100,0000	17,9717	55,1782	100,0000	100,0000	100,0000
es23	La Rioja	100,0000	34,9713	25,9242	79,3123	98,4880	46,2349	75,6102
es24	Aragón	94,1067	12,5102	17,0527	85,3168	73,4045	22,5096	94,1067
es3	Madrid	74,7063	4,5341	8,8000	70,7879	57,8474	13,9441	74,7063
es41	Castilla y León	56,1040	22,4813	16,0303	36,8581	55,8929	14,1891	56,0919
es42	Castilla-la Mancha	76,2968	23,0737	12,5614	67,2534	74,5070	9,7822	76,2774
es43	Extremadura	33,5585	8,6942	29,3880	27,6276	29,0816	9,5608	33,5585
es51	Cataluña	77,3954	20,6466	15,4605	65,7328	61,2014	36,0876	77,0280
es52	C. Valenciana	53,2735	19,6176	22,9276	33,0097	50,4860	18,5961	52,4368
es53	Illes Balears	100,0000	29,7372	100,0000	93,4494	100,0000	43,0782	100,0000
es61	Andalucia	37,2637	7,9721	17,8252	31,3780	31,9395	10,1789	37,2637
es62	Región de Murcia	48,8058	9,0628	13,4159	42,8275	45,1632	8,2039	48,8058
es7	Canarias (ES)	47,6109	10,3728	39,4173	39,7795	42,5295	15,0653	47,6109
itc1	Piemonte	94,3754	45,8279	16,2797	78,2407	78,5737	91,8081	86,5747
itc3	Liguria	46,9901	7,4828	23,0513	39,4671	38,0689	26,5081	45,4436
itc4	Lombardia	100,0000	39,8157	31,1423	100,0000	100,0000	100,0000	100,0000
itd2	P.A. Trento	84,2211	8,3429	76,5208	67,9758	72,1853	77,6855	73,1541
itd3	Veneto	100,0000	57,3048	95,9852	79,5874	90,4495	100,0000	92,2820
itd4	Friuli-Venezia Giulia	44,4018	16,0148	28,3091	36,7585	38,7754	35,4235	41,2929
itd5	Emilia-Romagna	82,4238	43,7929	62,3488	63,8891	55,5081	82,4238	60,1377
ite1	Toscana	47,6895	11,2811	44,8718	30,2410	32,2022	45,2559	33,7900
ite2	Umbria	55,2404	15,0636	51,2064	23,6196	42,0000	36,1693	51,9391
ite3	Marche	100,0000	45,3599	100,0000	46,1642	84,8123	100,0000	83,4263
ite4	Lazio	52,2126	2,0002	15,4329	46,9706	49,1609	18,2735	52,2126
itf1	Abruzzo	49,0348	13,3519	21,8183	38,4550	35,8026	19,3752	47,9964
itf2	Molise	100,0000	72,0227	33,7315	44,1892	100,0000	0,0004	100,0000
itf3	Campania	24,9508	6,4191	10,7327	20,4852	19,4950	5,1825	24,9475
itf4	Puglia	37,0348	10,4181	28,0727	27,2921	32,7053	15,6855	36,7851
itf5	Basilicata	41,8255	6,7355	28,0916	34,8394	35,7159	17,1128	41,7028
itg1	Sicilia	31,9403	10,2547	20,6646	18,8571	27,0097	12,1627	30,7627
itg2	Sardegna	60,0716	9,0698	60,0716	23,8566	50,3992	19,1371	60,0716

Source: Own elaboration

Considering two of 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. Typology of regions, based on efficiency in patents and employment

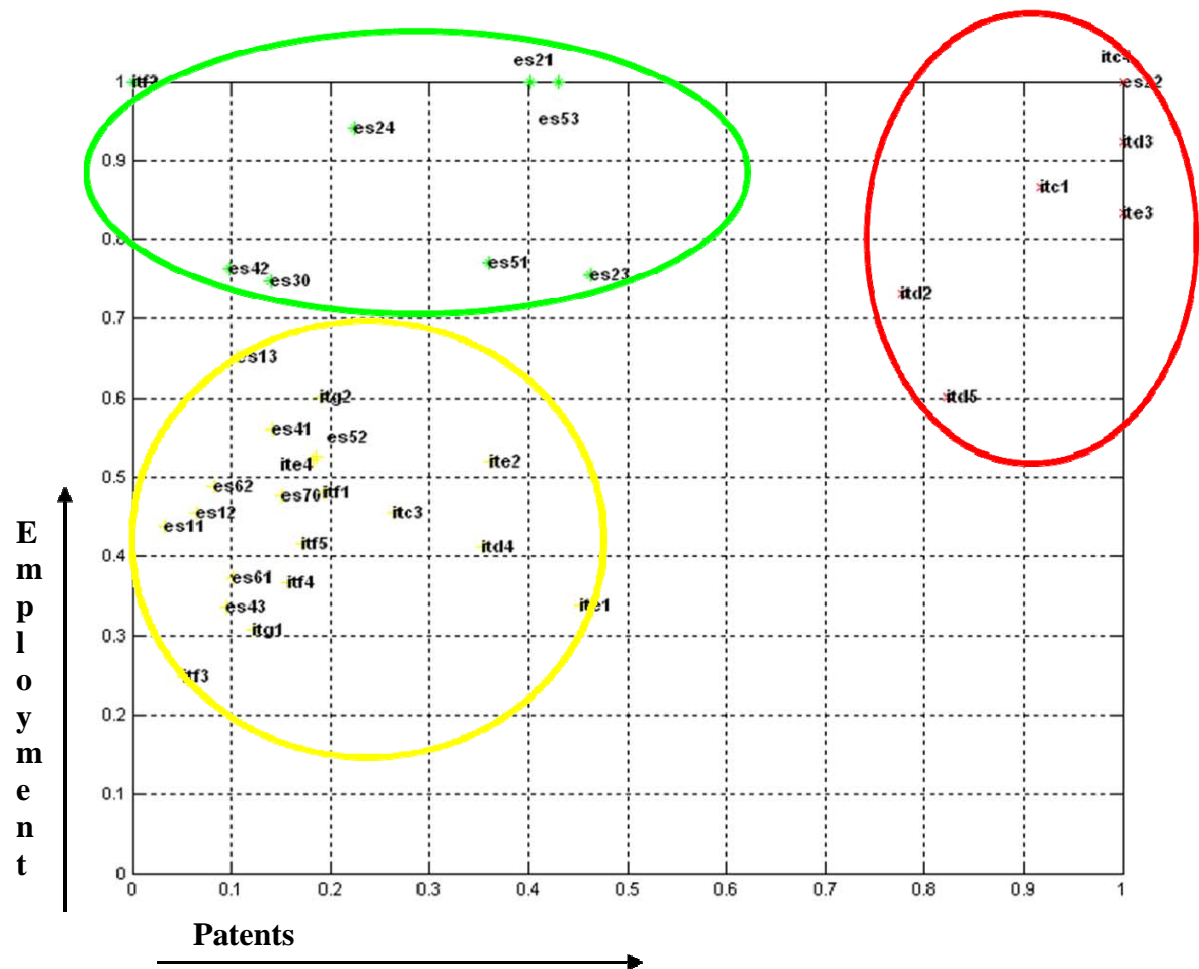


Table 6. Groups of regions resulting from cluster analysis

Cod.	Region	Cluster	Number	Cod.	Region	Cluster	Number		
es21	País Vasco	1	8	es11	Galicia	2	20		
es23	La Rioja			es12	Asturias				
es24	Aragón			es13	Cantabria				
es3	Madrid			es41	Castilla y León				
es42	Castilla-la Mancha			es43	Extremadura				
es51	Cataluña			es52	C. Valenciana				
es53	Illes Balears			es61	Andalucía				
itf2	Molise			es62	Región de Murcia				
es22	C. F. de Navarra	3	7	es7	Canarias (ES)			2	20
itc1	Piemonte			itc3	Liguria				
itc4	Lombardia			itd4	Friuli-Venezia Giulia				
itd2	P. A. Trento			ite1	Toscana				
itd3	Veneto			ite2	Umbria				
itd5	Emilia-Romagna			ite4	Lazio				
ite3	Marche			itf1	Abruzzo				
		itf3	Campania						
		itf4	Puglia						
		itf5	Basilicata						
		itg1	Sicilia						
		itg2	Sardegna						

Each group present averages in the two variables under study that are different with statistical significance (table 7):

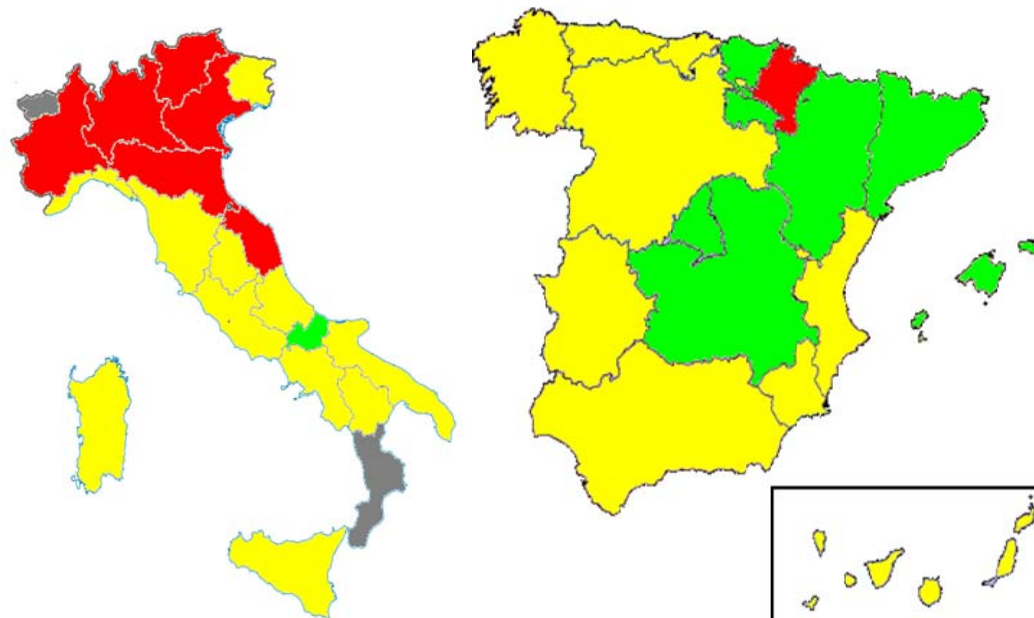
Table 7. Averages of the 3 groups of regions in the two variables considered

Cluster	Patents	Tec Employment
1	87,2161	26,4809
2	44,8607	17,3234
3	85,0821	93,1311
General Average	62,5862	34,5781

Source: Own elaboration

While group 3 presents higher efficiency values in the two variables, group 2 presents the lowest results. In group 1, the result is high on the efficiency of job creation (analogous to the leader group) and lower in the efficiency of patents (but higher than low efficiency groups). Figure 4 shows the geographic distribution of regions in the three clusters.

Figure 4. Geographical representation of cluster analysis



Source: Own Elaboration

In figure 4 we can observe the geographic concentration of the leading regions in efficiency (red), the regions with a high level of efficiency regarding to employment in knowledge and technology intensive sectors (green) and regions with a low efficiency level (yellow). In both countries the largest group of regions is the one with a low level of efficiency. While in Spain these regions are spread throughout the geography, in the Italian case these regions are concentrated mainly in the south area and in the islands. In contrast, the leading regions in efficiency are concentrated in northern Italy (six regions), while only one region in Spain (Navarra) is part of the leading group (group 3). Efficient regions only in employment in knowledge and technology intensive sectors are abundant in Spain (6 regions, including Madrid and Cataluña), while in Italy only one region is in this cluster (green cluster, group 1).

We can conclude from this analysis that in Italy there is a strong geographic polarization among the leading regions (located in the north) and the low efficiency regions (islands and south), with only one region in between. By contrast, in Spain there is only one

region within the leading group (group 3) and the number of regions of intermediate efficiency belonging to group 1 (efficient only in employment in knowledge and technology intensive sectors) is high.

6. CONCLUSIONS

The aim of this study has been to measure the efficiency of R+D activities performed at the regional level in Spain and Italy using the data envelopment analysis (DEA). In addition to the basic model (that model includes 3 inputs and 3 outputs) we have built 6 models in order to measure the efficiency of one input or one output. After analyzing the seven DEA models we have grouped all regions in 3 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 Spain and Italy. 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. Madrid and Cataluña (they concentrate more than 50% of total R&D investment in Spain), for example, obtain satisfactory results in general terms, but they show a clear weakness in terms of EPO patent application. If these regions improve their situation in that field, they could achieve higher levels of efficiency. In Italy, Lazio region presents a low efficiency level in comparison to the leading regions situated in the north part of the country. These northern Italian regions are the leading regions not only among Italian regions, but also considering regions in Spain.

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.

BIBLIOGRAPHY

Aguado, R. (2007): *Economía y Política de la Innovación Empresarial. El caso de la Red Vasca de Parques Tecnológicos*. Tesis Doctoral. Servicio de Publicaciones de la Universidad del País Vasco, Bilbao.

Álvarez, Aguado and Martínez (2008): *Estructura, Innovación y Crecimiento Económico*. DDB, Bilbao

Arrow, K. J. (1962): "Economic Welfare and the Allocation of Resources for Invention". Nelson, R. (ed.) *The Rate and Direction of Inventive Activity: Economic and Social Factor*. Princeton. Princeton University Press, pp. 609-625

Balmaseda, M. and Melguizo, A. (2007): "I+D como factor productivo en la economía española: un análisis empírico regional y sectorial". *Hacienda Pública Española*, 180- (1/2007),. pp. 9-34.

Banker, R. D., Charnes, A. and Cooper, W. W. (1984): "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis". *Management Sciences*, Vol. 30, N° 9, 1078-1092

Beige, P (1998): *Technological Change in the modern economy. Basic topics and new developments*. Edward Elgar, Cheltenham

Brioschi, M., Cassia L., Colombelli A., (2006) "Sistemi regionali di innovazione in Europa: lezioni per le province italiane ad alta specializzazione industriale", *working paper 2006 in Quaderni del Dipartimento di Ingegneria gestionale*, Università degli Studi di Bergamo.

Buesa et al. (2007) : *Sistemas Regionales de Innovación : nuevas formas de análisis y medición*. Funcas, Madrid.

Buesa, M. and Heijs, J. (2007) : «Los Sistemas Regionales de Innovación en España » in Buesa et al. (2007) : *Sistemas Regionales de Innovación : nuevas formas de análisis y medición*. Funcas, Madrid.

Cameron, G. (1998): “Innovation and Growth: a survey of the empirical evidence”. Mimeo. Nuffield College, Oxford.

Charnes, A., Cooper, W. W. and Rhodes, E. (1978): “Measuring Efficiency of Decision Making Units”. *European Journal of Operational Research*, Vol. 2, 325-331

Coelli, T., Rao, D. and Battese, G. (1998): *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer.

European Commission (2009): *European Innovation Scoreboard 2008*. Bruselas.

Cooper W. W., Seiford L. M. and Zhu J. (2004): *Handbook on Data Envelopment Analysis*. Springer (Kluwer Academic Publishers), Boston, 2004.

Coronado, D. and Acosta, M. (1999): “Innovación tecnológica y desarrollo regional”. *ICE* nº781 Octubre 1999

Dogson, N. and Rothwell, R. (1994): *The Handbook of Industrial Innovation*. Edward Elgar, Aldershot.

Escribá, F. J. and Murgui, M^a J. (2007): “El Capital Tecnológico como Factor de Producción en las Regiones Españolas, 1980-2000”. *Investigaciones Regionales*, 10 (Primavera 2007), pp. 33-52.

Farell, M. J. (1957): “The measurement of productive efficiency”. *J. R. Statist. Soc. A*, 120, 253-281.

Graves, S. B. and Langowitz, N.S. (1996): “R&D Productivity: A Global Multi-industry Comparison” *Technology Forecasting and Social Change*, Vol. 53, Nº 2, 125-137.

Kamien, M. and Schwartz, N. (1975): “Market Structure and Innovation: A Survey”. *Journal of Economic Literature*, vol. XIII, pp. 1-37.

Lee, H-Y and Park Y-T (2005): “An International Comparison of R&D Efficiency: DEA Approach”. *Asian Journal of Technology Innovation* 13, 2 pp. 207-222

Lundvall, B. A. (1992): *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*. Pinter, London

Mani, S. (2002): *Government, Innovation and Technology policy*. Edward Elgar, Cheltenham.

Martínez, J. and Aguado, R. (2009). “Incentivos fiscales a la I+D en el País Vasco: Un Análisis comparado con la UE-15”. *Boletín de Estudios Económicos*, nº 197, Vol. LXIV

Martínez Pellitero, M. (2002): “Recursos y resultados de los sistemas de innovación: elaboración de una tipología de sistemas regionales de innovación en España” *IAIF Working paper*, 34.

Martínez Pellitero, M. (2007): “Los sistemas regionales de innovación en Europa: tipología y eficiencia” en Buesa et al. (2007): *Sistemas Regionales de Innovación: nuevas formas de análisis y medición*. Funcas, Madrid.

Miceli, V. (2010): “Sistemi regionali di innovazione e distretti tecnologici. Il caso italiano”, *ed. Il Mulino*, Bologna.

Navarro, M., Gibaja, J., Aguado, R. and Bilbao-Osorio, B. (2009): “Patterns of innovation in EU-25 regions: a typology and policy recommendations” *Environment and Planning C: Government and Policy* advance online publication, doi: 10.1068/c0884r

OECD (2001): *OECD Science, Technology, and Industry Scoreboard*. Paris, OECD

Porter, M. (1998): “Clusters and the New Economics of Competitions”. *Harvard Business Review*, nov-dec. 1998, pp. 77-90.

Porter et al. (2000): “The Determinants of National Innovative Capacity”. *National Bureau of Economic Research. Working Paper 7876*, Cambridge, Massachusetts.

Smith, P. C. and Street A. (2005): “Measuring the efficiency of public services: the limits of analysis”. *J. R. Statist. Soc. A*, 168, Part 2, 401-417

Thanassoulis, E. (2001): *Introduction to the Theory and Application of Data Envelopment Analysis*. Dordrecht: Kluwer.

Tödtling, F. and Trippel, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy* n. 34: 1203-1219.

Velasco, R. (1996): *Los economistas en su laberinto*. Taurus. Madrid.