Novel applications of existing econometric instruments to analyse regional innovation systems: The Spanish case.

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1.- Introduction

This paper tries to get to grips with the measurement of the national and regional innovation systems.[1] In this article we present novel applications of existing econometric instruments for the measurement and evaluation of regional innovation systems using multivariate analysis methods.[2] On the one hand, the evolutionary theory underpins the heterogeneity of the innovative performance, which has to be considered as a multidimensional activity. The literature emphasize the difficulty and the weakness of the use of individual indicators to measure the global concept of innovation, as well as patents, R&D expenditures, percentage of sales related to new products, etc. Each of those indicators –although highly correlated- gives a different view of apparently the same subject.[3] Therefore in this paper we try develop some new ways to measure innovation (systems) considering this concept as not directly observable. To create "combined" indicators that reflect different aspects of the regional innovation systems we used the *factorial analysis.* This technique, from a set of quantitative variables, allows us to reduce the set of existing variables to a lower set of non-observable hypothetical variables, called factors, which summarise practically all the information contained in the original set (see section 2).

[1] For a discussion about the concept of innovation systems see Lundvall, 1992; Nelson, 1993; Edquist, 1997

[2] The study is part of a large research project, carried out since 1999 by the "Instituto de Análisis Industrial y Financiero" (IAIF), aimed at the collection and development of indicators to analyse the regional innovation activities in Spain. In this project we collected and elaborated over 70 variables related to with different aspects of the Spanish Regional innovation systems.

[3] For example the technological level of Spain (in 2001 in comparison to the European Union (=100) is 45 percent, taking into account the R&D expenditures by GNP and 62 percent in the case of employment in R&D by total employment. However if we use the number of patents per capita as an indicator this level is only 15 percent.

We found four “unobservable variables” or factors that are homogeneous in their consistency and are clearly interpretable in terms of the theory on innovation systems (regional and productive environment for innovation; Higher Education System and research of Universities; Role of Civil Service and risk capital and the role of the innovating enterprises and the technological infrastructure). We consider that those four factors –which are nothing else than a combination of a set of different highly related variables- reflect better the four components of the innovation system than each of the individual variables would have done. The use of factors not only better reflect the different elements of the innovation system as we will show in the paper, they do avoid, in a certain way, the problem of important irregular fluctuations in time of the values of the individual variables.

The results of the *factor analysis* by them selves are not the principal objective of this paper. Rather our main aim is their use in following up studies. Once we have the factors, for each region “*standardised factor values”* will be assigned which will be used for further research. We developed four novel applications of the factors. First we establish a typology of Regional innovation systems. Secondly we created the *IAIF-index of regional innovation*. Thirdly we estimate a *knowledge production function*. And fourth we compare the *efficiency* of the regions through a data envelopment analysis.

These four analyses are complementary because they correspond to each of the perspectives of an economic analysis that tries to evaluate the innovation system. The typology of regional innovation systems describes the structure of configuration of the RIS, the IAIF-index summarize these typologies and offer the possibility to analyse their development over time. The “ideas production function” establishes the relationship between the “structural aspects” indicating the determinants of the creation of knowledge, while the “envelopment analysis” evaluates the efficiency of the innovative activities on a regional level. We did not detect any study that analyses the efficiency of the regional innovation systems, therefore it can be stated that this last aspect aims to close one of the gaps of the studies on innovation systems.

The results of these analyses not only can be interpreted correctly from the perspective of the evolutionary theory of innovations and technological change, however they can also be considered as stable and consistent.

In concluding: we consider that the combination of these applications in one sole article is important. Due to the absence of earlier studies with the same method, it is difficult to value the reliability of the outcome of our analysis. However the results of the four analyses do confirm each other reciprocally. Also the techniques are complementing because we use a multidimensional approach to analyse more or less the same subject —comparing the quality or capacity of the Spanish Regional innovation systems—, from different points of view using complementary econometric approaches.

2- Factor analysis as a multidimensional way of measuring Regional innovation systems

The different approaches to analyse the Spanish regional innovation systems used in this paper are based on the use of existing information on variables and indicators related to science, technology and innovation, from the viewpoint of resources and results, as well as certain aspects of an institutional nature and the productive structure. The years studied range from 1994 to 2000, both inclusive[4] and as a regional study unit we have worked with the 17 Autonomous Communities, corresponding to the level II NUTS according to the European nomenclature.

2.1 Variables and indicators

According to the outline presented by Heijs,[5] the variables we have worked with stand for the following aspects: firms and their relationship with the Regional innovation system; support infrastructure for innovation; Civli Service innovation-linked performance; and the regional and national environment for innovation.[6] It should be noted that the border between these subsystems is at times not very clearcut and there is a certain overlap between the different areas, so it is not always easy to classify each of the factors, actors or elements according to

[4] The indicators and variables used in the research are found on an existing database in the *Instituto de Análisis Industrial y Financiero* of the *Universidad Complutense* in Madrid. This was created as a result of research being carried out there, particularly the *Programa de Indicadores de la Ciencia y la Tecnología de la Comunidad de Madrid* (Program of Science and Technology Indicators of the Community of Madrid). To create this database data have been used which were provided by the *Instituto Nacional de Estadística* (INE). In some cases it has been necessary for INE to draw up “ad hoc” uses. In other cases, we had to apply some estimation model —for example the stock of technological and scientific capital— and, finally, others have been directly obtained from prime sources-technological patents or centres-. The methodological problems which arise in the use of different statistical sources are studied in Buesa, Casado, Heijs, Martínez Pellitero and Gutiérrez-Gandarilla (2002). See, also for these matters Buesa, Navarro et al (2001).

[5] Heijs (2001)

the four subsystems. Nonetheless, this classification is useful as an analytical outline to establish the indicators, and point out the aspects they represent within this study, as well as to indicate the influence of the evolutionary viewpoint which propounds the existence of interdependence relationships between the parts or elements of the system

In the case of firm*s*, we start from the hypothesis that these are the most important elements in innovation systems, not just as instruments for generating knowledge, which materialises in products and processes, but also as sources of internal learning, and as linking elements between the productive system and that of innovation in the case of *innovating firms*. Therefore, in the research several variables have been included relating to human and financial resources devoted to R&D, as well as the stock of firms' technological capital in Spanish regions.

Regarding the *support infrastructure for innovation*, understood as the group of bodies conceived to facilitate firms' innovatory activity, we make a distinction between a private part and a public one. The private part refers to the wide range of services among which are found technological centres and parks. Within the public domain, we consider the Public Research Bodies (OPI) and the universities with their resources and findings. To these are added human resources in science and technology[7]

In the case of the Civil Service we also use as a base the idea that this institution plays a very important part in the development of systems. On the one hand, the public sector manages an important part of regions' scientific apparatus, while exerting an important role as a financing agent for innovation. On the other, it also has an outstanding role as an agent linked to the development of technological policies. The research has tried to include those aspects via the indicators which reflect the human and financial resources used in R&D, the stock of scientific capital deriving from the latter, as well as part of technological policy, by means of the projects approved by the Centre for Industrial and Technological Development (CDTI)[8] in the different Autonomous Communities.

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[6] A more detailed analysis of the variable can be found in Martínez Pellitero (2002).

[7] Human resources in science and technology have been measured in accordance with the methodology proposed by the OECD (1994).

[8] The CDTI is a public institution managing credit funding of business projects involving technological innovation. It is probably one of the most important instruments of Spanish technological policy. See Molero and Buesa (1998), Buesa (1998) and Heijs (2001a).

Finally, the regional innovation environment is a broad concept including aspects which indirectly impinge on regions' technological and innovation capacities. Five aspects have been included in this research: the productive structure as quantified via NAV, employment and exports in industries with varying technological content; accessibility to venture capital systems; accumulated knowledge,[9] as quantified by means of an indicator of the quality of the universities; the size of the regional market represented by GDP value; and representative social indicators of the population's cultural preferences and traits, specifically, one relating to the information society and another stressing reading habits.

2.2. Factor analysis of main components

From the above-mentioned variables and indicators, a multivariate technique of the *factori analysis* has been applied with the object of determining implicit factors in Spanish regional innovation systems. This technique, from a set of quantitative variables, allows us to determine a lower set of non-observable hypothetical variables, called factors, which summarise practically all the information contained in the original set.[10]

In this study we have started out from a total of 35 variables in determining the implicit factors of the Spanish regional innovation systems. Using as a base the concept of *community quality of a variable*- which is defined as the proportion of the total variable recorded by the factors preserved- the variables and indicators have been established which form part of the final model via a process of trial and error; if the variable is found to be associated with a small community it will be reasonable to include another factor, provided that it is of better use to explain the model, or, rather, to eliminate it, if, on the contrary, it did not provide it

[9] In previous studies (Martínez Pellitero, 2002, Buesa, Martínez Pellitero, Heijs, Baumert, 2003) patents were also used as an indicator of accumulated knowhow. However, given that in the following section they are used as a measure of output-in statistical terms as a dependent variable of regression-they are omitted from this first part of the analysis.

[10] In this analysis we have worked with the SPSS 10A statistical program. From *Barlett's Sphericity Test and the KMO Measurement of Sample Suitability* the possibility has been verified of carrying out a factorial analysis on the basis of existing data. In the analysis no more than 20 or 25% of the original variability has to be lost, and the *autovalue* concept is used to represent the part of the total variability that a factor is able to record. The program's criterion by default —*Kaiser's criterion*— preserves all factors with autovalues of one or more. Nevertheless, it is obvious that the lower the number of variables in an analysis, the greater is the proportion of variability rejected when eliminating factors with autovalues close to one. When this technique is used, variables could be obtained for each factor present in the analysis, though that would lead to a non-valid solution since dimensionality or the volume of data remains constant. Moreover, it should not be understood in the initial solution that each component extracted is associated with the same variable, that is 1st factor with 1st variable, 2nd factor with 2nd variable, and so on, since the interpretation and, thus the significance of the factors, is obtained by analysing the so-called *factorial components matrix.*

with a significant value. The factorial method of data reduction that we have worked with is that of *main components*, and the final solution chosen was that made up of four factors, where 85% of the variance of the model was preserved, and where the communities take satisfactory values.[11]

Before beginning to interpret the factors obtained in the exercise by means of the *factorial components matrix*, it is worth pointing out that during this process a series of variables have been eliminated, specifically the three related to human resources in science and technology, those of a more social nature (population of people who normally read newspapers and population of people who use Internet), and one related to technological centres (staff on the payroll of technological centres). This exclusion is due to the fact that, in the specific case studied, and in the time period analysed, these indicators have been rejected as explanatory variables in the analysis.[12] Regarding the variables linked to human resources in science and technology, a possible explanation could be that these indicators reflect concepts which, in part, are already included in others on R&D, so to a certain extent they may be redundant. And the same can be said for the people working in technological centres.As for the indicators of a more social nature, exclusion could mean that at the present time the regional differences are not clearly significant.

In Table 1 a synthesis of the information provided by the *rotated components matrix,*[13] is presented, aimed at facilitating a correct view of the indicators classified by factors. Moreover, arrows have been included, to show the relationships between the variables and indicators linked to more than one factor.[14] Each factor records a series of indicators with a high degree of saturation in them. The allocation of a name has been based on their

[11] After the extraction of the four factors 73% of the variables show communality qualities over 0.800.
[12] In similar studies, where a lower time series was analysed, the extraction of the same variables has taken place. See Martínez Pellitero (2002).
[13] *The components or factorial matrix* contains the linear correlations between the different variables of the analysis and the preserved factors. These correlations are also called *saturations of the variables in different factors*. It is convenient to have a matrix in such a form that the variables are saturated in the factors, or what amounts to the same thing, they should have an important correlation. If the different variables are saturated in different factors, the solution is clearer and simpler to solve. A *rotation technique,* specifically the *Varimax*, has been used to improve the solution. The rotation of the factors is aimed at achieving a components matrix which has the greatest likelihood of being interpreted, that is, it fits in with the *simple structure principle,* under which each variable is saturated in a different factor. It may occur, however, that certain variables, even after rotation, are correlated to several factors, and that can be assumable because the variable participates from the significance of all of them. As has already been indicated, with four factors the model preserves 85% of the original total variance, so it can be stated that it is right to reduce the 35 initial variables to four factors. But, it is also important to interpret the meaning of the factors after the rotation. This will be done bearing in mind the saturation of the variables in them.

composition, and corresponds to the elements considered essential by theory in innovation systems.

2.3. Factors determining Regional Innovation Systems

The first factor —*Regional and productive environment of innovation*— registers a 28.67% variability, and is organised around three aspects: the productive structure-production, employment and exports linked to the industrial sector-support institutions for innovation and the size of the regional market. All the variables are found to be highly saturated, with values higher than 0.8, except for the one representing medium-low technology exports. This variable was in turn also found to be correlated with the fourth factor which registers elements linked to the area of innovating firms.

The second factor clearly reflects the role of the *University*. It records a 21.58% variability. Particularly noteworthy is the fact that the variables with a higher degree of saturation are those referring to the research environment in its strictest sense —postgraduate students, staff and researchers—. Regarding the indicators related to university results in the first and final part of the degree course, there is a lower degree of correlation.

The third factorial axis registers 18.19% variability and basically records variables referring to *the Civil Service* regarding innovation. To these can be added the variable referring to the venture capital system.

Finally, the fourth and ultimate factor, which records 16.89% variability, shows those elements alluding to knowledge creation activity in *Innovating firms*. Moreover, variables referring to technological centres are saturated in the factor, due to being support units for firms in research, absorption and diffusion of technology activities.

[14] The exclusion barrier for variables has been placed in saturations below 0.5.

Table 1: Factors of Spanish Regional Innovation systems

FACTOR 1: REGIONAL AND PRODUCTIVE ENVIRONMENT FOR INNOVATION

1) Productive Structure

- NAV High and medium technology industry in million € 1999 **(0.859)**
- NAV Low technology industry in million € 1999 **(0.968)**
- Employees high and medium technology industry **(0.890)**
- Employees in low technology industry **(0.975)**
- Export. High and medium-high technology industry in million € 1999 **(0.870)**
- Export. Medium-low technology industry in million € 1999 **(0.666)**
- Export. Low technology industry in million € 1999 **(0.978)**

2) Support institutions for innovation

- National projects approved by the CDTI in million € 1999 **(0.882)**

3) Size of the region

- GDP in million € 1999 **(0.860)**

FACTOR 2: UNIVERSITY

- Internal university R&D expenditure, % of GDP **(0.686)**
- Internal university staff (FTE) in R&D, % of active population **(0.931)**
- University researchers (FTE) in R&D, % of active population **(0.917)**
- Students enrolled in first and/or second part of degree course compared to population aged 16 and over (each 100.000 inhabitants) **(0.631)**
- Students who have finished 1st and /or 2nd part of degree course compared to population aged 16 and over (each 100.000 inhabitants) **(0.694)**
- Students registered in postgraduate courses compared to population (each 100.000 inhabitants) **(0.892)**
- Students who have read their thesis compared to population aged 16 and over (each 100.000 inhabitants) **(0.916)**
- Research quality indicator of university **(0.854)**

FACTOR 3: CIVIL SERVICE

1) Civil Service

- Internal Civil Service expenditure on R&D, % of GDP **(0.908)**
- Internal Civil Service staff (FTE) in R&D, % of active population **(0.899)**
- Civil Service R&D Researchers, % of active population **(0.928)**
- Scientific capital stock in R&D (1999 € per inhabitant) **(0.791)**

2) Others

- **Venture Capital investment (million € of 1999)** (0.533)

0.500

FACTOR 4 INNOVATING FIRMS

0.533

- Firms internal R&D expenditure (percentage of GDP) **(0.809)**
- Internal staff (FTE) of firms in R&D, %o of active population **(0.801)**
- R&D researchers (FTE) of firms, %o of active population **(0.755)**
- Firms` technological capital stock in R&D (1999 € per inhabitant).**(0.693)**
- Regional distribution of technological centres
- Annual income of technological centres **(0.701)**

Source: own elaboration with the IAIF-RIS(Spain) Database

3 Typology of Regional innovation systems

Identification of the factors mentioned has been used in building up a typology of Regional innovation systems. The technique used for this purpose has been the cluster or conglomerate analysis from the values adopted by the factors in each of the cases. The cluster analysis is a multivariate technique which enables "individuals" to be classified in groups, without the sets constituting them or their number being known a priori. In this case the individuals are the selfsame Autonomous Communities in the different years of study and the grouping methods are both the one considering the proximity between units of each group and the one constructed from the separation between those units.[15]

Bearing in mind the findings, and on examining the variables closely, the solution chosen is the one which establishes five clusters or groups. This result coincides in the two procedures carried out, which adds an element of confidence regarding the choice opted for. Consequently, the Regional Innovation System typology set up on the basis of the factors identified in the previous section defines five systems types, four of which comprise just one Autonomous Community —Madrid, Catalonia, Basque Country and Navarre— and another the remaining regions, regardless of the year of study[16].In order to show that there exists a significant differentiation among the five previously defined groups, as well as to highlight the factors which, in each case, characterise innovating activities, a variance analysis has been made via the factor classifying the Autonomous Communities in each of those systems. Given a quantitative dependent variable (four identified latent factors) and a qualitative independent variable (a variable or factor identifying each region with a relevance cluster), the variance analysis with a factor consists of determining the behaviour of the dependent variable in the established groups by the values of the independent one. Using a 99% level of significance the null hypothesis was rejected, so it can be stated that the types of regional innovation systems that have been detected register different behaviour in the four factors. Graph 1 shows the

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[15] To use the technique it is necessary to fix a difference and a method of group building. Distance is an index reflecting the greater or lesser similarity among individuals, so the greater it is the lesser the similarity between the defined systems of innovation. The distance used here, *Euclid squared*, can be seen to be affected by the type of units being handled, so this problem has been corrected by standardising the variables according to the Z scores method. With regard to the group-forming method, two *agglomeration* procedures have been used —*the nearest neighbour and the most distant neighbour*— that is, all the individuals are considered to belong to isolated groups and they become members of the cluster consecutively. In the case of the *nearest neighbour method* the groups are formed on the basis of lesser distance, and in that of the *most distant neighbour,* the nearest groups of individuals join together within the most distant ones.

[16] This same solution had already been achieved in previous studies where a similar list of variables was used for the average of 1996, 1997, 1998. (Buesa, Martínez Pellitero, Heijs, Baumert, (2003).

solution obtained by means of the factorial scores of the variables charged with summarising the statistical information regarding the mean.

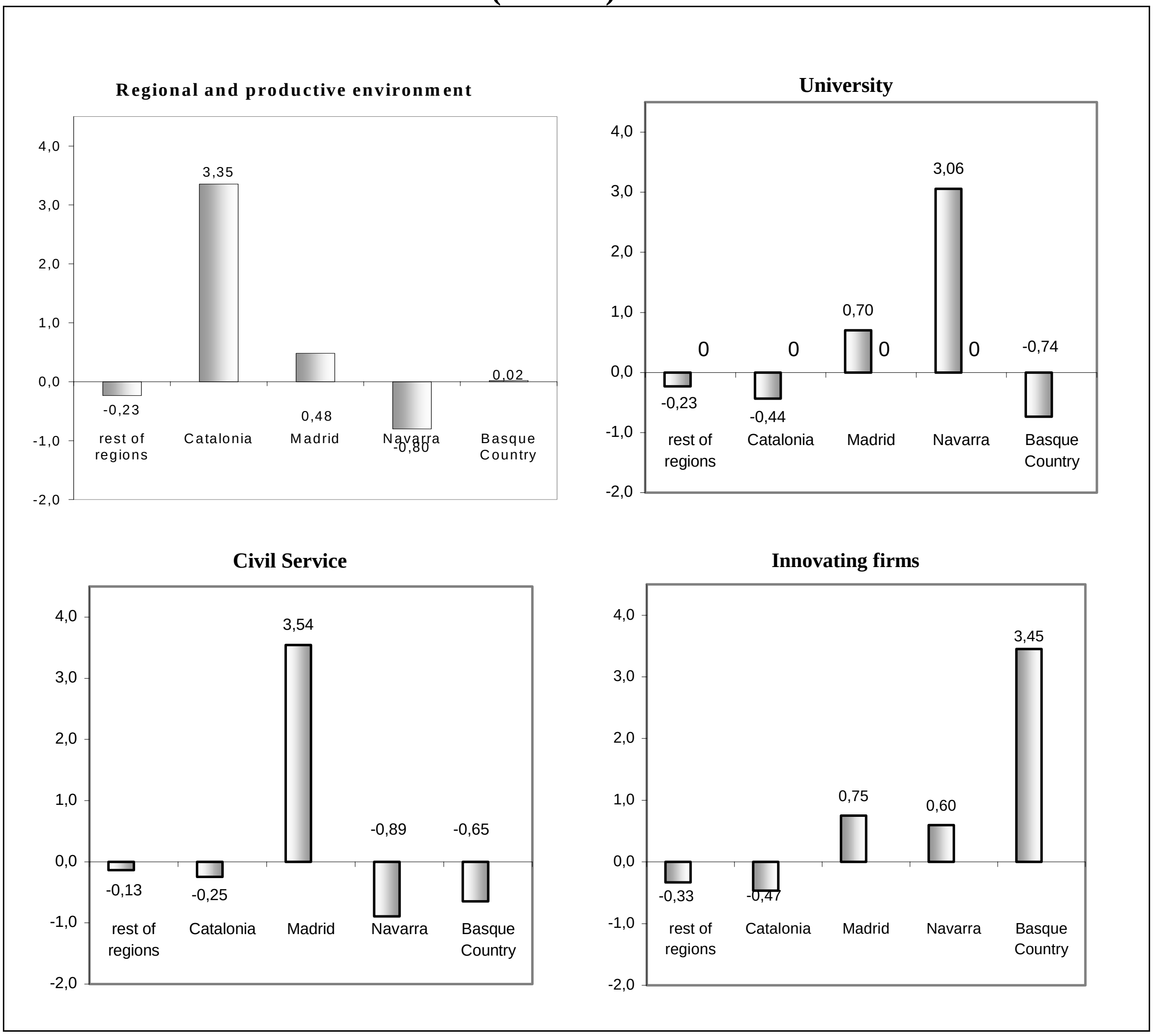
The first factor identified —*Regional and productive environment of innovation*— shows different behaviour in the regional systems defined via the cluster technique. The Autonomous Community with a higher value than the rest of the regions for this hypothetical variable is Catalonia. In second and third place, with quite lower, albeit positive values[17], are Madrid and the Basque Country. The lowest, and negative mark is for Navarre. Also negative is the score for the group registering the rest of the regions of Spain. Thus we can see how important within the Catalonian innovation system are the elements linked to environment and support infrastructures, such as the productive structure, aid to innovation in firms, accumulated knowledge and regional size. And it also shows the lesser importance of these variables in the remaining cases, among which Madrid and the Basque Country score positive, as we have already mentioned.

Moreover, the factor referring to the *University* system has a clearly more outstanding relative role in the case of Navarre than in the other regions. Madrid, with a positive score, fills second place, though some way behind the former region. Whereas, on the opposite side, and with negative results which leave them in a position of the greatest disadvantage, we find the Basque Country, Catalonia and the other Autonomous communities.

In the case of the factor recording elements linked to the *Civil Service*, the situation is also striking. Here we find a region, Madrid, where the average is way above those obtained by the remaining Communities. The importance of the *Civil Service* axis can be seen in this region, which gives it different characteristics to the others. Conversely, and most markedly in the Basque Country and in Navarre, the other regions are characterised by having negative scores in this factor, which is not strange if we take into account that Civil Service institutions dealing with science and technology are more likely to be sited in the Spanish capital.

[17] Positive values denote a certain intensity of the higher-than-average factor of the group of Autonomous Communities; and the negative ones the opposite.

Graph 1.Value of the factors in regional clusters (mean=0)



Source: own elaboration with the IAIF-RIS(Spain) Database

Finally, in the case of the factor representing aspects most linked to the area *of Innovating firms*, noticeable differences appear once more. The average of this hypothetical variable is very high in the case of the Basque country, which highlights the importance of this subsystem within the regional innovation itself. In second and third place, with positive values, we find respectively, Madrid and Navarre, with Catalonia and the other Communities achieving negative scores.

By way of conclusion, it can be mentioned that Madrid is the region with the most complete innovation system, as verified by its factorial scores which are always positive, and thus above average. Catalonia, the Basque Country and Navarre take what could be considered as an *assymetrical system*, since only one of the four factors is found in a developed form. The remaining regions have weak innovation systems, and have not achieved important development in any of its components. They are, therefore, regions which still have important weaknesses which should receive preferential treatment in comparison with the other above-mentioned ones as far as scientific and technological policies are concerned.

4. The IAIF Index of Regional Innovation Capacity: How has the innovative capacity of the regions changed over time?

The regional typology obtained by cluster analysis, which has been described in the previous chapter, has pointed out the heterogeneity that characterises the Spanish innovation system. Nevertheless, it gives us only a static view of the situation for the whole period studied. In order to complement these findings by a dynamic perspective, we have developed an innovation index, which allows us to observe the evolution of the relative innovative capacity of each region between 1994 and 2000.[18]

4.1 Development and composition of the Index

The so-called *IAIF Index of Regional Innovation Capacity* is composed of the weighted sum of four partial indexes, which match with the four factors previously calculated. Each of these partial indexes is composed, in turn, by the weighted sum of standardised variables that form each factor. Differing from preview studies [19] we decided not to do the weighting of the variables and partial indexes discretionally but objectively, using multivariable statistical instruments[20]. This allows us to overcome most of the disadvantages pointed out by Grupp

[18] The index was originally calculated for 1994-1998. Nevertheless, as the weighing obtained have turned out to be very robust, presenting only small changes over the years, it is possible to use them further on (in this case until 2000), without having to recalculate the entire series.

[19] Most of these studies are based on national data —so the Technology Achievement Index (UNDP, 2001 and Desai et al. 2002), the Technology Index (WEF, 2001, 2002, 2003); and the Indicator of Technological Capabilities (Archibugi and Coco; 2004)—, include developed and less-developed countries, and measure innovation in a "broad" sense. The WEF study includes "soft" data based on the opinions of entrepreneurs (WEF, 2001). A more detailed analysis of these indexes can be found in Archibugi and Coco (2004). Other study for the European countries is the European Innovation Scoreboard (2001, 2002, 2003, 2004). We have only detected one regional study, the European Innovation Scoreboard for EU regions (European Commission, 2002b, 2003b).

[20] The deficiency of most of these studies lies in the small number of variables used —specially at the regional level—and in determining *a prior*, relying on theoretical proposes, at least three sub-indexes: creation of technology, technology transfer, and human capital. As we point out in the text, by doing so they intentionally leave aside two major methodological problems: First, it is necessary to calibrate and generate the sub-indexes, conveniently weighting the included variables. Second, the adequate aggregation of those partial indexes in a single, weighted index has to be found. All studies mentioned before, use subjective criteria in doing so, considering that each sub-index has the same importance or just assigning in a discretionary way, a certain

(2003), who affirms, that in calculating scoreboards "the space for manipulatation […] by selection, weighting and aggregation is great". In doing so we have to cope with two methodological problems: First, it is necessary to calibrate the variables that form the partial indexes.

Table 2: Composition and weightings of the IAIF Index of Regional Innovation

Partial indexes and their weighting[21]	Variables	Weight of the variable
Partial index 1: **Regional and productive environment for innovation (weighting: 37%)**	Medium tech exports	4%
	Spanish patents	8%
	European Patents	8%
	Number R&D projects supported by public policies	9%
	High and Medium tech industrial added value	9%
	High and Medium tech industrial Employment	9%
	Gross regional product	10%
	High tech exports	9%
	Low tech industrial employment	11%
	Low-tech industrial added value	11%
	Low tech exports	12%
Partial index 2: **Universities (weighting: 24%)**	Matriculations secondary education*	7%
	Number of persons that finished secondary education*	8%
	Internal R&D expenditures of Universities	14%
	Matriculations tertiary education*	13%
	Quality of research in Universities	14%
	Number of persons that finished tertiary education*	14%
	Number of researchers in the universities**	15%
	Total employment at the universities**	15%
Partial index 3: **Civil Service (weighting 20%)**	Risk Capital	11%
	Stock of scientific capital per person***	17%
	Internal R&D expenditures of the CS (% GDP)	24%
	R&D employment of the CS**	24%
	Researchers of the CS**	24%
Partial index 4: **Innovating firms (weighting: 19%)**	R&D employment in firms**	15%
	R&D expenditures in firms (% GDP)	16%
	Number of Regional technology centres	15%
	Income of the technology centres	16%
	Number of Researchers in firms**	16%
	Stock of technological capital	12%
	Expenditures in innovation per inhabitant	10%

Source: own elaboration with the IAIF-RIS(Spain) Database

* Population above 16 years (for each 100.000 inhabitants).
** Full Dedication Equivalent by each 1000 persons of the active population.
*** Accumulated amortised R&D expenditures.

weight to each of them. As has been conveniently pointed out by Grupp (2003), these subjective criteria are not always disinterested, as they seem to be in some cases "country friendly", optimising the results of a certain country or region by what he calls "country-tuning".

[21] Notice, that the partial index *Innovating firms* presents the smallest weights of all, due to the fact, that many of the variables that are commonly assigned to the firms, such as patents and exports, are included through the

Second, we have to find the proper weighting for each of these partial indexes in forming the *IAIF Index of Regional Innovation Capacity*. Starting with the second matter, the weighting of each partial index has been calculated as the percentage of the variability explained by each factor with respect to the total retained variability.

In turn, the weighting of the variables that form the partial indexes is calculated as the degree of saturation of the variables in the corresponding factor. Specifically it is the correlation coefficient between the variables and the factor, expressed as the percentage with regard to the total correlation, obtained from the coefficient matrix for calculating points in the components, and corresponds to the inverse of the component matrix.[22] The values obtained are presented in table 2.

Once the weights have been obtained, we have to take a second step in order to find the most adequate procedure for standardising the variables so that the results for the different years of our series might be comparable. After different trials, we have opted for the following:[23]

$$X^*_{r,j} = \frac{X_{r,j} - X_j^{MIN}}{X_j^{MAX} - X_j^{MIN}} \times 100$$

Where: $X^*_{r,j}$: standardised value region r, year j.
$X_{r,j}$: observed value region r, year j.
X_j^{MAX}: maximum observed value, year j.
X_j^{MIN}: minimum observed value, year j.

In turn, the sum of standardised variables X*, conveniently weighted and multiplied by hundred, gives us the value of each of the partial indexes —*Regional and productive environment for innovation, Universities, Civil Service* and *Innovating Firms*—, which will range between zero and a hundred. In the same way, the *IAIF Index of Regional Innovation Capacity* results from the weighted sum of partial indexes, which will also range between zero and a hundred.

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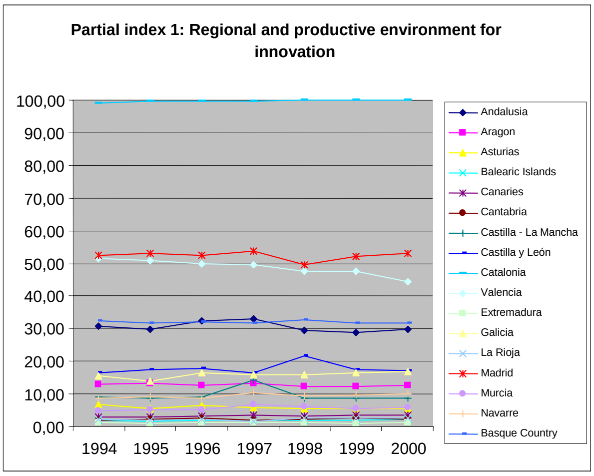
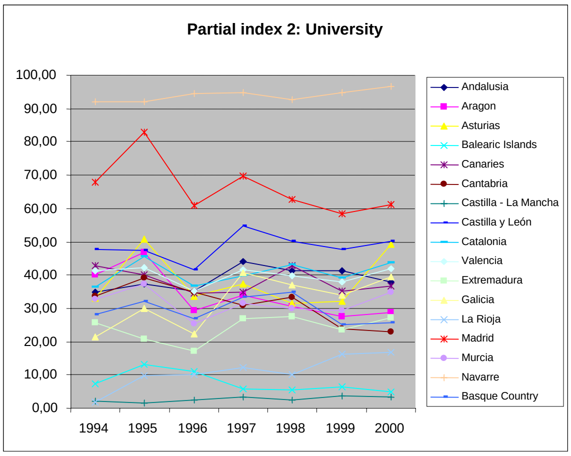
factorial analysis to the partial index *Regional and productive environment for innovation*. For this reason, the weight of the *Innovating firms* is reduced in favours of the former. See Martínez Pellitero y Baumert (2003).

[22] For a detailed description on how to calculate the weighting, see Martínez Pellitero and Baumert (2003) and Buesa, Heijs, Baumert and Martínez Pellitero (2003).

[23] After the first publication of the IAIF Index of Regional Innovation Capacity, (march 2003) this procedure has also been adopted by the European Commission (2003).


Partial index 1: Regional and productive environment for innovation
100,00
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
1994
1995
1996
1997
1998
1999
2000
Andalusia
Aragon
Asturias
Balearic Islands
Canaries
Cantabria
Castilla - La Mancha
Castilla y León
Catalonia
Valencia
Extremadura
Galicia
La Rioja
Madrid
Murcia
Navarre
Basque Country


Partial index 2: University
100,00
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
1994
1995
1996
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Andalusia
Aragon
Asturias
Balearic Islands
Canaries
Cantabria
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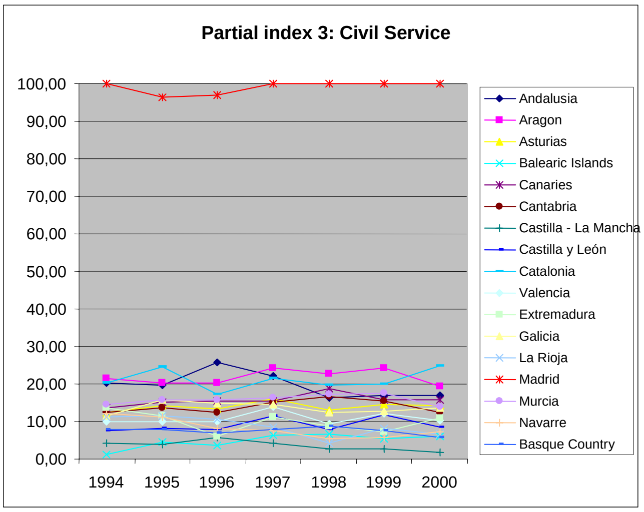
Partial index 3: Civil Service
100,00
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
1994
1995
1996
1997
1998
1999
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Andalusia
Aragon
Asturias
Balearic Islands
Canaries
Cantabria
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Castilla y León
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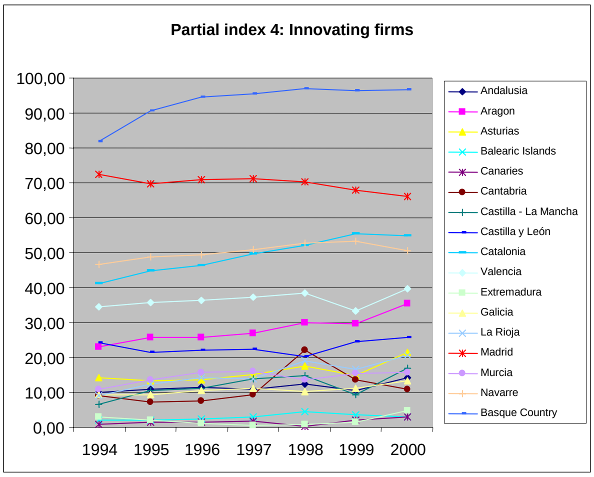
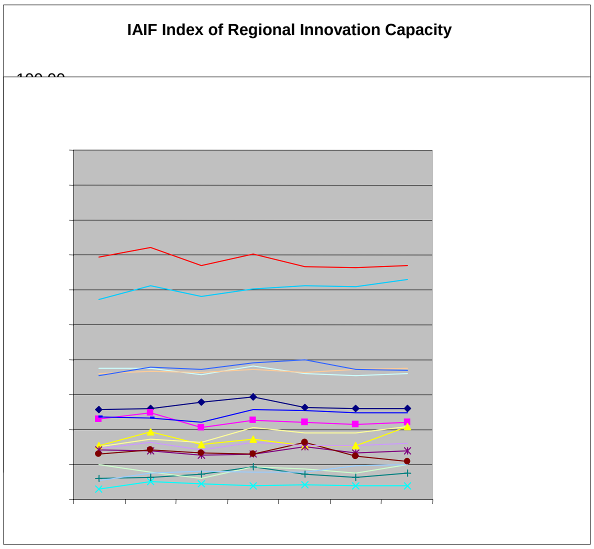
Basque Country





4.2 Results

As we have already pointed out, the partial index 1 contains the variables linked to the *Regional and productive environment for innovation*. It is possible to distinguish four levels of regions: Catalonia holds the leading position, with the highest possible score since 1988. Madrid and the Community of Valencia, which form the second level, follow at a great distance. Notice, that although Madrid seems to shorten the distance from Catalonia, Valencia shows the opposite behaviour. A third category encloses the Basque Country and Andalusia, with scores around 30, while the rest of the regions form the fourth group, all of them obtaining values below 20.

(partial index 1)

We find a different situation in the case of the second partial index (*University*), as the tendencies are less neat than before, due to the high volatility of the variables included.

Nevertheless, it is again possible to distinguish four different groups of regions. In this case, the index is headed by Navarre, and followed distantly by Madrid. The rest of the regions form the third group, with the exception of La Rioja and Castilla- La Mancha (fourth group), whose results are close to zero.

GRAPH 3 (partial index 2)

The third partial index (*Civil Service*) offers a slightly different distribution, as it is only possible to distinguish two groups: Madrid, which stays on its own at the top (the region of Madrid due to its capital status[24] accounts for most of the R&D performed by the Civil Service), obtaining the highest possible score since 1997, and the rest of regions, all of them (except Catalonia) showing scores beneath twenty.

GRAPH 4 (partial index 3)

Finally, the last of the partial indexes (*Innovating firms*), is headed by the Basque Country, with its values growing over the whole period. The second position in the rank is occupied by Madrid, though it has to be pointed out, that the difference between them has grown substantially. Simultaneously, Catalonia and Navarre, which form a third group, have shortened distances with respect to the Basque Country.

GRAPH 5 (partial index 4)

As we have already explained, the weighted sum of the partial indexes make up the IAIF Index of regional innovation capacity. As we see in graph 6, none of the regions obtains values above 70, from which we may conclude, that there is still enough "innovation potential" to de developed. In turn, it is possible to clearly distinguish three types of regions: the first group is formed by Madrid (the leading region) and Catalonia, which we might consider highly innovative, as both obtain the highest score in one of the partial indexes but also present scores above the average in the other three partial indexes. The second group (innovative regions) includes the Basque Country, Navarre and Valencia, which (with the exception of the latter)[25] lead one of the partial indexes, but do not stand out in any of the others. Finally, the rest of the regions, which we may consider not innovative, all present scores below 30.

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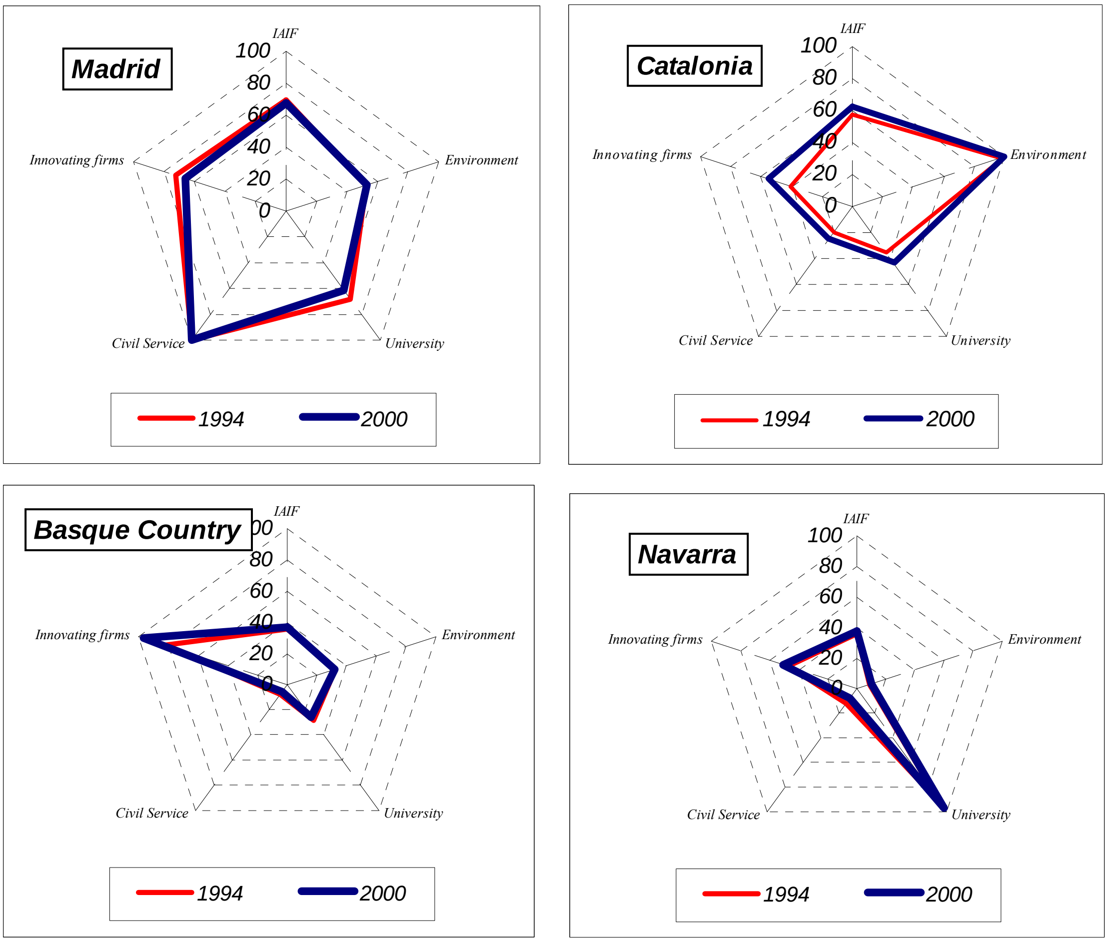
[24] See also point 3.

[25] The position of Valencia is singular, and though it does not lead any of the partial indexes, it presents a notable equilibrium between each of the partial indexes, which has important consequences on the innovative efficiency of the region, as will be shown in the next chapter.

4.3 Conclusions

As we have seen, no region obtains values clearly above 70 in the composite index, as none of them stands out notably in more than one of the partial indexes. In concordance with the findings of the previous chapter, Catalonia achieves the highest score in the partial index *Regional and productive environment for innovation*, Navarre in *University*, Madrid in *Civil Service* and the Basque Country in *Innovating Firms*.

Graph 7: Index points of the four leading regions



Source: own elaboration with the IAIF-RIS(Spain) Database

Secondly, as we can observe in graph 7, from the four regions that lead one of the partial indexes, only two —Madrid and Catalonia— present a certain equilibrium between the partial indexes, what we could consider *symmetric* innovation systems[26], while the others —Navarre and the Basque Country— have to be considered as *asymmetric* innovation systems. Note that

[26] See also note 7.

over the period studied, Catalonia has experienced a noticeable expansion of its innovation capacity, while Madrid's has slightly decreased.

Summing up, we may conclude that the Spanish regional innovation system presents a very heterogeneous structure, with strong asymmetries between the strengths and weaknesses of each region. Simultaneously, while the distance between the leading region of the composed index (Madrid), and the second one (Barcelona) has shortened over the period studied, the partial indexes show a differentiated behaviour over time: The partial indexes 1 (*Regional and productive environment for innovation*) and 3 (*Civil Service*) seem to evolve relatively constantly, while in the partial index 2 (*University*) shows a greater volatility. The partial index 4 (*Innovative firms*) is the most dynamic: While the gap between the leading region (Basque Country), and the second (Madrid) has increased between 1994 and 2000, Catalonia and Navarre (and, to a lesser extent also Valencia and Aragon) have managed to reduce it significantly.

5. The innovation system and knowledge generating processes

Once the factors implicit in regional innovation systems have been detected, we went on to make a multiple regression least squares analysis, to determine what is the combination of them which enables the calculation of innovation flow, by means of the *number of patents* to be estimated[27].

There is a broad range of empirical studies indicating the existence of a high correlation between a measurement of innovatory input —such as R&D costs— and measurement of output, such as the number of patents.[28] Moreover, compared to other measurements of innovation output, patents guarantee a minimum level of originality, as well as being highly likely to become an innovatory product.[29] Undoubtedly, the use of patents as a measurement of technological innovation also has some disadvantages which were already pointed out by Griliches.[30] Firstly, not all innovations materialise in the form of a patent, since firms may opt for other ways of protecting their inventions, such as, for example, the industrial secret in itself. Secondly, even though the patents-by their own definition-guarantee a certain level of newness and originality, it is also true that the value of the patents is heterogeneous, that is, they do not reflect differences of quality between them. Moreover, not all of them reflect technology used in productive activity. However, it is a restriction the effects of which are minimised due to the fact that, if data are used for a large number of patents, their quality should be expected to be distributed in a similar manner for any type of aggregation, probably following a normal pattern.[31]

The output indicator takes into account the patents requested and published by the Spanish and European Patents Offices. We have deemed it necessary to reflect the greater value of European patents, which have higher registration costs both in time and money, using a factor

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[27] This type of analysis fits in with the line of empirical studies which have investigated the presence of spillovers in their respective areas of analysis. Basically a distinction can be made between two types of models: those which analyse national innovation systems (Stern, Porter and Furman, 1999, 2000, 2002) and those which do the same for regional systems. Among the latter can be distinguished those which study the American regional innovation system (Jaffe, 1989, Acs et al, 1992, Feldman, 1994; Anselin et al, 1997; and those who have done it for Spain (Gumbau, 1996; Coronado and Acosta, 1997; García Quevedo, 1999).

[28] See among others Griliches, 1990; Trajtenberg, 1990; Patel and Pavitt 1994.

[29] Buesa et al. (2001).

[30] Griliches (1990).

[31] Buesa et al. (2001).

of five to weight them in comparison with the Spanish ones, since European patents are registered on average for five countries, so that:

$$PAT_{r,t} = PAT_{r,t}^{ESP} + 5 \times PAT_{r,t}^{EUR}$$

Where $PAT_{r,t}$ is the weighted sum of the patents of region r in year t and $PAT_{r,t}^{ESP}$ y $PAT_{r,t}^{EUR}$ are respectively, Spanish and European patents for each region:

As our aim is to detect which of the above-mentioned factors enable innovation flow to be estimated and to what extent, the generation of fresh knowledge function is fixed by the following equation:

$$PAT_{r,t} = \delta_{ENV} W_{r,t}^{ENV} + \delta_{CIV} X_{r,t}^{CIV} + \delta_{INN} Y_{r,t}^{INN} + \delta_{UNI} Z_{r,t}^{UNI}$$

Where W^{ENV} designates the *environment* factor, X^{CIV} measures the *Civil Service* factor*,* Y^{INN} indicates the *Innovating firms* factor and Z^{UNI} records the value of the *university* factor, and in which the subindices r and t designate, respectively, the region and the year. Note that we have done without a lag between *input* and *output,* considering that in Spain the relationship between R&D and patents is almost simultaneous.[32]

Table 2: Regression results

	Non-standardised coefficients	*Standardised coefficients*	*Parametric contrasts*	
	B	*BETA*	*t*	*Sig.*
(Constant)	201,506		28,428	.000
ENVIRONMENT	267,463	,874	37,510	.000
CIVIL SERVICE	106,291	,347	14,907	.000
FIRMS	68,356	,223	9,587	.000
UNIVERSITY	45,104	,147	6,326	.000
R	R^2	Durbin Watson		
0,978	0,957	2,02		

Source: own elaboration with the IAIF-RIS(Spain) Database
a Dependent variable : Weighted sum patents
Heteroskedasticity robust coefitients.

[32] Buesa and Molero (1992).

In Table 2, there is a presentation of the findings obtained by applying an ordinary least squares procedure by the stepwise method. The necessary validation steps[33] have been carried out on this model. From the findings it is confirmed that the four factors turn out to be statistically significant and also have a positive sign, which confirms the validity of the evolutionary approach in arguing that knowledge creation is the result of the interaction of different elements considered to be under the concept of regional innovation system. Now, it is also of interest to interpret the relative weight of those factors in the model. That will be done by taking into account the values of the standard BETA coefficients[34], which enables us to compare the importance of the factors in the model. As can be seen, it is the factor related to *Regional and productive environment* which has a greater prominence in the model, specifically with a 0.874 Beta value. Secondly, and at an important distance, we find *Civil Service* (Beta 0.347), followed by the role of *Innovating firms* (Beta 0.223), and finally, with a relatively lower weight in the model we have the *University* (Beta 0.147).

Within the economic interpretation, we will be able to highlight that for the Spanish case there is a strong influence of environment variables in the quantified innovation flows across the weighted sum of patents. Specifically, a larger-sized productive structure plays a key role in achieving results related to technological innovation, which ratifies the importance of a certain critical mass and a minimum market size. In this way, the hypothesis which states the importance of the business segment within innovation systems is verified. If we also bear in mind the relative weight of the factor related *to Innovating firms*, this hypothesis is reinforced. Moreover, the *Civil Service* and the *University*, albeit with a significant, positive role, are reduced to a secondary role, which is not an obstacle to their interaction with the other factors contributing to obtaining greater innovation results.

The findings obtained via the use of factors corresponding to regional innovation systems are in accordance with those of preceding studies where the work was carried out with a set of

[33] To validate the model we have carried out the usual tests on residuals, comparing their normality, lack of statistically significant correlation among the forecast values and the residuals and, finally checking their homocedasticity, which ensures the model's robustness and, thus, the validity of the coefficients calculated .In a complimentary way a colinearity diagnosis was carried out, producing a lesser condition index of 15, and this, along with the regression procedure used, avoids any multicolinearity problem that might restrict the validity of the findings.

[34] This coefficient represents, in terms of elasticity, the increase in the dependent variable-in typical deviations-produced when the typical deviation increases by one unit the value of the dependent variable under the *ceteris paribus* hypothesis.

non-hypothetical indicators —as is the case with factors— but real ones,[35] for the same time period and using the same dependent variable (weighted sum of patents) and, at the same time, they are in keeping with those that have been highlighted in international literature, both for regional and national cases[36].

6.- Analysis of the efficiency of innovation systems

Until now we analysed the structure of the regional innovation systems (input side) and the determinants of the innovative capacity (output side). The only question left, which we will analyse in this section, is: Do the regions use the resources in an efficient way. In this section we combine both perspectives -input versus output- analysing if the regions use a minimum of resources to reach a maximum of output. In this way it is possible to establish the efficiency in the assignation of resources in the regional innovation systems. The methodology used is the *Data Envelopment Analysis*.[37]

The evaluation of efficiency has its origins in the microeconomic perspective of the *Pareto Optimum.* By this concept the assignation of resources will be efficient if it is impossible to improve the situation of some person or economic unit without worsening the situation of some other individual or economic unit. This idea is supported by the concept of a production function in which a assignation will be always efficient if a certain amount of production resources, or input, generate a quantity of output or production situated on the frontier of the production possibilities (maximum output with a minimum of input.[38]

[35] Buesa, Baumert, Heijs and Martínez Pellitero (2003).
[36] See the works quoted in note 16.
[37] The mathematical background of the Data Envelopment Analysis combines techniques of the linear programming and non-parametric models. This methodology is frequently used in microeconomic studies whose main objective is the control and evaluation of the efficiency of different agents and activities from the Public and the private sector (See among others Martínez Cabrera (2003), Cook y Green (2000), .Thore y Rich (2000). However, recently they also use this method in the literature on regional analysis (see among others Aldaz y Millan (2003), Loikkanen y Susiloto (2002).
[38] The empirical evidence demonstrates that the economic units do not always behave in an efficient way. To generate a better understanding of the notion of efficiency, Farrel (1957) defined different concepts of efficiency: technical and price efficiency. Due to the limited space for this paper we can not discuss this aspect broadly. However, technical efficiency is the obtaining of a maximum output using a given combination of input. On the other hand the price efficiency is the situation in which a certain output is obtained by an optimum quantity of resources given their prices or costs. Farrel uses these two concepts to establish the global efficiency which is the product of the technical and price efficiency. That is if they obtain a maximum output at the lowest possible costs See Farrel (1957).

The methodology to measure or quantify the efficiency distinguishes between two types of models. The parametric model requires the specification of a certain production function and a specific distribution of the residuals. The second type - non-parametrical models-[39], do not require a specific production function.[40] The Data Envelopment Analysis (DEA) is an outstanding model within the non parametric group of models. Two of those models are the most frequently used ones. On the one hand the *CCH Model* (developed by Charnes, Cooper y Rhodes, 1978), assumes constant scale returns, and on the other hand the *BCC model,* (Banker, Charnes y Cooper, 1984) admits other types of returns, including variable ones.

The aim of our analysis is to quantify the degree of efficiency of the Spanish regional innovation system. Therefore we take into account the inputs explained and used in section two -*regional and productive context, innovative firms, university and public administration*- and use as output variable *the weighted sum of patents* already used in the section about the "ideas production function". The methodology used here to analyse the efficiency is the BCC Data Envelopment Analysis model.[41]

The BCC Data Envelopment Analysis models the efficiency concept proposed by Farrels, and moreover amplifies the analysis for multi-product output.[42] The multi-product model explains that an economic unit is efficient if it is impossible to generate with a certain quantity of input a higher level of output without producing a lower quantity of another type of output.

Similar to the Pareto-optimum the model assumes that an economic unit is always efficient if given a certain quantity of input it is impossible to obtain a greater quantity of a certain type output without the reduction of other types of output. Or the other way around, an economic unit is always efficient if given a certain quantity of output it is impossible to obtain the same level of output without the reduction of the input quantity. On this argumentation the maximum level of efficiency -in our case, the technological frontier will be defined by the

[39] The parametric perspective distinguishes between two models: The deterministic model of the frontier *(DMF)* and the stochastic model of the frontier (MEF). For a revision of those models see Martínez Cabrera (2003) y Silkaman (1986).
[40] Although in this methodology they do not specify a certain production function it requires the accomplishment of some assumptions: free availability of inputs and outputs, convexity and constant scale return..
[41] We use this model due to the better suitability of the non-parametric models to the type of research because we do not know the exact patent production function. In the selection of the model between CCH and BCC we took into account the problem that the BCC model overestimates the efficiency and the fact that earlier studies confirmed the existence of constant scale returns in the case of innovation. See Quiros, C (2002).
[42] The studies of Farrell(1957) about efficiency refer to production units that only produce one output.

most efficient observable economic units. Their efficiency will be expressed by fictitious units as a result of the linear combinations of the real observed in and outputs of the analysed economic units. Defined the frontier of the production possibilities once, the observed cases that are situated on this frontier do reach the maximum level of efficiency reflected by an index value of 1 (or 100%) while the other analysed cases get lower index values compared to the most efficient units.

Briefly: It has to be highlighted that the model analyses the relative efficiency. That is, of all the units included in the analyses it defines which of them are the most efficient ones. Their level of efficiency will be established as the maximum level of efficiency or the technological frontier, while the degree of (relative) efficiency of the other units will be related to that frontier, being expressed as the percentage of efficiency compared with the most efficient units.[43]

The mathematical model defined by Charnes, Cooper y Rhodes (CCR) for *n* production units that produce *s* outputs using *m* inputs can be analysed by the perspective of the maximisation of the outputs or the minimisation of the inputs. The output perspective indicates how the efficiency of a unit corresponds to the rate of the weighted sum of outputs in relation to the weighted sum of inputs (for the mathematical details see box 1).

[43] This method is similar to the Benchmarking Analysis.

BOX 1: CCR Model Data Envelopment Analysis

Output orientation

$$\text{Maximize } h_0 = \frac{\sum_{r=1}^{s} U_{r0}\ Y_{r0}}{\sum_{i=1}^{m} V_{i0} Y_{i0}}$$

$$\text{Accomplishing} \quad \frac{\sum_{r=1}^{s} U_{i0} Y_{rj}}{\sum_{i=1}^{m} V_{i0} X_{ij}} \leq 1;\ j = 0, 1, 2, ..., n$$

$U_{r0} \geq 0 \quad r = 1, 2, ..., s$

$V_{i0} \geq 0 \quad i = 1, 2, ..., m$

Y_{rj} = Quantity of output *r* produced by unit *j*
U_{r0}= Assigned weighting to the output *r* corresponding to the evaluated unit
X_{ij} = Quantity of input *i* consumed by unit *j*
V_{i0} = Assigned weighting to input *i* corresponding to the evaluated unit

The solution of this mathematical equation determines the values U_{r0} and V_{r0} and, therefore the efficiency index h_0 assigned to the evaluated production unit. Resolving this equation for each of the *n* units their efficiency level will be obtained.

The same problem can be proposed in a linear[44] form:

Output orientation

$$\text{Maximize } \Phi_0 = \sum_{r=1}^{s} U_{r0} Y_{r0}$$

$$\text{Accomplishing: } \sum_{r=1}^{s} U_{r0} Y_{rj} - \sum_{i=1}^{m} V_{i0} X_{ij} \leq 0\ ;\ j = 0, 1, 2, ..., n$$

$$\sum_{i=1}^{m} V_{i0} X_{i0} = 1$$

$U_{r0} \geq \varepsilon \quad r = 1, 2, ..., s$

$V_{i0} \geq \varepsilon \quad i = 1, 2, ..., m$

I*nput Orientation*

$$\text{Maximize } \varphi_0 = \sum_{i=1}^{m} V_{i0} X_{i0}$$

$$\text{Accomplishing:: } \sum_{r=1}^{s} U_{r0} Y_{rj} - \sum_{i=1}^{m} V_{i0} X_{ij} \leq 0\ ;\ j = 0, 1, 2, ..., n$$

$$\sum_{i=1}^{m} U_{r0} Y_{r0} = 1$$

$U_{r0} \geq \varepsilon \quad r = 1, 2, ..., s$

$V_{i0} \geq \varepsilon \quad i = 1, 2, ..., m$

The variables Φ_0 and φ_0 represent the efficiency index [45] obtained from both perspectives and satisfy the relationship $\varphi_0 = 1/\Phi_0$, due to the assumption of constant returns of scale. The decision about the orientation of the model depends on the aim of the analysis.

[44] In 1979 Charnes, Cooper y Rhodes introduce a rectification on the original fractional program requiring that the weighting would be strictly positive $U_{r0} \geq \varepsilon$ y $V_{i0} \geq \varepsilon$, where ε is a sufficiently small positive number.
[45] For further information see Charnes, Cooper y Rhodes (1978,1979, 1981)

The application of this methodology to the Spanish regional innovation system generates the following results:

Level of efficiency of the Spanish regional innovation system (Frontier of efficiency = 100)

	1994	1998
Madrid	100	100
Catalonia	100	100
Comunidad Valenciana	*58,62*	*53,55*
Basque Country	*46,48*	*42,0*
Navarre	26,65	19,93
Andalucia	22,32	26,08
Aragón	12,98	15,96
Castilla y León	9,47	12,80
Galicia	4,25	8,49
Cantabria	3,3	3,93
Asturias	*8,58*	*7,68*
Murcia	5,6	8,64
Canaries	4,03	8,35
Castilla-la Mancha	2,92	6,60
Baleares	3,01	7,89
Extremadura	1,17	1,95
La Rioja	3,64	1,78

Source: own elaboration with the IAIF-RIS(Spain) Database
In italics the regions with a declining relative efficiency level

Observing the results we can see that in 1994 two Spanish regions —Madrid and Catalonia— define the efficiency frontier of the Spanish regional innovation systems. In the third and fourth position —far behind the frontier— we find Valencia and the Basque Country with a relative efficiency level of 58.6 and 46.5 percent respectively. For 2000 we found similar results. Madrid and Catalonia are still the most efficient regions by minimising the required inputs to obtain a certain level of output (patents), followed by Valencia and the Basque Country, who hold the third and fourth position in the efficiency ranking again.

It can be highlighted that ten of the seventeen regions have a relative level of efficiency below 15% (one less than in 1994). In general the regions —with the exception of La Rioja and Asturias and especially Valencia— have improved their relative efficiency level in relation to Madrid and Catalonia. However our model does not explain if this improvement is a catching-up process of the peripheral regions or if it is a slowdown of the efficiency of the leaders.

Concluding, it can be stated that in the period 1994-2000 we observe a modest improvement of the innovative efficiency of the non-leading regions in relation to the most efficient ones.

These results confirm the already mentioned existing heterogeneity of the Spanish regional innovation systems. As seen before Spain has two leading regions—Madrid and Catalonia— in terms of efficiency. These are the same regional innovation systems that in the former sections were defined as the ones with a higher level of development and also with a more balanced relationship between the four main factors of the system —*Regional and productive environment, Innovating firms, University* and *Civil Service*—.

For two cases -Basque Country and Valencia- the efficiency level is just below half in relation to the technical frontier. And for other three regions -Navarre, Andalusia and Aragon- the relative efficiency is in between 20-30%. These three regions show, as can be observed in sections 3 and 4, an unbalanced innovation system. The rest of the regions have a very low efficiency index, as can be expected for peripheral strongly unbalanced regions.

This result does not mean that the individual agents of those regions, especially the firms, are inefficient, however the total regional efforts in R&D do generate a relatively a low level of new ideas reflected in patents. Partially this could be due to the orientation of the R&D activities to incremental innovations. However we think that also the over-dimension of the public activities with a low impact on the business system is an important determinant of the low efficiency level. However these results are an approximation and to our knowledge it is the first time that Data Envelopment Analysis has been used to measure the efficiency of regional innovation systems. These are our first results and at this moment we are broadening and deepening this work in two directions[46]. First, the inclusion of more output indicators[47] and secondly the analysis of the efficiency of the European regions. Another research option is the analysis of selected regions, only peripheral ones.

7.- Conclusions and final remarks

This paper can be considered as a first approximation to using combined indicators ("factor") to analyse the structure, determinants and efficiency of the regional innovation system. We developed some new ways to measure innovation (systems) considering this concept as non-directly observable. The *factorial analysis* allowed us to reduce the set of existing variables to

[46] These amplifications, which probably will be available at the end of 2005, are part of the PhD thesis of one of the authors: Monica Martinez Pellitero

a lower set of non-observable hypothetical variables. These variables we used to do further empirical analysis.

The four presented analyses are complementary because they correspond to each of the perspectives of an economic analysis that tries to evaluate the Innovation System. The *typology of regional innovation systems* describes the structure of configuration of the Regional Innovation System, the *IAIF-index* summarize these typologies and offers the possibility to analyse their development over time. The ideas production function establishes the relationship between the “structural aspects” indicating the *determinants of the creation of knowledge* and their impact in boosting innovation, while the Data Envelopment Analysis evaluates the *efficiency* of the innovative activities on a regional level.

As we did not detect any other study that uses this methodology, we controlled our results comparing the outcome of four different analyses of this paper. Although we proposed some further analysis, especially in the case of the efficiency index, the outcome seems reliable. The results do confirm each other and are the expected ones taking into account the literature on technological change, economic growth and (regional) innovation systems.

In any case, further empirical work is needed to control and refine the proposed methodology. The main problem is the lack of information at regional level.

[47] Spanish patents and publications.

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Annexe

Year 2000	Partial Index 1 *Regional Environment*	Partial Index 2 *Universities*	Partial Index 3 *Civil Service*	Partial Index 4 *Innovative firms*	Composed Index *IAIF Index*
Andalusia	29,67	38,07	16,84	14,23	26,21
Aragon	12,73	28,63	19,47	35,39	22,06
Asturias	5,63	49,37	14,39	21,56	20,76
Balearic Islands	2,21	5,03	5,93	3,14	3,81
Canaries	3,57	36,78	15,79	2,98	13,86
Cantabria	2,24	23,03	12,52	10,78	10,86
Castilla - La Mancha	8,58	3,39	1,70	16,97	7,48
Castilla y León	17,28	50,16	8,46	25,77	24,87
Catalonia	100,00	43,63	24,74	54,70	62,89
Valencia	44,31	41,77	10,31	39,74	35,93
Extremadura	1,16	27,14	10,87	4,72	9,98
Galicia	16,70	39,33	13,63	13,35	20,84
La Rioja	2,59	16,70	6,62	20,75	10,11
Madrid	53,19	61,27	100,00	65,99	67,02
Murcia	5,70	34,72	14,07	15,75	16,17
Navarre	10,10	96,50	7,40	50,65	37,57
Basque Country	31,84	25,77	5,71	96,57	36,97

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