A NOVEL WAY OF MEASURING REGIONAL SYSTEMS OF INNOVATION: FACTOR ANALYSIS AS A METHODOLOGICAL APPROACH

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ABSTRACT

This working paper deals with the problems in measuring such a complex phenomenon as an innovation system, offering a new empirical approach for measuring regional innovation systems. The evolutionary theory on technological change shows the complexity of the innovation systems which leads to the conclusion that individual indicators are not the optimum way to value such systems. Therefore we defend the use of a broad number of variables and the use of the Factor Analysis Technique to reduce the information of those variables converting them into a few non-observable hypothetical ones, called factors. Each of those new synthetic variables includes a set of correlated variables that reflects together some specific aspect of the innovation system. These factors reflect better the reality of those systems than each of the individual indicators could do on its own.

Keywords

Regional innovation system, indicators for R&D, technological change; regional economics

RESUMEN

Este artículo de trabajo trata de los problemas que surgen al medir un fenómeno tan complejo como lo es un sistema de innovación, ofreciendo una nueva aproximación empírica para medir sistemas regionales de innovación. La teoría evolutiva del cambio tecnológico muestra la complejidad de los sistemas de innovación y llega a la conclusión de que indicadores individuales no son el camino idóneo para valorar dichos sistemas. Por tanto nosotros defendemos el uso de un amplio número de variables y el uso de la Técnica de Análisis del Factor para simplificar la información de esas variables convirtiéndolas en unas pocas hipotéticas no observables, denominados factores. Cada una de esas nuevas variables sintéticas incluye un juego de variables correlacionadas que juntas reflejan algunos aspectos específicos del sistema de innovación manifestando de mejor manera la realidad de estos sistemas que mediante indicadores individuales.

Palabras clave

Sistemas de innovación regionales, indicadores de I+D, cambio tecnológico, economía regional

SECTION "0":

GENERAL INTRODUCTION: FOUR COMPLEMENTARY IAIF WORKING DOCUMENTS

As indicated by Edquist (2005) and shown by the work of Navarro (2007), Pellitero (2008) and Baumert (2006), there are scarcely any empirical research works on regional innovation systems with aggregate data at regional level. This is particularly due to the lack of regionalised statistics and sources. At the present time, there are various scattered sources of information, but there is not just one database collating data of different sorts which is available to the public. In the last few years the Institute of Industrial and Financial Analysis (IAIF) –under the direction of Mikel Buesa y Joost Heijs- carried out several research projects[1] aimed at providing solutions to both shortages. On the one hand, they recollect data from varying sources and of a different nature, to prepare a broad database. Furthermore, a broad group of studies was carried out trying to fill, at least partially, the gaps shown by the literature in the empirical field on regional innovation systems, as well as to promote a clearer understanding of the reality of Spanish and European regions and promote regional "benchmarking".

This publication is part of a set of five working papers that reflect the outcome of these research activities dedicated to the measurement of regional innovation systems and to the novel application of econometrical techniques to carry out empirical analysis on innovation systems.

Five complementary IAIF working documents

- MARTÍNEZ-PELLITERO, M; .BUESA, M.; HEIJS, J; BAUMERT, T. (2008). *A Novel way of measuring regional systems of innovation: Factor analysis as a methodological approach.* Documento de trabajo, Nº 60 (2008).
- MARTÍNEZ-PELLITERO, M; .BUESA, M.; HEIJS, J. (2008). *The IAIF index for European regional innovation systems* Documento de trabajo, Nº 61 (2008). Instituto de Análisis Industrial y Financiero de la Universidad Complutense Madrid.
- BAUMERT, T., BUESA, M; HEIJS, J. (2008). *The production of "ideas" in European regional innovation systems: An econometric approach.* Documento de trabajo, Nº 62 (2008). Instituto de Análisis Industrial y Financiero de la Universidad Complutense Madrid.
- MARTÍNEZ-PELLITERO, M; .BUESA, M; HEIJS, J. (2008). *Novel Applications of Existing Econometric Instruments to Analyse European Regional Innovation systems: A regional efficiency index.* Documento de trabajo, forthcoming (2008). Instituto de Análisis Industrial y Financiero de la Universidad Complutense Madrid.
- MARTÍNEZ-PELLITERO, M; .BUESA, M; HEIJS, J.(2008). *Una tipologia de los sistemas regionales de innovación en la Europa ampliada.* Documento de trabajo, forthcoming (2008). Instituto de Análisis Industrial y Financiero de la Universidad Complutense Madrid.

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http://www.ucm.es/BUCM/cee/iaif/

[1] In fact it is the outcome of several complementary projects, of which in particular we can mention the Project: *Indicadores de recursos en investigación e innovación tecnológica de la Comunidad de Madrid (Directed by M*ikel Buesa) and the project: *"Innovación en la Comunidad Autónoma de Madrid y su impacto sobre la competitividad, crecimiento y eficiencia"* led by Mikel Buesa and Joost heijs.

The projects had two complementary parts. The first one consists of the construction of a database related to the regional innovation systems for 15 Countries of the European Union (The former EU-15) and about the 17 Spanish “Comunidades Autonomas”. Both databases included respectively around 60 variables about a broad number of aspects of the regional innovation systems and their environment. During the second part of the research project the IAIF carried out the elaboration of empirical studies based on econometric multivariate techniques. Therefore we did a number of complementary studies that deal with different aspects and perspectives of the regional innovation systems. A typology of regional innovation systems (RIS) was created to describe the structure or configuration of the RIS. The IAIF index for RIS was elaborated to summarize this typology and offer the possibility to analyse its development over time. Afterwards an “ideas production function” was estimated to establish the relationship between the “structural aspects” and to reveal the determinants of the creation of knowledge on a regional level. Moreover the Data Envelopment Analysis” was used to evaluate the efficiency of that innovation production process.

The first analysis and publications, of which we can highlight, among others, the following publications, did evaluate the Spanish regional innovation systems:

- BUESA, M., HEIJS, J., MARTÍNEZ PELLITERO, M. y BAUMERT, TH. (2005): “Regional systems of innovation and the knowledge production function: the Spanish case”; *Technovation* (2007).
- BUESA, M.; HEIJS, J.; BAUMERT, T.; MARTÍNEZ-PELLITERO, M. (2007). *Novel Applications of Existing Econometric Instruments to Analyse Regional Innovation systems: The Spanish Case.* In: Suriñach i Caralt, J. (Editor). Knowledge and Regional Economic Development" (Editor: Edward Elgar – ISBN 978 1 84720 120 1)).
- BUESA, M.; HEIJS, J.(2007) (Coordinators) (2007). *Sistemas regionales de innovación: tipología y eficiencia en España y la Unión Europea.* Authors: Mikel Buesa, Joost Heijs, Björn Asheim, Mikel Navarro, Thomas Baumert y Mónica Martínez Pellitero. Editor: Fundación de Cajas de Ahorro (FUNCAS). (ISBN 978-84-89116-32-0)

The European case is reflected partially and synthetically in the book of FUNCAS while broader information about the methodological problems and solutions for the measurement of (regional) innovation systems and about the empirical analysis are offered in the four complementary working papers of IAIF. The first one, -A *Novel way of measuring regional systems of innovation: Factor analysis as a methodological approach.* - is about the problems to measure such a complex phenomena as an innovation system. The heterogeneity of such systems requires the simultaneous use of a broad number of variables which could be synthesised by the use of the “Factor Analysis” technique. Therefore in this first working paper we explain the creation of the regional data base for the EU-15 regions and clarify the use of the Factor Analysis Technique. The factor analysis allows us to work with a broad number of variables whose information will be reduced and converted to a few non-observable hypothetical variables called factors. Each of them includes a set of correlated variables that reflect together some specific aspect of the innovation system. From our point of view these new synthetic variables or factors better reflect the general aspects of the regional innovation systems than could do each of the individual variables included in the factor. In the next three working papers we use those factors or hypothetical variables to carry out empirical studies.

In the second working paper the “factors” are used to elaborate *The IAIF index for European regional innovation systems*- that measures the innovative level of the region and permit us to analyse the development of this technological capacity over time.

The next working paper - *The production of "ideas" in European regional innovation systems: An econometric approach*.- estimates an "ideas production function" to establish the relationship between the "structural aspects" (factors) and to reveal the determinants of the creation of knowledge (patents) on regional level. While the fourth working paper – *Novel Applications of Existing Econometric Instruments to Analyse European Regional Innovation systems: A regional efficiency index*- tries to analyse the efficiency of the "production of ideas". In this fourth document we suggest a first approach to measure the efficiency of the regional innovation system by using the factors -calculated in the first working document- as input variables of the Data Envelopment Analysis to evaluate the efficiency of the R&D and innovation activities.

A NOVEL WAY OF MEASURING REGIONAL SYSTEMS OF INNOVATION:

FACTOR ANALYSIS AS A METHODOLOGICAL APPROACH.

SECTION 1: INTRODUCTION

This paper tries to get to grips with the measurement of the national and regional innovation systems[2] using novel applications of existing econometric instruments to measure regional innovation systems by means of the multivariate analysis method of factor analysis.[3]

As indicated by Edquist (2005) and shown by the work of Navarro (2007), Pellitero (2008) and Baumert (2006), there are scarcely any empirical research works on regional innovation systems with aggregate data at regional level. Therefore the appearance of empirical studies represents an important advance in the approach of regional innovation systems. The main cause of the absence of empirical studies is the lack of regionalised statistics and sources. At the present time, there are various scattered sources of information, but there is not just one database collating data of different sorts which is available to the public. The IAIF collected those data for 15 Countries of the European Union[4], for the period 1995 to 2001. Once the IAIF-RIS (EU-15) Database –that initially contains 60 variables- was created we used a multivariate methodological approach that permits us the reduction of the variables to a lesser amount of indicators or factors using a factor analysis. In this paper we explain the construction of the database and the outcome of the factor analysis. The empirical analysis carried out with the "factors" –typology, regional innovation index, "ideas" production function and efficiency- are developed in the mentioned working papers.

The evolutionary theory underpins the heterogeneity of the innovative performance, which has to be considered as a multidimensional activity. The literature emphasizes 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.[5] It is worthwhile treating the concept and the different elements of an innovation system as something which is not directly observable[6]. In this case by means of a multivariate methodology[7] and despite the statistical limitations always to be found in these topics, in this paper we elaborate and describe a series of hypothetical variables registering the most important relationships related to technological change. For the creation of "combined" indicators that

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

[3] 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 different aspects of the Spanish Regional innovation systems.

[4] Specifically Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, Low Countries, Austria, Portugal, Finland, Sweden and the United Kingdom. These fifteen countries are those comprising the European Union prior to the expansion of 2004. Henceforth, when reference to the European Union is made, these nations will be mentioned to make it easier for the reader to understand.

[5] 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.

[6] Buesa, Martínez Pellitero , Baumert and Heijs (2007)

[7] In Hollestein (1996) the improvements deriving from working with compound indicators when studying the innovating profile of firms from the multivariate technique of factorial analysis, instead of using individual variables, are shown. Other works dealing with the topic of compound indicators are Grupp and Mogee (2004) and Archibugui and Coco (2005).

reflect the different aspects of the regional innovation systems we used *factor 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.

For the European case (146 EU-15 regions and initially 60 variables) we found six "unobservable variables" or factors that are homogeneous in their consistency and are clearly interpretable in terms of the theory on innovation systems (1.- regional and productive environment; 2.- the innovating enterprises; 3.- Higher Education system and University research; 4.- National innovation environment; 5.- Role of Public Administration and risk capital and 6.- the role of and degree of sophistication of the demand). We consider that those six factors —which are no more than a combination of a set of different highly related variables—reflect better the different components of the innovation system than each of the individual variables would have done. The results of these analyses not only can be interpreted correctly from the perspective of the evolutionary theory of innovations and technological change, they can also be considered as stable and consistent[8].

The results of the *factor analysis* by themselves are not the principal objective of this paper. Rather our main aim is their use in follow-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 novel applications of the factors and its results are included in the working documents complementary to this one and mentioned in the general introduction of this paper.

SECTION 2.-

CREATION OF A DATABASE FOR REGIONAL INNOVATION SYSTEMS FOR EU-15 COUNTRIES

SECTION 2.1.-

COMPONENTS OF THE NATIONAL AND REGIONAL INNOVATION SYSTEMS

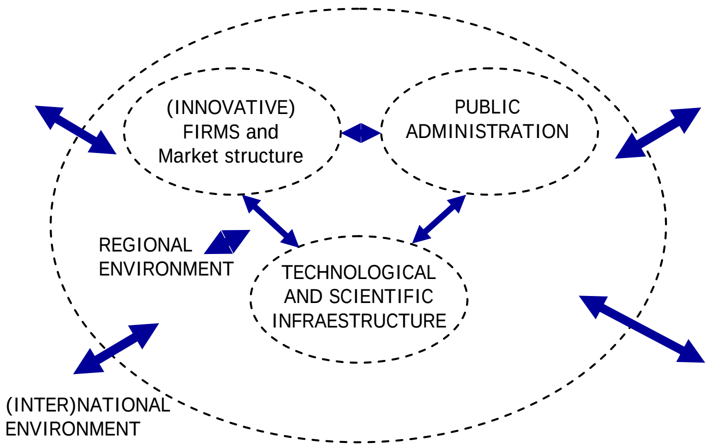
In this section we will offer a synthetic description on the concepts and components of the framework on regional innovation systems. Starting with a general look at the literature written up to the present time, the term regional innovation system is to be understood here as a set of connections between public and private agents who interact and feed off each other in a specific territory, taking advantage of their own infrastructure for the purposes of adapting, generating and spreading knowledge and innovation[9]. A *broad* definition will be used in order to include all those aspects which may be linked to innovation and which impinge on their economies. In this way the factors comprising the systems can be determined, quantified and studied, and they are characterised and given a higher degree of efficiency. Moreover, the analysis framework will be the regional one, since the literature-both empirical and theoretical-has highlighted the role of proximity in innovation processes, and the heterogeneity of this type of system, despite their sharing the same State,

[8] The use of factors not only better reflects 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 often based on statistical effects due to exceptional or occasional like those caused by changes in the law or application norms that delay the assignment of subsidies or patents.

[9] Martínez Pellitero (2002), p.17.

Initially, the study of innovation systems made reference to the national environment (Lundvall, 1992; Nelson, 1993; Edquist, 1997;) but in a short space of time various authors have applied the concept at a regional level (Braczyck, Cooke and Heidenreich, 1996; Cooke, Gómez Uranga and Etxebarría, 1997; Howells, 1999; Landabaso, Oughton, Morgan, 1999; Morgan and Nauwealears, 1999; Cooke, Boekholt, Todling, 2000; Koschatsky, Kulicke and Zenker, 2000; Cooke, 2000; Cooke, 2001; Doloreux, 2002; Buesa and Heijs, 2007). The reasoning behind this analysis is based on the extended idea that industries tend to concentrate in specific spaces, as well as on the existence of decentralising policies which can be applied at regional level (Porter, 1990) .The concept of the regional innovation system can be understood as a section of the *national* one, where its main, identifiable characteristics are still valid when studies are made of smaller areas. Thus, a regional innovation system (SRI) can be defined as a set of networks between public and private agents which interact and give mutual feedback in a specific territory by taking advantage of their own infrastructure, for the purposes of adapting, generating and extending knowledge and innovations. In general, the processes for absorbing external or foreign technology, for creating "regional" or national technology, or spreading it within a particular space, are determined by various institutions, organisations and agents who influence the region's interactive learning capacity. In this way, effort and sufficient development of local and regional infrastructure is needed, taking the concrete form of interfirm relationships, and relationships between the latter and the rest of the physical and support infrastructure, in training suitable human capital, in accumulating and transferring knowledge and in shaping the production structures (Buesa, Martínez Pellitero, Heijs and Baumert, 2003).

Scheme 2.1
Regional Innovation System



Adapted from Baumert 2006.

As can be seen in Scheme 1.1. we distinguish –from a analytical point of view- the following components of the regional innovation system such as the (innovative) firms and market structure, technological and scientific infrastructure, public administration, the regional environment and the national environment. 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 the four subsystems[10]. 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

[10] Some agents are active in several sub-systems. For example the Public Administration manages scientific infrastructure and has "public enterprises".

influence of the evolutionary viewpoint which propounds the existence of interdependence relationships between the parts or elements of the system

A more specific description of the different aspects of a national or regional innovation system can be observed in scheme 2.2 (taken from Heijs, 2001). The theoretical elements of the RIS stand for the following aspects: firms and their relationship with the regional innovation system; support infrastructure for innovation; Public Administration innovation-linked performance; and the regional and national environment for innovation.

In the case of firms, we start from the hypothesis that these are the most important element 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 science and innovation in the case of innovating firms. It is clear that the firms have a central role in innovation system while they are the basic element that converts the innovations or (public) scientific research results in products useful in the society. Specific aspects of this subsystem are its innovative intensity (Expenditures in R&D and innovation) and its openness and motivation to innovate (innovative culture). Other aspects with a direct influence on the firms´ innovating activities are their size and the existing accumulated knowledge or innovation capacity, (such as number of patents) that reflects the learning capability of the firms. Moreover the level of concentration and market structure also has a clear influence on the innovative behaviour of the firms. It seems that smaller firms –except small (new) technology based firms- and those operating in a monopolistic market have fewer incentives to innovate than large firms in a highly competitive market. Another important aspect is the level of internationalisation and protection of the national market. Firms that operate on international markets do compete on the technological frontier with the most outstanding firms in terms of quality, price and technical excellence which force them to be innovators. The opposite case is the protection of the domestic markets which would lead to a competitive less exigent market in which firms invest less in innovations, especially if the consumers or firms in the region do not require technologically advanced products (Conditions of the demand). Also the sectoral distribution of the productive structure is important to measure or evaluate the regional innovation systems. Comparing for example the R&D intensity of countries or regions we have to take into account that this is very different for regions with more traditional sectors than those with high-tech sectors. As explained by Porter the interfirm relationships (based on cooperation and networking) are very important. A good level of horizontal cooperation with competitors and vertical cooperation with clients and providers are considered as essential for the good functioning of a (regional) innovation system.

The public administration –on all administrative levels- plays a very important part in the development of systems. First of all the legal and institutional framework is very important to assure the investments in R&D and innovation. Not only the protection of industrial and intellectual property –which is considered as a must for technological advanced regions- but also all kinds of requirements related to the quality of the products and their technical characteristics have a high impact on the innovative behaviour of the firms. An exigent policy of public procurement -i.e. the government as a customer requiring a technologically advanced supply of goods and services- also has a positive impact on the innovation behaviour of the firms. Moreover the important role of the public administration as a financing agent for innovation in firms, private and public research organisations or technology centres and to foster the technology transfer can be highlighted. On all administrative levels -national, regional and European- the support for R&D and innovation has a central role. The state is also responsible for the education and training of the human capital devoted to R&D and innovation-related activities.

On the one hand, the public sector manages an important part of regions' scientific apparatus. This aspect overlaps with the sub-system of Scientific and technological Infrastructure. Regarding this subsystem, 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 (human) resources and findings[11]. Another classification of the Infrastructure to support the innovation or the supply of advanced technology and R&D related Services distinguish between those bodies that do research in the form of R&D and innovation (like public Research Organisations (PRO); Higher Educational Institutes (Polytechnics, Universities…) or Technology centres), and those bodies devoted to fostering technology transfer and the innovative culture (consultancy and information points). These include technology transfer Centres, Information centres and Services of information and consultancy. This is an analytical classification because most of the research organisations offer a broad range of innovation related services.

Finally, the regional innovation environment is a broad concept including aspects which indirectly impinge on regions' technological and innovation capacities. Here we could include a large number of aspects. The literature on RIS includes here –among others- human capital (level of education and number of engineers and researchers available on the labour market) and the financial system especially the availability of risk capital. Another aspect is the innovative level of the demand side (Consumer demands measured by the - GDP per inhabitant, the penetration of the ITC technologies-, or the demand for innovative goods and services including the public procurement). Moreover the quality of life and the general innovative culture are also important aspects mentioned frequently in the literature. We also included some characters on a national level which are general for all regions of a country, such as the index of economic freedom.

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

Outline 2.2
COMPONENTS OF A NATIONAL AND REGIONAL INNOVATION SYSTEM

Firms and their internal organisation, inter-firm relationships and market structure

- Innovative intensity and culture
- Size of the firms and accumulated knowledge
- Market Structure and level of concentration
- Level of internationalization and the protection of the national market.
- Sectoral distribution of the firms
- Cooperation networks
- Relation with clients and providers
- Conditions of the demand

Activities of the public administration en relation con la innovation

- Legal and institutional framework
- Protection of industrial and intellectual property
- Finance of innovation and R&D
- Promotion of technology transfer
- International, national and regional policy making
- Scientific and technological Infrastructure (S&T Parks or centres or large R&D facilities)
- Education and training

Infrastructure to support innovation
Advance Technology and R&D related Services

Bodies that do R&D and innovation

- Public Research Organisations (PRO)
- Higher Educational Institutes (Polytechnics, Universities…)
- Technology centres

Bodies devoted to fostering technology transfer, (consultancy and information points)

- Technology transfer Centres
- Information centres
- Services of information and consultancy
- Firms or Innovation Centres
- Technology Parks

National and regional environment

- Human Capital
- Financial System (risk capital)
- Demand for innovative goods and services (including the public procurement)
- Quality of life.
- Innovative Culture
- Innovative level of Consumer demand (GDP per habitant)
- Index of economic freedom
- Penetration of the ITC technologies

Taken from Heijs, 2001) and Heijs et al (2007)

2.2. IAIF-RIS (EU) DATABASE: RESEARCH VARIABLES AND INDICATORS

2.2.1.- INTRODUCTION

The outline of scheme 2.2 was our starting point to design the IAIF-RIS regional database for the EU-15 countries. So the first task performed in the empirical study presented here-and one of the fundamental parts of the research- has been to create a database with the job of registering the main aspects linked to the regional innovation systems. Henceforth, when reference is made to this it will be called IAIF-RIS (EU). This database includes traits which are characteristic of production systems, of the main variables related to R&D and the materialisation of innovation. In creating them the following stages are of importance:

1. Obtaining the primary information through the REGIO database from EUROSTAT.

2. Determining the regional levels to work on based on principles and characteristics of the European nomenclature NUTS (*Nomenclature commune des unités territoriales statistiques),* as well as the territorial organisation of member states. The total number of regions per state and their correspondence with NUTS are recorded in Table 2.1

3. Obtaining the regionalised information provided by EUROSTAT (REGIO-database etc…) information

4. Introducing the information provided by the different Statistical Offices of the countries analysed, since some regionalised data not included in REGIO are available in these Offices[12]

5. Estimating some indicators which in particular years or regions were not provided by REGIO. From the information available different methods of estimating have been used. Specifically, if the unavailable data was for particular full years, aggregated growth rates have been used-when there were continuous time series for a number of years-and arithmetical means –if information was available for the previous and following year not offered by the national Statistics. Likewise, in certain regions of Greece and Austria, where it is impossible to obtain the value of the variables at the NUTS 2 level, these have been estimated from the higher NUTS 1 level[13], in proportion to the most suitable indicator for it. Finally, it must be mentioned here, that for the case of Ireland, in the last three years, it has been necessary to add the NUTS 2 levels[14], with the aim of obtaining the corresponding values of the NUTS 1 level which have been used,

6. Creating new indicators from the calculation of variables in relative terms[15] .

[12] Specifically, in some regions of Spain, the United Kingdom and Low Countries, the data are not displayed. As an example, the variables regarding human resources in Extremadura and la Rioja did not appear in REGIO, but, nevertheless are offered by the Instituto Nacional de Estadística.
[13] As weighting, those resulting from the variables most related to the case have been used.
[14] This fact derives from the changes which have occurred in the NUTS nomenclature.
[15] As an example that can be mentioned, calculation of R&D expenditure can be calculated using as weighting the percentage of GDP of the total accounted for by the region.

7. Including variables of a national range by means of different statistical sources[16].

Table 2.1. Correspondence between countries and NUTS level

Status analysed	NUTS level	Nº of regions
Belgium	NUTS 1	3
Denmark	NUTS 2/3	1
Germany	NUTS 1	16
Greece	NUTS 2	13
Spain	NUTS 2	17
France	NUTS 2	22
Ireland	NUTS 1	1
Italy	NUTS 2	20
Luxembourg	NUTS 1/2/3	1
Low Countries	NUTS 2	12
Austria	NUTS 2	9
Portugal	NUTS 2	5
Finland	NUTS 2	6
Sweden	NUTS 2	8
United Kingdom	NUTS 1	12
European Union		*146*

Source: own preparation

The **total number of variables composing the IAIF-RIS (EU) database is 60 for a total of 146** regions, and the time span included the period from 1995 to 2001. With regard to the variables handled, it has to be said that they can be included in three categories or subgroups. *innovating firms, scientific infrastructure and human resources,* and *regional and national innovation environment.* These three groups are found to be related and have a not very clear frontier, facts that are already indicated by the selfsame innovation systems approach[17]. If we compare the included indicators in the database with the outline 2.2 we con observe that almost all aspects are included, though for some elements we did not find any publicly available information. Especially the case of the scientific and technological infrastructure there are almost no data found. The database includes data on universities but about the technology centres, technology transfer centres etc… we did not find homogeneous data available for all 15 countries. The same is the case for the regional data for innovation policies.

[16] For example the economic freedom index
[17] The approach of the innovation systems includes different institutions and organisations-and their relationships as well- which are linked directly or indirectly to the innovation processes from their initial phases till their diffusion. However, the terms registered by the approach present open definitions, so setting up subgroups of elements has to be viewed more as a way of simplifying the analysis than setting up real frontiers.

INNOVATING FIRMS

1.- Inout or innovative efforts of the production sector (firms)

- Firms' expenditure on R&D (%of GDP)Firms' expenditure on R&D (%of GDP) EUROSTAT-REGIO
- Staff engaged in R&D in firms (number of people) (%of total employment) *EUROSTAT-REGIO*
- Staff in R&D in PAs (full time equivalent (% of total employment) *EUROSTAT-REGIO*

2. Patents and accumulated knowledge (Pool of existing knowledge)

- Patents (with regard to each million of population) *EUROSTAT-REGIO*
- Patents (with regard to each million of working population) *EUROSTAT-REGIO*
- Hi-tech patents, requests (with regard to each million of population) *EUROSTAT-REGIO*
- Hi-tech patents, requests (with regard to each million of working population) *EUROSTAT-REGIO*

PUBLIC RESEARCH SYSTEM AND SCIENTIFIC INFRASTRUCTURE

1. Resources in the Public Administration (PA)

- Expenditure in R&D of the PAs (% of GDP) *EUROSTAT-REGIO*
- Staff in R&D in the PAs (number of persons) (% of total employment) *EUROSTAT-REGIO*
- Staff in R&D in PAs (full time equivalent (% of total employment) *EUROSTAT-REGIO*

2. University results and resources

- Expenditure in R&D of PAs (% of GDP) *EUROSTAT-REGIO*
- Staff in R&D in the University (number of persons) (% of total employment) *EUROSTAT-REGIO*
- Staff in R&D in the University (full time equivalent) (%of total employment) *EUROSTAT-REGIO*
- Number of students in third cycle (% of population) *EUROSTAT-REGIO*

REGIONAL AND NATIONAL INNOVATION ENVIRONMENT

1. Market size and productive activity

- Gross Added Value (millions of €, base 1995) *EUROSTAT-REGIO*
- Gross Fixed Capital Formation (millions of €, base 1995) *EUROSTAT-REGIO*
- Wage remuneration (millions of €, base 1995) *EUROSTAT-REGIO*
- GDP per capita (€ per inhabitant) *EUROSTAT-REGIO*
- GDP per worker (€ per worker) *EUROSTAT-REGIO*
- Number of people employed *EUROSTAT-REGIO*
- Gross Domestic Product (millions of € , base 1995) *EUROSTAT-REGIO*
- Average annual population (thousands of inhabitants)

2. National indicators

- Index of economic freedom *THE HERITAGE FOUNDATION/WALL STREET JOURNAL*
- ICT penetration *INFOSTATES*
- Seed and start up capital (% of GDP) *EUROSTAT-NEW CRONOS*

3.- Human Capital (Human resources in Science and Technology)

- Human resources in S&T in high technology (total)*EUROSTAT-REGIO*
  - Human resources in S&T in services (total) *EUROSTAT-REGIO*
  - Human Resources in Science and Technology in knowledge-intensive services Human resources in S&T in intensive knowledge services (total) *EUROSTAT-REGIO*

* In italics there appears the primary statistical source
Source: Own preparation

Finally, the fact that the research has centred on the years 1998, 1999 and 2000 needs some justification. The reasons can be summarised in the following points: in the first place, the fact of working with three-year groups may reduce the skewness which in some cases may appear in the statistical information, deriving from the primary sources themselves or from certain current contexts which could lead to a mistaken interpretation; secondly, given that the results are very similar for the whole group of years 1995,1996 and1997 it is more logical to refer to the latest available time period and, finally, the non inclusion of the year 2001 in the research is due to the excessive number of estimates that existed for that year, when the empirical study got under way. Once more there exists the underlying idea and need for continuing this research with successive updatings of the IAIF_RIS (EU) database[18].

2.2.3.- VARIABLES USED IN THIS STUDY

In Table 2.3 the variables and indicators –a total of twenty-nine –with which the work has been done are shown, as is the primary statistical source from which they have been obtained[19]**.** Below a synthesis is made of the information recorded by the variables used in this study in accordance with the subgroups defined.

Innovating firms

1.- Input or innovative efforts of the production sector (firms)

The business sector is defined from Frascati's Manual[20] as a group of firms and institutions whose main activity is the production of goods and services for sale to the public in the market and in general, at a price linked to the economic reality of the time. As has been stressed in the review of the literature firms and even more those linked to Research and Development processes[21] are key elements in the regional Innovation systems since they have the capacity to generate knowledge and materialised results both in products and processes[22]. What is more, it can be stated that they are the components connecting the production and innovation systems. On these lines it has been considered essential to include indicators on innovatory effort which are therefore linked to business R&D. Work has been carried out both

[18] In Buesa, Navarro and Heijs details are registered of the advantages and disadvantages of these variables.
[19] The variables expressed in monetary terms present as base year 1995-the first year of the IAIF-RIS (EU) base-and the *implicit GDP deflator* is used in its standardisation, obtained from the EUROSTAT CRONOS database.
[20] OECD (2002b-pp54-62)
[21] Frascati's Manual denominates Research and Development (R&D) as a set of creative tasks which begin to develop systematically and whose aim is to increase the amount of knowledge of man, culture and society so that its use can enable new applications to be developed. This term encompasses three activities: Basic Research, Applied Research and experimental Development (OECD 2002b, p.30). This very same manual classifies information according to four agents: Business sector, Higher Education (University), Public Administration and non-profit-making private Institutions (OECD 2002b, p.55). In this research work has only been carried out with the first three groups, since the fourth was practically devoid of regionalised information. In general, the definitions used related to R&D which are explained in this section for the business case-expenditure on R&D and staff-are the same as those subsequently used when reference is made to Public Administration and the University.
[2222] The important role played by firms in innovation-linked processes within the approach dealt with here has been studied, among others, by Meeus *et al,* (1999), Coriat and Weinstein (2002), Agrawal and Cockburn (2003) and Lazonic (2005. The matter of small and medium-sized firms can be seen in Asheim ***et al*,** (2003

with monetary and staff resources –in absolute terms (*head count)* and in the equivalent to full time work (*full time equivalent)*[23] devoted to these activities[24].

The final variables we have worked with are: R&D expenditure by firms in % with regard to GDP, staff of firms in R&D in absolute terms as % of total employment and staff of firms in R&D with the full time equivalent as % of total employment.

2. Patents and accumulated knowledge (Pool of existing knowledge)

Given the importance of knowledge in innovation systems, its aggregation is a way of quantifying the results of the processes taking place there. In this context, the indicators worked with here are those related to patents. The term patent refers to an industrial property right or invention in the technological field. It may be granted to physical persons or legally designated ones, who will have to meet a series of requirements: "the invention must be brand new, represent a breakthrough not evident to specialists and have an industrial application[25] .The patents must be considered as an *output* of technological activity. Its use involves a series of advantages among which the outstanding ones are: regular availability of data and with long time series: a degree of international comparison; the reflection of obtaining new technologies and incremental innovations as well as the detail from agents and technological fields. Nonetheless, there also exist limitations in their use among which it is worth mentioning the almost total exclusion of the findings from research of a scientific nature, which do not reflect technological success or impact and the differences in the individual quality of each patent[26].

In this research the work has been carried out with the data regarding patents requested in the European Patents Office (EPO) and registered in the REGIO database. The main advantage of working with EPO data is the so-called "headquarters" effect with the patents allocated to the inventor's place of residence[27]. is avoided The indicators used are: Patents per each million population, Patents with regard to each million working population and Hi-tech patents with regard to each million working population.[28]

Patents are considered as the output of private R&D because most patents are produced by the enterprises and are near to the market. Here it could be interesting also to add information on publications. These data reflects the pool of scientific knowledge or the results of basic R&D. However, except for some countries- no regionalised data are available on this subject.

Public Research System and scientific infrastructure

[23] For a more detailed analysis on these terms, see OECD (2002b), specifically chapter 5
[24] R&D expenditure includes current R&D related costs, as well as capital costs. A more accurate analysis on this aspect can be consulted in OECD (2002b) specifically chapter 6.
[25] European convention on patents, October 5, 1973, Art 52(1). Taken from Baumert (2006) p. 90.
[26] For a more detailed analysis of patents see among others, Griliches (1990), Trajtenberg (1990),OECD (1994b and 2004),Buesa, Molero, Navarro, Aranguren and Olarte (2001), Baumert and Heijs (2002), Baumert (2006), Buesa, Navarro and Heijs (2007).
[27] The patents are thus allocated on the basis of where inventors live and regardless of where the titular owner of its rights lives.
[28] For a more detailed analysis, as well as the comparative findings of 161 countries analysed here see Miles *et al* (2004).

The term *Scientific infrastructure* refers to the group of agents and actions which impinge on the development of regional innovatory and scientific activity. This infrastructure is closely linked to the human resources available to the region in scientific and technological areas. There are three areas included in this section: *Public Administration Resources, Resources and results of the Universities and Human resources in Science and Technology.*

- *Public Administration Resources*

Frascati's Manual defines the Public Administration (abbreviated to PA) as the group of ministries, offices and other bodies supplying –for free or at fixed rates-public services and goods which otherwise would not be profitable in the market, whilst administering public services and developing social and economic policy[29] . In developing innovation systems the PAs play a significant role[30] in the scientific field, and proof of this is found in the centres of specialised research[31]. Just as in the business case, another of the factors or determinants in the regional innovation systems is the resources used by the PAs, which serve as support for their scientific and technological development. In the research an attempt has been made to introduce these aspects by means of the following indicators: R&D expenditure by the PAs as a % with regard to GDP, PA staff in R&D in absolute terms as % of total employment and PA staff in R&D in the full time equivalent as % of the total employment.

- *University resources and results*

In Frascati's Manual Higher Education[32] is defined (henceforth University) as the group of Universities-faculties, higher technical schools and university schools-technological institutes and other postsecondary bodies, regardless of the source of their financial resources and legal status. In the definition are included research institutes, experimental stations and clinics under the direct control of Higher Education units, whether administered by them or whether they are associated with them. Given that Universities are a key agent in the region's scientific infrastructure and for the supply of Human Capital[33] , the available indicators on the topic must be introduced. Here specifically work has been carried out with four: University R&D expenditure as a % with regard to GDP, University staff in R&D in absolute terms as a % of total employment, University staff in R&D as a full time equivalent as a % of total employment and the number of students in the third cycle (postgraduate) as a % of the region's population[34]

Regional and national innovation environment

The *regional and national innovation Environment* is a broad concept that includes different elements impinging indirectly on the region's own capacity in scientific, technological and innovation matters. Three aspects have been considered in this study: *Market size and productive activity, human capital* and *national Indicators*

[29] OECD (2002b), p. 62
[30] The importance of the Public Administration in the context of innovation is dealt with among others, in OECD (2003) and Guellec and van Pottelsberg (2003).
[31] Outstanding here are the Centres of agrarian, health and aerospace research.
[32] OECD (2002b), p.68. A more detailed description is found in OECD (2002), pp.68-72.
[33] The matter of the importance of the Universities as agents linked to innovation processes is dealt with among others by Etzkowitz and Leydersdorff (2000), Kossonen (2002) and Mowery and Sampat (2005.
[34] The importance of including indicators deriving from Education Statistics in innovation studies is stressed by authors such as Jacobson and Oskarsson (1995).

- *Market size and productive activity*

Market size and *productive activity* may be considered as one of the fundamental supports of the environment and therefore of regional innovation systems. Since important differences of size exist in the regions studied -either in population or production terms- it is important to reflect them because they may have effects on the extent of the development of systems and their working[35]. The variables used to represent this aspect are: Gross Domestic Product, Gross Added Value, Gross fixed capital Formation, Salaries, per capita GDP, GDP per worker (productivity), the number of workers or employees and the annual mean population.

- *Human capital (Human resources in Science and Technology)*

As well as staff linked to R&D it is important to add human resources in Science and Technology, since this is a key axis in the innovation-backing infrastructure[36].

The information provided by EUROSTAT is based on the definitions of human Resources made by Manuel Canberra, and implies the following conditions for them to be considered as such[37]:

a) Having finished third level studies-in Spain it would be the second level, that is graduate or equivalent-in a scientific-technological field[38].

b) Being employed in a technological-scientific field without meeting the previous condition, which is normally required.

c) A third measurement is given by those people who have completed third level studies and are employed in the scientific-technological field.

d) Finally, the fourth measurement is given by the total of those people who meet one requirement or another[39]

In this research the work has been carried out with the fourth type of indicator, specifically with human resources in Hi-tech Science and Technology, human Resources in Science and Technology in services and knowledge-intensive human Resources in Science and Technology[40].

[35] It is to be noted that from the innovation systems approach market size is going to be an important element, since it will have effects on the processes of generating and spreading knowledge.
[36] The outstanding role played by human Resources in innovation systems has been analysed among others by Amable, Barré and Boyer (1997) and Amable and Petit (2001).
[37] OECD (1995), p. 16.
[38] The academic areas considered as scientific technological are: Exact and Natural Sciences, Engineering and Technology, Experimental and Health Sciences, Agrarian and Social Sciences. Thus Humanities-related disciplines are excluded.
[39] These variables in the database have been given the denomination of *total.*
[40] The importance of knowledge-intensive services within innovation systems has been analysed by, among others, Muller and Zenker (2001).

- *National indicators*

On various occasions it has been pointed out that the approach of regional innovation systems is not exclusive of the national environment itself. From this viewpoint and since the work has been done here with fifteen countries-which have their own characteristics in their territorial organisation and economic development-it would appear logical and necessary to include variables showing the aspects of the national innovation systems themselves ,where the regions are situated. The included variables in question are:

1. *Index of economic freedom:* This index, prepared by the *Heritage Foundation* and *the Wall Street Journal,* shows economic freedom in various countries via 50 independent variables subdivided into 10 general factors. These factors charged with reflecting the degree of economic freedom are: Trade policy, Government tax levy, Government intervention in the economy, Monetary policy, Foreign capital inflows and investments, banking and financial activity. Wages and prices. Property rights and informal Market. Low marks in this indicator are the most convenient, since the higher the mark in the factor, the greater the level of interference by the Government in a country's economy, and the systemic analysis of these factors shows that States with high levels of economic freedom have the highest standards of living.

2. *Penetration of TICs*[41] *(Infostates Index)* The new information and communication technologies are elements of what are called knowledge-based societies. The *Infostates*[42]index is drawn up by Orbicom[43] and is calculated from two partial indices, *Infodensity* –which includes all TIC stocks of capital and labour-and by *Info-use*-which measures the consumption of TICs by periods- with the aim of differentiating their degree of penetration by countries.

3. *Variables related with venture capital.* In the present context of innovation, increasing importance is given to the venture capital market since it is considered to be a necessary agent in the promotion of new innovatory firms[44]. Under the heading of venture capital are included firms not quoted on the Stock Market, including those made by bodies administering their own capital or that of private investors and outside institutions, and/or informal investors or *business agents.*[45]. In this research two variables have been used: seed capital and start up as a% of GDP and development investment capital as % of GDP.

Finally, in concluding this section it must be pointed out that the research attempted to record those indicators highlighted by the innovation systems approach and those for which regionalised information is available. Nonetheless, there are still weaknesses in statistical sources which have not made it possible for other aspects to be included such as those related to cooperation between agents, R&D Policies, or the very same sectorial characteristics of the area. In this way, it is hoped that they might be included in similar future works.

[41] Information and Communication Technologies
[42] A detailed description can be consulted in Sciadas (2003).
[43] International network of professorial chairs Communication UNESCO.
[44] COTEC (1998), pp.99-103. An analysis on the relationships between financing and innovation can be seen in Lamorreaux and Sokoloff (2004) and O'Sullivan (2005). Also, for the state of the venture capital market in Spain see Martí Pellón.
[45] On the EUROSTAT NEW CRONOS database it is called "*early stage*" and "*expansion and replacement*". N

SECTION 3 FACTOR ANALYSIS FOR EUROPEAN REGIONAL INNOVATION SYSTEMS

3.1 THE FACTORIAL ANALYSIS

After explaining the methodological part of our how our data base was constructed and the variables included in our study we offer here the description of the way we reduced those variables to a few "hypothetical non-observable indicators. Using a factor analysis we reduced those variables to six factors that reflect the synthesized information of all the 29 variables and can be used as "variables" in all kind of econometric applications, such as regression models or studies to create a typology of RISs or a measure of innovative efficiency.

The factorial analysis[46] is a multivariate statistical technique which from a group of quantitative variables -scale interval or reason measurements- enables a clearly smaller group of hypothetical or non-observable variables to be determined, and these summarise practically the whole of the information to be found in the original group. These hypothetical variables receive the name of factors, and among their characteristics of particular significance is the fact that they are unrelated among each other[47].

Factorial analysis makes it possible, given a sample of observations or cases in a group of quantitative variables, for them to be represented in a small area, known as factorial space, enabling the relations among them to be interpreted[48]. Specifically, this type of factorial analysis, which manages to reduce the variables to others of a theoretical or hypothetical nature-factors-, as well as identifying the structures by means of a data summary, receives the name of factorial analysis R[49].

It is important to point out that one of the advantages possessed by this technique, compared to others, is that from the statistical viewpoint, the accomplishment of assumptions of normality, homoscedasticity and linearity are not required or applied less restrictive. That is, the basic assumptions implicit in the method are more conceptual than statistical in nature. In this way, the multicolinearity –which usually causes serious problems in another type of multivariate analysis-in this case is desirable, given that the aim is to identify series of variables which might be found to be interrelated[50]. Moreover, whenever certain clearly differentiated subgroups of variables can be determined in which on the one hand, within each of them the same ones are highly interrelated, and, on the other, those of the different subgroups show no relationships, the original series of indicators will be able to be simplified to a few factors. These will summarise the information held in common by the several variables included in each factor .[51]

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[46] For the methodological aspects dealt with in this section basically the previous work by Martínez Pellitero (2002) is followed.
[47] The procedures applied have made it possible to obtain unrelated factors, even though it will subsequently be seen that this is not always the case.
[48] Ferrán (2001) ,p. 340
[49] There is also what is called factorial analysis Q where the grouping instead of variables is of cases. Nevertheless, for this purpose another multivariate technique known as *cluster* analysis is normally used. Hair *et al* (2001), pp. 83-84. For a description of the main aspects of the *cluster* analysis the reader is recommended to consult Chapter 5.
[50] Hair *et al,* (2001), p.88.
[51] Ferrán (2001), p. 340

Once the analysis has been carried out, the factors obtained will have the same character and nature as the original data, but they will be fewer in quantity and will enable the components of the European regional innovation systems to be better understood, and to be used in subsequent analyses. It can be highlighted that the factor analysis we will present in this paper grouped the variables without any restriction. That is we did not assign a priori the variables to a "factor", though it is the automatic procedure of factor analysis that grouped the variables to each other in the factors. This is important because, as will be seen, the variables included in each factor belong to the same component or sub-system of the overall regional innovation system. This can be considered as a success because it should not be forgotten that one of the main criteria to revise a factor analysis, besides that of the statistical requirements being fulfilled, is that the factors –or hypothetical non-observable variables- include a set of variables that can be correctly interpreted from a practical point of view and within the theoretical framework.

3.2. FACTORIAL ANALYSIS AS A TOOL FOR STUDYING EUROPEAN REGIONAL INNOVATION SYSTEMS

From the IAIF-RIS (EU) database-already described in section 2- a factorial analysis has been carried out with the statistical information related to the years 1998, 1999 and 2000. In carrying out this task the following stages are seen[52];

1. Control the appropriateness of the data and adapt them to meet the requirements of the Factor Analysis .

2. Analysis of main components: selection of factors and variables.

3. Analysis of the extraction and rotation of factors

4. Calculation of factorial scores.

3.2.1. Control the appropriateness of the data and adapt them to meet the requirements of the Factor Analysis

Although in the factorial analysis it is not necessary to prove the classical statistical assumptions-normality homoscedasticity and linearity- it is convenient to carry out some type of test to reinforce the idea that using this technique is relevant[53]. To that end work has been carried out with different results shown by the statistical programme which is described below:

- *Prior analysis of the correlations matrix and the anti-image matrix*

Firstly, the *correlations matrix* has been observed among the variables. The latter shows clearly that there is a substantial number of high correlations, which at first sight would justify applying the technique. Nonetheless, working only with this information, it would be very

[52] To perform this analysis the statistical package used is the SPSS 11.0.
[53] The final variables worked with are those related to Table 2.2.of Chapter 2. The choice of these variables of the database has been carried out by means of a process of *trial and error* which, as will be explained later, allows better results in terms of variance, as well as better interpretation of the findings to be obtained. .

complicated to set up groups of variables similar among themselves and in that sense it will be the findings of the selfsame factorial analysis which will confirm them.

The relationships between the variables can also be analysed through calculation of the so-called partial correlations. These can be defined as the correlations among variables when the effects of other variables are not taken into account. In this context, factors will exist in the study when partial correlations are small, since this would indicate that it can be explained by the factors. The programme offers the *anti-image correlation matrix* –which is the negative value of the partial correlations-and in this case, an initial analysis shows an important number of small coefficients, which previously also expressed the relevance of applying the technique.

- *Kaiser-Meyer-Olkin Sample Adaptation measurement (KMO)*

This statistical proof is based on the study of the partial correlation coefficients. The KMO *Sample Adaptation Measurement* [54] is constructed in inverse form to the partial correlations, so the smaller the latter, the greater the adaptation measurement will be. Thus, the optimum values of the *KMO Index* are those nearest to 1.As is seen in Table 3.1., the suitability of using the technique is verified.

- *Barlett's sphericity test*

With this test the null hypothesis identifying the *correlations matrix* with the identity matrix is compared. Given that it is of interest for the coefficients of the correlations matrix to be high, this entails such a matrix not being the identity one, since if such were the case, there would be no linear associations between the variables and therefore, applying the factorial technique would make no sense. The fact of rejecting the null hypothesis –Table 3.1. allows the possibility to be stated of carrying out the analysis.

Table 3.1. KMO Measurement and Barlett's test

Kaiser-Meyer-Olkins' sample adaptation measurement		0,822
Barlett's sphericity test	Approximate Chi-squared	29384,007
	gl	406
	Sig.	0,00

3.2.2 Analysis of main components and choice of factors and variables

The factorial analysis method which has been used to determine the factors of the European regional innovation systems is the one known as main components[55]. The aim of this

54 $KMO = \frac{\sum\sum_{i \neq j} r_{ji}^2}{\sum\sum_{i \neq j} r_{ji}^2 + \sum\sum_{i \neq j} a_{ij}^2}$ *Where* r_{ji} are the correlations between the variables i, j y a_{ij} are the partial ones.

55 There also exists the so-called *common factorial analysis* technique. However, the complications involved in carrying out this analysis have led to the generalised use of the main components analysis, and more so in cases where the aim is to reduce the number of existing variables. What is more, although there are still experts who continue to argue as to which factorial model is the most suitable one, empirical research has shown an important

technique is to form linear combinations of the independent variables observed, that is, to obtain new hypothetical variables-factors-uncorrelated from real or observable variables which are correlated[56]. In graphic terms, the factors will therefore be orthogonal. The first factor will thus have the maximum variance and successive factors will explain increasingly smaller proportions of the variance, with no correlation [57]existing between them.

The problem may be posed in the following way: Let ($X_{i1......}X_{ip}$), *i= 1, ...,n* a group of *n* cases of variables $X_{1......}X_p$, the main components analysis is a method for extracting the factorial space, where from the representation of the *n* cases as *n* points in a *p*-dimensional case a new *p*-dimensional space will be extracted in such a form that the first axis or F_1 factor of the new *p*-dimensional space will be that which, given all possible projections of the points cloud on just one axis, the minimum deformation is obtained with F_1, the second factor F_2 will be that which, given all possible projections of the points cloud on a two-dimensional space generated by the axis F_1 and a second axis perpendicular to it, the minimum deformation is that obtained with F_2 and so on with the other factors.

In this point it is worth pointing out a series of aspects related to the factorial technique. In the first place, with this procedure the variables are typified or standardised, so each of them comes to variance 1, and, moreover, the variable of the sample will coincide with the number of variables present in it. Secondly, it will always be possible to obtain as many factors as the number of variables one is working with. Nonetheless, this is not the purpose of the analysis, since that would not give rise to a reduction in the volume of data or dimensionality. Thirdly, neither will it have to be understood that in the solution each one of the extracted components is associated with the same variable, for example, the first factor with the first variable, the second factor with the second variable, and so on. Fourthly, when this procedure is carried out, one should try to lose the least possible amount of sample variability, that is, at most 30 or 25% of the original. Finally, each of the model's variables will also have to be well represented by the factors obtained.

With regard to the variance retained by the factors obtained the concept of *self-value* is used. A *self-value* represents the part of the total variability which a factor is able to register. If a number of factors equal to the number of variables are used, the total variability of the sample is perfectly represented. Given the method of factor extraction, the first is that where the variability of the sample is best represented, the second would be the second best, and so on. In this context the sum of all the auto values would coincide with the number of variables[58].

Regarding the retained variability of each of the real indicators used in the factorial analysis the term *communality* is used. The *communality* of a variable is defined as the proportion of the total variability (1) recorded by the retained factors. In this way, if the total variability of the sample is perfectly explained-as is the case when the number of factors is the same as the variables-the variability of each of them in particular would be thus explained. From this idea those maintaining *communalities* near to the unit will have to be kept in the analysis. Moreover, it will have to be borne in mind that the *communalities* will change in accordance with the number of factors chosen.

similarity in results on many occasions. For a more detailed analysis on the subject see Hair *et al,* (2001), pp. 89-92.

[56] Ferrán (2001), p.341

[57] From the *p*-dimensional space, the attempt will be to find a *k*-dimensional subspace so that *k* is small with regard to *p* but with a small loss of the initial variability. Ferrán (2001), pp...341.

[58] Ferrán (2001), pp.344.

Taking into account the aspects mentioned, in the choice of factors and variables to work with several criteria have been used in combined form:

1. The factors extracted will have to be consistent and interpretable in accordance with the theory of regional innovation systems, since it is one of the aims of the factorial analysis in this research.

2. In determining the number of factors two criteria have been used. The first of these is the one called *Kaiser's criterion or that of the latent root,* which by default is the one used by the statistical programme we worked with. In accordance with this a set of factors will be extracted the auto values of which will be greater than 1. The logic on which this criterion rests is that any individual factor should justify the variance of at least one variable, where each of them contributes with a value of 1 for the *total auto value*. Therefore, only factors containing *latent roots or auto values* higher than 1 are considered, and those with lower values[59] will be non-significant. Here the best situation arises when the chosen factors have high *auto values* and present a reduced number in comparison with the original variables. The second criterion is the retained variance of the model. The outcome of the factor analysis is satisfactory if it retains a high percentage of the total variance of the sample high, which should be more than 75%.

3. As already mentioned in section 3.2.1 the selection of the variables starts with the control of their correlation and partial correlation. Because several variables were combinations or transformations of other variables of the data-base …… of the sixty variables were excluded already in the first step of the analysis due to the high level of correlation (over 90%).

4. Once the high correlated variables are excluded we started with the elaboration of the factor analysis. This analysis is based on a large number of *trial and error* attempts, starting with the inclusion of all the variables and including and excluding different variables. This is not only important to select the included variables and the factors. It is also to assure the consistency, reliability and robustness of the final result. An important selection criterion of the variables is the value of the *communalities*. It has been taken into account that if small *communalities* exist it is reasonable to increase the number of factors, or eliminate the variable, since this may not add a significant value to the model. Also in this case it must be remembered that many of the indicators which were not chosen are combinations or transformations of those that have been included. At the end we used 29 variables.

5. The fifth reason to exclude some variables is their powers to enssure a clear unequivocal and unambiguous interpretation of the factors. If some of the factors include variables statistically related to each other, even though conceptually totally different, we could not interpret the factor and its use makes no sense.

[59] It must be taken into account that the use of an extraction based on *self values* higher than one is more reliable when the number of variables is between 20 and 50, which supports the use of this criterion in the work presented here.

The application of the statistical requirements and the need of a unequivocal interpretation of the factors brought us to a model of six factors that include 29 variables. Although one could think that some variables reflect very similar concepts the statistical tests confirm that the data are sufficient unequal and identify different fine points of the same global factor[60]. Given that we are working with an important heterogeneity of regions it can be stated that there will exist cases in which these differences will be significant and therefore, it is not a good idea to eliminate them provided that their use can be statistically justified[61]. What is more, it must also be pointed out that in this case the number of variables-twenty-nine- is not high. Bearing in mind that we are not attempting to perform a predictive-type analysis, but rather a descriptive one, it is understood that it will be enriched by the use of a larger number of indicators.

Finally, it must be mentioned that the number of factors chosen, given their important theoretical interpretation, is six. This solution coincides with that obtained by the *latent root criterion.* During the calculation it has also been proved with a higher number of factors with the intention of checking whether there existed a significant improvement in the results. Such has not been the case.

In Table 3.2 the *communalities* of the initial variables and later the extraction of the six factors according to the main components method are registered. As can be understood, the *communalities* are high, which guarantees the reliability of the results and, furthermore, many of them are close to the unit, indicating the high degree of preservation in their variances. Only four variables present a *communality* below 80-%- *Risk capital, Risk seed capital, Expenditure on R&D by the University* and *Third cycle students-. T*heir elimination does not imply a significant improvement of the model. However given the importance of the information provided and taking into account the innovation system approach it was decided to include them in the model.

The solution with six factors-as shown in Table 3.3.-preserves 88.92% of the variance, so it can be said that it is statistically correct to reduce twenty-nine variables to six factors. Also included are the *initial auto values* as well as the aggregated non-rotated and rotated variance for each factor .The rotation process, as will be detailed in the next section, has the purpose of facilitating the interpretation of the six factors obtained by the analysis.

[60] By way of an example, we point out that the *Gross National Product* and the *Gross Domestic Product* have been included. From the economic point of view the quoted macro magnitudes that present a high correlation reflect clearly different concepts however. Moreover in some cases the differences, especially at regional levels are important, as in the case of the Irish regions

[61] In this sense it is once more worth remembering that the variability of the chosen indicators is well represented and that the factorial analysis shows consistent results.

Table 3.2. Communalities

	Initial	Extraction
Average annual population (thousands of inhabitants)	1	0,951
Patents (with regard to each million population)	1	0,917
Patents (with regard to each million working population)	1	0,911
Hi-tech patents (with regard to each million population)	1	0,885
Hi-tech patents (with regard to each million working population)	1	0,892
Human resources in Sc and T in high technology (total)	1	0,940
Human resources in Sc and T services (total)	1	0,985
Human resources in Sc and T in knowledge-intensive services (total)	1	0,955
Gross Domestic Product (millions € base 1995)	1	0,990
Gross fixed Capital Formation (millions € base 1995)	1	0,965
Wages (millions € base 1995)	1	0,986
Gross Added Value (millions € base 1995)	1	0,988
Number of people employed	1	0,976
Firms’ expenditure on R&D (%of GDP)	1	0,830
PA expenditure on R&D (%of GDP)	1	0,868
University expenditure on R&D (% of GDP)	1	0,762
Staff in R&D in firms (number of people) % of employment	1	0,870
Staff in R&D in (full time equivalent) % of employment.	1	0,883
Staff in R&D in PAs (number of people) %of employment	1	0,932
Staff in R&D in PAs (full time equivalent) % of employment	1	0,963
Staff in R&D in the University (number of people) % of employment.	1	0,863
Staff in R&D in the University (full time equivalent) % of employment	1	0,869
GDP per worker (€ per worker)	1	0,920
GDP per capita (€ per worker)	1	0,909
Seed and start up investment capital (% of GDP)	1	0,662
Capital investment development (% of GDP)	1	0,843
Penetration of TICs	1	0,849
Number of third-cycle students (% of population)	1	0,649
Economic Freedom Index	1	0,777

Method of extraction. Analysis of main components

Table 3.3. Variance explained by the model

Component	Initial autovalues			Sums of the saturations to the extraction square			Sum of the saturations to the rotation square		
	Total	% of the variance	% acumulate	Total	% of the variance	% acumulate	Total	% of the variance	% acumulate
1	11,902	41,041	41,041	11,902	41,041	41,041	8,878	30,614	30,614
2	5,392	18,594	59,634	5,392	18,594	59,634	6,095	21,019	51,633
3	3,083	10,630	70,264	3,083	10,630	70,264	2,976	10,261	61,894
4	2,345	8,085	78,349	2,345	8,085	78,349	2,891	9,969	71,863
5	1,808	6,235	84,584	1,808	6,235	84,584	2,775	9,569	81,432
6	1,260	4,344	88,928	1,260	4,344	88,928	2,174	7,497	88,928
7	0,687	2,371	91,299						
8	0,545	1,881	93,180						
9	0,474	1,634	94,814						
10	0,352	1,214	96,028						
11	0,219	0,754	96,782						
12	0,207	0,715	97,498						
13	0,163	0,562	98,060						
14	0,121	0,417	98,477						
15	0,096	0,332	98,809						
16	0,077	0,264	99,073						
17	0,069	0,236	99,309						
18	0,052	0,178	99,487						
19	0,040	0,139	99,626						
20	0,034	0,116	99,742						
21	0,025	0,085	99,827						
22	0,019	0,066	99,893						
23	0,009	0,032	99,925						
24	0,008	0,028	99,953						
25	0,005	0,017	99,971						
26	0,004	0,014	99,985						
27	0,003	0,012	99,996						
28	0,001	0,003	99,999						
29	0,000	0,001	100,000						

Method of extraction. Analysis of main components

3.2.3. Analysis of the extraction and rotation of the factors or hypothetical non observable variables

An important aspect of the factorial analysis refers to the interpretation of the factors, given that they are abstract, multidimensional variables that can be considered as hypothetical non observable variables that reflect the regional innovation systems. Therefore, the interpretation will be made from the *components matrix and the rotated components matrix.* The *components matrix* 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 the factors or *factorial loads* and graphically they are projections of the original variables on the six factors[62]. Given that the method used is the *main components* one, the correlations will vary between 1 and -1. This matrix thus indicates the original variables presented by the greatest percentage of the data variances. Thus, the first factor is the one which best summarises the relationships shown by the data via a linear combination of variables. The second factor is defined as the second best linear combination of the variables, subject to the limitation of being orthogonal to the first. For this purpose, the second factor must derive from the remaining variance after the first has been extracted and so on with the remaining factors[63].

The *components matrix* (Table 3.4) shows *the* correlations between the original variables and the factors that is the retained variability after the extraction. The sum of the squares of the saturations of a variable in the factors as a maximum is one. The correlations between the original variables and the factor are ordered from greater to lesser value[64]. If saturation on a factor is high, on he remaining ones it will be low. What is more, if a group of variables presents high *factorial loads,* such variables will be correlated among each other[65].

Although with this information some interpretation can be made of the results, a matrix in which the variables may be saturated in the different factors is of interest for a clearer, simpler definition. For this purpose an *orthogonal rotation*[66] has been made where the axes preserve a 90 degree angle-specifically the one known as *Varimax*[67]. The rotation is aimed at achieving a *components matrix* which would be as interpretable as possible, that is, one which might adjust to the *simple structure principle,* under which each variable is saturated in a different factor, or what amounts to the same thing, that the variables which are interconnected present high saturations-in absolute value-on a same factor and low ones in the rest[68]. As its name

[62] In the *factorial matrix* it occurs that the sum of the squares of the saturations in a same factor coincides with the corresponding *self value,* and that the sum of the squares of the saturations on the factors of a variable coincide with the corresponding *communality* .Ferrán (2001) p. 348

[63] Hair *et al*(2001), p. 94

[64] Given that the number of observations making up the simple is 146 it can be considered that the factorial loads of less than 0.50 are not significant, so they have been omitted from the table to make interpretation easier. Hair *et al,* (2001), p. 96.

[65] Ferrán (2001), p. 348.

[66] There also exists what are known as *oblique rotations,* albeit with this procedure the orthogonality is not guaranteed and therefore the factors may not be correlated. For a more detailed analysis of the factor rotation see Hair *et al* (2001) pp.95-99.

[67] In this type of rotation what is achieved is that in the *factorial matrix* by rows there are high saturations in some column-and thus, a clear association between the variable and the factor- and in the remaining ones near to 0. For a more detailed description of the *Varimax* rotation, see Ferrán (2001), pp.349-351 and Hair *et al.* (2001), p. 98.m

[68] Ferrán (2001), p. 349

suggests, in the rotation the reference axes of the factors turn on their origin and, unlike the non-rotated factorial solution, the variance of the first factors to the last is distributed, thus attaining a redistribution of it among the components and thus a simpler and theoretically more significant structure.

Regarding rotation, it can be said that if two variables present high saturations near to one on the same factor, then they are correlated among themselves and the factors obtained are mathematically independent[69]. In Table 3.5. the results of the *matrix of rotated components* are shown[70] In this matrix it can be seen how each of the variables presents high saturation in each factor, but this is not so with the remaining groups[71].

In view of the results after the rotation the existence of six factors implicit in European regional innovation systems can be appreciated. The assignation of a name to each of them has been based on their composition, and there is a clear appreciation of their correspondence to the essential elements of the innovation systems that have been examined in the outline presented in section 2.1. (Scheme 2.2).

[69] It must be borne in mind that after each rotation the *communality* of the variables will be the same, not so, however, in the case of the *self values* and thus for the variance explained by each one, as can be seen in Table 3.3. This derives from the already mentioned redistribution of the variance.
[70] Once again the saturations with a value below 0.50 are not indicated, to make interpretation easier.
[71] Note that the *saturation* is less depending upon the degree of its *communality*.

Table 3.4. Non-rotated components matrix

	Components					
	1	2	3	4	5	6
Human resources in Sc and T in high technology (total)	0,867					
Gross Fixed Capital formation(millions € base 1995)	0,862					
Human resources in Sc and T services (total)	0,860					
Human resources in Sc and T in knowledge-intensive services (total)	0,855					
Gross Domestic Product (millions € base 1995)	0,854	-0,501				
Gross Added Value (millions € base 1995)	0,852					
Wages(millions € base 1995)	0,835	-0,509				
Number of people employed	0,798	-0,570				
Patents per each million of active population	0,783					
Patents per each million of population	0,781					
Staff in R&D in (full time equivalent) % of employment.	0,780					
Firms' expenditure on R&D (%of GDP)	0,755					
Average annual population (thousands of inhabitants)	0,754	-0,600				
Firms' staff in R&D (number of people) as ‰ of employment	0,750	0,513				
GDP per capita (€ per inhabitant)	0,658					-0,532
Hi-tech patents (with regard to each million working population)	0,599	0,562				
Hi-tech patents (with regard to each million population)	0,590	0,561				
Penetration of TICs		0,500				
Seed and start up investment capital (% of GDP)						
Staff in R&D in the University (full time equivalent) % of employment			0,703			
Staff in R&D in the University (number of people) % of employment.			0,699			
Number of third cycle students (‰ of population)			0,517			
Economic Freedom Index						
PA expenditure on R&D (%of GDP)				0,721		
Staff in R&D in PAs (number of people) %of employment			0,514	0,646		
Staff in R&D in PAs (full time equivalent) % of employment				0,642		
Capital investment development (% of GDP)				0,521		
University expenditure on R&D (% of GDP)					0,563	
GDP per worker (€ per worker)	0,566					-0,658

Method of extraction. Analysis of main components
6 Extracted Components

Table 3.5.Rotated components matrix

	Components					
Number of people employed	0,980					
Average annual population (thousands of inhabitants)	0,973					
Gross Domestic Product (millions € base 1995)	0,972					
Gross Added Value (millions € base 1995)	0,970					
Gross Fixed Capital formation(millions € base 1995)	0,967					
Human resources in Sc and T services (total)	0,966					
Wages(millions € base 1995)	0,964					
Human resources in Sc and T in knowledge-intensive services (total)	0,946					
Human resources in Sc and T in high technology (total)	0,926					
Hi-tech patents (with regard to each million working population)		0,913				
Hi-tech patents (with regard to each million population)		0,907				
Patents per each million of population)		0,875				
Patents per each million of population activa)		0,862				
Firms' expenditure on R&D (%of GDP)		0,822				
Firms' staff in R&D (number of people) as ‰ of employment		0,805				
Staff in R&D in (full time equivalent) % of employment.		0,788				
Staff in R&D in the University (number of people) % of employment.			0,877			
Staff in R&D in the University (full time equivalent) as % of employment			0,857			
University expenditure on R&D (% of GDP)			0,835			
Number of third cycle students (‰ of population)			0,773			
Capital investment development (% of GDP)				0,902		
Economic Freedom Index				0,830		
Penetration of TICs				0,735		
Seed and start up investment capital (% of GDP)				0,710		
Staff in R&D in PAs (full time equivalent) % of employment					0,940	
Staff in R&D in PAs (number of people) %of employment					0,938	
PA expenditure on R&D (%of GDP)					0,915	
GDP per worker (€ per worker)						0,866
GDP per capita (€ per worker)						0,783

Method of extraction. Analysis of main components
Method of rotation: Varimax with Kaiser Normalisation.
The rotation converged after 6 iterations

Factor 1: *Regional productive economic environment*

This factorial axis -which records a 30.61% of the total variability of the total variability of the 29 variables included in the factor analysis- contains those indicators which determine the productive economic environment of innovation. Two blocks can be identified:

1. Size and productive activity of the market In the analysis of the different regional innovation systems market size and productive activity are going to be their distinctive elements, given the degree of heterogeneity of the regions worked with. A priori it seems logical to think that those regions with a greater market size and a more complex productive activity might have a more developed regional innovation system. Because that permits them to diversify their innovation-related activities taking advantage of specialisation (based on labour division) and scale advantages. The variables included here are:

- Number of people employed
- Average annual population
- Gross Domestic Product
- Gross Added Value
- Gross Fixed Capital formation
- Wages

2. Human resources in Science and Technology .Within the *Environment* of the innovation systems human resources specialising in Science and Technology are also going to be an important *input.* The greater amount of this type of resource will condition the capacity of the regional innovation systems themselves. The indicators belonging to this group are:

- Human resources in Science and Technology in services
- Human Resources in Science and Technology in knowledge-intensive services
- Human Resources in Hi-tech Science and Technology

Factor 2: *Innovating firms*

This factor registers 21.01% of the total variability and is made up of indicators that determine the resources and results of firms with a more innovatory behaviour.

1. Resources of innovatory firms As the systems' approach records to what extent a firm uses R&D resources it is going to determine greater results in innovation. That will impinge on the capacity of the regional system itself. The variables responsible for this aspect are:

- Firms' R&D expenditure as % of GDP
- Firms' staff in R&D (number of people) as % of employment
- Firms' staff in R&D (full time equivalent) as % of employment

2. Results of innovative firms The *output* of innovating firms can be quantified through patents, since most of the requests for patenting come from the enterprises while the public research Organisations or Universities are less inclined to patent their results. So their patents accounts relatively low percentage of the total Spanish patents. The variables included are:

- Patents per each million of population
- Patents per each million of working population
- Hi-tech patents per each million of population
- Hi tech patents per each million of working population

Factor 3: ***University***

This factorial axis retained 10.21% of the total variance of the 29 variables included in the factor analysis and contains those indicators relating to University resources and results. The University forms part of the region's scientific infrastructure and therefore is an important part of innovation systems. The included variables also can be differentiated in two groups:

1. University resources

- University expenditure on R&D as % of GDP
- Staff in R&D (number of people) as % of employment
- Staff in R&D in the University (full time equivalent) as % of employment

2. University results

- Number of third cycle students as % of population

Factor 4: ***National innovation environment***

This factor retained a 9.96% of the total variability and is made up of variables which represent some of the characteristics inherent to the Nation-State to which each region belongs. Note that the starting point is a group of countries with significant differences in the geographical, economic and political aspects, so indicators are needed to express their heterogeneity. The variables of the national environment are:

- Capital investment development (% of GDP)
- Seed capital investment (% of GDP)
- Economic freedom index
- Penetration of TICs

Factor 5: ***Public administration***

This factor, which records 9.56% of the variance of the 29 variables included in the factor analysis, shows the resources used by the Public Administration in areas of Research and Development and also forms part of the regions' scientific apparatus .The variables composing it are:

- PAs' expenditure on R&D as % of GDP
- PA staff in R&D (number of people) as % of employment
- PA staff in R&D (full time equivalent) as % of employment

Factor 6: ***Degree of sophistication of demand***

This factor has been called *degree of sophistication of demand,* explains 7.49% of the variance, and includes two key economic indicators (Living standard and productivity) which relate the production of the country to its population and number of employees. The two variables are:

- GDP per worker
- Per capita GDP

In Table 3.6. there is a synthesis of this information with the intention of making it easier to visualise. In brackets the existing correlations between the factors and the variables of the research are included.

3.2.4. Calculation of factorial marks

Table 3.6. Factorial analysis years 1998, 1999 and 2000.

REGIONAL PRODUCTIVE ECONOMIC ENVIRONMENT (30, 61%)

1. ***Size and productive activity of the market***
   - Number of people employed (0,980)
   - Average annual population (thousands of inhabitants) (0,973)
   - Gross Domestic Product (millions € base 1995) (0,972)
   - Gross Added Value (millions € base 1995) (0,970)
   - Gross Fixed Capital formation(millions € base 1995) (0,967)
   - Wages(millions € base 1995) (0,964)
2. ***Human resources in Science and Technology***
   - Human resources in Science and Technology in services (0,966)
   - Human Resources in Science and Technology in knowledge-intensive services (0,946)
   - Human Resources in Hi-tech Science and Technology(0,926)

INNOVATING FIRMS(21, 01%)

1. ***Resources of innovatory firms***
   - Firms' expenditure on R&D (%of GDP) (0,822)
   - Staff in R&D in firms (number of people) % of employment (0,805)
   - Staff in R&D in (full time equivalent) % of employment. (0,788)
2. ***Results of innovative firms***
   - Hi-tech patents (with regard to each million working population) (0,913)
   - Hi-tech patents (with regard to each million population) (0,907)
   - Patents per each million of population) (0,875)
   - Patents per each million of working population (0,872)

UNIVERSITY (10,21%)

1. Universityresources
- Staff in R&D in the University (number of people) % of employment. (0,877)
- Staff in R&D in the University (full time equivalent) % of employment (0,857)
- University expenditure on R&D (% of GDP) (0,835)

2. University results
- Number of third cycle students as % of population(0,773)

NATIONAL INNOVATION ENVIRONMENT(9,96%)
- Capital investment development (% of GDP) (0,902)
- Economic Freedom Index (0,830)
- Penetration of TICs (0,735)
- Seed and start up investment capital (% of GDP) (0,710)

PUBLIC ADMINISTRATION(9, 56%)
- Staff in R&D in PAs (full time equivalent) % of employment (0,940)
- PA staff in R&D (number of people) as % of employment(0,938)
- PA expenditure on R&D (%of GDP) (0,915)

DEGREE OF SOPHISTICATION OF DEMAND(7,49%)
- GDP per worker (€ per worker) (0,866)
- GDP per worker(0,783)

Source :own preparation. (Within brackets the existing correlations between the variable and the factor)

Finally, concluding the explanation of the factorial analysis of main components, it is worth qualifying that the marks have been calculated of the six factors for each of the three years in the 146 regions. These factorial marks constitute compound measurements of each factor for each case, in which the relationship of all the variables with the factor is taken into account, not just with the most saturated ones, shown in the *components matrix*[72]. In graphic terms, these marks are the projections of the cases on each of the six factors. These six new variables which are registered in the IAIF-RIS (EU) database will be responsible for summarising the original information explaining 88.92% of the total variability of the sample and with each one of them represented in the same proportion as the *communality* on the set of the six factors. The method chosen to estimate the coefficients is the Regression one[73] and its standardised- values-could be subsequently used in other statistical calculations.

SECTION 4.- CONCLUSIONS

In this research project we created in a first phase the database for the 147 regions of the EU-15[74]. In a second step we determined the implicit factors making up the regional systems of European innovation[75]. In these conclusions we will explain the advantages and problems with the used methods and data, we will show that the outcome fits well in the theoretical innovation system approach and explain the possibilities to use the factor scores for future research.

4.1. THE CONVENIENCE OF THE FACTOR ANALYSIS TO MEASURE REGIONAL INNOVATION SYSTEMS

From a battery of indicators available for different European regions in the period 1998-2000, the multivariate technique of factorial analysis of the main components is used. Like already argued, the factorial analysis is a technique which determines for a set of variables a smaller set of hypothetical indicators by merging the variables which are highly correlated in just one combined indicator. The latter, which take the name of factors, summarise practically all the information to be found in the original set of variables and among their characteristics that of being uncorrelated is the outstanding one. The technique thus makes it possible, given a sample of observations or cases or a set of quantitative variables, for them to be represented in a small space-a factorial space- where the relationships between them can be interpret[76].

The new hypothetical or "non observable" variables found in this study are: *Regional productive and economic environment, Innovatory firms, University, national innovation*

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[72] For a more detailed analysis of techniques with additional uses of the factorial analysis see Hair *et al,* (2001), pp.103-107.
[73] Via this method the resulting marks have median 0 and variance equal to the square of the multiple rotations between the estimated factorial marks and the true factorial values (SPSS 11.0). A normalisation of the data occurs and they go on to achieve a median of 0 and a typical standard deviation of 1.
[74] We should like to highlight that the first database was elaborated by Thomas Baumert and Monica Martinez Pellitero during different research activities directed by Mikel Buesa y Joost Heijs.
[75] The factorial analysis has already been used in the study of Spain to determine the components of their regional innovation systems, in Works such as Martínez Pellitero (2002), (Buesa, Heijs and Martínez Pellitero (2002), Buesa, Martinez Pellitero, Heijs and Baumert (2003), Buesa, Baumert, Heijs and Martínez Pellitero, (2003), Buesa, Heijs, Martínez Pellitero and Baumert (2006), Buesa, Martínez Pellitero, Baumert and Heijs (2007), Buesa and Heijs (2007a) and Buesa, Heijs, Martínez Pellitero *et al* (2007). In this latter work findings from European regions are also included.
[76] Ferrán (2001), p.340

environment, Public Administration and Degree of sophistication in that of demand. Given the methodology employed, these 6 factors will practically summarise all the information of a primary set of 29 variables, and will show, better than individual-type indicators, the components of the regional systems of European innovation. This methodology can be considered as a *holistic approach of the empirical studies on (regiona)l innovation systems because of the u*se of a great number of variables. Moreover the high number of correlated variables is one of the main handicaps for the traditional econometric analysis. The factor analysis is one of the solutions that could avoid the problems of multicolinearity.

It can be highlighted that the factor analysis presented in this paper grouped the variables without any restriction. I.e. the statistical programme classified or assigned the variables to each in groups or so called factors without previous indications or influence of the authors of this paper. This is important because, as will be seen, the variables included in each factor belong to the same component or sub-system of the overall regional innovation system. Which can be considered as an important achievement because it should not be forgotten that one of the main criteria to judge the correctness of a factor analysis is , besides that the statistical requirements are fulfilled, that the factors –or hypothetical non-observable variables- can be correctly interpreted from a practical point of view and fit properly within the theoretical framework of the innovation system approach. So, the variables assigned to a factor have to be somehow interrelated and reflect different aspects of the same overall concept.

On one side the variables included in each of the factors can be interpreted correctly. Moreover, the appropriateness of our variables and factors to measure the framework of the national innovation systems can be observed once we compare them with the main descriptions in the literature of national and regional innovation systems. Revising some literature[77] on national and regional innovation systems we summarised the main elements of an innovation system in table 4.1. mentioned among others by Nelson, Lunvall and Edquist Comparing our outcome with this summary and our own outline (se table 2.2) we can observe that our "factors" and the variables synthesised in them include most of the aspects mentioned by those authors, although some aspects are not in our database and factors.

The first of our factors or hypothetical non observable variable "*the regional productive and economic environment"* is based on variables expressed in absolute figures. It includes data on the size of the productive sector and of the human capital. Its inclusion is justified to incorporate somehow the problem or advantages of the critical mass or scale advantages related to R&D systems. I.e. smaller regions or regions with small innovation systems have specific problems to assure the benefits of innovation related activities. The small number of innovating agents and the low demand of innovative products or service impede the necessary regional based labour division of the innovation process between firms, technology centres, consultancy offices, specialised providers, etc…. Therefore we could conclude that regions with a larger innovation systems has a more developed and differentiated system with more dynamic mutual reinforcing agents, effects and spillovers. I.E They can diversify their innovation-related activities by a broad number of specialised agents. The division of labour provides a network of specialised agents that offer advanced R&D related services. Such a network is important –especially for SMEs- to solve the problems of critical mass and to take

[77] Lundvall (1992a); Edquist y Johnson (1997); Edquist (2005); Nelson (1993; Patel y Pavitt (1998); Radosevic (2004)and Koschatzky (1997/2001)

advantage of the scale advantages of certain R&D activities, especially in the case of the large scale facilities or other components of the technology infrastructure.

The second factor or the "hypothetical variable" called *Innovatory firms*, reflect the innovative intensity of the private sector and its results. In both cases indicators are based on relative data. And as already said the firms are considered as one of the main pillars of the RIS. However, one of the deficiencies of our factors is the absence of data related with inter-firm cooperation or other forms of interactions.

The public involvement is reflected in two factors *–University and Public Administration-*. However about other important aspects, like the R&D and innovation related public support programmes or the technology centres, we did not found any homogeneous data for all the EU-15 regions.

The national and regional environment is reflected by two complementary factors, the first one we called "*national innovation environment"* and include three apparently very different aspects. First of all two variables that reflect the capital market (risk capital and ***capital investment development***). While on the other side this factor includes the Economic Freedom Index and the penetration of the ICT. However, somehow the factor analysis shows us that these three aspects are related to each other.

The second variable of the environment of the regional innovation systems is the "*Degree of sophistication of the demand",* considered in the literature as an important aspect that influence the innovative behaviour of firms. It is supposed that consumers with a higher living standard are more exigent in the innovative level of the product they buy (Quality, design or technical specifications) and therefore these variables are very important.

Relevant elements and components of national innovation system by some selected authors

Lundvall (1992a)	*Edquist (2005) Edquist y Johnson (1997)*	*Nelson (1993)*	*Patel y Pavitt (1998)*	*Radosevic (2004)*	*Koschatzky (1997/2001)[a]*
■ Internal Organization of firms. ■ Inter-firm Relationships ■ R&D of the Public Administration. ■ Institutional Structure of the Financial sector. ■ Organization e intensity of the R&D.	■ Organizations (firms, universities, associations of risk capital, etc.) ■ Institutions (laws of patent, norms about the relationships between universities, firms, etc.)	■ Institutional Structures. ■ system of incentives for innovation. ■ Capacity and creativity of the economic and innovative agents. ■ Cultural Peculiarities.	■ Firms (innovative ones). ■ Universities y High Educational Intsitutes. ■ Governments (Public Administration). ■ Mixed Institutions	■ Creation of knowledge ■ Capacity to absorp and adapt new tecnologies ■ Capacity of diffusion ■ Level de sophistication of the demand ■ Capacity of government	■ Firms R&D ■ Regional environment . ■ Politics. ■Technological supply. ■Technological Services. ■Inter-firm Relationships.

[a] Paper focussed on regional innovation systems: Source: Baumert, 2006 .

However we have to admit that some important aspects of the RIS and its components are missing. Especially there is a lack of information or data about the interaction between the agents of an innovation system like data about cooperation and technology transfer. Moreover we did not find any homogeneous regionalised data on the public support for R&D. Maybe some of such data are available in the European Innovation Survey (EIS) although the first editions were not representative on a regional level[78], while for the most recent ones we are not sure for which countries they are representative at regional level. Moreover we worked with data in a longer period, while the EIS is carried out only in some specific years. To overcome the lack of information on some of the important aspects missing in this paper we propose to work with a smaller number of countries for which we can find homogeneous data on some specific variables like scientific publications or inter-firm relationships

Concluding, although there is more and more information available on the R&D and innovation related activities, it is still difficult to recollect aggregated homogeneous data for a large number of regions or even countries. Therefore, our approach is just a step forwards in this kind of studies. Its main advantage is the creation of the so called hypothetical non observable variables. Which is nothing less than a reduction of a larger number (29) variables into six factors that reflect, from our point of view, better the reality of a RIS than each or a few of the individual variables.

4.2. THE POSSIBLE USE OF THE FACTORS OR THE HYPOTHETICAL NON OBSERVABLE VARIABLES IN ANALYTICAL STUDIES

The creation of the non observable hypothetical or virtual variables to reflect the regional innovation system was not an aim on itself. However, we applied the factor analysis to use the so called factor scores for further analytical research.

The factors can be considered as combined variables that can be used for econometric studies as if they were normal variables. To understand the possible use of the factors in analytical studies it has to be pointed out that the method employed in determining the factors is that known as *main components,* in which in graphic terms the factors are orthogonal. This is important because the absence of possible multicolinearity between the new "non-observable" variables permit their use in further econometric studies like regression models

In the general introduction (see section "0") we mentioned already that we carried out different types of analysis. We did a number of complementary studies that deal with different aspects and perspectives of the regional innovation systems. A typology of regional innovation systems (RIS) was created to describe the structure or configuration of the RIS. The IAIF index for RIS was elaborated to summarize this typology and offer the possibility to analyse its development over time. Afterwards an "ideas production function" was estimated to establish the relationship between the "structural aspects" and to reveal the determinants of the creation of knowledge on regional level. Moreover the Data Envelopment Analysis was used to evaluate the efficiency of that innovation production process. Here we give a short overview of the type of studies we carried out for the case of Spain[79] and for the case of the EU-15[80].

[78] In fact for the case of Spain we used those data see Buesa et al 2005, 2007 (in English) and Buesa and Heijs (Coordinators) in Spanish.
[79] We can highlight the English written publications published in Technovation (Buesa et al. 2006) and Buesa et all 2007
[80] See the PhD thesis of Baumert, 2006 and that of Martínez-Pellitero, 2008. Also the complementary working documents related to this one and referred broadly in section "0" of this paper can be recommended.

Once the factors have been specified we went on to quantify the extent of innovatory capacity in European regions by means of the construction of what is known as the IAIF index of regional innovation[81]. This index, calculated from the results obtained in the previous stage-factorial analysis-, establishes a ranking of regions according to the extent to which their systems are developed .In the same way, an order can be set from each of the factors detected-*Regional productive and economic environment, Innovatory firms, University ,National innovation environment, Public administration and degree of sophistication of demand-*, which correspond here with the subindexes making up the general indicator. Given the nature of this index, the relative weight of the factors, as well as the variables comprising them have been calculated from the findings produced by the multivariate analysis. The idea is to weight the variables and the six partial indices in accordance with their real participation in the innovation systems bearing statistical criteria in mind.

Also a typology of regional innovation systems in Europe[82] was created. In this study European regions were be classified in ten groups, and there also exist here the cases of atypical systems. In the development of this work the multivariate technique known as *cluster* analysis or analysis of conglomerates has been used .The *cluster* analysis is a method, descriptive in character, which enables “individuals” to be classified without the number of groups or the number which will be formed being known a priori. It is, therefore, a technique which is geared to forming conglomerates or *clusters* in such a way that with regard to the distribution of the values of the variables, each conglomerate should be as homogeneous as possible, but also, different among each of them. In this research the factors making up the regional innovation systems developed in this paper will be used to determine the clusters, and each of them will have their own characteristics differentiating them from the others clusters in the context of innovation.

Moreover we carried out a study based on the neoclassical concept of efficiency, in the use of resources available to the innovation systems. The technique used here has been the Data Envelopment Analysis (DEA) [83], which models this term through linear programming. With this procedure an efficient frontier is constructed made up of those units of analysis (the regions) which use the least amount of *inputs* per unit of *output* produced, as well as by other units of a fictitious nature resulting from linear combinations of *inputs* and *outputs* from the cases analysed. The cases located on the frontier will attain a100% index of relative efficiency, whereas the other units will obtain a relative efficiency compared to some efficient case which is on the frontier. In this research we applied the DEA to European regions, the *input* variables are the factors of the regional innovation systems and the *output* variables requests for patents.

[81] The IAIF index of regional innovation has been applied to the study of Spanish regional innovation systems in Martínez Pellitero and Baumert (2003) Buesa, Heijs, Baumert and Martínez Pellitero (2003a and 2003b). Buesa, Heijs, Baumert, Martínez Pellitero et *al* (2007). In the latter findings for European regions are also included.

[82] A similar analysis for Spanish regions can be seen in Martínez Pellitero (2002), Buesa, Martínez Pellitero , Heijs and Baumert (2003) and Buesa, Heijs, Martínez Pellitero and Baumert (2006) Buesa, Martínez Pellitero , Baumert and Heijs (2007), Buesa and Heijs (2007a) and Buesa, Heijs, Baumert Martínez Pellitero *et al,* (2007). In this latter work and in Martínez Pellitero (2007) the results for European regions are presented.

[83] This topic, in the area of Spanish regional innovation systems has been dealt with by Buesa, Martínez, Pellitero, Baumert and Heijs (2007), Buesa and Heijs (2007a) and Buesa, Heijs, Baumert, Martínez Pellitero *et al* (2007). In this latter work and in Martínez Pellitero the European regional results are presented.

Another type of analysis based on the factors is the estimation of the Ideas Production Function. Starting from the seminal work by Griliches (1979), it has since then been widely applied, both on the national and subnational level. 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). In this case a new factor analysis has to be made excluding the patent data because the number of patents will be the dependent variable in the regression model.

4.3.- FINAL REMARKS

The methodological approach here presented could be a first step in a new direction about the empirical analysis of regional innovation systems. It has to be clear that we have still long way to go. First of all we need much more information on specific topics, like the cooperation and interaction between agents of the regional innovation systems public policies or technical infrastructure. Still the data are incomplete or heterogeneous in the way they are measured between countries and even between regions of the same country. Secondly, it is even more difficult to obtain homogeneous data for a longer time span and data are available with some delay of at least two years. In fact the use of the data for all regions of the European EU-15 or EU25 means that we always analyse the situation of at least two years ago. This is especially problematic in the case of countries like Spain with a yearly increase of the public R&D expenditures of the national government of 25% and the entrance of a large amount of new innovation related funds (ERDF and the European Technology fund).

However we think that this approach could teach us quite a number of new insights and maybe can lead to new empirical studies. Currently within the IAIF (together with the Bask Institute for Competiveness) we are updating the database and amplifying it to the EU-25 regions. Moreover we are designing new applications, using the factors or hypothetical non observable variables in the regional economic growth model and the analysis of the technological or economic convergence between European regions

Also benchmark studies can be carried out to compare the situation of specific regions with there counterparts in other European countries. A last new research line would be the applications of simulations. If you want to analyse a specific aspect (for example the impact of the public policies) you could exclude from the factor analysis the variables related to this specific topic and mix them together in a later analysis with the revealed factors or hypothetical non observable variables.

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En la página 1, dentro de un recuadro sencillo, debe figurar el título (en negrilla y mayúsculas), autor (en negrilla y mayúsculas) e institución a la que pertenece el autor (en letra normal y minúsculas)
En la primera página del trabajo, se deberá incluir un Resumen en español e inglés (15 líneas máximo), acompañado de palabras clave
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