ARE WE SPENDING OUR SCARCE R&D RESOURCES ADEQUATELY? ANALYZING THE EFFICIENCY OF EU´S REGIONAL INNOVATION SYSTEMS

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ABSTRACT

This paper aims to analyze the efficiency of the innovative activity and its determinants. The efficiency index determines to what extent it maximizes the relationship between the effort and R&D results at regional level. For this purpose, data from 132 European regions were used and the yearly level of efficiency in the period 2000-2010 was established through a Data Enveloping Analysis (DEA).

In addition to efficiency, the paper addressed an important aspect: "spatial externalities". The literature on national innovation systems (Lundvall, 1992), growth theories (Marshall, 1919; Perroux, 1955; Myrdal, 1957; Krugman, 1998) and the literature on competitiveness indicate that the advantages of localization influence on the level of success of firms and the competitiveness of regions. In this work, a two-stage DEA (Simar & Wilson, 2007) has demonstrated the influence (*spillovers*) of national innovation systems on the level of efficient innovation in their regions and the existence of potential externalities.

Keywords

Efficiency, Regional Innovation Systems, DEA, Malmquist Index, Scale Efficiency

1. - INTRODUCTION

The economics of innovation, mainly driven by its evolutionary approach, has devoted considerable effort to the analysis of the processes of allocation of resources to building activities of scientific and technological knowledge, taking into account the relationships established between actors these processes and institutions in which they are located and policies that seek to promote them. However, there have been few occasions when economists of innovation or managers of science and technology policy have wondered about the limits in the use of resources for the creation of knowledge. In general, it is assumed that any level of R&D is relevant and that their results will always be positive for economic development. In other words, neither the scholars of the discipline, nor managers of R&D, have been interested in the potential efficiency problems underlying the use of these resources. It is in the current crisis years when the issue has gained increasing attention and, although there have been detected in recent years various (purely descriptive) studies measuring innovation efficiency level of countries and regions, only some isolated studies have tried to analyze the determinants of efficiency.

The issue of efficiency is not new as an essential part of the reflection of economists about innovation. Schumpeter referred to it by highlighting the role of innovation in achieving the expansion of the economy in the long term by multiplying the product from a limited amount of resources. In turn, in the neoclassical field, authors can consider pioneer in the economics of innovation, also have influenced the efficiency issues. For example, Nelson (1959) was concerned with the analysis of the use of resources in basic scientific research; an analysis which concludes that, this is being subject to external economies, to achieve efficiency the best option is that implementation takes place in universities, because *"a dollar spent on basic research in an university laboratory is worth more to society than a dollar spent in an industrial laboratory."* (Nelson, 1959: 306).

Moreover, Arrow (1962) studied the problem of optimal allocation of resources to the invention from the characteristics of the knowledge market; a market subject to indivisibilities, inappropriability and uncertainty, all faults that lead to the need to achieve efficiency, it is necessary that the government, or some other entity not governed by criteria of profits, fund research and invention but not in an unlimited amount, but considering the limit set when *"the expected social benefit equals the marginal social benefit in alternative uses"*. (Arrow, 1962: 623). Similarly, Griliches (1958), in his study of the social costs and yields of hybrid corn research concludes that, although yields of research *"in general have been very high, ... that does not mean we should spend any money on anything called 'research'"*. (Griliches, 1958: 431)

In order to focus the thematic of the efficiency in the regional systems of innovation from an empirical point of view, two techniques of multivariate analysis were combined. The first one (factor analysis) is used to create combined input variables that allowed us to describe in a synthetic way the complexity of regional innovation systems. The second technique (DEA) was used to construct the efficiency frontier and to determine the position of each of the systems with reference to it, also allowing study the causes of their inefficiencies. This last aspect allowed us to draw some relevant conclusions and suggestions for the design of innovation policies.

The paper complements to the classic calculations of efficiency by DEA a series of aspects related to the methodological advances to respond to the inconsistencies and criticisms to the nonparametric methods. Using the Super-Efficiency technique for the detection of outliers (Simar, 2003; Banker & Chang, 2006) as well as the bootstrap technique to contrast the returns to scale hypothesis (Simar & Wilson, 2002) and construct confidence intervals and not biased efficiency scores (Simar & Wilson, 1998, 2000; Kneip *et al.*, 2008).

2. - THE INNOVATION SYSTEMS

The national/regional innovation system (NIS) is one of the concepts that has seen its importance greatly revalued, which is reflected in the numerous academic contributions published in this regard. Such system can be defined as *"the set of distinctive institutions that jointly and individually contribute to the development and diffusion of new technologies and provide a framework in which governments formulate and implement policies with the purpose of influencing the process of innovation. It is, therefore, a system of interconnected institutions designed to create, store and transfer knowledge, skills and artifacts that define new technologies"* (Metcalfe, 1995). The NIS concept reflects the process of division of labor in the field of innovation with the corresponding participation of a wide range of interrelated agents and institutions, whose activities should generate synergies or save costs. In fact, innovation is an increasingly complex and interdisciplinary activity and its development requires the interaction of a large number of institutions, agencies and companies. The activities of these agents of the innovation system are often complementary, based on a division of labor, where large public research centers (including universities) are engaged in basic research which is often not economically exploitable Companies are engaged in the development of new products or processes through applied research. In the middle there is a wide range of agencies and institutions dealing with the transformation of scientific knowledge into tradable products and the transfer, diffusion and adaptation of new technologies.

3. – METHODOLOGY

In order to study the efficiency of regional innovation systems (RIS) in Europe, a methodology was applied —factor analysis— that allows the reduction of information from a broad set of variables (29) to a few hypothetical or unobservable variables. Each of the factors reflects the essential aspects (being the different components or subsystems) of RIS and these hypothetical variables —called factors— collect almost all the information of the original set of variables (around 83% of the original variance). These synthetic factors or variables better reflect the reality of each RIS component that each of the individual variables could make. This methodology could be considered holistic since it works with a large number of very heterogeneous variables. The synthetic variables thus obtained (reflected in the factorial score of the obtained factors) were used as inputs for the subsequent analyzes in the elaboration of an index of efficiency at regional level.

Taking into account, like Baumert (2006), certain criteria that affect the areas of competence in R&D in European regions, we have finally chosen to use the following geographical units in our analysis: the Belgian Régions (NUTS 1), the German Bundesländer (NUTS 1), the Spanish Autonomous Communities (NUTS 2), the French Regions (NUTS 2), the Italian Regions (NUTS 2), the Dutch Provinces (NUTS 2), the Austrian Bundesländer, the Portuguese Regional Coordination Commissions (NUTS 2), the Finnish Suuralueet / Storområden (NUTS 2), the Swedish Riksområden (NUTS 2) and the Government Office Regions of the United Kingdom (NUTS 1). In the case of Luxembourg, Denmark and Ireland, due to their smaller territorial extension, a subnational division (NUTS 1, 2 and 3) has not been carried out (Baumert, 2006). In this way, there were 132 DMUs (decision-making units), the units that will be analyzed from the point of view of the efficiency of their innovation systems. (See map 1)

From the factor analysis, five clearly interpretable factors can be distinguished, which correspond to the **Regional Economic Environment**, to the (innovating) **Firms** —which includes the specific activity of creation of technological knowledge—, institutions of higher education (**Universities**), that reflect the specific generation of scientific knowledge, the **Public Administration** and the **Sophistication of Demand**[1] (in the technological sense). The results obtained through the factor analysis therefore coincide basically with the determinants pointed out by the theory. In summary, the factorial model we have estimated provides adequate representation of RIS in Europe (EU14), as all the statistical and conceptual requirements that are required are met. Therefore, the resulting factors in this model —expressive of the resources, organization and interrelationships that describe the innovation systems— can be used to address the analysis of the efficiency with which the activities of creation and diffusion of technological knowledge are developed in the European regions. (See table 1 and figure 1).

The output variables refer to quantitative indicators that express the results of such systems, either as technological products or as scientific products. The level of innovative efficiency of European regions and their evolution over time distinguishes three efficiency indexes (EI):

● Global IE (GEI): the output is a composite variable that collects the number of patents and scientific publications simultaneously.
● The EI of the productive or technological sector (TEI): the output is the number of patents requested.
● The EI of the scientific sector (CEI): the output collects the scientific publications as the best results of research in the scientific world.

Regarding the determination of efficiency an important aspect has to do with the time lag between effort in R&D and the time of patent application or publication. Empirical studies seem to show that this relationship is almost contemporary in the case of patents (Schmoch, 1999; Hall *et al.*, 1986, OECD, 2004: 139) but not in the case of articles for scientific publications. On the other hand, among the variables chosen is the stock of technological capital, which, according to its calculation methodology, incorporates R&D expenditures with delays and stock depreciations, that is, implicitly a delay structure is used. Finally, factor analysis smoothes the time series of data so that the possible divergences in the values from one year to another of a variable are reduced, making the distinction of delays less relevant. In this way, the model presented in this study did not assume explicit delays between the independent variables and the different outputs.[2]

We propose a new design to measure the influence of national innovation systems on R&D activities in a particular region. To this end, the synthesis of national systems as potential explanatory variables (by a new factor analysis, see table 2) was added to the data of the region itself. These variables are used in the formulation of a *"function that analyzes the*

[1] GDP per capita would indicate the standard of living and indirectly the technological level of consumer demand. In the case of a high level of GDP per capita, consumers would require products with a higher level of quality and performance, which in turn would induce companies to increase their innovative effort. On the other hand, a higher standard of living and higher salaries serve to attract new talent and the best researchers and / or inventors.

[2] However, calculations were made with one and two delays without changing the conclusions of the study.

determinants of the efficiency level of the regions". Some of these variables proved to be statistically significant, demonstrating the existence of *spillovers* from national innovation systems to the R&D efficiency of their regions.

4. – RESULTS OF THE FIRST STAGE: STATIC AND DYNAMIC ANALYSIS

The results of Super Efficiency for the global model include four regions that show Super Efficiency ratings in all the years of the series: Baden-Württemberg in Germany, Etelä-Suomi in Finland, Groningen in the Netherlands and Östra Mellansverige in Sweden. However, the only region with Super Efficiency ratings that would recommend its exclusion from the series is Noord-Brabant in the Netherlands, which in 2001, 2002 and 2003 obtained Super Efficiency scores higher than 2. Despite this, it was decided not to exclude this region from this dataset since more than an outlier is a region of high industrial development with a strong propensity to patent where one of the largest technology companies in the world as Philips is based and is entirely appropriate to consider it a benchmark level European. (See table 3 with results for global model for years 2000, 2005 and 2010).

The technological model highlights four regions that in several years of the series have higher efficiency scores than one: Baden-Württemberg in Germany, Etelä-Suomi in Finland, Noord-Brabant in the Netherlands and Voralberg in Austria. The scientific model includes: Groningen, Utrecht, Ostra Mellansverige and Ovre Norrland. However, no region has Super Efficiency ratings that would recommend its exclusion from the series.

Global leaders can be divided into three distinct groups. The leading technological regions headed by Baden-Württemberg, Etelä-Suomi, Noord-Brabant and Voralberg; the leading scientific regions such as Groningen, Östra-Mellansverige, Övre-Norrland and Wien. A third group is formed by those regions that are jointly such as Sydsverige, Stockholm and Bayern. One thing that should be emphasized is that the leading regions in some field are pushed to greater overall efficiency when considering the complementary field. For example, Baden-Württemberg and Etelä-Suomi, technology leaders in eight years have been global leaders in 11 years.

Comparing the means, standard deviations (SD) and probability distributions, it can be seen that the global model is the one with the highest annual mean values between 0.41 and 0.45 followed by the scientific model with values ranging from 0.31 to 0.37; and finally the technological one with values between 0.14 and 0.27. When considering the standard deviations, it is observed that the technological model is the most homogeneous (SD = 0.15 - 0.22); followed by the scientist (SD = 0.20 - 0.26) and the global one is the most heterogeneous with SD between 0.23 and 0.26.

This confirms one of the most forceful hypotheses in the European context, which is the so-called "European Paradox" (Dosi *et al.*, 2006). It points out that in general EU countries are apparently very good at basic or scientific R&D but are less successful in converting their scientific results into marketable products, whereas Japan and the "Asian Tigers" have obtained historically much success in product innovation without being highlighted in the basic R&D.

The inequality in efficiency was calculated for each of the models using the Gini index. This index is widely used in calculations of income inequality and takes values between 0 and 1, being 1 extreme inequality, only one is the most efficient, and 0 means total equality (all are equally efficient). The calculations were made for the years 2000, 2005 and 2010 and indicate that the technological model is the most unequal with Gini indexes equal to 0.48, 0.45 and 0.46; followed by the scientific model with indexes of 0.42, 0.37 and 0.34; and finally the global model with Gini indexes equal to 0.38, 0.34 and 0.33, for each of the considered years respectively.

The results obtained allow us to point out, firstly, that only a few European regions are located on or very close to the efficiency frontier, with many regions systematically obtaining low efficiency scores. The dispersion of these levels of efficiency is very broad both within and between countries. Moreover, the differences in efficiency with which regions allocate their resources to innovation are a common feature of all multiregional nations, regardless of their income level. In addition, RISs that are on or near the frontier belong to countries whose GDPs per capita are above the European average; at the same time in all countries whose GDPs per capita are below the European average, their regions show efficiency levels below 20% of the frontier.

The estimation of an index of scale efficiency for RIS as well as the test for returns to scale reveals that much of the estimated inefficiencies in our model are caused by a dimension problem. Technical efficiency is high in many regions but its scale efficiencies are very far from the frontier. This result highlights the fact that inefficiency maintains some relation with the need to reach a critical mass of economic and institutional resources of each region for the development of its innovation activities. However the present paper does not go into this question.

The final result should be considered by those responsible for designing and implementing innovation policies, aiming to economize resources employed with the highest possible returns. In other words, not any objective nor any actor is equally efficient developing R&D activities.

According to this, there is no room for homogenous or 'coffee for all' policies; if not rather for 'tailor-made' innovation policies (see Tödtling & Trippl, 2005) which implement an improved mix of science and technology instruments and R&D (see Chen & Guan, 2012: 368), as innovation activities differ strongly between regions in terms of their structural and institutional development.

For a dynamic analysis of the changes in the efficiency of European RIS, this work uses the input-based Malmquist index approach for three reasons, also discussed in Pastor (1995). The greater conceptual and intuitive relationship between the potential savings of inputs and the waste of resources, Farrell's measure of inputs has more properties than that linked to increases in outputs and given the characteristics of innovation systems, R&D are reflections of free adjustments in inputs, therefore a model oriented in these would be more appropriate.

To study the cause of the change in relative efficiency, a decomposition of the Malmquist index is applied, following the methodology proposed by Färe *et al*. (1989, 1992). According to this approach, the change in efficiency can be explained by the effect of two components:

● The change in pure or actual technical efficiency (CTEI or catching-up effect), which reflects the actual efficiency variation experienced by an RIS in relation to improvements in its own innovative system. That is, a real improvement in techniques or the innovative process that converts the inputs into results of R&D (outputs).

● The change of the technological frontier (CTFI or frontier shift effect), which reflects a nominal change or an apparent improvement in efficiency due to the efficient frontier shift between two periods of time.

The product of both provides the efficiency index change (IMQ). It should be noted that these changes are based on relative indicators and, therefore, do not always vary in the same direction. The analysis of the decomposition of the Malmquist index is very important because it allows explaining the evolution and the causes of the change of the productivity or efficiency of the RIS over time.

The main conclusions of the dynamic analysis are: the greatest increase in productivity of the scientific model in relation to the technological one, there is technological convergence between the European RISs during the analysis period, which is explained both by an approach of the lagging regions as well as by a displacement of the frontier that would indicate a loss of relative efficiency of the leading regions. Among the possible causes of the latter phenomenon could be mentioned the intensification of international and interregional competition due to the greater integration of the markets, the relocation of some companies with a strong propensity to patent and the search by the agents of the leading regions of more sophisticated but also more expensive innovations.

5. - RESULTS OF THE SECOND STAGE: *SPILLOVERS* FROM NIS TO RIS

Finally, the potential externalities of NIS on RIS have been studied. The concept of a national innovation system is complex, difficult to quantify, and where the whole is more than the sum of its parts. Given this complexity, the methodology proposed in this paper is an approximation to the analysis of the true interactions that occur between the regional and national levels in the innovative process. Thus, the national variables were corrected by the respective regional variables to each particular region in order to avoid double counting, implicitly assuming that a national innovation system is the sum of the regional innovation systems that compose it. Therefore, we are not strictly studying the effect of a national innovation system in all its complexity, but rather the effect on the efficiency of a regional innovation system of the sum of regional innovation systems minus the regional innovation system under consideration.

Another clarification relates to the difference between the concepts of externalities and *spillovers*. Although in many areas and contexts, both concepts are used interchangeably, in the particular case of R&D, they are not necessarily the same. Although it is a necessary condition for the presence of *spillovers* to exist externalities, it is not enough, since in the case, for example, of positive externalities, if the cost associated with the *spillover* is internalized by the innovative agents, the externality disappears, and given that externalities in R&D are mostly associated with expenditure variables, this phenomenon would be recurrent. For this reason, the correct interpretation of econometric results is that the presence of a statistically significant coefficient indicates the presence of *spillovers* that would give rise to potential externalities. We used the estimation method proposed by Simar & Wilson (2007) for two-stage DEA.[3]

According to econometric results, national factors do have effects on the efficiency of regional innovation systems, whether positive or negative, thus affecting the distribution of efficiency scores across regions. In other words, the presence of national factors in efficiency

[3] For expository purposes the results also are presented with OLS and Tobit methods.

estimation models expresses the relevance of national innovation systems in the generation of knowledge at the regional level and that the presence of *spillovers*, *ceteris paribus*, are more fluid between regions of same country for the different types of proximity reviewed in the literature (see Boschma, 2005).

Nevertheless, it is observed that the evolutionary processes of the regions in terms of their economic development and innovative level, i.e. their technological capacity,[4] imply a change in the role of *spillovers* generated within their national contexts. In all three models (global, technological and scientific) the estimates of the moderately developed regions include less statistically significant national factors than regions with greater technological capacity and therefore with greater absorptive capacity. The coefficients are also different, with much greater impacts in developed regions. Less developed regions benefit greatly from their environment and the technological convergence found is related to this phenomenon. (See tables 4, 5 and 6).

The most important national factors in terms of their potential positive externalities are the **Degree of Interaction (or Cooperation)** (technology push) between the actors of the national innovation system and the **Sophistication of Demand** (demand pull). The effect of **Universities** is asymmetrical. This confirms the idea that the relations between the actors of the innovation system, in particular the industry-university relationship, are complex interactions that depend not only on proximity.

When dividing the period into three sub periods it is observed that the *spillovers* are presented mainly in the first one (2000-2003) (see table 7); which results in higher levels of efficiency and convergence towards the end of the series.

Finally, considering that the more and less technologically developed regions receive more *spillovers* towards their efficiencies, both in terms of the statistically significant factors and in the magnitudes and signs of their coefficients with respect to the moderately developed ones, it can be established that the possible externalities generated by innovation systems would flow asymmetrically. To this we must add the differences between cognitive proximities and regional sectoral specializations that somehow affect the flow of knowledge. The study of these relationships goes beyond the scope of this paper but opens up areas for future research.

[4] Using the factor analysis we made a technological capacity index, dividing up the regions in three clusters according with this index. See map 2 with the clusters.

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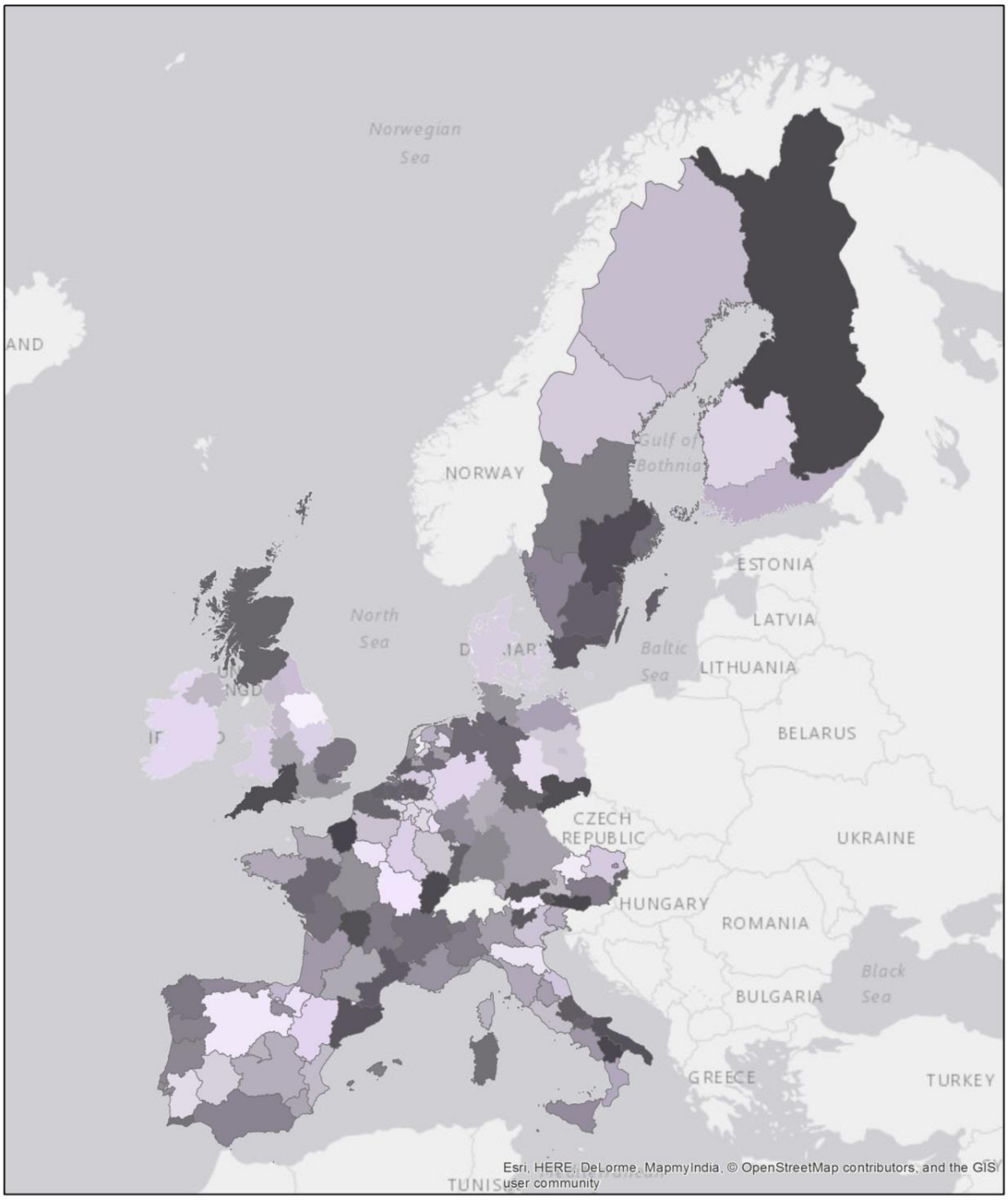
Map 1. - Regional innovations systems in Europe



Source: Own elaboration

Table 1.- Matrix of rotated components

	Component				
	1	2	3	4	5
Wages (millions € 2010)	,977				
GAV (millions € 2010)	,976				
GDP (millions € 2010)	,975				
Number of people employed (thousand)	,975				
Human Resources in C&T - Occupation (thousand)	,969				
Annual average population (thousand)	,964				
Human Resources in C&T - Core (thousand)	,962				
Human Resources in C&T - Education (thousands of people.)	,950				
Gross Fixed Capital Formation (millions € 2010)	,945				
Total R&D staff Nº	,900				
Total expenditure R&D (millions € 2010)	,860				
Firms R&D staff Nº	,851				
Firms R&D expenditures (millions € 2010)	,818				
Firms R&D staff (HC) ‰ employment		,881			
Firms R&D expenditures (‰ GDP)		,877			
Firms R&D staff (HC) ‰ employment		,861			
Stock of technological capital firms per capita (€ 2010)		,852			
Regional Employment Hi-Medium Tech Manufactures (% of employment)		,587			
Universities R&D staff (HC) ‰ empleoyment			,909		
Universities R&D staff (FTE) ‰ empleoyment			,893		
Universities R&D expenditures (‰ GDP)			,860		
Regional 3rd cycle students (% population)			,833		
Stock of techonological capital universities per capita (€ 2010)			,829		
Public Administration R&D staff (FTE)) ‰ employment				,944	
Public Administration R&D staff (HC) ‰ employment				,924	
Public Administration R&D expenditures (‰ GDP)				,921	
Stock of technological capital Public Administration per capita (€ 2010)				,901	
GDP per worker (€ 2010)					,799
GDP per capita (€ 2010)					,793

Source: Own elaboration

Figure 1. - The factorial model

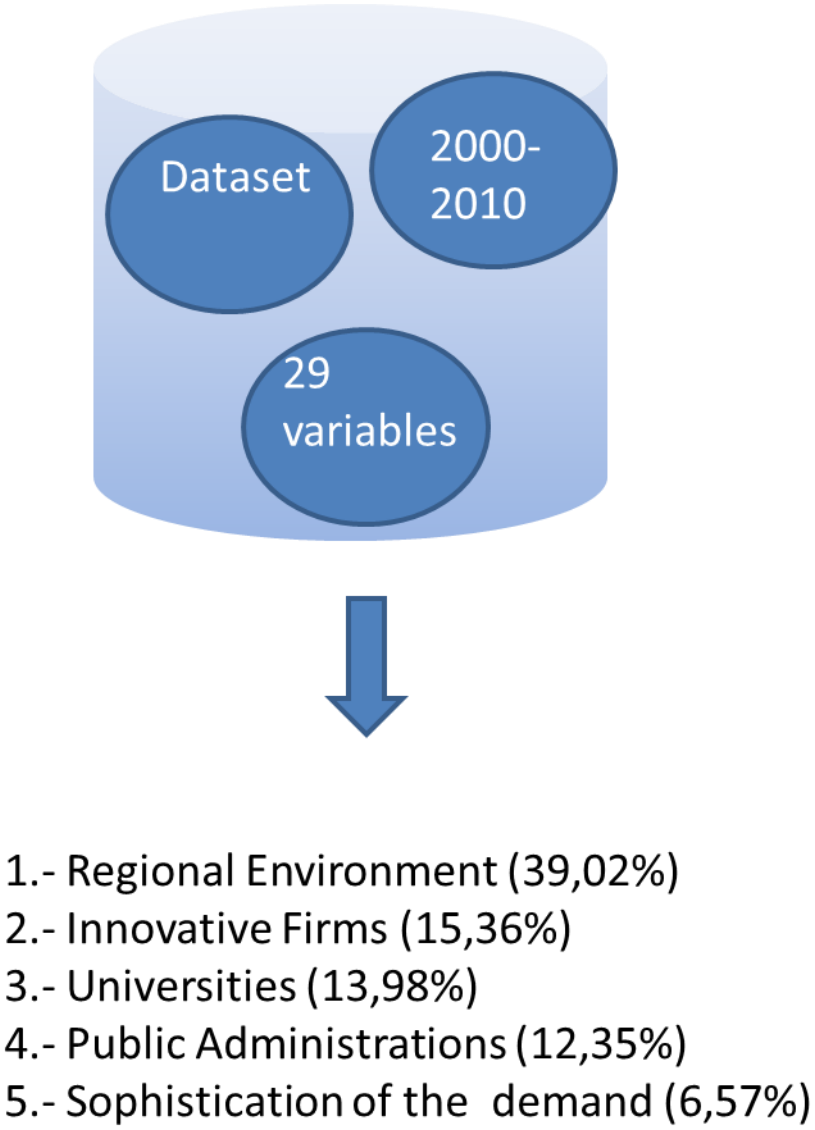


Table 2.- Matrix of rotated components
(National Model)

	Component							
	1	2	3	4	5	6	7	
Number of people employed (thousand)	.980							National Economic Environment and Human Capital
Human Resources in C&T, Services (thousands of people)	.969							
Human Resources in C&T, Intensive Knowledge, (thousand)	.968							
GDP (millions of € of 2010), National	.961							
Annual average population, National	.952							
Imports (% World Imports)	.933							
Gross Fixed Capital Formation (millions of € of 2010	.914							
Exports (% World Exports)	.853							
Firm´s R&D staff (FTE.) ‰ of employment		.944						National Innovatory Firms
Firm´s R&D expenditure (‰ of GDP)		.940						
Firm´s R&D staff (HC) ‰ of employment		.907						
Relevance R&D National Private Sector (%)		.882						
GDP per worker (€ 2010)		.607						
Industrial GAV (% Total)			-.957					National Economic Structure and Wages
Services GAV (% Total)			.923					
Wages (millions € 2010)			.739					
National average wage (€ 2010)			.692					
National Public Administration´s R&D staff (HC) ‰ of employment				.914				Public Administrations
National Public Administration´s R&D staff (FTE) ‰ of employment				.910				
National Public Administration´s R&D expenditure (‰ of GDP)				.690				
Co-patents per capita					.761			Interaction NIS players
Firms R&D expenditure funded by PPAA (%)					.726			
PPAA R&D expenditure funded by firms (%)					.709			
Universitie´s R&D staff (HC) ‰ of employment						.838		Universities
Universitie´s R&D staff (FTE) ‰ of employment						.827		
National 3rd cycle students (% population)							.860	Academic Training and Sophistication of the Demand
GDP per capita (€ 2010)							.854	

Source: Own elaboration

Table 3. - Global model efficiencies years 2000, 2005 and 2010

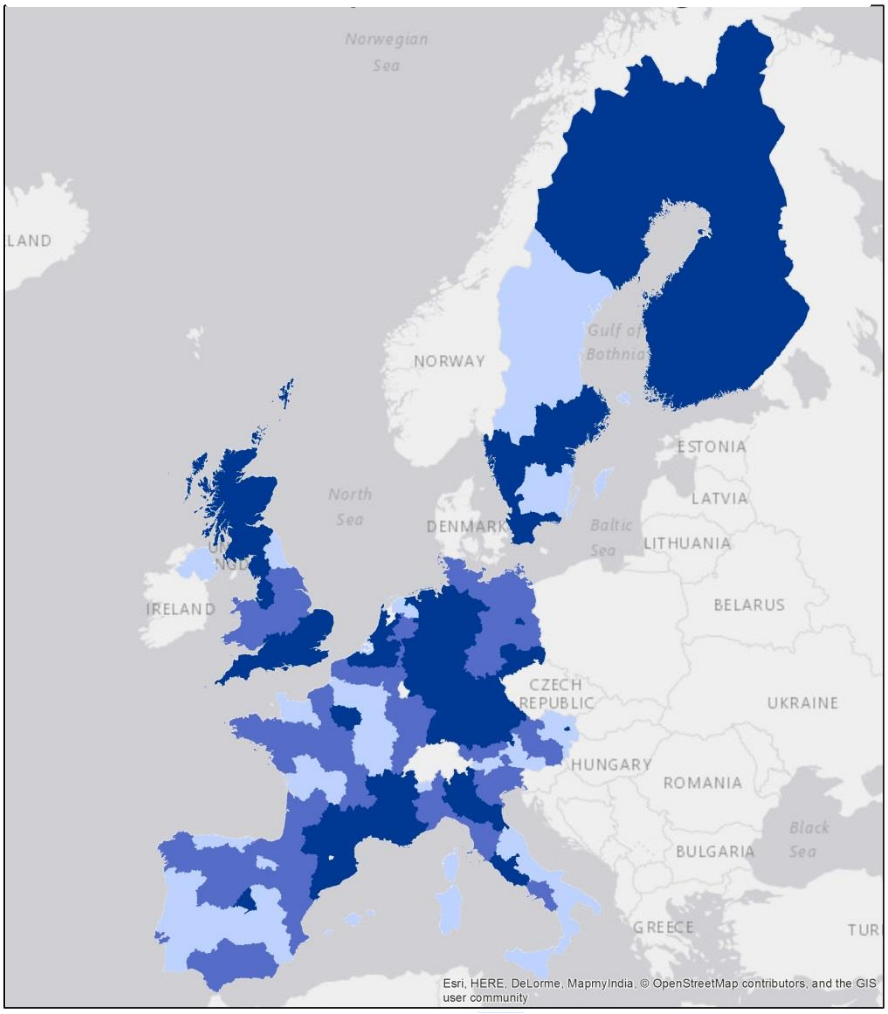
		years		
Regions	Country	2000	2005	2010
Vorarlberg	Austria	0.714	0.982	1.000
Baden-Württemberg	Germany	1.000	1.000	1.000
Etelä-Suomi (NUTS 2006)	Fnland	1.000	1.000	1.000
Groningen	Netherlands	1.000	1.000	1.000
Stockholm	Sweden	0.962	0.992	1.000
Östra Mellansverige	Sweden	1.000	1.000	1.000
Övre Norrland	Sweden	1.000	0.994	1.000
Sydsverige	Sweden	1.000	1.000	0.991
Noord-Brabant	Netherlands	1.000	1.000	0.939
Bayern	Germany	0.912	0.873	0.913
Wien	Austria	1.000	0.912	0.869
Berlin	Germany	0.777	0.762	0.764
Nordrhein-Westfalen	Germany	0.751	0.816	0.749
Gelderland	Netherlands	0.558	0.532	0.744
London	United Kingdor	0.813	0.726	0.705
Noord-Holland	Netherlands	0.770	0.815	0.683
Denmark	Denmark	0.684	0.658	0.675
Utrecht	Netherlands	1.000	1.000	0.672
Tirol	Austria	0.691	0.716	0.665
Vlaams Gewest	Belgium	0.648	0.724	0.656
Zuid-Holland	Netherlands	0.681	0.643	0.649
Hessen	Germany	0.724	0.697	0.628
Rhône-Alpes	France	0.512	0.566	0.614
Länsi-Suomi	Fnland	0.585	0.564	0.608
Scotland	United Kingdor	0.805	0.618	0.603
Västsverige	Sweden	0.825	0.838	0.603
Île de France	France	0.588	0.586	0.595
Bremen	Germany	0.491	0.569	0.593
Rheinland-Pfalz	Germany	0.567	0.667	0.588
Pohjois- ja Itä-Suomi	Fnland	0.628	0.553	0.588
Région de Bruxelles-Capitale/Brussels Ho	Belgium	0.806	0.718	0.584
Steiermark	Austria	0.650	0.556	0.578
Limburg (NL)	Netherlands	0.460	0.544	0.578
Emilia-Romagna	Italy	0.650	0.693	0.567
South East (England)	United Kingdor	0.903	0.626	0.560
Centro (PT)	Portugal	0.230	0.374	0.532
Oberösterreich	Austria	0.344	0.382	0.532
Provincia Autonoma Trento	Italy	0.456	0.604	0.529
Comunidad Foral de Navarra	Spain	0.433	0.464	0.526
East of England	United Kingdor	0.934	0.643	0.526
Friuli-Venezia Giulia	Italy	0.568	0.572	0.516
Sachsen	Germany	0.411	0.458	0.512
Toscana	Italy	0.548	0.584	0.502
Alsace	France	0.454	0.495	0.490
North East (England)	United Kingdor	0.655	0.514	0.485
Salzburg	Austria	0.336	0.423	0.485
Niedersachsen	Germany	0.446	0.470	0.484
Saarland	Germany	0.481	0.516	0.474

Mecklenburg-Vorpommern	Germany	0.322	0.424	0.470
Overijssel	Netherlands	0.345	0.423	0.460
Thüringen	Germany	0.326	0.379	0.459
Hamburg	Germany	0.689	0.687	0.453
Wales	United Kingdom	0.577	0.427	0.450
Lombardia	Italy	0.472	0.498	0.450
Yorkshire and The Humber	United Kingdom	0.644	0.540	0.448
Norte	Portugal	0.154	0.265	0.447
Midi-Pyrénées	France	0.288	0.330	0.439
South West (England)	United Kingdom	0.588	0.451	0.437
Lazio	Italy	0.502	0.490	0.433
Schleswig-Holstein	Germany	0.516	0.428	0.431
Cataluña	Spain	0.379	0.422	0.422
Lisboa	Portugal	0.209	0.296	0.420
Aragón	Spain	0.350	0.419	0.416
Ireland	Ireland	0.353	0.390	0.412
East Midlands (England)	United Kingdom	0.643	0.466	0.410
Veneto	Italy	0.401	0.470	0.407
Umbria	Italy	0.485	0.482	0.404
Northern Ireland	United Kingdom	0.573	0.466	0.389
Picardie	France	0.371	0.347	0.384
North West (England)	United Kingdom	0.529	0.429	0.381
Liguria	Italy	0.489	0.461	0.370
Luxembourg	Luxembourg	0.362	0.472	0.366
Piemonte	Italy	0.332	0.379	0.358
Languedoc-Roussillon	France	0.355	0.343	0.354
Comunidad de Madrid	Spain	0.388	0.379	0.351
Provence-Alpes-Côte d'Azur	France	0.269	0.326	0.348
Galicia	Spain	0.278	0.337	0.347
Bretagne	France	0.273	0.347	0.342
West Midlands (England)	United Kingdom	0.480	0.365	0.339
Principado de Asturias	Spain	0.284	0.329	0.336
Aquitaine	France	0.328	0.313	0.334
Cantabria	Spain	0.362	0.377	0.333
Marche	Italy	0.355	0.390	0.332
Abruzzo	Italy	0.457	0.378	0.331
Franche-Comté	France	0.255	0.282	0.320
Comunidad Valenciana	Spain	0.298	0.332	0.309
Région Wallonne	Belgium	0.316	0.331	0.307
Brandenburg	Germany	0.179	0.281	0.303
Algarve	Portugal	0.206	0.416	0.291
Norra Mellansverige	Sweden	0.279	0.251	0.281
Pais Vasco	Spain	0.211	0.220	0.269
Auvergne	France	0.166	0.167	0.268
Småland med öarna	Sweden	0.186	0.259	0.260
Haute-Normandie	France	0.212	0.239	0.258
Región de Murcia	Spain	0.234	0.290	0.257
Sardegna	France	0.285	0.299	0.255
Pays de la Loire	France	0.172	0.211	0.248
Centre	France	0.218	0.243	0.247

Niederösterreich	Austria	0.194	0.280	0.247
Campania	Italy	0.243	0.262	0.245
Andalucia	Spain	0.210	0.243	0.240
Castilla y León	Spain	0.201	0.251	0.233
Sicilia	Italy	0.193	0.216	0.228
Molise	Italy	0.174	0.236	0.227
Bourgogne	France	0.246	0.232	0.226
Lorraine	France	0.283	0.242	0.225
Provincia Autonoma Bolzano-Bozen	Italy	0.148	0.195	0.224
La Rioja	Spain	0.199	0.232	0.221
Mellersta Norrland	Sweden	0.258	0.235	0.221
Limousin	France	0.125	0.191	0.220
Poitou-Charentes	France	0.205	0.202	0.213
Nord - Pas-de-Calais	France	0.188	0.185	0.209
Canarias (ES)	Spain	0.160	0.182	0.201
Puglia	Italy	0.176	0.217	0.196
Basse-Normandie	France	0.186	0.173	0.195
Calabria	Italy	0.160	0.194	0.193
Extremadura	Spain	0.142	0.219	0.180
Champagne-Ardenne	France	0.178	0.174	0.165
Castilla-la Mancha	Spain	0.086	0.146	0.153
Illes Balears	Spain	0.168	0.197	0.152
Kärnten	Austria	0.162	0.218	0.151
Burgenland	Austria	0.120	0.120	0.147
Alentejo	Portugal	0.045	0.096	0.142
Friesland (NL)	Netherlands	0.087	0.117	0.129
Corse	France	0.154	0.162	0.126
Drenthe	Netherlands	0.148	0.120	0.114
Flevoland	Netherlands	0.205	0.125	0.111
Zeeland	Netherlands	0.112	0.096	0.105
Sachsen-Anhalt	Germany	0.093	0.105	0.104
Åland	Fnland	0.275	0.013	0.093
Valle d'Aosta/Vallée d'Aoste	Italy	0.131	0.171	0.091
Basilicata	Italy	0.007	0.025	0.019

Source: Own elaboration, using rDEA package from R

Map 2. - Clusters by the technological capacity index



Technologically backward regions

Technologically moderated regions

Technologically advanced regions

Source: Own elaboration.

Table 4. - Econometrics results factors NIS on RIS efficiency. Global Model

FACTORS NIS	TOTAL			CLUSTER 1			CLUSTER 2			CLUSTER 3		
	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+
Economic Environment	-0.016	-0.016	-0.016	-0.012	-0.011	-0.018	-0.001	-0.000	0.001	-0.020	-0.019	-0.021
Innovatory Firms	-0.009	-0.009	-0.011	-0.018	-0.019	-0.015	-0.018	-0.019	-0.016	-0.006	-0.006	-0.011
Economic Structure	-0.026**	-0.026**	-0.024*	-0.003	-0.001	-0018	-0.031	-0.034	-0.017	0.007	0.006	0.012
Public Administration	0.017	0.017	0.017	-0.012	-0.011	-0.020	0.021	0.023	0.008	0.043**	0.043**	0.048**
Degree of Interaction	0.037***	0.037***	0.039***	0.042**	0.042**	0.049**	0.022	0.023	0.018	0.015	0.015	0.021
Universities	-0.001	-0.001	-0.000	0.037	0.036	0.043*	-0.006	-0.007	-0.001	-0.021	-0.022	-0.021
Sophistic. of Demand	0.020***	0.020***	0.020***	0.021**	0.020*	0.026**	0.023**	0.024**	0.023*	0.025***	0.025***	0.029***
Years												
2001	-0.026	-0.025	-0.038	-0.048	-0.050	-0.047	-0.072	-0.077	-0.050	0.029	0.032	0.001
2002	-0.009	-0.009	-0.011	-0.024	-0.027	-0.017	-0.057	-0.062	-0.036	0.016	0.016	0.013
2003	-0.012	-0.012	-0.013	-0.009	-0.012	-0.003	-0.048	-0.053	-0.027	-0.007	-0.007	-0.013
2004	0.062	0.063	0.060	0.069	0.064	0.101	0.046	0.048	0.030	-0.020	-0.020	-0.031
2005	0.099**	0.099**	0.096**	0.092	0.084	0.142	0.085	0.087	0.072	0.009	0.010	-0.001
2006	0.091**	0.091**	0.085**	0.127*	0.124*	0.150*	0.058	0.057	0.060	0.044	0.046	0.031
2007	0.096**	0.096***	0.089**	0.131*	0.127*	0.152**	0.099	0.097	0.100	0.050	0.052	0.035
2008	-0.001	-0.000	-0.009	0.015	0.010	0.039	0.065	0.064	0.064	-0.003	-0.001	-0.026
2009	0.105***	0.106***	0.089***	0.108*	0.113*	0.087	0.167***	0.171***	0.155***	0.141***	0.147***	0.117**
2010	0.168***	0.170***	0.147***	0.031	0.034	0.011	0.226***	0.237***	0.164**	0.213**	0.220**	0.180**
Constant	0.297***	0.297***	0.300***	0.442***	0.445***	0.429***	0.433***	0.434***	0.433***	0.503***	0.503***	0.516***
N	1419	1419	1419	473	473	473	473	473	473	473	473	473
Adj R^2 (%)	3.78%			5.88%			8.79%			2.21%		
F Test (p value)	0.00			0.00			0.00			0.05		
N truncaded		10	10		8	8		6	6		10	10
Chi^2 Test (p value)		0.00			0.00			0.00			0.04	
Wald Test (p value)			0.00			0.00			0.00			0.04
Log likelihood		176.21	245.86		40.14	80.02		110.01	137.85		61.45	110.63

***; **; *; mean significance of 1%, 5% and 10%. + Simar & Wilson 2007, first algorithm.

Source: Own elaboration using software Stata12.0.

Table 5. - Econometrics results factors NIS on RIS efficiency. Technological Model.

FACTORS NIS	TOTAL			CLUSTER 1			CLUSTER 2			CLUSTER 3		
	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+
Economic Environment	0.002	0.002	0.004	-0.031	-0.030	-0.036	0.004	0.004	0.002	0.019	0.019	0.022
Innovatory Firms	-0.007	-0.007	-0.008	-0.011	-0.011	-0.013	-0.008	-0.009	-0.007	-0.008	-0.008	-0.010
Economic Structure	-0.030***	-0.030***	-0.030***	-0.024	-0.023	-0.035	-0.022	-0.022	-0.016	-0.031*	-0.031*	-0.031*
Public Administration	0.024***	0.024***	0.024***	0.013	0.013	0.012	0.029***	0.029***	0.025**	0.047***	0.047***	0.048***
Degree of Interaction	0.023***	0.023***	0.024***	0.042**	0.042**	0.044**	0.008	0.008	0.006	0.015	0.015	0.017
Universities	-0.002	-0.002	-0.002	0.049*	0.050*	0.047*	-0.005	-0.005	-0.002	-0.025	-0.025	-0.023
Sophistic. of Demand	0.004	0.004	0.004	0.022*	0.022**	0.023**	-0.001	-0.001	-0.001	0.002	0.002	0.002
Years												
2001	-0.090**	-0.090**	-0.102***	-0.052	-0.052	-0.048	-0.076	-0.076	-0.060	-0.148*	-0.146*	-0.179**
2002	-0.070**	-0.069**	-0.074**	-0.067	-0.068	-0.067	-0.070	-0.070	-0.057	-0.124*	-0.124*	-0.135**
2003	-0.055**	-0.055**	-0.058**	-0.082	-0.082	-0.085	-0.057	-0.057	-0.047	-0.086	-0.086	-0.093*
2004	0.008	0.008	0.004	0.054	0.052	0.081	-0.009	-0.009	-0.009	-0.056	-0.056	-0.064
2005	0.035	0.035	0.031	0.079	0.077	0.108	0.017	0.017	0.015	-0.024	-0.023	-0.033
2006	0.018	0.018	0.015	0.101	0.101	0.095	0.006	0.006	0.010	-0.046	-0.046	-0.052
2007	0.008	0.008	0.005	0.073	0.073	0.064	0.010	0.010	0.013	-0.053	-0.053	-0.060
2008	-0.048*	-0.048*	-0.051*	-0.088	-0.089	-0.082	-0.010	-0.010	-0.006	-0.076	-0.076	-0.085
2009	0.026	0.026	0.025	-0.015	-0.015	-0.009	0.037	0.037	0.034	0.047	0.047	0.046
2010	0.052	0.052	0.046	-0.050	-0.053	-0.024	0.075	0.076	0.046	0.070	0.071	0.057
Constant	0.162***	0.162***	0.166***	0.265***	0.266***	0.265***	0.188***	0.188***	0.185***	0.304***	0.303***	0.311***
N	1419	1419	1419	473	473	473	473	473	473	473	473	473
Adj R^2 (%)	1.64%			5.29%			0.87%			2.55%		
F Test (p value)	0.00			0.09			0.22			0.80		
N truncaded		1	1		2	2		1	1		1	1
Chi^2 Test (p value)		0.00			0.08			0.20			0.79	
Wald Test (p value)			0.00			0.01			0.25			0.71
Log likelihood		716.33	737.08		26.00	41.82		317.98	341.43		145.00	156.91

***; **; *; mean significance of 1%, 5% and 10%. + Simar & Wilson 2007, first algorithm.

Source: Own elaboration using software Stata12.0.

Table 6. - Econometrics results factors NIS on RIS efficiency. Scientific Model.

FACTORS NIS	**TOTAL**			**CLUSTER 1**			**CLUSTER 2**			**CLUSTER 3**		
	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+
Economic Environment	-0.023**	-0.024**	-0.023**	*-0.011*	*-0.011*	*-0.014*	*-0.008*	*-0.009*	*-0.003*	-0.031*	-0.031*	-0.030*
Innovatory Firms	*-0.002*	*-0.002*	*-0.004*	*-0.010*	*-0.010*	*-0.012*	*-0.012*	*-0.011*	*-0.016*	*-0.001*	*-0.000*	*-0.005*
Economic Structure	*-0.005*	*-0.005*	*-0.005*	*0.025*	*0.026*	*0.017*	*-0.022*	*-0.024*	*-0.001*	*0.029*	*0.029*	0.029*
Public Administration	*-0.007*	*-0.007*	*-0.005*	*-0.033*	*-0.034*	*-0.034*	*-0.011*	*-0.010*	*-0.020*	*0.014*	*0.014*	*0.019*
Degree of Interaction	0.022***	0.022***	0.023***	*-0.003*	*-0.003*	*0.002*	*0.018*	*0.019*	*0.014*	*0.007*	*0.006*	*0.008*
Universities	*0.005*	*0.005*	*0.004*	*-0.017*	*-0.016*	*-0.021*	*0.006*	*0.006*	*0.006*	*-0.002*	*-0.002*	*-0.004*
Sophistic. of Demand	0.019***	0.019***	0.019***	*0.010*	*0.010*	*0.011*	0.027**	0.027**	0.024**	0.029***	0.029***	0.029***
Years												
2001	*0.058*	*0.058*	*0.054*	*0.113*	*0.114*	*0.111*	*-0.007*	*-0.009*	*0.003*	*0.125*	0.126*	*0.116*
2002	*0.062*	*0.062*	*0.057*	*0.117*	*0.118*	*0.122*	*0.009*	*0.008*	*0.018*	*0.099*	*0.100*	*0.088*
2003	*0.042*	*0.042*	*0.036*	*0.123*	*0.124*	*0.129*	*0.007*	*0.005*	*0.015*	*0.047*	*0.048*	*0.036*
2004	0.086**	0.087*	0.082**	*0.100*	*0.100*	*0.106*	*0.106*	*0.110*	*0.063*	*0.014*	*0.014*	*0.004*
2005	0.101***	0.101***	0.097***	*0.097*	*0.094*	*0.123*	*0.111*	*0.115*	*0.072*	*0.026*	*0.027*	*0.017*
2006	0.105***	0.105***	0.100***	*0.114*	*0.113*	*0.130*	*0.079*	*0.081*	*0.056*	*0.081*	*0.082*	*0.069*
2007	0.119***	0.119***	0.114***	0.165*	0.165*	0.182**	0.122	0.124*	0.100	0.094*	0.095*	*0.083*
2008	*0.053*	*0.054*	*0.047*	0.184*	0.184**	0.189**	*0.101*	*0.102*	*0.088*	*0.056*	*0.057*	*0.041*
2009	0.096***	0.096***	0.091***	0.192***	0.191***	0.208***	0.145***	0.146***	0.142***	0.140***	0.141***	0.131***
2010	0.145***	0.146***	0.133***	*0.205*	*0.207*	*0.212*	0.191**	0.197**	*0.137*	0.183**	0.186**	0.159**
Constant	0.214***	0.214***	0.218***	0.264***	0.265***	0.257***	0.333***	0.332***	0.347***	0.360***	0.360***	0.368***
N	1326	1326	1326	408	408	408	456	456	456	462	462	462
Adj R^2 (%)	4.46%			4.92%			6.60%			5.86%		
F Test (p value)	0.00			0.00			0.00			0.00		
N truncaded		3	3		3	3		2	2		3	3
Chi^2 Test (p value)		0.00			0.00			0.00			0.00	
Wald Test (p value)			0.00			0.00			0.00			0.00
Log likelihood		410.14	438.18		-0.21	16.40		91.51	103.78		151.94	172.07

***; **; *; mean significance of 1%, 5% and 10%. + Simar & Wilson 2007, first algorithm.

Source: Own elaboration using software Stata12.0.

Table 7. - Econometrics results factors NIS on RIS efficiency, by sub periods.

FACTORS NIS	**TOTAL**			**2000-2003**			**2004-2007**			**2008-2010**		
	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+	OLS	TOBIT	S/W+
Economic Environment	*-0.016*	*-0.016*	*-0.016*	-0.051**	-0.054**	-0.040*	*-0.126*	*-0.126*	*-0.147*	*0.053*	*0.052*	*0.063*
Innovatory Firms	*-0.009*	*-0.009*	*-0.011*	*-0.003*	*-0.001*	*-0.014*	*0.060*	*0.059*	*0.072*	*-0.027*	*-0.027*	*-0.031*
Economic Structure	-0.026**	-0.026**	-0.024*	*-0.054*	*-0.060*	*-0.025*	*0.038*	*0.037*	*0.052*	*0.007*	*0.003*	*0.029*
Public Administration	*0.017*	*0.017*	*0.017*	*0.019*	*0.020*	*0.014*	*0.021*	*0.023*	*0.007*	0.074**	0.075*	0.076**
Degree of Interaction	0.037***	0.037***	0.039***	0.071**	0.072**	0.068**	*-0.011*	*-0.008*	*-0.036*	*-0.062*	*-0.061*	*-0.077*
Universities	*-0.001*	*-0.001*	*-0.000*	*-0.009*	*-0.007*	*-0.022*	*-0.058*	*-0.061*	*-0.047*	*-0.015*	*-0.015*	*-0.017*
Sophistic. of Demand	0.020***	0.020***	0.020***	0.031***	0.034***	0.027**	*-0.025*	*-0.028*	*-0.009*	*-0.023*	*-0.021*	*-0.036*
Years												
2001	*-0.026*	*-0.025*	*-0.038*	*0.025*	*0.025*	*0.020*						
2002	*-0.009*	*-0.009*	*-0.011*	*0.056*	*0.057*	*0.054*						
2003	*-0.012*	*-0.012*	*-0.013*	*0.039*	*0.039*	*0.036*						
2004	*0.062*	*0.063*	*0.060*									
2005	0.099**	0.099**	0.096**				*0.031*	*0.030*	*0.037*			
2006	0.091**	0.091**	0.085**				0.107*	0.107*	0.109**			
2007	0.096**	0.096***	0.089**				0.110*	0.110*	0.119**			
2008	*-0.001*	*-0.000*	*-0.009*									
2009	0.105***	0.106***	0.089***							*0.057*	*0.058*	*0.047*
2010	0.168***	0.170***	0.147***							*-0.007*	*-0.001*	*-0.056*
Constant	0.297***	0.297***	0.300***	0.321***	0.316***	0.321***	0.287***	0.289***	0.264***	0.512***	0.513***	0.517***
N	1419	1419	1419	516	516	516	516	516	516	387	387	387
Adj R^2 (%)	3.78%			3.89%			2.25%			0.56%		
F Test (p value)	0.00			0.00			0.01			0.26		
N truncaded		10	10		14	14		10	10		13	13
Chi^2 Test (p value)		0.00			0.00			0.01			0.29	
Wald Test (p value)			0.00			0.01			0.04			0.07
Log likelihood		176.21	245.86		-49.55	15.34		8.15	64.74		-5.75	70.72

***; **; *; mean significance of 1%, 5% and 10%. + Simar & Wilson 2007, first algorithm.

Source: Own elaboration using software Stata12.0.