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ANALYSIS AND MEASUREMENT OF INTERACTIONS IN REGIONAL INNOVATION SYSTEMS: NEED TO DEFINE NEW NETWORK INDICATORS

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1 Introduction

Innovation has become one of the main priorities for economic development. In this framework, the regional dimension is becoming more and more relevant, as the diverse initiatives promoted by various public administrations and regional governments being implemented in different territories show. In this context, various methodologies are being developed to measure the Innovative Capacity. By means of these methodologies it is aimed at offering new empirical knowledge regarding Innovation Systems.

Currently, and according to most of the indicators offered by R&D and Innovation statistics, Innovation Systems are mostly considered like input-output systems with a particular emphasis on the amount of employed resources. In this sense, the literature agrees in a lack of suitable measures. Therefore, there is still a long research path to be covered in this regard as the undertaken studies and the available statistics do not consider by now institutional features, interactions, cooperative activities… which are key elements according to the main characteristics of a competitive System of Innovation [5]. So, the need to define and measure new indicators not only aims at improving Innovation Systems' representation, but also deepening in their particular features.

Interactions among the agents in an Innovation System are considered to be one of the key points in the related literature [4]. Within this framework, this paper aims at illustrating the relevance interactions have on the Innovative Capacity and this way offer some possible measures that could help to better understand the dynamics of Innovation Systems.

The paper is organized as follows. In the first chapter, the main methods concerning the Innovative Capacity will be described and their main results will be shown. The analysis will be focused on two methodologies. First, the measures employed in the European Innovation Scoreboard (EIS) will be analyzed, and next a complementary analysis to the EIS will be done in terms of Regional Innovation Systems' efficiency [6]. In the next chapter and related to the previous methodologies, two conclusions can be obtained. On the one hand the fact that interactions are one of the key aspects that impact on the Innovative Capacity will be empirically shown. On the other hand, it will be exposed how the efficiency analysis can complement and improve Regional Innovation Systems' evaluation. Last the main conclusions obtained as well as the further steps to be undertaken will be described.

2 Innovative Capacity of Regional Innovation Systems in Europe

In the benchmarking on Innovation related literature it is possible to detect the existing variety of measures oriented towards the definition of an Innovative Capacity index. Nevertheless, it is necessary to state that in many of the later methodologies, their validation and empirical testing can not be easily completed due to the lack of statistical data [3].

Maybe the method with a higher diffusion in the last years has been the "European Innovation Scoreboard". 17 indicators structured into four main groups constitute the European Innovation Scoreboard (EIS). The data employed to devise this Scoreboard derive from EUROSTAT. Even though up to date the amount of available regional indicators is 7 so far, it is possible to obtain a ranking about the most innovative regions in Europe by means of two composite indicators. The RNSII (Regional National Summary Innovation Index) explains the relative position of each region within its origin country, while the REUSII (Regional European Summary Innovation Index) describes the relative position of each region with regard to the European average.

$$RNSII_j = (100/n) * \sum_i (X_{ijk} / \overline{X}_{ik}) \quad (1)$$

$$REUSII_j = (100/n) * \sum_i (X_{ijk} / \overline{EU_i}) \quad (2)$$

where X_{ijk} refers to the value of the i indicator in the j region in the k country, $\overline{X}_{ik}$ represents the mean value of the i indicator in the k country, $\overline{EU}$ represents the average of the i indicator for the European Union, and n represents the number of regional indicators X_i considered.

Thus, the next composite indicator, RRSII (Revealed Regional Summary Innovation Index), can be obtained as the average value of the last two indicators.

The data base employed in the analysis with the regional information obtained from the EIS in 2002 and 2003 covers 148 and 172 European regions respectively.

As a resume of the previous data, and due to the fact that the RRSII index is the measure employed to characterize Regional Innovation Systems (RIS) in Europe, its distribution will be shown for 2002 and 2003. The same figures could also be obtained for each regional indicator. This way, the distribution of each measure may suggest some interesting information about the regional performance, but so as not to overload the paper, merely the figures for the RRSII will be offered.

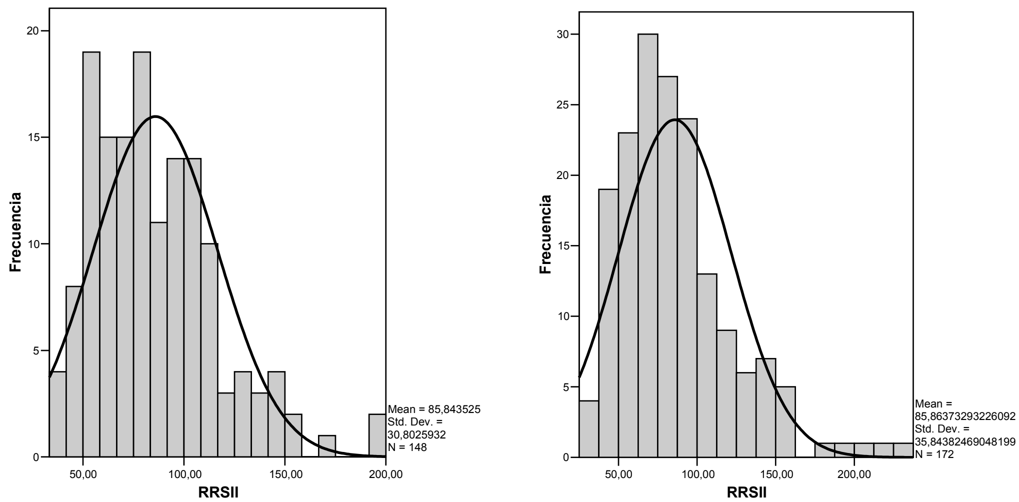

Figure 1. Distribution of European Regions according to the RRSII index for 2002 and 2003.

As it can be seen the figures in 2002 and 2003 are quite similar each other (with scores about 85 points). The mean value has maintained constant, despite of the relative increase in the standard deviation in 2003.

But how to evaluate a complex system's performance, such as RIS, in a broader sense? What could be a proper approach? How to obtain a suitable indicator that could complement the Scoreboard ones?

In this regard we propose to evaluate the RIS performance according to their efficiency levels. This is, by relating their multi-input/multi-output measures [1]. Accordingly, the fact that the innovative capacity of a RIS can be treated like the measurable efficiency of the corresponding input-output relation is assumed in order to complement the RRSII index. This could encourage a new research path within the Innovation Systems' literature, as not many efficiency analyses have been done in this context so far [6].

In contrast to the proposed efficiency approach, the common Scoreboard indicators are based on a "more = better" relation, as they are strongly based on the amount of employed resources in the system. Consequently, it is expected that the two approaches will tell a different but complementary story. Accordingly, different "best practice examples" could be identified and become, the draft for a new innovation policy evaluation.

In fact, there are two general approaches to measure efficiency: parametric models, like Stochastic Frontier Analysis (SFA) and non-parametric models, like Data Envelopment Analysis (DEA). In this regard, it is commonly argued that the DEA has some comparative advantages in opposition to the SFA when analysing the public sector. Hence, DEA will be applied for this analysis [2].

In this case, the 7 regionalized indicators from the EIS have been divided into two main groups. Correspondingly, the selected indicators considered as inputs for the model are: Tertiary education (% of population between 25-64 years with high education), Lifelong learning (% of population between 25-64 years who are participating in lifelong learning activities), Medium/high-tech employment in manufacturing (% of total workforce), High-tech employment in services (% of total workforce), Public R&D expenditure (% of GDP), Business R&D expenditure (% of GDP), High-tech patent applications to the European Patent Office (per million population). Conversely and as the main output of RIS, the corresponding GDP per capita has been used.

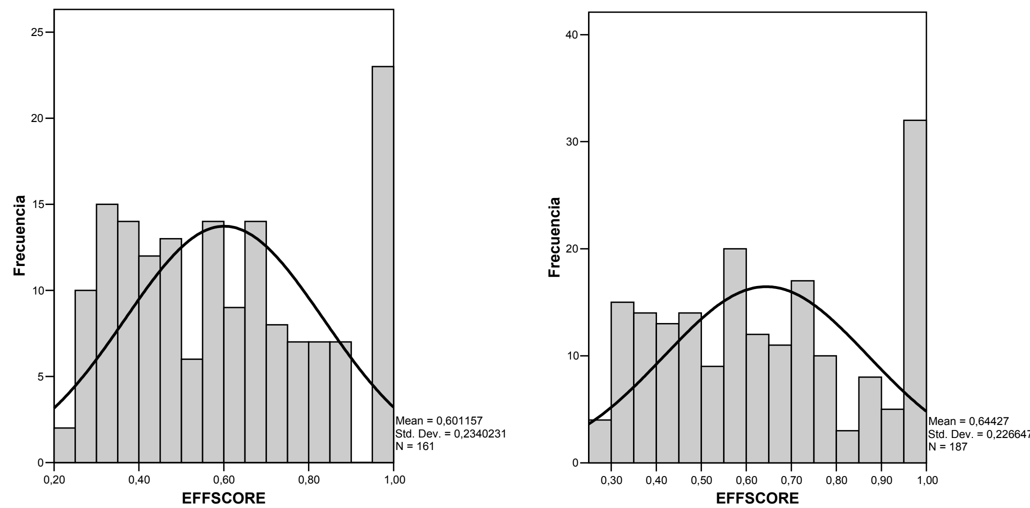

Figure 2. Distribution of the Technical Efficiency of RIS in Europe in 2002 and 2003.

The overall mean of all calculated RIS efficiency scores in 2002 is 0.60 and 0.64 in 2003. Even though this might be assumed to be a promising trend, it does also point towards the fact that remains a huge potential for upgrading RIS performance. Regarding the standard deviation the values are around 0.2.

Comparing the results obtained with the RRSII index and the efficiency analysis, it can be perceived how on the one hand, the mean value for the RRSII stands underneath the 50% of the highest value the RRSII gets, while the mean value stands above the 50% in the efficiency analysis. On the other hand, the standard deviation measures around the 40% of the mean value in both cases.

Nonetheless, these are not the main differences found out in the analysis. In this sense, it can be easily appreciated how the amount of regions standing at the top values differ a lot from one analysis to the other. In the RRSII analysis, just a scarce 1% of the regions get the highest results, while when dealing with efficiency rates this increases up to a 30% in 2003. This is explained because of the difference in the methodologies in both cases. The RRSII index is obtained as the average value of two composite indicators, and the same process is applied to all the regions. Alternatively, the efficiency is measured relatively to the corresponding best practice observation, as it is looking for a fictive optimum of a certain input/output relation.

With this efficiency approach RIS are just depicted as a more or less efficient input-output transformer. This seems to be strange at a first glance as cooperative and interactive activities constitute one of the crucial aspects of any Innovation System [5]. Since an assessment of RIS overall performance is a matter of particular interest and the goal of the chapter was to develop a method that could complement the conclusions obtained with the EIS, this procedure can be justified. Nevertheless, the crucial institutional features should not be neglected completely. Therefore in the next chapter it will be confirmed how interactions, which are considered to be one of these key institutional aspects, do play a role in the Innovative Capacity of RIS.

3 The role of interactions and cooperative activities in Regional Innovation Systems

Up to now, the main results obtained regarding the Innovative Capacity of RIS in Europe have been described from two complementary viewpoints. The main aim of this chapter consists of analyzing whether Innovation Networks, cooperation activities and interactions among the agents that constitute an Innovation System do also play a role in this Innovative Capacity.

In order to get that aim, some proxy variables related to the size of networks and their impact on the competitiveness of territories will be employed. These variables are: Population density, Active population, Nº of persons employed, GDP Growth rate and Gross Added Value. The main reason why these indicators have been selected as proxy measures of interactions and not others is just the availability of data. It has to be taken into consideration that according to the Innovative Capacity, European Regions are the units of this analysis, so that some indicators that could be found in all these regions should be considered.

So as to analyze to what extent does the interactive behaviour influence or not the Innovative Capacity, two linear regression models have been run. On the one hand, the RRSII composite index has been considered as the dependant variable and all the rest (the ones that constitute the European Innovation Scoreboard and the ones considered as proxy measures) as independent. On the other hand the same process has also been applied with the technical Efficiency index for the European Regions as the dependant variable.

In the first regression an extremely high explanation of the System of Innovation is obtained, with an R^2 around 93%. At a first glance, obtaining these high scores seems quite logic as the RRSII index is considered to be one of the main tools to analyze and evaluate RIS performance in Europe. However, some interesting results are obtained regarding the significance of each indicator on the RRSII index.

Table 1. Results for the linear regression for the RRSII index.

Modelo	R	R^2	R^2 corregida	Error típ. de la estimación	Durbin-Watson
1	,968(a)	,937	**,933**	8,74473	2,028

a Variables predictoras: (Constante), Growth rate, Employment, Population density, High Tech patent applications, Public R&D, Lifelong learning, Medium/high tech employment in manufacturing, Tertiary education, GDP per capita, Business R&D, Hightech employment in services, Gross value added, Active Population
b Variable dependiente: RRSII

Modelo		Coeficientes no estandarizados		Coeficientes estandarizados	t	Sig.
		B	Error típ.	Beta		
1	(Constante)	**23,586**	3,767		**6,261**	,000
	Tertiary education	,234	,101	,053	2,327	,021
	Lifelong learning	-,046	,134	-,009	-,342	,733
	Medium/high tech employment in manufacturing	**1,992**	,251	,208	**7,931**	,000
	High-tech employment in services	**5,676**	,722	,247	**7,859**	,000
	Public R&D	**13,940**	2,016	,157	**6,916**	,000
	Business R&D	**9,154**	1,017	,260	**8,997**	,000
	High Tech patent applications	**,284**	,018	,394	**15,982**	,000
	GDP per capita	7,3E-05	,000	,014	,458	,647
	Employment	**,058**	,011	1,846	**5,337**	,000
	Active Population	**-,047**	,010	-1,564	**-4,814**	,000
	Population density	**,003**	,001	,098	**4,859**	,000
	Gross added value	,000	,000	-,202	-2,220	,028
	Growth rate (GDP)	,602	,236	,052	2,554	,011

a Variable dependiente: RRSII

According to the results obtained from the linear regression, it can be noticed that not all the variables included in the model have a direct impact on the dependant variable. The variables that a higher influence show, are the Medium-High Technology employment in Manufacturing sectors, High-Tech employment in Services, Public and Business R&D, High-Tech patent applications to the European Patent Office (EPO), Employment, Population Density and Active population. On the other hand it is remarkable that regarding those variables that could be considered as the main outputs of any System of Innovation, such as the GDP per capita, its growth rate, and the Gross added value, there is no evidence for any relation with the dependant variable. So, a question arises from these results. The RRSII index could be considered as a good proxy measure of the inputs in an Innovation System, but to what extent does it also represent the outputs?

It can also be depicted from the later analysis that those variables introduced as proxy measures of interactive behaviour are also related to the dependant variable, despite not to such a high extent as the High tech patent applications. This could seem irrelevant at a first glance, but it is not at all. Patent applications are the variable with higher impact on the RRSII index. Analyzing the Innovation Network related literature within the Systems of Innovation framework, it can be easily noticed how many of the network analysis undertaken up to date are based on Patent citation and Patent co-authorship analyses. This does clearly explain the increasing trend that patent and network analysis have experienced in the last decade in the Innovation related literature.

Regarding the results obtained in the linear regression, when the Technical Efficiency index is considered as the dependant variable, a really good explanation of the Innovation System is obtained, with a R^2 of about a 60%. It could be argued that this value is not as high as the one obtained before with the RRSII index. As it was said in the second chapter, when dealing with the methodology carried out in the efficiency analysis of the RIS, the main reason for this analysis to be done was the fact of complementing the weaknesses that a composite index as the RRSII could have and not criticizing nor replacing it at all.

Hence, the results obtained in this case, do reinforce the later statement, as the variables that a higher significance obtained in the RRSII regression do not in this case and vice versa.

Table 2. Results for the linear regression for the Efficiency index.

Modelo	R	R^2	R^2 corregida	Error típ. de la estimación	Durbin-Watson
1	,791(a)	,626	**,603**	,12204	1,047

a Variables predictoras: (Constante), Growth rate, Employment, Population density, High Tech patent applications, Public R&D, Lifelong learning, Medium/high tech employment in manufacturing, Tertiary education, GDP per capita, Business R&D, Hightech employment in services, Gross value added, Active Population
b Variable dependiente: Efficiency Score

Modelo		Coeficientes no estandarizados		Coeficientes estandarizados	t	Sig.
		B	Error típ.	Beta		
1	(Constante)	**,846**	,053		**16,097**	,000
	Tertiary education	**-,009**	,001	-,358	**-6,459**	,000
	Lifelong learning	**-,009**	,002	-,320	**-4,944**	,000
	Medium/high tech employment in manufacturing	-,004	,004	-,081	-1,271	,205
	High-tech employment in services	-,022	,010	-,170	-2,226	,027
	Public R&D	-,071	,028	-,140	-2,538	,012
	Business R&D	-,037	,014	-,181	-2,583	,010
	High Tech patent applications	,000	,000	,040	,663	,508
	GDP per capita	**8,2E-06**	,000	,276	**3,708**	,000
	Employment	,000	,000	,719	,855	,393
	Active Population	,000	,000	-1,814	-2,298	,023
	Population density	1,162E-05	,000	,060	1,211	,227
	Gross added value	**3,9E-06**	,000	1,177	**5,326**	,000
	Growth rate (GDP)	,005	,003	,071	1,441	,151

a Variable dependiente: Efficiency Score

The variables related to the efficiency score are the Tertiary education, Lifelong learning, GDP per capita and Gross added value. These variables were not related in the previous case, so it could be concluded that the Innovation System's efficiency does effectively complement the RRSII index.

As a result, two conclusions come up from the undertaken analysis. On the one hand, interactions do really play a role in the Innovative Capacity of regions (Table.1). To that extent, it has to be kept in mind that the RRSII is considered to be an Innovative Capacity index and due to the lack of regional data, some proxy variables were selected in order to represent the interactive and cooperative behaviour produced within a RIS. In this fashion, it becomes necessary to deepen in the study of networks and interactions within Innovation Systems, and define new measurable indicators that could be applied in all European Regions in order to increase the knowledge about Innovation Systems and their dynamics.

In this regard, some steps are being carried out in Europe by the Community Innovation Surveys (CIS). The CIS collect data on the innovative characteristics of European firms. It is the main statistical instrument that allows monitoring Europe's progress in innovation related activities, being the "Oslo manual" which provided its methodological basis. The CIS was carried out for the first time in 1992, CIS2 took place in 1996 and CIS3 in 2001. In the third CIS survey those measures related to R&D and Innovation cooperation were incorporated for the first time. Thus, by now it becomes possible to know to what extent firms cooperate in innovation activities according to two criteria, the agents cooperating with and their location. This initiative has not still reached the regional level, and the data are just available since 2002 on to the national level. So, further steps are needed to reach the regional level and this way determine the relevance that cooperation activities play on the Regional Innovative Capacity and Efficiency respectively.

Second, comparing the results that the two linear regressions show, it can be said that the study of the efficiency in the Innovation Systems framework could complement the information that the RRSII index and the variables employed in the European Innovation Scoreboard suggest (Table.2).

Some propositions for this sort of indicators can be found in the literature [7]. Hence, some of these possible measures to be considered could be: R&D financing, joint publications, joint patents, contract research and joint research projects, buying of university research results, employing faculty members… Some other possible measures that could also help to better understand the dynamics of Innovation Systems are: Nº of KIBS (Knowledge Intensive Business Services), Start-ups, Spin-offs, sources of information for innovation, qualify the cooperation done, mobility of personnel, student mobility, qualification of personnel, Nº of students from university involved in firm projects…

4 Conclusion

In the literature Innovation Systems are mostly considered input-output systems. In this regard, the available statistics do not consider by now institutional features of Innovation Systems so there is an increasing need to define and measure new indicators [7].

In the benchmarking on Innovation related literature several methodologies aiming at defining an Innovative Capacity composite index can be found [3]. In this paper one of the most diffusing ones is analyzed, the European Innovation Scoreboard. Nevertheless, and despite this Scoreboard is employed as the main tool for he definition of European Innovation policies, it has been observed its great resource based orientation. In order to cover this gap, an efficiency analysis was run out, so as to see whether the two studies methodologies were compatible or not.

To undertake this empirical set, the data have been obtained from the European Innovation Scoreboard for 2002 and 2003 covering 148 and 172 European regions respectively.

When comparing the results obtained with both methodologies some differences can be found. The most stunning distinction consists of the variation in the amount of regions standing at the top values from one analysis to the other. This may be explained because of the existing differences in the employed methodologies. The RRSII index is obtained as the average value of two composite indicators, whilst the efficiency is measured relatively to the corresponding best practice observation. This is, looking for a fictive optimum of a certain input/output relation.

Nonetheless, with these approaches Regional Innovation Systems are illustrated as more or less efficient input-output transformer systems, without taking into consideration any sort of institutional assets.

To deal with it, some proxy measures for cooperative and interactive behaviour were added to the ones provided by the European Innovation Scoreboard. From the undertaken analysis two main conclusions are obtained. On the one hand, interactions do really play a role in the Innovative Capacity of regions. This way, it can be justified the need to deepen in the study of networks and interactions within Innovation Systems, and define new measurable indicators that could be applied in all European Regions in order to increase the knowledge about Innovation Systems and their dynamics. Second, it can be said that the study of the efficiency in the Innovation Systems framework could complement the information provided by the RRSII index, so the use of both methodologies would involve better decisions not only in the blueprint of Innovation Policies in Europe but also in the knowledge about its Regional Systems of Innovation.

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