Regional Innovation Systems: How to Assess Performance

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Regional Innovation Systems: How to Assess Performance[1]

Abstract

This paper applies Data Envelopment Analysis [DEA] methodology to the evaluation of regional innovation system performance based on information provided by the European Innovation Scoreboard [EIS] for 2002 and 2003.

We find that those European regions ranked in the EIS as showing better performance in high-technology areas, are ranked somewhat differently according to DEA. The results of our study show that the higher the technological level of a region, the greater is the need for system coordination. Where this is lacking there is a loss of performance efficiency compared to other similar regions.

Policy making in relation to Regional Innovation Systems (RIS) has in the past depended on systemic analysis. Here, we propose a methodology that combines quantitative and qualitative analyses to enrich the knowledge base for future policy decision making.

Keywords: Regional Innovation Systems, Efficiency, DEA.

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Introduction

Within the context of increasing globalisation, regional differences are becoming more apparent. The goal of marginal regions is to close the gap with the more developed regions; that is, to enable economically underperforming regions to catch up with more prosperous ones. One of the core aspects of economic growth is technological progress, which it is assumed is triggered by innovation. Since to induce and/or manage innovations is a multi-dimensional, social, interactive and complex task, analytical studies of these issues must be wide ranging, and encompass the whole system of innovation[2]. Most of the existing approaches in this area focus on the in depth examination of a particular region to explore its RIS (BRACZYK et al., 1998); investigation of the internal relations among the actors involved (KOSCHATZKY et al., 2001), and assessing the importance of institutions (TÖDTLING and TRIPPL, 2004). In short, the focus is on the operation of a successful RIS (DÍEZ, 2002). A RIS can be defined as combining a variety of regional settings in order to provide an environment that is conducive to innovation (FERNANDEZ DE LUCIO et al., 2003).

It is important to measure system performance as a whole, rather than quantifying particular measures or key indicators (LEYDESDORFF, 2001). This should involve an empirical as well as a qualitative[3] assessment (i.e. both numeric and based on a normative 'better – worse'- scale). The Oslo Manual (OECD, 1992, 2005) can be seen as an example. Some work has also been done on analysing what is referred to as National Innovative Capacity (FURMAN et al., 2002). In this regard the European Commission's EIS and the 'Community Innovation Surveys' [CIS] are invaluable in providing indicators that are increasingly being acknowledged to be measures of the performance of European countries and regions. However, when we examine the data in detail, several problems arise, and particularly in relation to cross-country benchmarking analyses, due to the heterogeneity of European regions, the multi-dimensionality of IS, and differences in the criteria applied by regional (and national) statistics offices.

Based on the indicators provided by the most available data, (R)IS are generally seen as pure technical input-output systems, with an emphasis on the amount of resources employed. However, this simple focus on the empirical assessment of (R)IS performance (based on one or a number of fairly isolated indicators) may provide a biased picture. There is agreement in the literature as to the lack of suitable measures (INZELT, 2004) not only with regard to benchmarking system performance, but also to the in-depth evaluation of the particular features of the system (KUHLMANN, 2003). Thus, there is an urgent need to achieve some balance between the data provided by empirical assessment and qualitative analyses in providing an evaluation.

What type of analytical approach should we adopt to studying an IS? And/or which indicators need to be incorporated (and how) to capture the true performance of a (R)IS? These are complex questions and, in fact, require some judgement calls. But, it is nevertheless important to establish how the performance of a complex system such as a (R)IS should be evaluated in a broad sense and to define the appropriate approach and the most suitable indicators.

In this paper, we measure RIS performance by comparing the multi-input/multi-output relationships (later referred to as *technical efficiency*) involved. The literature has called for the consideration of efficiency analyses in the evaluation of public sector activities such as Science and Technology [S&T] (GEORGHIOU, 1998; NIOSI, 2002[4]). However, very few studies of the efficiency or RIS have been carried out (SUSILUOTO, 2003), although they have been applied to other areas (KARADAG et al., 2005). We hope that the work described in this paper will encourage new research directions in relation to the IS and policy evaluation literature, which will provide new evidence and contribute to the literature in these areas. The evaluation of RIS performance in Europe in terms of (technical) efficiency [TE] thus constitutes the main goal of our research. In accordance with EIS and R&D and Innovation statistics, the amount of resources available within an IS is a crucial aspect. That is, the more resources that are invested, the more competitive the system will be. Thus, we believe that although identification of these resources is important how efficiently they are exploited is even more important. It is not evident that those regions with the highest incomes (highest value added, GDP, etc.) are also the most efficient ones (SUSILUOTO, 2003). The efficiency of use of a system's resources is indicated by the degree to which these inputs generate soaring returns, or whether output results fail to reflect the amount of investment.

Analytical Approach

As indicated above, our aim is to discuss the application of frontier approaches commonly used to estimate efficiency, to the context of regional innovation. The aim is to measure technical, cost, and allocative efficiency (FARRELL, 1957). Since we are dealing with S&T indicators in order to illustrate regional performance in innovation, we assume that a RIS can be characterized by the efficiency of the input-output relation, based on consideration of all relevant inputs and outputs.

This approach challenges the measurement of IS by single factor indicators (GRUPP and MOGEE, 2004), and should shed some light on the true performance of particular (R)IS.

Any estimated efficiency score refers to the spatial performance of the related RIS and thus, can be used to evaluate the entire system, by establishing a fictitious optimum for the relationship between input and output and relating observations to that level. From this point of view, RIS are depicted as a technically more or less efficient transformer of inputs into outputs.

It should be remembered that institutional aspects have a role to play within this framework (TÖDTLING and TRIPPL, 2004), and may influence the performance of RIS, and explain some of variations in individual observations. Therefore, a second dimension should be included in the efficiency analysis. Taking efficiency scores as benchmarks, we need to examine why one observation shows a lag or an increase compared to another. What are the key variables (institutions, norms, laws, etc.) that affect these differences in RIS performance? How can they be measured? What is their role in overall system performance? As the ultimate aim is to demonstrate the possibilities provided by an efficiency analysis of the RIS in Europe, regional governments and their S&T related policies, norms, laws, funds, etc. require in-depth investigation. This should be seen as an important area for future research[5].

But, what is the point of comparing RIS performance? What does it mean if estimates differ? In spite of the embeddedness of innovation policies (DÍEZ, 2002), it is common in the laying down and evaluation of policy measures and institutional settings, to use examples of *best practice* as a blueprint for all regions (KOSCHATZKY et al., 2001). The European Commission stated that “The benchmarking of research and innovation policies consists of a mutual learning tool for policy making, scoreboard and indicators” (2002). Therefore, defining what ‘best practice’ is becomes a crucial aspect. Since any successful RIS is in reality a very complex framework, it is not easy to identify 'true' and generalizable examples of best practice.

The Lisbon Strategy established the European Trend Chart on Innovation initiative, designed to analyse and benchmark innovation policies at European level, and yield information and statistics on innovation policies, performance, and trends in the EU (EUROPEAN INNOVATION SCOREBOARD, 2002). One of the core tools in this initiative is the EIS, which tracks the EU's progress in innovation activities based on 17 indicators divided across four groups. These groups are: human resources for innovation, creation of new knowledge, transmission and application of knowledge, and innovation finance, outputs and markets[6].

The EIS 2002-2003 applies seven out of the total 17 indicators[7], and also includes regional GDP as one of the main outputs of a RIS. These indicators are used to identify those regions with the highest investments in high-tech R&D and innovation related activities as being the leaders, but take little account of regions with future potential, and those that require specific innovation policies. In our view, this offers a partial picture of the European landscape, focusing only on high-tech activities and underestimating aspects such as organizational and social innovation, entrepreneurship, and the contribution of low-tech SMEs.

According to the data available from the EIS, based on these seven regionalized indicators, two composite indicators can be derived: (1) the RNSII (Regional National Summary Innovation Index), which explains the position of every region within its home country, and (2) the REUSII (Regional European Summary Innovation Index), which refers to the positioning of every region compared to the European average. The indices are calculated as follows:

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

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

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

A composite RRSII (Revealed Regional Summary Innovation Index) can be obtained as the unweighted average of RNSII and REUSII. This index is designed to pinpoint 'local leaders', taking account of the region's relative innovative performance both within the EU and within the country of origin. Thus the RRSII seems to be most appropriate measure to compare RIS efficiency scores with the corresponding Scoreboard indicators.

Since the Scoreboard indicators are resource-based indices, a region that invests more resources and thus obtains a higher RRSII, will be ranked higher than regions whose investments are lower. However, this does not mean that the competitiveness of the former group will be higher (i.e. their RIS is better) than that of other regions. The efficiency measurement approach aims at providing information about the use (misuse) of these resources. Due to the different perspectives of these two approaches it is possible that different 'best practice examples' will be identified and could, rightly or wrongly, become the blueprints for well meaning but perhaps mistaken, policy adjustments.

Methodology

The accurate empirical evaluation and explanation of any unit's performance is a very complex task, regardless of the analytical context. Generally speaking, the notion of efficiency relates a vector of inputs to a vector of outputs. Unfortunately, in public sector analyses all three definitional elements of efficiency (inputs, outputs, and the functional relation of the two) are affected by severe conceptual and measurement problems (LOVELL, 2002). Hence, in analysing RIS, one is dealing with a multi-input, multi-output relation, in which inputs as well as outputs might be heterogeneous and sometimes not even comparable. Time, history and stochastic influence may affect the system, and output generally is lagged (EDQUIST, 1997). All these factors have to be considered in establishing a data base and an appropriate model for an efficiency analysis of public sector activities in general, and they are even more important with respect to RIS, since it comprises a mix of private and public activities.

There are two general approaches to measuring efficiency: (1) parametric models, such as SFA (Stochastic Frontier Analysis: see e.g. KUMBHAKAR and LOVELL, 2000), and (2) non-parametric models, such as DEA (Data Envelopment Analysis: COOPER et al., 1999) and FDH (Free Disposal Hull: DEPRINS et al., 1984). Both these approaches have been developed in a straightforward way with considerable model-specific enhancements of the basic frontier concept and, depending on their individual strengths and limitations, are frequently applied to empirical analyses (CHERCHYE et al., 2001; MARTIN et al., 2004).

It has frequently been claimed that the DEA has certain advantages in the analysis of public sector activities (CHARNES et al., 1994; MARTÍNEZ CABRERA, 2003) and semi public activities like RIS. Thus, DEA represents a new approach to learning from outliers and inducing new theories of best practice (CHARNES et al., 1994). Therefore we chose DEA for this analysis.

According to the DEA methodology every convex combination of feasible production plans is also feasible (FARRELL, 1957; CHARNES et al., 1994). In fact, the assumption of convexity, even if widely used in economics, could be important in terms of methodological strengths and limitations (CHERCHYE et al., 1999). One could argue that in this context, the production technology (in this case, regional innovation) might allow increasing returns to scale (i.e. outputs increase faster than inputs). For the very highly aggregated context we are analysing here, this seems to be of minor interest[8], but for not so aggregated studies in which particular technologies are analysed (MARTIN et al., 2004) it could be crucial[9].

Data Base

Our data base was compiled from information from the EIS covering 161 European regions for 2002, and 187 regions for 2003 (country aggregates as benchmarks included)[10]. Although these indicators are supposed to adequately characterize the performance of an IS[11], the question with regard to the frontier analysis concerns what we consider to be an input and/or an output. Since increased competitiveness and better social conditions are among the common goals of political measures, and are a main objective of RIS, GDP per capita can be considered to be an output (system performance) indicator. But, what about patents, for instance? Are they inputs or outputs? Or even both? In order to answer this, we have to reflect on the causal relationship: (1) are patents, in the sense of a property right, more of an input for high and/or medium-tech industries operating within a certain region than (2) a countable output of successful R&D in the sense of a satisfactory working environment, such as productive Higher Education Institutions [HEI], industry interactions, functional networks, etc.,in other words, a successful RIS?

The literature suggests that patents can be considered to be one of the main outputs of a RIS (BROUWER and KLEINKNECHT, 1999; ERNST, 2001) but, when we tested for this in our efficiency analysis, the empirical results were very similar[12]. In other words, considering patents only as innovation outputs (which they are) and not also as inputs (benefits) for industry in general should perhaps be reconsidered (GRILICHES, 1990).

Due to the lack of any other regional indicator for output in our study we use patents but at the same time, following AZAGRA et al., (2003), who argue that the acquisition of patents could increase the innovative competitiveness of industries, patents are also considered to be an input. Therefore, in the context of the measurement of RIS performance, patents might constitute more of an input than an output[13] in regional GDP.

The indicators we employ in the efficiency model are those provided by the EIS. Thus, the indicators considered as inputs for the frontier model are: higher education (% of population between 25-64 years with higher education), lifelong learning (% of population between 25-64 years 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 [EPO] (per million population); and the measure of RIS output is regional GDP per capita.

Empirical Results

Figure 1 illustrates the distribution of RIS efficiency scores obtained from the frontier estimations (year 2002 on the left, 2003 on the right) [14].

[Figure 1 here]

The overall mean of the calculated RIS efficiency scores rose from 0.60 in 2002 to 0.64 in 2003. Even if this trend is seen as promising, it indicates that there is a huge potential for improved RIS performance. In other words, according to our empirical results, RIS potentials are widely under-exploited in Europe (by more than one-third on average). This is on the basis of already existing best practice examples and not of a hypothetical 'optimal RIS', which could shift the frontier significantly.

We found that a number of regions had highly efficient RIS (see bars at the right hand side of each histogram). Since the methodology is designed to look for best practice examples and take them as a benchmark (with respect to each of the seven input dimensions), one can expect a relatively high number of observations to be 100% efficient, since all those regions with the lowest values for any indicator will be considered as being technically efficient. In fact, this is the case for most Greek, Portuguese and Spanish regions, where low technology sectors are very widespread and the regional institutions have few innovation policies[15]. Theoretically, most observations could be expected to be close to the frontier, and to behave as efficient units, but the histogram shows that there is wide variance in RIS performance in Europe.

With regard to the position of each region in relation to the frontier (level, near, far away) and its related TE score, all observations can be ordered by their achieved RIS efficiency. This ranking was compared with that provided by the RRSII, which according to the EIS, measures innovation competitiveness of European regions. In Figure 2(a-b) the two rankings are related: the y-axes refer to the RRSII index (region's position in years 2002 (3a) and 2003 (3b), respectively), and the x-axes refer to the efficiency based RIS values (TE).

[Figure 2 here]

If the two performance indicators coincided, one would expect the majority of points to be along a 45° line. But this is not the case. Indeed, the trend line has a negative slope, which indicates a negative relationship. Rank correlation coefficients for the two indices were calculated in order to check this evidence empirically. The Spearman rank correlation coefficients for 2002 and 2003 rankings are -0.645 and -0.453, respectively. In addition, the rank correlations for the subsequent years in each index were considered in order to see whether the variation in the scores and/or rankings was random. This yielded positive scores: 0.74 for TE ranking and 0.91 for the RRSII. Thus, both indices are consistent from an empirical point of view as the measures obtained are robust, and therefore it can be said that there is a difference in the 'best practice examples' identified. To some extent, the rankings are reversed; therefore, as argued above, radically changing the 'blueprint' on which policy recommendations are based. The negative relation of these indices must result from their different conceptual settings, since the measures employed in both cases are the same. While the RRSII is created as a measure mainly oriented to the inputs in the system in the sense of 'the more the better', the efficiency measure refers to the how these resources are used relative to a particular output. The RRSII, on the other hand, takes account of the relative position of a region in relation to the national average and to the EU average, whilst the efficiency index allows a comparison between the difference levels of regional performance since it compares among regions.

Thus, although a region that is at the top of the TE ranking but which employs very few RIS resources might be efficient in terms of resource use (top in terms of TE), in terms of enhancing regional development, closing the gap in growth rates, social welfare, etc. this same region might be contributing very little and be classed as lagging. On the other hand, a region that invests huge amounts of resources to improve its innovation system (i.e. is top in terms of RRSII), but whose use of resources is identified as inefficient compared to the peer group of best practice regions, cannot be seen as an example of best practice. Hence, in order to assess the performance and institutional quality of a RIS both aspects must be considered. The policy evaluation related literature agrees about the need to combine different approaches, methodologies and indicators to avoid a biased picture of system performance (KUHLMANN, 2003).

Taking this into account we checked our estimates for those regions with a relatively high ranking in both indices; i.e. comprehensive RIS and highly efficient use of available resources. We found some regions that might be considered to be examples of *best practice* and used as blueprints for policy recommendations, including London/UK and Ile de France/FR, which were consistently among the top ranked regions with respect to both RRSII and TE scores. On the other hand, some regions such as Itae-Suomi/FIN, Chemnitz/DE and Andalusia/ES had a low ranking in both indices. A significant number of regions were either ranked high in terms of RRSII but low for TE (e.g. Noord-Brabant/NL, Uusimaa/FIN, Sydsverige/SE, Eastern/UK), or vice versa (e.g. Aaland/FIN, Friesland/NL, Balearic Irelands/ES, Kriti/GR, Algarve/PT).

[Figure 3 here]

Taking into account the spatial distribution of the empirical TE scores, some common clusters can be distinguished: (see Figure 3). Northern France (Champagne-Ardenne, Picardie, Haute-Normandie, Bourgogne, Ile de France and Alsace), Luxembourg, Northern Italy (Piemonte, Liguria, Lombardia, Trentino-Alto Adige, Veneto, Emilia Romagna), and Southern / Western Germany (e.g. Baden-Württemberg, Ober- and Nieder-bayern) all score fairly high for TE. However, there are many examples of relatively high as well as relatively low TE rankings across all European countries, which justifies our approach of relating all regions to a common frontier (a peer group of regions identified as examples of best practice)[16].

The need to harmonise the RRSII and TE indices is demonstrated by the results for the Spanish RIS (see Table 1).

[Table 1 here]

According to the published statistics (EUROSTAT, INE) Madrid is seen as the leading Spanish region in terms of RIS-related efforts. Thus, it is not surprising to find Madrid among the top ranked regions across Europe (RRSII positions: 10th in 2002, and 23rd in 2003). However, in terms of Madrid's resource allocation and use, its ranking is low (estimated TE rankings of 118th, and 125th for 2002 and 2003 respectively across all European regions). The results for Catalonia are similar[17]. In contrast, regions such as Navarre and the Basque Country[18] - both with well performing RIS – (OLAZARÁN and GOMEZ URANGA, 2001) are more efficient and competitive in terms of RRSII. Some Spanish regions (e.g. Valencia) are medium/low in terms of both allocation and efficient use of resources. Some regions, such as the Balearic Islands and Castilla la Mancha, invest comparatively small amounts of resources to RIS, but use them in a highly efficient way[19].

Having identified both the best and the least efficient regions, there remains the question of how to close the gap? Or in other words, to identify what hampers or restricts the efficiency of a RIS. The solution is direct action in terms of regional development and regional policies.

The results we obtained might perhaps be explained by the complexity of innovation and thus the need to coordinate the activities promoted by innovation policies (FRENKEN, 2000). Those countries with higher R&D expenditure levels, that have a tradition of good science and are therefore oriented towards high-tech industries, tend to risk more in terms of their innovation policy proposals (CARAYANNIS et al., 2005). As a result, the systems in these countries receive more inputs and make more efforts to be better coordinated, and consequently are likely to be ranked as less efficient , since management activities absorb a great deal of attention (GEORGHIOU, 2001). Similarly, those territories with lower absorptive capacity and fewer resources, adopt the embodied knowledge and the innovations of others, which involves lower levels of development, but at the same time is efficient since risk is avoided, and the 'new' knowledge is rapidly adopted (FERNÁNDEZ DE LUCIO et al. 2003).

When we focus on the national level in relation to Spain, the results follow the above patterns. Those regions, such as Madrid and Catalonia, that devote greater amounts of resources to R&D and Innovation activities, are considered, based on the RRSII scale, to have the most comprehensive RIS. Their innovation policies are oriented to a great variety of emerging sectors, requiring a great deal of coordination among institutions and agents. These initiatives render the systems very dynamic, but the high levels of coordination required, reduces their levels of efficiency. Those regions with fewer resources to invest have to pay much more attention to how they are used. They cannot afford to squander the scarce resources dedicated to innovation activities. Their more cautious behaviour produces unexpected and unforeseen efficiencies.

The importance of innovation policies being embedded in their territory must not be overlooked (DÍEZ, 2002). Therefore, it can be said that innovation policies as well as territories, agents and institutions are path-dependent, and thus policies based on best practice examples will only be successful under certain conditions (GEORGHIOU, 1998; DÍEZ, 2002). Thus, it is crucial that regions learn from evaluations (SHAPIRA AND KUHLMANN, 2003) in order to reorient their policies to their particular circumstances.

In Europe there are several efforts that are encompassed by the 'new governance' (SCOTT AND TRUBEK, 2002). The open method of co-ordination (BORRÁS AND JACOBSSON, 2004) is one such and is a new model for coordination, learning and policy integration. These new governance methods see efficiency as the key issue in the analysis and evaluation of policies[20]. The evaluation of the efficiency of public (S&T) policies constitutes one approach to analysing a region's ability to use its basic productive resources to improve the welfare of the region (SUSILUOTO, 2003).

In this way, efficiency estimates provide direct answers when considering an inadequate allocation of resources (too much of x_n, not enough of x_{n+1}, etc.). The calculation can be broken down to show efficiency in relation to each (input) dimension[21]. The following could be applied to analyse existing inefficiencies, arising from under- or over-allocation of a particular input:

(4) $$1 - TE = |\mathrm{E} - \mathrm{X}| / \mathrm{X},$$

where **X** is a i x j matrix of inputs as defined above, and E is a i x j matrix of input efficiency levels. Hence, if E = **X** it follows that TE = 1. E ≠ 0 refers to TE < 0.

Thus, we can empirically measure whether a certain input is allocated and used to the best advantage, with respect to the frontier, which may serve as a useful empirical indicator for the formulation of policy recommendations. Since we have data for 161 regions in 2002 and 181 in 2003, and seven inputs for each RIS, for space reasons we cannot present this measurement in detail[22]. Institutional restrictions have to be considered, and their role could be analysed by regressing the TE-scores for the effects of an ad-hoc selection of explanatory variables reflecting the current status of the institutions in each system. This will be the subject of a future study[23].

Conclusions

In this study we set out to evaluate RIS performance. We based our approach on a well known methodology comprising efficiency measures used to gauge RIS performance in terms of technical efficiency. Underlying this research is the fact that although the amounts of resources within a RIS are important, it is not evident that those regions with larger amounts of resources are the most efficient ones.

In order to test the proposed methodology (DEA), we constructed a European regions efficiency ranking using data from the 2002 and 2003 EIS. The results were compared with those obtained using the RRSII index, recommended by EIS to measure the EU's progress in innovation activities.

The EIS indicators identify those regions with high investment in high-tech related activities as 'leading regions', ignoring the regions with potential and those that require specific innovation policies. The EIS demonstrates that the results based on efficiency measures reflect that in general terms RIS are widely under-exploited in Europe and that there are important variances among regions. We have shown that regions with fewer resources devoted to innovation achieve outstanding levels of efficiency and, contrary to what the EIS predicts, regions with consolidated innovation systems do not show efficiency levels commensurate with their expected competitiveness. A focus on the Spanish national level yielded similar evidence. Those regions (e.g. Madrid and Catalonia) that devote large amounts of resources to R&D and innovation are considered to be the areas with the most comprehensive RIS, according to the RRSII scale, but are not the most efficient ones. On the other hand, those regions (e.g. Balearic Islands, Castilla la Mancha) with fewer resources necessarily have to pay much more attention to the way they exploit them, and hence achieve better results in terms of efficiency.

It has been shown that the higher a region's technological level, the greater is the need for coordination of the system (GEORGHIOU, 2001). Thus, those regions where higher coordination efforts are needed, show lower efficiency levels in comparison to other regions with similar investments in terms of RRSII. Territories with lower absorptive capacity and fewer resources adopt the embodied knowledge and the innovations of others, which is less risky and involves lower levels of development; this 'new' knowledge is rapidly adopted by traditional sectors and in an efficient way.

Both innovation support policies, and territories, are path-dependent and therefore identified best practice cannot be replicated everywhere. Innovation support policies must be customized to support the particularities of each unit of analysis (i.e. sector/region/country). That is, innovation support policies have to be embedded in the territory. This means that it is crucial that regions learn from evaluation exercises in order that they can redefine their policies, and assess the performance and the institutional quality of their RIS with greater accuracy (NAUWELAERS and WINTJES, 2002).

The policy evaluation related literature agrees about the need to combine different approaches, methodologies and indicators in order to avoid biased assessments of system performance, and to produce a realistic evaluation. The present paper contributes in this respect by incorporating a quantitative approach based on efficiency measures.

From a quantitative perspective, traditional indicators seem to offer a partial view of the actual state of innovation systems. We have shown that the use of these indicators within different methodological frameworks yields differing, but not necessarily contradictory results. Thus, they provide a partial picture of the phenomenon being examined; different approaches should be seen as being complementary. Therefore, policy makers will need to consider the results of different and complementary analyses to obtain a comprehensive picture of RIS. The sum of each partial view will provide a clearer picture than that provided by each in isolation (DÍEZ, 2002).

Current policy is based on a systemic view and the interpretation of the agents involved. Based on our research, we would recommend that a combination of the methodology presented here, with qualitative analyses and other sources of information provided by empirics, should be used as the basis for the decision making process to provide better information at the start of a new policy cycle. These types of evaluations should provide useful information not only for those responsible for defining new innovation support policies, but also for the whole set of agents participating in the RIS. This should ensure an interactive process enabling regions to develop from being passive innovation producers (adopters) to becoming new learning and social systems.

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[2] LUNDVALL, 1992; EDQUIST, 1997; BRACZYK et al., 1998.

[3] In the Policy Evaluation literature it is commonly accepted that the effects of any policy can not be reducible to a single criterion, so the use of both quantitative and qualitative measures is indispensable (GEORGHIOU, 1998; KUHLMANN, 2003).

[4] "The Systems of Innovation literature takes an ambiguous stand on efficiency" (NIOSI, 2002). Thus, "we would like to propose that the most relevant performance indicators on … IS'… should reflect the efficiency and effectiveness in producing, diffusing and exploiting economically useful knowledge. Such indicators are not well developed today" (LUNDVALL, 1992). To conclude "aggregate statistics … may reveal some types of efficiency or effectiveness … it thus may be necessary to desegregate statistics, and to build new ones, to understand some observed yet unexplained x-inefficiency of the system as a whole" (NIOSI, 2002).

[5] Conducting a European wide comparison at a regional level always involves more or less substantial data problems, e.g. the lack of suitable indicators due to different definitions, short time series, differences in the criteria applied by

different statistics offices, etc. Hence, we differ among three different levels of analysis in this emergent research path. This first step aims to demonstrate the possibilities of this approach in the context of Europe. In a second stage, the study could be replicated for each country, to allow institutional aspects to be considered. A third step would involve examining the evolution of efficiency scores, region by region. The time series needed for these studies will necessarily have to be longer, but the increasing uniformity in each territory as we go down in the level of analysis will provide much deeper qualitative information for their evaluation.

[6] Human resources for innovation (5 indicators): New S&E graduates (% of 20-29 age class), Population with tertiary education (% of 25-64 age class), Participation in life-long learning (% of 25-64 age class), Employment in medium-high and high-tech manufacturing (% of total workforce), Employment in high-tech services (% of total workforce). Creation of knowledge (4 indicators): Public R&D expenditures (% of GDP), Business expenditure on R&D (% of GDP), EPO high-tech patent applications (per million population), USPTO high-tech patent applications (per million population). Transmission and application of knowledge (3 indicators): SMEs innovating in house (% of manufacturing SMEs), Manufacturing SMEs involved in innovation co-operation, Innovation expenditures (% of total manufacturing turnover). Innovation finance, outputs and markets (6 indicators): High-tech venture capital investment (% of GDP), New capital raised on stock markets (% of GDP), New to market products (% of sales by manufacturing firms), Home internet access (% of all households), ICT expenditures (% of GDP), % of manufacturing value-added from high-technology.

[7] The seven indicators that constitute the EIS indices for 2002 and 2003 are: Population with tertiary education, Participation in life-long learning, Employment in medium-high and high-tech manufacturing, Employment in high-tech services, Public R&D expenditures, Business expenditure on R&D, EPO high-tech patent applications.

[8] The fact that any unit's performance can be obtained as the convex combination of other DMUs – providing virtual units – does not involve any lack of judgment in our analysis. In fact, policymakers play a direct role in the amount of resources being employed within each subsystem and affect the role of the institutions with the definition and implementation of their regional innovation policies.

[9] In the efficiency related literature concern has been expressed about the convexity restriction and its utility, although there is no consensus to date (CHERCHYE et al., 1999). The Free Disposal Hull (FDH) (DEPRINS et al., 1984) could be another suitable alternative to test the role of convexity in this context. The FDH estimator relies on the free disposal assumption of the production set, but not, as DEA does, on their convexity. Hence, FDH is a more general estimator than DEA (PARK et al., 2000).

[10] According to the Nomenclature of Territorial Units for Statistics [NUTS] adopted by the European Union and EUROSTAT, the administrative division corresponding to NUTS2 are the units considered as regions. Where data were missing we used the country average and/or assumed inter-temporal constant scores for a certain region.

[11] The 49% variation in per capita regional income can be explained by differences in innovative performance – measured by its RRSII - for 2002 and 2003 (EUROPEAN INNOVATION SCOREBOARD 2002 and 2003).

[12] Two models were estimated. In the first one, both patents and GDP per capita were considered as the desired outputs of any RIS. In the second we considered patents to be an input rather than an output (ceteris paribus). The results obtained from both models were, surprisingly, quite similar and significant (the correlation between the models was 65.4% in 2002 and 63.8% in 2003).

[13] The patents granted in “t” can be the result (output) of the efforts previously made in time “t-n”. In turn, from “t” on, once the patents are already granted, they could be considered as an input for all regions/sectors (GEORGHIOU et al., 2003). However, the time period in the database is not long enough for this assumption to apply; Thus, patents are considered as an input for innovative activities in European regions, due to the fact that most patents are generated by a very few regions, but the benefits spill over to all the others(COE and HELPMAN; 1995; GEORGHIOU et al., 2003). Nevertheless, we estimate this temporal issue as a relevant point that might produce a really interesting outcome regarding the appropriability of innovation. This could have implications for policy making.

[14] The procedure was performed using XploRe.

[15] A further step in this analysis might be to study regions with a high degree of homogeneity (i.e. the Nordic Countries, the Mediterranean area), whose institutions play similar roles, and where the technological level of firms, the number of universities, etc., are similar.

[16] If there was strong evidence of national clusters (e.g. due to major differences in RIS, legal frameworks, institutional settings, technological barriers, administrational restrictions, etc.), our proposed second and third levels of aggregation would be more appropriate.

[17] RRSII/TE respective rankings: 42nd/110th for 2002, and 36th/124th for 2003.

[18] RRSII/TE respective rankings in Europe: 36th/85th and 45th/62nd (Navarre), and 50th/55th and 47th/46th (Basque Country) for years 2002 and 2003 respectively.

[19] Balearic Islands: RRSII-position: 134th/158th, and TE-scores of 0.87 (28th) and 1.0 (10th), respectively. Castilla la Mancha: 138th/163rd (RRSII ranks), and TE: 0.89 (25th), and 0.98 (27th) for 2002/2003 respectively.

[20] An example of the application of the Open Method of Co-ordination in education policy can be found in Gornitzka (2005).

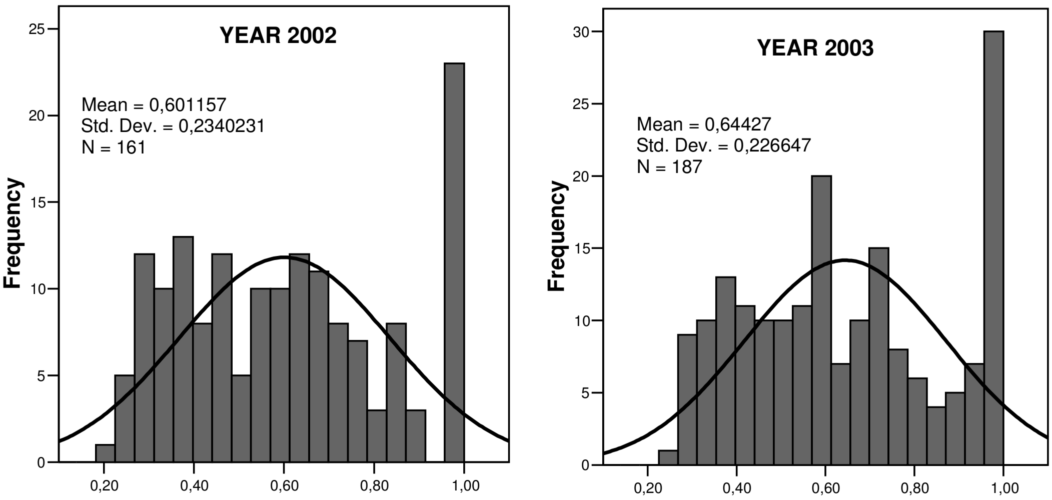
[21] According to the methodology, any 'under-use' of inputs will occur only in very particular cases where achieving a certain amount of output with less input might be considered as a higher efficient input/output-relation and, therefore, would shift the frontier.

[22] Since the study aimed at a European wide comparison and testing the availability of an efficiency approach in this framework, this task cannot be presented in detail. However, in this context, our proposed second and third levels of aggregation would be more appropriate, allowing decision makers and stakeholders to reorient the resources being used in their RIS.

[23] Due to the enormous data base that would be needed for a European wide analysis of these issues we would intend to conduct these future analyses at

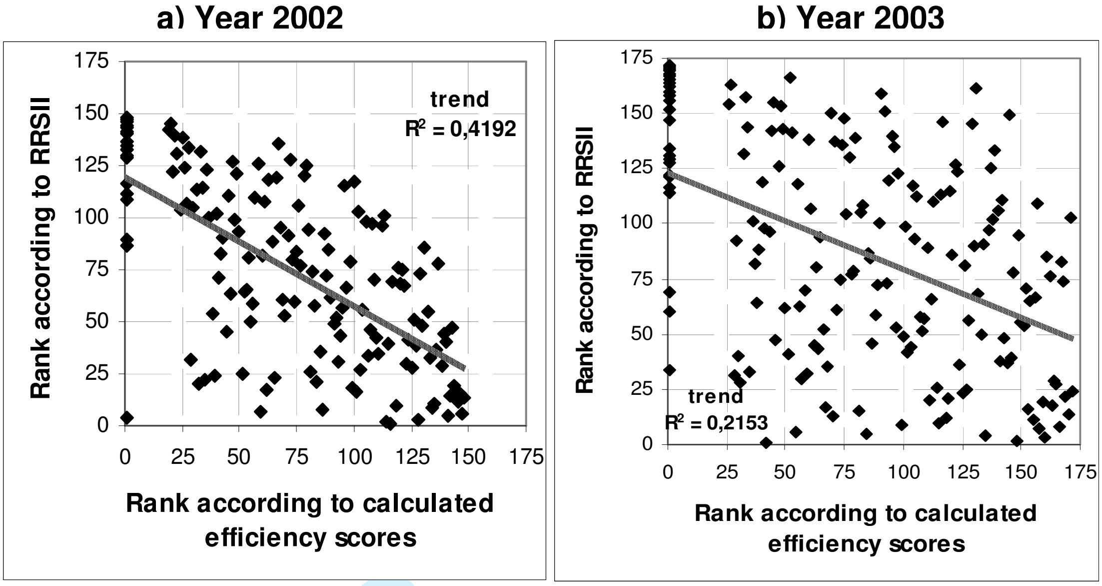
national level (probably based on Spain), when the second level of the analysis has been accomplished.

Figure 1: Distribution of RIS Technical Efficiency in Europe (per year)



Source: Authors' calculations.

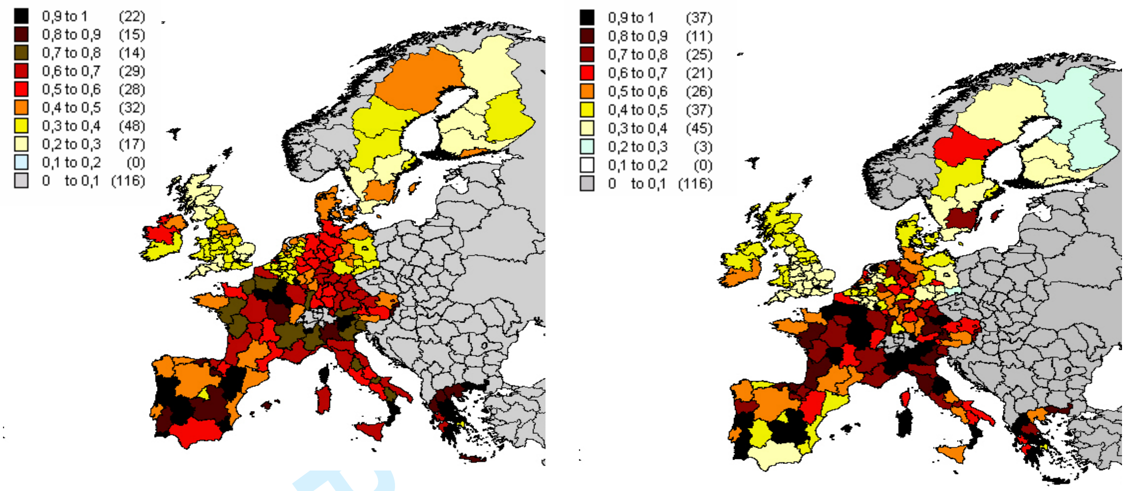
Figure 2: Ranking of RIS performance according to RRSII and TE



Source: Authors' calculations.

Figure 3: Spatial distribution of calculated TE scores: RIS in Europe

a) Year 2002 b) Year 2003



Source: Authors' calculations.

Table 1: RRSII and TE scores and rankings of Spanish RIS (2002 and 2003)

Region	RRSII score		Rank according to RRSII		TE-score		Rank according to TE-scores	
	2002	2003	2002	2003	2002	2003	2002	2003
Galicia	60,26	59,35	115	135	0,471	0,599	96	96
Asturias	58,48	53,63	117	145	0,461	0,467	100	129
Cantabria	68,45	55,61	100	142	0,811	0,855	37	44
Basque Country	96,51	98,69	50	47	0,676	0,825	55	46
Navarre	102,91	100,09	36	45	0,554	0,724	85	62
La Rioja	61,22	57,42	114	138	0,834	0,729	34	60
Aragon	75,10	77,97	87	87	1,000	0,636	1	85
Madrid	140,06	127,51	10	23	0,367	0,487	118	125
Castilla Leon	68,88	65,22	98	117	0,444	0,576	105	104
Castilla la Mancha	48,78	42,01	138	163	0,894	0,981	25	27
Extremadura	47,67	43,91	139	161	0,981	0,459	22	131
Catalonia	100,24	107,58	42	36	0,425	0,488	110	124
C. Valencian	69,10	70,71	97	106	0,430	0,422	108	140
Balearic Islands	51,81	45,24	134	158	0,866	1,000	28	1
Andalusia	55,91	51,33	125	149	0,573	0,395	79	145
Murcia	52,45	59,61	133	133	1,000	0,422	1	139
Canary Islands	54,90	52,76	130	148	1,000	0,686	1	75

Source: Author's calculations.