"Definition of a methodology to analyze and measure interactions inside Regional Innovation Systems"

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1.- Introduction

The aim of the present thesis proposal is to define a methodology to measure the interactions among the agents involved in a System of Innovation, due to the fact that the literature agrees in a lack of measures in this respect.

The conceptualization of Regional Innovation Systems (Cooke and Morgan, 1993) can be understood like an extension and adaptation arisen from the concept of National Innovation Systems defined in the works of Freeman (1987), Nelson (ed., 1993) and Lundvall (ed., 1992) and in the subsequent development of Edquist (ed., 1997). It consist of analyzing the existence of actors (institutions, clusters, universities, industries…) and regional competences, and the interactions into Innovation Networks among them, providing regional authorities with a tool to define policies to increase competitiveness.

A first stream work in which relations and flows among the main agents of an Innovation System are shown, is the one made up by the works of Scherer, (1982), Pavitt (1984), Archibugi (1988), Galli and Teubal (1997), DeBresson (ed., 1996). Another is due to Andersen (1992, 1996) on Innovation Systems, using "graph theory" and simulation models (Andersen and Lundvall, 1997).

Recently, some different research projects can be found in which relations established among the agents in Innovation Systems are studied (European Planning Studies, Vol. 8, Not. 4, 2000). Besides, diverse simulation models created to measure the characteristics of Innovation Systems in different environments (Simulating Self-Organizing innovation networks" -SEIN-) are also detailed.

There is a growing need to elaborate indicators that allow to predict changes in the regional innovation capacity beyond those employed in the linear model. We have also noticed the need to measure other processes such as those related to institutional relations and the creation of networks, in order to evaluate innovation policies (Zenker, 2001; Landabaso, Oughton, Morgan, 2001; Saviotti, 1997; Archibugi, Howells and Michie, eds., 1999). This is supported by the fact that several policies fostering innovation have been defined, such as RIS, RTP, RITTS, etc…

In this context, and due to the importance of co-operation practices within Regional Innovation Systems, the present research project tries to contribute with a model as well as an Indicator Scoreboard which helps quantify the interrelations that occur among the agents in an Innovation System.

2.- Conceptual framework: need of interactions' measurements

The Systems of Innovation approach (Freeman, 1987; Lundvall ed., 1992; Nelson and Rosenberg, 1993; Freeman, 1995; Edquist ed., 1997) is mainly based on the interactive learning theory (Lundvall ed., 1992) which emphasises the linkages among several agents aiming at producing innovations. It consists of analyzing the existence of actors (institutions, clusters, universities, industries…), their competences, and the interactions within Innovation Networks, providing (national, regional, local) authorities with a tool to define policies.

It is possible to find several definitions on the concept of System of Innovation in the literature:

> "network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987).
>
> "a number of elements and the relationships between these elements… which interact in the production, diffusion and use of new, and economically useful knowledge…" (Lundvall ed., 1992)
>
> The National Systems of Innovation are constituted by "interconnected agents" that interact influencing on the execution of the innovation in the national economy. These interactions occur into a specific context and under certain shared norms, routines and established practices. (Nelson and Rosenberg, 1993).
>
> "way of encompassing these numerous facets (of the relationship between technology, trade and growth) so as to suggest that the performance of national economies depends on the manner in which organizational and institutional arrangements and linkages conducive to innovation and growth have been to thrive in different countries." (Francois Chesnais, 1995)
>
> "specialized cluster of firms supported by a developed infrastructure of supplier firms and regional knowledge and technology diffusion organisations, which tailor their services to the specific need of the dominating regional industry" . (Asheim and Isaksen, 1997)

According to these definitions it is possible to conclude that an Innovation System is a social, opened and dynamic system (Lundvall ed., 1992), because of the interactions that occur not only among the socio-economic agents involved in the Innovation System's Networks, but also due to the interactions of the system as a whole with the surrounding environment.

Firms seldom innovate in isolation due to several influences that innovation processes have from many factors and agents. Across innovation processes, agents interact each other to gain, develop and exchange various kinds of knowledge, information and other resources (Edquist ed., 1997).

Despite most of the previous definitions consider interactions as one of the key elements, the models created on Innovation System seem to fail at representing the behaviour of the system not only due to interactions among agents inside the Innovation System but also to interactions produced among the system and the rest of the innovation systems around.

Among these numerous models, Lundvall (ed., 1992) differs the agents that constitute an Innovation Systems into some groups, being the most relevant ones:

- The internal organization of the firms
- The inter-firm relationships
- The role the public sector performs
- The institutional set-up of the financial sector
- R&D intensity and R&D organisation.

In spite of this list, some other actors could be included such as other firms (suppliers, customers, competitors), universities, research institutes, investment banks, schools, government ministries… (Edquist ed., 1997; Cooke et al., 2000; Fernández de Lucio, 2000)

Parallel to the Systems of Innovation (national, regional and local) approach around which the present research is being developed, some other approaches such as "Sectoral Innovation Systems" (Breschi and Malerba, 1997), "Technological Systems" (Carlsson and Stankiewicz, 1991), "Research Systems in Transition" (Cozzens et al. eds., 1990; Zyman, 1994), the "Post Modern Research System" (Rip and VanderMeulen, 1996) the "Triangle Model of Sábato" (Sábato, 1975) and the "Triple Helix Model" (Etzkowitz and Leydesdorff eds., 1997) can be found among others.

All the previous models defined above take interactive terms into account in order to show the interactions that occur into Innovation Systems, which are one of its key characteristics (Edquist ed., 1997).

Conversely, and as it has been argued before, none of the models manages to measure interactions. It could be said that despite the Innovation System exists because interactions occur within it, the concept of "system" will become meaningless, as long as the models created do not manage to measure those interactions and allow to know their dynamic behaviour (Kautonen, 2000; Archibugi, Howells and Michie eds., 1999).

Nevertheless, despite the innovation activity is mainly territory based (Asheim and Isaksen, 2000; Olazaran and Gomez Uranga eds., 2000), interactions between different regions and countries are becoming more and more usual due to the fact that systems are also becoming more global. Because of this, Innovation System models, should be modified not only in order to properly represent the interactions, but also to consider that the Innovation System must be open and dynamic.

The fact that these aspects have not been studied yet reflects the "youth" of the Innovation System approach, and the difficulty to measure innovation flows and interactions in a dynamic context.

As interactions are becoming more relevant (Saviotti, 1997) in the definition of a dynamic and open system, their measurement and the comprehension of their path-dependent dynamic behaviour requires a more detailed analysis (Kautonen, 2000; Archibugi, Howells and Michie eds., 1999; Tappi, 2003).

As Charles Edquist (ed., 1997) agreed, "…we simply do not know enough about these relations. It is important to be able to capture these interdependencies in empirical work – which includes the development of concepts and indicators - that relate elements to each other. This is needed for the development of a more sophisticated systemic and interactive view of innovation processes."

Due to the fact that the literature agrees in the lack of measures in this respect, and in order to be able to better understand the way interactions occur and evolve, this thesis proposal intends to define a new methodology to allow their measurement.

3.- Empirical framework: state of the art in Innovation Networks

Once the theoretical contribution of this proposal has been set out, the studies already done trying to measure these interactions will be introduced. We will show later that two main groups can be distinguished. On the one hand it is possible to find studies using some indicators trying to give an empirical measure of the interactions that occur into an Innovation System. On the other hand some studies about Innovation Networks' Simulation can also be found, where some simulation models are defined and run out.

We find two main deficiencies in the previous research studies. On the one hand many of the used indicators do not contribute to know the behaviour of the dynamics of the interactions and therefore of the system. On the other hand, some of the used indicators do not really measure interactions since they are measures concerning the analyzed agents involved in the Innovation Systems. That is, some of the indicators are not "co-operation" or "interaction" referred measures.

In order to achieve the goal of measuring these interactions, and as it will be shown later, theories about complexity and chaos can be used in order to provide the Systems of Innovation approach a new perspective contributing to its development and consolidation.

The research work concerning the analysis of the Innovation Networks and the interactions produced among the agents rises a special interest due to (Archibugi, Howells and Michie eds., 1999):

- Networks and consequently Innovation Systems, consider the amount of agents participating in, their characteristics and the interactions among them. Therefore, in absence of interactions, the existence of a system can not be conceived.
- The relations produced into the system are relevant when defining and analyzing the behaviour of an Innovation System.
- The analysis of the way in which interactions are modified is a key element which gives an adequate perspective to the evolution and the dynamics of the system.

Due to the fact that policies supporting innovation are being defined, such as RIS, RTP, RITTS, etc… shows the growing need to elaborate indicators allowing to measure processes related to the establishment of networks and the evaluation of these innovation policies (Zenker, 2001; Landabaso, Oughton, Morgan, 2001; Saviotti, 1997; Archibugi, Howells and Michie eds., 1999).

The first studies about Innovation Networks, have provided an important empirical source of information for later studies (Callon and Law 1989).

Andersen's work uses a simulation model to analyse vertical relationships which seems to be a promising path (Andersen and Lundvall, 1997) to simulate the evolution of complex production and Innovation Systems. Nevertheless, it needs to be reviewed, systemized and applied in recent empirical studies (Olazaran and Gomez Uranga eds., 2000).

Nevertheless, among the recent research studies many other interesting indicators can be obtained. That way, it is possible to see how interactions established among some agents involved in the Regional Innovation System of Baden Württemberg are studied (Emmanuel Muller, 2001) by means of:

- the knowledge used,
- the interactions space considerations,
- the influence in terms of business innovations.

Related to the previous analysis, Knut Koschatzky (2003) studies the characteristics of co-operation carried out in the five German EXIST regions via the promotion of university-based start-ups.

Javier Revilla Díez (2001) shows the main results obtained in a project developed to measure the types of co-operation produced in some European regions like Barcelona, Vienna and Stockholm analyzing: the amount of industrial companies in each region, their year of foundation, their sectoral analysis, the technology areas their activities belong to, the sources of information, and the agents co-operating with depending on the phase of the innovation process.

A further study on the way co-operations take place in the industrial sector in Slovenia (Koschatzky and Bross, 2001) analyzes the composition of the industrial population, the sectors, the amount of workers, technology centres and foreign businesses they co-operate with, and the co-operation degree of technology centres with businesses, technology institutes and public administration. A similar study is done by Arne Isaksen (2003) concerning the case of the offshore engineering in the Oslo Region.

Franz Pleschak and Frank Stummer (2001) analyze the competitiveness through innovation in East German Industrial Research, studying the frequency of interactions between a technology centre and the rest of agents by means of joint projects, acts organized jointly, supply of consultants, common use of technological means, and research results' transfer.

An empirical work about the inter-industry co-operation in innovation projects in Spain (Navarro Arancegui, 2002) also studies the innovative industries that co-operated in innovation projects during 1996 according to their size, sectors, types of co-operation, the partners they co-operated with, and their technological level.

In reference to the simulation models several studies can be found in the work of Andreas Pyka and Günter Küppers (eds., 2002) where numerous simulation models studying the characteristics of the behaviour of Innovation Networks can be found.

In the later study Andreas Pyka and Pier Paolo Saviotti (2002) compare real measures of an Innovation Network in the biotechnology sector with the ones obtained in a simulation model using the Ucinet software (Borgatti, Everett and Freeman, 1999).

Some other studies such as the role of the knowledge-intensive business services (KIBS) in e-commerce (Windrum, 2002), the Innovation Networks and the transformation of large socio-technical systems in the case of combined heat and power technology (Weber, 2002), and the evaluation of an Innovation Network (Ahrweiler, de Jong and Windrum, 2002) can also be contemplated.

Finally, Daniele Archibugi and Simona Iammarino (1999) make a taxonomy analyzing the behaviour of interactions among some agents of an Innovation System (industry-industry, government-government, government-industry) which depends on the way innovations are produced.

As explained before, some authors have used some indicators and done some empirical approaches to Innovation Networks framework, in order to identify the interactions that take place into them, without having obtained so far, neither a quality methodology that allows the identification of the Innovation Networks' behaviour nor an approach to increase the knowledge about their dynamics.

Related to this, something similar occurs from a theoretical point of view about the Innovation Networks approach. In this case, some authors have tried to define and qualify the networks existing within Innovation Systems, but no definition has been totally agreed among researchers.

Though it is possible to find several approaches in the literature, most of them give some particular definitions, classifications or qualities about these Innovation Networks but none of them offer a consensual framework.

Innovation networks are a relatively recent phenomenon emerged at the beginning of the 90´s (Pyka and Saviotti, 2002), and is considered "a useful tool to explain some phenomenons such as the dynamics of the business organizations and the ones of the local productive systems" (Vázquez Barquero, 1999).

The relations and connections between activities (productive, commercial, technical, financial and assistencial), actors (industrial firms from the local productive system), and resources (human, natural, infrastructures) have been growing for a long time, so it depends on the socio-cultural and productive way of live of communities (Vázquez Barquero, 1999). They also have a great internal dynamic as a consequence of economic relations and its open character, which involves an ongoing reorganization of the system, and also the structures´ change. As Innovation Networks are a governance way in a continued disequilibria as a consequence of the dynamics of interactions, it is necessary to create a new innovation model that considers and explains these dynamics and openness of the system with indicators.

As innovations occur due to interactions between economic, politic and scientific agents, it can be said that Innovation Networks are "all those organizational forms between the market and the hierarchy that allows the information, knowledge and many other resources exchange, and that also help to implement innovations by means of the learning processes between the networks" (Koschatzky, 2001).
But also, "as a collective action among which local firms and institutions are culturally grounded for the creation and diffusion of additional knowledge (Pilon and DeBresson, 2003). Or "interaction processes among many heterogeneous agents, that produce innovations (at the national, regional, or supranational levels) (Pyka and Küppers, 2002)

Summarizing, the economic, sociologic and politic literature has began to show that recent developments in the generation of new knowledge can be conceptualized in terms of Innovation Networks. Despite this fact, still there is a long path to walk. There is not a clear definition about what an Innovation Network is, although many definitions, each one emphasising a particular feature can be considered (Pyka and Küppers eds., 2002)

Not only many definitions of Innovation Networks can be found, but also many taxonomies and classifications, advantages of the networking, roles of the networks, etc. depending on the author´s point of view (Freeman, 1991; DeBresson/Amesse, 1991; Cooke and Morgan, 1993; Guerrieri and Tylecote, 1997; Vázquez Barquero, 1999; Pleschak and Stummer, 2001; Pyka and Küppers, 2002; Koschatzky, 2002; Fornhal and Brenner eds., 2003; Koschatzky, 2003).

Several authors (Pleschak and Stummer, 2001; Fornhal and Brenner eds., 2002; Pyka and Küppers, 2002; Vaux and Gilbert, 2002; Lutz, Sydow and Staber, 2003) also explain the main facts that should take place into an Innovation System and the main characteristics the agents of systems should have, so that Innovation Networks could be generated and developed. However, these recommendations still have not empirically been proved. Hence, as long as the indicators used to measure interactions into Innovation Systems do not allow to undertake and understand their dynamics, this facts can not be considered a tool to define more efficient Science, Technology and Innovation policies.

According to the main goal of this thesis proposal and in order to be able to define some new indicators to measure their relevance and understand their dynamics, one of the possible ways to do it could be using theories of complexity and chaos (Lorenz, 1995; Briggs and Peat, 1999; Hayles, 1998). There is a need to undertake the study of complexity to be able to understand the behaviour of the interactions and their relevance into the Systems of Innovation (Andersen, 1997).

The concept of the dynamic complexity is referred to an assembly of interrelated processes and heterogeneous elements interacting each other, although there is not a clear definition of what complexity concerns (Pyka and Küppers, 2002). Networks in this context represent a mechanism for the diffusion of innovations through the collaboration and the interactive relations (Zuscovitch and Justman, 1995).

The dynamics of this complexity are formed by a specific amount of independent processes, each one with its own dynamic, that relate each other and generate a new system's dynamic which differs from the dynamics of each process (Pyka and Küppers, 2002).

In spite of the need to undertake further research in this field and the fact that several authors mention this possibility offered by complexity as being an alternative approach to Innovation Networks (Seri, 2001; Pyka, Gilbert and Ahrweiler, 2002; Pleschak and Stummer, 2001) not many empirical nor theoretical approaches have been made. Thus, authors that make use of these theories of complexity and chaos to analyze the produced interactions (Frenken, 2000) try to measure them my means of simulation models like the NK-model (Kauffman, 1993) and by means of entropy. Nonetheless, the used indicators do not really refer to complexity and chaos, so they do not really offer an alternative point of view.

4.- Description of the research work

So far, main deficiencies of the Systems of Innovation approach have been pointed out, main studies concerning Innovation Networks have also been explained, and the possibilities offered by both complexity and chaos theories in the study of interactions have been shown. Now, a description of main goals of this thesis proposal will be inroduced.

The main objective of the research is:

> "The definition of a methodology that allows to measure interactions in open and dynamic Innovation Systems, and to quantify how these explain their dynamic behaviour."

By means of this research work, we will try to give an answer to some previously formulated hypothesis:

- Interactions (relations) influence the dynamic behaviour of Innovation Systems.
- Interactions produced within an Innovation System are complex and show a chaotic behaviour.
- Interactions produced within an Innovation System are measurable with quantitative as qualitative indicators.
- It is possible to give a definition of the network concept in the Systems of Innovation framework.
- The degree of intensity, and the interactions strengths or weaknesses as well as co-operation among the agents of an Innovation Systems depends on the nation, region, or sector … historic trajectories.

Finally and in order to be able to accept or reject the hypothesis above, some questions will be formulated in the research work:

- What kind of interactions are produced in an Innovation System to support co-operation among the agents? Among which agents are produced?
- Is it possible to measure the interactions produced? How are they measurable?
- Are theories of complexity and chaos an alternative research path to undertake the measurement of Innovation Networks?
- Do the simulation models analyze the dynamics of Innovation Networks according to the empirical results observed in the Innovation Systems?
- To what extent do interactions explain the Innovation Systems dynamics?
- Do the historic trajectories of nations, regions, sectors… act as a constraint in the development of interactions in Innovation Systems? Do the different (nation, region, local, sector…) Innovation Networks differ in their dynamics?

5.- Work programme and methodology

After having explained the main contribution that the present thesis proposal intends to carry out, and those considered useful tools to this goal, the main phases in which the research work is going to be developed will be shown.

1.- Main literature and state of the art.
The bibliography to be considered can be divided into three groups. First of all, it will be necessary to identify in a higher extent main characteristics and deficiencies of interactions produced in the Innovation Systems. Second, both theoretical as empirical studies regarding Innovation Networks should be reviewed to know the state of the art as well as in the construction of simulation models and in the definition and measurement of possible indicators to be used. The bibliography concerning theoretical approaches related to complexity and chaos theories should also be reviewed to define the possible contributions that these theories could offer to Innovation Networks measurement.

2.- Definition of a taxonomy of ossible kinds of interaction or co-operation that could be undertaken within an Innovation System.
As it has been exposed above, several approaches provided by many authors intend to identify and classify possible types of interactions produced in Innovation Systems. That way, the definition of some indicators to measure and qualify the types of interactions will become somehow easier as the main characteristics each type have are known.

3.- Development of an Indicator Scoreboard for the measurement of interactions using complexity and chaos theories.
Many authors have identified the need to undertake the measurement of Innovation Networks, which are open, complex, and dynamic. Some efforts have been done in their measurement, but the used indicators do not really offer an alternative approach to networking, and do not manage to measure their complexity. That way, and making use of these theories, it will be possible to identify some characteristics of the Innovation Networks which will allow the identification and definition of a new Indicator Scoreboard representing interactions.

4.- Development of a simulation model which allows to increase the knowledge about the behaviour and the measurement of the interactions in a static way.
In order to be able to construct this simulation model some more tasks should be undertaken such as the identification of main simulation models already constructed to analyze interactions in Innovation Networks and main measures they provide, as well as a review of the simulation softwares that allow the construction of these simulation models.
Initially, the main goal of this task is the development of a static model which attempts to reflect the state of interactions (despite their dynamics) that occur in an Innovation System.

5.- Adjust the behaviour of the simulation model as well as the indicators employed, comparing the results obtained in the model with real ones.
Although many interaction measures can not be quantified so far, in order to adjust the model created as much as possible to reality, making use of the tacit knowledge about some Sectoral Innovation Systems in a region, it could be possible to get that goal.

Once we have managed to adjust the behaviour of this static Innovation Network model in order to make it as real as possible, the next step will be to allow for dynamics, according to the evolution shown by the studied indicators during the last years.

6.- Determine and evaluate the historic trajectories impact when studying the dynamics of Innovation Networks and their interactions.
In order to develop this part of the work, two tasks will be done. To carry out them, it will be necessary to select both the sectors and the European regions where the constructed model is going to be used:

a) On the one hand the behaviour of interactions in different sectors in the Basque Country region will be studied,
b) On the other hand, there will be studied the behaviour of interactions in a sector present in several European regions

Thus, as we expect that the obtained measures will reflect the differences in the behaviour of the interactions observed in both cases, it will be possible to predict to what extent, the historic paths of the regions constrain the interactions produced in their respective Innovation Systems.

It will be necessary to deepen in the features and evolution of the selected regions and sectors, as well as to obtain as many measures as possible from their Sectoral Innovation Systems during the last years.

Once we have obtained the results from the simulation and empiric models, a comparison between them should be done to determine the adaptation to real systems and the main deficiencies the model has.

7.- Finally, the *methodology to measure interactions produced in Innovation Networks of Innovation Systems will be developed*, using the experiences and the results obtained during the research work.

6.- Interest of the expected results

We have introduced several aspects in this document. First of all the framework of the Innovation Systems within the research is going to be developed has been explained, depicting the main lacks several authors have found and the different models defined. That way, the key role interactions play within Innovation Systems was demonstrated and the need of a further research trying to cover this lack has been shown.

Recently some authors have undertaken this need defining a new approach to the Innovation Systems from the Innovation Networks side. Their evolution, definition and some empirical studies were shown on the second chapter. Here also, the fact of having a lack of measures concerning interactions was shown, despite the studies already done.

As many authors agree when defining an Innovation Network and the interactions produced into an Innovation System, one of the key characteristics of their behaviour is their complexity and dynamism. This is the reason why theories of complexity and chaos seem to be an interesting research approach that could contribute to cover the lack of indicators concerning interactions in the Innovation Systems.

Within this general context, the main results that are expected during the development of the thesis are:

- Definition of a methodology to understand and measure the interactions' behaviour into the Systems of Innovation framework.
- Contribute to the economy of Science and Technology indicators through the definition of a new Indicator Scoreboard for the measurement of interactions within Innovation Systems.
- Contribute to the Systems of Innovation approach with a new alternative research line through theories of complexity and chaos, covering this way the existing gap in the measure of interactions and the knowledge of the dynamic behaviour of Innovation Networks.

Finally, one of the possible uses of this methodology, is the design and implementation of more efficient Science, Technology and Innovation policies from different approaches such as financial, scientific, politic, technologic, and co-operation policies, in order to increase the competitiveness of Regional Systems of Innovation.

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