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The architecture of firms' innovative behaviors

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Abstract

During the last decades the amount of studies published about innovation systems has been massive, originating a great interest for policy makers in search for scientific background and technical support to find out the most adequate strategies for development. Although from different perspectives, studies point out knowledge creation and innovation, as the major drivers of change and growth. The consensus is broken, however, as soon as the complexity of innovation and knowledge are tackled: Innovation goes much beyond new product or process development due to its interactive nature, and knowledge surpasses the firms' attributes because, frequently, it is a spatial endogenous characteristic.

The present paper is a contribution to the earlier discussion and represents an effort to develop a model able to answer how institutions are relating to each other, tracing networks of innovation.

The available database compromises an extensive set of Portuguese innovative firms, spatially identified and able to permit spatial connectivity to understand where and how strong are the links for innovation in Portugal and to analyze the respective level of concentration or dispersion.

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INTRODUCTION AND THEORETICAL FRAMING

The comprehensive systemic approach of innovation

During the last decades the amount of studies published about innovation systems has been massive, originating a great interest for policy makers in search for scientific background and technical support to find out the most adequate strategies for development. Although from different perspectives, studies point out knowledge creation and innovation as the major drivers of change and growth, the consensus is broken, however, as soon as the complexity of innovation and knowledge are tackled: Innovation goes much beyond new product or process development due to its interactive nature, and knowledge surpasses the firms' attributes because, frequently, it is a spatial endogenous characteristic.

Scientists prompted a worldwide interest in the driving forces and socio-economic impacts of innovation and entrepreneurship (see Nijkamp 2009a, 2009b; Stimson et al. 2006) for which innovation has been a critical parameter of human intelligence and cognitive ability of human kind. Both factors are considered, nowadays, as the major drivers of socio-economic and technological change, able to stimulate the continuous production of new products or processes. To persuade society to continuously consume them requires a ***systematic and integrative combination of knowledge assets*** managed within a framework of institutions, regulations, and some kind of social cognitive mechanisms (Hall et al. 2005).

The trajectories of technological development

The complexity of the innovation system is structured under conditions related to ***governance systems and respective spatio-temporal industrial organization*** and their cognitive capacity. This argument calls for Schumpeter's interpretation on the propensity of innovations to geographically group and generate clusters, encouraging innovation as a powerful instrument of growth. On this basis ***innovation and its factors*** became of crucial interest and tracing the complexity of governance systems one of the key vectors to explain the success of efforts to promote innovation. Countless efforts have been made to identify such factors: Some researchers adopted the resource-based view of the firm by accepting the heterogeneous character of firms emphasizing their strategic behaviour (Knudsen 1995 and Noronha Vaz and Cesário 2008).

When knowledge became recognized as a key resource for firms and other economic agents, some authors demonstrated the essential role of linkages between industry and external research organizations for the successful transfer of technological knowledge among firms, later distended and referred to as the Triple Helix concept, a triangular interaction between the research community, governments and industries seen as the solution to successful innovation (Doloreaux (2005)

As linkages among institutions became long lasting and consistently robust, it became possible to addresses the consequential configuration in ***forms of networks and/or industrial clusters.*** In effect, a great variety of studies on clustering were influential in describing how and why institutions get together to react to competitive pressures. Westlund and Bolton 2006, for example, described clusters as geographical space with normative isomorphism, "*where managers and decision makers follow similar values, cognitive references, perceptions, and experiences therefore with propensity to connect and pursue analogous patterns of organizational behaviour*".

In such a context, the concept of ***Regional Innovation Systems*** (RIS) was introduced as "*a network of organizations, institutions and individuals, within which, the creation, dissemination, and exploitation of new knowledge and innovation occurs*" (Cooke et al. 2004), influencing the perception of the dynamics of clustering and admitting that for a given national or regional economy, technological and industrial development takes place following certain trajectories determined by spatial systems traced by groups linked firms, research organizations, policy institutions, government authorities, and financial actors (Teigland and Schenkel 2006).

Networking, the strategic choices of firms and the spatial impacts

Basically, the previously pointed out structures when observed from a global perspective, tend to outline long-lasting technology trends that could, among others help explaining the difficulties in reducing the different growth capacities among countries and regions. In general, the causes for this diverse behaviour and the propensity to have a cyclic nature of disadvantages in many lagging parts of the world have attracted the attention of many researchers and policy makers since a long time (Hall and Wee, 1995 and Landabaso, 1997).

As proved by the Italian School founded by the GREMI group (Camagni, 1991, 1995a, 1995b) and, later on, by many other northern European researchers, such as Asheim and Isaksen (2003), ***there is a direct contribution of individual firms or even of industrial clusters to foster regional growth.*** Such has been even more emphasized in the research related to ***spillover-effects***, developed by Kaiser, 2002 and Fischer, 2006. But yet, much stays unsolved:

- Fuzzy concepts related to the definition of firms' environment. Either from the geographical or from the geometrical perspective, the market area each firm and its dominant role vary in function of its nature.
- Teigland and Schenkel, 2006, argue that the firm's environment should be defined by those agents involved in the historical path-dependent development of skills.
- Other authors propose that the firm's environment is mostly responsible for all those strategic interactions that contribute to productive links within the firm's industrial structure.
- Sure is that firm's environment is highly influenced by the nature of the involved public institutions and their regulations as they may help or obstruct interactions.

Assuming that the firms environment is formed, and shaped coherently by the presence of significant linkages. Sometimes, and assuming that, in spite of uncertainty, the firms face future new needs of resources and clients, cluster formations are still emerging. In this case, it becomes important to detect if the strategic decision of firms is internally or externally driven: Langlois and Robertson (1995) first developed the idea that many questions related to firm strategy and firm boundaries are correlated. As assessed by Freel (1998), not much is understood on how technologically innovative firms grow, learn or adapt to transformations taking place in their environments: i. Will the strategic choices be solved by firms using market solutions? ii. And if so, through which decision-making process?

Frequently, innovative firms accumulate knowledge through learning, as a process to reduce uncertainty and not necessarily to get economies of scale. Therefore, facilitating the better decision, knowledge acquisition could engage the entrepreneur in strategic learning – an occasion to absorb economies of scope rather than scale. Thus, the routines of innovative firms are different from those of their non-innovative partners.

Empirical studies often underline the role of the firms' environment as the local context within which firms develop their activities (Keeble, 1997 and Freel, 1998) in and interactive mode between the parts and the set (Noronha Vaz et al., 2004) and proving that organizational learning and institutional networking combine to boost the performance of innovative firms (Fagerberg, 2003).

Occasionally, firms find possible solutions in specific networks for technological learning through external sources and manage interfaces which help them to combine sources of technical know-how, information and relations (Stough et al., 2007). In such cases, firms may also be organized in institutional local networks.

MEASUREMENTS OF FIRMS' INNOVATIVE BEHAVIOR AT A REGIONAL CONTEXT

At the same time that innovation and entrepreneurship were accepted as major factors of growth, the measurement of innovative activities received much scientific and public attention. However, the measurements related to this systemic concept still remain in progress. Since the 1990s, statistical surveys have supplied data concerning proxies such as R&D expenditures and number of patented inventions, for example. Sometimes such proxies were improved by adding up employment in R&D related activities or other data of similar kind but so far it cannot be confirmed that an unambiguous direct measure of innovation outputs is consensual.

Because the market structure influences the innovative activities and the extent to which technological change has an impact on the size distribution of firms, great part of the research done are of empiric nature and mostly related to advanced industrial countries. Rarely studies have observed rural or lagging areas (Noronha Vaz et al., 2004). The debate already started up in 1991 by Acs and Audresch, 1991, invariably points out that there are considerable ambiguities and inconsistencies in the results of empirical studies directly relating R&D or patents to innovation and even more extensively in less favoured areas.

Innovation output indicators have been defined having as reference the total number of innovations. Kleinknecht and Bain (1993) proposed several methods for collecting data: postal surveys for self-assessment by managers of their innovations or literature-based counting of innovations (in trade journals). Both these methods helped to highlight the issues, indicating related ways to work towards general inquiries. Applied in different countries, the first method in Great Britain, Norway, Denmark, Germany and the Netherlands and the second one in United States, the Netherlands and Ireland these methods proved to be quite subjective, making a scientific consensus difficult for the general use of the scientific community.

The European Community Innovation Survey (CIS), implemented by EUROSTAT to collect ***firm-level data on inputs to and outputs of the innovation*** process across a wide range of industries and across European member-states and, occasionally, across regions, finally a great toll facilitated in the progress of comparative analyses of innovativeness across firms, regions and nations. CIS has its limits but provides evidence of the actual composition of inputs engaged by the firms for implementing technological change: In terms of expenditures committed in the EU to innovative activities, formal R&D in labs corresponds to only 41% of the total, while product design costs represent 22%, and in trials, tooling up and training there are about 27% invested.

Also, at macro-level, data suggests that firms are job creators and engines of economic growth. However, such statements do not help to produce enough scientific evidence on the precise role that firms play in the growth mechanisms. Within the context of a learning economy, all enterprises have to adapt their technology to new standards of distribution and to logistic channels and in particular when included in an environment of large competition. There, all categories of enterprises, which may belong to different regional or local innovation systems, are interacting and competing for innovative and market activities, using the same tools and the same knowledge flows (Lester, 2006).

In our opinion, regional or local innovation systems result from historical, path-dependent processes, with high degrees of institutional and organizational specificities – ***the technological regimes.*** Firms are embedded in a technological regime and are defined by the level and type of opportunities for innovations, by the accumulation of technological knowledge, and by the means of knowledge transmission. The examination of the technological regime of an industry allows some predictability about the kind of enterprises which may innovate, because of the possibilities for protecting innovations, the strength of a dominant design, the nature and the continuity in the learning processes, and the *tacitness* of knowledge and the means for its transmission.

The above theoretical framing suggests that regional imbalances should be studied by means of a better understanding of the regional firms' capacity to dynamically innovate. The fact that such capacity may be quantitatively addressed and analysed helps to support the argument even further. Consequently, a key question for further investigation is to detect ***firms' innovation patterns***, sorting out their structures and handle them as ***facilitators of regional or local growth,*** eventually development.

1. A mesoeconomic Model to evaluate the structures of innovation

A multilevel model able to improve the analytical tools is required for better understanding the complexity expressed by all the determinants of knowledge and innovation outlined earlier. Figure 1 supplies the model for which knowledge assets are circulating simultaneously between the micro- and macro-levels of economic activity:

- An exterior cycle represents the global conditions for change, in general mostly related to the macroeconomic conditions for growth such as GDP, employment, taxes, rates of interest, investment climate, inflation;
- The intermediary cycle, however, reproduces the knowledge diffusion taking place at the mesoeconomic where institutional relationships occur: Institutional proximity, technological learning and regional or local conditions:
- There is a permeable boundary between the previous cycle and the next, interior one. Economic effects cross this boundary in relevant issues associated to

organizational management (entrepreneurship, strategic choices, creativity, clustering and networking) and regional policy, (political choices, governance, regulation and environmental awareness) determining an interior cycle which embodies knowledge application that may end in new products and processes. The core of the cycle illustrates a sharp microeconomic component confined to aspects such as market competition, costs, prices and marketing issues – they are the last facilitators of the success of new products and processes.

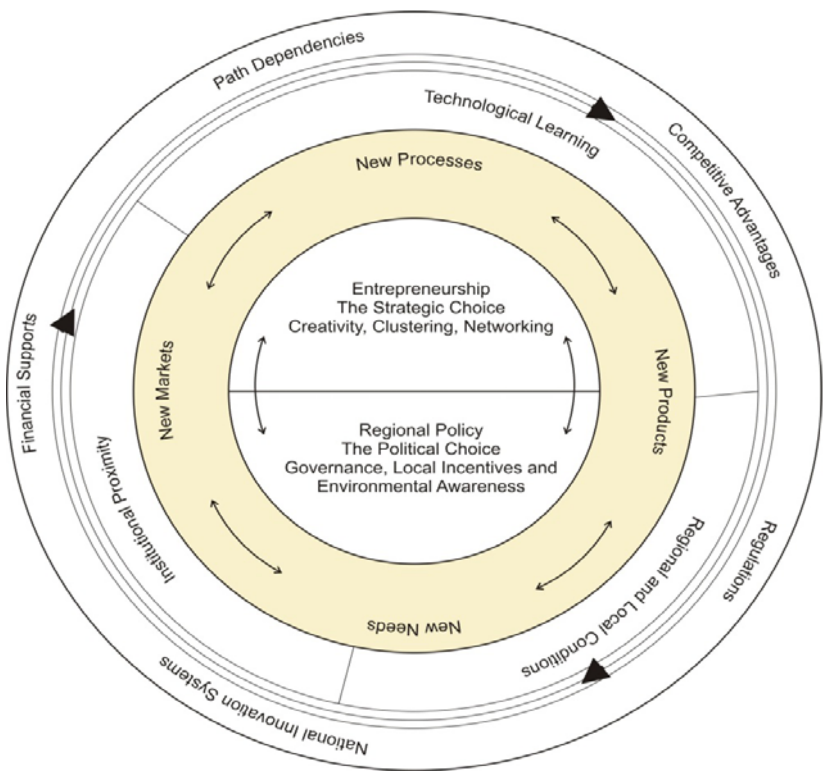

Figure 1. The knowledge circuit
Source: Noronha Vaz and Nijkamp (2009)

In this paper we concentrate our attention exclusively at the intermediary cycle, the mesoeconomic level. Our goal is to model the almost chaotic, eventually frenetic, state of relationships occurring among institutions, happening as result of the three vectors: ***proximity***, ***learning and cooperating*** when in presence of ***regional or local conditions to interact***.

We assume that firm’s proximity can be detected by a GIS application to a statistically significant sample of institutions, if possible, tracing their interaction with others actors belonging or not to the same sample. Learning and cooperating (measured as technological learning) and external conditions to interact are variables obtained by means of direct approach to institutions, either using questionnaires or by consulting the respective web-sites and with application of content analyses for the obtained primary data. In the next Figure 2, a model proposition for measuring firms’ innovative behaviour is provided, for which spatial, institutional and environmental conditions combine.

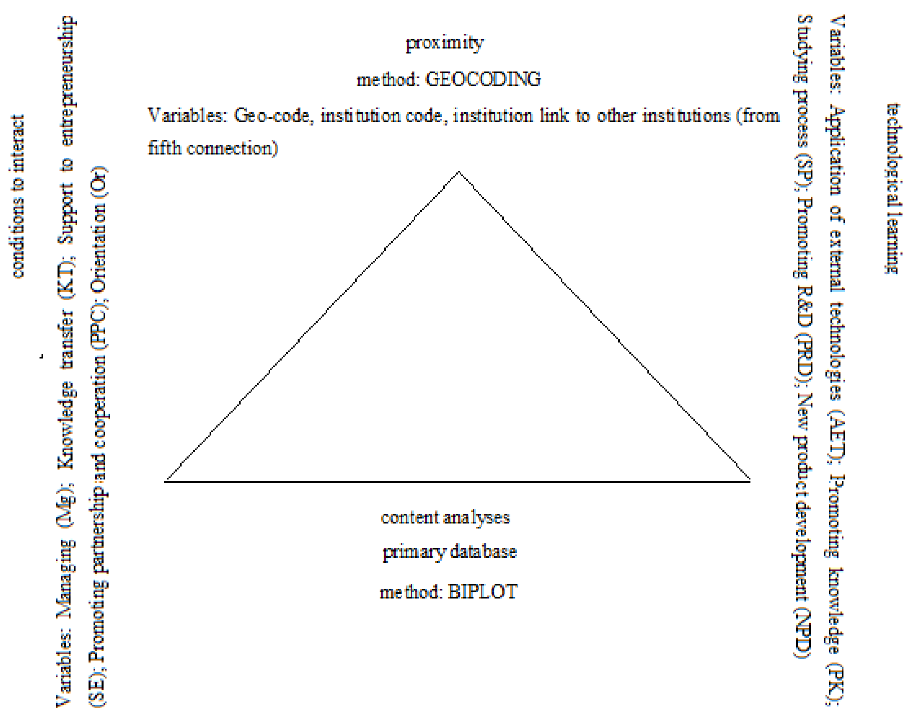

Figure 2. Firms’ innovative behaviour model (FIBE)

1.1. Application of FIBE

Our investigation applies the previous model (FIBE) to an extensive set of Portuguese private and public institutions detected by their Webpage contents on innovation: 820

Internet sites have been detected and interpreted, giving place to a filtered sample of 623 institutions (which have been considered to be able to provide reliable data through the respective websites). These institutions were classified into nine groups, each characterized by ten variables.

The selection of the variables was based on earlier developed research work (more details in Noronha Vaz and Nijkamp, 2009, for the theoretical basis, and Vicente et al., 2010, for the measurement methods). The various constructed variables are assumed good proxies of factors favouring innovation and are identified ***as attributes of innovation***. To follow our mesoeconomic model assumptions, these attributes (defined as variables in the model) have been grouped (as in Figure 2) in:

- Variables for technological learning: Application of external technologies (AET); Promoting knowledge (PK); Studying process (SP); Promoting R&D (PRD); New product development (NPD);
- Variables for improving conditions to interact: Managing (Mg); Knowledge transfer (KT); Support to entrepreneurship (SE); Promoting partnership and cooperation (PPC); Orientation (Or).

As grouping factors the following institutions, ***actors of innovation***, have been considered: governmental agencies, associations, technological parks and science centres, R&D organizations, entrepreneurship support entities, technological schools, university interfaces, financial institutes – as well as venture capitalists or high risk investors and, finally, other institutions.

As pointed out in the theoretical model, a third group of variables was built to evaluate proximity. Those resulted from Geo-coding each innovative institution[4] and respective links to other institutions with whom each institution had kept cooperation (from first to the fifth connection) of any sort for the considered period of time. All the variables have been worked out by use of two different but complementary methodologies: BIPLOT and SPATIAL CONNECTIVITY. The results have been submitted to separate analyses and discussed in different contexts. The observed time period was the year 2006, so that the analysis has a static-comparative nature.

4 Innovative institutions have been classified following the previous research inVicente et al., 2010

1.2. *The methods*

1.2.1. The BIPLOT analyses

The information used in our analysis was organized in an IxJ binary data matrix obtained from several innovation attributes, in which the I rows correspond to the above-mentioned 623 units (18 governmental entities, 297 companies, 70 associations, 20 technological parks and centres, 58 R&D organizations, 48 entrepreneurship support entities, 12 technological schools, 80 university interfaces, and 14 other entities) and the J columns correspond to the above-mentioned 10 binary innovation characteristics scored as binary variables, viz. present or absent: (PK), (SP); (Mg); (PRD); (KT); (SE); (NPD); (PPC); (AET); (Or).

The applied algorithm was described in Demey et al., 2008. In Annex 1, we go into the detailed procedure to get the External Logistic Biplot based on a Principal Coordinates Analysis, and in a second step of the algorithm, adjusting a logistic regression model for each variable as illustrated in Figure 3.

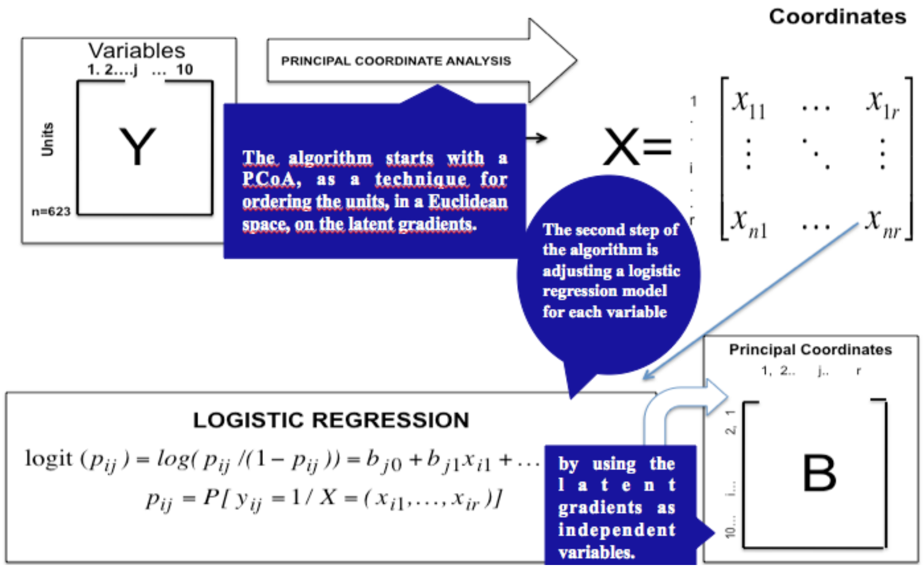

Figure 3. Steps for external logistic biplot

Source: Vicente et al., 2010

The geometric results represent the principal coordinate scores in a map where the regression coefficients act as vectors indicating the directions that best predict the probability of presence of each variable.

According to the geometry of the linear Biplot for binary data as Vicente-Villardón et al., 2006, each variable is represented as a direction vector through the origin. For each variable, the ordination diagram can next be divided into two separate areas predicting presence or absence, while the two areas can be separated by a line that is perpendicular to the characteristic vector in the Biplot and cuts the vector at the point predicting a 0.5 probability.

The characteristics associated with the configuration are those that predict the respective presences adequately. Once the coordinates of the points which represent the entities (in our case the institutions) in the plane are obtained by the External Logistic Biplot, we can apply a K-Means analysis to identify the centroids of the resultant clusters. To produce an elegant solution, we may present a Voronoi diagram of the spatial relationships.

The above described method was applied to our sample, thus eventually indicating the existing force field of the Portuguese innovation system. Figure 4A represents a Voronoi diagram of the existing spatial relationships. Four well defined clusters can be detected, each characterized by the presence or the absence of the different sets of variables. Cluster 1 is characterized by the presence of SP, AET, and NPD and absence of SE; Cluster 2 is characterized by the presence of PK, PPC, OR, KT, Mg and PRD, and absence of SE; Cluster 3 is characterized by the presence of SE, PK, PPC, OR, KT, Mg and PRD and absence of NPD, AET and SP. Cluster 3 is characterized by absence of all the indexes of innovation. By the characteristics of the firms, Cluster 1 has been identified as the one comprehending the largest number of firms, therefore the most innovative one. Figure 4B represents the regional distribution of firms of Cluster 1 for the country, showing that it is mostly represented in the region of Lisbon and Norte.

The application of this method can be extended to different observation levels, including the regional or the local level. If the provided databases are at national level and location is a variable as it should be the case, it is possible to reach the local level.

In such case the number of observations should be sufficient for the statistical application. As this is not always the case, in particular inside peripheral regions, the thickness of the entrepreneurial tissue constitutes the first major obstacle to the use of FIBE.

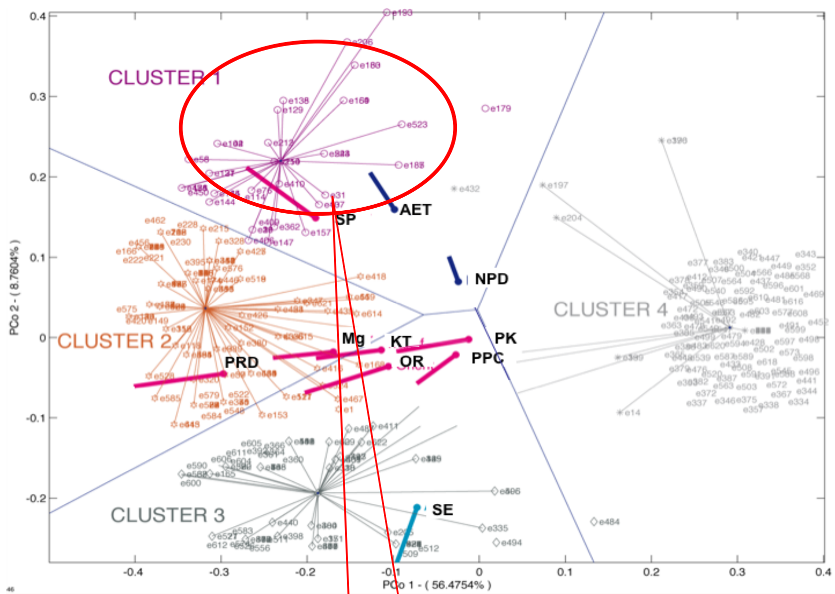

Figure 4 A. Logistic BIPLOT and Voronoi diagram representations of spatial relationships and clusters

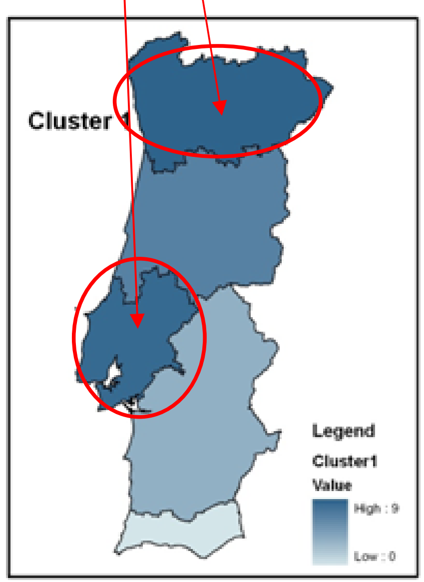

Figure 4 B. Regional distribution of Cluster 1

1.2.2. Spatial connectivity

Spatial information has enabled the possibility to understand the relations over space of different types of features (Jankowski, 1995). The spatial properties of location of activities and respective impacts are still far from being completely understood, and have developed into a complex integration of economics, mathematics and geography. A reason for this is the underlying complexity of the spatial patterns formed (Gustafson, 1998), and the connectivity established among the different agents in a complex network of interactions over space, traditionally studies in Ecology (Moilanen and Hanski, 2002).

The possibility to merge the configuration of features with networks may be assessed elegantly through generating a network which connects spatial information of features. The connectivity of features in space, allows understanding and fostering the dynamics of collaborations of innovation from a spatial perspective. This was achieved by converting the provided street addresses of the businesses into a point vector in space. The address is categorized into its locational determinants entailing its street number, street name, and postal code. This was then added into ArcGIS 10.1 where the process of spatial connectivity – correspondent to the transformation of the address into a point – was carried out. The geocoded addresses were than exported into Google Earth, to match the consistency of the location through attribute properties of the surrounding area, as well as confirmation of metadata related to the geocoded feature.

In our precise case all the institutions belonging to Cluster 1, assumed to be the most innovative one were investigated and the respective links reported till the fifth connection – considered at any geographical level (local, national or international). Because several institutions had no reported links, the sample that was used for the mapping was reduced to 37 institutions in a total of 65 point features. The point features were than aggregated into groups corresponding their partners, defining of 15 aggregated groups. These groups of points were then connected by relevance of indicated partners, allowing establishing a spatial understanding of small networks with spatial connectivity. The points thus, were then converted into line segments and projected accordingly on the map.

Figures 5, 6 and 7 define the connections found at different scales: global, national and local and report to the 50 most innovative institution in Portugal, all included in Cluster 1 and considered to be the most innovative in the country. Only a few relations are pointed out to exist between the spatial component of countries and business innovators. In fact, most of the relations even at national level are formed only above the Tejo valley, being Lisbon and Porto the main hubs for partnerships.

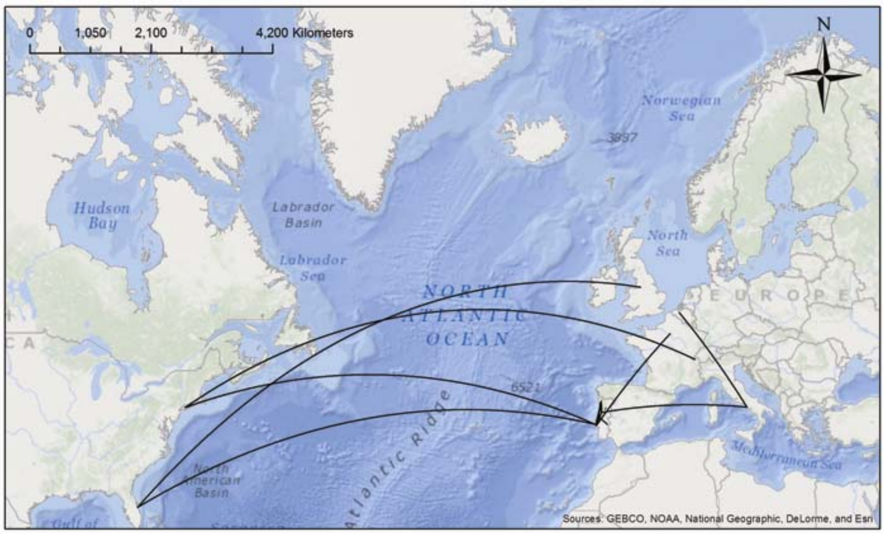

Figure 5. Flow design for international connexions

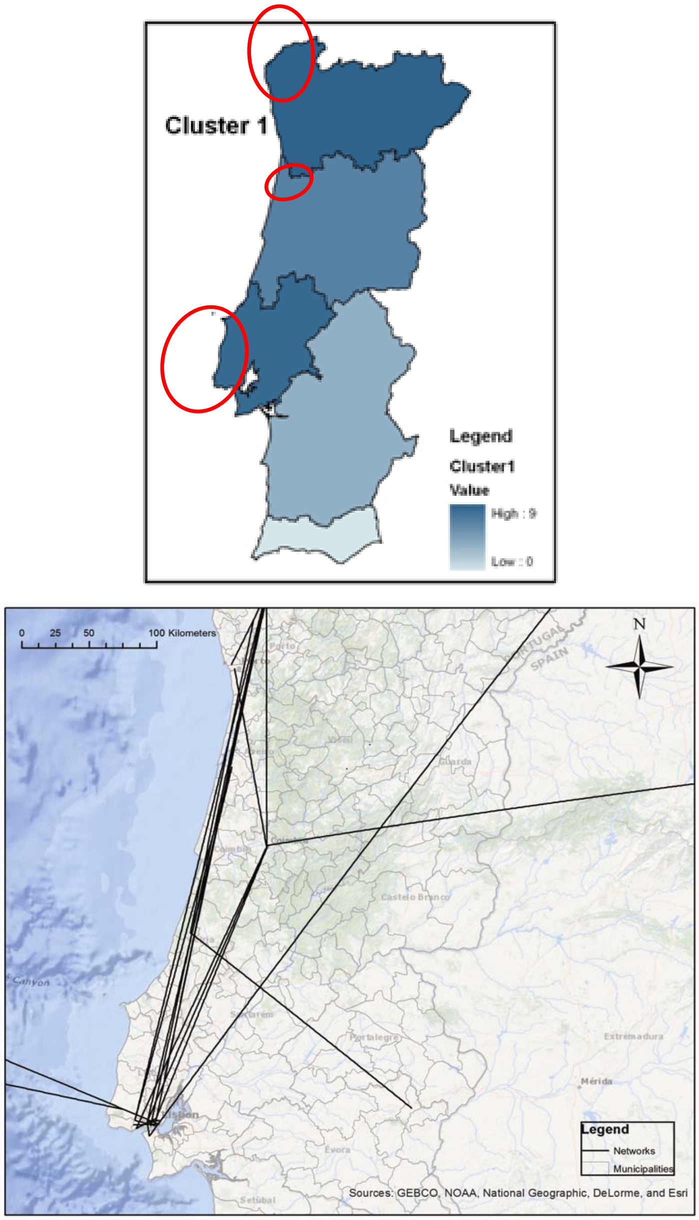

Figure 6. Flow design for internal connexions in Portugal

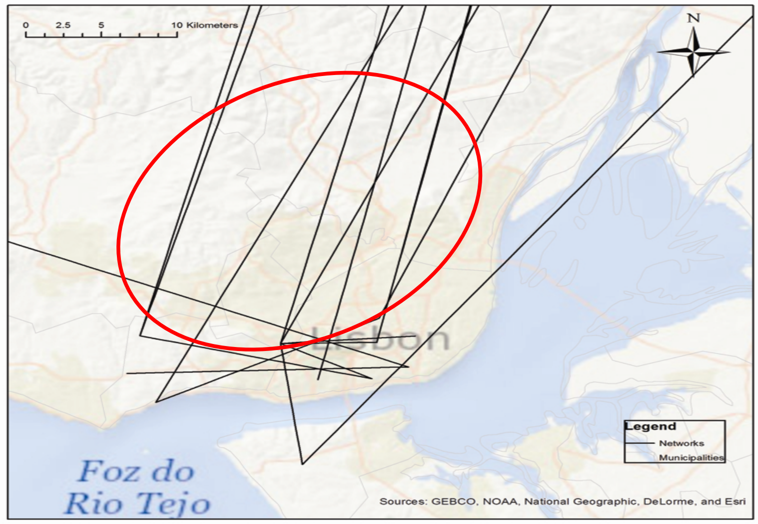

Figure 7. Details of connections in Lisbon area

2. FIBE Model results

By detecting the types of patterns of structures of innovation in Portugal, many advantages and fragilities may be identified and clearly interpreted from a mesoeconomic perspective:

- FIBE delivers a combined method able to evaluate the kind of connections underlining the innovation taking place at a certain region or country;
- In our particular case – the application for Portugal - we can confirm the asymmetric flow distribution resulting from the connections from the most innovative institutions, which have based their innovation above all on the study of processes (SP), on the use of external technologies (AET); and on new product development (NPD);
- The asymmetric distribution shows predominant flows concentrated in Lisbon area and Oporto (in this case much less intensively) that occasionally extend across Europe or to the USA. When observing the connections at country level, we may find two hubs and a small focal point in Centro Region. The method permits to pick up the individual institution responsible for this flow, searching for its innovative prospects.
- Contrarily to what was expected, not many connections start in the same point in the Lisbon region. This indicates that different institutions are able

to sustain their own innovation paths in a structure that although still not very complex or elaborated defines inter-connections at an elaborated level.

CONCLUSION

The addressed model is able to offer multiple advantages to access the performance of companies by its leaders and policy makers.

Leaders of companies or other institutions can compare their individual profiles, reproduced in a geometrical location, with that of the system average by using a simple tool, concluding whether or not they should reinforce specific measures to improve their relative positioning – this may be done by looking for a more rigorous use of the missing attributes, for example.

Also for policy makers and planners FIBE could become a powerful tool. As pointed out, this study confirms the need to implement ***tailor made policies*** to endorse innovation at regional level. Such is only possible when identifying the specific choice of attributes used by the set of companies and others institutions. The pattern they define to innovate may suggest those specific measures required to act directly on each described attribute contributing to a new concept of intervention – the **r*egional cluster-architecture***, to help focus policies for regional development.

The examination of flow designs recommends that the emergence of innovation is also a result of the flow intensity which submits the innovation processes as a spatial determinant. Therefore, major general policies to promote it will not be able to be entirely efficient if flows design is not considered. Resulting paths should be able to create some sort of path dependency; in this case, the efficiency of promoting policies in such environments should tend to increase. The contrary is to expect when no flow design emerges in the regions.

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