*World Journal of Social Sciences*
*Vol. 6. No. 3. September 2016. Pp. 27 – 46*

# How do Institutions Deal With Different Dimensions of Scientific Collaborations? An Analysis of Distance and Stability in the Co-Authorship of the Biotech Sector

Rosamaria d'Amore[*], Roberto Iorio[†], Sandrine Labory[‡] and Agnieszka Stawinoga[§]

*Scientific collaborations may present very differentiated characteristics and many dimensions may be taken into consideration. Among such characteristics, we consider the following: the spatial distance between the collaborating institutions, the institutional distance (we assume that there is institutional distance if the collaborating institutions are of a different kind), the stability of the collaborations (if they are occasional or repeated) and the content of the research (if basic or applied). We analyse what kind of relationship exists between such dimensions. The phenomenon of collaborations among different institutions (firms, universities, hospitals and research centres) is seen through the lens of co-authorship of scientific publications in the Italian "red" biotech sector. As empirical tools, we adopt some indexes built in the context of the social network analysis (the E-I index and the equivalence coefficient) usually used in different applications. This kind of analysis may highlight how knowledge flows among innovative agents and should be taken into consideration by the policy maker that aims to promote research collaboration between different institutions.*

**Keywords:** University-industry collaboration; Co-authorship; Spatial distance; Institutional distance; Knowledge flows.

## 1. Introduction

In a modern knowledge-based economy, the innovation is usually derived from a collaboration of different agents, often located in different regions or countries, and often belonging to different institutions (OECD, 1996). A rich literature underlines, on one hand, the ease given by modern information technology to distant collaborations, on the other hand, the persistent importance of vis-à-vis collaboration (Katz, 1994; Liang and Zhu, 2002; McKelvey, Alm and Riccaboni., 2003). Other scholars studied the difficulties encountered when collaborating with different institutions, particularly between university and industry, which have different research goals and incentive structure (Dasgupta and David, 1994). Nevertheless, collaboration between different innovative institutions may be fruitful in terms of quality, because of the existence of complementarities (Bonaccorsi and Thoma, 2007; Iorio, Labory and Paci, 2012). In other words, there are two kinds of distance, spatial and institutional, that represent a

[*] Rosamaria d'Amore, University of Salerno. E-mail: riorio@unisa.it
[†] Roberto Iorio, University of Salerno. E-mail: riorio@unisa.it. Corresponding author.
[‡] Sandrine Labory, University of Ferrara. E-mail: sandrine.labory@unisa.it
[§] Agnieszka Stawinoga, EURAC. E-mail: Agnieszka.Stawinoga@eurac.edu

form of, more or less, high barrier to the collaborations, which is not completely overcome by the opportunities given by the modern technologies and by the incentives given by the benefits derived, as reported above, from the cooperation with distant subjects.

This framework becomes even more complex, considering the fact that different institutions are not perfect substitutes, but each of them has specific competencies, embodied in the single individuals and in the research groups. Therefore, a partner is identified not only by its spatial and institutional distance, but also (and perhaps, mainly) by its peculiar knowledge. This last consideration does not, however, prevent anyone from identifying some regularities in the behaviour of the institutions involved in the scientific collaborations toward the management of spatial and institutional distance, which is the goal of our study; moreover, assuming that the institutions do not consider the two kinds of distance separately, but take their interaction into consideration, we also try to shed some light on the theme of the relationship between the two dimensions of the distance. Given this articulated theoretical framework, an all-inclusive view may be misleading. In our opinion, it is important to distinguish between the collaborations according to their degree of "stability": we assume that the choices of the institutions, under the aspect of distance of the partners, may be different for occasional and usual collaboration. Another distinction is also needed according to the nature of knowledge involved in the common research. This paper entails an in depth analysis of the nature of the knowledge flows between institutions, distinguishing between basic and applied research.

We observe the phenomenon of research collaboration through the lens of co-authorship of scientific publications in the Italian "red" biotech sector (biotechnology applied to life sciences). The co-authorship networks has been widely used in the analysis of scientific collaboration in different disciplines (Barabasi et al., 2002; Newman, 2004; Powell, Koput and Smith-Doerr, 1996). The biotech sector is particularly suitable for such kind of study, as it is characterized by a complex knowledge base, where the sources of expertise are widely dispersed and network relations are frequently used to access and to exchange this knowledge (Powell, Koput and Smith-Doerr, 1996).

Basing on a database, including all the publications done by the Italian biotech firms from 2003 to 2005, we build the network of co-authorship, where the institutions the authors of the publications belong to are the nodes of the network. They are classified into four categories (firms, universities, hospitals and research centres) and their localization is also registered. The main instrument of analysis are two indexes born in the context of the social network analysis, but previously adopted for different topics: the E-I index, which measures the homogeneity of links in a network (a link is considered homogeneous, if a co- authorship is between authors belonging to the same kind of institution, otherwise heterogeneous) and the equivalence coefficient, which measures the frequency of links between two subjects relative to the total number of links of the same subjects. Therefore, this paper contains both an innovation in terms of theoretical content and a methodological innovation, given by the application of such indexes in a context, where they are not frequently used.

The paper is structured in the following ways: after this introduction, in the second section, there is a review of the more relevant literature for our theoretical premises; in the third section, some considerations about costs and benefits derived from distance

are presented; in the fourth section, we present some characteristics of collaborations and joint publications in the biotech sector; in the fifth session, the used database and a descriptive analysis of the data is presented; in the sixth session, the methodology used for the analysis is illustrated, and the seventh section contains the empirical analysis (the results of the analysis and a brief discussion); in conclusion, some final considerations are made.

## 2. The Relevant Literature

The economic studies about innovative networks mainly focus on the networks involving firms and they particularly analyse the behaviour of the firms. The focus of this paper is not concentrated on the firms, but this perspective is not out of place, as we have to consider the peculiar nature of our data, which are papers involving, at least, one biotech firm. The importance of networks between innovative agents, built by firms, in order to enhance knowledge flows within and outside the firms, has been widely stressed, especially in the high tech sectors.

A number of studies have shown the structure of firms' innovative or productive networks, particularly focusing on the territorial aspects of collaborations, often related to other relevant dimensions of the collaborations; Wagner and Leydersdorff (2005) reported that there is evidence of the growth of international collaboration in science; the authors explain it using the principle of preferential attachment. They suggest that international collaboration arises as a self-organising phenomenon, whereby the selection of partners and the location of the research depend on choices made by the researchers themselves, rather than choices emerging through national or institutional incentives or constraints. This interpretation implies that the networks emerging in specific disciplines should overtime be relatively stable.

Autant-Bernard et al. (2007) analysed the role of geographical distance and of the "network effects" (the position and role in the network of collaboration) in determining the probability to collaborate in R&D projects. They also take the frequency of collaborations into consideration. They discovered that, among the firms that are involved in many projects, there is no evident influence of spatial distance on the probability to collaborate, while there is a clear influence of the firm's position within the network (number of direct and indirect partners; social distance between firms); if the firms involved in one single project are also taken into account, both geographical distance and social network effects are important. Scherngell and Barber (2011) reported that the spatial proximity increases the probability of different organizations to collaborate, but other factors may act in like manner: the thematic distance, the experience in projects of the same kind, the prior acquaintance and the centrality of the institution in the network of collaborations.

Other papers explicitly analyse the relationship theme between spatial and institutional distance. McKelvey et al. (2003), in a study similar to the present one, as they treat biotechnology in a national context (Sweden), found a trade-off between spatial and institutional distance: geographical co-location is more important for inter-institutional collaboration (firms with universities) than for collaboration among the same kind of institutions (firms with firms; universities with universities). Ponds, Van Oort and Frenken (2008) argued that both spatial and institutional distance imply a cost; as agents try to minimise costs, there is a trade-off between the two kinds of distance: the higher is the spatial distance, the lesser is the institutional distance and *vice versa*;

therefore, local networks should be more heterogeneous than international networks. They observed the co-autorship in scientific publications, in eight technological fields and their conclusion is consistent with their hypothesis.

In many papers, D'Amore and Iorio, with or without some co-authors, analysed the same database considered in the present paper and obtained several results. D'Amore et al. (2013), while comparing actual collaborations with those derived by conditional randomization, found a trade-off between spatial and institutional distance, if international and national dimensions are compared, while there is no statistical evidence of the trade-off, if regional and extra-regional dimensions (inside the same country) are compared; they also take the research nature (if basic or applied) into consideration, finding that the trade-off holds in each kind of research; another result of this paper, found using the same E-I index and Equivalence coefficient used in the present paper, is that links become closer, on an institutional point of view, when more frequent collaborations are considered. Findings of d'Amore and Iorio (2016) confirmed the institutional-geographic trade-off, considering different indexes of institutional distance end even extending their analysis of Italian biotech firm's publications for a period of fifteen years. The paper by d'Amore, Iorio and Stawinoga (2016) gives on original justification of the institutional-geographic trade-off: they hypothesize that highly specialised competencies are largely dispersed, on a geographic and institutional point of view, therefore, a firm that needs on-the-frontier knowledge activates an international and heterogeneous network of collaboration; if, on the contrary, the required knowledge is more ordinary, a local and homogeneous network may be activated. If this argument is correct, local networks should be more homogeneous than international networks. Indeed, those authors suppose that the effects indicated by the two hypotheses (trade-off and complimentarity) coexist and the predominance of one or the other may depend on other factors, like the quality and relevance of the scientific project or may be different for different kinds of institutions. In fact, they discovered that the relationship between spatial and institutional distance is inverse among rarely cited papers (supposing they are derived from research projects of limited quality or relevance), while the relationship is direct among frequently cited papers (derived from research projects of high quality or relevance). They also found that different institutions have different behaviour and attitudes towards managing the balance between the two kinds of distance.

Other papers analyse the relationship between spatial distance and the content of research: Broström (2010) finds that geographical proximity is important for short-term projects of a very applied nature, because the exchange of tacit knowledge is particularly relevant for this kind of research, while in long-term projects, it is generally easier to work across geographical distance.

## 3. Costs and Benefits of "Distant" Partnerships

Ponds, Van Oort and Frenken (2008) are of the opinion that both institutional and spatial distance imply a cost: collaborating with a distant partner (in institutional or geographic terms) is more expensive than collaborating with a near one: the collaboration with physically distant partners implies direct costs, given by transportation and communication costs (even though such costs are decreasing) and the loss of the benefits given by the face-to-face contacts, particularly important for the transmission of tacit knowledge; the costs derived from the institutional distance are given by the differences in goals, rules and values. On the other side, collaborating with an

international or a different (in institutional terms) partner may give more benefits than a local or similar one, because the former may own that knowledge not owned at a local level or among institutions of the same kind (d'Amore, Iorio and Stawinoga, 2016). There are therefore, negative (in terms of costs) and positive (in terms of benefits) incentives in collaborating repeatedly with more heterogeneous and distant partners. Indeed, looking more in depth on the front of the costs, the collaboration with a distant partner rather than with a close one may imply a higher "cost of entry", to establish a collaboration, but, once it is activated, the cost to repeat the cooperation (the "marginal cost") may be not significantly different.

Theoretical notions or empirical studies are insufficient in this research to precisely establish such differences in terms of benefits and costs; anyway such considerations may address the empirical analysis and help to interpret the results. In fact, it may be useful to assume the very simple framework of a profit maximising agent, where the collaborations are the inputs of a "production function"[1]. A very simple model will consider four kinds of collaboration (spatially close and distant; institutionally close and distant) and each innovative institution has to decide the optimal number of each kind of collaborations to activate, that is the optimal value of the inputs. Each collaboration increases the total benefits of the firms, but implies a cost. The balance between benefits and costs (more precisely, in the "neo-classical" view, between marginal benefits and costs) determines the optimal solution. It is of course possible that, for different kinds of distance, the balance between benefits and costs is different. It is, for instance, possible that an increase in spatial distance increases the benefits rather than the costs, while the opposite happens in institutional distance, generating a relationship between the stability and the spatial distance of the collaboration which is different from the relationship between stability and institutional distance. If this is true, the relationship between the two dimensions of distance, spatial and institutional, is not univocal but it may be different if we consider more stable or more occasional collaboration.

As we deal with aggregate values and we have different scales of collaborations (some institutions have few collaborations, some others have many), we do not consider the absolute number of collaborations for each institution, but a relative measure with respect to their scale of collaboration, that will be illustrated later[2]. Finally, the optimal solutions may depend on several "exogenous" factors (the parameters of the problem): we consider if and how the distinction between basic and applied research is one of these factors, therefore if it has an effect on the relationship between the elements considered above (two kinds of distance and stability of collaborations).

The above context can be summarised as follows: we consider four elements of the co-authorship: spatial distance, institutional distance, stability of the collaborations and nature of the research; we analyse the relationship between such elements; we do not formulate specific hypothesis regarding the direction of these relations, but we are of the opinion that such relations are somehow systematic, therefore, it is possible to identify some regularities. The novelty of the paper consists of the fact that, to our knowledge, such four dimensions of the relationship have never been organically and systematically considered together before.[3]

## 4. Research Collaboration and Joint Publications in the Biotech Sector

We investigate the way innovative agents deal with spatial and social distance, focusing on the co-authorship of scientific publications in the biotech sector, and within it, the "red" biotech, namely, biotechnologies with biomedical applications. Moreover, we choose a specific national context, Italy. The biotech sector is particularly suitable for a study about research collaborations involving different institutions, because it relies mostly on inter-organizational collaborations. Powell, Koput and Smith-Doerr (1996) revealed that collaboration venture networks serves as a primary institutional arrangement governing exchange and production in this sector. The idea why networks are so pervasive in this sector is also shown to be as a result of its complex and expanding knowledge base, meaning that firms' learning processes arise in networks rather than within the firm boundaries. The relevance of networks in biotech sector is confirmed by the abundance of studies, using the social network analysis in this sector. Besides the paper cited above, we remind at least Gay and Dousset (2005).

The new knowledge generated by the collaborations not only takes the form of industrial innovations, but it is often disclosed through the scientific publications: research collaborations often generate co-authored publications. Over two-thirds of even formal alliance partners in this field also appear as partners in scientific publications (Gittelman, 2005), and there is a close link between successful patents and scientific publications (Gittelman and Kogut, 2003; Murray and Stern, 2007).

Therefore, the aim of this study is to look into the characteristics of the knowledge exchanges inside a technological field; considering that data on publications are usually of high quality and are easily accessed, it is possible to study the publications of the firms. The sector used in this study is particularly interesting to distinguish types of knowledge and type of networks, because the organisation of the innovation process in this case is not straightforward, in that, it is not clear how activities aimed at understanding fundamental problems and activities orientated towards practical problems are distinguished and organised in specific networks. Therefore, an exploratory study of this kind is useful.

Regarding the geographical context of analysis, although the Italian biotech sector is not a leader in this sector, it has been perpetually growing in the last decade and Italian biotech firms have been able to build global innovation networks. Iorio, Labory and Paci (2012) showed that Italian biotech firms' networks expand both geographically and institutionally, as relationships extend in the national territory and abroad and as firms build relationships with different institutions, including universities, other research centres and hospitals.

## 5. Data

In order to build a database of scientific publications in the biotech sector, we made an intersection of two databases: *i*) RP Biotech database; *ii*) ISI Web of Science. *RP Biotech* database is a collection of all the potential Italian firms belonging to the biotech sector, active on December 2005 (d'Amore and Vittoria 2008, 2009); in this study, we considered only the 306 life-science for profit firms. *ISI* databases, especially the Science Citation Index®, and the web-based version Web of Science, is a detailed

bibliometric database of journal articles and citations of worldwide research literature, that contains 14.000 international peer-reviewed scientific and technical journals.

We collected information about publications of the selected firms across the period 2003 - 2005. The record of each publication in ISI-Web of knowledge reports, among other kinds of information, the name of the authors and the name of the institutions the authors belong to. We extracted all the publications where the name of at least one of the selected firms (Italian life-science for-profit biotech firms) appeared among the institutions of affiliation. Then, we identified five categories of institutions (universities, research centres, hospitals, Italian life-science for-profit biotech firms, other firms) and established which category each institution belongs to. In the analysis presented in this paper, all firms are considered together. Therefore we have four institutional categories.

The 115 considered firms made at least one publication during the period 2003 - 2005. The total number of publications is 1,053. The total number of the affiliation institutions of the authors is 900; besides the 115 Italian life-science biotech firms, we identified 218 universities, 289 hospitals, 134 research centres and 114 other firms. The institutional co-operation in publication is very frequent: in 918 of the total number of 1053 publications (87.18%), the authors belong to more than one institution (in the other 135 publications, the only institution of affiliation is one of the biotech firms). The average number of institutions per paper is 3.43.[4]

Based on this data, we built the network of co-authorship: the institutions the authors of the publications belong to are the nodes of the network. In order to analyse the impact of spatial distance, we divided the papers into two categories: national papers (all the institutions the authors belong to are Italian) and international papers (at least one of the institutions the authors belong to is non Italian). In our analysis, we excluded papers not written in collaboration (that is, written by authors belonging only to Italian biotech firms), therefore, we have 918 papers. Among these, 550 (60.57%) are national papers, 362 (39.43%) are international papers. Based on this classification, we obtained two sub-networks, one including all the national papers, one including all the international papers.

We also control for the research level (basic or applied) of the publication. The classification has been built by adapting the methodology developed by Lewison and Paraje (2004), who classified papers into applied and basic using a filter (list of words) of articles' titles; we prefer to classify the papers using their subjects because, altough it is a more general categorisation of papers than the specific words in the title and the subjects, they provide a fairly adequate idea of whether the research is applied or basic. We have classified all the publications of biotech firms, being biomedical or not. The choice of filter is arbitrary to a certain degree: we review different classification method (Narin and Hamilton, 1996) and analyse the single terms contained in the subject, in order to establish our filter (see Iorio, Labory and Paci, 2012, for details of the filter). Excluding the papers not possible to classify, the papers that are in a mixed category, between basic and applied research, and the papers written without collaboration, that we also excluded from the analysis, we obtained 439 papers of basic research content (259 are national papers, 180 are international papers) and 339 of applied research (213 are national papers, 126 are international papers). We were, therefore, able to build the two sub-networks of basic and applied papers, and, crossing the information about the location and nature of research, the four sub-networks (national basic, national applied, international basic, international applied).

## 6. Methodology

In order to explore more in depth spatial and institutional distance and to be able to consider other two aspects, such as the kind of research and the "strength" of collaboration in the scientific collaboration of the Italian biotech sector, we proposed the following strategy. In order to represent the data as a co-authorship network, we start with an affiliation matrix Z of size (n × m), which is represented by a bipartite graph with two sets of nodes for institutions and publications and links connecting institutions and papers written by the institutions. In the matrix Z, the generic element z(i, j) (i = 1, …, n; j = 1,…, m) equals 1 if the paper j was written by the author affiliated to the institution i and 0 otherwise. Then, to obtain a collaboration network which is viewed as a social relationship between authors and can be represented by co-authorship in a publication, we derive an adjacency matrix W (n × n) from the affiliation matrix Z by the product:

$$W = ZZT$$

The matrix W is an undirected weighted adjacency matrix, of which the value of the element w(i, j) represents the number of co-authored papers for institutions, i and j. If two institutions have no publication in common, the entries are equal to 0. The diagonal elements represent the total number of publications for each institution. If we are concerned in taking into account only the presence and absence of ties, we have to transform the matrix W in an undirected binary adjacency matrix A, by setting all entries greater than zero to 1 and removing the diagonal elements.

In order to analyse the strength of collaboration among different institutions, we take into account the information about frequency of collaboration, and we carry out further analysis on the weighted adjacency matrix W. In addition to the relational information, we associated a categorical attribute with each node: the type of institution (universities, research centres, hospitals, firms).

In our opinion, it is difficult to assess the strength (intensity) of collaboration between two institutions by simply calculating the number of papers in common (co-authorship frequency), as it also depends on how many publication each institution wrote. The co-authorship frequency needs to be normalized. In order to do it, we propose to use a similarity index, namely the Equivalence Coefficient (EqC), originally defined by Michelet (1988). This index has been used to normalize the frequency in co-word analysis (Polanco and San Juan 2006; Van Cutsem, 1994). According to the equivalence index, the degree of co-authorship between two institutions, i and j, is defined as:

$$EqC(i,j) = w(i,j)2/w(i,i)\cdot w(j,j).$$

The element w(i,j) represents the number of papers written by institutions i and j; the w(i,i) is the total number of publications of institution i. The value of this coefficient range from 0 to 1, and it is maximized for pairs of institutions which collaborated in all papers they wrote. According to this index, we indicate a "weak" co-authorship relationship between two institutions i and j, if the value of EqC(i,j) is close to 0. A "strong" relationship will be observed if EqC(i,j) is close to 1.

For the purpose of the paper, we investigate the issue of homophily by analysing the degree of homogeneity of co-authorship relations among different institutions. In this

part of analysis, the institutional distance will be seen as the heterogeneity of relations among different institutions in the network. In order to measure this aspect of relational system, we focus on the E-I index proposed by Krackhardt and Stern (1988). This index measures the relative homophily of a group, while comparing the numbers of ties within groups and between groups and it is defined by:

**E-I index = (E-I) / (E+I)**

where E (External) is the number of external ties (ties between nodes belonging to different groups); I (Internal) is the number of internal ties (ties between nodes belonging to the same group). The E-I index can be applied at three levels: the entire population, each group and each individual. It ranges from -1 (all ties are internal: E=0) to +1 (all ties are external: I=0). In our case, the groups are the four kinds of institutions. A co-authorship relation between two hospitals indicates a collaboration within the same institutional group, therefore, it is an internal link. A co-authorship relation between a firm and a university is a collaboration between two different institutional groups, therefore, it is an external link. Value of the E-I index is a measure of the mean propensity of each institutional actor to collaborate with a "different" actor, rather than with a similar one. As described above, besides the complete networks of co-authorship, we built some sub-networks dividing the papers according to the localization (national or international) of the institutions and the content of the research (basic or applied)[5].

For the purpose of the joint analysis of the four important aspects of collaboration (spatial distance, institutional distance, "strength" of the links, content of the paper), we empirically investigate what happens to the different networks if the ties of different strength (from more occasional to more stable relations) are removed. The cutoff value is defined by the value of equivalence coefficient, starting with 0.1 and considering the increment of 0.1. At each step, the networks related to matrix A have as many links as the values, in the matrix EqC, equal or greater than the cutoff value of the respective step. Furthermore, based on the binary network, we calculate the number of edges, the number of components the networks consist of and the E-I index. Finally, we compare the results of all cutting steps for all the networks.

In summary, we have the E-I index as a measure of heterogeneity of the collaborations, the equivalence index as a measure of stability; the distinction between national and international papers gives information about the spatial distance and the nature of the research is obtained through the Lewison and Paraje method. Making use of such measures and with the help of some graphics, we analyse the relationship between such dimensions of the scientific collaborations.

## 7. Results of the Empirical Analysis

As illustrated above, the basic instrument of our analysis is the equivalence index. If a paper has been written by authors belonging to two institutions (we call them A and B), an edge between A and B is built. If A and B have written more than a paper together (for example, 8 papers), the edge is weighted (the weight is 8). The equivalence coefficient calculates the relative weight of the edge, with respect to the total number of edges (papers) of the two institutions; in other words, it calculates the "relative intensity" of the co-authorship between A and B (in the following, when this index is low, we talk of "occasional" collaborations, when it is high we will talk of "stable" collaborations).[6]

Our strategy consists in analysing what happens to the different networks, if we restrict the observation to the ties of even greater strength. With regard to the complete network of 900 nodes and 1778 edges, we observed that 62.4% of collaborations are weak and can be considered occasional because the value of the equivalent coefficient edges is less than 0.1 (Figure 1). Obviously, the number of edges remaining in the network reduces, if we consider progressively higher thresholds of the equivalence index. 18.9% of the edges are above the threshold of 0.3; 15.1% of the edges are above the threshold of 0.5; 8.6% of the edges are above the threshold of 0.7; 8.3% of the edges are above the threshold of 0.9. Therefore, we observe a strong decrease when we pass from the complete network to the threshold of 0.1 (more than half of the collaborations are removed, being very occasional), then the decrease continues more slowly, becoming very limited after the threshold of 0.6.

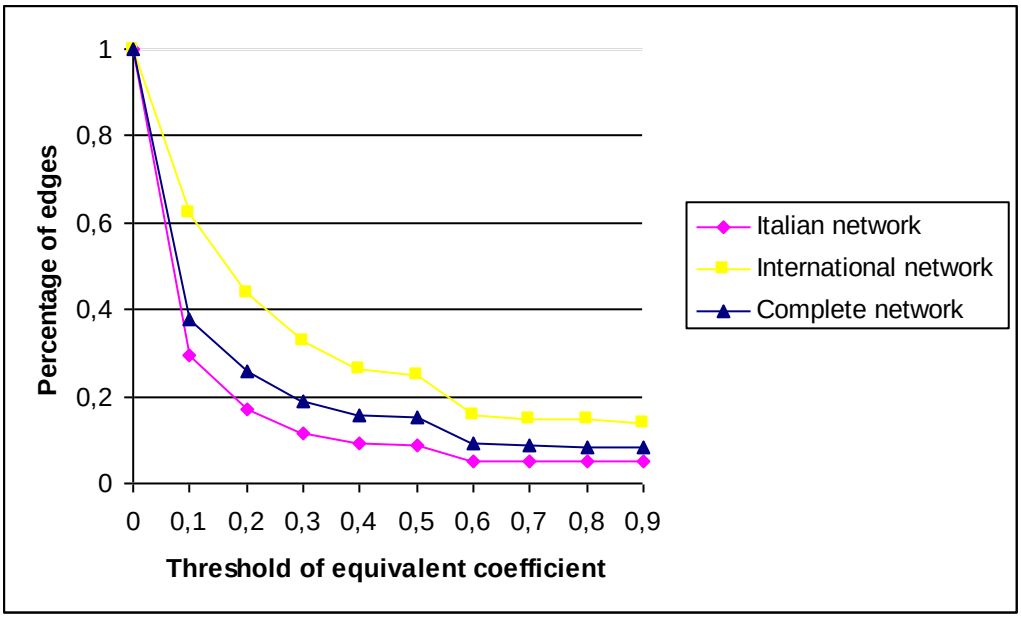
But, as the aim of the analysis is to evaluate how the agents deal with spatial distance, we conduct the same kind of analysis in the two sub-network of national and international collaborations. We observed that, in the national network (379 nodes, 1847 edges), only 29.6% of the collaborations are above the threshold of 0.1, while in the international network (668 nodes, 3079 edges), the percentage of collaborations above that value is 62.1% (Figure 1). Even considering higher thresholds, the percentage of edges that are above is always higher in the international network, even if the difference between the two networks reduces. If we consider the threshold of 0.9, in the national network, 5% of the collaborations are so intense to be above that threshold; this percentage is 13.8% in the international network.

This comparison remarks an interesting difference, that brings about the first main conclusion:

> *1. A large majority of the collaborations involving only Italian institutions are occasional, while the collaborations involving at least one international institution are significantly more "stable".*

Figure 1 shows, for the various thresholds of the equivalence coefficient (on the horizontal axis), the percentage of edges that are above that threshold (on the vertical axis), and this is shown for the complete network of co-authorship (blue line), the national sub-network (purple line) and the international sub-network (yellow line).

**Figure 1: Percentage of edges above thresholds of equivalence coefficients: complete network, national and international sub-networks**




Another aspect of our analysis relates to the "institutional distance", calculated through the E-I index. We recall that the index goes from -1, indicating a complete homogeneity of linkages (each institution has only "internal" linkages: it collaborates only with institutions of the same kind), to +1, indicating a complete heterogeneity of linkages (each institution has only "external" linkages: it collaborates only with institutions of a different kind).

The value of such index for the complete network of co-authorship is 0.346, indicating a predominance of "external" linkages.

This value is calculated considering all the co-authorships of our database. Let us now analyse what happens if we restrict our analysis to the network after removing weak relations. If we exclude the more occasional collaborations (edges with EqC equal or smaller than 0.1), the value of the E-I index decreases to 0.116, which means that stronger relations are more homogeneous. Indeed, the value of the E-I index constantly decreases if we consider even higher thresholds of the equivalent coefficient, becoming negative (it is -0.003 if we consider the edges above the threshold of 0.5; it is -0.089, if we consider the edges above the threshold of 0.9) (Figure 2).

This result enable us obtain the second main result:

> *2. More "stable" collaborations happen among more homogeneous (of the same kind) institutions; more occasional collaborations happen among more heterogeneous (of a different kind) institutions.*

Let us now move to the further point of our interest, that is the relation between the spatial and institutional distance. We obtain a measure of such relationship comparing the value of the E-I index in the two sub-networks, national and international.

If we consider all the papers (whatever the stability of collaboration) no significant difference emerges: the E-I index is 0.393 for the national network and 0.331 for the international network: considering all the papers, the institutional homogeneity is almost the same in the international and national sub-networks.

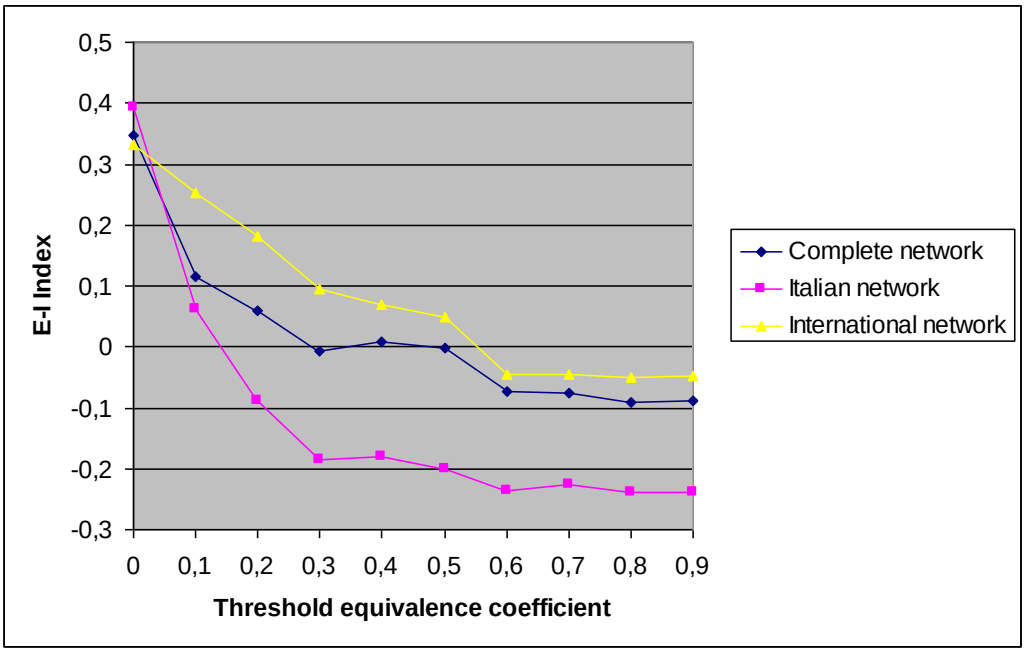
If we remove from the sub-networks the more occasional collaborations (edges with the value of the EqC less than 0.1), we observe that the E-I index is significantly higher for the international network than for the national one (0.254 vs. 0.062): among the more stable collaborations, the institutional homogeneity is greater among international than national collaborations; given the above result among all the papers, it was derived that, among the more occasional collaboration, the institutional homogeneity is greater among national than international collaborations. If we raise the threshold of the equivalent coefficients above 0.1, we continue to observe that the value of the E-I index is higher in the international networks; besides, as for the whole network, for both sub-networks, the value of the E-I index decreases continuously.

So we obtain the third main conclusion of our analysis:

> *3. Considering all the papers, no significant difference in homogeneity exists between national and international collaborations; considering more occasional collaborations, international collaborations are more homogeneous than international one; considering more stable collaborations international collaborations are more heterogeneous than national ones.*

Figure 2 shows for the various thresholds of the equivalence coefficient (on the horizontal axis), the value of the E-I index (on the vertical axis), and this is shown for the complete network of co-authorship (blue line), the national sub-network (purple line) and the international sub-network (yellow line).

**Figure 2: E-I index for different thresholds of equivalence coefficient: complete network, national and international sub-networks**

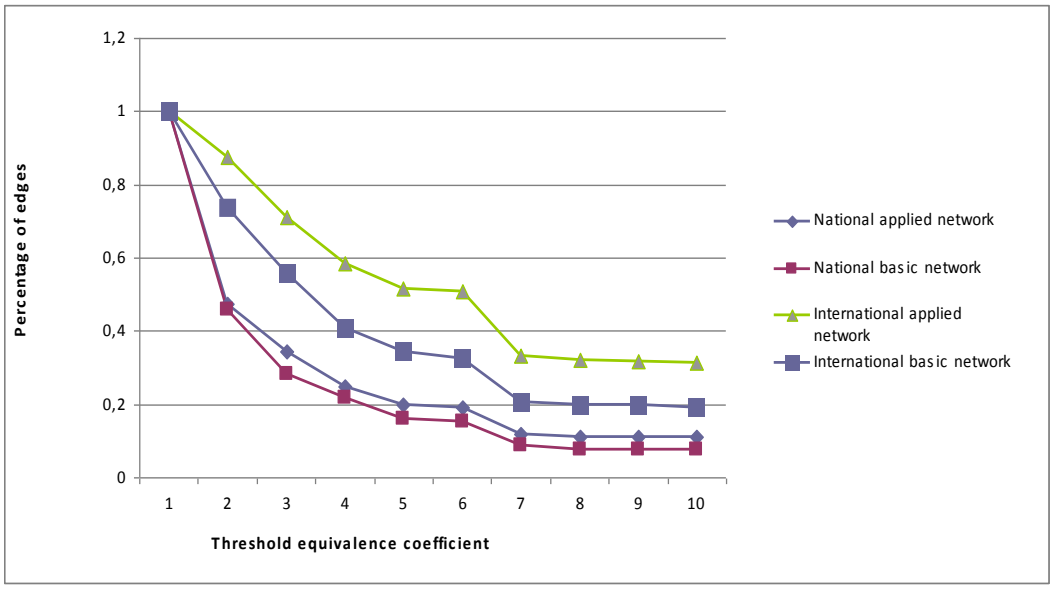



Our data let to take another dimension of analysis into consideration: the content of the research, distinguished between basic and applied one. We can therefore verify if the three propositions reported above, regarding all the papers, are still valid in the two sub-groups, identified by the two kinds of research. For this purpose, we identified four sub-groups of papers and, on this basis, we obtained four networks: national basic (196 nodes, 665 edges), national applied (261 nodes, 501 edges), international basic (387 nodes, 1399 edges) and international applied (354 nodes, 1537 edges).

The first proposition continues to hold (there is a higher proportion of occasional collaborations in the national than in the international context), with a slight difference between the two kinds of research: considering the threshold of 0.1 of the EqC, 73.8% of the collaborations in the basic-international network are above this threshold, while the percentage is 45.7% in the basic-national network. The difference is even greater in applied research: the percentage of collaboration above the 0.1 threshold is 87.6% in the applied-international network and 45.7% in the applied-national network (Figure 3). Therefore, we can also conclude that in the basic research network, there is a higher ratio of occasional collaborations.

Figure 3 shows for the various thresholds of the equivalence coefficient (on the horizontal axis), the percentage of edges that are above that threshold (the vertical axis), and this is shown for four sub-networks: national basic (purple line), national applied (blue line with rhombi), international basic (blue line with squares) and international applied (green line).

**Figure 3: Percentage of edges above thresholds of equivalence coefficients: national basic, national applied, international basic and international applied sub-networks**

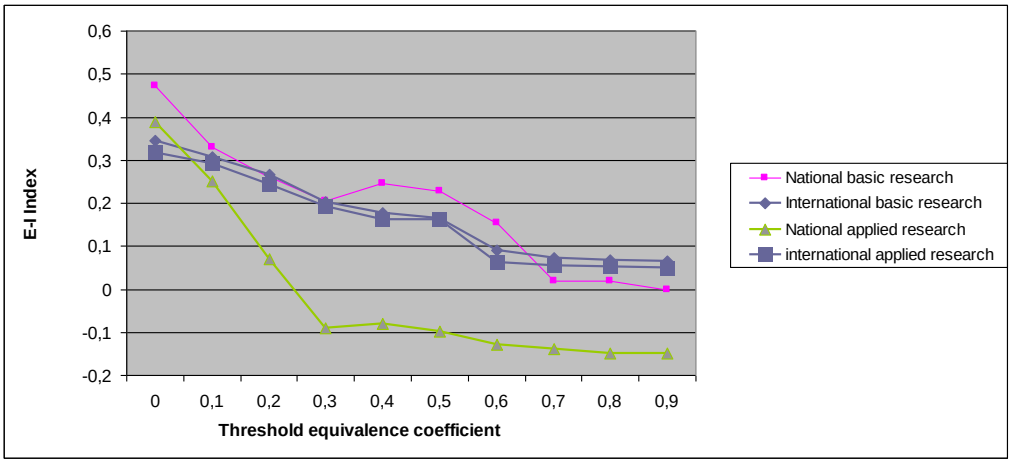



The second proposition holds for each of the four sub-networks (when the equivalent coefficient increases, the E-I index constantly decreases: the stronger ties are more homogeneous from the institutional point of view). The third proposition is valid for the applied research: if we consider all the collaborations, they are more homogenous in international ambit, but, when we consider the values of the equivalence index higher than 0.1, the E-I index of the national network strongly decreases, going below the value of the international network: when we consider the more stable collaborations, the national collaborations are more homogeneous than the international ones. For the networks of basic research, the relationship between stability of collaboration and homogeneity is not clear: for ties with the thresholds from 0.1 to 0.3, no significant difference is found between national and international collaborations; considering the stronger relations (EqC from 0.4 and 0.7), the international collaborations are more homogeneous from the institutional point of view, while the opposite holds for the strongest relations (EqC equal to 0.8 and 0.9).

Figure 4 demonstrates what is stated above: it shows for the various thresholds of the equivalence coefficient (on the horizontal axis), the value of the E-I index (the vertical axis), and this is shown in the four sub-networks: national basic (purple line), national applied (blue line with rhombi), international basic (blue line with squares), international applied (green line).

We can conclude that the distinction between basic and applied research substantially confirms the general conclusions of the previous analysis, with two further considerations: the ratio of stable collaborations in an international ambit is particularly high in the applied research; the fact that the more stable collaborations are more homogeneous in a national ambit is clearly true in the applied research, while it is less evident in the basic research.

**Figure 4: E-I index for different thresholds of equivalence coefficient: national basic, national applied, international basic and international applied sub-networks**




## 7.1 Discussion of the Results

If we look at the empirical results in the light of the third section, we discover that they are consistent with the idea that, when the scientific collaboration implies different kinds of distance, different kinds of costs prevail: collaborating with spatially distant partners implies higher "costs of entry", but once the barrier is overcome, the "cost" of each collaboration (the "marginal cost") is not particularly high, however not much higher than the costs derived from the collaboration with close partners; on the other side, the marginal benefits derived from each collaboration with an international partner is assumed to be higher than with a national one, as competencies may be found in a wider context; this may induce the agents to collaborate frequently, and this may be the reason why the ratio of stable collaborations is higher with international partners than with national one. On the contrary, the results are consistent with the hypothesis that each collaboration with an institutionally different partner implies not only a higher "fixed cost", but also a higher "marginal cost" than a collaboration with a similar partner, and this difference is not fully compensated by higher benefits; therefore, the more stable collaborations occur with similar partners.

The third result of our analysis gives a new empirical contribution to the debate about the relationship between spatial and institutional distance, clarifying that a tradeoff may be identified only in occasional collaborations, while a relation of complimentarity (more spatial distance, more institutional heterogeneity) holds, when the relations are stable. More occasional collaborations likely reflect less ambitious projects, where the attention to the cost is more important for the agents; therefore, when the cost derived from one kind of distance increases, the other must decrease; on the contrary, more stable collaborations rise for more ambitious projects, where the importance of specific competencies, that must be found wherever they are, is much more important than the attention given to the costs. Our analysis shows that these considerations, if correct, are particularly true for the applied research, where the illustrated effect are more evident than in the basic research-based papers.

## 8. Conclusions

In this paper, we explore in depth the behaviour of the institutions involved in the scientific collaboration toward two dimensions of distance, spatial and institutional, considering two other aspects: the stability of ties and the kind of research. We analyse this issue, thanks to a database of the co-authorship of scientific articles in the Italian "red" biotech sector. We start from the hypothesis that both kinds of distance imply a cost, but the collaboration with a distant, on a spatial and/or institutional point of view, partner, may also incur a benefit, as the competencies owned by the distant partner could not be owned by a close one. In order to have a deep understanding of this behaviour, we distinguish the collaborations according to their degree of co-authorship frequency, supposing that the choices of the institutions may be different for occasional and more frequent collaborations. Another aspect necessary in our opinion, for the analysis of scientific collaboration, is the nature of knowledge involved in the common research, if basic or applied.

We find a higher ratio of stable partnerships among spatially distant (outside the national borders) and institutionally close (of the same type) partners. We can interpret this result in the sense that the cost derived from each collaboration involving institutional distance is particularly high, more than the costs derived from each spatially distant pareartners. Furthermore, we discovered that, among more stable partnerships, the two kinds of distance move in the same direction (international collaborations are more heterogeneous than national one). Finally, we discovered that these results are stronger in applied research.

The contribution that this paper aims to give to the existing literature is under the profile of contents and methodology. We propose a systematic and multifaceted analysis of the complex relations between the kinds of distance, using instruments taken from the social network analysis, but usually applied in different contexts, like the equivalence index, as a measure of the stability of the relationship, and the E-I index, as a measure of homophily of linkages, therefore of institutional distance. By this, we desire to contribute to the understanding of how knowledge flows among innovative agents. We hope this contribution may be useful in designing proper policy measures in the field of scientific collaboration, that is important for the competitiveness in the contemporary knowledge-based economy.

## Attributions and Aknowledgments

This paper comes from a strict collaboration between the authors, both on the conceptual and empirical point of view. Anayway, sections 2 and 5 (except the last paragraph) have been written by Rosamaria D'Amore; sections 3 and 7 by Roberto Iorio; section 4 and the last paragraph pf section 5 by Sandrine Labory; section 6 by Agnieszka Stawinoga; introduction and conclusions have been jointly written. For many precious suggestions we are grateful to Maria Rosaria D'Esposito, Giuseppe Giordano and the anonymous reviewers of different versions of this paper.

## Endnotes

[1] Of course, we bear in mind that the substitutability among the institution is far from perfect, because, as reported previously, each of them has its peculiar knowledge. Besides, the linkage between input and output of the research is not deterministic. Anyway, this "neo-classical" view may correspond to some

really existing driving forces, particularly with an aggregate view, therefore, it may help in understanding the phenomenon under analysis.

[2] Let us assume that an institution A has 9 collaborations with close partners and 1 collaboration with distant partners; an institution B has 15 collaborations with proximate partners and 5 collaborations with distant partners and an institution C has 40 collaborations with proximate partners and 60 with distant partners. Considering the absolute values of collaborations, we should settle for a prominence of collaborations with distant partners (66 against 64). But the percentage of collaborations with proximate partners is 90% for A, 75% for B and 40% for B; with distant partners is 10% for A, 25% for B and 60% for B: considering the "intensity" of collaborations, we may conclude that this is overall stronger for proximate partners rather than for distant ones. Indeed, we will use a more sophisticated measure of the "intensity" of collaborations.

[3] The only partial exception, to our knowledge, is represented by Iorio, Labory and Stawinoga (2013), which analyses the same dimensions considered in this paper and put them in relation, but the role of stability of collaborations is marginal in the context of the paper and it never takes into account the four dimensions together, as we do at the conclusion of the empirical part of this paper.

[4] A more detailed description of the biotech sector, of the data and more statistical information may be found in D'Amore, Iorio and Stawinoga (2010).

[5] The graph of the National and International networks may be found in the Appendix; for the main statistics of the networks, see D'Amore, Iorio and Stawinoga, (2016).

[6]An example may be useful: if, given that A and B (authors belonging to A and B) have written 8 papers together, A (authors belonging to A) have written 10 papers overall, B (authors belonging to B) has written 20 papers overall, the edge between A and B has an equivalence coefficient of $8^2/10*20 = 0.32$. In this example, A have written the 80% of its paper with B; B has written 40% of its papers with A. If these percentages increase (the "relative intensity" of collaborations between A and B increase), the equivalence coefficient increases: if A and B have written 7 papers together, but A has written 8 papers overall (therefore 87.5% of its paper with B), B has written 10 papers overall (therefore 70% of its papers with B), the equivalence coefficient is $7^2/8*10 = 0.61$. The example clearly shows that the equivalence coefficient depends on the relative weight of the collaboration, not on the absolute weight (in fact, in our example, it increases even if the number of the collaborations decreases, from 8 to 7).

## References


Autant-Bernard, C, Billand, P, Frachisse, D & Massard, N 2007, 'Social Distance versus Spatial Distance in R&D Cooperation: Empirical Evidence from European Collaboration Choices in Micro and Nanotechnologies', *Papers in regional Science*, vol.86, no.3, pp. 495-520

Barabasi, A, Jeong, H, Neda, Z, Ravasz, E, Schubert, A & Vicsek, T 2002, 'Evolution of the social network of scientific collaborations' *Physica*, vol. A 311, nos. 3-4, pp. 590–614.

Bonaccorsi, A & Thoma, G 2007, 'Institutional complementarity and inventive performance in nanotechnology', *Research Policy*, vol. 36, no. 6, pp. 251-283.

Broström, A 2010, 'Working with Distant Researchers-Distance and Content in university-industry interaction', *Research Policy* vol. 39, no. 10, pp.1311-1320.

d'Amore, R & Iorio, R 2016, 'New insights on the relationship between geographic and institutional distance in research collaboration: a long period analysis', *World Journal of Management, vol. 7, no. 1, pp. 107-128.*

d'Amore, R, Iorio, R, Labory, S & Stawinoga, A 2013, 'Research collaboration networks in biotechnology: exploring the trade-off between institutional and geographic distance', *Industry and Innovation*, vol.20, no.3, pp. 261-276.

d'Amore, R, Iorio, R & Stawinoga, A 2016, 'The Effect of Research Quality and Different Institutional Behaviour on the Relationship between Institutional and Geographic Distance in Scientific Publications', *World Journal of Social Sciences, vol. 6, no. 1, pp. 1-19.*

d'Amore, R, Iorio, R & Stawinoga, A 2010, 'The Role of Institutions and Firm Characteristics in the Network of Firm Publications. An analysis of the Italian Biotech Sector through the Social Network Analysis', *World Journal of Management,* vol. 2, no. 3, pp. 81-100.

d'Amore, R & Vittoria, P 2008, 'Il nuovo settore delle imprese biotecnologiche. Fonti informative, indicatori statistici e ambiti di policy', *L'industria*, no. 2, pagg. 329-346.

d'Amore, R & Vittoria, P 2009, 'Assessing statistical standards for emerging industries. Applying OECD statistical codes to Italian biotech population lists', *World Review of Science, Technology and Sustainable Development*, vol. 6, no. 2/3, pp. 233-243.

Dasgupta, P & David, P 1994, 'Toward a New Economics of Science', *Research Policy*, vol. 23, no. 5, pp. 487-521.

Gay, B & Dousset, B 2005, 'Innovation and Network Structure Dynamics: Study of the Alliance Network of a Major Sector of the Biotechnology Industry', *Research Policy*, vol. 34, no 10, pp. 1457-75.

Gittelman, M 2005, 'What makes research socially useful? Complementarities between in-house research and firm-university collaboration in biotechnology', *Revue d'Economie Industrielle*, vol.110, no.2, pp.57-73.

Gittelman, M & Kogut, B 2003, 'Does Good Science Lead to Valuable Knowledge? Biotechnology Firms and the Evolutionary Logic of Citations Patterns', *Management Science,* vol. 49, no. 4, pp. 366-382.

Iorio, R, Labory, S & Paci, D 2012, 'The Research Collaboration and Publication's Citation Impact: Evidence in the Italian Biotech Sector', *Rivista Italiana degli Economisti*, vol. 18, no. 1, pp. 75-100.

Katz, J 1994, 'Geographical Proximity and Scientific Collaboration', *Scientometrics*, vol. 31, no. 1, pp. 31-43.

Krackhardt, D & Stern, N 1988, 'Informal Networks and Organizational Crisis: An Experimental Simulation', *Social Psychology Quarterly*, vol. 51, no. 2, pp. 123-140.

Lewison, G & Paraje, G 2004, 'The Classification of Biomedical Journals by Research Levels', *Scientometrics*, vol. 60, no. 2, pp. 145-157.

Liang, L & Zhu, L 2002, 'Major Factors Affecting China's Inter-Regional Research Collaboration: Regional Scientific Productivity and Geographical Proximity', *Scientometrics*, vol. 55, no. 2, pp. 287-316.

McKelvey, M, Alm, H & Riccaboni, M 2003, 'Does Co-location Matter for Formal Knowledge Collaboration in the Swedish Biotechnological-Pharmaceutical Sector?', *Research Policy*, vol. 32, no. 3, pp. 483-501.

Michelet, B 1988 ' *L'Analyse des Associations'* Thèse de doctorat, Université de Paris 7.

Murray, F & Stern, S 2007, 'Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the Anti-Commons Hypothesis', *Journal of Economic Behaviour and Organization*, vol. 63, no. 4, pp. 648-687.

Narin, F & Hamilton, KS 1996 'Bibliometric Performance Measure', *Scientometrics,* vol. 36, no 3, pp. 293-310.

Newman, MEJ 2004, 'Coauthorship networks and patters of scientific collaboration', *Proceedings of the National Academy of Sciences*, vol.101, suppl. 1, pp. 5200–5205.

OECD 1996, *The Knowledge-Based Economy*, Paris.

Polanco, X & San Juan, E 2006 'Text Data Network Analysis Using Graph Approach', *Proceedings of the 1st International Conference on Multidisciplinary Information Sciences and Technologies* (InSciT2006), vol. 2, pp. 586–592.

Ponds, R, van Oort, F & Frenken, K 2007, 'The Geographical and Institutional Proximity of Scientific Collaboration Networks', *Papers in Regional Science ,* vol. 86, no. 3, pp. 423-443.

Powell W, Koput K & Smith-Doerr, L 1996, 'Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology', *Administrative Science Quarterly,* vol. 41, pp.116-145.

Scherngell, T & Barber, M 2011, 'Distinct Spatial Characteristics of Industrial and Public Research Collaborations: Evidence from the Fifth EU Framework Programme', *Annals of Regional Science* , vol. 46, no. 2, pp. 247-266.

Van Cutsem, B (Ed.) 1994 '*Classification and Dissimilarity Analysis* (LNS 93). Springer.

Wagner, CS & Leydersdorff, L 2005, 'Network Structure, Self-organization and the Growth of International Collaboration in Science', *Research Policy*, vol. 34, no. 10, pp. 1608-1618.

## Appendix

The following figures (Figure 1 and Figure 2) show the graphs of the national and international network of co-authorship. Different shapes represent the different kinds of institutions (while in the previous analysis, we considered four categories of institutions, in the graphs below, there are five categories, because the Italian biotech firms are distinguished from the other firms), different colours represent different localizations (in the graph there are distinctions between Italian, European and Extra-European institutions, but in all the analysis, we only considered the dichotomization Italy-abroad).

**Figure 1: National network**

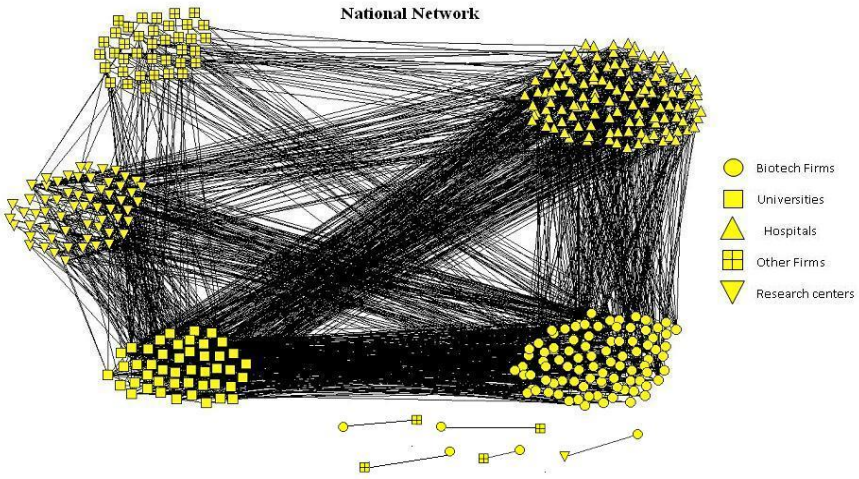



**Figure 2. International network**