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Co-authorship in Regional Science: A Network Approach

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1. Introduction

Today, "networking", "clusters" and "agglomeration effects" are catchwords in the regional science literature. Networking is particularly important in the context of innovation and knowledge creation. Therefore, it seems logical to apply the network concept also to the explanation of the creation of knowledge in the field of regional science itself. In this paper we will try to shed light on the network structure of regional science in Europe on the basis of co-authorship of the papers presented at the six ERSA conferences European Regional Science Association (ERSA) over the period 1998 – 2003. In the literature several studies can be found that deal with co-authorship in various disciplines. These studies mainly deal with the explanation of rising incidence of co-authorship over time and with the effect of co-authorship on the quality of the publications. Among the explanatory arguments for increasing co-authorship are the growing stock of knowledge, the increasing complexity of the problems to be analyzed, the strong increase in the use of specialized quantitative methods by means of computers and strategic behavior of authors. These factors are most likely also relevant for the explanation of co-authorship in regional science, but until now we are not aware of any studies that analyze the determinants of co-authorship in regional science or related fields as geography, planning or regional and urban economics. The only figure we found about co-authorship in regional science is in the Golden Anniversary Issue of the *Papers in Regional Science* (Florax and Plane, 2004, Table 3). For the papers published in this journal the average number of author's increases from 1.2 for the period 1955-1964 to 1.7 for the period 1985-1994 and to 1.8 for the period 1995-2003. If these figures are representative for regional science in general, the number of co-authors in regional science is higher than in economics in general, where the average number of co-authors in three prominent economic journals equals 1,5 by the mid 1990s (Laband and Tollison, 2000, p.635). The latter study also provides some evidence that co-authorship occurs more often in urban and regional economics.

A factor largely neglected in the existing literature on co-authorship is the spatial dimension. In this paper about co-authorship in regional science we will explicitly pay attention to spatial factors like: the role of distance and the presence of agglomeration effects, clusters and networks in the decision to cooperate with other authors. Can we identify spatial concentrations of locations of authors? Do authors in these locations mostly cooperate with each other or with authors in other locations? Are the contacts national of international? By means of formal methods for the analysis of networks we are able to identify to what extent there exists cooperation between countries, cities and individual authors. We can also detect how countries, cities and authors are connected directly or indirectly to each other and, therefore, form publication networks. The formal analysis permits also the identification of the most important nodes in the networks in terms of centrality. In this way we are able to detect which countries, cities and even authors form the centers of the network of regional science in Europe.

In the next section we will discuss the theory and methodology of the spatial dimension of co-authorship. This will lead to a series of hypothesis with explicit attention to spatial arguments. In section 3 a detailed analysis of co-authorship of the papers presented at these conferences will be provided. In these sections networks of countries, cities and individual authors will be identified. The paper ends with a section that summarizes the results and formulates conclusions relevant for the spreading of knowledge in regional science and leads to recommendations for the future developments in the field.

2. Networks of co-authors: theory, methodology and data description

In this section we will pay attention to theoretical notions and the methodology for the analysis of the spatial concentration of regional scientist and of spatial networks based on co-authorship. Furthermore, the data used in the empirical analysis will be described.

One of the goals of this paper is to identify spatial concentrations in the production of regional science research. Within the worldwide Regional Science Association International (RSAI), the European Regional Science Association (ERSA) has a prominent position. About 46% of the 1637 members of RSAI in 2003[1] are European residents, whereas the U.S and Japan each have 24% of the RSAI-members. From the Golden Anniversary Issue of the *Papers in Regional Science* we can learn that the geographical distribution of authors in this journal shows an uneven distribution over space which changes over time (Florax and Plane, 2004). The Golden Anniversary Issue of the *Papers in Regional Science* gives a global sketch of the worldwide development of regional science over about half a century. In the period 1955-1964 84% of the pages were written by authors from the US. This figure has declined to 38% for the most recent period 1995-2003. The share of Europe increases over time. In the early years the countries from Central and Eastern Europe and the former USSR were large producers, whereas in later periods countries from Western Europe dominate. Within Europe ERSA has 18 sections that cover substantially more countries, because some sections are based on a common language. Because only a small proportion of the members of sections are also members of RSAI, we may conclude that the field of regional science in Europe consists of a large group of scientists living in nearly all European countries.

For the identification of possible clusters and/or agglomeration an analysis at the city level might be more appropriate than at the country level, because of the large spatial scale and associated spatial heterogeneity. In the Golden Anniversary Issue Florax and Plane (2004) already made a start with an analysis at the cities level by presenting a worldwide top 25 of cities with a high share in author-pages published in PIRS. From this worldwide analysis we can already get a first impression of the most important European cities in regional science (see Table 1). Over the total period we see Amsterdam, London, Rotterdam and Stockholm in North-west Europe and Warsaw, Vienna and Budapest in central and Eastern Europe as cities with a high concentration of regional science production. When we look at the most recent period we see the Spanish cities Barcelona and Zaragoza in top positions. Another representative of Southern Europe is Milan. Groningen, Helsinki and Glasgow are located close to the overall top cities in Northwest Europe.

Another way to identify important countries and cities in regional science is to look at the locations of of the 45 ERSA congresses held until 2005 (see Appendix 1 for the complete list). The 45 congresses were hosted by 33 cities in 20 countries. In five countries the congress has been twice, in Austria, Denmark, England, Italy, Hungary and Poland the congress has been three times. Most often it has been hosted by The Netherlands, which in 2005 will organize the congress for the sixth time, followed by Germany with four congresses. Budapest, Krakow and Vienna are the most popular cities with three

[1] Figures obtained from RSAI Executive Director Graham Clark on July 5, 2003.

congresses each, whereas the seven cities Barcelona, Copenhagen, Groningen, London, Rome, The Hague and Zurich hosted the congress twice.

Table 1. Ranking of European cities in the worldwide top 25 according to author-pages published

Rank	1955-1964	1965-1974	1975-1984	1985-1994	1995-2003	1955-2003
1	Zagreb	London	Amsterdam	Liverpool	Barcelona	Amsterdam
2	Warsaw	Warsaw	Stockholm	Vienna	Zaragoza	London
3	Athens	Moscow	Rotterdam	Ume?	Amsterdam	Rotterdam
4	Barcelona	Geneva	Vienna	Amsterdam	London	Stockholm
5		Budapest	Laxenburg	Eindhoven	Groningen	Warsaw
6		Paris	Munich	Milan	Helsinki	Vienna
7			Budapest	Stockholm	Glasgow	Budapest
8			Karlsruhe	Athens	Milan	
9			Leeds	Groningen		
10				Laxenburg		
11				Paris		
12				Madrid		
13				Florence		

Source: Florax and Plane (2004), Table 7, p. 20.

Analysis of co-authorship

Since the beginning of the sixties there has been a rising incidence of co-authorship in many academic disciplines. This has led to a growing body of studies in which this phenomenon is analyzed. A notable example is a recent article by Laband and Tollison (2000). They focus on the analysis of co-authorship in economics, but also make a comparison with other disciplines like biology. To our knowledge there has been no study of co-authorship in the specific field of regional science, regional economics or economic geography. The only exception is, as mentioned in the introduction, the publication by Florax and Plane (2004) in which some very general statistics are reported. Some additional information can be obtained from studies of co-authorship in economics that take explicitly into account JEL code, where JEL code 900 represents urban and regional economics (but also welfare programs and consumer economics). This may shed some light on co-authorship in regional science. Before we will summarize the results of this empirical work we will give an overview of some general trends in co-authorship and will discuss theoretical arguments that may encourage or discourage co-authorship mainly on the basis of the existing literature dealing with the economic discipline. Finally we will pay attention to another spatial aspect of co-authorship, viz. the physical distance between co-authors as an explanatory variable for joint work. Until now also this spatial dimension of co-authorship has hardly got any attention as explanatory variable, besides in the studies by Laband and Tollison (2000), Hamermesh and Oster (2002) and some basic statistics in the Golden Anniversary Issue of the *Papers in Regional Science* (Florax and Plane, 2004).

Laband and Tollison (2000) show that while in the fifties only 10% of the papers published in three prominent economics journals (American Economic Review, Journal of Political Economy and Quarterly Journal of Economics) are co-authored; the share of

multi-authored papers has gone up to 70% in the nineties of the previous century. This trend is confirmed by Hudson (1996) in an analysis of eight leading journals and for regional science by Florax and Plane (2004). Several attempts have been made to explain this trend. McDowell and Melvin (1983) provide the argument of specialization. The enormous growth in the stock of knowledge in economics over time made it necessary for individual researcher to specialize. The nowadays complex problems of the functioning of regions can only adequately be dealt with by combining the complimentary knowledge of specialists. This argument is based upon Adam Smith's fundamental observation of division of labor. Hudson (1996) links the argument of complementarities also to technological factors. In the sixties the introduction of the mainframe computer stimulated the use of statistical and econometric methods in publications in quantitative economic research. This trend is further enhanced by the introduction of the personal computer in the eighties together with the increasing availability of more and more statistical software packages. Hudson finds support for the technical explanation by showing that the rise in multi-authorship in the Economic History Review is much more modest: the incidence of multi-authorship increased from 4% in the period 1950-1965 to 12% in the period 1974-1993. Economic history is clearly less quantitative and technical than economics as a whole.

Hudson (1996) argues that besides from harnessing skill complementarities the gains from collaborative work might result also "from a sort of synergy where multiple contributors develop ideas that none would have developed on his or her own. Synergy differs from skill complimentarily in the sense that it can exist between individuals with very similar skill sets. When collaborative work draws upon such complementarities and synergies, it is most likely to represent a gain in knowledge in the economics profession." As a result one may expect that papers with more authors have a higher quality than single-authored papers. Although quality can be measured in different ways, the acceptance rate of a journal and the number of citations of a published article seem to be a relevant indicator. However, from studies by Laband and Tollison (2000), Durden and Gaynor (1997ab), Medoff (2003), Sauer (1988) and Barnett et al. (1988) we may tentatively conclude that there is no convincing evidence that multiple authorship increases the quality of research output. Besides higher quality work there might be other reasons for collaboration.

Barnett et al. (1988) find empirical support for other causes of increasing co-authorship. They suggest that multiple-authorship might be the result of the increasing importance of the publication output for an individual's career pattern. Co-authorship leads to longer lists of publications and is a method for risk-spreading. The rejection of a manuscript by journals is often hard to predict and contains a substantial random element. When through collaboration n authors produce p papers the risk of rejection can be substantially lower than when p/n single authored papers are submitted. Co-authorship becomes even more attractive when through synergistic effects it leads to the production of more papers than the total production of each researcher separately. Medoff (2003) labels this as the output effect. Medoff also suggest that collaboration can be practiced for consumption reasons. Working with co-authors offers opportunities for friendship and camaraderie and is a way to escape from working in academic isolation where much academic work is of an independent solitary nature. Of course this argument applies in particular to the data we will use, because travel opportunities are almost by definition related to conference participation.

Besides possible advantages of collaboration there must also be disadvantages. Otherwise everyone would be collaborative and the number of collaborators would be very large. Hudson (1996) mentions three disadvantages. First, collaborating scholars have to compromise on the text. Especially more than two authors may even prevent the dissemination of innovative ideas when not all co-authors can be convinced. A second disadvantage of multi-authored papers is the imposed cost of organization and communication (transaction cost). Due to the recent developments in ICT the burden of this cost might have been reduced, but it still exists. A final disadvantage is that collaboration is primarily undertaken to increase the length of the list of publication in the curriculum vitae. As Medoff (2003) argues some authors may supply less effort (shirk) or only make minor or insignificant contributions to the research project (free-riders). This may increase the number of papers but at the same time reduce the quality of the publications.

Co-authorship in the discipline of regional science

As mentioning earlier in this section in absence of specific studies on co-authorship in the field or regional science we may get some idea from studies that explicitly pay attention to co-authorship in economics for JEL code 900 representing urban and regional economics (but also welfare programs and consumer economics). Laband and Tollison (2000) report that JEL code 900 shows a relatively high level of co-authored papers (coefficient significant at the 10% level). However, five of the ten other JEL codes show higher rates of co-authorship with higher significance levels. It seems that this is partly due to the rather quantitative nature of the work in this field. However, when indicators for the quantitative nature of the field are added to the model in the form of variables reflecting the presence of equations, tables, figures and appendices, the high degree of co-authorship disappears for most fields. However, the papers in JEL code 900 with urban and regional economics remains to show a high degree of co-authorship when controlled for the quantitative nature. The only exception is the model that controls for the number of tables where the JEL-code 900 becomes insignificant. This result may indicate that in the field of urban and regional economics co-authorship happens more frequently for other reasons. A possible explanation for more co-authorship in JEL 900 might be the multidisciplinary orientation and comparative aspects of the work in this field that may require collaboration of authors from various disciplines. The results of Laband and Tollison are based on a very long time period of only three journals. Piette and Ross (1992) use data for 15 economic journals of only three years (1984, 1985 and 1986) and find that the number of co-authors in JEL 900 does not differ from the reference group where three of the ten JEL codes show significantly higher and also three JEL codes show significantly lower co-authorship than the reference group.

The spatial dimension of co-authorship

Until now the spatial dimension of co-authorship has hardly received any attention as explanatory variable. Exceptions are the studies by Laband and Tollison (2000), Hamermesh and Oster (2002), and Florax and Plane (2004). Laband and Collision (2000, p.644) try to identify the factors that determine whether or not co-authors are working at different locations. Given the dramatically fallen cost of communication over time and the easy use of electronic communication media they expect that this phenomenon increases over time and this hypothesis is confirmed by a geometrically increasing time trend that is statistically highly significant. Another result worth noting is that females are

less likely than male economist to engage in long distance scholarly team production although females in general are significantly more likely to participate in teamwork. A possible explanation might be that teamwork with colleagues at other locations still requires a substantial amount of travel which is not attractive for females that often work part time or take care of children.

One might expect that in the field of regional and urban economics interregional cooperation might be more likely, for instance for comparative research requiring detailed knowledge of regions and cities, than in non-spatial fields. However, this hypothesis is not confirmed by Laband and Collison. In contrast, JEL code 900 which includes urban and regional economics, is the only field with a negative (although insignificant) coefficient, implying that cooperation by authors from different locations is less likely. Only authors in business administration and finance (JEL code 500) and in agriculture and natural resources (JEL code 700) are significantly more likely to work together with someone in another location. Hamermesh and Oster (2002) use the location of co-authors in order to test to what extend the extra cost of working with a distant co-author pays off in form of a higher quality paper. Higher quality is operationalized as the number of citations. Due to the technical improvements resulting in lower cost of distant cooperation they expect that the distant cooperation results in higher quality research but that this difference will diminish over time. However, they find that distant cooperation does not at all lead to high quality research. They conclude that distant cooperation is mainly driven by consumption effects. This view is supported by evidence obtained in personal communication of Hamermesh and Oster with the authors in the sample. Although a lot of co-authors have indeed been spatially separated for more than fifty miles for various years, they have often been friends in the past. The present paper is the first joint paper of the authors after having met each other for almost 20 years mainly at ERSA conferences and in ERSA organizational bodies. Without this we probably never would have started this paper. Working together facilitates enjoyable research activities and is a way to remain in contact with old friends and thus to maintain the personal network. In the context of the analysis of conference data this may be even a stronger explanatory argument. Attending a conference with a joint paper is a good occasion to meet again and continue working on a paper. At conferences draft papers can be presented that will not always lead to a journal publication, for instance when the long distance cooperation turns out to be cumbersome. Medoff (2003) argues that the decision to collaborate may be endogenous with the type of publication. We expect that co-authorship over long distances is more likely with the conference papers we analyze than in the case of journal articles.

The dataset

Most of the existing studies are based on the analysis of articles in prominent journals in the field whereas our analysis is based on conference papers. For our empirical analysis we use information about the annual European Congress of the Regional Science Association Since 1996 the organizers of the congresses have published a subset of the papers presented at the conference in electronic form on CD-ROM. For the congress in 1998, the software and database system conf-vienna[2] has been developed and used for all subsequent conferences.

[2] See http://www.wu-wien.ac.at/usr/iir/maier/conf-vienna/conf-vienna.html for more information on this system.

This gives two potential sources for our analysis. On the one hand the content of the databases of the various conferences, on the other hand the content of the CD-ROMs. Both sources offer advantages, but also have disadvantages. The database has the advantage to provide very detailed information about the various conferences. One can track the submitted abstracts and their authors, which abstracts have been accepted, who have registered for the conference and who have actually participated in the event. However, the various conference organizers used the database in very different ways. Some used it only for abstract submission; others did not register whether a participant actually checked in at the event. Moreover, the databases for the congresses 1999 and 2000 have been deleted from their respective servers and thus are not available for analysis any more. The CD-ROMs have the advantage that they are an official product derived from the conference. They give precise information about co-authorship, much better than the database, where the co-authors are typically recorded at the abstract submission stage. However, not all presentations at the conference are actually recorded on the CD-ROM, since the deadline for papers to be included on the CD-ROM is typically a few weeks before the congress and not all papers are available by this date. So, the CD-ROM includes fewer presentations than are usually given at the congress. On the other hand, a paper may be on the CD-ROM, but may have been withdrawn from the program in the last moment. Moreover, not all co-authors mentioned on the CD-ROM actually participate in the congress. Frequently, only one of the co-authors signs up at the event to present the paper.

In our analysis we decided to use the CD-ROMs as our basis of information. We did so for two reasons: (1) because it allows us to look at more conferences than the other information source, and (2) because the research question of co-authorship is of more importance than the question of congress participation. However, one has to be aware of the weaknesses of this dataset and take them into account when interpreting the results.

In order to be able to compute distances between co-authors of papers and between participants and congress locations, we have identified latitude and longitude of the participant's home locations. This has been done by use of the Geographic Names Information System (GNIS; http://geonames.usgs.gov/) for locations in the US and the GEOnet Names Server (GNS; http://earth-info.nga.mil/gns/html/index.html) for others.

On social network analysis

We will end this section with a brief description of the method of social network analysis that we will use to identify the (spatial) networks of co-authorship. Social network analysis is a technique for displaying, characterizing, and analyzing relationships. It builds on graph theory and combines it with concepts developed in sociology, antropology, sociometrics, etc. (Scott, 1991). The roots of social network analysis go back to the first half of the twentieth century. In recent years, it has received new impulses through the development of new, user-friendly software like Ucinet, Netdraw, Pajek, or Mage. These programs make the techniques of social network analysis easily available to researchers and partly save them the tedious task of handling complex relational data. The programs also make use of the graphical capabilities of today's computing environments.

As in graph theory, there are nodes and links. The nodes are connected by links, which may be either directed – pointing in one direction, but not necessarily in the reverse one – or undirected – always pointing in both directions. An undirected network may be used to represent marriage (when A is married to B, by definition B is also married to A), a directed network may represent sympathy (when A likes B, B does not have to like A). Since we will only deal with undirected networks in our empirical analysis, the following discussion will only focus on undirected networks. One of the major challanges of social network analysis is the adequate definition of nodes and links.

The most straight forward application of social network analysis is to plot a given network. For a large number of nodes and links, this raises the question of how the nodes should be arranged so that the picture transports the intended message. A number of algorithms (e.g., Kamada-Kawai, Fruchterman Reingold) exist for this task, but nodes can also be arranged manually or according to geographical location. Different methods for arranging the nodes create very different pictures for one and the same network.

Networks can be characterized in a number of ways. Examples are density of connections, number of links originating/terminating at a certain node, subdivisions and blocks of the network, centrality of nodes, linking of different parts of the network. For an overview and a discussion of these concepts see e.g. Scott 1991, Hanneman 2001. We will only deal with those measures that we will use in our paper.

Components are sub-networks of a network. A component contains only those nodes that are directly or indirectly connected to all its other nodes. Nodes that are not directly or indirectly linked to its nodes belong to another component. So, components are fundamental divisions of networks. They can be used to identify different groups in a social network.

The *centrality* of a node is another key concept of social network analysis. The search for the most well known or most influential players is typically operationalized by measuring centrality. However, different concepts and measures of centrality exist. *Degree centrality* is based on the number of direct connections a node has. This number of connections is called „degree“ of that node. There are variants of degree centrality that take into account not only the number of connections of the node, but also the degree of those nodes it is directly connected to. Another concept of centrality is *betweenness centrality*. It „measures the extent to which a particular point lies ‚between‘ the various other points in the graph“ (Scott, 1991, p. 89). A node may be connected only to few other, but play a central role in tieing the network together. *Eigenvector centrality* is based upon the eigenvalues and eigenvectors of the whole interaction matrix of the network. It is a concept of centrality that takes into account the full information in the interaction matrix. Because of this, however, it sometimes yields results that are difficult to interpret.

3. Analysis of co-authorship

Besides congregating at the conference site, an important element of networking in a scientific discipline is jointly writing papers for that conference. This typically involves interaction over a longer period of time between the co-authors, beginning with identifying a suitable topic and writing an abstract for the joint paper. In the next phase they have to discuss the research strategy, the theoretical concept and the method of analysis, and finally the results need to be presented in a coordinated form.

We can capture this aspect of conference related cooperation by looking at co-authorship of papers that were published at the conference CD-ROM's. In a first step we will analyse the overall numbers, in a second step we will focus on the networks underlying these numbers. In both steps we will distinguish three levels of aggregation: (1) persons, (2) cities, and (3) countries. The motivation behind this distinction is our interest in distance sensitivity. We suspect that collaboration between researchers from the same city, in practice often colleagues of the same institute, is much easier than that between researchers from different cities or even different countries. We expect a marked decline in co-authorship when we move from the individual to the city and to the country level. Since countries are of very different sizes, we will augment this analysis with one based on Euclidean distance.

3.1 Co-authorship: an explorative analysis

The following scheme (Figure 1) summarizes the categories of papers in our dataset and gives the total number of papers in each category. We see that when we extend the necessary spatial reach of collaboration (more individuals involved, more cities involved, more countries involved), the smaller the number of papers gets. This shows a clear distance effect in collaboration. Regional scientists are much more likely to write joint papers for an ERSA congress when they work in the same country, and even more likely when they work in the same city.

Figure 1: Papers with one or more authors, cities, and countries

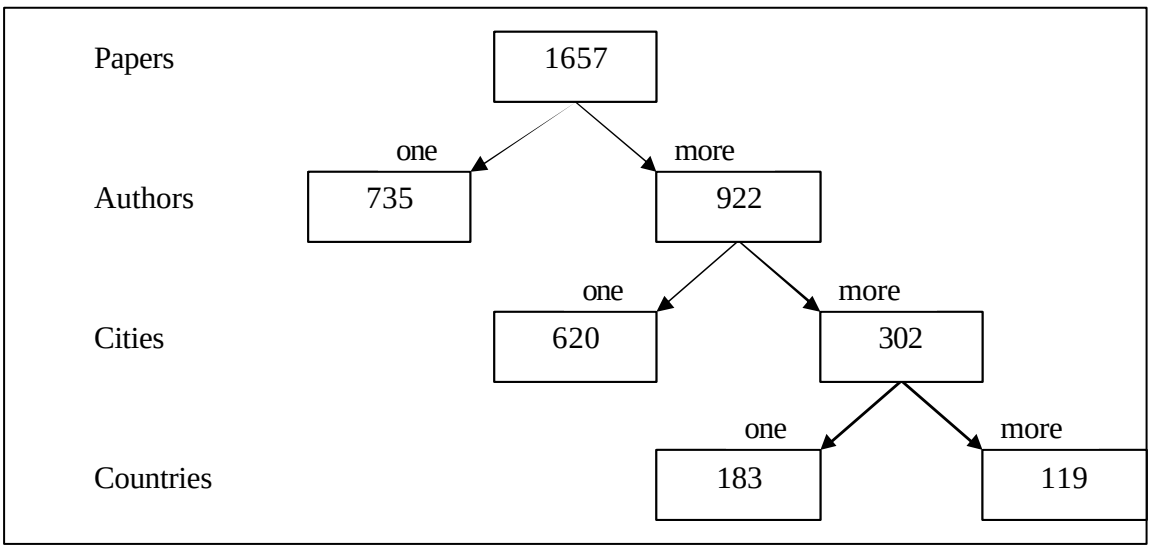


Table 2 gives a detailed overview of the co-authorship in general and by taking into account co-authorship by authors from more than one city or country. Of the 1657 papers in our dataset over the whole time period 735 (44%) are single authored and 922 (56%) co-authored. In average there are 1.82 co-authors per paper. As can be seen from Table 2, the maximum number of authors for one paper is 6. Close to 80% of the papers have one or two authors.

Of the 922 co-authored papers, less than one third (33%, 302 papers) involve authors from more than one city. For 620 co-authored papers all the co-authors come from the same city. This difference supports our hypothesis that distance between researchers constrains their collaboration. Only in 27 of the papers co-authors from more than two cities are involved. Compare this with the 337 papers with three or more co-authors. The largest number of cities involved is four. Over the period of our six conferences, four such papers can be found. In average, over all co-authored papers, 1.37 cities are involved.

Table 2. Co-authorship in general and by authors from different cities and countries.

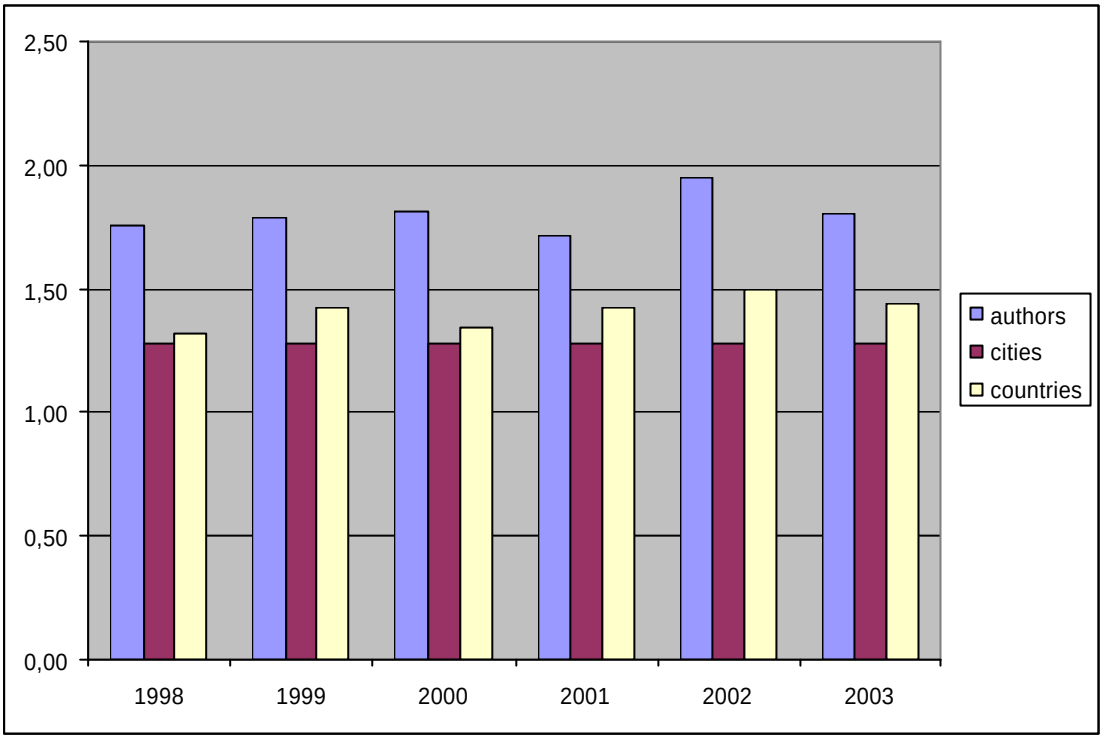
Number of authors, cities or countries	**Co-authorship**		**Co-authorship with other cities**		**Co-authorship with other countries**	
	Number of papers	*Percent of papers*	*Number of papers*	*Percent of papers*	*Number of papers*	*Percent of papers*
1	735	44%	620	67%	183	61%
2	585	35%	275	30%	112	37%
3	264	16%	23	2.5%	6	2.0%
4	60	3.6%	4	0.4%	1	0.3%
5	11	0,7%				
6	2	0,1%				
Total	1657	100%	922	100%	302	100%

Of the 302 papers with authors from different cities that we have identified above, 183 (61%) involve authors from only one country. International collaboration (authors from more than one country) can be found in only 119 papers. They represent 13% of the co-authored papers and 7% of all the papers in the dataset. In average over all the papers with authors from more than one city, 1.42 countries contribute to a paper. Multinational collaboration (authors from more than two countries) can be found in only seven papers (2.3% of papers).

As we see from Figure 2, the average number of authors per paper has not changed much over the years. The lowest number can be found in 2001 with 1.72 authors per paper, the highest a year later with 1.95 authors per paper. The average number of cities involved varies between 1.28 and 1.42 and for countries this is slightly higher with a variation ranging from 1.32 till 1.50. Over the years the pattern of the average number of cities and countries is very much the same. The minimum (1998, Vienna) and the maximum (2002, Dortmund) are in the same year for cities and countries. Although the differences are small, it seems that the number of cities and countries involved increases slightly more over time than the number of authors indicating an increase in interregional cooperation.

From the detailed information provided in Appendix 2 we can conclude that the number of papers with various numbers of authors in the individual years pretty much follows the overall trend. Besides the differences in the total number of participants, that we have already discussed above, the only interesting exception is the year 2002 (Dortmund), where we find more papers with two authors than single authored papers.

Figure 2. Average number of authors, cities and countries per paper



3.2 **Co-authorship: an analysis of networks**

Thus far we have only looked at the numbers of papers in the various categories. The question arises, of course, who are the countries, cities, and individuals primarily involved in this collaboration? We will deal with this question in the following subsection. For this task we will use social network analysis as discussed in section 2. This method can not just produce nice and illustrative pictures, it also generates indicators about the structure of the network that can either be reported as statistical measures or used for displaying these aspects of the network graphically. Since it becomes more and more difficult to understand such networks with increasing numbers of nodes and links, in this subsection we will proceed in reverse order than before, i.e., from countries to cities and finally to authors. We deal with symmetric one-mode networks. The nodes are countries, cities, and individuals, respectively, the links are always numbers of co-authorships. Number of co-authorships differs from the number of co-authored papers in the sense that when a paper has been written by one Dutch and two Swedes, it yields two co-authorships between Sweden and the Netherlands (although there is only one co-authored paper involved).

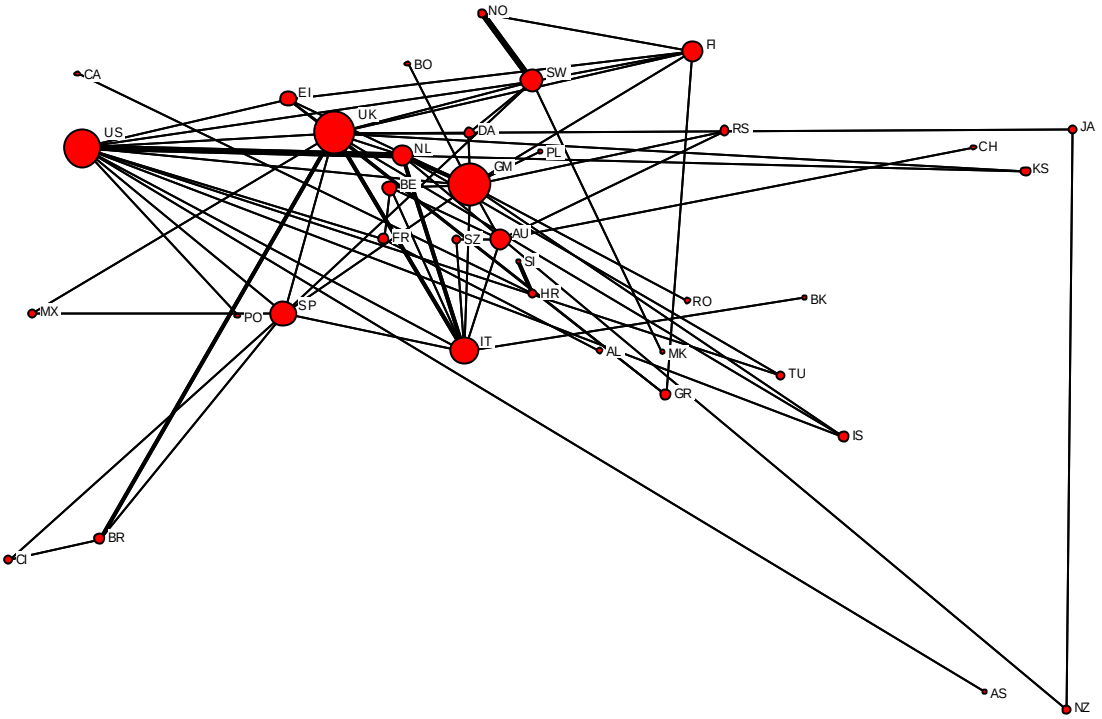
Analysis by country

Let us start by looking at publications with authors from more than one country. This links 37 of the 52 countries in the dataset (see Appendix 3). Fifteen countries are not connected with any other country and are, therefore, not included in the network analysis. These countries are: Argentina, Egypt, Estonia, Czech Republic, Hungary, Indonesia, India, Latvia, Lithuania, Slovakia, Luxembourg, Morocco, South Africa, Taiwan and Ukraine. The other 37 countries form two components, one small one consisting of Canada, Croatia and Slovenia, and a much larger component of all other countries. In Figure 3 the nodes representing the 37 countries are allocated roughly according to their geographical location. The size of the nodes represents the degree of connectivity and the width of the links the number of co-authorships.

From Figure 3 we see a clear core-group of countries, namely the UK (UK), the US (US), Italy (IT), the Netherlands (NL), and Germany (GM). These countries have the largest number – more than 20 – of connections (degree represented by the size of the node). The strongest links (twelve co-authored papers) exists between The Netherlands and the US on the one hand, and between Sweden (SW) and Norway (NO) on the other. The link between Italy and The Netherlands is based upon ten papers. The same number of papers exists between Croatia (HR) and Slovenia (SI). When we lower the threshold to eight co-authored papers, Germany gets connected to the Netherlands, the UK to Italy, and Brazil (BR) to the UK. The countries form three separate components (NO-SW, HR-SI, GM-NL-IT-UK-US-BR) that are connected only by weaker ties. The first and third components get connected by links representing five papers. These links form between the US and Sweden. In addition to that, the group of countries is enlarged by Greece (GR), Ireland (EI), and Spain (SP), all getting connected to the UK. When we lower the threshold to four papers, we add Austria (AU), Switzerland (SZ), Finland (FI), Israel (IS), Portugal, (PO), and Turkey (TU).

Since the network is arranged roughly according to geographical structure, the strong ties between some (West- and Central-) European countries and across the Atlantic become obvious. The ties to Eastern and South-eastern Europe, Asia, and Australia / New Zealand are quite weak. As compared to its high share of active participants, the weak connections of Spain (SP) are interesting and quite surprising.

Figure 3. Structure of the largest component of 34 countries of the ERSA-network



Analysis by cities

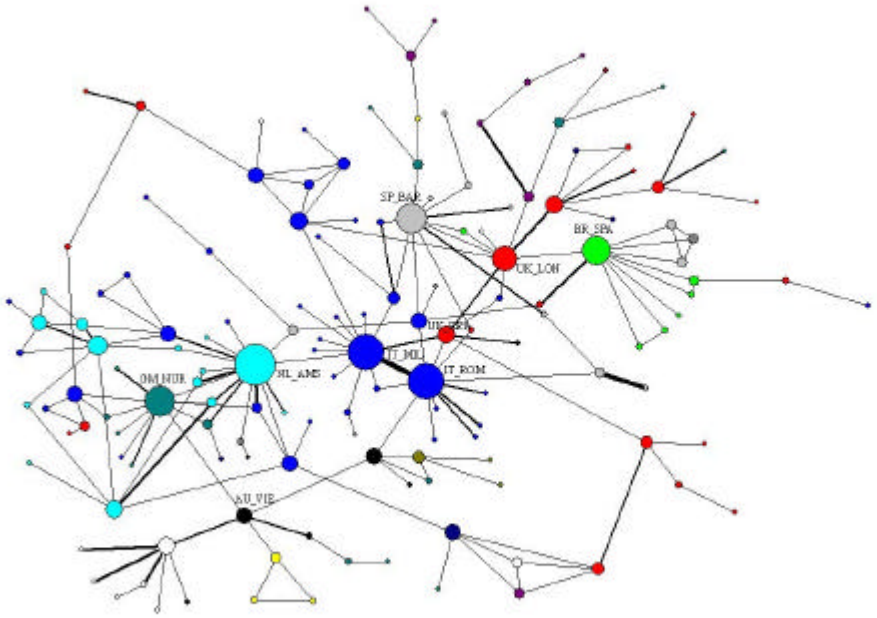
As we know from our previous analysis, many of the co-authored papers are written by authors from the same country. Let us widen our perspective and look at papers written by authors coming from more than one city. The structure and components of this network are depicted in Appendix 4. In this case, the nodes of our networks represent cities; the links are again the number of co-authorships. Since some of the different cities are also located in different countries, the networks in this section contain the connections of the previous networks as subsets. In the dataset 429 cities are represented, of which 271 are connected to at least one other city. 158 cities remain isolated. Contrary to the network by countries, where we had only two components, the network by cities is broken up into many components. Within the network we can count 46 components, most of them, namely 31, connecting only two cities. The number of components of various sizes is listed in Table 3. Half of these components contain only cities from one country; the other half spans country borders.

Table 3. Components of the ERSA co-author network for *cities.*

Size of Component	Number of Components
2	31
3	8
4	3
5	2
13	1
150	1

The largest component ties together 150 cities. It is clearly the core component of the ERSA-network by cities. Its network is displayed in Figure 4. In this graph the colour (shading) of nodes identifies countries.

Figure 4. Structure of the core component of the ERSA-network by cities



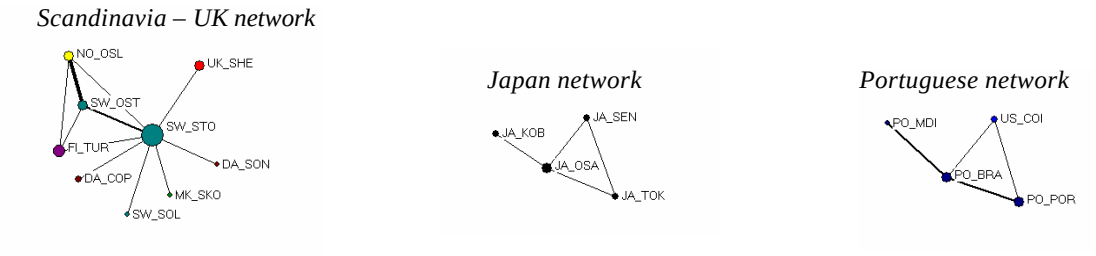
We have marked the most important nodes. These are clearly Amsterdam (NL_AMS), Milan (IT_MIL) and Rome (IT_ROM). They are among the top four nodes with respect to all centrality measures. These three cities form a strong core, each of them connecting to many other cities. Most of the cities they connect are from their own country. Amsterdam is clearly the key node that ties together the Dutch cities and connects many of them to the rest of the network, in Italy this function is split between Rome and Milan. In Spain, this role is played by Barcelona (SP_BAR). A few cities serve as gateways for a set of other cities connecting them to the core part of the network. Those cities are London, UK (UK_LON), Reading, UK (UK_REA), Nuremburg, Germany (GM_NUR), and Vienna, Austria (AU_VIE). Together with the core cities Amsterdam, Milan, and Rome they reach the highest scores in betweenness centrality. Sao Paulo in Brazil is an

important node outside Europe in this network. It serves as a gateway to other Latin American cities.

Some of the countries in our dataset are not connected at all to the core component of the cities network. These are those countries that do not show up in the countries network (listed above), Canada, Croatia, and Slovenia, which formed a separate component in the countries network, and seven more. The seven countries which belong to the main component of the country network, but are isolated from the core component of the cities network are: Albania, Bosnia and Herzegowina, Belarus, Denmark, France, FYR Macedonia, and Portugal. With France and Portugal two countries with strong ERSA sections do not belong to the core component of the cities network.

While the core component contains 150 cities, the next components in size are much smaller. The second largest links 13 cities, at number three are two components with five cities each. Their respective networks are displayed in the graphs Figure 5.

Figure 5. Structure of three medium sized components of the ERSA-city network



The first component (left) is the second largest in the network and consists of 13 cities. With two exceptions all these cities are located in Scandinavia and the UK. The two exceptions are Skopje, FYR Macedonia, and Norman, OK, USA. Also the other two components have a clear spatial dimension. The second component (middle) consists of only Japanese cities, with Osaka being its centre, the third component (right) contains four cities from Portugal and Columbia, SC, USA. Its centre nodes are Braga and Porto. These observations show that collaboration in ERSA is strongly influenced by distance and country. Relations of co-authorship typically tie together a small set of cities with no connections to others.

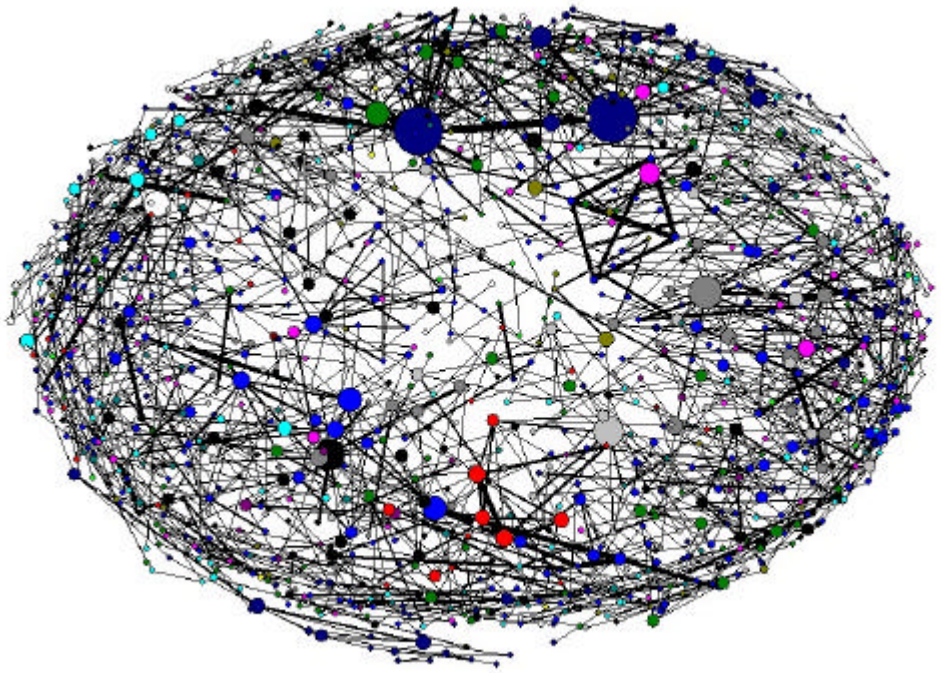
Our analysis by city shows a clear differentiation between core and periphery in the ERSA co-authorship network, when we analyze it at the city level. When we compare the outcome of the analysis of the network of cities with the cities that are in the top 25 as locations of authors publishing in PIRS (see Table 1) and with the cities that are centres of regional science as host of the European congress (see Appendix 1) the following cities can be identified as the main centres of regional science in Europe: Amsterdam, Barcelona, London, Milan, Rome and Vienna.

Analysis by authors

The most detailed and most direct level of analysis of the ERSA publication networks is at the level of authors. In the end, it is individuals, not cities or countries that collaborate

in order to give a joint paper at one of the ERSA congresses. Figure 6 shows the network with the full set of papers. The size of the nodes gives again the degree, the width of the links the number of joint papers. The colour (shade) of the nodes represents the countries.

Figure 6. Structure of the ERSA-network by author



Because of the large number of authors (1459) it is difficult to see much structure in this network. To get a clearer picture, we divide it into components. As it turns out, the network has 396 components. Almost half of them link only two authors. Size and number of all components is given in Table 4. The largest component connects 91 nodes. In 243 (61%) of those components all the authors come from the same city, in 330 (83%) of the cases from the same country.

Table 4. Components of the ERSA co-author network for *authors*.

Size of component	Number of components
2	192
3	87
4	50
5	20
6	15
7	8
8	6
9	4
10	2
11	3
12	1
15	3
16	1
17	1
22	1
27	1
91	1

In the remainder of this section we will extensively discuss the four largest components with at least 17 cities. Also the medium sized components with 15 and 16 cities will be described in more detail. There are marked differences and in most case places and/or individuals who represent the respective component of the network.

The Dutch network

The largest component (91 nodes) of the author's network is displayed in Figure 7. It can be called the Dutch network, the Amsterdam network or even the Nijkamp-Rietveld network. The two largest nodes – i.e., nodes with the highest degree – represent Peter Nijkamp and Piet Rietveld. They connect a large number of authors to their network, many of them from the Netherlands. Almost 65% of the authors (59 out of 91) connected to this network are from the Netherlands, 33 of them from Amsterdam. The strongest foreign links are with Germany (11) and with the US (10).

The size of the nodes in the graph reflects the degree of this node, i.e., the number of links connected to this node. This is a rather crude measure of centrality. However, the dominant position of Peter Nijkamp and Piet Rietveld also shows up when using more sophisticated centrality measures. In addition to the number of immediate neighbours, closeness centrality takes into account the distance of a node from all others in the network component. Also with respect to this measure Nijkamp and Rietveld clearly occupy the top two positions. The same holds for betweenness centrality, a measure which focuses on the number of connections running through a certain node.

Figure 7. The Dutch network

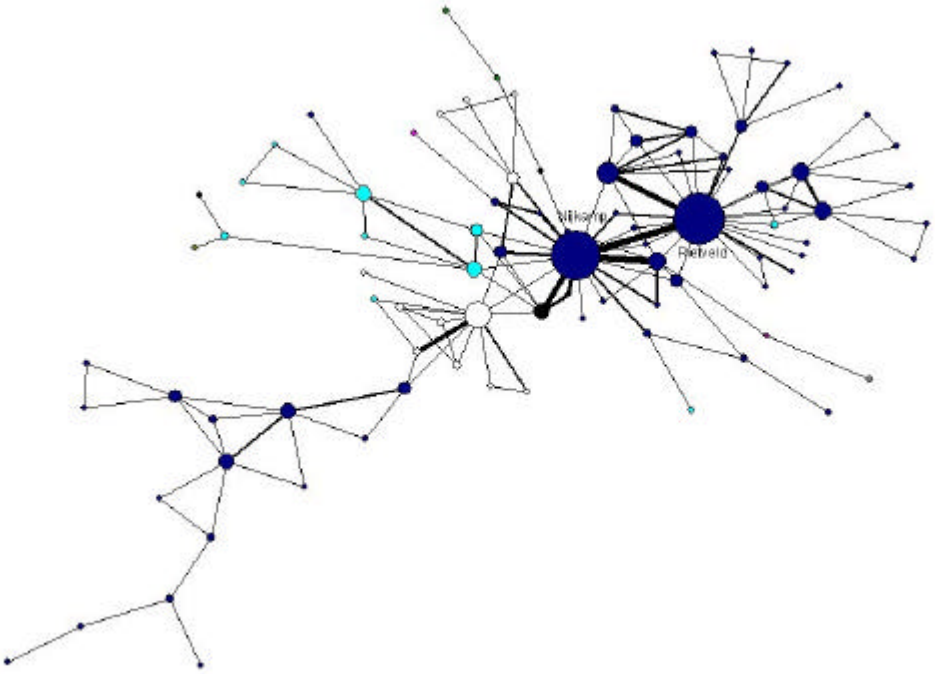
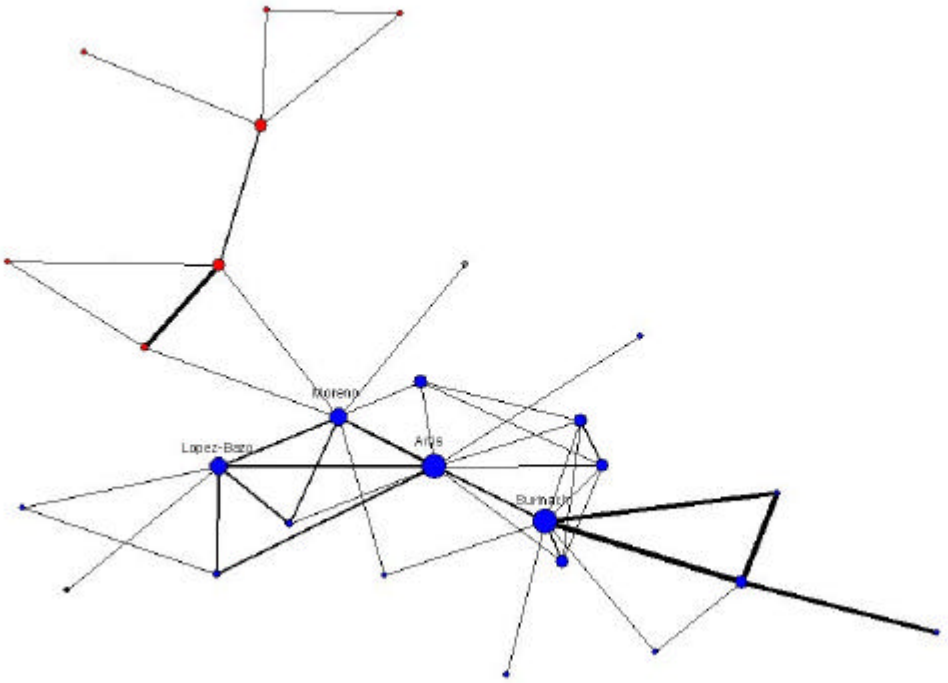


Figure 8. The Barcelona network



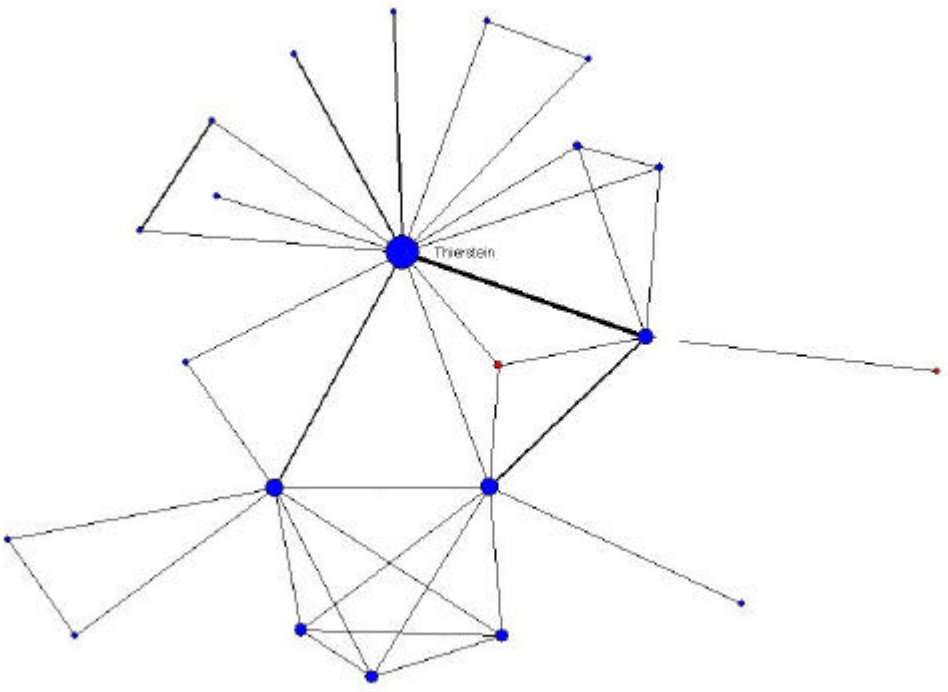
The Barcelona network

The second largest component of the authors' network contains 27 nodes. It can be called the Barcelona network and is displayed in Figure 8. In this network 18 of the 27 authors are from Barcelona. No other Spanish city than Barcelona belongs to this network. The nodes to the left of the graph are Italian, five of them from Cagliari. This network is much less dominated by one or two individual nodes than the previous one. The author with the largest number of connections (highest degree) is Jordi Surinach. According to closeness centrality and betweenness centrality, the most central person is Rosina Moreno. Based on the eigenvector, Manuel Artis is the most central author in this network.

The Swiss network

The third largest component as shown in Figure 9 consists of 22 nodes representing 20 Swiss and two Austrian authors. This network is clearly centered at one author, Alain Thierstein. He reaches the highest values in all indices.

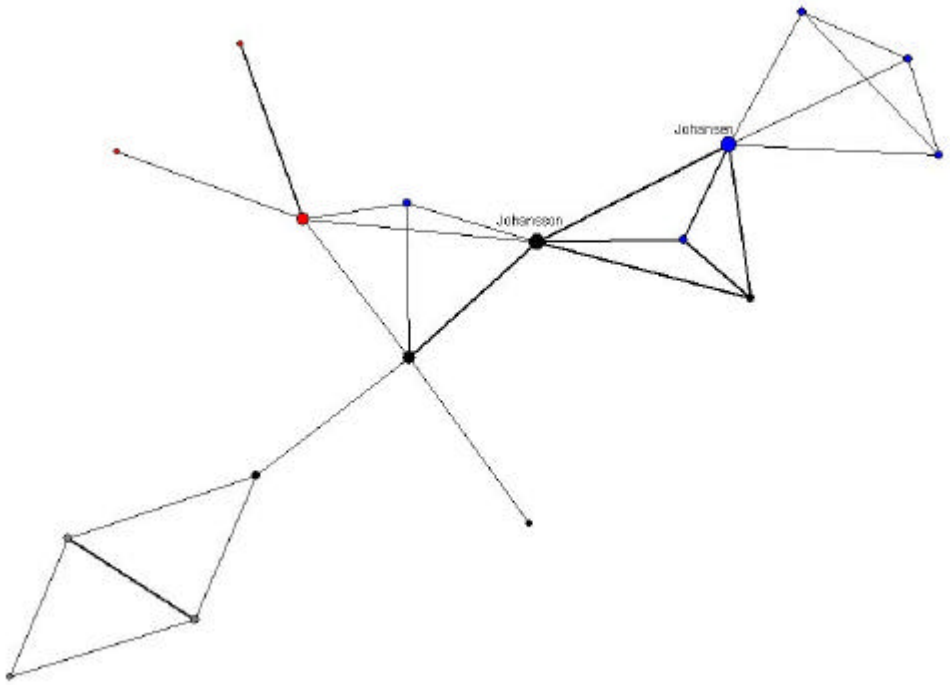
Figure 9. The Swiss network



The Scandinavian network

The fourth largest component shown in Figure 10 consists of 17 nodes, 14 of them from Scandinavian countries. Six authors are from Norway, five from Sweden, and three from Finland. The three non-Scandinavian authors are from the UK. The most central author by all indicators is Mats Johansson from Sweden. As far as degree centrality is concerned, he shares first place with Steinar Johansen from Norway.

Figure 10. The Scandinavian network



Four additional networks

We will briefly describe the next four components of the author's network, without displaying them graphically. One of these networks has 16 nodes; the remaining three have 15 nodes each. The main characteristics of these networks are summarized in the Table 5.

Table 5. Main characteristics of the four smaller networks.

Name	**Size**	**Composition**	**Most central author**
Patras network	16	Patras, Greece (10), Dublin, Ireland (3), Aberdeen, UK (2), Seinajoki, Finland (1)	Dimitris Skuras (Patras)
Milano network	15	All Italy: Milano (5), Torino (3), Rome (3), Bergamo, Parabiago, Monza, Pisa (1 each)	Giovanni Rabino (Milano)
UK-Israel network	15	London, UK (3), Belfast, UK (3), Haifa, Israel (3), Karlsruhe, Germany (2), Limerick, Galway, Ireland, Birmingham, Kingston, UK (1 each)	Stephen Roper (Belfast)
London-Volos network	15	London, UK (6), Volos, Greece (5), Milano, Ancona, Segrate, Italy, Sao Paulo, Brazil (1 each)	Andres Rodriguez-Pose (London)

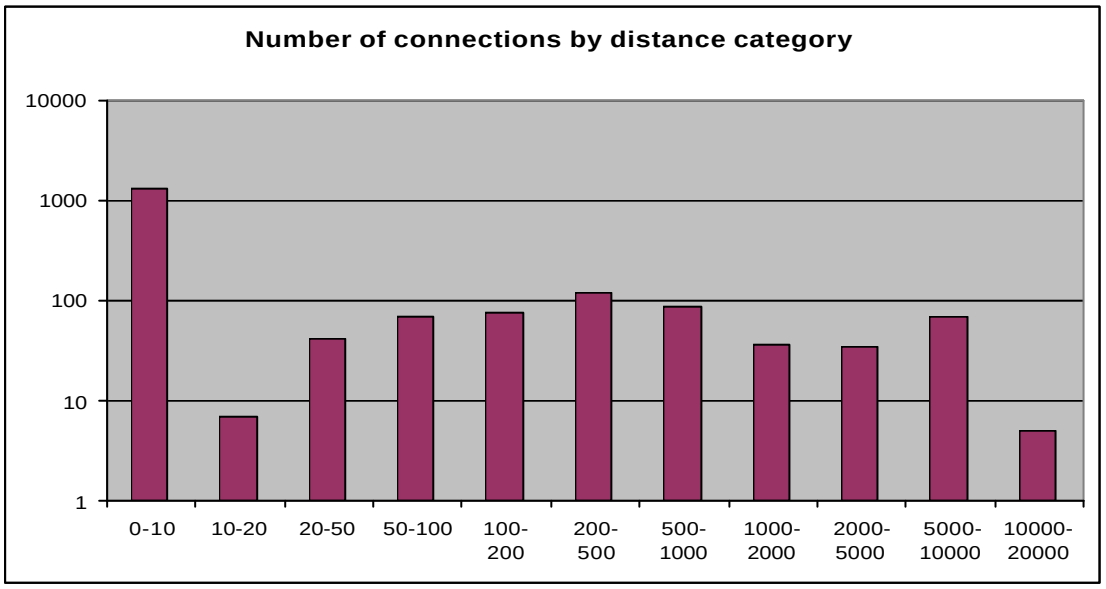
We can see some interesting differences between those networks. The Milano network ties together different cities in Italy, but no locations outside of Italy. The Patras network, for example, connects Greece, Ireland, UK and Finland, but in each of the countries only

one city. No Greek author outside Patras belongs to this network. Authors from Volos, Greece, belong to a different component, the London-Volos network.

Distances

The cooperation's by authors that we have analyzed above, cover quite different distances. We have already seen the differences in the networks when we switched between analysis by author, city, or country. Since we know the locations of the authors and the respective latitude and longitude, we can calculate distances between their locations. Since we can only identify the coordinates of the author's city, not distinguish locations within cities, the distance between co-authors from the same city is zero. The breakdown by distance category can be seen in the Figure 11. Note that the chart uses a logarithmic scale. The average distance covered in cooperation is 468 km with a standard deviation of 1700. The largest distance is 18,588 km, cooperation between Amsterdam, The Netherlands, and Wellington, New Zealand. Since both authors are from Dutch origin, this observation is in line with the argument of Hamermesh and Oster (2002) that cooperation over longer distance often takes place between friends or former colleagues.

Figure 11. Number of connections by distance category in kilometres



The chart clearly shows co-authors are mostly located in the same city. Cooperation over a distance of 10-20 kilometres is relatively rare, possibly because cities with research institutes are not very close to each other. From 20 kilometers onwards cooperation increases slightly up to a distance of 500 kilometres. Then it declines slightly. The peak in the distance category 5.000 – 10.000 kilometres represents cross-Atlantic cooperation. Out of 65 cooperations in this category, 59 are across the Atlantic Ocean. This type of cooperation is obviously more likely than cooperation between two peripheral locations within Europe.

4. Summary and conclusions

In this paper we try to shed light on the (spatial) structure of regional science in Europe. During the last half century Regional Science has emerged from a new field to a well-known discipline with a whole series of scientific journals and scientist in all parts of the world. The Regional Science Association International (RSAI) is a worldwide organisation with three supraregional organizations in North-America, Europe and the Pacific that all consist of national and language sections. In terms of number of pages published and number of members of RSAI the share of Europe has increased substantially over time. The annual congresses of the European Regional Science Assocaciation (ERSA) are the single most important regional science activity in Europe. Therefore, the CD-ROM's with information of the six ERSA conferences over the period 1998 – 2003 are useful sources of information to analyze the structure of regional science in Europe. The aim of this paper is twofold:

1. to identify spatial concentrations of the production of region science knowledge
2. to explore to what extent there is an exchange of scientific knowledge and cooperation in knowledge creation between scientists, with special attention for the role of distance

The academic question deals with insight in the spatial aspects of the creation and diffusion of knowledge in regional science. We have used the information on the CD-ROM's to analyze co-authorship. The theory and methodology for this analysis are discussed in section 2 together with a description of the data. Like in many other disciplines co-authored papers are very common in regional science as well. There is even some tentative evidence that co-authorship is more widespread in regional science than in the total discipline of economics. In our data we find on average 1.8 authors and this corresponds with the figure by Florax and Plane (2004, Table 3). It is higher than the average 1.5 authors per paper reported for economics by Laband and Tollison (2000, p.635). From the total number of papers 44% was single authored. When we take into account the spatial dimension by looking at the number of papers that have been written by authors from different cities and countries we see that distance is clearly a barrier. While 56% of all papers was written by more than one author, only 18% was written by authors from different cities and just 7% by authors from different countries. When we look at the number of authors we see that only 20% of the papers were written by three of more authors. The number of locations involved is only in 2% of the relevant cases more than two cities of two countries.

The final step in the analysis of co-authorship has been the identification of networks of countries, cities and authors by means of social network analysis. Of the 52 countries in the database 15 are not connected to any other country. There is one big network of 34 countries and a small one of 3 countries. Within the large network component Germany, the UK, the Netherlands and the US form the core-group of countries. The strongest link is between the Netherlands and the US, both belonging to the core-group of countries. The next strongest links are found between Norway and Sweden, Italy and the Netherlands and between Croatia and Slovenia. From this we can draw the conclusion that although there are countries with a very central position in the network, this does not imply that the links are mainly within this group of countries but that there exist also strong relations between these countries and more peripheral countries in the network and between some of the peripheral countries itself. When we go down from countries to cities, the network becomes more complex with 46 components. Only four of them

consist of more than four cities. There are two small networks of five cities with Japan and Portugal in a central position and a Scandinavia – UK network or 13 cities. However, most striking is the large component that connects 150 cities. The most important nodes are Amsterdam, Rome and Milan, followed by Barcelona, London, Reading, Nuremburg and Vienna.

The most detailed and most direct level of analysis of the ERSA publication networks is the level of authors. In the end, it is individuals, not cities or countries that collaborate in order to give a joint paper at one of the ERSA congresses. With the increasing level of detail the network becomes more and more complex with almost 400 components. However, only 8 networks consist of 15 authors or more. The largest component (91 nodes) can be called the Dutch network, the Amsterdam network or even the Nijkamp-Rietveld network. The other medium sized networks are centered in: Barcelona (27 nodes), Switzerland (22), Scandinavia (17), Patras (16) and finally Milan, UK-Israel and London-Volos with 15 nodes each. A more detailed analysis of the geographical distance between co-authors learns that by far the most co-authors are located in the same city. Although the average distance covered in cooperation is 468 km, there is hardly any further distance decay after more than 20 km. From 20 kilometers onwards cooperation increases slightly up to a distance of 500 kilometres. Then it declines slightly. When we take a more detailed view at the participants in the various networks just mentioned it is clear that the medium sized networks are strongly based on personal relations. This confirms the argument of Hamermesh and Oster (2002) that cooperation at longer distance often takes place between friends or former colleagues.

When we compare the outcome of the analysis of the network of cities with the cities that are in the top 25 as locations of authors publishing in PIRS (see Table 1) and with the cities that are centres of regional science as host of the European congress (see the beginning of section 3 and Appendix 1) the following cities can be identified as the main centres of regional science in Europe: Amsterdam, Barcelona, London, Milan, Rome and Vienna. Within these cities there are concentrations of regional scientist, but often there are only a few persons that are really the spiders in the web. These geographical concentrations do not mean that regional science does not exist elsewhere. Based on the origin of the conference participants we may conclude that regional science has been spread out over Europe to almost all countries and many regions. There is also a substantial interaction with scientists from other continents. Conferences take place all over Europe and this has proven to be a good way to recruit new participants to the ERSA-network. Once scientists are really part of the network they keep on coming to the congresses irrespective of the location. Therefore, we can tentatively conclude that the scientific concentrations can take the role of engines in the production or further knowledge in regional science. It would be interesting for future research to analyse more in debt the way how personal contacts influence the forming of networks of co-authors. For instance, the role of language barriers and the transfer of knowledge between generations by co-authors that differ in age and location can lead to more insight in the role of cooperation between scientist in the diffusion and production of regional science. Another interesting question is to what extend congress papers lead to journal publications.

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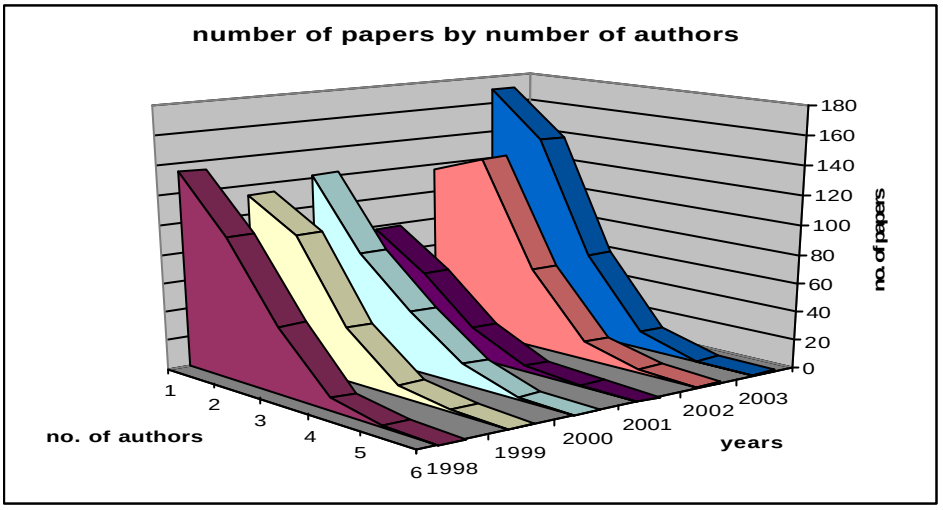
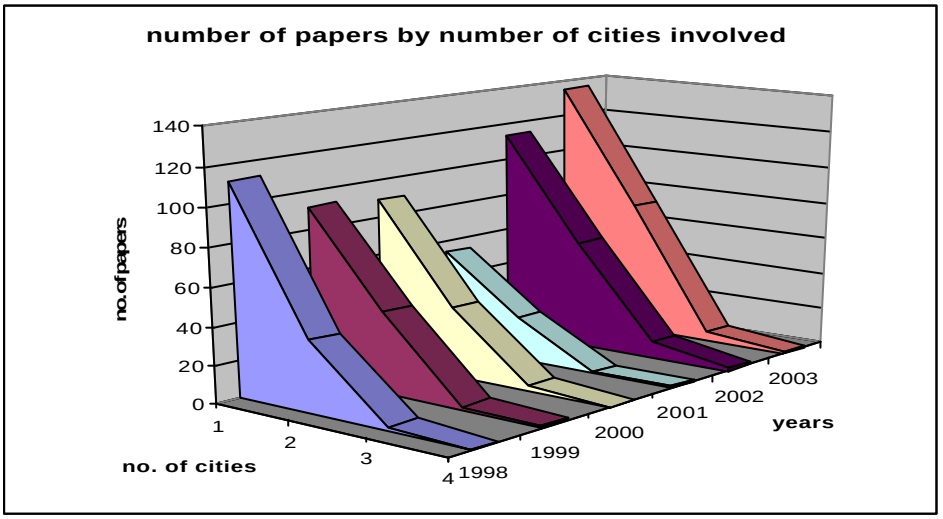
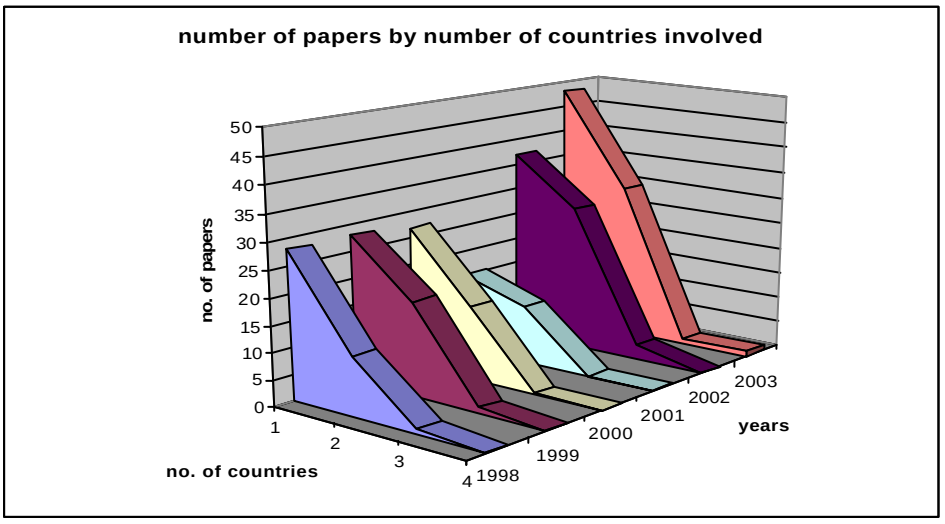
Appendix 1: Conference places of the ERSA congresses

Year	*Conference place ERSA congress*	*Country*
1961	The Hague	Netherlands
1962	Zurich	Switzerland
1963	Lund	Sweden
1964	Ghent	Belgium
1965	Krakow	Poland
1966	Vienna	Austria
1967	The Hague	Netherlands
1968	Budapest	Hungary
1969	Copenhagen	Denmark
1970	London	UK
1971	Rome	Italy
1972	Rotterdam	Netherlands
1973	Vienna	Austria
1974	Karslruhe	Germany
1975	Budapest	Hungary
1976	Copenhagen	Denmark
1977	Krakow	Poland
1978	Fribourg	Germany
1979	London	UK
1980	Munich	Germany
1981	Barcelona	Spain
1982	Groningen	Netherlands
1983	Poitiers	France
1984	Milan	Italy
1985	Budapest	Hungary
1986	Krakow	Poland
1987	Athens	Greece
1988	Stockholm	Sweden
1989	Cambridge	UK
1990	Lisbon	Portugal
1991	Istanbul	Turkey
1992	Louvain la Neuf	Belgium
1993	Moskou	Russia
1994	Groningen	Netherlands
1995	Odense	Denmark
1996	Zurich	Switzerland
1997	Rome	Italy
1998	Vienna	Austria
1999	Dublin	Ireland
2000	Barcelona	Spain
2001	Zagreb	Croatia
2002	Dortmund	Germany
2003	Jyvaskyla	Finland
2004	Porto	Portugal
2005	Amsterdam	Netherlands

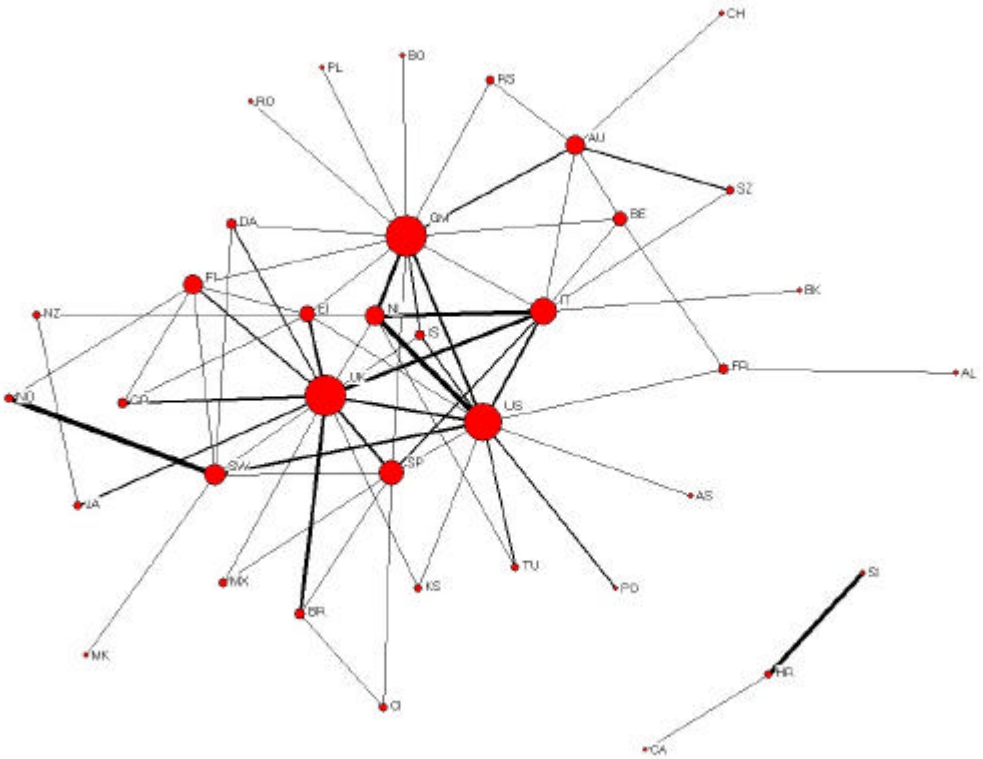
Appendix 2. Co-authorship in general and by city and country 1999-2003



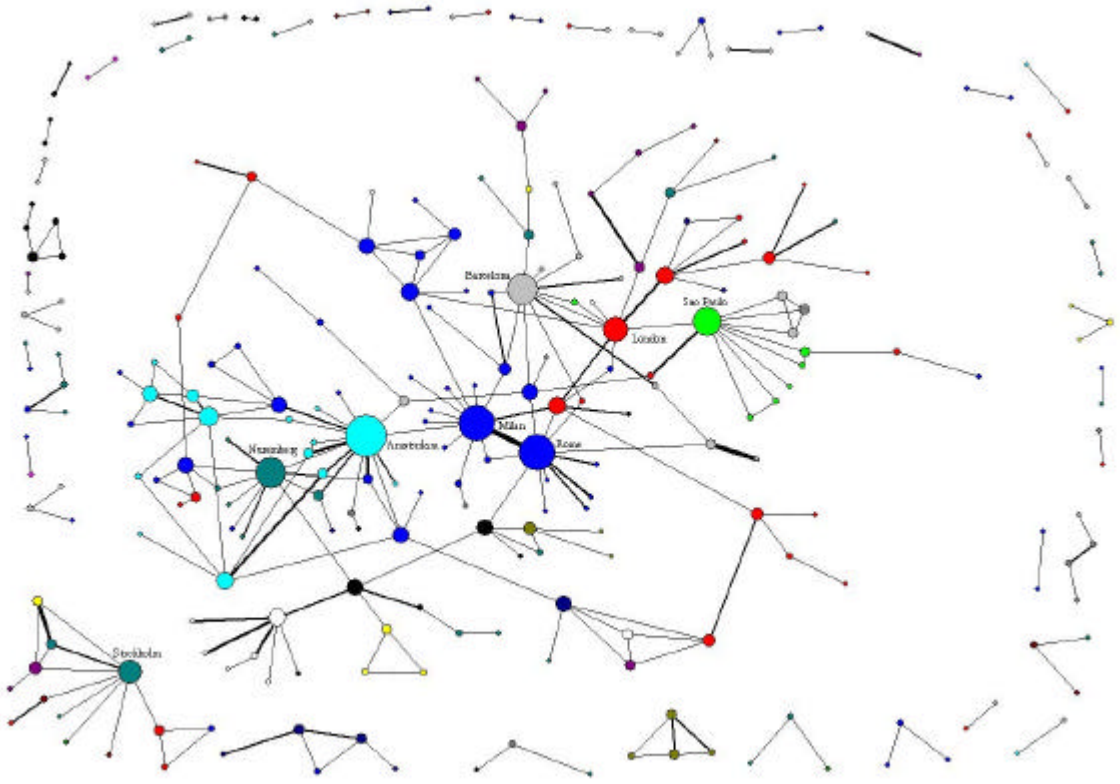




Appendix 3. Components and structure of the ERSA co-author network for *countries.*



Appendix 4. Components and structure of the ERSA co-author network for *cities*.



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