Visibility of Collaboration between Immunology Institutions on the Web Including Aspects of Gender Studies

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Abstract
A number of studies can be found in the literature about analyzing scientific collaboration networks through co-authorship but very few have examined the reflection of these networks on the Web. In this paper the collaboration between 80 German institutions of immunology is analyzed, including gender collaboration. The percentage of co-authored papers visible on the Web increased from 1997 to 2002. In this connection the visualized Web network in 2002 is slightly more similar to the bibliographic co-authorship network than in 1997. Highly productive institutions have a higher central position in both collaboration networks and consequently greater influence on the entire scientific community than the lower productive institutions. The contribution of female members of the German Society of Immunology in both the bibliographic and Web networks is very low in relation to the male counterparts. That corresponds with general results of a large gender study conducted by the European Commission.

Introduction

Immunology is an important field of medicine. The human immune system plays the fundamental role in fighting pathogens or degenerated cells. To fulfill this function the immune system has to discriminate between "own" and "external" or between "dangerous" and "safe". If this mechanism is destroyed the body cannot be protected against viruses, bacteria and tumors. On the other hand, undesirable allergies and auto immune reactions such as arthritis or inflammatory bowel disease do emerge. In the last decades immunologists have investigated the complex mechanisms of the immune system to control the balance between immune reaction and tolerance. Most hospitals have their own immunology department and separate institutions also exist.

It is therefore not surprising that the degree of cooperation between experts in this field from different departments and institutions is heavily increasing, particularly over the last few years. Societies of immunology are fostering this process all over the world. In addition, there are other motivational factors that account for the increased cooperation in all scientific disciplines and mainly in medicine and natural sciences. These are, for example, economic factors, massive funding, changing communication patterns, increasing mobility of scientists, etc. (Glänzel 2004, Beaver 2001, deSolla Price 1963, Luukkonen 1992).

Let us come back to the societies. The German Society of Immunology was founded 1967 in Frankfurt a. Main and has approximately 1700 members in 2005. Links to about 80 research institutions or departments of immunology in Germany are available in the website of the society: www.immunologie.de.

In addition, a member list of the society was also available for gender identification of the authors of publications. A number of studies are available in the literature about collaboration in science in different scientific disciplines between individuals, institutions or countries analyzing scientific networks through co-authorship (for example, Newman 2001, Glänzel 2004, Tijssen & Moed 1989, Okubo et al. 1992, Miquel & Okubo 1994, Glaenzel & de Lange 1997, Zitt et al. 2000), but very few studies have examined the reflection of collaboration on the Web.

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Therefore, this paper is based on investigations related to this topic. The first results of this type of studies are outlined in three other papers (Kretschmer & Aguillo 2004), (Kretschmer & Aguillo 2005), (Kretschmer et.al. 2005) and it is the continuation of these studies that follows in this paper.
A new approach of *Web visibility indicators of collaboration* for measuring both the visibility of bibliographic multi-authored papers and the visibility of bibliographic co-authorship networks on the Web was presented in Kretschmer& Aguillo (2004). More details can be found in the section entitled "Methods".

Two of the results presented in the earlier three papers form the basis for the assumptions we check in the new study. The two results are as follows:

1. The percentage of multi-authored papers by Indian and German institutions visible on the Web is changing over time, leading to an increasing visibility of bibliographic papers.
2. The collaboration amongst the members of an international research network (COLLNET) results in a publication set with a different pattern to other gender studies in science, which show low contribution rates of women in collaboration activities.

We found out that with Web visibility indicators and other indicators for gender studies, there is a real continuation of gender equality in COLLNET over time both on-line and off-line. The question is open as to which extent these results also can be shown in the field of immunology in Germany. Therefore in this paper, the following assumptions are checked:

1. The percentage of co-authored papers by German institutions of immunology visible on the Web is significantly higher in 2002 than in 1997.
2. In connection with the 1st assumption we expect the similarity between the bibliographic and the Web networks to be higher in 2002 than in 1997, i.e. the percentage of the edges and the percentage of the nodes (except singletons) visible on the Web are higher in 2002 than in 1997.
3. The co-authorship pattern amongst members of the German Society of Immunology is different from the special COLLNET pattern but more similar to the usual pattern of gender studies in medicine and life sciences, which show low contribution rates of women in collaboration activities. We expect this difference exists because the COLLNET members are working in another scientific field, i.e. in the area of scientometrics-bibliometrics-informetrics.

Data

80 institutions of the German Society of Immunology are included in our study. From the SCI data (year 1997 and year 2002) all publications were selected that appeared in co-authorship between authors affiliated to at least two institutions of the 80 research institutions of the German Society for Immunology. Thus, it concerns 48 bibliographic co-authored publications from 1997 and 87 from 2002.

Additionally for each of the 80 institutions separately the total number of publications was selected both from 1997 and from 2002. The Web searches took place in October 2004.

Methods

Web Visibility Indicators of Collaboration

The reflection of the bibliographic co-authorship networks on the Web is studied with *Web visibility indicators of collaboration.*

As mentioned above this new approach of Web visibility indicators was presented in Kretschmer& Aguillo (2004). It is a continuation of Vaughan and Shaw's (2003) method of searching article quotations in the Web (*Web citations*):

- The *Web visibility rate of a multi-authored publication i won by bibliographic data (WVP_i)* is measured as a frequency of the different websites on which the title of this bibliographic publication is mentioned after entering the full title of a co-authored publication into Google or into another search engine.

- A multi-authored publication won by bibliographic data is visible on the Web if the following is valid: $WVP_i>0$.
- The *Web visibility rate of a pair of collaborators A and B (WVC_{AB})* is equal to the sum of Web visibility rates of all of their co-authored publications:
  $WVC_{AB} = \Sigma_i WVP_{ABi}$

A pair of collaborators is visible on the Web if the following is valid: $WVC_{AB}> 0$
These data were basis for the social network analysis (SNA) of the co-authorship network won by webometric data. The two collaborators are nodes in the network and there is an edge between them if $WVC_{AB}> 0$.

The edges visible on the Web are a *subset* of the set of edges off- line. Using Web visibility indicators, the similarity between the collaboration networks off-line and on-line is increasing, with an increasing number of visible edges and nodes in the Web network.

Indicators of Social Network Analysis Used in Bibliographic and in Web Networks
A social network analysis was performed (Wassermann & Faust 1994). The collaboration networks of institutions off-line and on-line from 1997 and 2002 are visualised by the maps drawn with Pajek (Figures 1 and 2).

In the collaboration network off-line (SCI data) between two institutions (node A and node B), there exists an edge if both have published at least one publication in co-authorship.
The institutions A and B are called "*pair of collaborators*" (A, B). These pairs of institutions (or edges between them) are studied. The on-line networks are compared.

The social network analysis (SNA) uses some indicators of centrality (Wasserman, S. & Faust, K. 1994) describing both the structure of networks and the role played by particular institutions (nodes). The Closeness Centrality is selected here for describing the central role played by particular immunology institutions in collaboration.

The *Closeness Centrality* of an institution A focuses on how close this institution is to all the other institutions in a "connected subset".
Explanation:

In a connected subset a path exists between all pairs of nodes. A path from node X to node Y is a sequence of distinct edges between pairs of collaborators:

$(X, A_1), (A_1, A_2), \ldots, (A_j, Y)$

The length of the path is equal to the number of distinct edges. The shortest path from X to Y is called *geodesic distance* d_{XY}.
Example: A path from node **52** to node **8** in Figure 1 (see above: bibliometric network 1997, you can find node 52 on the right) is the sequence of the distinct edges

(**52**, 32), (32, 19), (19, **8**)

The length of the path is equal to 3. However the shortest path from node **52** to node **8**

(**52**, 32), (32, **8**)

is equal to 2= *geodesic distance* $d_{52; 8}$

The *Closeness Centrality* is a function of geodesic distances. The centrality is inversely related to distance. As a node grows farther apart in distance from other nodes its centrality will decrease.
Sabidussi's (1966) index of node closeness is the inverse of the sum of the distances from node A to all the other nodes Y:

$CC_A= [\Sigma_Y d_{AY}]^{-1}$

However, the co-authorship structure of the institutions is a "disconnected graph", i.e., there is not a path between each pair of nodes, i.e. the geodesic distance is infinite between a pair of nodes F and G if there is not a path between them.

Furthermore, the institutions can be divided into several connected subsets. The connected subsets are denoted as "components" or "clusters". As mentioned above a path exists between all pairs of nodes in a connected subset however between a pair of nodes from different components there exists no path.

Thus we have focused our study of geodesic distances on the large central component in a network, i.e. on the component with the highest number of institutions.

Components with only one node (institution) are called "singletons". These singletons are not collaborating with other institutions.
It makes sense to study the large central component in a network because a very high percentage of the collaborating institutions belong to this cluster:

- in the bibliometric network (1997) 27 of the 31 collaborating institutions (=87.1%)
- in the Web network (1997) 23 of the 25 collaborating institutions (=92%)
- in the bibliometric network (2002) 47 of the 50 collaborating institutions (94%)
- in the Web network (1997) 47 of the 50 collaborating institutions (94%)

Indicators of Gender Co-operation Used in Bibliographic and in Web Networks
Naldi et al. (2004) introduced three bibliometric indicators in order to evaluate patents and publications produced by co-operation among inventors/authors of different gender:

- *Participation* counts the number of publications with at least one author of a given gender;
- *Contribution* measures the involvement of each gender in the production of a publication assuming that each author contributed the same amount;
- *Presence* total count of the authors of a given gender in each publication.

In addition to the bibliometric indicators of co-operation, the three corresponding Web indicators (already introduced in Kretschmer & Aguillo, 2005):

- *Web Visibility of Participation*
- *Web Visibility of Contribution*
- *Web Visibility of Number of authors*

are used in a similar fashion to the three bibliometric indicators *but here in order to process multi-authored publications visible on the Web.*

Results

Bibliographic and Web Networks
The comparison between the data of the bibliographic and Web networks from 1997 and 2002 is shown in Table 1.

As expected from the changing visibility over time of the co-authored papers by Indian and German institutions, there was also a lower percentage of the number of the SCI papers in immunology visible on the Web in 1997 (70.8%) compared to 2002 (88.5%), statistically significant on the 1 % level (Chi-square test: $p<0.01$). In this connection also the percentages of both visible nodes of collaborating institutions and visible edges on the Web increased from 1997 to 2002 (percentages shown in the last two columns in Table 1).

Thus, the Web network is in 1997 slightly less similar to the bibliometric co-authorship network than in 2002. The collaboration networks of institutions off-line and on-line from 1997 and 2002 are visualised by the maps drawn with Pajek (Fig. 1 and Fig. 2).

Table 1: Comparison between Bibliographic and Web Networks in 1997 and in 2002

	1997 (SCI)	1997 (Web)	2002 (SCI)	2002 (Web)	Web/SCI in % (1997)	Web/SCI in % (2002)
Number of papers	48	34	87	77	70.8	88.5
Number of nodes (collaborating)	31	25	50	50	80.6	100
Number of edges	32	25	70	63	78.1	90.0

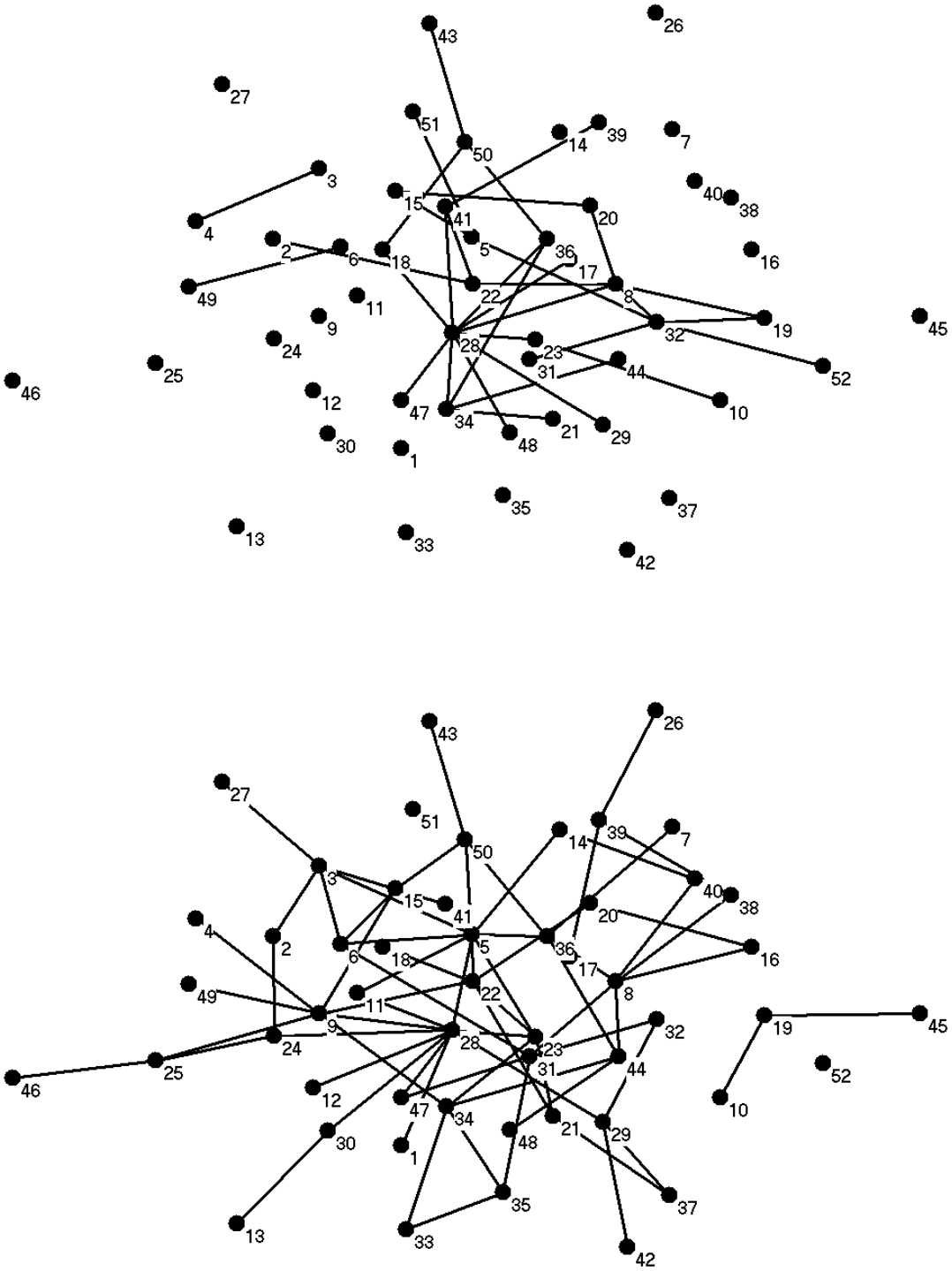

Fig. 1: Comparison between the Bibliometric Collaboration Networks of the German Immunology Institutions from 1997 and from 2002. For Explanation see the Appendix
Note: Bibliometric network 1997 above and 2002 below

In total 52 different institutions collaborate with at least one of the other institutions in 1997 or in 2002. Thus, 28 of the 80 institutions are singletons in both years. For better visualization of the networks these singletons are excluded from Figures 1 and 2. 29 of the 31 collaborating institutions

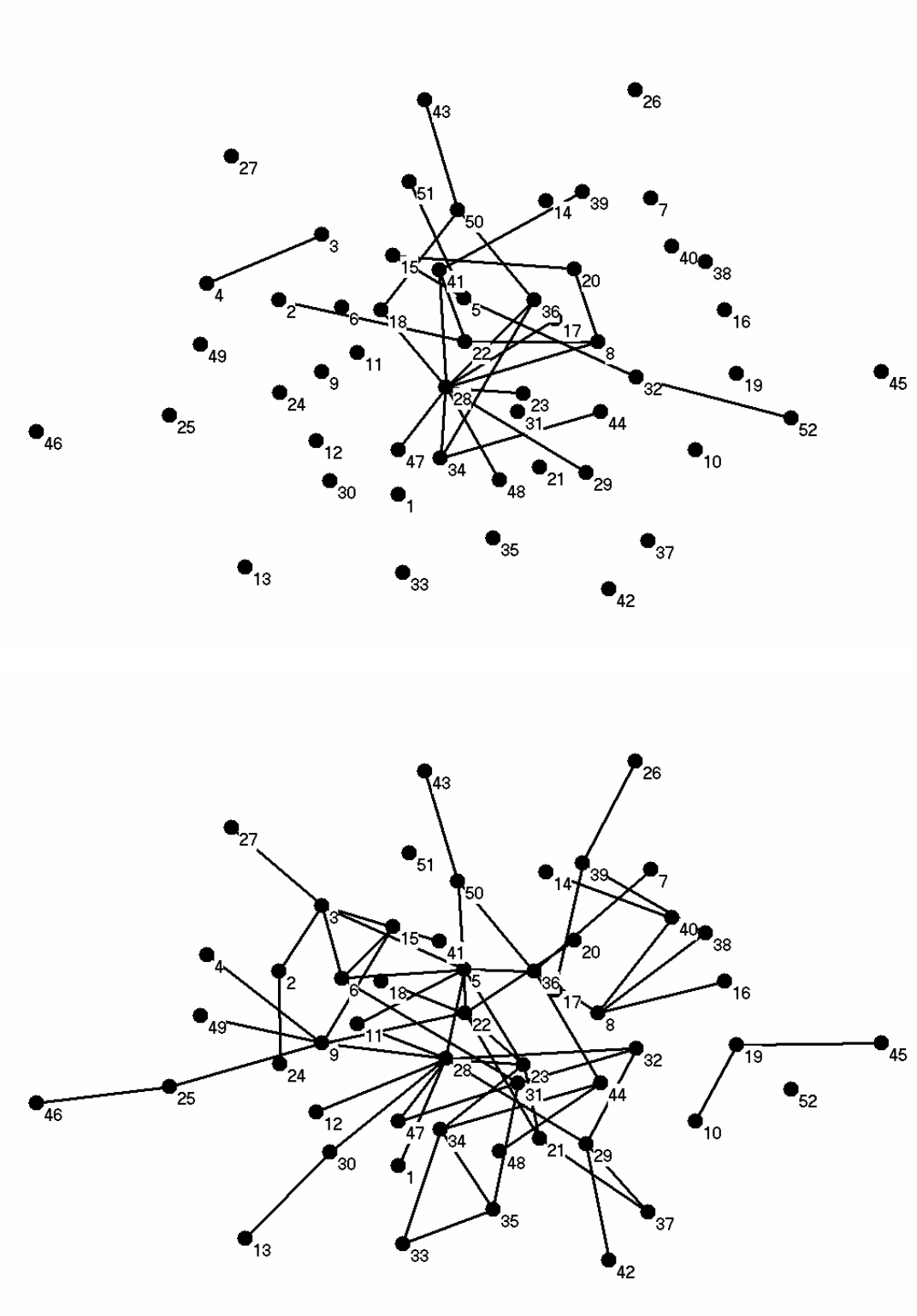

Fig. 2: Comparison between the Web Collaboration Networks of the German Immunology Institutions from 1997 and from 2002. For Explanation see the Appendix
Note: Web network 1997 above and 2002 below

in 1997 are also collaborating in 2002 (bibliographic networks). However, the pairs of collaborators are different with few exceptions. This phenomenon will be examined further and explained in a forthcoming study.

Comparing the 4 networks in Figures 1 and 2, both the difference between the 2 bibliographic networks from 1997 and 2002 (Fig. 1) and the difference between the 2 Web networks from 1997 and

2002 (Fig. 2) are more visible than both the difference between the bibliometric network (Fig. 1 above) and the Web network (Fig. 2 above) from 1997 and the difference between the bibliometric network (Fig. 1 below) and the Web network (Fig. 2 below) from 2002.

This pattern demonstrates that the collaboration between the institutions measured, either by bibliographic co-authorship data or Web data, is growing faster than the similarity between bibliographic and Web networks, because already in 1997 the similarity between the networks off-line and on-line is very high when measured by the percentages of visible nodes (collaborating institutions) or edges [see in Table 1: column "Web/SCI in % (1997)"].

Taking into consideration the so-called ecological fallacy: "What is true for trees, is not necessarily true for a wood" we checked to see if there was a correlation between the central role of institutions and other special characteristics of them as found earlier between the central role of single scientists and their characteristics in a special field of physics which was established by von Klitzing in 1980 with the discovery of Quantum-Hall effect (Kretschmer 2004).

By taking into account the observation of Braun, Glänzel and Schubert, (2001) that so far there are only a few bibliometric investigations about the relation between the productivity of single authors and their cooperation, we decided in the earlier study (Kretschmer 2004) to examine whether there is a relationship between the geodesic distances and the productivity of the authors. The study has shown in average the geodesic distances of authors are decreasing with increasing productivity as measured by the number of publications.

Therefore in this paper, in continuation, the following assumption is checked: that there is a relationship between productivity of institutions and their geodesic distances (or Closeness Centrality), i.e. we assume high productive institutions also have a high central position in the collaboration network of institutions.

We found that the Spearman correlation- coefficient between Closeness Centrality in the bibliographic networks and productivity (total number of papers) of institutions amounts to R=0.60, statistically significant on the 0.01 % level with 27 pairs in 1997 and to R=0.52, statistically significant on the 0.01 % level with 47 pairs in 2002. There is also a similar structure in the Web network between the Closeness Centralities and the productivity of institutions. (R=.42 in 1997 and R=0.48 in 2002).

As an example for comparison of institutions with high and low Closeness Centrality, consider the node (no. 28) in the middle of both networks of Fig. 1. This institution (German Cancer Research Center, Heidelberg) with the highest productivity both in 1997 and in 2002 also has the highest Closeness Centrality, i.e. the lowest geodesic distances to all the other institutions.

We also want to mention in this connection the historic publicity of the German Cancer Research Centre, Heidelberg. This centre is situated in a town with an historic and famous university. Despite high productivity, this is another factor that explains why scientists came and come to this town for collaboration.

Another node, number 43 (on the top of the networks), indicates an institution with lower productivity connected with low Closeness Centrality. A similar pattern can be found in the Web networks (Fig. 2).

In brief, highly productive institutions have, on average, low geodesic distances and thus shorter length of paths to all the other institutions compared to low productive institutions. This indicates that highly productive institutions have a higher central position in the collaboration networks and following greater influence on the entire scientific community than the lower productive institutions.

In addition, institutions which belong to the small clusters or singletons (non-collaborating institutions) are on average statistically significant less productive than the institutions of the large component (Both in the bibliographic and in the Web networks. For example, the mean productivity of institutions which belong to the small clusters or singletons is 5.31 and the mean productivity of institutions in the large cluster is 33.5).

Reflection of Gender Co-operation in Bibliographic and in Web Networks

The bibliometric results of Naldi et. al. (2004) were compared with bibliometric and Web results of both the new study in immunology and the former COLLNET study (Kretschmer 2004).

The bibliometric study of Naldi et al. is based on a data sample of about 10,000 items published during the year 1995 in scientific journals of international relevance and written by 35,000 authors

from six European countries. The publications produced by co-operation were from several areas of science (mainly medicine and life sciences).
The bibliometric study of the 64 COLLNET members is based on a data sample of 223 multi-authored publications between at least two COLLNET members working in the field of bibliometrics-informetrics-scientometrics.

135 papers including the addresses of at least two of the 80 German institutions of immunology were studied. These papers are produced by 872 authors in co-authorship during the years 1997 and 2002. The gender was identified for 147 authors.
The different size of these three studies has to be taken into consideration during comparison of the results.

However let us first examine the different problems of the data collection in the 3 different studies. Naldi et al. were using bibliographic databases for gender studies. However bibliographic databases do not contain the first names of the authors but only their initials. So it was necessary to collect the names manually from the original paper. However, the first name was available in less than 50% of cases. Due to these problems the sampling procedure by Naldi et al. (2004, p. 305) was based on an 'a priori' selection of journals. Additionally a 'First Name Data Base' covering 6 European languages was created by the authors for identification of the gender of the first name in the 6 different countries, because the same first name can be female in one country and male in another. The whole method was very time consuming.Therefore, in our investigations we looked for another method.

Whereas Naldi et al. started with the collection of publication data followed by searching the gender of the authors in the by-line, we started with groups of scientists including the well-known gender of the members of these group followed by analyzing their publication data.

In the first pilot study we selected COLLNET for analyzing the collaboration structure of individual scientists on-line and off-line. The gender of each of the COLLNET members was well known. Every member was asked for his or her publication list (Kretschmer & Aguillo 2004). Thus the first name was available in 100% of the cases including the knowledge about the corresponding gender.
As a comparison, we selected the Society of Immunology with the possibility of using the member list including the well-known gender of the members.

However contrary to our assumption we could find very few members of the Society of Immunology in our SCI database, i.e. 62 out of 300 authors in total (=20.7%) in 1997 and 85 out of 572 authors in total (=14.9%) in 2002.

Thus the number of authors with well-known gender was low in 1997 and in 2002 (=16.9% in average). This percentage is even less than the percentage of cases (less than 50%) in the study of Naldi et al.

Perhaps the reason is the different data collection methods adopted compared to the first pilot study. Whereas for every COLLNET member all of the co-authored papers with other COLLNET members were collected, not all authors of the studied SCI publications (immunology) are members of the German Society of Immunology. After receiving this result we found one of the reasons for this phenomenon on the basis of interviews with scientists of immunology institutions: PhD students represent a high percentage of researchers but because of their position not all of them are members of the society. Usually they have only one or two publications. However we were not able to identify the gender of this percentage of authors who are employed in the immunology institutions because we were not able to find them in the list of members of the German Society for Immunology.

Nevertheless, we will present the immunology results below in comparison with the data produced by Naldi et al. and with the data of the COLLNET members. We have to emphasize that caution is necessary regarding interpretation of the results because of the problems in data collection previously described. However the visible trends in the data can be used as basis for creation of future studies. An overview about the results is presented in Table 2.

Table 2: Bibliometric and Web Indicators of Gender Co-operation

	Participation of women in %	Participation of men in %	Contribution of women, in%	Presence of female authors in%
Naldi et al.	45.8	94.7	19.5	22.2
Immunology bibliometric 1997	21.9	93.8	12.9	12.9
Immunology Web visibility 1997	28	91.9	16.5	15.4
Immunology bibliometric 2002	17.2	96.6	8.9	10.5
Immunology Web visibility 2002	16	96	6.8	10.3
COLLNET bibliometric	65.3	76	45	47.9
COLLNET Web visibility	67	73.9	46.2	47.7

Naldi et al. (2004) have shown the participation of women could only be found in 45.8% of all items as opposed to the participation of men in 94.7%. The contribution of women resulted in 19.5% and presence of female authors in 22.2% of all authors. Although these results are related to average values of different disciplines and countries, in general the low position of women in co-operation is striking.
This low position of women in co-operation is also shown in German immunology institutions and even more striking than shown in the general results by Naldi et al. (especially in 2002). As the general results are averages of 6 countries, let us examine the differences between these countries. Naldi et al. mentioned that scientific publications show two patterns of countries – Italy, Spain and France with a relatively high female contribution and Germany, Britain and Sweden with significantly lower contribution.

The female contribution is lowest in Germany, i.e. 13.5% only (Naldi et al. 2004). This result is similar to the contribution in German immunology in 1997 (12.9%). The 3 Web visibility indicators (Web Visibility of Participation, Web Visibility of Contribution and Web Visibility of Presence of female authors) show slightly better results for women than the 3 corresponding bibliometric indicators but these differences are without statistical significance.
Comparing both the bibliometric and the Web results of 1997 with 2002 the question arises as to whether there is even a slight possible decrease of the position of women from 1997 to 2002 in German immunology or not. This question should be studied by interviews in the immunology institutions.

However the results of the former analysis of the co-operation of COLLNET members oppose both the above mentioned study by Naldi et al. and the gender study in immunology. Collaboration patterns between male and female members of COLLNET are almost equally distributed (Details of COLLNET member analysis and interpretation in: Kretschmer & Aguillo 2004).

These findings lead to the question of why there are such drastic differences between the German Society of Immunology and COLLNET in gender studies. According to our assumption above one reason could be that it is caused by the different scientific disciplines or fields.

The next question is based on the especially low position of women in co-operation in Germany compared with the average of the 6 EU-countries.

Going higher in the hierarchy, few women are found in science in general with even fewer in Germany. This could be based on the role of women in the public German society: Women get pregnant, bring up children. This leads to a deficiency of time for research work and subsequent fewer opportunities for a career. In Germany men dominate the higher hierarchy positions. Countries like France have a good system for the care of children, and this could explain why gender distributions differs between countries.

Conclusion

Otte and Rousseau (2002) have shown that social network analysis (SNA) can be used successfully in the information sciences, as well as in studies of collaboration in science. The authors refer in their paper to the variety of application possibilities of SNA, as well as to the applicability of SNA to the analysis of social networks in the Internet (webometrics). Therefore this paper deals with examinations using SNA to establish the extent to which the bibliographic co- authorship network of German institutions of immunology is reflected in the Web and how similar the networks are. However, because of the limited size of this paper the methods used are restricted to a small selection of indicators for analyses of collaboration networks. Thus, the variety of the application possibilities of SNA and other methods should be extended in a future study of collaboration networks including gender aspects.

We assume extensive discussion with scientists in the field of immunology about the results of this kind of studies and personal interviews are useful for the future development of new indicators and methods relevant to the practical use in science policy.

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Appendix: Explanation for Figures 1 and 2

Full details are available after request: kretschmer.h@onlinehome.de

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