Diplomarbeit

Policy Networks: A Citation Analysis of the Quantitative Literature

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English abstract

Since the mid-1970s, the quantitative literature on political networks has grown to approximately 200 publications. A number of scholars have recently tried to organize the "Babylonian variety" of different policy network concepts and schools of thought in political network analysis. It will be demonstrated that they fail to grasp the important distinctions between the research specialties, and an empirical assessment of the quantitative literature is offered by analyzing co-citation data and data of bibliographic coupling.

The similarity between any pair of citing publications is determined by the number of citations these publications have in common, and the similarity between any two cited articles is shaped by the number of common citing bibliographies. A 193x8490 affiliation matrix containing the links between citing and cited documents is transformed into two square adjacency matrices and then examined separately by means of multivariate data analysis and Social Network Analysis. Using clique analysis, cluster analysis and blockmodels in conjunction with multidimensional scaling and correspondence analysis, the important schools of thought can be identified as clusters in an n-dimensional space. Once the clusters have been delineated on the level of cited publications, the citing documents can be classified and a likelihood distribution for each publication of belonging into any school of thought can be given.

The results show that four large clusters can be separated and interpreted in a meaningful way in terms of research design, topic, use of methods and some other characteristics. These schools of thought are preliminarily called "exchange cluster", "governance cluster", "elite cluster" and "participation cluster". Results are discussed in the light of Crane's invisible-colleges framework and other approaches from the sociology of science as well as recent theoretical contributions to the study of policy networks.

The citation-based analysis of the discipline is complemented by an analysis of the methods and relations used in the citing documents and their distributions of actors, countries, levels of analysis and areas of inquiry examined.

German abstract

Seit Mitte der 1970er Jahre ist die quantitative Literatur über Politiknetzwerke auf ungefähr 200 Publikationen angewachsen. Mehrere Wissenschaftler haben in letzter Zeit den Versuch unternommen, die “Babylonische Vielfalt” an Konzepten und Denkschulen in der politischen Netzwerkanalyse zu ordnen. In der vorliegenden Diplomarbeit wird gezeigt, dass bisherige Strukturierungsversuche nicht systematisch genug durchgeführt worden sind, und es wird eine empirisch fundierte Abgrenzung der quantitativen Literaturströmungen anhand von Kozitationsdaten und bibliografischer Kopplung vorgenommen.

Die Ähnlichkeit zwischen zwei beliebigen zitierenden Publikationen wird durch die Überlappung ihrer Bibliografien bestimmt, während die Ähnlichkeit zwischen zwei zitierten Publikationen durch die Häufigkeit angegeben wird, mit der sie gemeinsam in Bibliografien aufgelistet werden. Eine 193x8490-Affiliationsmatrix mit den Verbindungen zwischen zitierten und zitierenden Dokumenten wird in zwei Adjazenzmatrizen transformiert, die dann separat mittels multivariater Techniken und Sozialer Netzwerkanalyse untersucht werden. Mit Hilfe von Cliquen- und Clusteranalysen sowie Blockmodellen in Verbindung mit MDS und Korrespondenzanalyse können vier kognitive Schulen als Cluster in einem n-dimensionalen Raum identifiziert werden. Nach dem Trennen der zitierten Cluster werden die zitierenden Publikationen klassifiziert und mit Wahrscheinlichkeitsverteilungen beschrieben, die ihre Zuordnung zu den jeweiligen Clustern ermöglichen.

Die vier kognitiven Schulen werden vorläufig als “Tausch-Cluster”, “Governance-Cluster”, “Elite-Cluster” und “Partizipations-Cluster” bezeichnet und bezüglich ihres Forschungsdesigns, Themas, der benutzten Methoden und anderer Charakteristika abgegrenzt und interpretiert. Die Ergebnisse werden im Lichte von Cranes Invisible-College-Hypothese und anderer Ansätze aus der Wissenschaftssoziologie sowie neueren theoretischen Arbeiten über Politiknetzwerke evaluiert.

Die Kozitationsanalyse wird durch eine Beschreibung der Verteilung von Methoden, Relationen, Akteuren, Analyseebenen, Ländern und betrachteten Themen in der Disziplin ergänzt.

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1. INTRODUCTION: STRUCTURING THE THEORETICAL LANDSCAPE

1.1 Social network analysis in political science

Since the publication of the first formal political network analyses in the 1970s (e.g. Laumann and Pappi, 1976), at least 200 quantitative social network analyses related to political science have appeared, along with a host of several hundred other case studies and applications of different network concepts. Numerous topics such as agricultural policy (Pappi and Henning, 1999), energy (Zijlstra, 1978; Laumann et al., 1985b), health (Carpenter et al., 1998) or elite networks (Heinz et al., 1990) have been covered, to name just a few. Political network analysis has become increasingly popular during the last 30 years.

Figure 1.1 summarizes the development of the subdiscipline: Since the early 1990s, there has been a steady increase in the number of both qualitative (red triangles) and quantitative (black circles) publications. Only in 2005 and 2006 the amount of new publications decreased, which may either be due to decreasing attention to network research or – which seems more likely – an artifact of data collection, since newer articles are less frequently cited and eventually less likely to be found during the process of data collection. Another drawback of this trend analysis is the general increase of scientific publications, hence it is impossible to judge whether the increasing amount of publications per year still stands out from the non-stationary time series of all political science publications unless the total distribution is known. Yet the trend is far from decreasing. The most conservative interpretation of these data would indicate that the prominence of political network analysis is at least not diminishing. According to Price (1963), the amount of science doubles every ten years, and the trend presented here conforms to this

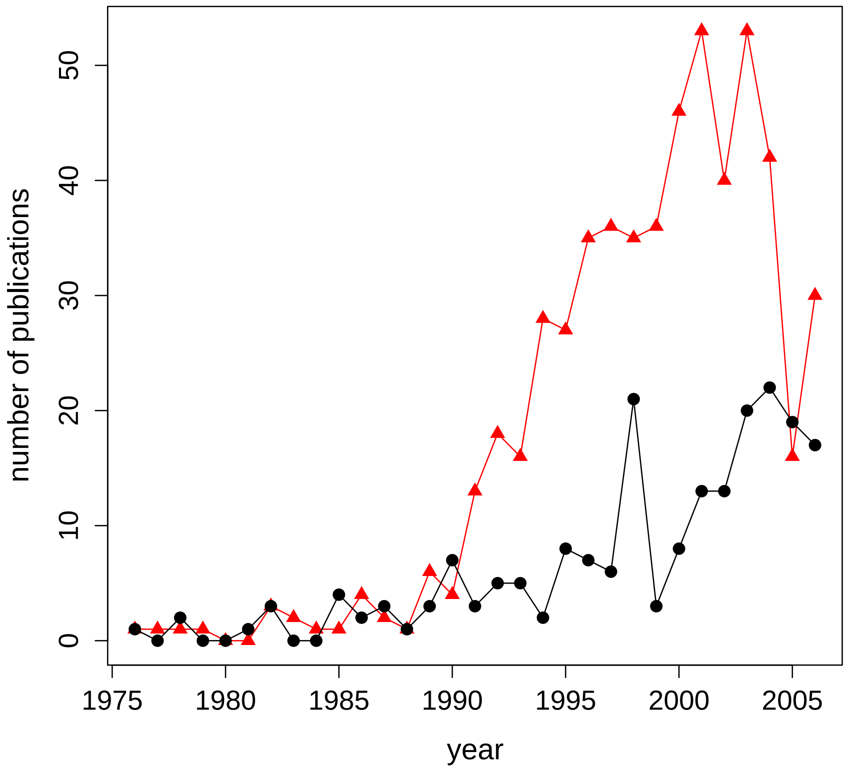

Fig. 1.1: The emergence of political network analysis

norm. Crane (1972) and others, in contrast, argue that any discipline grows exponentially and later declines – similar to the structure of scientific revolutions set out by Kuhn (1962). Further elaboration of this point can be found in section 2.2.2. If this theory holds, political network analysis is currently either in the middle or at the end of the stage of exponential growth.

The concept of policy networks and its theoretical usefulness were extensively discussed in the 1990s and in recent years (Dowding, 1995; Kenis and Schneider, 1991; Raab and Kenis, 2006), while uncertainty arose over the question on how to structure or synthesize the growing number of network concepts and contributions in the field (Dowding, 2001). In an effort to do so, British and German scholars described several configurations of state-society relations (Jordan and Schubert, 1992; Rhodes and Marsh, 1992; van Waarden, 1992) and were in turn criticized for creating typologies instead of theories (Pappi, 1993). In 1998, Börzel surmounted the plain description of competing subgroup labels by structuring the theoretical landscape according to two research schools, the "interest intermediation school" and the "governance school", which she suspects to be bound by diverging convictions regarding the mode of analysis: While the former (mainly Anglo-Saxon) research tradition is predominantly concerned with modeling different state-society relations, "German works tend to treat policy networks as an alternative form of governance to hierarchy and market" (Börzel, 1998, p. 1), or put in different words, networks are conceived to be the result of an effective change of decision-making structures (Mayntz, 1993). It is noteworthy, however, that Börzel's distinction is solely concerned with "policy networks", in contrast to "political networks", which can be thought of as a broader category including both policy networks and other network models in political science, e.g. political elite networks (e.g. Higley and Moore, 1981) or networks of voters (e.g. McClurg, 2006).

Another approach of organizing the set of concepts and research schools in the field of policy networks has recently been made by Raab and Kenis (2006), who view the "Organizational State" (Laumann and Knoke, 1987) as the source of subsequent works by a) "Pappi, Knoke, and colleagues", b) European scholars like Marin and Mayntz and c) a "somewhat different strand [...] in the British context" (Raab and Kenis, 2006, p. 193). Apart from this distinction, they mention some "more recent work" as well as a subgroup of "studies that combine a policy network and a rational choice/game theoretic approach", i.e. that is made up of structural and agency-based components (p. 193). Raab and Kenis (2006) posit that much more empirical work has been done by European researches than by American scholars. This conclusion, again, stems from the fact that their classification treats only policy networks (as a subset of political networks). While Börzel's distinction is based on mutually relatively isolated branches, the latter enumeration is less clearly structured.

Schneider and Janning (2006) describe relational approaches as one form of policy analysis and stress that the basic assumption of these relational approaches is sociological exchange theory. A distinction between several forms of exchange relations existing in the literature becomes possible: one of them is Coleman's formal exchange model and another one may be, for example, communication (p. 86 ff.). In contrast to the former categories, this time a classification of the literature could possibly be achieved by examining the relations between actors immanent in quantitative analyses.

As it has been argued above, the dispersed structure of political network research has been a "hot topic" for almost two decades in political science. Yet there is no single review article available that examines this field in a coherent and empirically based way. Current accounts of the structure of the discipline tend to be unsystematic, if not subjective and arbitrary. In either case, they are incomplete and obfuscate the real structure of political network analysis. As Dowding (1995) points out, the most promising of all approaches to networks is the utilization of sociometric methods that can pinpoint individual positions in complex configurations. This thesis aims at examining this significant quantitative branch of political network analysis in a more systematic way than previous accounts of the overall structure of political network research could follow. The complex structure will be analyzed in the light of scientometric and bibliometric theories and methods. Co-citation analysis will be used to map research schools and the embeddedness of publications into the broader theoretical landscape of political networks. The analysis presented here aim at filling the gap left behind by unsatisfactory overview articles. It seeks to replace existing approaches by employing statistical and mathematical tools allowing the systematic description of research schools or invisible colleges on the basis of bibliographies of a population of 193 political network publications.

1.2 Outline of the thesis

The first part of this thesis deals with theoretical aspects of sciento-, biblio- and informetrics. Diana Crane's invisible college theory and related sets of concepts from the sociology of science are discussed as the theoretical basis of citation analysis. A distinction can be made between co-citation analysis and bibliographic coupling as two interrelated levels of analysis.

The second part gives an overview of the data set and its collection. Topics like boundary specification, the use of appropriate software and matching techniques are briefly treated. The subsequent analysis draws on a structured bibliography of more than 1,000 publications related to political networks which has been collected in the context of a small-scale research project on "Policy Networks and Political Theory".[1] The database includes information on the geographic focus of the analyses, the level on which actors are analyzed, the utilization of methods, network relations being examined, actors included in the publications, and area of inquiry. These descriptive information will be presented to give an overview of the characteristics of the data under consideration.

The third part is dedicated to the actual quantitative citation analysis, the core of this thesis. As a first step, methods to map the *theoretical* landscape of political network analysis, which is not covered in the second part, are discussed. A huge number of methodological obstacles and (if available) their solutions are described. Citation-based data mining will be characterized as a process of separating signal from noise. The most influential literature (the "top 20" cited works) as well as a core of highly cited documents are identified and visualized using means of Social Network Analysis. On the level of co-citation analysis (i.e. for the cited documents), a number of cluster, blockmodel and clique analyses are performed. The resulting "core" cluster structure is extracted and displayed via a non-linear mapping technique. The most important and distinct members of each of the four clusters identified are named and used to achieve a clear-cut classification of the citing publications on the level of bibliographic coupling. For each of the 193 citing publications, the likelihood of belonging to any of the four clusters is estimated based on the clustering results and then visualized in a level plot. Correspondence analysis is used to map this probabilistic classification in a two-dimensional space.

The fourth part is a detailed discussion of the results in the light of sociology of science. The research schools that are identified in this thesis are qualitatively

[1] This project is hosted by the Chair of Empirical Theory of the State, Prof. Dr. Volker Schneider, University of Konstanz, Germany. The structured bibliography will be available from http://www.polnet-school.info.

evaluated by looking into the publications and interpreting the cluster structure based on common observations in the literature being examined. It will be shown that the interpretative attempts of Börzel (1998) and Raab and Kenis (2006) at "organizing babylon" and "taking stock of policy networks" (see discussion above) are incomplete and lack empirical foundation.

The fifth and last part of this thesis sums up the major findings and points to further areas of research related to the analysis presented here.

2. INVISIBLE COLLEGES AND EPISTEMIC COMMUNITIES

2.1 Citation analysis as a bibliometric tool

The idea of employing citation data in scientific research dates back to the 1960s when Eugene Garfield (1966) came up with the Institute for Scientific Information (ISI) and citation indexing, as in the (Social) Science Citation Index. In the aforementioned paper, he already talks about the notion of similarity, which is nowadays crucial for conducting any scientometric analysis. Citation analyses and meta-science studies are used in a variety of scientific disciplines like mathematics (Wagner-Döbler and Berg, 1993), physics (Nadel, 1980; Todorov, 1990), information science (Schlögl, 2000; White and McCain, 1998), medicine (Small, 1977) and especially business administration and related fields (Bricker, 1989; Cox III et al., 1976; Culnan, 1986, 1987; Hoffman and Holbrook, 1993; Lee, 2006).

The fields that embrace these studies are called informetrics, bibliometrics and scientometrics. Even in the articles mentioned above, these terms are often confused. According to Brookes (1990), the following distinction can be made:

1. *"Bibliometrics"* refers to the utilization of statistical and mathematical methods to analyze the structure of anything related to librarian interest and all specialized citation and co-authorship studies of interest to specific research fields. Examples include the mapping of journals of a specific field via citation analysis (Cox III et al., 1976), networks of keywords found in journal articles (van Raan and Tijssen, 1993) or the connectedness of certain authors to other scholars.

2. *"Scientometrics"* includes all measures related to the sociology of science like applications of Crane's invisible college theory or anything related to science policy and citation indexing.

3. *"Informetrics"* is a label for theoretical and methodological contributions from information science such as special distributions like the Lotka distribution (e.g. applied in Wagner-Döbler and Berg, 1993), web link data, which are also treated under the heading "webometrics", or advances in information visualization (e.g. Börner et al., 2003).

If a specific research specialty is examined using citation analysis – as in this thesis – it is usually done from the specific point of view of a discipline, sometimes drawing on sociological theories. Hence the kind of work presented here should be termed "bibliometrics" with a slight scientometric focus.

Citation analyses can be distinguished in at least two dimensions: First, some bibliometric studies track the development of a research area over time in order to clarify the origin and diffusion of ideas within a discipline or different ideational epochs (Culnan, 1986; Pickering and Nadel, 1987; Small, 1977). Other researchers employ citation analysis in a cross-sectional research design in order to isolate multiple sub-disciplines from each other, ignoring possible developments over time (Bricker, 1989; Griffith et al., 1974; Hoffman and Holbrook, 1993; Small and Griffith, 1974). This latter research design is used in this thesis because all quantitative political network analyses have been published in a comparatively small time frame and are not characterized by ground-breaking inventions like in physical science.

Another distinction can be made between co-citation analysis and bibliographic coupling (Garfield, 2001), both employed in this analysis. While in a co-citation analysis in the proper sense, two articles are considered to be similar if they *are cited* by the same documents, the notion of bibliographic coupling draws on the level of the citing articles: Here two articles are assumed to be similar if they actively *cite* the same documents. Figure 2.1 summarizes this two-level procedure. In the case of co-citation analysis, the aims are to determine the most influential literature and to detect subgroups of documents that are frequently cited together, being a first insight into the separation of research schools or topics. Bibliographic coupling is finally examined to partition the selection of citing publications into these previously identified meaningful clusters. The first level of

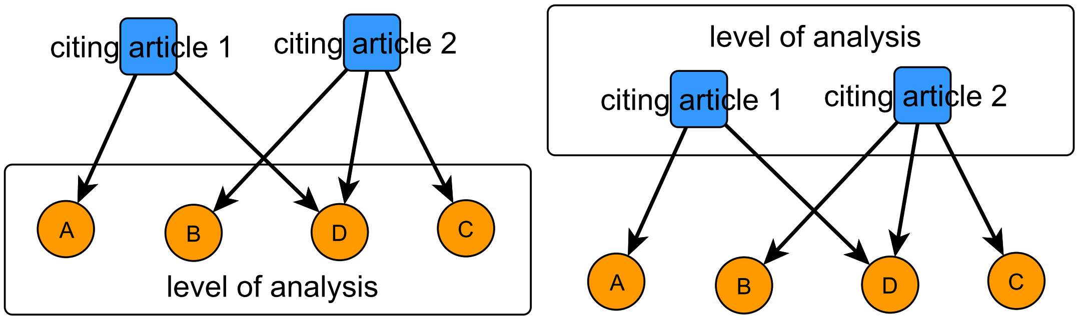

Fig. 2.1: Co-citation and bibliographic coupling (from left to right)

analysis, co-citation, is an example of unsupervised classification, while the latter can be described as supervised classification, similar to discriminant analysis or Bayesian classification. Co-citations in the quantitative political network literature are studied in section 4.2 and bibliographic coupling is treated in section 4.3.

2.2 *Invisible colleges and scholarly communication*

The "Babylonian variety" of different network concepts and theoretical understandings knocked up by Börzel (1998) raises the question whether there are distinguishable approaches or schools of thought in the empirical studies as well. These schools of thought may be characterized by distinct attribute or relational features combined in certain configurations, similar to the notion of policy network configurations brought up by van Waarden (1992) or Rhodes and Marsh (1992). Now the question remains to be solved which micro processes may drive such differentiation into research schools.

Theories from the sociology of science may provide explanations or even predictions why and how scientific disciplines are structured. The notion of "invisible colleges", models of scientific growth and the diffusion of scientific innovation as well as Granovetter's notions of weak and strong ties will be reviewed in the following sections in order to illustrate in how far a distinction of research cliques or the identification of certain structural positions are possible.

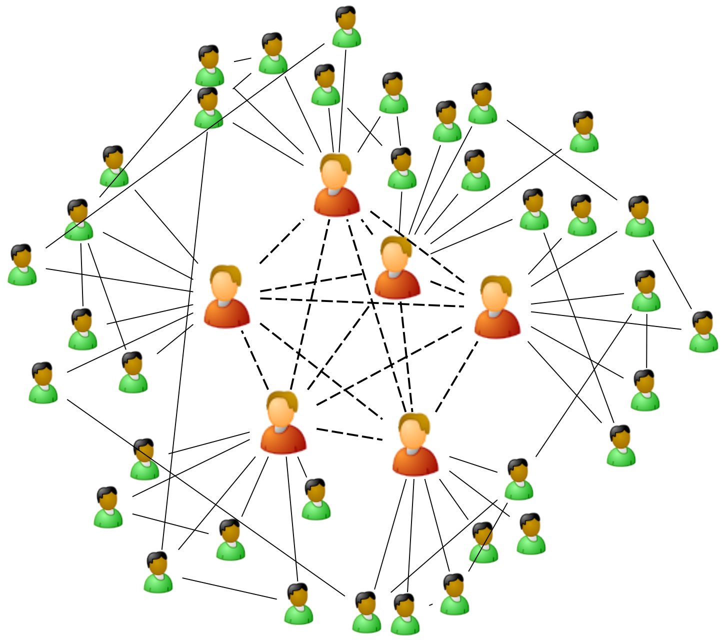

Fig. 2.2: Price's prediction: core-periphery structure

2.2.1 Price's conception of hierarchical networks in science

The notion of "invisible colleges" is first used in the context of the Royal Society of London, the UK's (voluntary) national science academy, in the 17th century. The members of its precursor, an informally connected group of scientists, refer to themselves as an invisible college because there are no institutional affiliations linking them together (Price, 1963; Zuccala, 2005). The term is picked up by Price (1963) some hundred years later as a catch word to describe informal linkages in the contemporary organization of science.

Price (1963) discovers that the amount of scientific output doubles approximately every ten years and that most scientific output is produced by few scientists. In his view, these key researchers must be tightly knit in networks of informal ties, just like the Royal Society in the 17th century, and surrounded by many less productive researchers. This type of scientific organization takes place in subsystems of the scientific universe, which can be called "research specialties" (Small and Griffith, 1974; Small, 1977; Mullins et al., 1977; Nadel, 1980) or "subject specialties" (Zuccala, 2005), the boundaries of which are defined by common research topics and concepts. In Price's conception, a maximum of 100 colleagues shaping the "invisible college" of a subject specialty frequently send each other preprints of their publications and regularly meet at conferences, summer schools, research centers or other institutions (c.f. Price and Beaver, 1966). The network of these outstanding researchers develops a high density over the course of several years and results in an elite structure, similar to the power elite model (Hunter, 1953; Mills, 1956) of the 1950s in political science . Price (1971, p. 75) conceptualizes this dense network as a "hierarchical elite resulting from an expectable inequality, and number about the square root of the total population of people in that area of research front". For research specialties such as quantitative political network analysis, Price's model would predict a core-periphery structure similar to the one depicted in figure 2.2 with few core scientists being perfectly connected by informal ties.

A subject specialty develops over a couple of years after an initial idea of a researcher has "infected" other researchers. The procedure is as follows: Once a ground-breaking idea is set out by a researcher, the theory or approach he develops becomes "his" domain. He gathers a group of collaborators interested in this theory or approach around him and begins to spread the word. A diffusion of the idea takes place, and after some time other researchers pick up the idea and either make new contributions in order to extend of falsify the existing theory, or they just pick up the basic idea as a simple concept or symbol and develop a new theory, sometimes in a slightly different context, out of the idea. As time goes by, a variety of researchers all over the world use either the original theory/approach or other theories/approaches with a cognitive link to the original work.

Simonton (1997) describes this process of idea generation as a "creative" and "blind" evolutionary selection process: Researchers randomly pick up ideas they encounter and keep some of them while they discard others. The selected set of ideas is partially combined to new entities which are then published in journals or books or presented at conferences. Apart from this first, cognitive variation-selection operation, there is a second evolutionary selection process on a socio-cultural level: The "audience" or the journal editors must decide on whether the new cognitive entity will become a contribution or not. Simonton (1997) proves that 10% of all researchers account for 50% of all creative products, and the non-linear distribution shows that there are few extremely creative researchers who gather the other 90% around themselves, which is in line with Price's observations described above.

The essence of these models is that after an initial creative, evolutionary process, the development of a subject specialty can be conceived as a diffusion or growth process of an idea or concept in a social system and that this social system results in a core-periphery structure.

2.2.2 Crane's theory of scientific networks as social circles

In line with Price, Crane (1972) posits that scientific growth is driven by social processes and describes the underlying interactions and structures that accompany the development of a research specialty. In doing this, she sticks to Kuhn's conception of paradigms and scientific revolutions (Kuhn, 1962).

A research area is first made up of an idea or "interesting cognitive event (possibly along the lines of a paradigm as described by Kuhn)" (p. 34). It attracts some researchers and initiates the growth process of the subject specialty. As in Kuhn's conception of "normal science" (Kuhn, 1962), the initial growth is followed by a "period of cumulative development of knowledge in the area" (Crane, 1972, p. 34) in which the number of new publications and authors grows exponentially. In this second stage, "a few highly productive scientists set priorities for research, recruit and train students who become their collaborators, and maintain informal contact with other members of the area" (p. 40). The junior researchers are recruited and socialized, so they become part of the cohesive "solidarity group" (Mullins 1968, cited by Crane 1972) whose important research questions are defined by the head of the group.

Apart from senior researchers "breeding" young talents, scientific growth can be conceived as a social contagion process (Coleman et al., 1966) where early adopters of an innovation influence the behavior of late adopters in a situation of general uncertainty about the usefulness of the innovation. Burt (1987) distinguishes between two alternative forms of social contagion: In the model of

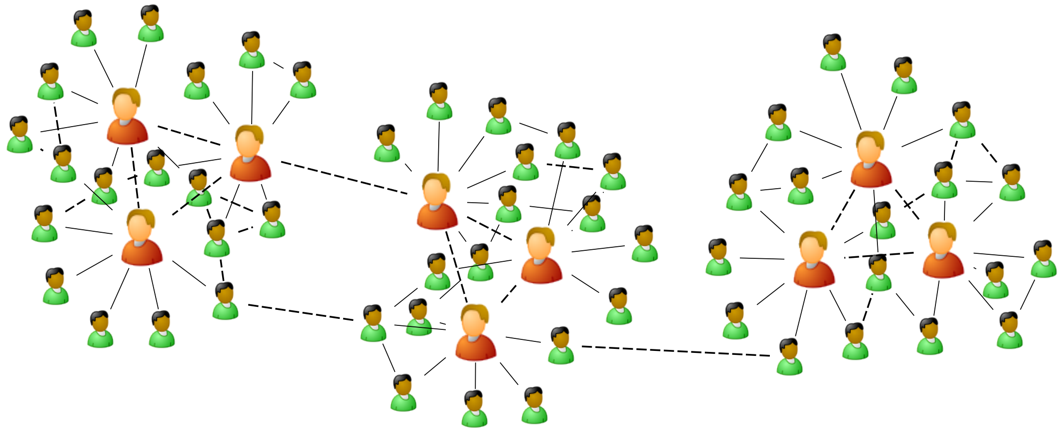

Fig. 2.3: Crane's prediction: social circles

"cohesion", social ties account for this influence, while in the model of *"structural equivalence"*, late adopters recognize the early adopters' action as advantageous and adopt their strategy. Either mechanism leads to an exponential increase in adoptions – or new publications and scientists entering the research specialty – and eventually results in a logarithmic growth curve (Crane, 1972, p. 40). Crane's model is obviously based on the cohesion model since she stresses informal communication ties between researchers as the driving mechanism behind scientific growth: "The rate of expansion will vary depending upon the number of people with whom each scientist has personal contact" (p. 23), e.g. if each researcher has three ties and if three "rounds" of information exchange take place, the piece of information can spread to 21 other people.

The third stage of the process of scientific growth is characterized by a saturation of the specialty. When new insights and idea generation become more difficult, the research specialty becomes less attractive for outside researchers, and the exponential growth is replaced by linear growth. This stage is followed by a growth decline because a new approach becomes more attractive and the old approach is incapable of acquiring any more new researchers.

Crane's conception of scientific growth incorporates social networks of researchers as its main element. The interconnectedness of scientists accounts for the degree of growth via the spread of information. A research specialty in the stages of exponential and linear growth features certain structural properties, which are also illustrated in figure 2.3:

- The subject specialty is composed of several hierarchically organized research groups. The groups are composed of a senior researcher, who is very productive, and several medium or less productive researchers surrounding the leading scientist. The important research questions are defined by the head of the group. Again, the distribution of creativity follows the distribution measured by Simonton (1997), but Crane's explanation is at the individual level rather than the macro level of a specialty. Within a research group, membership is usually made up of *formal* ties.

- In contrast to these formal within-group ties, there are strong *informal* between-group ties connecting the leading scientists of important research groups. These informal ties enable the senior researchers "to monitor the rapidly changing research 'front' and to keep up with new findings during a period of rapid growth" (p. 35). This second informal network is not easily visible to outside observers and therefore labeled the "invisible college".

- There may be some ties between junior researchers of two different groups, but the main path of information flow is between the senior researchers. The subject specialty is characterized by "social circles" (Kadushin, 1968; Alba and Kadushin, 1976), i.e. several research groups with more than one between-group tie cluster together. Eventually the whole field is characterized by several social circles that are separated only by differing subject focal points. According to Crane (1972, p. 14), these circles have four important elements:

    1. There is no formal membership.
    2. Social circles are decentralized and not hierarchically organized.
    3. They are defined by common commitment.
    4. The boundaries and the subject are fluid.

In comparison with Price's idea of an invisible college, Crane's concept is more "fragmented" (Zuccala, 2005, p. 3), and one should be able to find clusters or "schools of thought" or "invisible colleges" within most subject specialties. If applied to quantitative political network analysis, a segmentation of the field into several large clusters according to topical focal points should be possible.

Crane's conception is perfectly in line with Granovetter's work on "The Strength of Weak Ties" (Granovetter, 1973) where formal within-group communication is called "strong ties" and informal between-group communication "weak ties". According to him, people "inherently form groups" or cliques that "tend to become internally cohesive having little contact with other groups" (Goodall, 2003, p. 3). The nodes in the network connecting several of these cliques are called "bridges". In Crane's framework, the senior scientists and some of their collaborators would be such bridges.

2.2.3 Invisible colleges revisited

So far, Crane's and Price's concepts and their implications have been described. Yet there are several other theories and definitions of invisible colleges. Zuccala (2005, p. 3) asserts that "one of the main problems associated with the concept [of invisible colleges, P.L.] is that it is used to describe different phenomena and has already been assigned too many definitions". Zuccala then proceeds to describe several of these concepts, ranging from tightly meshed communities shutting themselves off from outside influence, and loosely coupled, unstable, fragmented and fluid subsystems (p. 3).

However, it seems to be the most straightforward assumption that a subject specialty can be subdivided into several clusters making up certain topical focal points within the specialty. On the other hand, this subdivision serves to define a connected set of research groups and their topic as a subject specialty of itself, which is then more or less centrally organized because the important researchers informally communicate within this social circle while junior researchers are less tightly connected. In breaking down Crane's meso level of distinct research schools into their components, i.e. several entities, there is a shift in the level of analysis rather than a radically different approach. The definitional problem is that a "subject specialty" or "research specialty" can actually be nested in a more general subject specialty, which in turn can be nested in an even more general subject specialty. If this assumption holds, there may be several social circles within a research specialty as described by Crane on one level of analysis, and only one connected group of scientists at each lower level of analysis, as hypothesized by Price. In this perspective, the subject specialty of social network analysis may be subdivided into the specialties of political network analysis, managerial network analysis, sociological network analysis etc., while the sub-specialty of political network analysis can in turn be subdivided into other nested research schools, which may be identified in this thesis. At an even lower level of analysis, it will be hard to isolate distinct specialties or branches, for the size of groups will be too small to identify meaningful subunits. Another complication is that an area of research may be nested in more than one higher-level specialty at the same time, e.g. elite networks may be affiliated with social network analysis and elite research at the same time.

Zuccala (2005, p. 10) names five criteria or "hints" for recognizing whether a specialty may function as an invisible college:

1. The specialty should not be too old, i.e. most scholars should still be alive. In Crane's terminology, the period of exponential or linear growth should be active. Considering the increasing rate of publications described in section 1.1, this seems to hold for quantitative political network analysis.

2. The specialty should "fit within an identifiable indexing or classification system" (p. 10). The only classification system in this field up to now is the analysis presented in this thesis. A general purpose indexing service is mentioned on the INSNA website, but it does not exclusively focus on the topic.

3. A specialty is likely to be composed of an invisible college if there is a specialty website where researchers can exchange or access information or preprints including conference announcements. This is the case as political network analysis is covered by the International Network for Social Network Analysis (INSNA) and its website and annual conference.

4. The number of active scholars should be appropriate, so that informal ties are possible.

5. The world-wide distribution of scholars, which is given in political network analysis, is another hint that a specialty may be composed of an invisible college. Chapter 3 will demonstrate the geographic distribution of the analyses.

Since four out of five criteria are met, quantitative political network analysis is likely to be composed of an invisible college (or several colleges, depending on the conceptualization). It is the task of the next section to establish a link between invisible college theory and citation analysis. It will be evaluated if this network can be traced using citation analysis and whether citations provide a sensible operationalization.

2.2.4 Invisible colleges and citation analysis

Soon after the invisible college conjecture of Price and Beaver (1966), Price (1971) and Crane (1972) has appeared, the idea of using citation analysis to test the invisible college hypotheses comes up. Mullins et al. (1977) use a blockmodel analysis of sociometric ties to examine the structure of a research specialty and the congruence of this structure with a co-citation cluster structure calculated beforehand. They largely confirm Crane's conjecture about the inner core-periphery structure of research groups and the development of invisible colleges as clusters within a specialty.

According to Lievrouw (1989, p. 617), "the real strength of citation analysis in communication research is that clusters or maps of research articles can be *interpreted* as networks of interpersonal contacts. [...] They seem to imply communicative interaction among members of the network, which is often neglected in the effort to describe concrete social structures.".

Nonetheless, Lievrouw (1989, p. 618) criticizes citation analysis for not distinguishing between process and structure: In line with Mullins (1968), scholarly communication as a *process* is not more than the individual perception of a researcher about his surrounding invisible college. It is seen as a process that is not measurable from the outside using structural citation analysis because it is only a perception of the researcher about his own influence. In contrast to this perspective, scholarly communication as a *structure* is measurable from the outside via citation analysis because citations are objective information contained in publications. This implies that the information are per se formal and not informal as stated in invisible college theory. Put differently, formal structures are used to track down informal communication patterns, which is not necessarily a valid inference. On these grounds, there may be objections whether citation analysis is indeed suited to map the informal communication structure.

Zuccala (2004) discusses this point of criticism in detail and proceeds to analyze whether formal co-citation analysis does reflect informal communication patterns. She conducts a co-citation analysis and a co-authorship analysis in the research specialty of singularity theory and also records quantitative and qualitative data on communication between the researchers in an ethnographic research design. Having collected all three sorts of data, she tests the congruity of all three measures using QAP matrix regression and concludes that citation data indeed reflect scholarly communication (for a related analysis, see White et al., 2004).

This overview indicates that there are competing points of view regarding the use of citation data as a proxy for social structure. Triangulation seems to prove that citation counts do reflect communication or contact among scholars and the strength of the relation is properly mapped by co-occurrence. Yet it remains unclear which kind of relation is touched by bibliographic data. Zuccala's solution reveals personal contact at conferences as the relation reflected by bibliometric similarity. White et al. (2004) measure some other patterns of interaction that are positively and significantly correlated with some forms of bibliometric structure.

The co-citation analysis conducted in chapter 4 should be perceived in the light of these sociological arguments. Mapping a whole specialty is certainly not suited to measure the inner cohesiveness of any research unit at the micro level because the subjects of measurement are publications and not research units. It may be used though to map distinct invisible colleges within the specialty, given the assumption that citation reflects interpersonal contact. There are four questions evolving from this theoretical framework:

1. What clusters (i.e. distinct invisible colleges) exist in the specialty of quantitative political network analysis? How can these schools of thought be described in a meaningful way? Or does the field consist of one single cohesive invisible college composed of the most creative minds as proposed by Price?

2. Are there researchers who float between the clusters and who are thus linked to a significant part of the whole discipline? This question relates to the identification of "bridges".

3. Is the internal structure of each college homogeneous or does it exhibit a great deal of overlap with the other colleges/schools of thought?

4. Who are the core researchers or "leading scientists" in each invisible college?

The goal of this thesis is not to test the hypotheses of invisible college theory. This has already been done by other researchers (see above). The goal here is to identify the research clusters predicted by this theory in a single specialty. In this context, the insights expected from the analysis are insights in the field of political network analysis rather than sociology of science.

2.3 Epistemic communities

Laying aside the concept of invisible colleges for a moment, important work has been done on the identification of "epistemic communities", a concept introduced by Haas (1992). He describes an epistemic community as "a network of knowledge-based experts [...] with an authoritative claim to policy-relevant knowledge within the domain of their expertise". This concept, just like Crane's interpretation of invisible colleges, predicts a decentralized set of research groups clustering in certain more or less formally organized subsets of experts, known as epistemic communities in this case. Unlike the former concept, the latter is not restricted to scientists but can be applied to political actors or other agents as well. An epistemic community deals with “a commonly acknowledged subset of knowledge issues” (Cowan et al., 2000), more explicitly described as a “common goal of knowledge creation and a common framework allowing to understand this trend” by Dupouet et al. (2001). Hence, not only theoretical aspirations drive the membership in an epistemic community, but these groups are constituted by common perceptions, belief systems, possibly the same methodology and certainly largely overlapping problems and topics. In analogy to the concept of invisible colleges, where clusters are nested in the broader category of “research specialties” or “subject specialties”, and these in turn constitute a discipline, epistemic communities emerge in “subdisciplines”, and subdisciplines are nested in disciplines or “paradigms” (Roth and Bourgine, 2005, p. 2). In comparison with invisible college theory, however, there is one major difference: Epistemic communities are not necessarily socially linked via communication or institutional linkages, which means that affiliation to the same topics, frameworks etc. is a sufficient condition for membership (Roth and Bourgine, 2005), and consequently epistemic communities are sometimes in a neutral fashion referred to as “schools of thought” or “cultural cliques”. Nevertheless, the predictions of invisible college theory and the epistemic community concept are essentially the same: decentralized research clusters with an orientation towards common approaches, theories or belief systems. Chapter 4 will track down these clusters or schools of thought making use of several statistical and mathematical methods.

3. THE DATA SET

As mentioned in section 1.1, the collection of publications related to political networks comprises more than 1,000 (currently: 1014) items. 193 of them are quantitative and 554 are qualitative or comparative studies, and the remaining publications are review articles or deal with methodological topics. Although the data set is certainly not complete, it should cover almost all important publications in the research specialty and also most not very frequently cited analyses. All publications have been collected by means of database and search engine queries.[1] Details about the boundary specification can be found in section 4.1.2. The publications have been tagged according to several categories which allow some descriptive statistics to be calculated. The publications and their tags have been saved in an EndNote[2] database. In order to extract the 200 variables from the file and convert them into a binary matrix, an EndNote export style can be created and a custom-made AWK[3] program can be written. Details and the source code can be found in appendix B.

The next subsections will give an overview over the research specialty of political network analysis from this descriptive point of view at the macro level. The distributions at the meso level will be described in chapter 5 where the individual clusters are evaluated in detail. The univariate statistics displayed below usually do not provide explanations *why* the field is structured in a certain way. Instead, they focus on *how* the discipline is structured and what focal points exist.

[1] Among some minor sources, the following search engines have mainly been used: ISI Web of Knowledge (http://isiwebofknowledge.com), Social Science Citation Index (http://scientific.thomson.com/products/ssci/), Vifapol (http://www.vifapol.de), JSTOR (http://www.jstor.org), EBSCO (http://www.epnet.com), KOALA (http://www.ub.uni-konstanz.de), Google Scholar (http://scholar.google.com), Google (http://www.google.com), Scopus (http://www.scopus.com).

[2] The software is available from http://www.endnote.com.

[3] AWK is a programming language designed for processing text-based data and strings. The free interpreter Gnu AWK can be obtained from http://www.gnu.org/software/gawk/gawk.html.

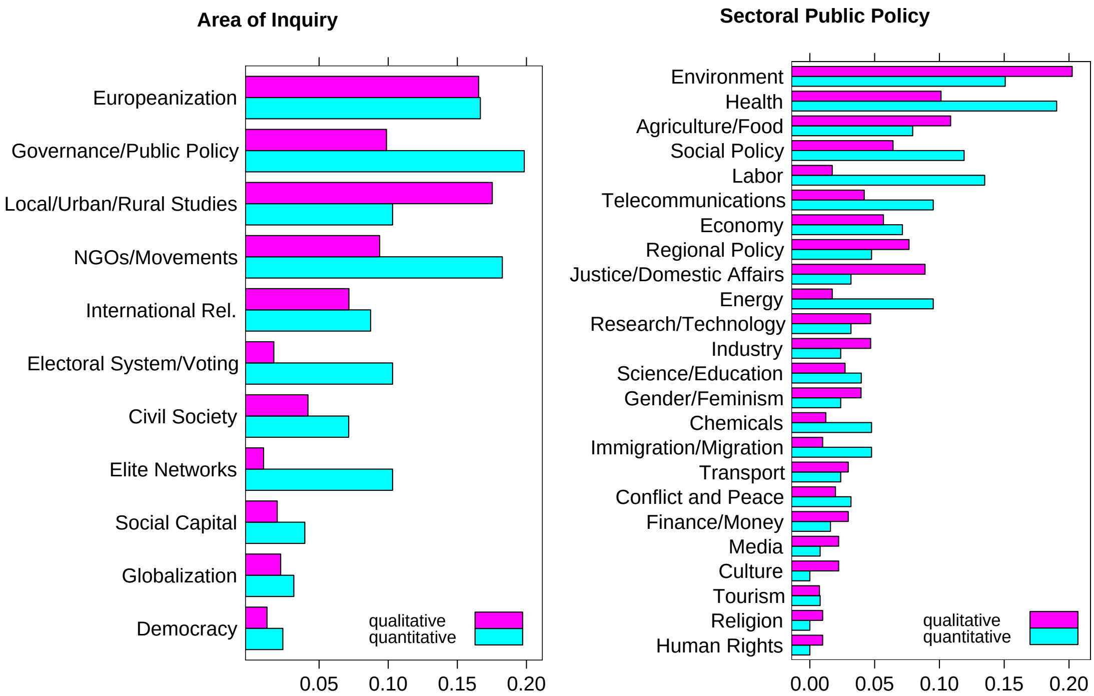

Fig. 3.1: Area of inquiry in comparison (Relative frequencies)

3.1 Area of inquiry

The first category is the area of inquiry of each publication. All 747 empirical analyses are assigned to one or several subject categories as displayed in figure 3.1. In the first bar chart, all categories except the most frequent one, sectoral public policy, are compared. The right half of figure 3.1 basically shows one specific area of inquiry and its subsets in detail. There are 126 quantitative and 405 qualitative publications (total: 531) dealing with sectoral public policy and 74 quantitative and 149 qualitative publications (total: 223) dealing with other areas of inquiry.

The left part of the figure compares only non-sectoral areas of inquiry regarding their relative frequencies of quantitative versus qualitative works, standardized by the non-sectoral total sum of quantitative (and qualitative, respectively) publications. The distribution indicates that studies about elite networks and the electoral system and voting are significantly more popular in the quantitative literature than in qualitative accounts. This is also the case for general studies about governance or public policy and non-governmental organization systems. On the other hand, local, urban and rural studies are more popular in the qualitative literature, possibly because they are more easily accessible for case studies.

The other bar chart presents a comparison of the relative frequencies of sectoral public policy. Both quantitative and qualitative studies have focal points in environmental and health policy. While quantitative accounts treat labor, social, energy and telecommunication policy comparatively often, qualitative works tend to concentrate on agricultural policy, domestic affairs, justice and regional policy. Striking differences are evident in labor policy and energy policy: In both sectors, there are far more quantitative than qualitative studies. An explanation for this may be the repeated usability of data that have once been collected, because collecting new complex data collections would be an immense effort. Another important point is that a "Matthew effect" (Merton, 1968) may be at work: Authors who publish their work and become more experienced in a subject matter, can use this knowledge again and again. It is easier for them to publish on the same topic as before than to dig into completely new areas of research. This is why the number of published works on any subject increases in a non-linear way over time. A similar mechanism may be at work for the knowledge pool of the whole political network analysis community.

3.2 Geographical distribution and level of analysis

The territorial frequency distribution presented in figure 3.2 reveals that Europe is the most frequently analyzed continent both in the quantitative and in the qualitative literature, followed by (North and South) America. Among the American countries, the United States are examined in 91% of the quantitative and 58% of the qualitative items. The relative strength of the United States is surprising considering that Raab and Kenis (2006, p. 187) assume that "it seems that the concept [of policy networks, P.L.] has been used much more frequently by European than by North American, especially U.S., scholars. This can be largely attributed to different research traditions but also to different political cultures." Obviously, their focus is only on "policy networks", in contrast to political networks in general.

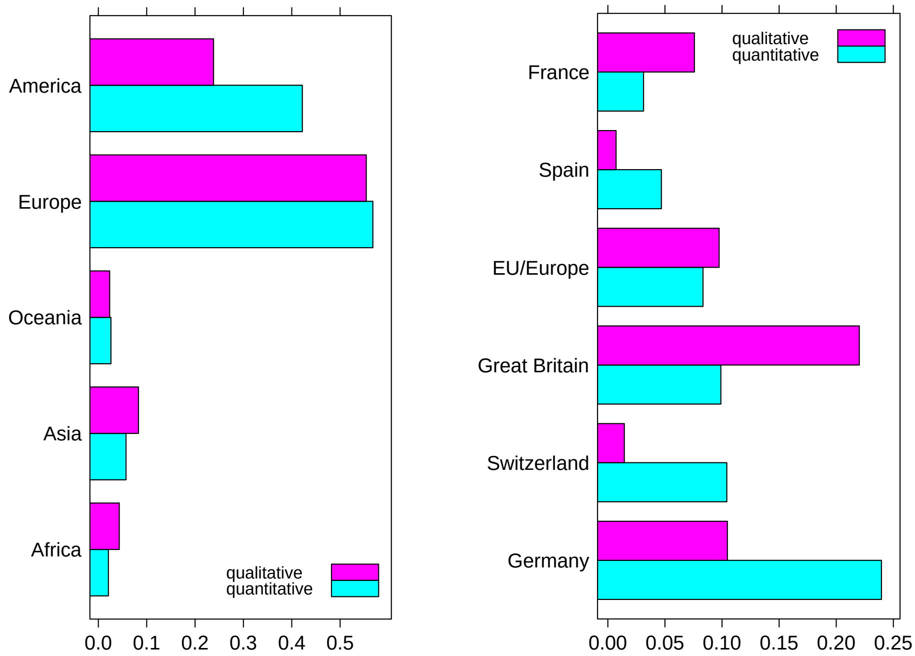

Fig. 3.2: Continents and European countries (Relative frequencies)

As far as European countries, the largest group of studies, are concerned, most quantitative analyses are from Germany. This is not very surprising: A selection bias is at work because the database of the project consists only of publications in English and German language. The same argument applies to the comparatively large number of Swiss contributions. There is, however, ample evidence that qualitative research designs are less popular in German and Swiss analyses than quantitative designs. Another interesting observation is that in Great Britain and partly in France, qualitative designs are more frequent than quantitative studies. A small part of this difference may be explained by the fact that it is popular to compare case studies between Western European countries (e.g. McKay, 1996).

The level of analysis (figure 3.3), which has only been measured for the quantitative literature, is in most cases the national level, followed by regional network analyses. Only since the mid 1990s, regional-level network analyses have gained popularity.

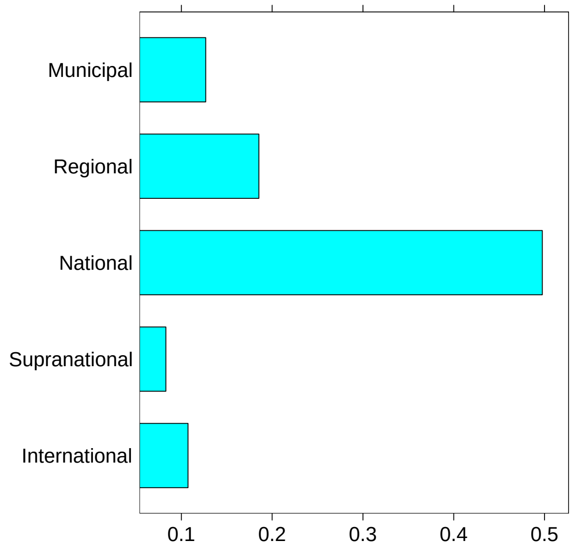

Fig. 3.3: Which territorial level is analyzed? (Relative frequencies)

3.3 Quantitative research methods

Social network analysis possesses a special set of quantitative methods some of which originate from mathematical graph theory and some of which from multivariate statistics. As can be seen in figure 3.4, centrality is used by 50% of all studies and is thus the most popular measure in political network analysis, followed by density (38%). Both centrality and density are based on graph theory. Clique analysis is far less popular (11%). One reason may be that it directly competes with blockmodels (25%) and cluster analyses (17%) in the aim of detecting subgroups. The latter two methods are often mentioned together as "subgroup analysis" and yield a common percentage of 33% if overlapping amounts are omitted.

The most frequently used measure, centrality, is reviewed in detail in the right bar chart of figure 3.4. The simplest measures, degree centrality and its derivatives for digraphs, account for most of the centrality percentage. The second most frequently used centrality measure after indegree is betweenness. Graph centralization, which can be calculated for any centrality measure at the graph level (as opposed to the actor level), is averagely popular while eigenvector centrality is the least popular method. This is surprising because eigenvector centrality "has been

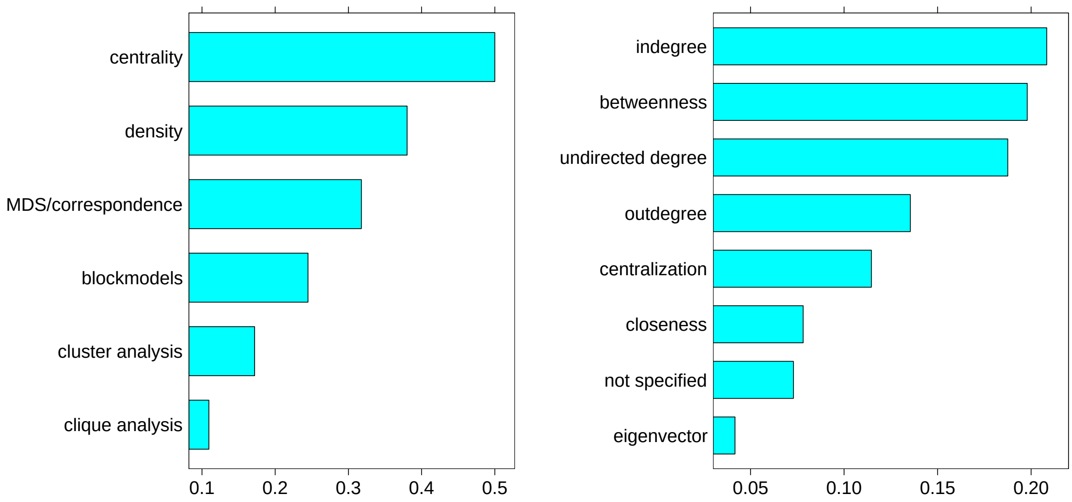

Fig. 3.4: Methods and centrality measures (Relative frequencies)

	centrality	density	clique	MDS	cluster	blockmodel
centrality	1					
density	0.46	1				
clique	0.17	0.13	1			
MDS	0.33	0.28	0.06	1		
cluster	0.18	0.16	0.08	0.32	1	
blockmodel	0.30	0.28	0.12	0.33	0.19	1

Tab. 3.1: Jaccard similarities of the quantitative methods

widely accepted as superior to the original measure [of degree centrality, P.L.]" (Hanneman and Riddle, 2005, chapter 10). The reason may be that the notions of indegree and betweenness are easily understandable while eigenvector and closeness centrality cannot be communicated in such an easy way. Another reason may be that eigenvector centrality is a relatively new measure and is therefore simply not present in any publication before 1987, the year of its invention.

Frequencies alone are not able to give a complete picture of the use of methods in political network analysis. There is a great deal of overlap because most authors use more than just one method. This common use can be quantified using a binary measure of association, the Jaccard coefficient. The similarities in table 3.1 reveal that centrality and density are often used in the same analysis while clique analysis and projection techniques are almost never used together. MDS is comparatively often employed in conjunction with blockmodels or cluster analysis. The results

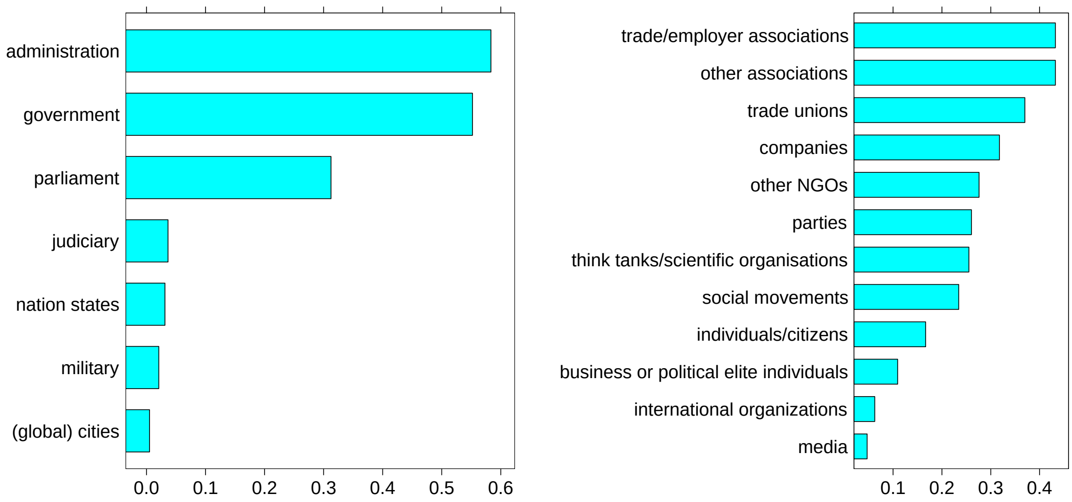

Fig. 3.5: Governmental and private actors (Relative frequencies)

are not caused by differences in absolute counts because Jaccard corrects for this.

3.4 Actors

Almost any network analysis focuses on a set of actors determined by boundary specification. Yet the actors that are included in the analysis vary. 70% of all publications include governmental actors and 88% include private actors. Only 60% are joint analyses of both kinds of actors. 10% focus exclusively on governmental actors and 29% only on private actors.

The left part of figure 3.5 shows how often certain categories of governmental actors are treated. In line with European terminology, the label "administration" refers to bureaucratic actors and "government" to the political executive, as opposed to North American definitions. Administration, government and parliament are the most interesting state actors for network analysts. All other state actors are rarely analyzed. The same distribution for private actors is presented in the right bar chart. Associations and unions dominate political network analyses. This is not surprising given the strong cleavages associated with labor and trade interests. The least interesting actors for network analysts seem to be from the media (only 4%).

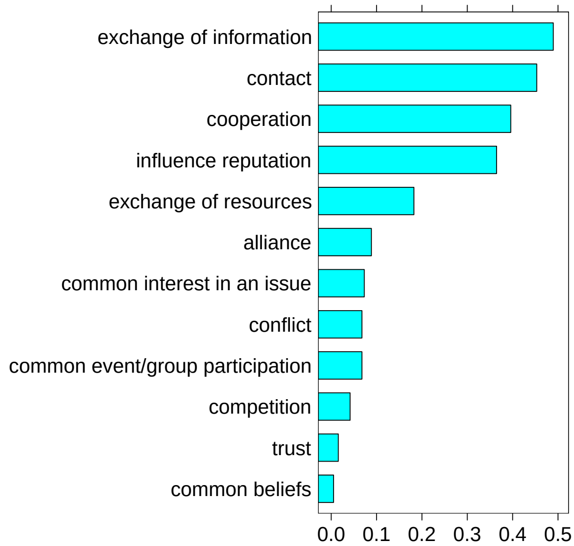

Fig. 3.6: Relations (Relative frequencies)

3.5 Relations

In social network analysis, any matrix containing the edges between the nodes represents a certain social relation between the actors. There are two structural types of networks: one-mode networks containing direct relations between the actors, represented by square adjacency matrices, and two-mode networks containing the affiliations of actors to events or groups, represented by rectangular incidence matrices. Adjacency matrices can be extracted from incidence matrices via calculating the crossproduct and they are also more intuitive and resemble the basic notion of a network, so one-mode networks (74%) can be found much more frequently than two-mode networks (27%) in the literature. There is a 25% overlap, i.e. a quarter of all quantitative studies use both one- and two-mode networks. Apart from structural networks, there are ego-centered networks, which are based on attribute variables rather than relational data and which make up 10% of the literature.

The relations present in the literature are shown in figure 3.6. Exchange of information and contact are the two most popular relations. Unfortunately, it is hardly possible to make a clear-cut distinction between the two based on the literature, and the same applies to cooperation and alliance as well as exchange of information and exchange of resources. The figures only allow the observation of some general trends: Relations based on communication, exchange and influence are very popular while two-mode affiliation relations are less frequently used. Negative relations like conflict or competition are rarely examined.

4. QUANTITATIVE ANALYSIS OF THE POLITICAL NETWORK LITERATURE

4.1 Methodological issues

4.1.1 Social network analysis as a descriptive tool

In quantitative social research, most applications focus on hypothesis testing and causal inference, often disregarding hypothesis generation or knowledge discovery via quantitative methods. It is legitimate to employ methods such as network analysis, cluster analysis or exploratory projection techniques to discover structures in data if this helps to either answer a research question of interest, generate a research question or simplify data (see below). In this thesis, the underlying theoretical arguments are provided by sociology of science, as set out in section 2.2. In addition, the identification of research traditions in the field of political networks itself is an interesting insight because it has been extensively discussed in the literature (Börzel, 1998; Dowding, 2001; Kenis and Raab, 2003; Raab and Kenis, 2006). In physical sciences, exploring data structures is a common task, the results of which are regularly regarded as advances in their research specialties, e.g. when subpopulations of a species can be distinguished in vegetation ecology, and in consequence new research questions about these species appear on the agenda. Similar to this example, multivariate methods or data mining may foster the development of political network analysis by clarifying which branches of network analysis exist and how they are related to other research schools, in order to stimulate the development of the discipline. In this regard, quantitative network analysis is considered a method or analytical toolbox rather than a theory itself. Kenis and Raab (2003) expect network methods to be accompanied by network theories: a network theory of organizations, a network theory of policy-making etc. In contrast to their view, I posit that the theories in network analysis are usually no intrinsic network theories, but they are hypotheses derived from the underlying, exogenous theoretical branch, like invisible college theory in this case or elite, governance, exchange, participation or voting theories in the case of political network analysis. This is compatible with the view that network analysis is an analytic technique just like the methods mentioned above, and not a theory by itself. This does of course not preclude the possibility that more general "network theories" may one day be developed by aggregating the results of several comparable network analyses.

From a methodological point of view, this thesis makes a descriptive statement and neglects causal relations. Accordingly, criteria of descriptive inference as set out by King et al. (1994) are applicable. Social research "involves the dual goals of describing and explaining. Some scholars set out to describe the world; others to explain. Each is essential" (p. 34). The question raised by unique events, like the development of quantitative political network analysis between 1976 and 2006, is the problem of complexity. The point is "whether the key features of social reality that we want to understand can be abstracted from a mass of facts. One of the first and most difficult tasks of research in the social sciences is this act of *simplification*" (p. 42). Simplification in this context means the construction of blocks or clusters as entities that are simpler to grasp than a clutter of 200 publications.

4.1.2 Boundary specification

The goal of the analysis is the detection of subgroups in quantitative political network analysis. Following this formulation, all English or German publications including articles, books, conference papers and reports containing a quantitative analysis of networks and belonging into the discipline of political science are eligible. In the context of a research project on "Policy Networks and Political Theory" at the Chair of Empirical Theory of the State at the University of Konstanz, 193 such publications have been identified (see appendix A) using online databases, generic search engines and bibliographies of already known publications. This list is probably not exhaustive but should cover almost all important and most less important publications.

4.1.3 Data collection

As citation analysis requires the collection and management of complex data, analyses are usually based on online databases such as the (Social) Science Citation Index. Using their data is fast and generates huge quantities of possibly related articles. Nonetheless, several disadvantages come into play when making use of their services:

- Only journal articles are listed in online databases. Books or published reports are usually not available. This would significantly reduce the amount of eligible items and eventually prohibit a reliable subgroup detection.
- Orthographic mistakes are common both in bibliographies and in databases. While typos can be corrected during manual data entry, this is hardly possible when downloading citation data. In addition, databases add even more mistakes since the bibliographies are often scanned and processed via optical character recognition (OCR). Such a lack of data quality hinders the matching of any two items: If “Leifeld” and “Leivelt” are not recognized as a match by the software, two different nodes are created in the network each of which has a lower likelihood of being co-cited with other articles. Probabilistic matching using phonetic algorithms like Soundex, NYSIIS or Phonex or string similarity functions like the Hamming distance might help, yet there is no standard software available implementing these algorithms for the purpose of matching BibTEX entries.
- Some works are published in more than one language, so matching these two items is not possible either if data entry and matching are carried out automatically.
- Sometimes, author names are listed in a wrong order – either in the database or in the bibliography of the publication.

- It is quite common to present a conference paper and then submit a very similar article to a journal. Usually the title is identical, but the year differs. Again, a match between these two publications cannot be established if automatic data collection is employed.

In this analysis, these five issues are addressed by manual data entry and the use of a master database: Whenever a new publication is coded, this master database is manually checked for existing entries which are copied to the file of the new citing publication. All non-existing citations are entered manually and later added to the master file, thus minimizing errors due to error-prone matching codes.

4.1.4 Data management

Each of the 8490 cited items from the bibliographies is given a unique key for the matching procedure. This identifying key of a publication is composed of the first author's last name, the year and the first title word (except "the", "an" etc.). All problems mentioned above can be solved using this data entry technique. Misspellings do not matter in the matching process as long as existing entries are copied from the master file. The disadvantage of this procedure is its time consumption. After several days of practice, approximately 40 publications can be typed into a reference software per hour, depending on the type of publications and their language. About the same amount of time is required for data management, i.e. copying entries from and to the master file and finding duplicate entries.

The bibliographies of all 193 publications are entered into 193 separate BibTEX files and copied into the master file. This yields a total of 8490 cited documents, i.e. 44 citations are listed on average per citing document[1]. The resulting 193x8490 binary matrix contains 1,638,570 possible links, 12,000 of which are realized. The dataset can be conceived of as a two-mode network containing 193 "stars" Scott (2000, p. 10) and 8490 "pendants" (Borgatti et al., 1999) or "receivers" (Wasserman and Faust, 1994, p. 128), as depicted in figure 4.1.4. This illustration maps only a small selection of citations for reasons of readability and space. The com-

[1] The software JabRef is used to generate unique keys and to copy them to a linked list DL file which is readable by UCINet (Borgatti et al., 1999)

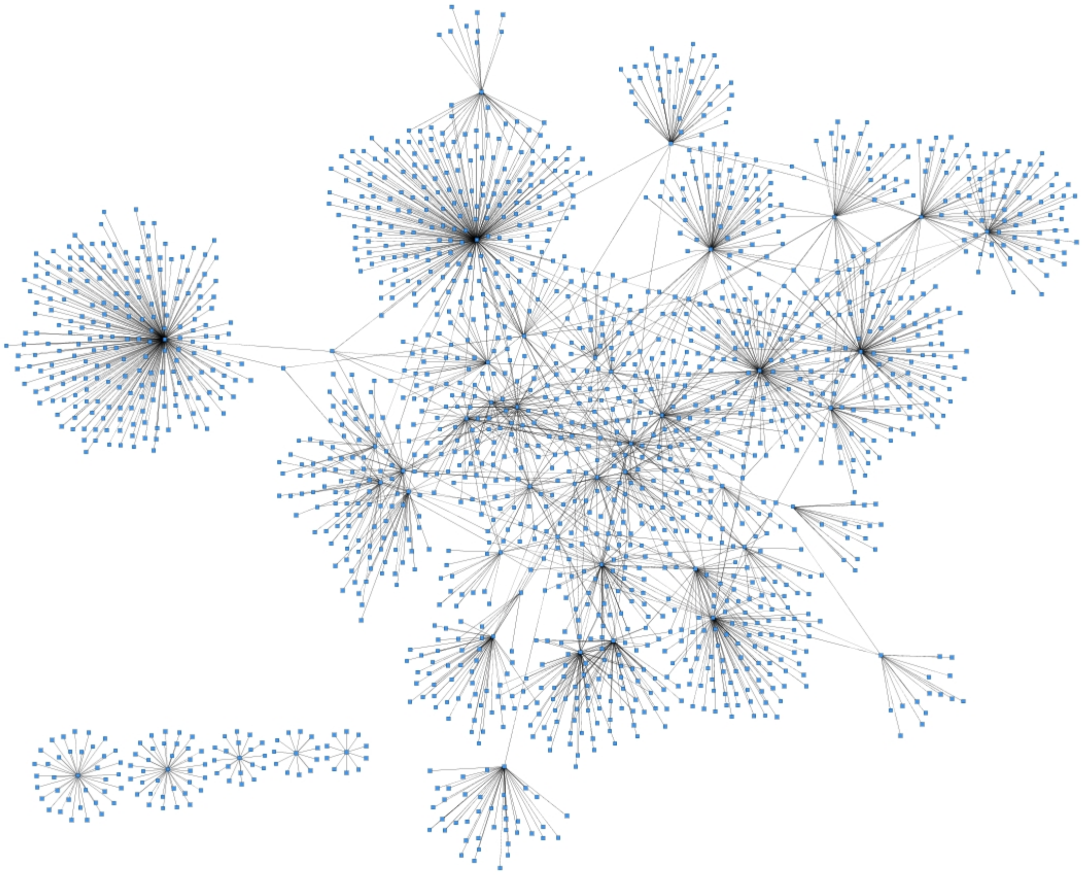

Fig. 4.1: Illustration of the two-mode citation network

plete network of 8683 nodes is presented in appendix C.

4.1.5 Galois lattices and epistemic communities

In section 2.3, the concept of "epistemic communities" was characterized as one possible way of interpreting scientific landscapes. Roth and Bourgine (2003) come up with a formal model that may aid to describe the structure of epistemic communities by making use of Galois lattices, a method of data or knowledge representation from the field of information science which serves to provide a link between social networks of agents and semantic or formal networks of concepts these agents are affiliated with.

In their framework (further elaborated in Roth and Bourgine, 2005), a social network is composed of a set of authors S who are connected by co-authorship relations or other undirected links. A single author s is connected to another author s' by relation R^S_α, where α is a threshold variable allowing to include only relations with a certain minimum weight $w > \alpha$, thus $s \; R^S_\alpha \; s'$. The same notation applies to a set of concepts C where one single concept c is related to another concept c' by means of $c \; R^C_\alpha \; c'$. A concept can be defined as a single word in a title or abstract, a term from a list of keywords, or any other sensible unit that an author may be affiliated with. This affiliation relation can be expressed as $s \; R^S_\alpha \; c$, i.e. an author exhibits a link to a concept.

So far, the framework presented here is nothing more than a graph-theoretic notation of one-mode networks and their interrelation in terms of an affiliation network (c.f. Breiger, 1974; Freeman and White, 1993). The added value lies in the application of lattices to these sets of authors, concepts and relations: A Galois lattice $\mathcal{G}_{S,C,\mathcal{R}}$ can serve as a clustering technique without the need for dissimilarity measures present in most other clustering approaches. Instead, it solely relies on empirically observed *maximal* combinations of agents and concepts to delineate existing schools of thought. If a combination of concepts, e.g. the co-occurrence of the words "exchange", "organizational", "collective", "domain" etc. within the same abstracts, is affiliated with a particularly large number of agents, e.g. the authors Pappi, Laumann, Knoke and some others, this latter enumeration of agents is identified as a school of thought. This simple clustering technique can be applied to citations as concepts, i.e. a school of thought or epistemic community can be identified as a set of authors commonly citing a certain set of references.

Usually, such lattices are visualized as Hasse diagrams: Figure 4.2 depicts a Galois lattice as a Hasse diagram based on a fictional number of authors and citations. The upper set contains five authors and no citations and the lower set no authors and six citations. At the second level from the top, a maximal number of authors with an affiliation to any citation is depicted as a subset. At the next level from the top, any combination of authors being a subset of the set at the previous level is listed together with its maximal number of affiliated citations, etc. It is the task of the researcher to find subsets that are distinct from the other subsets at the same level. If a larger than usual number of authors belongs to a subset of citations, e.g. at the third level, this subset is likely to be an epistemic

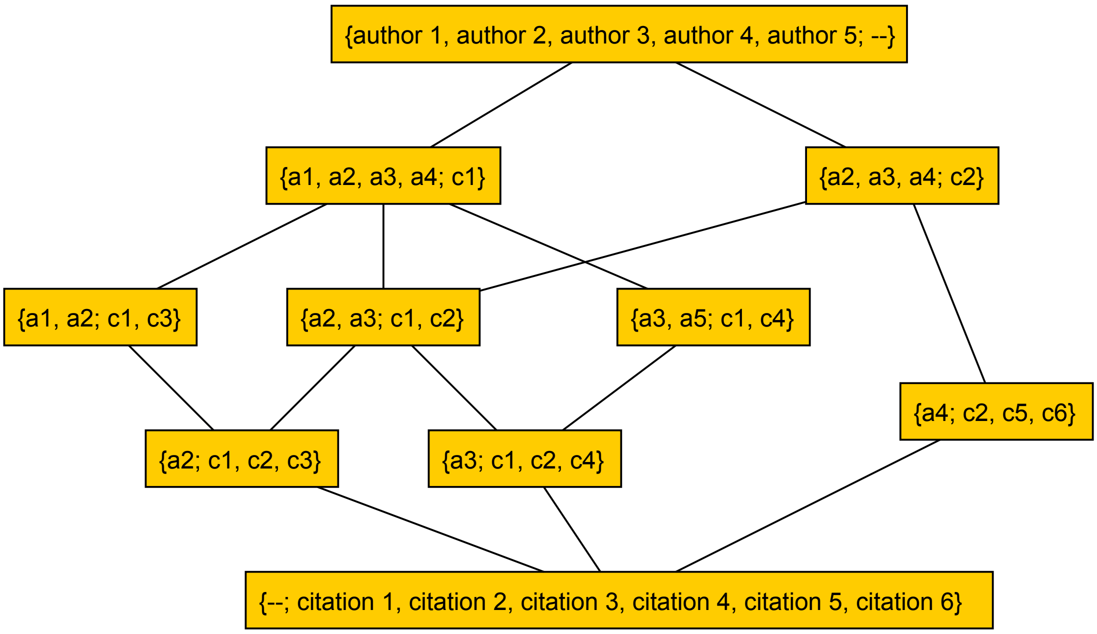

Fig. 4.2: A Galois lattice of citation affiliations

community since it contains several authors with common orientations toward scientific concepts (citations in this case). This method offers several advantages over other clustering techniques:

- The possibility of cross-classification of authors or concepts into more than one community. As Roth and Bourgine (2003, p. 7) put it, “a dendrogram is a tree whereas a GL [Galois lattice, P.L.] is a lattice, i.e. a generalization of trees where ascendancies can be multiple”, which means that “an agent can be part of many non-embedded communities, he can be to some extent 'pluridisciplinary' ”.
- The nested structure of Galois lattices (i.e. the subsets at level four are nested in the subsets at level three etc.) directly accounts for the nested structure prevailing in the real world of scientific disciplines or specialties as observed by Roth and Bourgine (2005).
- Cluster results are more exact than those of distance-based measures.

A more detailed assessment of the differences between similarity-based clustering and lattice clustering is offered by Valtchev and Missaoui (2000).

Unfortunately, Galois lattices have not been implemented in any standard software yet[2], and visual inspection of the lattice would be hard to perform on actor or concept sets with several hundred or thousand agents and concepts. In consequence, this thesis has to rely on conventional, distance-based clustering methods, which are less precise and do not directly offer cross-classification of items because they are nested in an exclusive way in agglomerative or divisive steps. Yet the following sections will develop and apply clustering procedures based on co-citation data which will eventually serve to bypass this latter constraint.

4.1.6 Separating signal from noise

Citation analyses suffer from a number of methodological problems which inhibit the precision of the clustering procedure. The most severe issue is that in order to obtain meaningful clusters, one must make several decisions which data to include and which citations to drop, that is, one has to separate signal from noise (Braam et al., 1988, p. 17): An $m\ x\ n$ citation matrix is given. If n citations are to be partitioned into k clusters, there is usually a fraction of s/n citations that cannot be meaningfully classified (assuming that the meaning of clusters can be anticipated). While a projection of $n - s$ citations would yield k clusters if projected onto a two-dimensional plane, including all n citations would render the data inseparable. Hence the remaining s citations can be regarded as noise cluttering between the subgroups (figure 4.3). The task of the researcher is to determine which citations belong to the meaningful subset $n - s$ and which citations belong to the noise subset s before any clustering procedure can be applied. This "fuzziness" of the classifications makes a careful interpretative work of the researcher extremely important (see chapter 5), and there is a high risk of arbitrariness. This arbitrariness is even increased because the identification of clusters critically depends on the clustering algorithm that is chosen (Braam et al., 1988, p. 16). There are several reasons why there might be noise or distortions in the data:

[2] Several algorithms are readily available that can convert a two-mode affiliation matrix into Hasse diagrams, yet they have not been implemented in statistical packages. Two such algorithms have been presented by Ganter (1984) and Valtchev et al. (2000).

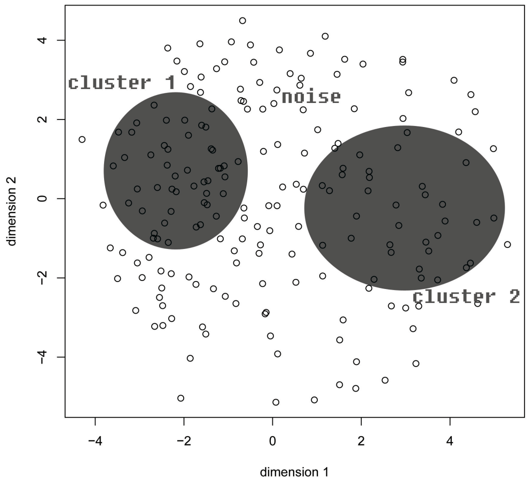

Fig. 4.3: Illustration of noise prohibiting efficient clustering

- A citation analysis is usually a cross-sectional design applied to time-variant data. In the case of political networks, the time span is 30 years – a duration in which some cited publications are certainly outdated and replaced by more recent insights, distorting the distance measure between any pair of citations. This makes the cluster structure more heterogeneous, and the data generating process cannot be easily recognized.

- Usually an author produces more than one paper about a topic or about a data set he has created. This is not a problem as long as the contents of these publications are distinct. In many cases, however, scientists can choose whether they cite an author's article or his book or another article with very similar contents. As a consequence, some ties between citations are underestimated, adding further random noise to the structure. An example from the current analysis is Pappi (1990) and Pappi and Knoke (1991).

- About 80% of the *cited* documents have a column sum of 1 in the incidence matrix, i.e. they do not have any overlap with other cited literature. These "pendants" (Borgatti et al., 1999) (or isolates in the one-mode network) decrease the dissimilarity score dramatically if they are not removed from the file. In addition, projection techniques such as non-metric multidimensional scaling yield degenerated solutions on the level of co-citation analysis if many data points are structurally equivalent and have only one tie to other data points.

- Similarly, many *citing* documents exhibit little overlap with the other papers. Again, an NMDS solution would yield a degenerated solution, i.e. all data points but the one under consideration are projected to nearly the same coordinates. The reason is that the distance between this item and the others is far larger than the distances between all other items. Examples are Futó et al. (2003) and Getimis and Demetropoulou (2004).

- Many authors frequently cite themselves. The consequence of these self-citations is that their publication is not classified into a specific thematic cluster but into a cluster with a different "identity" containing other publications which cite the author's earlier work.

- Articles and conference papers as well as books are included in this citation analysis. While the former usually name 45 other publications on average in their bibliographies, the latter's bibliographies consist of several hundred citations and are spatially projected between the distinct clusters, prohibiting the unambiguous detection of the subgroups and thus considerably adding noise. Publications expected to be projected between the clusters include Brechtel (1998) and Lang (2006).

- Authors not only cite publications they feel acquainted with or they agree with. Sometimes negative examples are cited, but the bibliography does not make a difference.

- Although a researcher may cite an article more than once because he feels this article is very important and influential for his work, all citations are weighted equally in the bibliography at the end of the article. In addition, methodological publications get the same weight as publications which are cited for content-related reasons. The measured distances between publications not always resemble the real dissimilarities.

- Some books are so frequently cited that they can be regarded as common-sense literature because researchers belonging to any research school refer to their contributions. These pioneering works or methodological text books add considerable noise to the cluster structure as they lead to an under-estimation of the "real" distance between any pair of publications. Clusters are literally contracted, so hierarchical clustering algorithms can hardly distinguish between the subgroups. In this analysis, the identification of common-sense literature is addressed in section 4.2.

These nine problems lead to a high intrinsic dimensionality of the data. Dimensionality is defined by the number of patterns included in the data. The citation analysis of the political network literature consists of 8490 patterns, i.e. cited documents that make up the pattern space. Using mapping techniques like non-metric multidimensional scaling or correspondence analysis, these 8490 extrinsic dimensions can be reduced to a lower number of dimensions. The lowest number of dimensions that can still be considered as an adequate representation of the data is called intrinsic dimensionality: The notion of intrinsic dimensionality "essentially determines whether the d-dimensional patterns can be described adequately in a subspace of dimensionality less than d" (Jain and Dubes, 1988, p. 42). In general terms, the main problem of citation analysis is that the fuzziness of the data increases the intrinsic dimensionality and hence requires more qualitative insight into the publications at issue.

4.2 Co-citation analysis: Partitioning the cited documents

Having discussed a number of methodological issues concerning citation analysis, an examination of the literature shall be attempted. As discussed in the previous section, a 193x8490 matrix X can be constructed from the raw citation counts:

$$\underset{193\times8490}{\mathbf{X}} = \begin{pmatrix} x_{1,1} & x_{1,2} & \cdots & x_{1,8490} \\ x_{2,1} & x_{2,2} & \cdots & x_{2,8490} \\ \vdots & \vdots & \ddots & \vdots \\ x_{193,1} & x_{193,2} & \cdots & x_{193,8490} \end{pmatrix} \tag{4.1}$$

This binary affiliation matrix can be transformed into two separate square adjacency matrices by a row-wise calculation (or column-wise calculation, respectively) of the cross product of the rectangular matrix.

$$\begin{aligned} \mathbf{X}^T\mathbf{X} &= \begin{pmatrix} x_{1,1} & x_{2,1} & \cdots & x_{193,1} \\ x_{1,2} & x_{2,2} & \cdots & x_{193,2} \\ \vdots & \vdots & \ddots & \vdots \\ x_{1,8490} & x_{2,8490} & \cdots & x_{193,8490} \end{pmatrix} \times \begin{pmatrix} x_{1,1} & x_{1,2} & \cdots & x_{1,8490} \\ x_{2,1} & x_{2,2} & \cdots & x_{2,8490} \\ \vdots & \vdots & \ddots & \vdots \\ x_{193,1} & x_{193,2} & \cdots & x_{193,8490} \end{pmatrix} \\ &= \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,193} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,193} \\ \vdots & \vdots & \ddots & \vdots \\ a_{193,1} & a_{193,2} & \cdots & a_{193,193} \end{pmatrix} \\ &= \underset{193\times193}{\mathbf{A}} \end{aligned} \tag{4.2}$$

This yields one new data set B containing dyadic information of how many times two documents have been cited by another publication (equation 4.3), which corresponds to the notion of co-citation analysis, and one data set A containing relational information of how many times two publications cite other documents in common (equation 4.3), which is a count of bibliographic coupling.

$$\begin{aligned}
\mathbf{X}\mathbf{X}^T &= \begin{pmatrix} x_{1,1} & x_{1,2} & \dots & x_{1,8490} \\ x_{2,1} & x_{2,2} & \dots & x_{2,8490} \\ \vdots & \vdots & \ddots & \vdots \\ x_{193,1} & x_{193,2} & \dots & x_{193,8490} \end{pmatrix} \times \begin{pmatrix} x_{1,1} & x_{2,1} & \dots & x_{193,1} \\ x_{1,2} & x_{2,2} & \dots & x_{193,2} \\ \vdots & \vdots & \ddots & \vdots \\ x_{1,8490} & x_{2,8490} & \dots & x_{193,8490} \end{pmatrix} \\
&= \begin{pmatrix} b_{1,1} & b_{1,2} & \dots & b_{1,8490} \\ b_{2,1} & b_{2,2} & \dots & b_{2,8490} \\ \vdots & \vdots & \ddots & \vdots \\ b_{8490,1} & b_{8490,2} & \dots & b_{8490,8490} \end{pmatrix} \\
&= \underset{8490\times 8490}{\mathbf{B}} \qquad (4.3)
\end{aligned}$$

These two matrices will be treated separately with the cited publications B representing the first step in the analysis.

4.2.1 The most influential literature

The study of bibliographic coupling first requires the identification of the most influential literature. To find out which publications matter most to all citing documents, column sums $x_{\bullet j}$ of the rectangular matrix can be calculated. These sums reflect the number of direct citations of each document. Table 4.1 lists the 20 most frequently cited publications in quantitative political network analysis, according to their column sum. This table shows that a few highly cited publica-

Count	Citation	Count	Citation
66	Wasserman and Faust (1994)	28	Coleman (1990)
62	Laumann and Knoke (1987)	25	Granovetter (1973)
50	Scott (2000)	24	Granovetter (1985)
47	Borgatti et al. (1999)	23	Dowding (1995)
41	Laumann and Pappi (1976)	23	Kenis and Schneider (1991)
41	Knoke (1990b)	20	van Waarden (1992)
36	Freeman (1979)	19	Dahl (1961)
33	Knoke and Kuklinski (1982)	19	Kingdon (1984)
31	Heclo (1978)	19	Knoke and Laumann (1982)
29	Knoke et al. (1996)	19	Olson (1971)

Tab. 4.1: The 20 most frequently cited publications

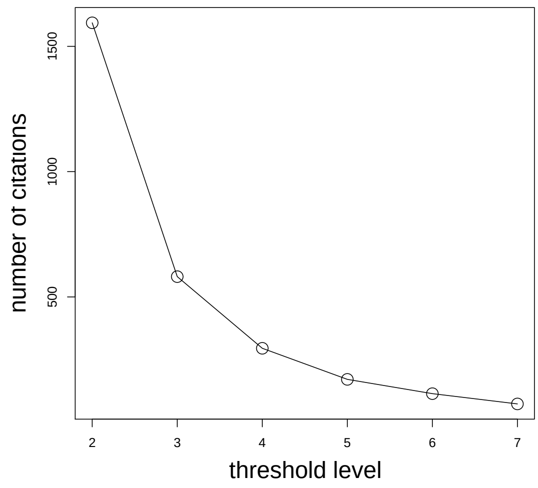

Fig. 4.4: Threshold levels and their corresponding number of citations

tions stand out from the rest of the distribution, i.e. they are cited so frequently that it seems unlikely that they can be reasonably classified into any possible research tradition. Among them, particularly methodological citations (Wasserman and Faust, 1994; Scott, 2000; Borgatti et al., 1999; Freeman, 1979; Knoke and Kuklinski, 1982) and the pioneering policy network studies of Laumann, Knoke and Pappi account for the largest part of the influence.

4.2.2 Citation threshold

The network of co-cited publications consists of 8490 nodes and more than 70 million possible valued relations very few of which are realized because most publications are cited only once. This is where signal has to be separated from noise, as discussed in section 4.1.6. Braam et al. (1988, p. 20) suggest using a "citation threshold" (c) for cited documents, i.e. all publications co-cited less than a specified number of times are dropped. This is a straightforward approach to dealing with noise: Rarely co-cited articles can be regarded as very specialized works which are less likely to belong into the field of political networks and which inhibit the identification of major research schools.

The difficult task is to justify which citation threshold can be considered appropriate for the data. In this analysis, a rather pragmatic decision is made by it-

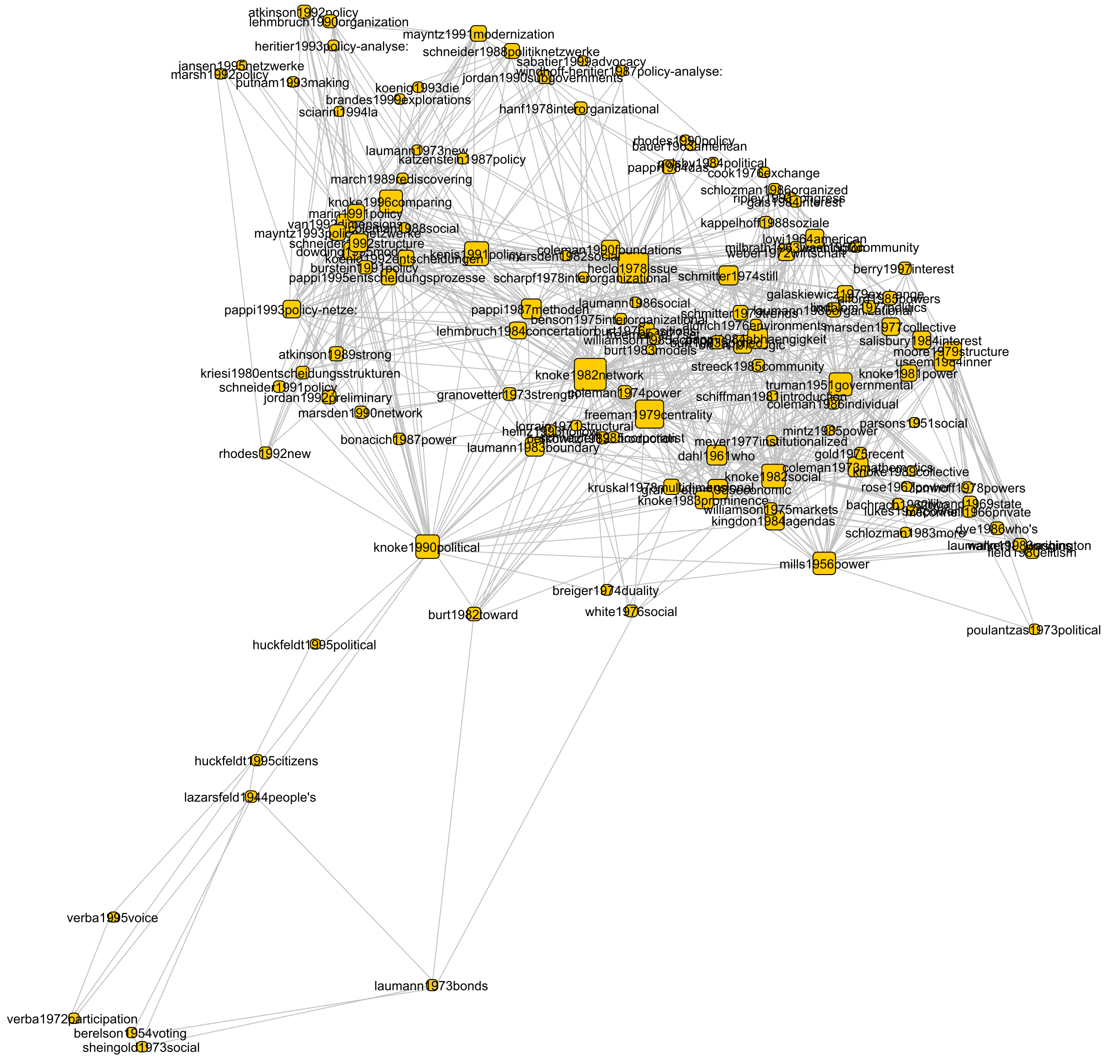

Fig. 4.5: Network of cited publications, $c = 5$

eratively increasing the threshold until subgroups become easily visible. Figure 4.4 shows the number of articles corresponding to each level: Including anything below three citing articles per cited document yields a vast quantity of publications. The subsequent subgroup analysis reveals that dropping anything below a threshold level of five removes just enough noise to make subgroups visible, i.e. both sensitivity and specificity are expected to be high while type I and II errors should be low, if regarded from a Bayesian classification point of view.

The calculation of the threshold network is performed on the affiliation matrix rather than the full rectangular matrix to ensure that the detection of "cliques at level c" is possible, as proposed by Wasserman and Faust (1994, p. 278). First, the 8490x8490 co-citation network B is constructed and the diagonal values are set to zero. Then the network is dichotomized (equation 4.4), i.e. all tie values below the threshold level are recoded to zero and all others to one. Finally, all isolates and pendants, i.e. those nodes without any tie or with only one tie, are deleted to retain only the core network.

$$\underset{c}{b_{m,n}} = \begin{cases} 0 & \text{for } b_{m,n} < c \\ 1 & \text{for } b_{m,n} \geq c \end{cases} \tag{4.4}$$

Once having removed the least cited articles, also the most cited "common sense" articles should be removed from the graph because they inhibit the detection of subgroups: If publications from distinct clusters cite the same common sense articles, clusters will be harder to separate. These common-sense articles can be identified by looking at the most frequently cited publications in table 4.1: Laumann and Knoke (1987) and Laumann and Pappi (1976) are the two most widely cited analyses throughout the literature, and Wasserman and Faust (1994), Scott (2000) and Borgatti et al. (1999) are the most frequently named methodological citations. If they are removed from the graph, the separation of clusters should be more precise. After these matrix operations, 129 and 81 cited publications remain at threshold levels 5 and 6, respectively.

4.2.3 The network of cited documents

Figure 4.5 shows the network of cited publications at threshold level 5 (i.e. anything below five is dropped). The network is mapped using the MDS layout implemented in Visone in order to gather a first insight into the rough structure of the network. The underlying algorithm tries to group similar nodes (i.e. with high co-occurrence counts in the adjacency matrix) together and dissimilar nodes apart. While the distances or edge lengths between the vertices roughly reflect the dissimilarities between the cited articles, the size (i.e. width and height) of the nodes depict their centrality scores, calculated using undirected degree centrality (Freeman, 1979). This measure is an indicator of how many other threshold publications an item is cited with. It simply counts the number of ties of one node to other nodes and standardizes this value by the total number of other nodes present in the graph, as described in equation 4.5. Some nodes have been manually jittered for reasons of readability.

$$C'_D(n_i) = \frac{d(n_i)}{g-1} \tag{4.5}$$

There is one relatively cohesive cloud of nodes in the upper left corner of the image, a second dispersed cloud of nodes in the upper right quadrant and a sparse group of nodes in the lower left part of the image. The former subgraph is built around the major influentials van Waarden (1992), Knoke et al. (1996), Kenis and Schneider (1991), Dowding (1995) and Pappi (1993) – mainly British and German publications from the 1990s. The second group appears to be composed of mainly American works between 1950 and 2000, spread around the rather central nodes Knoke and Kuklinski (1982), Freeman (1979), Heclo (1978), Mills (1956) and Useem (1984). The outlying nodes in the lower left part are concerned with participation in the United States and obviously do not include any particularly central node in terms of degree centrality. There is one very central node regarding both its degree and its connectedness to the three groups: Knoke (1990b) almost acts as a cut vertex (Wasserman and Faust, 1994, p. 113), i.e. its removal would almost cause the graph to be decomposed into separate components, and it is frequently co-cited with all three groups of papers.

4.2.4 Subgroup analysis

Having given an overview of the co-citation network, the next task is the formal detection of subgroups. Finding subgroups in the data can be done either using clique analysis, cluster analysis or blockmodel analysis.

Clique analysis

To start out with the procedure, "cliques at level c" (Wasserman and Faust, 1994, p. 278) are calculated, i.e. the threshold level is gradually increased and an ordinary 1-clique analysis is conducted at each threshold level after performing a dichotomization of the data (see above). According to the procedure, a threshold level is optimal if it reveals the clique structure in a better way than other levels, or in other words when between-group ties are largely absent while within-group ties still allow the detection of cliques.

A 1-clique is defined as a maximal and complete subgraph (Scott, 2000), i.e. all nodes of a clique are adjacent to one another, and no other node meeting this requirement can be added to the subgroup. As previously mentioned, the separation of cliques becomes most obvious at threshold level 5, but it is still visible at levels 4 or 6. This can be interpreted as a sign of robustness or stability of the subgroup solution. 331 cliques of minimum size four can be found in the graph at threshold level 5 and 135 cliques at level 6.

The overlap of these cliques indicates cohesive groupings and resembles the notion of social circles (Kadushin, 1968; Alba and Kadushin, 1976). Put in a different way, if a large number of triads (or in this case, 1-cliques composed of at least four nodes) have many members in common, they can be seen as a social circle. This overlapping structure is analyzed using a hierarchical cluster analysis in order to see which articles are part of which clusters and at which height they are members. For this purpose, a clique overlap matrix is produced. It shows the number of common clique memberships between any set of two nodes and can be interpreted as a distance matrix. A cluster analysis is performed on this distance matrix in order to reveal the patterns of interacting circles. This interpretation of distance is compatible with the analysis of social circles in the context of Crane's work on invisible colleges, where patterns of socially interacting scientists are traced.

Figures 4.6 and 4.7 show the resulting dendrograms of hierarchical cluster analyses based on the average linkage method, which is a compromise between single linkage and complete linkage clustering: While the single linkage method is based on minimum inter-cluster distances and complete linkage on the maximum distances between members of different clusters, average linkage takes the mean distance between two clusters as the criterion of separation. Average linkage is an

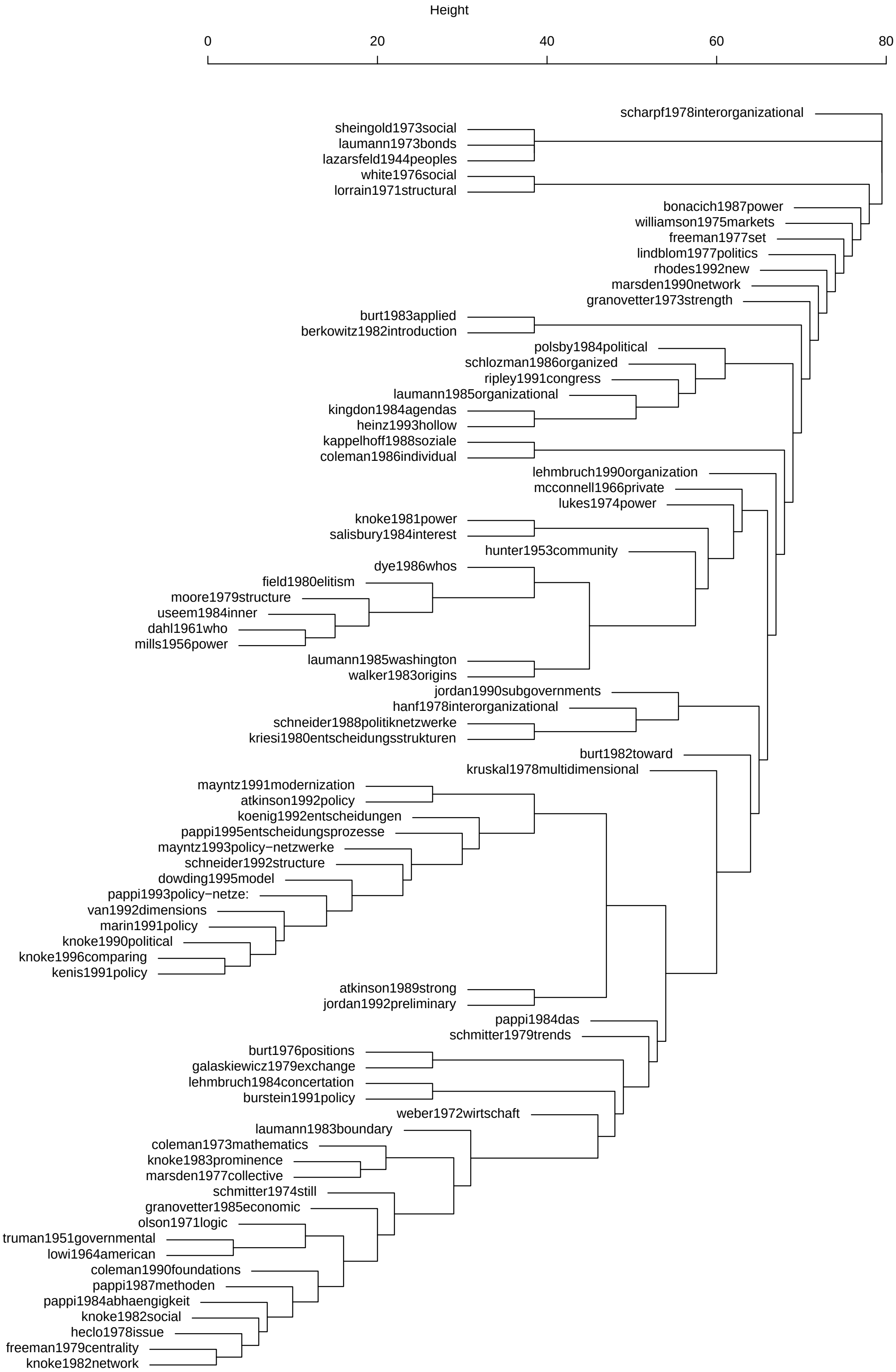

Fig. 4.6: Hierarchical clustering of the clique overlap matrix at threshold level 6

agglomerative method: Clusters are built as agglomerations of individual nodes with low dissimilarity scores rather than by dividing existing clusters into sub-clusters, which would be divisive clustering. The agglomerative algorithm first merges the pair of two nodes with the lowest dissimilarity score into one cluster. It proceeds by calculating a new distance matrix including the first cluster and all remaining objects by applying a distance function. In the case of average linkage, this distance function is represented by equation 4.6: The distance between clusters/objects R and S is given by the average inter-cluster distance, i.e. the sums of distances between nodes within R and nodes within S divided by the total number of distances (Timm, 2002, p. 528).

$$d_{(R)(S)} = \frac{\sum_r \sum_s d_{rs}}{n_R \cdot n_S} \tag{4.6}$$

The next step is the fusion of the pair of least distant objects based on the new distance matrix. The distances between the newly created cluster object and the other objects are again established by the above distance function. The algorithm is repeated until all objects have been partitioned and a nested cluster structure has been created.

Single linkage takes the minimum distance between two objects as $d_{(R)(S)}$ and sometimes causes a problem of “chaining” and “may result in too few and heterogeneous clusters” (Bacher, 2002, p. 48) when at each step the existing cluster is absorbed into a larger cluster rather than agglomerating competing clusters. The max function of complete linkage on the other hand takes the distance between the two most distant r and s values and “results in dilatation [...] and may produce too many clusters” (p. 48). Average linkage avoids these effects and is therefore used in this analysis.

When applying the average linkage hierarchical clustering technique to the cited documents at threshold level 6 with the five common-sense articles being removed from the data set, three major clusters can be seen, accompanied by a number of publications that obviously do not belong into any cluster. The largest subgroup appears at the bottom of the dendrogram with 23 citations being nested into a chain-like structure. This group of cited publications has several striking properties:

- The cluster includes exclusively American and German authors.
- The literature was mainly written between 1950 and 1990 with a focus on the late 1970s and early 1980s.
- Knoke, Pappi, Laumann and Coleman appear more than once.
- Exchange theories seem to be a very prominent topic in this group. They are featured in Coleman (1973), Coleman (1990), Galaskiewicz (1979), Marsden and Laumann (1977) and Pappi and Kappelhoff (1984), among others. Especially Coleman's model of political exchange is prevalent. Based on this observation, the cluster will preliminarily be called the *"exchange cluster"*.

The second large group in figure 4.6 is composed of the next 15 citations (counting from the bottom). Again, there is a nested chain structure. Like the previous cluster, this one has certain distinct characteristics:

- The authors are almost exclusively from Germany or Britain.
- All publications were published between 1989 and 1996, which is a rather compact period compared to the first cluster.
- Four topical focal points can be recognized:
  - Literature dealing with the concept of policy networks, its scientific sensibility and its metaphorical, methodological and theoretical usage (e.g. Dowding, 1995; Kenis and Schneider, 1991; Pappi, 1993).
  - Articles enumerating and classifying different empirically observable state-society network configurations into typologies, assigning labels to them and treating them as ideal types (e.g. van Waarden, 1992).
  - Publications dealing with networks and comparable arrangements as a specific form of governance (e.g. Mayntz, 1991).
  - Empirical policy network analyses (Knoke et al., 1996; König, 1992).

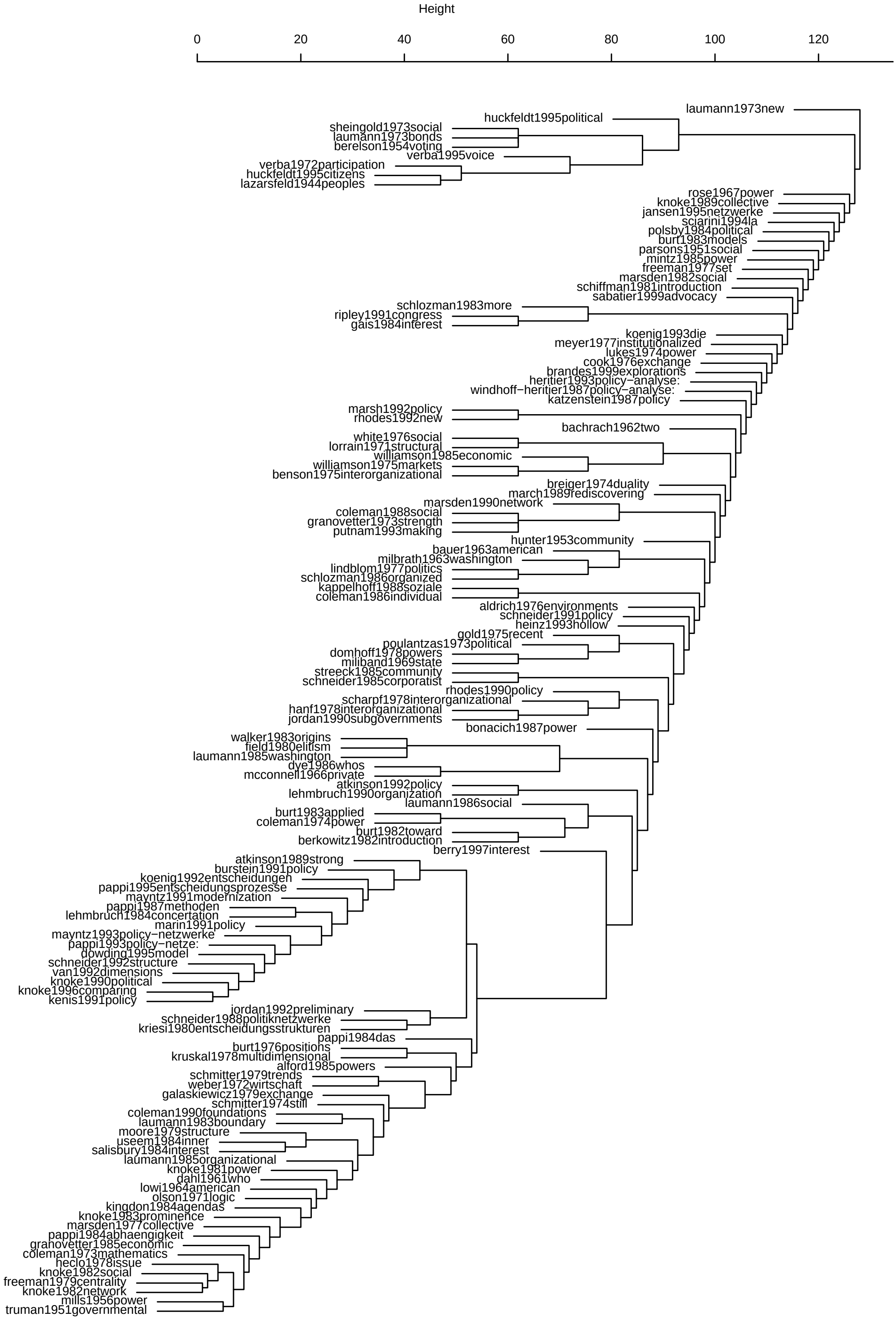

Fig. 4.7: Hierarchical clustering of the clique overlap matrix at threshold level 5

Taking into account the topics covered here, this group will be assigned the tentative label *"governance cluster"*.

The third subgroup is at the center of the dendrogram and is composed of the 13 citations between McConnell (1966) and Walker (1983) (from top to bottom):

- The publications were created between 1953 and 1986.
- The literature is exclusively from the United States.
- All items deal with elite theory and the American power structure, therefore they are assigned the label *"elite cluster"*.

In addition to the three clusters characterized above, several publications are not really partitioned into any subgroup. Nonetheless, at the top of the dendrogram, a small but distinct cluster emerges, being composed of three American books dealing with participation and voting (Laumann, 1973; Lazarsfeld et al., 1944; Sheingold, 1973). Lowering the threshold level to 5 will show whether this cluster can be confirmed or if the clustering is spurious. Another subgroup can be recognized between Polsby (1984) and Heinz (1993) – in this case, lowering the threshold level shows that its members merge in the "exchange cluster" when more publications are included. Yet the analysis of the overlap of cliques at level 5 can not only serve to confirm or discard clusters that have been found at level 6, but it can also serve to enlarge these clusters, i.e. a larger number of characteristic publications can be identified that belong into these subgroups.

Figure 4.7 shows the hierarchical cluster analysis for cliques at level 5. The dendrogram reveals some more publications belonging into the subgroups described above: The British-German governance and policy network cluster is extended by Kriesi (1980) and Schneider (1988), and the smaller fourth cluster has now grown to nine members, all discussing issues of participation and voting. It is therefore termed the *"participation cluster"*. On the other hand, the elite cluster cannot be separated from the exchange cluster anymore, which is either due to an increase of noise at the lower threshold level or because the clusters indeed exhibit some overlap in the real world.

Cluster analysis using Jaccard dissimilarities

Figure 4.8 shows the results of a re-analysis of the same data at threshold level 6. This time, the cluster solution is not obtained via clique analysis but via performing a direct hierarchical cluster analysis.

Using plain co-occurrence counts obtained by the column-wise cross-products as well as a normalization of the data have recently been criticized for not being able to map the similarity structure between the publications correctly (Leydesdorff, 2007a,b; Waltman and van Eck, 2007). The main argument is that the distribution of citation counts per document is skewed and sometimes spurious and that the Jaccard similarity coefficient may provide better results, which can abstract from the underlying distribution of citation counts (Leydesdorff, 2007a, p. 6). Waltman and van Eck (2007, p. 3) assert that in the case of plain co-occurrence data "an author who is frequently cited would on average have high similarities to other authors, whereas an author who is rarely cited would on average have low similarities to other authors", i.e. the number of citations received from the citing documents crucially depends on the overall popularity of the publication within quantitative political network analysis. In spite of this observation and the claim that normalization is needed, this skewed distribution actually reflects the circumstance that less frequently cited authors are usually less inclined to communicate with top scientists than highly cited authors. If clusters can be interpreted as invisible colleges and eventually as scholarly communication as it is often claimed, this particular feature of the data should not be corrected for. However, in order to avoid the criticism about using co-occurrence data, figure 4.8 is based on Jaccard dissimilarities of the asymmetrical, raw citation matrix – as proposed by Leydesdorff (2007a) – and largely confirms the results of the previous clique analysis.

Klavans and Boyack (2006) compare several normalizing similarity/dissimilarity measures for the mapping of science on a quantitative basis. Their conclusion implies that the Jaccard coefficient produces similar results as the cosine index, which is also popular in citation analysis, and that the overall performance of Jaccard is comparably good.

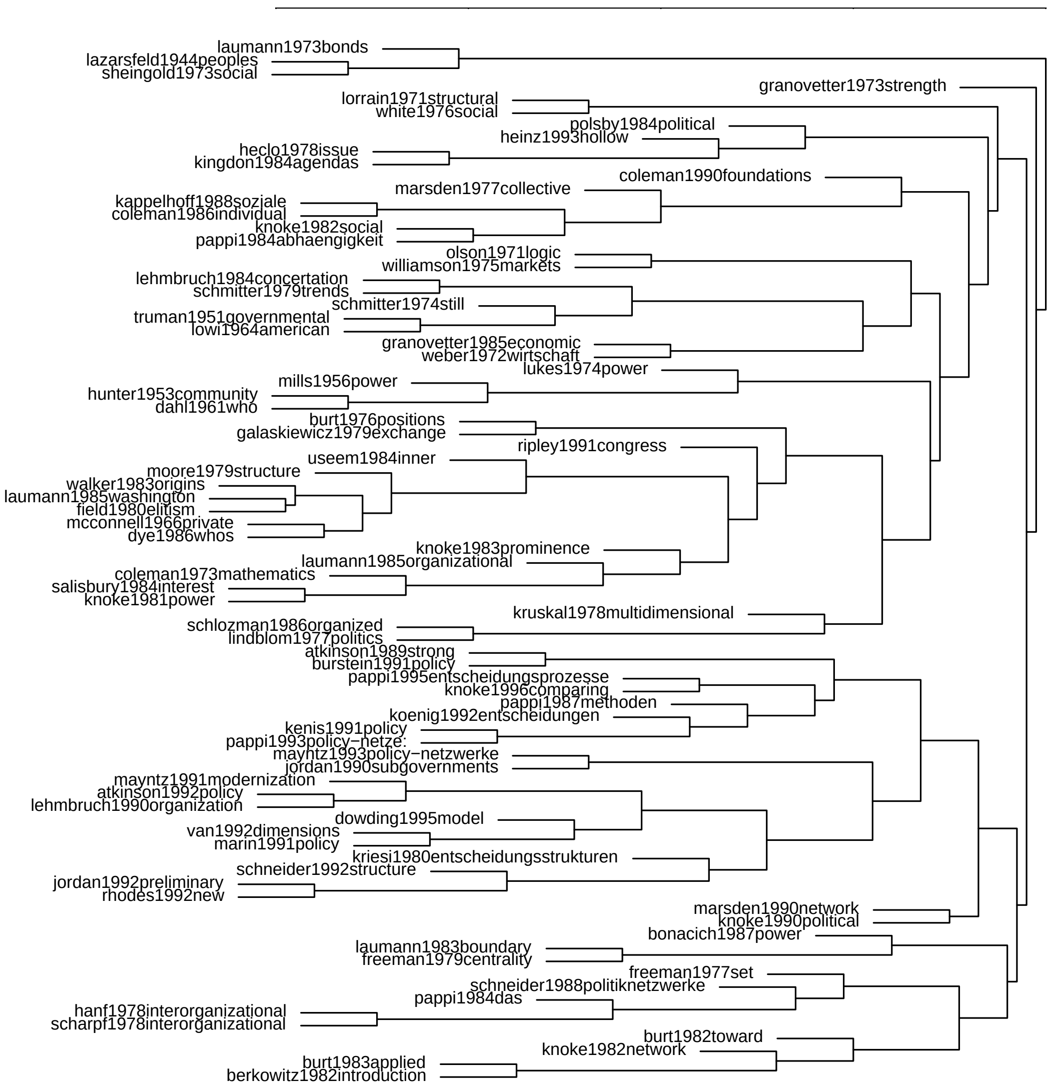

Fig. 4.8: Clustering at threshold level 6 using Jaccard

According to Timm (2002) and Jain and Dubes (1988), a measure needs to satisfy three conditions in order to qualify as a dissimilarity measure. For any two objects y_r and y_s in an n-dimensional space, the distance between them must not be negative (equation 4.7), the distance between them can only be zero if the nodes are identical (equation 4.8), and the distance matrix must be symmetrical (equation 4.9).

$$d_{rs} \geq 0 \text{ for all objects } y_r \text{ and } y_s \tag{4.7}$$

$$d_{rs} = 0 \text{ if and only if } y_r = y_s \tag{4.8}$$

$$d_{rs} = d_{sr} \tag{4.9}$$

In order to calculate this type of dissimilarity, all threshold level 6 articles are extracted from the raw rectangular matrix in a column-wise fashion so that their affiliations with the citing documents shape a new 193x81 matrix. The Jaccard coefficient is calculated for each column (i.e. as a dissimilarity between the cited documents), and the resulting distance table is analyzed using the average linkage method. The Jaccard dissimilarity coefficient is a binary measure and is thus more appropriate than Pearson's correlation coefficient or other measures of association for continuous or ordered data. Following equation 4.10, it takes into account those references citing both publications (a), all references citing only the first publication (b) and all references citing only the second publication (c).

$$d_{Jaccard} = 1 - \frac{a}{a+b+c} \tag{4.10}$$

The inclusion of b and c provides a standardization by overall popularity and in consequence possesses the desirable property that similarity is not overestimated for popular publications.

In contrast to the clique overlap analysis at threshold level 6, the elite cluster is now nested inside the exchange cluster. This was already the case when analyzing cliques at level 5 and may indicate a large overlap between the two groups. All other results are roughly equal.

To go one step further, the Jaccard distances can be calculated on a different selection of articles: While the selection above is still based on the threshold level of the adjacency matrix, cited publications may alternatively be selected by imposing a threshold level on the column sums of the raw affiliation matrix, i.e. only publications with an absolute citation count $x_{\bullet j}$ of more than 5 (or any other arbitrary value) are considered. The Jaccard distances are calculated for these 186 citations using their affiliation data. After computing the average linkage hierarchical cluster analysis, the resulting dendrogram draws an even clearer picture of the co-citation cluster structure, as becomes evident in figure 4.9. Here, even more citations are partitioned into each cluster while the quality of cluster separation does not suffer from adding additional items.

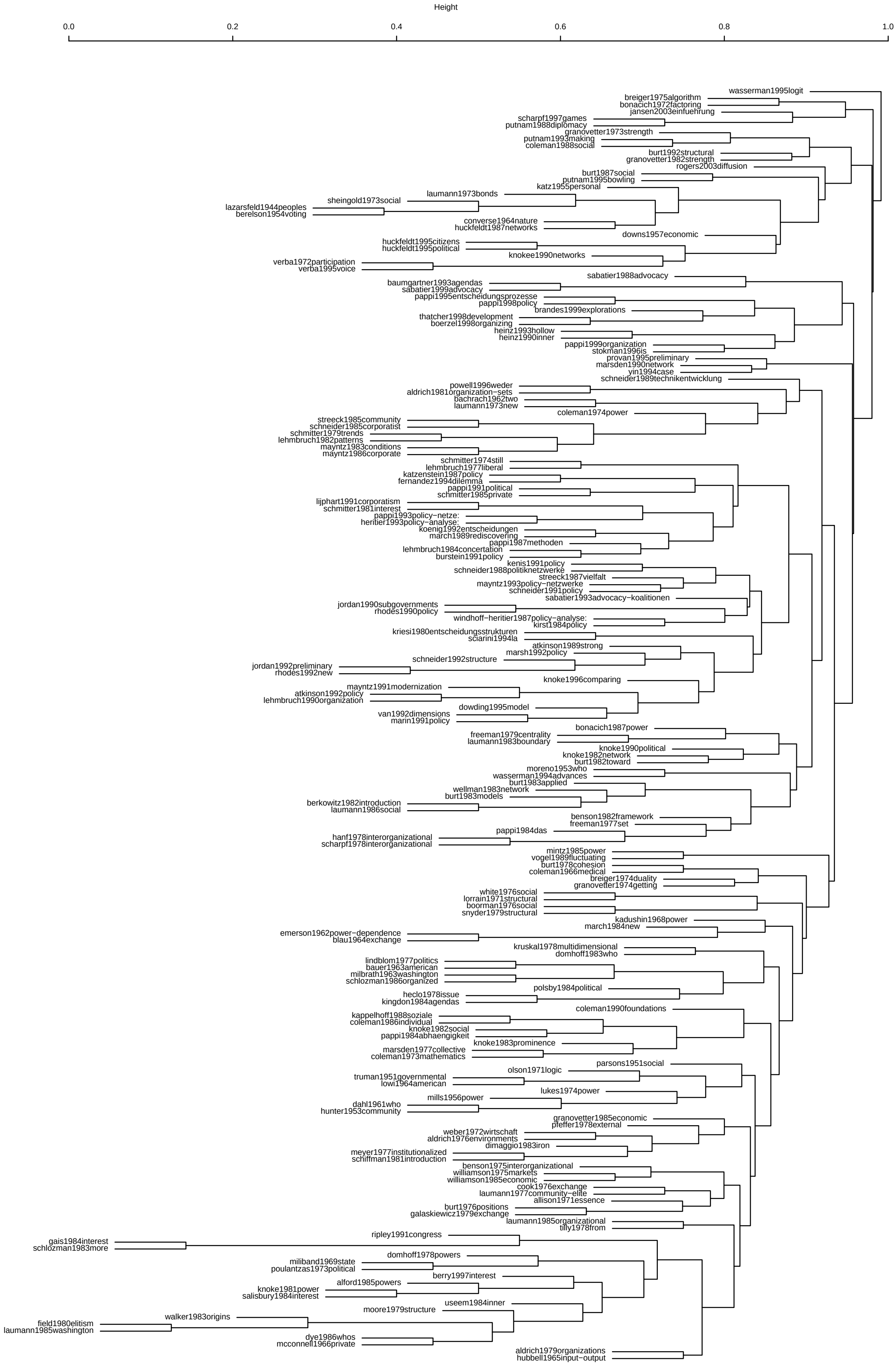

Fig. 4.9: Clustering at column sum > 5 using Jaccard

Confirmatory blockmodeling

A final confirmation that the cluster structure is not due to the clustering method is given in appendix D where a factions analysis via tabu optimization has been performed, as implemented in UCINet (Borgatti et al., 1999). Tabu search tries to group "together those actors who are most similar into a block" (Hanneman and Riddle, 2005, chapter 13). It minimizes the sum of within-block variances in the tie profiles so that the variance of actors around the block mean profile is small. This optimization algorithm permutes the rows and columns and tries to find an optimal solution for a predefined number of blocks. In the permuted (valued or binary at level c) adjacency matrix, these "factions" are located along the diagonal and take the form of rectangular blocks.

	1	2	3	4
1	2.00	0.41	0.03	0.04
2	0.41	2.35	0.31	0.43
3	0.03	0.31	0.72	0.11
4	0.04	0.43	0.11	2.67

Tab. 4.2: Density table of the factions

In this analysis, valued co-occurrence counts are used. The first faction along the diagonal largely corresponds to the elite cluster identified above, the second one to the exchange subgroup, the third one to the participation clique and the fourth faction to the governance and policy network cluster. Only the participation faction is somewhat blurred; this is documented by the relatively low within-faction density of the third block as presented in table 4.2. All density scores of the diagonal factions except the density of the participation cluster are ≥ 2. The reason for the low density of the third faction is the inclusion of some exchange or elite cluster members that also change their membership in the conventional cluster procedures if different threshold levels are applied. Summarizing the tabu search results, the subgroups detected earlier on are precisely confirmed by this blockmodeling approach.

Aggregating the subgroup structure

All three subgroup approaches produce similar results with only minor differences between the statistical techniques and the threshold levels. There are some cluster members that can be partitioned in any subgroup analysis and some publications with a lower likelihood of really constituting the cluster structure since they are sometimes cluster members and sometimes not. To achieve a clear-cut separation of the citing documents, only those publications which can be robustly partitioned should be included as discriminant criteria.

Table 4.3 gives an overview of the average cluster structure found in the analyses above. It lists only those cited publications which can be robustly classified. One striking feature of this list is the cross-classification of a small set of authors (not publications!) into more than one cluster. Especiallly the authors David Knoke (four clusters), Edward O. Laumann (three clusters) and Franz Urban Pappi (two clusters) are influential in more than one research tradition, providing a hint at the inter-cluster connectivity of leading researchers hypothesized by Crane's invisible college theory (Crane, 1972). These authors seem to be the leading political network analysts because their influence is highly present in several otherwise distinct research schools.

It may be noteworthy that only 59 publications constitute the discriminatory core network of cited publications. This is a low number of citations if compared to the initial data set of 8490 cited sources. The inclusion of more cited documents would not make sense because the quality of separation would be significantly decreased.

4.2.5 Spatial arrangement of the cited documents

To give a graphical representation of the structure of cited articles, a two-dimensional projection technique like correspondence analysis, principal coordinates analysis, principal components analysis, Sammon mapping or non-metric multidimensional scaling can be employed. Since the raw data are only on a nominal level of measurement (in fact binary), non-metric multidimensional scaling might be a sensible technique (see Jain and Dubes (1988) for details). Figure 4.10 shows a non-

Governance cluster	*Exchange cluster*
Atkinson and Coleman (1989)	Coleman (1973)
Atkinson and Coleman (1992)	Coleman (1986)
Dowding (1995)	Coleman (1990)
Hanf and Scharpf (1978)	Freeman (1979)
Jordan (1990)	Heclo (1978)
Jordan and Schubert (1992)	Kappelhoff (1988)
Kenis and Schneider (1991)	Knoke and Kuklinski (1982)
Knoke et al. (1996)	Knoke and Laumann (1982)
König (1992)	Knoke and Burt (1983)
Kriesi (1980)	Laumann et al. (1983)
Lehmbruch (1990)	Marsden and Laumann (1977)
Marin and Mayntz (1991)	Olson (1971)
Mayntz (1991)	Pappi and Kappelhoff (1984)
Mayntz (1993)	Pappi (1987)
Pappi (1993)	
Pappi et al. (1995)	
Rhodes and Marsh (1992)	
Schneider (1988)	
Schneider (1992)	
van Waarden (1992)	

Participation cluster	*Elite cluster*
Berelson et al. (1954)	Dahl (1961)
Huckfeldt and Sprague (1987)	Dye (1986)
Huckfeldt and Sprague (1995)	Field and Higley (1980)
Huckfeldt et al. (1995)	Hunter (1953)
Knoke (1990a)	Knoke (1981)
Laumann (1973)	Laumann et al. (1985a)
Lazarsfeld et al. (1944)	Lukes (1974)
Putnam et al. (1993)	McConnell (1966)
Rosenstone and Hansen (1993)	Mills (1956)
Sheingold (1973)	Moore (1979)
Verba (1972)	Salisbury (1984)
Verba et al. (1995)	Useem (1984)
	Walker (1983)

Tab. 4.3: Summary of clustering results – stable solution

metric MDS of the 59 cited publications. The four clusters are clearly separated with only three items slightly detracting from the cohesive groups. This latter observation might be caused by a relatively high stress value of 0.18. Stress is “more of a descriptive statistic than a confidence statistic”, and “several researchers have de-emphasized the importance of stress as a precise measure” (Cox III et al., 1976,

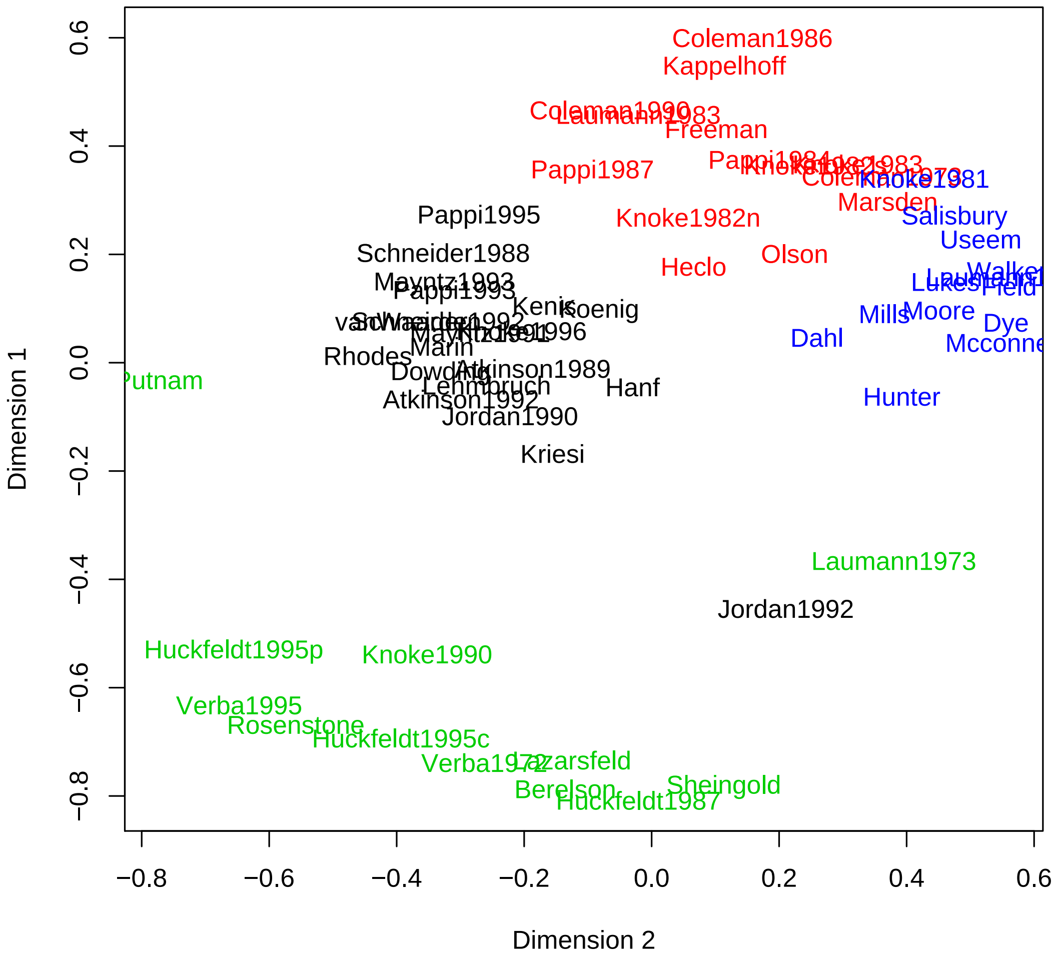

Fig. 4.10: NMDS of the 59 cited core publications

p. 261), so this fair fit should be acceptable - even more so considering the fact that the cluster structure has been revealed by means of hierarchical cluster analysis.

The black labels at the center of the plot stand for the governance cluster, the green names for the participation group and the red and blue colors for the exchange and elite group, respectively. Three important things can be learned from the MDS solution:

1. The elite cluster and the exchange cluster are neighbors, i.e. they slightly overlap because authors tend to cite publications from both clusters.

2. The green participation cluster is relatively far away from the other clusters.

It must be a very distinct type of article that cites this group of publications.

3. The MDS solution confirms that the 59 selected publications are suitable to clearly separate the citing articles from each other (see section 4.3).

The detailed interpretation of the clusters will be the task of chapter 5.

4.3 Bibliographic coupling: Classifying the empirical analyses

The ultimate goal of this thesis is the classification of all quantitative political network analyses into research traditions according to empirically derived criteria. These criteria for separation have been developed in the previous section, making use of subgroup analyses and projection techniques to find out which cited documents are well suited to separate the citing publications. In the following paragraphs, graphical and multivariate methods will be applied to the citing documents based on the above results.

4.3.1 Classification via likelihood estimation

The information in table 4.3 are used to construct a 193x4 matrix which contains absolute counts of how many cluster documents are cited by each of the 193 publications. For example, if Schneider (1988) cites two core documents from the governance cluster, ten core documents from the exchange cluster, no participation article and four elite publications, his values are 2, 10, 0 and 4. These numbers are each divided by their row sum (16 in this case) to achieve a standardization. The resulting numerals – 0.125, 0.625, 0 and 0.25 in this case – can be interpreted as their likelihood to belong into any of the four clusters, e.g. Schneider (1988) would have a likelihood of 62.5% to belong into the exchange cluster, given his core cluster distribution. The term "likelihood" is used because the data are given and we are trying to find the likelihood that the model is true (in this case that a publication belongs into a certain cluster) given the data.

Appendix A lists all articles and their corresponding distributions. In figure 4.11, these data are visualized using a level plot, which is often referred to as "image plot" (Murrell, 2006; Venables and Ripley, 2002): The column labels one

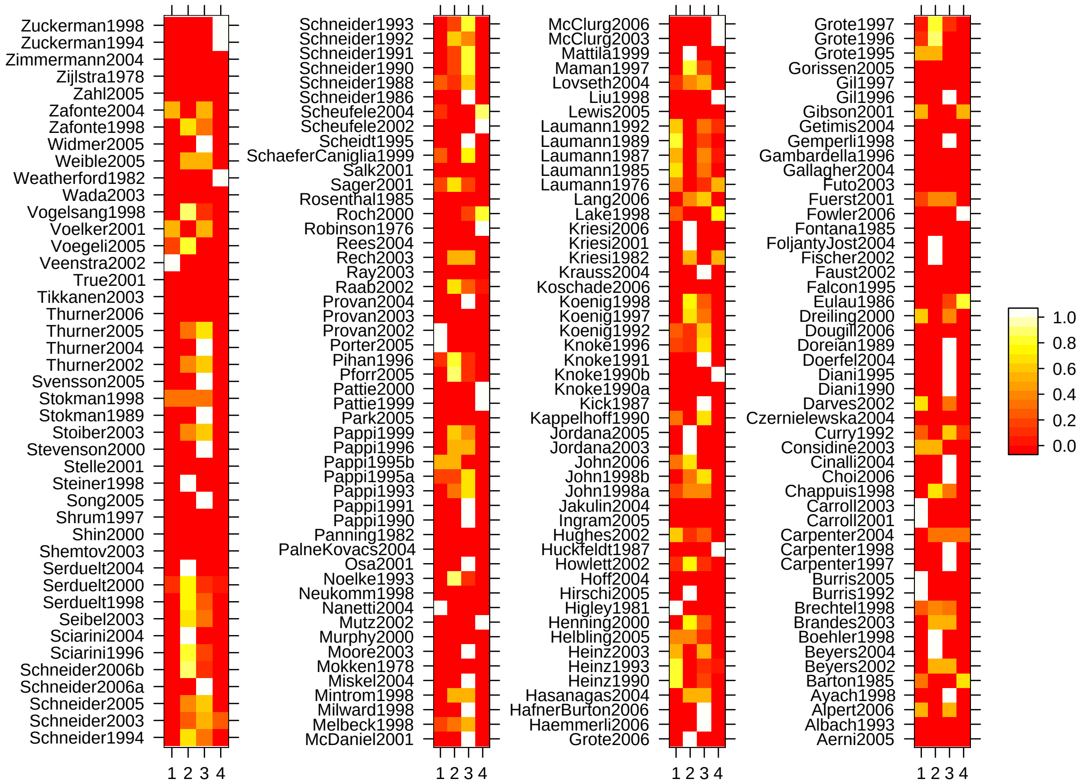

Fig. 4.11: Likelihood distributions of the citing publications; level plot

to four reflect the cluster category (elite, governance, exchange, and participation, from left to right), and the cell color symbolizes the likelihood of the category. White stands for 100% likelihood, red for 0% and yellow for a medium likelihood.

Compared to the aforementioned table, using this kind of plot makes it easier to review the distribution per item. On the other hand, there are two minor drawbacks of this procedure: First, a standardization by record is chosen instead of a standardization relative to the total number of cluster core members. The advantage is that probabilities can be directly compared between the categories, the disadvantage is the lack of precision when only few items are cited. For example Krauss et al. (2004) are perfectly (mis-)classified into the exchange category because their one and only cited core document belongs into this group. Secondly, the classification completely relies on the results of the cluster analyses of section 4.2.4. The results appear to be relatively robust. Nevertheless they are still fuzzy because the threshold level is required to be rather high and thus only a small number of documents (59 out of 8490) decide on the classification likelihood of all publications. This latter problem cannot be avoided since its origin lies in the data, not in the method. If the threshold level were lowered and more cluster members were added to the classification system, the separation between the clusters would be error-prone, and the problem of small-n inference would be substituted for a problem of biased estimators. Together with the number of underlying counts shown in table A, the reader is certainly able to judge the quality of classification for each item.

4.3.2 Spatial display of the citing articles and their clusters

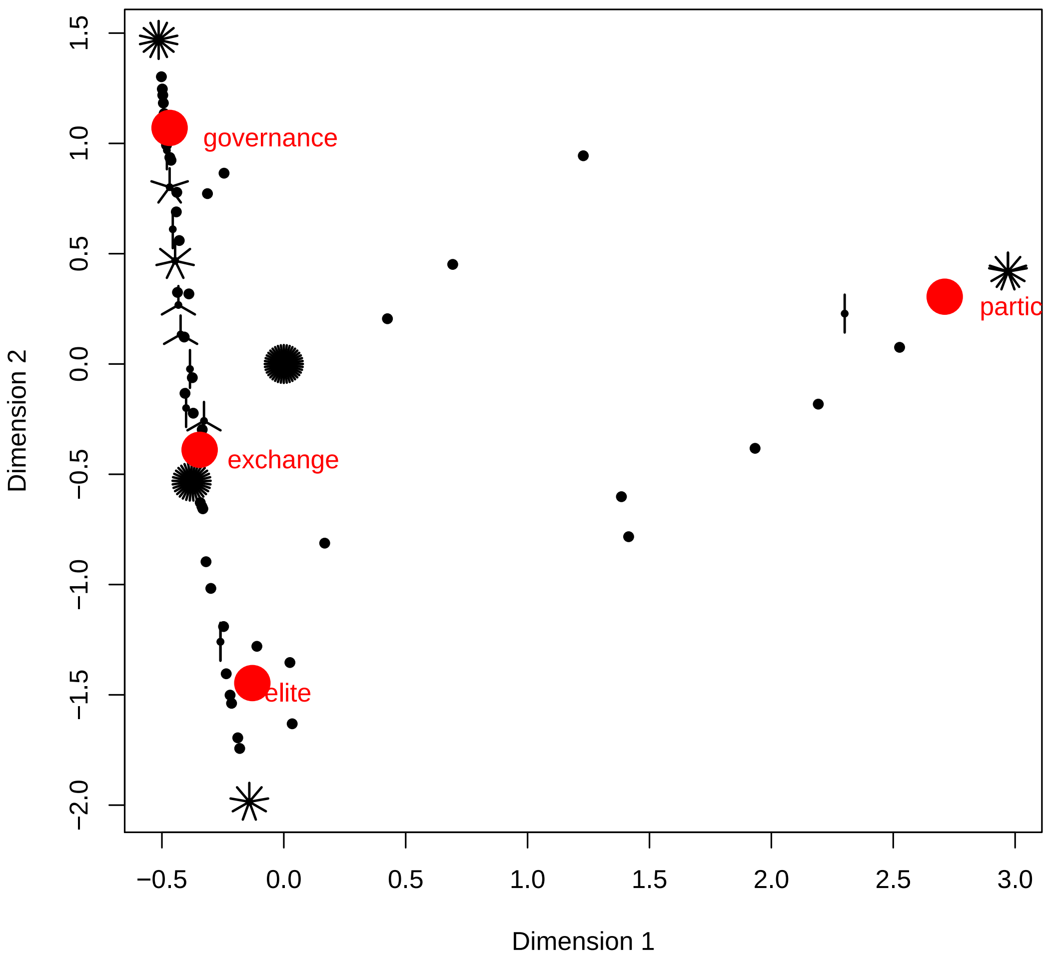

Fig. 4.12: Correspondence analysis using CGS scaling

In order to review the fuzzy classification, a spatial representation of the citing publications and their cluster affiliations can be employed. A method is required that serves to display row items and column items of a contingency table in the same low-dimensional space (Hanneman and Riddle, 2005, chapter 17). Furthermore, it would be helpful if the relation between the rows and the columns were directly interpretable, with the columns (i.e. the cluster labels) representing the medoids of the research schools of the citing publications. This can be achieved using a correspondence analysis (CA) of the core cluster counts displayed in figure 4.11.

Correspondence analysis is based on singular value decomposition of the matrix. The CA presented here is enhanced by employing a Carroll-Green-Schaffer scaling of the data, a transformation that enables us to interpret the positions of the cluster medoids in direct relation to the positions of the citing articles (see Carroll et al., 1986, for technical details). Greenacre (1989) criticize CGS scaling on statistical grounds for having "serious deficiencies" and sometimes leading "to misinterpretation of the correspondence analysis display". In their rejoinder, Carroll et al. (1989) argue that these deficiencies are not characteristic for CGS scaling but for multiple correspondence analysis (MCA). However, in the case of this citation analysis, CGS scaling and other types of correspondence analysis yield about the same results, and these results are in accordance with previous findings presented in section 4.3.1.

Figure 4.12 shows such a CGS correspondence analysis. The cluster centers are marked by a red dot and a red text label. This plot shows the configuration of the 193 citing publications, which are scattered around the research schools identified in the previous section. R^2 is 0.87, so the two-dimensional solution can be considered appropriate for the data. Since many data points are situated at similar or even the same coordinates, displaying the publication labels would be useless in this case. Instead, the layout of a sunflower plot is chosen to indicate high local densities (Murrell, 2006; Schnell, 1994). Single publications are denoted by a simple dot. If two items share the same coordinates, a line is drawn. If three items coincide, the dot bears three "petals" etc. There are two rather central locations where a huge number of items are present – these are publications with an identical distribution in appendix A. As for the spatial distribution, one can observe that the participation cluster on the right is clearly separated from the other three research schools, which in turn have several overlapping members. This is no surprise since the same observation could be made on the level of co-citation analysis. The exchange cluster occupies the most central position among the research schools, and the governance school as well as the elite school are clustered around it. However, the latter two clusters do not share a great deal of members. Given the early occurrence of exchange school members in time, it then seems likely that these other two schools were in part influenced by exchange scholars and developed in different directions.

5. DISCUSSION

This fifth chapter is dedicated to the interpretation and discussion of the results produced in the previous chapters. After initial proof that the structure of political network analysis as a research specialty has often been discussed and that it needs empirically based realignment, co-citation analysis was presented as a scientometric tool that combines both social network analysis and theories from sociology of science. The notions of "schools of thought" or "invisible colleges" were discussed in this context. It was argued that citation analysis alone can never be able to test these theories without a triangulation of qualitative and quantitative methods in order to really map the communication between researchers, which is claimed to be the driving mechanism behind the emergence of invisible colleges. Nonetheless, citation analysis is an important tool in mapping the final structure that is predicted by these theories.

The first step in the actual elaboration of quantitative political network analysis was the detailed description of trends and key figures along six dimensions: area of inquiry, geographical subject, level of analysis, use of quantitative methods, actors and relations. Political network analysis has been shown to be a rather dispersed and heterogeneous research specialty requiring a realignment of the different schools of thought.

The second step of the analysis was the enumeration of the 20 most frequently cited publications, which are assumed to exert the most influence, along with a display of the network of cited publications at a certain threshold level. Mechanisms were developed and applied to separate the important structures from distorting and irrelevant information. Three different types of subgroup analysis were then applied in order to empirically find criteria that can serve to structure the set of 193 quantitative political network analysis under examination. The results were four robust clusters (or colleges, in the terminology of sociology) which will have to be described in the following sections. They were preliminarily termed "elite cluster", "governance cluster", "exchange cluster" and "participation cluster".

The third step was the classification of the quantitative network analyses into the four colleges by assigning a likelihood distribution to each of them. The overlap between the four colleges was quantified and visualized using multivariate techniques. Summing up the preceding chapters, it has been possible to achieve a fuzzy classification of all 193 quantitative political network analyses into four schools of thought which will now be further elaborated.

5.1 Political exchange in the Organizational State

In a chronological perspective, the school of thought which has tentatively been termed the "exchange cluster" was predominantly active in the 1980s and the early 1990s and is thus one of the earlier network approaches in political science. There are three typical factors present in these works which cannot be observed in any other college as reliably as in this cluster:

- The analysis of national (and later also supranational) policy sectors with a focus on organizations as corporate actors.
- The relations being analyzed are typically interpreted as social exchange processes. A subset of these studies focuses on Coleman's model of political exchange (Coleman, 1986, 1990).
- Non-linear projection techniques like ALSCAL, INDSCAL or MDSCAL together with blockmodeling or cluster analysis are comparatively often employed.

After the 1976 community elite study of Laumann and Pappi (1976), their methodology is borrowed by a large set of subsequent works by Laumann, Knoke, Pappi, Schneider, König, Stokman and other typical representatives of this school of thought, who combine this methodology with the meso-level perspective of the "organizational state" (Knoke and Laumann, 1982; Laumann and Knoke, 1987), one of the two most important theoretical influences of this set of publications. This becomes evident when surveying the introductory chapters of several of their publications: König and Bräuninger (1998, p. 446) "used the organizational state framework to delineate the German labour-policy domain", and other authors like Schneider (1986), Pappi (1990) or Pappi and Schnorpfeil (1996) refer to the "organizational state perspective" as well. As König and Bräuninger (1998) put it, "their framework starts with the commonplace observation that public decision-making in western democracies is characterized by the collective action of organized, corporate actors such as associations of interest groups, political parties or ministries [...]. It applies a policy domain concept to the study of public decision-making which is analysed in specific subsystems of political systems." The actors of this subsystem are usually "identified by specifying a substantively defined criterion of mutual relevance" (Knoke and Laumann, 1982, p. 256). The insights that this kind of analysis produces are usually the identification of coalitions and the measurement of individual interest and power positions. Power in this regard is a relational construct drawing on the ability of actors to control events in social systems. This is where Coleman's exchange model (Coleman, 1986, 1990) comes into play: The policy network is seen as a marketplace where purchasing power is equivalent to an actor's ability to control events. The "price" or value of an event is determined by an equilibrium between demand and supply side. As a consequence, any policy outcome is the result of an initial influence configuration and the equilibrium resulting from political exchange.

Typical examples include the analysis of the German and American labor policy domains (Knoke and Pappi, 1991; Knoke et al., 1996; König, 1992; Pappi, 1990; Pappi and Knoke, 1991; Pappi et al., 1993, 1995), chemicals control in Germany and in a transnational context (Schneider, 1986, 1988, 1990) and energy and health policy exchange networks (Laumann et al., 1985b; Laumann and Knoke, 1987, 1989; Stokman et al., 1989). Other works of the same school of thought are often authored by their collaborators or alumni (Brechtel, 1998; Kappelhoff and Pappi, 1990; Melbeck, 1998; Pappi and Henning, 1999; Stoiber, 2003; Thurner, 2004; Thurner and Stoiber, 2002; Thurner et al., 2005). Other researchers are obviously strongly influenced by this framework without being directly affiliated with the above authors (Milward and Provan, 1998; Miskel and Song, 2004).

While Kenis and Raab (2003) argue that network variables should be used as independent variables in policy network analysis, the exchange models *implicitly* do so by explaining political outcomes by exchange equilibria. Few examples *explicitly* use network independent variables in causal models: The analysis of Laumann et al. (1985b) about the determinants of organizational involvement in political events employs a path analysis and includes communication network position and participation in a resource exchange network as intervening (and hence causal) variables.

In the case of this school of thought, the label "invisible college" may indeed hold because even the CVs of the researchers named above are connected by several links. They cross each other's way several times at multiple locations. Prominent in this respect are the Universities of Michigan, Chicago, Mannheim, Kiel and Cologne. However, this point needs further systematic research. CVs may be compared where available from the World Wide Web or co-authorship may be measured, and a new network with multiplex relations may be constructed. A comparison (possibly using matrix correlation) might show if the colleges identified in this thesis are indeed shaped by communication patterns with significantly more communication taking place within a college than between the colleges. Qualitative and perhaps even ethnographic methods like conference observation may provide further proof that invisible colleges are at work. Zuccala (2004) proved this triangulation to be a fruitful approach for theory testing purposes in singularity theory, and similar research could be done to test if the invisible college hypotheses hold in the specialty of political network analysis. Unless this is done in a systematic way, the clusters identified here can safely be considered no more than schools of thought or "sub-specialties within specialties".

5.2 Elite networks in North America and World System theory

Another of the four clusters identified in the quantitative analysis of part 4 has preliminarily been called the "elite cluster". This label refers to analyses with a special topical and methodological focus as described below.

The publications of this school of thought predominantly deal with North American political or business elite systems. In contrast to the previously described cluster, it emphasizes either individuals or "elite groups" (e.g. think tanks or corporations) as the actors whose relations or attributes determine the network structure. There is neither an organizational perspective in most cases, nor do formal exchange models play a major role.

Topical focal points are the influence of membership in think tanks on economic attitudes and political action of the business elite (Barton, 1985; Darves and Dreiling, 2002), the structural description of interlocking think tanks (Burris, 1992; Carroll and Shaw, 2001), the significance of interlocking directorates for the political cohesion of economic elites (Burris, 2005), the structure of committees in the U.S. House of Representatives as determined by overlapping memberships (Porter et al., 2005) and the integration of elites into political systems (Higley and Moore, 1981). Some important works with an affinity towards the exchange framework described above examine the cohesion or similarity of national-level representation of private interests in Washington (Heinz et al., 1990; Heinz, 1993; Laumann et al., 1992).

The conceptual roots of this school of thought are mainly from different forms of traditional elite research. Four influential streams can be identified in the bibliographies of the citing publications:

- The *power elite* model as represented by Dye (1986), Hunter (1953) and Mills (1956). In this elite model, "there is a clear hierarchy of power and influence among elite groups, with business, political and perhaps military elites located at its apex" (Higley and Moore, 1981). Other actors like legislators, top civil servants, media, academic or trade union leaders are peripheral.

- The model of Domhoff (1967) as an example of *ruling class* models. Here, elite configurations are interpreted in the light of class struggles from a marxist point of view. Again, business elite members are usually predicted to occupy central positions within the "ruling class".

- The *plural elite* model of Dahl (1961) with a decentralized perspective on elite networks: There is no core-periphery structure as in the power elite model, nor are relational patterns necessarily persistent over time. Attribute variables like being a certain type of actor, class affiliation or other background characteristics are ignored in favor of relational variables. Prominence as a purely relational construct is the driving factor in shaping the network structure (c.f. Higley and Moore, 1981, p. 584).

- The theory of an *inner circle* of tightly connected elites within the overall elite structure as put forward by Useem (1984). Useem's inner circle theory slightly resembles the idea of a ruling class and outlines the vision "of a well-connected set of directors and corporations able to communicate and act upon the political interests of big business" (Bond, 2004, p. 4) and is therefore rather a theory of corporate political action than of individual elites.

Most publications focus either on the question which structural elite configuration exists (Burris, 1992; Porter et al., 2005) or in how far this structure determines attribute variables, i.e. in how far political attitudes of elite members are shaped by their embeddedness (Barton, 1985; Burris, 2005; Darves and Dreiling, 2002). In either case, they usually neglect what impact this structure eventually has on policy-making or more specifically on policy outcomes. This observation is related to the strong appeal of finding out who really governs a democratic system (Dahl, 1961; Domhoff, 1967; Dye, 1986), i.e. unraveling the "shadow structure" behind governmental, "official" hierarchies, which is rather consequential in the American practice of political consulting.

Summing up, there are several key features of elite network analysis which are not present in most other schools of thought:

- The unit of analysis: In most cases, individuals and groups are jointly considered (instead of groups only like in the organizational and exchange college). In some cases, only individual elite members and their mutual relations are analyzed.

- The goal is neither to yield valid predictions on policy outcomes nor to explain outcomes by configurations of actors. The goal is rather to reveal who is powerful in a democracy. This does not rest upon social exchange processes but rather common memberships.

- In the pursuit of measuring structure, interlocking directorates are used. This is consequential for data analysis as either two-mode networks must be analyzed or one-mode networks must be created by calculating the cross-product of the incidence matrix. Beside the usual and prominent methods of network data analysis, special purpose measures such as social circles (Scott, 2000, p. 119) or measures related to the core-periphery structure (Hanneman and Riddle, 2005, chapters 11 and 17) are employed.

There is a small group of publications dealing with the structure of the world system. They are rather similar to elite network research because they basically analyze elites on an international scale, but with organizations, countries or cities as global actors. Indeed, a part of this stream of literature is classified into the elite research tradition. Carroll and Carson (2003) write about the interlocks between global think tanks, Kick and Kiefer (1987) analyze the influence of a capitalist global economy on the militarization of developing countries from a Marxist point of view, and Shin and Timberlake (2000) examine the positions of Asian cities in the world system of mega cities.

5.3 Participation and Social Capital

The third cluster is mainly located in the United States and to a lesser extent in Great Britain. As pointed out in the quantitative analysis of part 4, the cluster is clearly separated from all other clusters. Its publications deal with networks as an explanation of political participation and social capital, including the influence of individual, interpersonal discussion networks or neighborhood networks on electoral preferences (Zuckerman et al., 1998), electoral turnout (Knoke, 1990b; McClurg, 2006; Pattie and Johnston, 2000), political knowledge and information (Scheufele et al., 2004) or citizens' involvement (Lake and Huckfeldt, 1998).

Three theoretical or conceptual influences can be observed when surveying the bibliographies of these works:

- The discussion on social capital, particularly set out by Putnam et al. (1993); Putnam (1995). In Putnam's words, "the core idea of social capital theory is that social networks have value. Just as a screwdriver (physical capital) or a college education (human capital) can increase productivity (both individual and collective), so too social contacts affect the productivity of individuals and groups" (Putnam, 1995, chapter 1).

- The insight of the classic "Columbia studies" (Berelson et al., 1954; Lazarsfeld et al., 1944) that attribute variables alone cannot provide sufficient explanations of electoral behavior (c.f. Sheingold, 1973). According to Eulau (1980, p. 207), "there is a growing interest in describing and explaining electoral and related patterns of behavior in terms of the 'social networks' to which people belong. The contribution of the Columbia studies to research on the effect of social networks in voting behavior and public affairs seem therefore worthy of retrospection."

- Other studies on political participation in general: Verba (1972) and Verba et al. (1995) analyze the socio-cultural reasons of voter turnout and participation and distinguish several ideal types of voters. Huckfeldt and Sprague (1995) examine the social contexts of voters (including relational variables) and "postulate that voters are intendedly rational but operate under conditions of substantial uncertainty" (Marsden, 1996).

The publications making up the participation and social capital cluster feature a very distinct methodological apparatus. They exclusively rely on ego-network data and their utilization as independent variables in regression and path analyses. This compatibility with conventional survey research involves two sides of the same coin: On the one hand, causal interpretation is far easier than in quantitative network analyses based on one- or two-mode networks because the effect of independent network variables on dependent individual-level variables can be estimated. The reverse side of the coin is a dissolution from the structural notion of networks in the strict sense. Macro-concepts like centralization, density or clique configurations cannot be measured anymore, and the boundary between survey research and network research is blurred.

Participation network studies focus on the individual level rather than organizations and they usually examine relations of communication or political discussion as independent variables. As the dependent variables are on an individual level as well and usually do not deal with policy outcomes, participation studies cannot be regarded as policy analyses even though this branch is related to political networks.

5.4 Governance and Interest Intermediation

The fourth group of quantitative analyses is predominantly active in the 1990s and in recent years and is a derivative of the organizational/exchange perspective: The studies in this cluster rely on the mapping of organizational configurations, but they are also heavily influenced by two newer developments:

1. This is on the one hand a theoretical discussion on policy networks in the British and German context focusing on the usefulness of the policy network concept as a metaphor, analytical tool or theory (Dowding, 1995; Evans, 2001; Kenis and Schneider, 1991; Marsh and Smith, 2001). One aspect of this discussion is the creation of typologies of different network configurations as models of state-society relations (Atkinson and Coleman, 1989; Howlett and Ramesh, 1995; Jordan and Schubert, 1992; Rhodes and Marsh, 1992; van Waarden, 1992). For example, van Waarden describes "sponsored pluralism", which is one of several possible state-society relations, as a specific form of policy networks with many interest associations being the

actors, relatively open boundaries, voluntary membership, horizontal linking pattern, medium institutionalization etc. along a variety of different dimensions. McCool (1998) sets out a cognitive bridge between these policy network configurations and the types of *interest intermediation* underlying the American elite school of thought described in section 5.2: A "trend in the literature concerns the numerous attempts to develop typologies of subsystems. [...] In Europe a number of scholars have created typologies of policy networks" (p. 557), and "the subsystem concept [...] fits well with the notion – which is widespread in American political culture – that lobbyists, intellectuals [...], and well-moneyed elites control the government" (p. 553), which alludes to the concepts of iron triangles and issue networks present in American elite research (Heinz, 1993, e.g.). The ambiguity and confusion caused by the variety of concepts and pluralism in the applications thereof is summarized by Dowding (2001) in his article "There must be an end to confusion: Policy Networks, Intellectual Fatigue, and the Need for Political Science Methods Courses in British Universities".

2. The other influence is the German literature on *governance*, where network structures and comparable arrangements are considered as a mechanism of coordination somewhere between hierarchy and market and at the same time as a real change within polities rather than a method (Mayntz, 1993). Streeck and Schmitter (1996) argue that organizational concertation with associations as a new mode of governance is in some situations superior to the traditional models of social order – atomistic competition (market coordination), hierarchical control (state) and spontaneous solidarity (community) – when it comes to the integration of different interests. This network-like mode of negotiating compromise is built on relations of political exchange (Streeck and Schmitter, 1996, p. 138) and thus exhibits a strong theoretical link to the exchange and Organizational State school of thought. Mayntz (1993) underlines the importance of networks as persistent and stable modes of coordination: They are in this respect different from exchange operations in markets and foster a certain problem-solving capacity. Summing up, from

the governance perspective networks are not a method but an observable change in coordination between state and society.

The distinction between these two influences has been described in detail by Börzel (1998). Together with these new influences, there is a shift in the level of analysis from the nation state to other territorial entities: While there is an almost exclusive focus on national-level policy-making in the exchange/organizational state school of thought, publications from the governance/interest intermediation college start analyzing policy-making on the local/municipal level (e.g. Serdült, 2000), on the regional level (Grote, 1997), in supranational contexts (Beyers and Kerremans, 2004) and at the international level (Nölke, 1995). At the same time, not only exchange relations, but other relations like communication or common memberships are dealt with while formal exchange models are neglected. In addition to the level of analysis and the relations, a methodological pluralism can be observed: While centrality, blockmodeling and non-linear projection are the most frequently used methods in the exchange college and density and subgroup analysis are popular in participation and elite studies, publications in the governance college make use of blockmodels, centrality and also density.

Summing up, a dispersion of network analysis is taking place. In contrast to earlier, more unified approaches, network analysis in this newer cluster is characterized by methodological, theoretical and relational pluralism. It absorbs the characteristics of the other three colleges and adds some new components.

5.5 Culturalistic Approaches

Not all citing publications are clearly classified into the four clusters, sometimes due to misclassification but in most cases because the publications indeed do not belong into any cluster and therefore do not include any of the core cluster citations. Another problem is that small, recently emerging clusters cannot be identified because they are interpreted as noise. Only large and elaborated schools of thought can be detected. One small college that has not been detected by means of citation analysis might be culturalistic approaches which are very rare and can only be found after 1997. Nonetheless, there are some publications featuring a theoretical perspective which is clearly different from the rest of the literature although they have been classified into the elite, governance or exchange cluster (yet based on a small n). They share a culturalistic view on policy-making, up to now exclusively based on the Advocacy Coalition Framework of Sabatier and Jenkins-Smith (1993).

Zafonte and Sabatier (1998) test whether congruence in belief systems leads to more successful policy coordination. One of their subsequent papers (Zafonte and Sabatier, 2004) deals with the stability of belief coalitions over time. Weible and Sabatier (2005) compare ally and coordination networks with the classic concepts of information and advice networks. There is apparently a small but growing community of Advocacy Coalition Framework scholars who are mostly affiliated with each other. For the most part, however, ACF applications can be found in the qualitative literature along with some publications on epistemic communities and issue networks.

6. CONCLUSION

6.1 Summary: What has been achieved

In this thesis, a number of schools of thought have been identified using multivariate methods, and the citing publications have been classified into these categories. Finally, the schools of thought have been described in detail. The insights presented here may help researchers to take advantage of knowledge produced in other schools of thought and may guide social scientists when writing introductory chapters of their analyses. The most important achievement, though, is the replacement of previously published review articles trying to structure the theoretical landscape of quantitative political network analysis (see section 1.1) by a more elaborate overview which is empirically backed.

At the beginning of this thesis, four research questions were posed. Their answers have been presented throughout the analysis and interpretation parts and will be summarized below. In addition, table 6.2 presents some of the results at a single glance.

- The first one refers to the identification of colleges in the specialty of political network analysis. This question has been addressed in detail in the previous sections, and the clusters have been described accordingly. Indeed, Crane's prediction of several “social circles”seems to hold while Price's core-periphery model seems inappropriate at first sight. Only if one of the clusters, for example elite network analysis, is regarded as a specialty, there may be more centralized or hierarchical communication patterns in the field, but this cannot be examined using citation analysis alone.

- The second question posed in the introductory chapter refers to the identification of bridges that connect the otherwise distinct invisible colleges, and

	governance	*exchange*	*elite*	*participation*
analysis	hierarchy, influence, power	control of policy events	cohesiveness, participation	influence of embeddedness
relation	exchange of resources, contact	exchange of resources, influence reputation	interlocks, contact	contact, common memberships
network	one-mode	one-mode, two-mode	two-mode	ego-network
methods	centrality, density, blockmodels	centrality, blockmodels, MDS	centrality, subgroups	density, subgroups, regression
level of analysis	any level	national, sometimes supranational	national, international	local/individual
core researchers	Beyers, Fischer, Grote, Jordana, Kriesi, Pappi, Sancho, Schneider, Sciarini, Serdült	Diani, Kappelhoff, Knoke, Pappi, Thurner, Schneider, Stokman	Burris, Carroll, Heinz, Laumann	McClurg, Pattie, Johnston, Zuckerman
overlap	overlap with exchange cluster	overlap with governance and elite colleges	overlap with exchange cluster	slight overlap with elite cluster; rather homogeneous
influences	governance, interest intermediation, Organizational State	Coleman's exchange model, Organizational State, community elite studies	various elite models, inner circle theory	social capital, voting, participation studies, Granovetter

Tab. 6.2: Results of the analyses

the third one to the homogeneity of the clusters and their potential overlap. These two questions are interrelated and shall be answered together: The analysis in section 4.2.4 has demonstrated that the authors Pappi, Laumann and Knoke are cited by more than one discipline and are therefore bridges at the co-citation level. On the part of the citing documents, section 4.3.1 has shown that König, Pappi, Schneider and some other authors work as hinges between the organizational/exchange college and the governance/interest intermediation school of thought. Laumann and Heinz can be considered bridges between the organizational/exchange cluster and the exchange school. There are no major ties between elite scholars and governance scholars. In this regard, the exchange school basically serves as a bridge between elite and governance scholars, as underlined by section 4.3.2. As can be derived from figures 4.3.1 and 4.12, there are some minor ties between the elite and the participation cluster (Barton, 1985; Gibson, 2001; Laumann and Pappi, 1976), but participation scholars are generally well isolated from the rest of the political network analysis specialty.

- The fourth research task is the enumeration of core researchers of each subdiscipline or college. This question is particularly difficult to address since invisible colleges are conceptualized as social circles and therefore as polycentric entities. In addition, ethnographic research designs might be better equipped to draw conclusions about the mutual attribution of prestige between researchers. What can be done, however, is the enumeration of the most frequently cited publications per school of thought. This can be hardly done in a deterministic-quantitative manner since the assignment to the colleges is probabilistic. Yet it can be observed that Diani, Kappelhoff, Knoke, Thurner, Stokman and the early works of Pappi and of Schneider are repeatedly and clearly classified into the exchange/organizational state college. Beyers, Fischer and Sciarini, Grote, Jordana and Sancho, Kriesi, Serdült and some later works of Pappi and Schneider clearly make up the governance/interest intermediation cluster. The elite cluster is dominated by Burris, Carroll, Heinz and Laumann. Finally, figure 4.3.1 reveals that

McClurg, Pattie and Johnston and Zuckerman are “leading scientists” in the participation cluster.

6.2 Outlook: What might be done in the future

Future research may want to evaluate whether these schools of thought reflect patterns of scholarly communication as posited by some invisible college theorists (c.f. section 2.2). Section 5.1 gives some hints at how this may be achieved. It seems likely, however, that at least the exchange/organizational state cluster and the belief system scholars form cohesive subgroups shaped by contact or co-authorship patterns. Another improvement can be made by employing Galois lattices as an exact clustering method as proposed in section 4.1.5.

A theoretical point of departure for further research might be the monitoring of the specialty of political network analysis. As disciplines are rapidly changing landscapes, in a few years it will most likely be possible to identify other research schools which cannot be traced using the current data. One such candidate with a potential to become a subdiscipline is the Advocacy Coalition Framework and related culturalistic approaches (section 5.5).

6.3 The value added by this analysis

In an ever changing world of scientific complexity, it is indispensable to rely on information-organizing systems like reference databases, search engines and review articles summarizing recent developments in scientific disciplines, and on information mining systems, which allow knowledge discovery in seemingly unimportant data like bibliographies. The analysis presented in this thesis has not only produced a clear-cut classification of already existing data, it has also developed a prediction model that may serve to classify upcoming works on political networks by surveying their bibliographies. Just like in section 4.3.1, a likelihood distribution may be calculated for any new article based on the 59 core citation counts, and a probability of belonging into any of the four clusters may be predicted.

Moreover, this analysis has contributed to the current discussion on the structure of political network analysis by discovering the previously unidentified research schools of elite networks, governance/interest intermediation, participation networks and the exchange/organizational state perspective and formally describing their relations to each other. In addition, most political network analyses published so far have been partitioned into these research traditions making use of fuzzy (not deterministic!) classification mechanisms, which is far superior to all other existing approaches of organizing the field of political network analysis. The subgroup analysis has been complemented by univariate statistics on general trends in the discipline, e.g. a survey of the methodology used in quantitative analyses or the topics covered by them. Altogether, this thesis presents unique insights into the structure of the subdiscipline, which can be valuable for any author in the field of political network analysis.

From a sociological perspective, the theoretical part of this thesis has contrasted several models of scientific structure and growth and worked out their predictions for the discipline at issue. Last but not least, some methodological advances have been made by introducing level plots to the visualization of affiliation matrices and by introducing Galois lattices to the field of citation analysis as an auspicious future alternative to well-known clustering and mapping techniques.

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APPENDIX

A. THE 193 CITING POLITICAL NETWORK ANALYSES

1 = Elite cluster likelihood

2 = Governance cluster likelihood

3 = Exchange cluster likelihood

4 = Participation cluster likelihood

n = Absolute sum of cited core items

Citation Label	1	2	3	4	n
Aerni (2005)	0.00	0.00	0.00	0.00	0
Albach (1993)	0.00	0.00	0.00	0.00	0
Alpert et al. (2006)	0.50	0.00	0.50	0.00	2
Ayach (1998)	0.00	0.00	1.00	0.00	1
Barton (1985)	0.33	0.00	0.00	0.67	3
Beyers (2002)	0.00	0.50	0.50	0.00	2
Beyers and Kerremans (2004)	0.00	1.00	0.00	0.00	1
Böhler and Vuilleumier (1998)	0.00	1.00	0.00	0.00	6
Brandes et al. (2003)	0.00	0.50	0.50	0.00	2
Brechtel (1998)	0.25	0.42	0.33	0.00	24
Burris (1992)	1.00	0.00	0.00	0.00	2
Burris (2005)	1.00	0.00	0.00	0.00	4
Carpenter et al. (1997)	0.00	0.00	1.00	0.00	1
Carpenter et al. (1998)	0.00	0.00	1.00	0.00	1
Carpenter et al. (2004)	0.00	0.33	0.33	0.33	3
Carroll and Shaw (2001)	1.00	0.00	0.00	0.00	2
Carroll and Carson (2003)	1.00	0.00	0.00	0.00	1
Chappuis et al. (1998)	0.00	0.67	0.33	0.00	3
Choi and Brower (2006)	0.00	0.00	1.00	0.00	2
Cinalli (2004)	0.00	0.00	1.00	0.00	3
Considine and Lewis (2003)	0.50	0.50	0.00	0.00	2
Curry and Thomas (1992)	0.29	0.00	0.57	0.14	7
Czernielewska et al. (2004)	0.00	0.00	0.00	0.00	0
Darves and Dreiling (2002)	0.67	0.00	0.33	0.00	3
Diani (1990)	0.00	0.00	1.00	0.00	1
Diani (1995)	0.00	0.00	1.00	0.00	3
Doerfel and Taylor (2004)	0.00	0.00	1.00	0.00	1
Doreian and Albert (1989)	0.00	0.00	1.00	0.00	1

Dougill et al. (2006)	0.00	0.00	0.00	0.00	0
Dreiling (2000)	0.60	0.00	0.40	0.00	5
Eulau and Rothenberg (1986)	0.00	0.00	0.20	0.80	5
Falcon (1995)	0.00	0.00	0.00	0.00	0
Faust et al. (2002)	0.00	0.00	0.00	0.00	0
Fischer et al. (2002)	0.00	1.00	0.00	0.00	3
Foljanty Jost and Jacob (2004)	0.00	1.00	0.00	0.00	3
Fontana (1985)	0.00	0.00	0.00	0.00	0
Fowler (2006)	0.00	0.00	0.00	1.00	1
Fürst et al. (2001)	0.20	0.40	0.40	0.00	5
Futó et al. (2003)	0.00	0.00	0.00	0.00	0
Gallagher and Marsh (2004)	0.00	0.00	0.00	0.00	0
Gambardella and Garcia-Fontes (1996)	0.00	0.00	0.00	0.00	0
Gemperli et al. (1998)	0.00	0.00	1.00	0.00	1
Getimis and Demetropoulou (2004)	0.00	0.00	0.00	0.00	0
Gibson (2001)	0.50	0.00	0.00	0.50	2
Gil Mendieta and Schmidt (1996)	0.00	0.00	1.00	0.00	1
Gil Mendieta et al. (1997)	0.00	0.00	0.00	0.00	0
Gorissen et al. (2005)	0.00	0.00	0.00	0.00	0
Grote (1995)	0.50	0.50	0.00	0.00	2
Grote (1996)	0.10	0.90	0.00	0.00	10
Grote (1997)	0.07	0.79	0.14	0.00	14
Grote and Schneider (2006)	0.00	1.00	0.00	0.00	1
Hammerli et al. (2006)	0.00	0.00	1.00	0.00	1
Hafner-Burton and Montgomery (2006)	0.00	0.00	1.00	0.00	2
Hasanagas (2004)	0.00	0.50	0.50	0.00	6
Heinz et al. (1990)	0.83	0.00	0.17	0.00	6
Heinz (1993)	0.80	0.00	0.13	0.07	15
Heinz et al. (2003)	0.50	0.00	0.50	0.00	4
Helbling et al. (2005)	0.43	0.43	0.14	0.00	7
Henning and Wald (2000)	0.00	0.75	0.25	0.00	8
Higley and Moore (1981)	1.00	0.00	0.00	0.00	6
Hirschi et al. (2005)	0.00	1.00	0.00	0.00	2
Hoff and Ward (2004)	0.00	0.00	0.00	0.00	0
Howlett (2002)	0.14	0.71	0.14	0.00	7
Huckfeldt and Sprague (1987)	0.00	0.00	0.00	1.00	1
Hughes et al. (2002)	0.63	0.13	0.25	0.00	8
Ingram et al. (2005)	0.00	0.00	0.00	0.00	0
Jakulin and Buntine (2004)	0.00	0.00	0.00	0.00	0
John and Cole (1998)	0.20	0.40	0.40	0.00	5
John (1998)	0.00	0.33	0.67	0.00	3
John and Musson (2006)	0.33	0.67	0.00	0.00	3
Jordana and Sancho (2003)	0.00	1.00	0.00	0.00	4
Jordana and Sancho (2005)	0.00	1.00	0.00	0.00	2
Kappelhoff and Pappi (1990)	0.33	0.00	0.67	0.00	6
Kick and Kiefer (1987)	0.00	0.00	1.00	0.00	1

Knoke and Burmeister-May (1990)	0.00	0.00	0.00	0.00	0
Knoke (1990a)	0.00	0.00	0.00	1.00	6
Knoke and Pappi (1991)	0.00	0.00	1.00	0.00	2
Knoke et al. (1996)	0.21	0.11	0.68	0.00	19
König (1992)	0.27	0.14	0.59	0.00	22
König and Brechtel (1997)	0.00	0.67	0.33	0.00	9
König and Bräuninger (1998)	0.00	0.75	0.25	0.00	12
Koschade (2006)	0.00	0.00	0.00	0.00	0
Krauss et al. (2004)	0.00	0.00	1.00	0.00	1
Kriesi (1982)	0.00	0.50	0.00	0.50	2
Kriesi and Jegen (2001)	0.00	1.00	0.00	0.00	2
Kriesi et al. (2006)	0.00	1.00	0.00	0.00	5
Lake and Huckfeldt (1998)	0.25	0.00	0.00	0.75	4
Lang (2006)	0.00	0.40	0.60	0.00	5
Laumann and Pappi (1976)	0.38	0.00	0.13	0.50	8
Laumann et al. (1985b)	0.69	0.00	0.31	0.00	13
Laumann and Knoke (1987)	0.54	0.00	0.42	0.04	24
Laumann and Knoke (1989)	0.80	0.00	0.20	0.00	15
Laumann et al. (1992)	0.62	0.00	0.31	0.08	13
Lewis (2005)	0.00	0.00	0.00	0.00	0
Liu et al. (1998)	0.00	0.00	0.00	1.00	6
Lovseth (2004)	0.10	0.40	0.50	0.00	10
Maman (1997)	0.00	0.83	0.17	0.00	6
Mattila (1999)	0.00	1.00	0.00	0.00	2
McClurg (2003)	0.00	0.00	0.00	1.00	6
McClurg (2006)	0.00	0.00	0.00	1.00	6
McDaniel et al. (2001)	0.00	0.00	1.00	0.00	1
Melbeck (1998)	0.20	0.30	0.50	0.00	10
Milward and Provan (1998)	0.00	0.00	1.00	0.00	1
Mintrom and Vergari (1998)	0.00	0.50	0.50	0.00	2
Miskel and Song (2004)	0.00	0.00	1.00	0.00	2
Mokken and Stokman (1978)	0.00	0.00	0.00	0.00	0
Moore et al. (2003)	0.00	0.00	1.00	0.00	1
Murphy and Maynard (2000)	0.00	0.00	0.00	0.00	0
Mutz (2002)	0.00	0.00	0.00	1.00	5
Nanetti et al. (2004)	1.00	0.00	0.00	0.00	1
Neukomm et al. (1998)	0.00	0.00	0.00	0.00	0
Nölke (1995)	0.00	0.92	0.08	0.00	12
Osa (2001)	0.00	0.00	1.00	0.00	1
Palne-Kovacs et al. (2004)	0.00	0.00	0.00	0.00	0
Panning (1982)	0.00	0.00	0.00	0.00	0
Pappi (1990)	0.00	0.00	1.00	0.00	5
Pappi and Knoke (1991)	0.00	0.00	1.00	0.00	6
Pappi et al. (1993)	0.00	0.33	0.67	0.00	3
Pappi et al. (1995)	0.18	0.18	0.65	0.00	17
Pappi (1995)	0.50	0.50	0.00	0.00	2

Pappi and Schnorpfeil (1996)	0.00	0.50	0.50	0.00	2
Pappi and Henning (1999)	0.00	0.57	0.43	0.00	7
Park et al. (2005)	0.00	0.00	0.00	0.00	0
Pattie and Johnston (1999)	0.00	0.00	0.00	1.00	2
Pattie and Johnston (2000)	0.00	0.00	0.00	1.00	2
Pforr (2006)	0.00	0.89	0.11	0.00	9
Pihan (1996)	0.10	0.80	0.10	0.00	10
Porter et al. (2005)	1.00	0.00	0.00	0.00	1
Provan et al. (2002)	1.00	0.00	0.00	0.00	1
Provan et al. (2003)	0.00	0.00	0.00	0.00	0
Provan et al. (2004)	0.00	0.00	1.00	0.00	2
Raab (2002)	0.00	0.67	0.27	0.07	15
Ray et al. (2003)	0.00	0.00	0.00	0.00	0
Rech (2003)	0.00	0.50	0.50	0.00	2
Rees et al. (2004)	0.00	0.00	0.00	0.00	0
Robinson (1976)	0.00	0.00	0.00	1.00	2
Roch et al. (2000)	0.00	0.00	0.20	0.80	5
Rosenthal et al. (1985)	0.00	0.00	0.00	0.00	0
Sager et al. (2001)	0.17	0.67	0.17	0.00	6
Salk et al. (2001)	0.00	0.00	0.00	0.00	0
Schaefer Caniglia (2001)	0.25	0.00	0.75	0.00	4
Scheidt (1995)	0.00	0.00	1.00	0.00	3
Scheufele et al. (2002)	0.00	0.00	0.00	1.00	4
Scheufele et al. (2004)	0.14	0.00	0.00	0.86	7
Schneider (1986)	0.00	0.00	1.00	0.00	7
Schneider (1988)	0.25	0.13	0.63	0.00	16
Schneider (1990)	0.00	0.20	0.80	0.00	5
Schneider and Werle (1991)	0.00	0.17	0.83	0.00	6
Schneider (1992)	0.00	0.57	0.43	0.00	7
Schneider (1993)	0.00	0.17	0.83	0.00	6
Schneider et al. (1994)	0.00	0.67	0.33	0.00	3
Schneider et al. (2003)	0.00	0.25	0.50	0.25	4
Schneider (2005)	0.00	0.40	0.60	0.00	5
Schneider et al. (2006)	0.00	0.00	1.00	0.00	2
Schneider (2006)	0.00	0.88	0.13	0.00	8
Sciarini (1996)	0.00	0.80	0.20	0.00	10
Sciarini et al. (2004)	0.00	1.00	0.00	0.00	3
Seibel and Raab (2003)	0.00	0.67	0.33	0.00	3
Serdült (1998)	0.00	0.76	0.24	0.00	21
Serdült (2000)	0.12	0.72	0.12	0.04	25
Serdült and Hirschi (2004)	0.00	1.00	0.00	0.00	2
Shemtov (2003)	0.00	0.00	0.00	0.00	0
Shin and Timberlake (2000)	0.00	0.00	0.00	0.00	0
Shrum and Beggs (1997)	0.00	0.00	0.00	0.00	0
Song and Miskel (2005)	0.00	0.00	1.00	0.00	6
Steiner et al. (1998)	0.00	1.00	0.00	0.00	1

Stelle (2001)	0.00	0.00	0.00	0.00	0
Stevenson and Greenberg (2000)	0.00	0.00	1.00	0.00	2
Stoiber (2003)	0.00	0.40	0.60	0.00	5
Stokman et al. (1989)	0.00	0.00	1.00	0.00	1
Stokman and Berveling (1998)	0.33	0.33	0.33	0.00	12
Svensson and Öberg (2005)	0.00	0.00	1.00	0.00	1
Thurner and Stoiber (2002)	0.00	0.43	0.57	0.00	7
Thurner (2004)	0.00	0.00	1.00	0.00	1
Thurner et al. (2005)	0.00	0.33	0.67	0.00	3
Thurner and Binder (2006)	0.00	0.00	0.00	0.00	0
Tikkanen et al. (2003)	0.00	0.00	0.00	0.00	0
True and Mintrom (2001)	0.00	0.00	0.00	0.00	0
Veenstra (2002)	1.00	0.00	0.00	0.00	1
Vögeli (2005)	0.20	0.80	0.00	0.00	5
Volker and Flap (2001)	0.50	0.00	0.50	0.00	2
Vogelsang (1998)	0.00	0.86	0.14	0.00	14
Wada (2003)	0.00	0.00	0.00	0.00	0
Weatherford (1982)	0.00	0.00	0.00	1.00	5
Weible (2005)	0.00	0.50	0.50	0.00	2
Widmer and Troeger (2005)	0.00	0.00	1.00	0.00	1
Zafonte and Sabatier (1998)	0.00	0.67	0.33	0.00	3
Zafonte and Sabatier (2004)	0.50	0.00	0.50	0.00	2
Zahl and Spiekermann (2005)	0.00	0.00	0.00	0.00	0
Zijlstra (1978)	0.00	0.00	0.00	0.00	0
Zimmermann et al. (2004)	0.00	0.00	0.00	0.00	0
Zuckerman et al. (1994)	0.00	0.00	0.00	1.00	6
Zuckerman et al. (1998)	0.00	0.00	0.00	1.00	6

Tab. A.1: Citing publications and cluster likelihoods

B. AWK SOURCE CODE

In order to extract tagged information from the underlying Endnote database and especially from its keyword field, an EndNote style must be created which writes the author field, year, document title and the keyword field into a new ASCII text file. In this output style, records (i.e. publications) must be separated by the phrase “NEWRECORD”, and the four fields mentioned above must be separated by two slashes (“//”). The resulting text file must be used as an input file with the following custom-made AWK program:

```
# The first lines define the input and output field separators
# as well as the keywords/tags. E.g. A3a is the tag for
# quantitative analyses and B3k for Switzerland in the input
# text file. The output field separator will be a semicolon
# because the output will be written as a CSV file.

BEGIN {
FS = "//"
RS = "NEWRECORD"
ORS = ";"
{
keyword[1] = "A "
keyword[2] = "A1"
keyword[3] = "A2"
keyword[4] = "A3 "
keyword[5] = "A3a"
keyword[6] = "A3b"
keyword[7] = "A4"
```

```
keyword[8] = "B "
keyword[9] = "B1 "
keyword[10] = "B1a"

# All other tags along with index numbers must be inserted here!
# The following lines print the header line of the new file
# including the variable names.

keyword[204] = "G15"
}
{ print ";ID" }
{ for (i = 1; i <= 204; i++) print keyword[i] }
{ print "\n" }
}

# The following lines perform the actual data conversion.
# The 'print' statements and the 'for' loops and 'if' conditions
# are required to write the new output file. The 'split'
# statement separates the first author's last name from the
# other authors' names to generate the row labels.
# The program will write 1 if the tag is present and 0 if it
# is absent, thus the result will be a binary matrix.

{ split($3, wort, " ") }
{ print $1 $2 wort[1] }

{ for (i = 1; i <= 204; i++)
{ if ($4 ~ keyword[i] " ") print "1"; else print "0" }
}

{ print "\n" }
```

C. THE COMPLETE TWO-MODE NETWORK

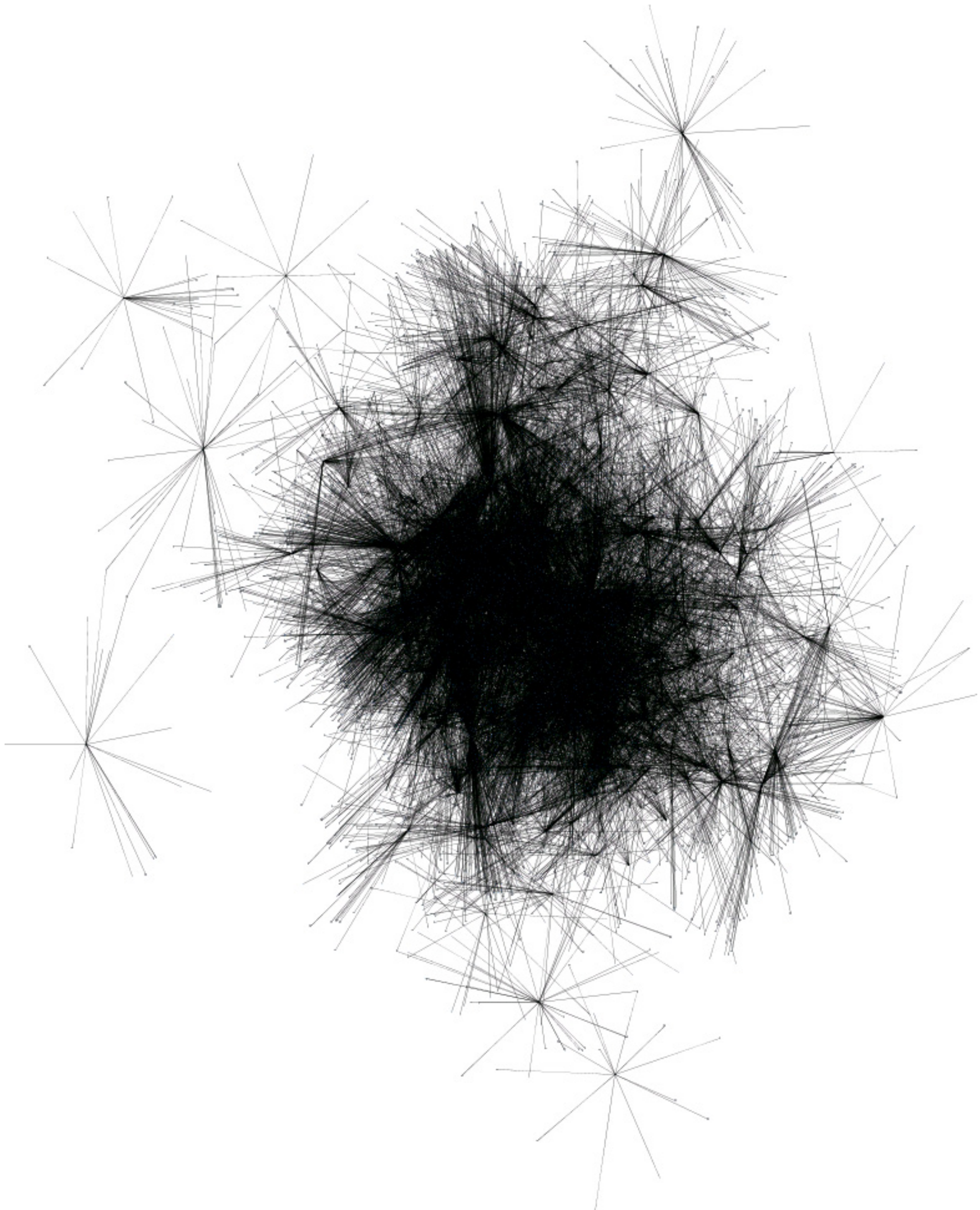

Fig. C.1: The two-mode network of 8683 publications. Zoom level 5%.

D. FACTIONS VIA TABU SEARCH

		71 kn	12 da	78 wa	74 sa	25 us	56 bo	47 mo	70 fi	49 hu	72 lu	76 la	79 mc	65 li	17 mi	69 dy
71	knoke1981power				6											
12	dahl1961who					6		6		10	6				12	
78	walker1983origins					6			6			6			6	
74	salisbury1984interest	6				7		6	6			6				
25	useem1984inner		6	6	7			8	7			7			9	7
56	bonacich1987power															
47	moore1979structure		6		6	8			7			6	6		7	6
70	field1980elitism			6	6	7		7				7			6	
49	hunter1953community		10												7	
72	lukes1974power		6												6	
76	laumann1985washington			6	6	7		6	7							
79	mcconnell1966private							6							6	
65	lindblom1977politics														6	
17	mills1956power		12	6		9		7	6	7	6		6	6		7
69	dye1986who's					7		6							7	
3	knoke1982network															
61	kappelhoff1988soziale															
8	granovetter1985economic															
53	weber1972wirtschaft															
30	knoke1983prominence															
31	kruskal1978multidimensional					6										
2	freeman1979centrality					7	7								7	
63	berkowitz1982introduction															
4	heclo1978issue		10					6		6				6	7	
15	olson1971logic		6												7	
6	coleman1990foundations															
27	pappi1984abhaengigkeit		6													
18	burt1982toward															
24	truman1951governmental		8			7									9	6
62	lowi1964american		6												6	
66	pappi1984das															
14	knoke1982social	7			6										6	
43	galaskiewicz1979exchange					6										
46	lehmbruch1984concertation															
37	burt1983applied															
38	coleman1973mathematics	7			6											
19	pappi1987methoden															
52	schmitter1979trends															
16	laumann1983boundary															
44	laumann1985organizational															
7	granovetter1973strength															
32	marsden1977collective		7			6										
34	schmitter1974still														6	
64	coleman1986individual															
75	schlozman1986organized															
20	white1976social															
73	ripley1991congress															
80	polsby1984political															
45	lazarsfeld1944people's															
41	laumann1973bonds															
81	sheingold1973social															
28	burt1976positions					6										
13	kingdon1984agendas															
50	lorrain1971structural															
29	heinz1993hollow															
48	freeman1977set															
68	scharpf1978interorganizational															
54	williamson1975markets															
58	hanf1978interorganizational															
55	atkinson1992policy															
57	burstein1991policy															
11	van1992dimensions															
21	marin1991policy															
60	jordan1992preliminary															
5	knoke1996comparing						6									
42	pappi1993policy-netze:															
67	rhodes1992new															
26	marsden1990network															
59	jordan1990subgovernments															
10	kenis1991policy		6													
51	mayntz1991modernization															
22	pappi1995entscheidungsprozesse															
23	schneider1988politiknetzwerke															
9	dowding1995model															
35	schneider1992structure															
36	atkinson1989strong															
77	lehmbruch1990organization															
33	mayntz1993policy-netzwerke															
39	koenig1992entscheidungen															
40	kriesi1980entscheidungsstrukturen															
1	knoke1990political															

Fig. D.1: Factions (labels and first column)

```
   3 61  8 53 30 31  2 63  4 15  6 27 18 24 62 66 14 43 46 37 38 19 52 16 44  7 32 34 64
  kn ka gr we kn kr fr be he ol co pa bu tr lo pa kn ga le bu co pa sc la la gr ma sc co
-------------------------------------------------------------------------------------------
|                                                  7           7                          |
|                         10  6     6     8  6                                   7        |
|                                                                                         |
|                                                  6           6                          |
|                 6  7                    7           6                          6        |
|                    7                                                                    |
|                          6                                                              |
|                                                                                         |
|                          6                                                              |
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|                                                                                         |
|                                                                                         |
|                          6                                                              |
|                    7     7  7           9  6     6                                6     |
|                                         6                                               |
-------------------------------------------------------------------------------------------
|        9  8  9  7 13  8  8  7  6  6  9     6  6  9  6  6  9  7  8     7  7  7  6  7     |
|                                8  7              7                                   6  |
|  9        8  6     8     7  7  8        6           6        6        6     6  6        |
|  8     8           6        7              6                    6                       |
|  9     6        6  9                             7  6     6  7        6        6        |
|  7        6     8     8                                               6                 |
| 13     8  6  9  8     6  7  8 11  7  9  9  7  6 10  7  6     7  8  6 13  7  6  7  6     |
|  8                 6                                      6                             |
|  8     7        8  7           7  7     7  8  6  9                 7        7     7     |
|  7     7  7        8           7  6     9  6                          6                 |
|  6  8  8          11     7  7     7                 8              8     6        6     |
|  6  7              7     7  6  7        7  6  6 10     6     8  6              8  6  7  |
|  9                 9                                         6                          |
|        6           9     7  9     7        8     6     6           6              8     |
|  6        6        7     8  6     6     8        6     6        6  6              6     |
|  6                 6     6        6                             6     6                 |
|  9  7        7    10     9     8 10     6  6        7        8  6        9     7  6  6  |
|  6     6     6     7                             7                             6        |
|  6                 6              6     6  6                    7  7              7     |
|  9           6        6                                      6                          |
|  7     6     7     7              8  6              8        6              6     8     |
|  8        6        8     7     8  6        6  6  6     7              7              6  |
|                    6        6              6  6              7              6           |
|  7     6     6  6 13           6              6                 7  6                    |
|  7                 7     7                       9           6                          |
|  7     6           6                                                                    |
|  6     6     6     7     7     6  8              7  6        8                       6  |
|  7                 6              6     8  6     6     7        6                       |
|     6                              7              6                             6        |
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|                          7                                                              |
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|  7                 8                                7                          6        |
|                         15              7  6     6                       7              |
|                                                                                         |
|                          9                                                              |
|  6                 7                                                                    |
|  6                                                                                      |
|                             7           6                                               |
|                          6                                                              |
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|                          6                             6        6                       |
|  6                       6                                                        6     |
|                          6                                      6                       |
|                                                                                         |
|                    7    10  6  6                                7                       |
|                                                                 7                       |
|                                                                                         |
|  6                                                                                      |
|                          8                                                              |
|  8                 7     9     8                                7                 7     |
|                                                                                         |
|                                6                                6                       |
|  9                                                                                      |
|                          7                                                              |
|  6                                                                                      |
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|                                                                                         |
|                          6                                                              |
|                          8     8                                6                       |
|                                                                                    6     |
| 12     9          10    12          8                 6                                |
-------------------------------------------------------------------------------------------
```

Fig. D.2: Factions (second column)

```
  75 20 73 80 45 41 81 28 13 50 29 48 68 54 58   55 57 11 21 60  5 42 67 26 59 10 51 22 23  9 35 36 77 33 39 40  1
  sc wh ri po la la sh bu ki lo he fr sc wi ha   at bu va ma jo kn pa rh ma jo ke ma pa sc do sc at le ma ko kr kn
--------------------------------------------------------------------------------------------------------------------
|                                              |                                                                   |
|                                              |                                6                                  |
|                                              |                                                                   |
|                                              |                                                                   |
|                       6                      |                                                                   |
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|                                              |                                                                   |
--------------------------------------------------------------------------------------------------------------------
|                       7           6  6       |        6                 6     8        9     6                12 |
|                                              |                                                                   |
|                                              |                                                                 9 |
|                                              |                                                                   |
|                                              |                                                                   |
|                                              |                                                                   |
|                       8           7          |                 7              7                               10 |
|                                              |                                                                   |
|  7     6  6             15     9           6 |     6  6  6    10           8  9           7           6  8    12 |
|                                         7    |                 6                                                 |
|                                              |                 6              8     6                    8       |
|                                              |                                                                   |
|                                              |                                                                 8 |
|                          7              6    |                                                                   |
|                          6                   |                                                                   |
|                                              |                                                                   |
|                          6                   |                                                                   |
|                       7                      |                                                                   |
|                                              |     6                                                           6 |
|                                              |                                                                   |
|                                              |                                                                   |
|                                              |     6     6     7  7           7     6                    6       |
|                                              |                                                                   |
|                                              |                                                                   |
|                          7                   |                                                                   |
|                                              |                                                                   |
|                       6                      |                                                                   |
|                                              |        6                       7                             6    |
|                                              |                                                                   |
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|                          6                   |                                                                   |
|                       7     7           6    |                                                                   |
|                          6                   |                                                                   |
|                          6                   |                                                                   |
|                 7  6                         |                                                                 6 |
|              7     6                         |                                                                   |
|              6  6                            |                                                                   |
|     7                       6                |                 6                                                 |
|  6     6  6                    7             |                                                                 6 |
|     7                 6                      |                                                                   |
|                          7                   |                                                                 6 |
|                                              |                                                                   |
|                                            6 |                                                                   |
|     6                                        |                                                                   |
|                                      6       |                                6        6                         |
--------------------------------------------------------------------------------------------------------------------
|                                              |        7  6     7  7           7  6        8        6             |
|                                              |                                                  6              6 |
|                                              |  7       11  9  9  7  7        7  7       12  9  9  7        7 10 |
|                                              |  6    11     6  6  6           9  6        9  7     7  6        6 |
|                                              |        9  6           7                       7  6           6  6 |
|                       6                      |  7     9  6        8          10  9 10  6 12     7  6  7  7  6 11 |
|                                              |  7     7  6     8             10     6     6           7  6     6 |
|                                              |        7     7                                6                   |
|                                              |                                               6                 8 |
|                                              |                                6        6              6          |
|                                            6 |  7     7  9    10 10        6     7  8  9  9  6  6     7  8     7 |
|                                              |  6     7  6     9              7           7        6             |
|                                              |                10  6           8           6     7     6          |
|                                            6 |                 6           6  9              6              6    |
|                                              |  8    12  9    12  6           9  7  6        7                 9 |
|                                              |        9  7  7        6  6     6        6  7           6        8 |
|                                              |     6  9     6  7              6     7                          7 |
|                                              |  6     7  7     6                 6                              |
|                                              |           6     7  7        6  7     6        6                 6 |
|                                              |                 7  6           8                                7 |
|                                              |        7     6  6                       6                         |
|              6           6     6             |     6 10  6  6 11  6     8     7           9  8  7     6  7       |
--------------------------------------------------------------------------------------------------------------------
```

Fig. D.3: Factions (third and fourth column)