Scientific Collaboration Networks: Knowledge Diffusion and Fragmentation in Turkish Management Academia

Bülent Özel

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Institute of Social Sciences

Istanbul Bilgi University

June 2010

Scientific Collaboration Networks: Knowledge Diffusion and Fragmentation in Turkish Management Academia

Bilimde Ortak Çalışmalar: Türkiye İşletme Akademisinde Bilginin Yayınımı ve Bölümlenme

Bülent Özel
103801001

Prof.Dr. Beyza Oba :..................
Prof.Dr. Cengiz Yılmaz :..................
Prof.Dr. Himmet Murat Güvenç :..................
Prof.Dr. Lale Duruiz :..................
Doç.Dr. Ufuk Çakmakçı :..................

Tezin Onaylandığı Tarih : 29.07.2010

Toplam Sayfa Sayısı:

Anahtar Kelimeler (Türkçe)
1) Social Networks
2) Knowledge Diffusion
3) Collaboration Networks
4) Longitudinal Analysis
5) Academia

Anahtar Kelimeler (İngilizce)
1) Sosyal Ağlar
2) Bilginin Yayınımı
3) Kolektif Ağlar
4) Boylamsal Yayınım
5) Akademi

Abstract

Focus of this dissertation study is the interplay between knowledge diffusion and social collaboration structures. Contribution to the field is three fold. First, it elaborates on mutuality of knowledge and social structure theory borrowed from sociology of knowledge literature, where knowledge is perceived as an essentially social and societal category. Second, it develops a coherent research framework which relates cognitive structure and the collaboration patterns into an integrated socio-knowledge analysis of a given scientific community. The framework combines and extends meta-network perspective and co-word analysis. It is enhanced by introducing a novel model. The model maps actors from co-authorship networks into a strategic diagram of scientists. The mapping is based on cohesiveness and pervasiveness of issues each author has published in the field. Third, it adopts a longitudinal approach to trace knowledge diffusion within peculiarity of a national level socio-knowledge system identifying (i) mechanism of knowledge diffusion within the community, (ii) interplay in between scientists socio-knowlesge structures and their research strategies, (iii) axes of fragmentation in the community, and (iv) their evolutions over time.

The exemplary longitudinal case from Turkey covers scientific publication activities in Turkish management academia spanning the years from 1922 until 2008. Amongst other findings, it is seen that management knowledge within local community is transferred following patterns of information diffusion rather then patterns of knowledge diffusion found elsewhere at cognitively demanding areas. On the other hand, publishing in citation indexed international journals reveals formation of cohesive team structures as a mean of collaborative knowledge production and transfer. Besides, while within lo-

cal community diffusion of management knowledge is lead by academicians with certain socio-knowledge properties, academicians publishing at international arena do not show any significantly differing socio-cognitive properties, instead, they are merely embedded in strongly connected groups. Leading academicians within local community exhibit a common cognitive structure relative to the rest of the community. They have more social ties and more diversified knowledge compared to the rest. Knowledge they have is distinct compared to their peers in the network, they hold certain part of their knowledge exclusively, thus knowledge-wise they don't resemble the rest, but they keep a level of common knowledge with the rest of the community.

The in depth analyses on the exemplary case are demonstrated with a rigorous set of computationally supported descriptive and visual tools, which are adopted or developed for this dissertation work.

Empirical findings of exemplary case are in align with theoretical discussions of the dissertation. They provide new perspectives within body of relevant literature and points the potential of proposed research framework to be employed for future directions.

Özet

Bu tez çalışmasının genel odağı, bilimsel bilginin yayınımı ile ortak bilimsel çalışmalarla gözlemlenebilen sosyal ağ yapıları arasındaki etkileşimler üzerinedir. Tez çalışması bu çerçevede, alana farklı, ama ilintili katkılar sağlar: İlk olarak, akademilerde bilginin yayınımı çalışılırken kullanılabilecek bir teorik çerçeve hazırlar ve sunar. Teorik çerçeve bilginin üretim ve yayınım sürecinin sosyal yapı ile karşılıklılık ilkesine vurgu yapan bilim sosyolojisi kuramından hareket eder. İkinci olarak, tartışılan teorik çerçeve ile uyumlu bir araştırma yöntemi geliştirir. Söz konusu yöntem, çalışılan bilim camiasının bilişsel yapısı ile kolektif çalışma motiflerini bir arada, sosyal bilişsel analizler dahilinde incelemeyi sağlar. Yöntem meta ağlar ile kelimelerin birliktelik analizleri yaklaşımlarını geliştirerek birleştirir ve önerilen yeni bir model ile güçlendirir. Yeni model her bir yazarı yayınlamayı tercih ettikleri konuların alandaki yaygınlığı ve kendi içinde çalışılmışlığı bilgisini kullanarak stratejik bir şema üzerine konumlandırır. Üçüncü olarak, teorik çeçreve ışığında geliştirilen yöntem, bilimsel bilginin ulusal düzeyde bir sosyal bilişsel sistem dahilinde boylamsal yayınımının incelenmesi üzerine uygulanarak örneklenir. Bu çerçevede Türkiye isletme akademisine özgü başlıca şu sorulara cevap verilmiştir: (i) Camia dahilinde belirginleşen bilginin yayınım mekanizmaları nelerdir? (ii) Camiadaki bilim insanlarının sosyal bilişsel yapıları ile yayın yapılan konuların stratejik seçimi arasında anlamlı bir ilişki var mıdır? (iii) Camia dahilinde bölümlenmenin eksenlerini hangi etkenler oluşturur? (iv) Söz konusu etkenlerin boylamsal evrimi nasıl bir seyir izler?

Örnek alan araştırması ise, Türkiye işletme akademisi tarafından 1922-2008 yılları arasında üretilen bilimsel makaleler üzerinden yürütülmüştür. Çalışma Türkiye işletme akademisine dair bir çok bulgu sunar. Öne çıkan bul-

gularda, yerel yayınlar kapsamındaki bilginin yayınımı rejiminin enformasyonun sosyal yapılardaki akışı gibi davrandığı görülmüştür. Diğer taraftan uluslararasi yayınlar kapsamında ise bilginin yayınımının çok yazarlı ortak çalışmaların yaygın tekrarlandığı grupların varlığı ve büyüklüğü ile orantılı arttığı görülmüştür. Ayrıca, yerel yayınlar kapsamında öne çıkan yazarlara ait belirgin sosyal bilişsel özellikler gözlemlenirken, uluslararası yayın yapan yazarlar arasında belirgin bir sosyal bilişsel ayrışmaya rastlanmamıştır. Onun yerine, uluslararası yayınlarda öne cıkan yazarların kolektif calismaların nispeten yoğun olduğu kliklere dahil oldukları gözlemlenmiştir. Yerel yayınlarda öne çıkan yazarlara ait belirgin sosyal bilişsel yapı ise şöyledir: Diğerlerine nispeten daha çok konuda yayın yapmaktadırlar ve ortak çalışma ağlarında merkezi konumlara sahiptirler. Meslekdaşlarına nispeten ayrık bilgiler içeren yayınları vardır. Ayrica alana dair müstesna konulara sahiptirler. Bu açıdan bilişsel yapıları diğerleri ile benzeşmese de alandaki genel konularda da diğerlerine nispeten daha sık yayın yapmaktadırlar.

Verilerin derlenmesi ve sayısal, betimsel ve görsel olarak incelenmesi için geliştirilen yeni yazılımlar, bu çalışmaya uyarlanan diğer ilintili yazılımlar ile bütünleştirilmiştir.

Söz konusu görgül bulgular tez calışmasının teorik öngörüleri ve tartışmaları ile aynı doğrultuda olup teorik çerçeve ile bütünleşik geliştirilen araştırma yönteminin sunabildiği sosyal ağlar literatürünü zenginleştirebilecek calişmalara işaret eden özgün türde sonuçlardır.

Değerli ağabeyim **Hüsnü Özel**'e

ve

Sevgili annem **Yıldız Özel**'in anısına.

Acknowledgments

I have enjoyed almost every stage of this dissertation study from its initial data collection step to final defense. I believe, it has a significant impact at transforming me towards being a better scientist and I am deeply indebted to many during the whole process. Hereby, I may only mention a few. First of all, I am very grateful to my advisor Beyza Oba: when I needed to be given advise, she gave it to me; when I needed to be given time, she gave it to me; when I needed to be alarmed, she gave it to me. Next, I specially would like to thank Cathleen Carley for seminars, discussions, and encouragements I am exposed to during my stay as a visiting Fulbright scholar at CASOS Center within Carnegie-Mellon University.

I am deeply grateful to Evren Hosgor for her invaluable time at helping me for data encoding and for her immediate comments on some parts of this dissertation. I would like to thank Harald Schmidbauer for his precious advices and discussions on the statistical methods I have attempted to employ. Additionally, I would like to thank to each member of the dissertation jury for their very constructive inputs. I would like to thank Mehmet Gencer for always being there to discuss any aspect of this work. I am further thankful to Ilhan Ikeda and Chris Stephenson for their constant encouragements and supports.

Last but not least, I am grateful to Bahar Muratoglu without her soothing eyes, warming smiles, and delicious foods nothing would be more enjoyable.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

> "Proliferation of structures, practices and worlds is what preserves the breadth of scientific knowledge, intense practice at the horizons of individual worlds is what increases its depth." (Thomas Kuhn, 2000: p. 250).

1.1 Motivation

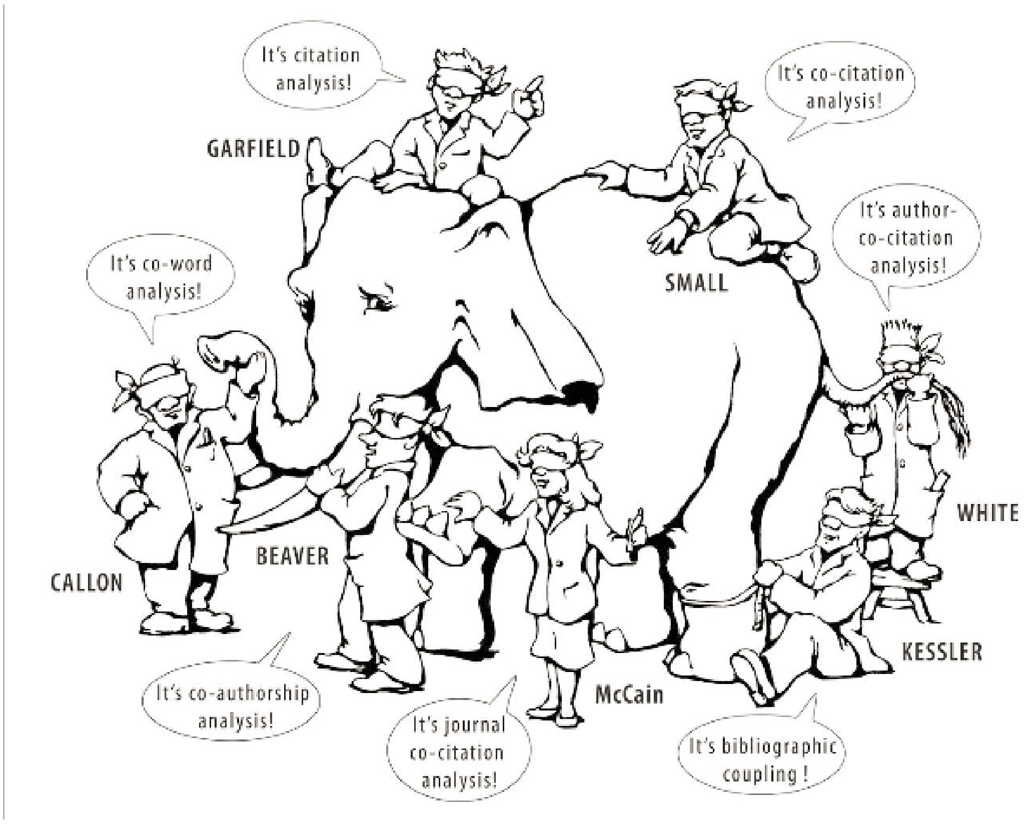
Collective knowledge production and diffusion processes in science and technology have captured attention of many sociology of knowledge scholars throughout history (Scheler, 1980; Mannheim, 1968; Merton, 1968; Kuhn, 1970; Kuhn, 2000). However, only relatively recent availability of large amount of digital information has made it possible to conduct analysis on large-scale patterns of scientific practices. Databases, mainly consisting of bibliographic information on scientific publications, have become standard mean and format of accumulating digital data on scientific practices. Existence and use of large amount of bibliometric data recorded in databases has given way to development of various advanced quantitative methods such as co-word analysis, co-citation analysis and co-authorship analysis. All of these bibliometric methods have adopted or have extended social network analysis framework.

Literature as a whole suggests that bibliometric methods could play an important role both in elaborating and measuring development of scientific knowledge. These analyses enables scientometricians not only to test classical ideas or premises from history, philosophy, and sociology of science, but also to come up with new explanations on fundamental aspects of scientific practices (Bettencourt et.al., 2009). A better understanding of these practices by probing communication channels of knowledge creation and transfer processes, for instance, may lead to development of public policies at various levels that could accelerate scientific and technological discoveries or may help to accelerate their diffusion in order to exploit benefits arising from scientific developments.

Nevertheless, it is also acknowledged that "studying the communication network of science as a whole is difficult because it is so vast, rapidly changing, and complicated that neither the participants nor the observers can attend to more than an isolated few of the communicative events at any given time. Moreover, the communicative practices overlie the cognitive processes, and these not only vary by field, but also are open to a wide variety of interpretations" (Morris and Martens, 2009: p. 218). For that reason, a set of different theoretical and methodological approaches have been developed or employed to examine various aspects of practices in scientific communities and institutions. Each of these approaches reveals a different view of practices in science and only "when combined, they can produce a multi-faceted map of the social structure, base knowledge, research topics" (Morris and Martens, 2009: p. 277). The cartoon, given in Figure 1.1, by Steven A. Morris and Betsy van der Veer Martens (Morris and Martens, 2009) which is printed in their recent review article in *Annual Review of Information Science and Technology* depicts shortcomings of isolated bibliometric perspectives.

The point of departure of this dissertation study from existing approaches is three fold. First, it primes mutuality of knowledge and social structure theory borrowed from sociology of knowledge literature, where knowledge is perceived as an essentially social and societal category. Second, it points limitations of existing approaches caused by applying isolated techniques which detach social structure from knowledge. Third, it addresses possibility of decoding fundamental aspects of scientific practices simultaneously, such

Figure 1.1: The blind men and the elephant (in Morris and Martens (2009: p. 277). A metaphor pointing limitations of approaches caused by applying isolated techniques at mapping a scientific research field.



as knowledge diffusion and collaboration structures which are encoded in bibliographic records.

The theoretical point of departure of this thesis study is best framed by Robert King Merton in his work titled *Social Theory and Social Structure*:

> "Social organization of intellectual activity is significantly related to the character of the knowledge which develops under its auspices." (Merton, 1968: p. 538).

This abstraction mutually interrelates social structure and knowledge. The perspective is based on conceptualization of knowledge by scholars such as Karl Mannheim (1968) and Max Scheler (1980). Mannheim and Scheler, they are known as early twentieth century founders of sociology of knowledge field, perceive knowledge as an essentially social and societal category (Durkheim, 1974).

In that mutuality, from the social side, scientists as knowledge carriers or knowledge producers 'do not orient themselves exclusively toward their data nor toward the total society but to special segments of that society with their special demands, criteria of validity, of significant knowledge of pertinent problems.' (Merton, 1968: p. 536). On the other side, knowledge is both a medium of social action such as co-authorship and the result of scientists' actions either be individual or collective. In that respect, as a medium, knowledge enhances the capacity for collaboration, as well as, impacts the shape of resulting collaborative structure.

In parallel to departure points made above, this dissertation work, first, aims to elaborate on a conceptual framework that incorporates social interaction and knowledge transfer. Then, it aims to advance a methodological framework which does examine knowledge diffusion and social structure interrelatedly. Eventually, it aims to demonstrate exploratory potential of proposed framework with a set of research questions relevant to an exemplary case.

1.2 Research Question(s)

There are separate yet interrelated research questions, I specifically address in this study. In first place, I argue that social structure formed by scientists around a scientific discipline, as well as, characteristics or nature of the knowledge that is being diffused is not static and change or evolve over time. This leads me to examine mutual influence of nature of knowledge that is being diffused and social structure organized around that knowledge diffusion process:

1. To what extent social collaboration structure is tailored by the nature of knowledge that is diffused, and vice versa?

Literature has already shown that creation and/or diffusion of new discoveries, methods and concepts within or across scientific communities leads to changes at collaboration structure in the communities (Kuhn, 1970; Bettencourt et.al., 2009). However, literature lacks to address explicit role of exhibited nature of knowledge within a specific community and its co-evolution with the collaboration structure of the community. For instance, in a Kuhnian perspective, it is assumed that a discovery takes place first among a small community of scientists or rooted on individual works. Later on, it diffuses, develops and becomes part of an established 'normal science'. Although this perspective implicitly addresses organization of social structure around the discovery of new paradigms, it does not address how knowledge is diffused later on through social ties.

Considering contingencies at social structures and nature of knowledge exhibited in various contexts, first, I engage in theoretical discussions deriving upon relevant empirical studies in the literature. Examining knowledge diffusion mechanisms in various networks (*See* Chapter 3), I argue that mechanisms of knowledge diffusion or efficient network models of knowledge diffusion are exhibiting a dichotomy. I discuss that cognitively demanding knowledge creation and transfer processes exhibit densely connected social network models, whereas networks where information is diffused exhibit small-worlds like models with multiple components bridged by weak ties.

This dissertation develops a comprehensive empirical research framework. Developed framework helps to address subsequent specific research questions relevant to interplay in between social structure and knowledge. As of a specific scientific field, management academia in Turkey from 1922 to 2008 is covered. The proposed framework which incorporates mutuality of knowledge and knowledge carriers or their overall collaboration structures enables to address and answer following specific research questions of this dissertation:

2. What knowledge diffusion mechanism(s) does co-authorship network of Turkish management academia exhibit?

3. To what extent co-authorship network structure of Turkish management academia is fragmented?

4. To what extent authors in Turkish management academia are distinguishable in terms of their individual level socio-knowledge patterns?

With the guidance of last research question, this study further envisions differences in between individual scientists in terms of role their network positions play at diffusing knowledge. Social condition of the different scientists, not necessarily their social network position but their motivations in general, is attributed as an important factor at advancement of a field (Merton, 1968). For instance, those social conditions of obtaining recognition and reputation in the scientific field is assumed to influence sociological regularities of the scientific field which in return not only contribute to scientific results, but seem to be their precondition (Bourdieu, 1998). As such, stressing a scientific field as a field of micro politics and the knowledge as result of strategic action has also contributed to motivation of this study to adopt `network perspective`, where co-action of scientists and other actors lead to emergence of social structures reflecting patterns of individual or group actions (Collins, 1998). Thus, units of analysis at sub-network levels enable to examine centers and peripheries, cliques as well as stars or isolates.

1.3 Conceptual Framework

Conceptual framework of this dissertation barrows, integrates and advances (i) relational perspective of contemporary social network analysis while studying social structures, (ii) and assumptions of co-word analysis which presumes that keywords, phrases or codified concepts reflects the social actors' cognition or knowledge structure. (iii) It develops a knowledge diffusion perspective which primes the nature of knowledge that is diffused through social ties. (iv) Besides, it employs models, metrics and stylized facts of co-authorship networks as lenses to observe scientific collaborations. Detailed discussions and further theoretical background on each constitutive element of this conceptual framework are given respectively in subsequent chapters, namely Chapter 2, Chapter 3, and Chapter 4.

Relational perspective of social network analysis derives upon structural intuition which focuses on the links among the objects of the study rather than the exclusive behavior or attributes of individuals in isolation (Wellman, 1988; Emirbayer, 1997; Freeman, 2004) . In other words, social network perspective, in this study, primes the ways scientists interact and affect each other by focusing on social aspects of scientific practices. The perspective grounds the use of bibliometric data in a relational manner which enables systematic examination of collaboration patterns and knowledge networks. The perspective further validates use of data visualization and employment of mathematical and computational techniques and models borrowed from studies on co-authorship networks.

Literature acknowledges that co-authorship networks are tangible and well documented forms of scientific collaboration as well as they provide reliable lenses to trace aspects of scientific collaboration networks (Zitt et.al., 2000). In align with this relational point of view on social action, scientists or academics are considered as interdependent actors or units; Co-authorship ties between scientists provide channels for transfer, exchange or share of knowledge and information; Structure is conceptualized as emerging or sustaining patterns of co-authorship relations in between scientists.

The framework enhances social network perspective in several ways. It assumes that networks as well as national level social, political, economical, and demographical contingencies constitutes the environment for social actions of academics. This extended environment provides both opportunities for academics and constraints on their actions. Selection of exemplary case for the dissertation is guided by this very aspect of conceptual framework. Primary data covers local publication activities in Turkish management academia spanning from 1922 up to 2008. This unit of analysis allows me to assume that individuals in the network, to some extent, are exposed to similar social, political and economical stimuli and other national level incentives as well as disciplinary specialty to publish locally. The assumptions allows to focus on very dynamics of knowledge diffusion mechanisms overall in the network. Besides, it enables to concentrate on the role of an individual's relevant set of knowledge relative to the alters in the network, and role of her ego networks at picking issues to publish.

A second line of enhancement extends classical social network analysis towards a meta-network perspective. Thus, in addition to co-authorship networks, knowledge network and knowledge dissemination networks are formed.

While node set of knowledge networks consists of keywords found in publication titles, node set of knowledge dissemination network is bi-modal consisting of authors and keywords. The edges in the knowledge dissemination network are unidirectional. An edge is drawn from an author to a keyword, if the author has used that keyword in her publications. An edge in knowledge network however represents co-occurrence of two keywords within the same title. Along with other methodological advantages, this meta-network extension enables to conceptualize that shared knowledge mediates interactions between co-authors (Carley, 1991; Stryker, 1980). Besides, it helps to integrate co-word analysis perspective along with co-authorship networks in a natural manner without falling into an eclectic amalgamation.

Co-word analysis conceptually grounds the characterization and analysis of a disciplinary field based on patterns of keyword usage in publications (Neff and Corley, 2009). Patterns of keyword helps to trace development of a field and pervasiveness and cohesiveness of issues in the field overtime. The framework has proved to be a powerful knowledge discovery tool to derive map of a sciences from bibliographic databases (Cahlik and Jirina, 2006; He, 1999; Leydesdorff, 1992; Law and Whittaker, 1992; Whittaker, 1989). Theoretical foundation of using the keywords co-occurring in the text to map the dynamics of science is based on Actor Network Theory (ANT). The assumption is that keywords, phrases or codified concepts reflects the social actor's, namely authors', cognition or knowledge structure (Callon et.al., 1986). For example, a scientist remains recognizable as long as he/she interacts appropriately with particular knowledge domain. "Overall, co-word analysis considers the dynamics of science as a result of actor strategies. Changes in the content of a subject area are the combined effect of a large number of individual strategies" (Qin, 1999: p. 138). ANT based conceptual framework of co-word analysis, in this dissertation study, enables me to develop a mathematical model to answer to what extent authors in Turkish management academia are distinguishable in terms of their individual level socio-knowledge patterns. Besides, it helps me to elaborate on overall diffusing nature of knowledge in the discipline overtime.

The knowledge diffusion perspective of this dissertation study focuses on explicitized knowledge. It does not cover internalized or socialized implicit knowledge or any other form of tacit knowledge. It proposes a conceptual framework while studying diffusion of explicit knowledge. The framework enables to understand (i) what is the nature of knowledge that is being diffused, (ii) at what stage of a knowledge chain do social interactions take place, (iii) and what mode of knowledge exchange governs the knowledge diffusion process. The question on nature of knowledge concerns to differentiate in between data, information and knowledge that requires high cognitive load. Stages of a knowledge chain comprises of knowledge creation, knowledge transfer, and its social and technological implementations phases (Geisler, 2007). Modes of knowledge transfer can be determined by either price mechanism of markets, contractual arrangements within organizations (hierarchies), or informal know-how transfers via networks (Cantner and Graf, 2006).

In this dissertation study, networks determine the mode of transfer and knowledge transfer stage of the chain is considered. However, although scientific collaborations intuitively may suggest that the nature of knowledge that is transferred should exhibit a cognitively demanding interaction in between authors, empirical findings of this dissertation suggests that the intuition should not be taken by granted. Theoretical background on exhibited nature of knowledge while being transferred through networks is elaborated within the body of the dissertation. The interrelation in between nature of knowledge and emerging interaction patterns in the networks is further debated.

Lastly, I would like to note that the conceptual framework of this dissertation encompasses an evolutionary perspective. Thus, instead of having a static view, it traces evolution of meta-networks of academia and accompanying map of disciplinary field overtime.

1.4 Limitations

Likewise its major strength, the major limitation of this dissertation study also stems from employment of the relational perspective of social network analysis which derives upon structural intuition and its representational formalism. The formalism of social network analysis is criticized in the sense that it reduces social structure to interaction (De Nooy, 2003). That is, it is criticized that social network analysts equate social structure to a network of relations among social actors. Within the realm of this critique, it is argued that network analysts do not take differential possession of social, economic and cultural capital into consideration. In other words, it is criticized that network analysts focus on interaction or exchange ignoring the background characteristics that leads to access to different type of resources. It is argued that background characteristics, for instance, may embody significant factors at the possession of social capital of an ego. The critics of social network further claims that interactions are the consequences rather than the sources or causes of social structure.

Recent directions in network studies however able to take social, economical, and demographical attributes of individuals within the realm of network analysis (De Nooy, 2003). Although a part of individual attributes may not serve to construct relational data they can be used within the network models as auxiliary or explanatory variables. Proposed research framework of this dissertation, in a way, can be considered as an attempt that enhances structural perspective at circumventing its aforementioned inherent drawback, the interactionist reduction.

Nevertheless, the empirical exemplary analysis part of this dissertation study faces some other limitations due to lack of valid relational as well as attributional data. Formation of collaboration structure in this study based upon co-authorship relations extracted from available publication data. Co-authorship represents an important yet a limited part of scientific collaborations. Empirical part of this dissertation is circumscribed by that very limitation. Besides, of various other informal and formal knowledge diffusion channels in any community of science, most of which can not be recorded, only particular impact of co-authorship ties on the overall diffusion process is attempted to be modeled in the empirical work.

One of the prime interest of social network analysis is the sub-structures or embedded groups that are present in the network since there may be a structural basis for stratification of the network. Turkish management sciences community may be composed of multiple sub-networks that are substantially more integrated within than with scientists in other groups. A tightly knitted core and a loosely connected periphery of the network also may emerge from the analysis. Sub-structures of the network are important in order to understand how individual scientists are embedded in the network. Some may act as 'bridges' between groups, while others may conduct most of their research isolated or within a single group. It may have important consequences for ultimate knowledge diffusion in the country or to explain why particular themes are studied by a particular group or why it has remained peripheral. However, such micro-level analysis on specific groups of scientists or on a particular area within the field is not covered in this study.

There are studies endeavoring to understand other aspects of scientific practices. Slaughter and Rhoades (1993), for instance, study commercialization of science at public universities in the states. They examine policy documents and texts on governmental regulations over time to trace ownership of scientific discoveries at the university campuses; reward mechanisms on intellectual properties generated by university scientists; ideological discourses at legitimizing commercialization of science; organizational arrangements on administrative roles and control mechanisms at university market interactions. In my case analysis, I am not attempting to examine such indirect factors which may help to further understand particular collaboration and knowledge diffusion patterns.

In this study, I am not primarily addressing the question why scientists do collaborate. Nevertheless, a part of literature on co-authorship lists two sets of reasons. The factors in the first set explain the global trends in science and the factors in the second set attempt to explain differences in between disciplines. Among the list of global trends are (1) increasing specialization within science as a whole which leads to division of labour in between collaborators; (2) growing number of scientists in all disciplines which increases the likelihood of finding suitable collaborators for research; (3) advancement in communication and information technologies which facilitate collaboration among geographically separated scientists (Acedo et.al., 2006).

Although there is a growing rate of collaboration in all disciplines which are explained by aforementioned global trends, propensity to collaborate differ significantly among disciplines. It is seen that rate of collaboration is more in disciplines with increasingly technical nature or quantitative work (Katz and Martin, 1997). Besides, shared use of laboratories and expensive equipment, such as in nuclear physics, produces a greater extent of co-authorship (Newman, 2004). In addition, fields with higher interdisciplinary research require the interaction of specialists from various fields, which in return tends to produce collaborative research (Moody, 2004). Alternatively, institutional differences which might be coined by geographical, political or cultural provenance of the scientific medium is seen to explain some other differences. For instance, a study by Üsdiken and Pasadeos (1995) explains different trends at co-authorship rate in between European and American management journals. There it is seen that single-authorship is more common in the less quantitative European journal, namely *Organization Studies* as opposed to American *Administrative Science Quarterly* journal.

Some of the studies in knowledge diffusion literature employ citation analysis or co-citation analysis. Use of citation analysis enable them to focus on influential documents in a field. However, a detailed discussion on paper citation networks is excluded from this study, mainly, due to its limited representation of actual social structure. The method isolates scientists and the very content of documents. This isolation provides a very limited perspective on communication in scientific fields, which can be supplemented by co-authorship analysis or content analysis (Chubin, 1976; Morris and Martens, 2009).

1.5 Contributions to the Field

Contribution of this dissertation to the field is both theoretical and methodological. Theoretically it emphasizes mutual influence between social structure and knowledge diffusion processes. The mutuality is elaborated within social network analysis research perspective. It discusses the interplay in between collaboration structures and knowledge diffusion in academia. Contributions of this dissertation in this respect is many fold. It proposes and elaborates a framework which relates knowledge structure and the collaboration patterns into an integrated socio-knowledge analysis of any academia. It adopts a longitudinal approach to trace knowledge diffusion within peculiarity of a national level socio-knowledge system. Besides, it demonstrates how use of a large and longitudinal dataset along with an explicit boundary, which is set by national level publications, overcomes delineation problems faced by some earlier relevant studies.

The research framework, which serves as a conceptual instrument, is developed deriving upon a comprehensive literature review on knowledge diffusion in science networks. The proposed framework that primes probation of nature of knowledge that is diffused helps to reveal competing models on efficient network structure of knowledge diffusion processes. Besides, it helps to explain contradictory or contrary results in the literature. In addition, revealing scope, coverage and time span of primary data used by researches elsewhere has served as lenses to identify and discuss discrepancies and fallacies at empirical studies on co-authorship networks. It is shown that how peculiarities of social boundaries and limitations of datasets result in distortions on proposed network models and lead to inconsistencies in between findings of similar case studies.

The dissertation develops an encompassing methodology which incorporates the conceptual interplay in between social network structure and knowledge. It combines two powerful perspective: (i) social network analysis oriented meta-network perspective; and (ii) co-word analysis oriented map of sciences. While the meta-network perspective enables to study co-authorship network, knowledge network and knowledge dissemination network of authors in a field simultaneously, strategic maps of a science that is formed by co-word analysis enables to visualize pervasiveness and cohesiveness of issues in the field in parallel to meta-networks. Rather than an eclectic use of existing methods, the proposed research framework enhances them with extensions and integrates them coherently by a new model along with new social network analysis metrics. The new model enables to map actors from co-authorship networks into strategic map of sciences generated by co-word analysis. The proposed methodological framework further demonstrates how co-word analysis can be extended in the direction of network analysis enabling researchers to examine semantic relations in between concepts and issues emerged on the strategic map of science.

The longitudinal exemplary case, based on primary data enriches the understandings on social network aspects of research and knowledge diffusion. It demonstrates explanatory power of the theoretically induced research method. In depth analysis on the exemplary case traces how management related knowledge is diffused and what collaboration structure is exhibited by Turkish management scientists from 1920s until 2008. It is shown that mechanism of knowledge diffusion via national publications follows patterns of information diffusion. It is further seen that mainstream issues within local publications are disseminated or made popular by authors who hold strong socio-knowledge power. On the contrary, it is observed that authors who publish internationally are embedded in cliques or cohesive groups. Moreover, rate of collaboration at international publications are observed to be significantly higher than local publications. Besides, contrary to local publication practices, mainstream issues are not correlated with star authors who hold strong socio-knowledge capital but correlated with authors who are embedded in cohesive collaborating groups.

This dissertation study addresses and points a set of future research directions which may further contribute to the field.

1.6 Organization of Dissertation Chapters

Chapter 2 introduces and discusses both theoretical and methodological backgrounds on conceptual framework of this dissertation study. Section 2.1 introduces social network perspective. Network analysis has lately adopted in many different disciplines which ranges from statistical physics, social anthropology to economics. The section does not attempt to engage in details of social network analysis. It rather briefly discusses the underlining assumptions of network theory within the realm of relational sociology and points its limits. Additionally, it briefs development of social network perspective discussing the milestones in its history. This brief history is aimed to shed light on the tenets of social network perspective both as a theory and as a method. Furthermore, recent and relevant directions in social network analysis is summarized along with pointers from the literature. These are (i) network perspective in organization studies, (ii) studies which focus on knowledge agents, (iii) discussions on topological models of networks which are deemed to suit recurrent social patterns in collaboration networks, and (iv) new extensions to network perspective. The section concludes with a summary of network principles and points to main references in the field. Section 2.2 outlines co-word analysis and its theoretical background along with a review of relevant literature. Discussions and observations on the premises of co-word analysis is further considered in Section 2.3. This last section in the chapter elaborates on theoretical and methodological insights of co-word technique which help to relate cognitive structure of individuals represented by their publications and the collaboration patterns in between individuals in order to develop an integrated socio-knowledge analysis perspective.

Chapter 3 deriving up on existing literature develops a conceptual framework which contextualizes co-authorship network studies. The framework is rooted by mutuality of social structure and knowledge. The proposed framework primes to elaborate or to contextualize a study on knowledge diffusion in co-authorship networks by answering a set of questions which are (1) what is the nature of knowledge that is being diffused, (2) what stage of a knowledge chain that is focused, (3) what mode of knowledge transfer that is assumed, (4) what unit of analysis that is taken, (5) what particular properties of knowledge actors or carriers that is considered or quested by studies, and (6) how social structure and nature of knowledge is related. The chapter reveals how clarification on the nature of knowledge can explain inconsistencies of previous research findings and suggests how to situate competing social network models from the literature. The chapter concludes by contextualizing the case of this dissertation using proposed conceptual framework.

Extensive and critical literature review in Chapter 4 further reveals contradictory mathematical models derived from empirical studies. The chapter demonstrates how proposed models from the literature is sensitive to the selection of primary data. It shows how source, scope and time spans of bibliographic data used as well as unit of analyses taken can result in deviations on proposed co-authorship network models. Results of literature review is reported and discussed in the same chapter. It first discusses to what extent co-authorship represents and explains scientific collaboration. Then, the review is detailed giving variety of metrics adopted in the literature by explaining what they represent and how they can be used to make sense of a corresponding social phenomenon; the focus of ego level and overall network level perspectives; topological models of the network structures and their corresponding mathematical models; debating models in longitudinal studies which attempt to explain how co-authorship networks grow or evolve over time; exogenous and endogenous factors which influence co-authorship patterns or influenced by them; and alternative means and methods at the study of scientific collaborations. The review concludes discussing new directions in the field, such as, studies which focus Web visibility of co-authorship patterns or offer to exploit co-authorship data extracted from the Web.

Discussions in Chapter 3 and Chapter 4 reveal the fact that isolating social practices and social structure from the organization of knowledge itself may lead an incomplete picture at explaining recurring patterns in collaboration structures of science communities. Co-word analysis as a bibliographic technique takes an approach from the other end. It studies the bulk of produced knowledge to derive map of sciences isolating knowledge from its carriers or from the very social structure. In that sense, Chapter 5 introduces a rather comprehensive empirical research framework which attempts to embody the theoretical framework of the study. Proposed methodological approach borrows and adopts existing relevant tools and models from previous body of knowledge and experience, as well as, it introduces new models, metrics and software tools. The chapter additionally reports data sources along with processes of data selection, parsing, pruning and coding stages.

Chapter 6 presents findings from the exemplary case of the dissertation. Chapter 7 discusses findings from the exemplary case, relevant studies in the literature, and the rationale at the selection of the exemplary case. Besides, the chapter reviews all of the earlier studies which have specifically targeted to understand practices of science and knowledge diffusion in Turkish academia. Chapter 8 concludes and points further research directions.

Chapter 2

Background on Research Framework

This chapter introduces and discusses theoretical and methodological backgrounds on conceptual framework of this dissertation study.

2.1 Social Network Analysis Research

2.1.1 Introduction

Social network analysis is both a theoretical framework and a research method. Network perspective within social and behavioral sciences is based on the premise that ties or relations in between units are fundamental (Scott, 2000). The units may vary from individuals to large groups of social groups. In some studies even socially constructed non-human actants are also considered as units (Butts, 2009; Emirbayer, 1997).

Modern social network analysis emerged as a paradigm for research. The paradigm combines analytical features used by investigators while conducting structural research on social phenomena (Freeman, 2004):

1. It is motivated by a **structural intuition** based on social links between units,

2. It is grounded in **relational empirical data** which enables systematic examination of social patterns,

3. It makes heavily use of data **visualization**,

4. It employs **mathematical and computational** techniques and models.

In short, social network analysis encircles theories, models, and research methodologies that develops upon relational concepts or processes. The wealth of network research methodologies is enhanced by a plethora of mathematical, computational and visualization applications.

2.1.2 Theoretical Foundations

Social network research departs from mainstream research by primarily focusing on the links among the objects of the study rather than focusing on the exclusive behavior of individuals in isolation. In other words, social network theory primes the ways individuals interact and affect each other by focusing on social aspects of behaviors (Freeman, 2004). In that sense, social network analysis bears a relational perspective portraying social reality in dynamic, continuos, and processual terms. This sociological perspective provides an alternative approach to statistical "variable" analysis of mainstream social science research. In statistical "variable" analysis social world is portrayed primarily by static attributes of individuals and emergence of relations between individuals are secondary in importance (Emirbayer, 1997).

This alternative relational point of view on social action is called *structural* analysis (Freeman, 2004). The structural intuition is based on the notion that "within a society the chains of interaction are infinitely complex and cover the society in the number of different ways" (Freeman, 2004: p. 58). Network analysts trace such principles of structural intuition back to pioneers of contemporary sociology such as Comte (e.g., Emirbayer, 1997), Durkheim (e.g., Segre, 2004) and Bourdieu (e.g., De Nooy, 2003).

Emirbayer (1997) in his work titled *Manifesto for a Relational Sociology* highlights the very strength of social network analysis as a viable structural approach while studying how patterns of social ties allocate resources in a social system:

> The best developed and most widely used approaches to the analysis of social structure are clearly those of social network analysis. This perspective is not primarily a theory or even a set of complicated research techniques, but rather a comprehensive new family of analytical strategies, a paradigm for the study of how resources, goods, and even positions flow through particular figurations of social ties. (Emirbayer, 1997: p. 298)

Contrary to some misperceptions, above discussion points that power of social network analysis does not stem from the partial application of some concepts or measures, but rather it stems from a comprehensive paradigmatic approach to the study of social structures (Wellman, 1988). Its integrated analytical strategies combines theoretical concepts, ways of collecting, analyzing and visualizing relational data. Wellman (1988) addresses five distinctive paradigmatic characteristics that underly conceptual framework of social network analysis:

- Behavior is interpreted in terms of social constraints on activity. This interpretation replaces approaches where behavior of units is interpreted as a push by inner voluntaristic forces towards a desired goal.

- Focus of the analyses is on the relations between units. This replaces approaches which primarily sort units into categories based on static attributes of units.

- How the patterned relationships among multiple units jointly affect network units' behavior is a central consideration.

- Structure is treated as a network of networks that may or may not be partitioned into discrete groups. This replaces an a-priori assumption that bounded groups are solely the building blocks of the structure.

- Analytical methods of social network analysis deal directly with the patterns that reveals relational nature of social structure. This extends mainstream statistical methods that demand independent units of analysis.

Mathematical, computational and visual tools and techniques enable sociologists to take a whole network approach at observing social phenomena. The whole network approach permits analysts "to trace lateral and vertical flows of information, identify sources and targets, and detect structural constraints operating on flows of resources" (Wellman, 1988: p. 26). As noted above, the distinctiveness of social network analysis is not the methods employed, but analytical principles used by researchers at addressing research questions. Some of those analytical principles or empirical generalizations used by network analysts are discussed in Wellman (1988, *see pp: 40-50*):

- Ties are usually asymmetrically reciprocal, differing in content and intensity.
- Ties link network members indirectly as well as directly. Hence they must be defined within the context of larger network structures.
- The structuring of social ties creates non-random networks, hence clusters, boundaries, and cross-linkages.
- Cross-linkages connect clusters as well as individuals.
- Asymmetric ties and complex networks differentially distribute scarce resources.
- Networks structure collaborative and competitive activities to secure scarce resources.

Mathematical and computational foundations of network research is based on a representational formalism borrowed from graph theory (Butts, 2009). Identifiable units or network entities are represented by a vertex set. Each element of this set, which is often called as a node, represents actors that potentially interact with others or have taken part in the relation under study. Relationships themselves are represented by a set of edges. The edges may represent symmetrical or unsymmetrical relations. Each edge may be assigned by a weight representing frequency or intensity of relation. Or it may be unweighted representing simply the existence of relation in between nodes. Although edges are used commonly to represent strictly dyadic relations among nodes, it is also possible to use hyper-edges each of which can represent a relation where arbitrary many nodes have involved in the relation simultaneously. For instance, group membership can be represented by an hyper-edge. A node set and corresponding edge set are used together to represent a network as a graph. For the computational models, in majority of studies, it is necessary to form edges among nodes that constructs a graph based on same type of relations, e.g. friendship.

2.1.3 Limitations

Representational formalism used by network analyst also bears its drawbacks in some of the studies. This formalism of social network analysis is criticized in the sense that it reduces social structure to interaction. In other words, it is criticized that social network analysts equate social structure to a network of relations among social actors (De Nooy, 2003).

Within the realm of this critique, it is argued that network analysts do not take differential possession of social, economic and cultural capital into consideration. That is, network analysts focus on interaction or exchange, they often times ignore the background characteristics that leads to access to different type of resources. It is argued that background characteristics, for instance, may have played important roles at the possession of social capital of an ego. The critics of social network further claims that interactions are the consequences rather than the sources or causes of social structure. For instance, 'power relations exist even if there is no interaction and this fact escapes the attention of network analysts' (De Nooy, 2003: p. 317).

These points are raised partly due to lack of data to represent subtle relations properly while conducting a network study. Lack of data or limited observations on social interactions may misguide network analysts leading them running into over generalizations. Proponents of social network analysis, however, argue that interactions, per se, can be used to measure underlying and subtle social structure or distribution of types of capital. In that respect relational indicators of social capital would have been used via social network analysis to explore subtle social structures.

Besides, it should be noted that social network analysis does not limit itself solely to interactions. Advanced social network techniques are able to accommodate the attributes of the actors in a network (De Nooy, 2003). These techniques can be employed has been employed to study antecedents of interactions asking whether interactions occur 'mainly between actors who belong to the same social category or who posses a particular amount or type of capital (e.g., Uzzi, 1997). In other words, these techniques offer the possibility to detect individual strategies as combinations of individual properties, collective classifications, and interactions.

2.1.4 A Brief on Development of Social Network Analysis

Historically, theoretical foundations of network analysis is influenced by several streams of studies. They are (i) empirical motivations from sociology, social psychology, and anthropology instrumentalizing Moreno's `sociogram` (1953) technique; (ii) sociological conceptions such as social groups, cliques, social cohesion, social influence, social position, social role and status, dominance, mutuality, reciprocity, structural balance, and structural equivalence; and (iii) mathematical motivations such as graph theory, statistical and probabilistic models.

Although network perspective and the relevant terminology has emerged simultaneously from different disciplines. Its first systematic use is attributed to the study by Barnes (1954), where he examined social relations within a neighborhood in Norway. Individuals were the entities and the relations in between them such as kinship or having worked on the same boat as fishermen were represented as the ties. The network perspective of the study has demonstrated power of social network approach at studying web of complex relations. Later studies demonstrated that social network analysis perspective can "provide formal statements about social properties and processes" (Wasserman and Faust, 1994: p. 11).

Earlier attempts by Moreno and Jennings (1938) to understand dynamics and structure of small groups lead them to develop `sociogram` as a technique to measure interpersonal relations within a group. The invention of the technique gave a way to the development field of **Sociometry**, which itself is the antecedence of Social Network Analysis (Scott, 2000; Wasserman and Faust, 1994). A sociogram is depiction of individuals or social units consisting of individuals as points and relations in between them as lines in a two dimensional space, on a paper for instance. Sociograms provide not only a visual display of structure of interactions in a group, but also a probabilistic or statistical model of structural outcomes.

Mathematicians or statistical physicists have long been interested in social network analysis. Graph theory from mathematics provide both representations and concepts to investigate social phenomena quantitatively. Erdos and Renyi (1959) have sketched the methodology to form and simulate random graphs in the study of social network analysis.

Milgram (1967) experiment and its implications has demonstrated the explanatory power of social network analysis. Stanley Milgram, came up with a social experiment, where randomly selected individuals in Omaha, Nebreska, USA were asked to get a folder delivered to a particular person in Boston, USA via mail. They were asked to mail the folder to someone whom they know with a better chance of having a direct tie with the target person. Of 160 initiated mail channels 44 of them reached to the target. The experiment setup enabled Milgram to trace statistical properties of communication channels. The average length of these successful chains was reported to be 6, which coined the 'small world' phenomenon as 'six degrees of separation'. Although 'small worlds' phenomenon have been studied earlier than Milgram experiment, even its mathematical models by mathematicians, social network analysis literature acknowledges Milgram experiment as the milestone work. The power of the experiment stems from the fact that the conduct and discussion of the experiment combines sociology, statistics and mathematics, which in return summarizes social network analysis perspective.

Social network analysis perspective has inspired a set of other non-social form of network analysis, where similar statistical models are interpreted contextually. For instance, information networks such as citations in between papers extends the social dimension of knowledge diffusion. Studies on hyperlinks and structure of World Wide Web is another example of information network where a network of Web pages is investigated. On the other hand, technological networks such as electric power grids or Internet as a network formed by physical connection in between computers have no social dimensions. Another recent application of network perspective can be seen within medical and biological sciences. For example, biological networks are formed via observed connections in between neurons, or from mechanistic physical connections in between proteins.

2.1.5 Some Recent and Relevant Directions in Social Network Analysis

Network Perspective in Organisation Studies

Network governance approach within organization studies integrates transaction cost economics (TCE) and network theory as an alternative and viable framework for assessing and studying governance forms other than markets and hierarchies. The network perspective is gained via adopting structural embeddedness concept of network theory. As such, network perspective shifts a mere TCE focus from exchange dyads to the network's overall structure or architecture. In other words, network theory "extends TCE by integrating structural embeddedness into the TCE framework and by moving TCE from a dyadic to a systems perspective" (Jones et.al., 1997: p. 935).

Social network analysis has also been adopted within strategic management studies. It is used both as a framework at understanding and analyzing collaboration in strategically important groups such as networks of top management boards, strategic business units, teams, communities of practice, joint ventures and mergers, as well as, a facilitating mean of these strategic collaborations. "By making informal networks visible, social network analysis helps managers systematically assess and support strategically important collaboration." (Cross et.al., 2002: p. 25).

Carley (1991) adopts social network theory to study dynamics of interactions within a team in a knowledge intensive work environment. She derives upon 'symbolic structural interactionism' (Stryker, 1980: cited in Carley, 1991, p. 332) and 'social differentiation theory' (Blau, 1977: cited in Carley, 1991). Both of these theories enhances the knowledge perspective in a network, where shared knowledge mediates interactions and social dimensions such as language, religion, sex and age. Carley (1991) further acknowledges the importance of institutional and environmental limits on interaction. This theoretical perspective allows her to model and simulate self-organized group formation and emergence. The framework additionally served her to study stability of formed groups from a socio-cognitive perspective (Carley, 1990).

Network Models

A stream of studies in social network analysis attempt to model and characterize recurrent patterns. They adopt graph theoretic methods to describe social phenomena.

Representations of social networks as graphs are significantly different from random graphs as social networks exhibit patterns or regularities of interactions which can not be explained by chance. This has lead many network scientists to discover and to explore recurring patterns in various social settings. There are a number of models which are discovered and examined extensively at characterizing very common social interaction patterns, specifically in collaboration networks.These are small-worlds, core-periphery structure and preferential attachment model.

In small-world model (Watts and Strogatz, 1998) regular and frequent interaction occur locally within cohesive sub-components. These internally cohesive sub-components are connected to each other globally via a small set of bridging nodes. These bridging nodes are observed to play crucial role at providing global level communication channels and brokerage.

A common urge in social network analysis the notion of core-periphery structure. The core consists of densely connected cohesive members whereas rather loosely connected sparse or unconnected members forms the periphery. Borgatti and Everett (1999) proposes quantitative methods for detecting this structure.

Barabasi and Albert (1999), in particular, were interested in patterns of network growth. They have demonstrated that formation of many social networks, such as scientific co-authorship, or derivative of social networks such as World Wide Web or paper citation networks exhibit a `preferential attachment` character. In preferential attachment model, principally, when new members join the network it is more probable to observe that they form links with the ones who already have relatively more links compared to the others. In other words, it summarizes the social phenomenon 'richs get richer', where one's social capital is the measure.

Nevertheless, not all social networks exhibit a preferential attachment network growth. For instance, Moody (2004) tests preferential attachment network growth in social networks at various scientific disciplines, where a structurally embedded group is dominant. He fails to examine one which still supports preferential attachment model.

Knowledge Agents in Network Perspective

Social network analysis as a methodology also extends the notion of actors in a network, where any sort of entity with the ability to take action or to regulate the interactions is considered as an agent. Deriving upon this definition Carley (1999) states that even books with ability of storing and containing knowledge can be considered as actors, even though they act 'passively' providing information. With this perspective any action is both constrained and/or resulted from cognitive limitations of actors.

Cognitive structure of an actor in a network of relations is modeled by actor's relevant set of knowledge. Defining the mental-model, namely cognitive structure, as a set of concepts, meta-concepts, relatively more closely related concepts, and the connections among them, Carley (1999) exemplifies such a form of structured knowledge. She stresses the fact that action of agents are also limited to inter-relation among actor's knowledge and social capabilities.

Notion of an actor can be further extended to aggregate levels. Then an aggregate level or a composite actor is any sort of actor, such as teams, institutions, societies, that is formed through synthesis of other individuals. Within domain of such an approach, for instance, a team mental model is "shared knowledge" by majority of the people. This is also referred as a social knowledge or cognitive structure of the composite.

Extensions of Social Network Perspective

Most of social network analysis extensions represent set of different types of relations in between actors as an ecology of networks. In such a meta-network approach, for instance, social network represents direct ties in between individuals; cognitive network represents the way individuals collectively links ideas or knowledge; transitive knowledge network, namely a knowledge-people network, represents how individuals are linked to ideas. The transaction knowledge, e.g., might be derived from publications. This approach circumvents limitations of conventional and static network analysis:

> Traditional structural analysis, which bounds the network by the type of agent, may result in erroneous or misleading conclusions about the role of the network in producing social change (Carley, 1999: p. 10).

Dynamic network analysis (DNA) further combines social network analysis (SNA), link analysis (LA) and multi-agent systems (MAS) within network science and network theory (Carley, 2003). DNA examines large scale networks in which there are multiple types of nodes (multi-mode) and links (multi-link). It utilizes simulation techniques to address issues of social networks when information is not complete or prone to noise.

2.1.6 Summary

In summary, network analysis[1] in general aims to detect and observe emerging phenomenon or realities. It develops upon a set of interrelated conceptions: (1) interaction is fundamental social act which shapes the social behavior, (2) actors be single or a set of them self organize due to capability and knowledge constraints, (3) presence of other relations is important in emergence of regularities due to fact that they emerge as agents interact, (4) social world continually restructures, (5) No ontological imperative is valid, in such an approach. That is, it is not possible to give more a-priori importance to one actor be it person, team, or institution over the others (Carley, 1999; Carley and Gasser, 1999).

Extensive details on social network theory, methods and applications are outlined and discussed in Scott (2000), Wasserman and Faust (1994) and Carrington et.al. (2006). A historical sketch on the principles of social network analysis is given by Freeman (2004). Emirbayer (1997) and Wellman (1988) independently engages in a comprehensive discussion on distinctive features of social network analysis as a relational research paradigm in the study of social structures.

2.2 Co-word Analysis

Discussions in Chapter 3 and Chapter 4 reveal the fact that isolating social practices and social structure from the organization of knowledge itself may lead an incomplete picture at explaining recurring patterns in collaboration structures of science communities. Co-word analysis as a bibliographic technique takes an approach from the other end. It studies the bulk of produced knowledge to derive map of sciences isolating knowledge from its carriers or from the very social structure.

This chapter, outlines the method and its theoretical background and reviews relevant literature. Discussions and observations on the premises of co-word analysis is further considered in Chapter 2.3. There theoretical and methodological insights of co-word technique is further employed at developing a methodological approach which better fits to mutuality of social structure and knowledge diffusion processes in science communities.

2.2.1 Introduction

The scope and volume of scientific research have increased tremendously since the second half of the 20th century. The duration of doubling amount of scientific information has shrunken to the order of a few years. This situation has lead scientists to develop methodologies to be able to detect subject areas and interrelations among these areas in their research fields (He, 1999). There are two major quantitative methods which attempt to map the structure of scientific knowledge: (1) co-word analysis, and (2) author co-citation analysis.

Co-word analysis is a content analysis technique developed to study relationship in between ideas within the subject areas presented in publication documents (He, 1999), whereas, author co-citation analysis is developed to study intellectual structure of a given scientific field (Lee and Jeong, 2008). Co-citation analysis derives upon co-occurrence of scientist pairs on the reference list of a paper. Although it helps to study mechanisms leading to formation of research frontiers formed by a set of key scientists, it is susceptible to errors and methodological difficulties when employed to map the structure of scientific knowledge (Cahlik, 2000a; Cahlik, 2000b). For that reason, in this dissertation I will adopt co-word analysis to study development of a scientific field in general and exemplify it by studying management science themes in Turkey.

"Co-word analysis is based on the theory that research fields can be characterized and analyzed based on patterns of keyword usage in publications" (Neff and Corley, 2009). The analysis based on co-occurrence frequency of pairs of words or phrases. Either a single word or a set of words forming a phrase may denote a key subject, a main theme or a basic concept. Then co-word analysis is employed to discover linkages among subjects or concepts in a field. Overall structure of linkages is used, for instance, to trace development of a field overtime. This technique has proved to be a powerful knowledge discovery tool to derive map of a sciences from bibliographic databases (Neff and Corley, 2009; Lee 2008; Cahlik and Jirina, 2006; Borner et.al., 2003; Cahlik, 2000a; He, 1999; Bhattacharya and Basu, 1998; Vanraan and Tijssen, 1993; Leydesdorff, 1992; Law and Whittaker, 1992; Whittaker, 1989).

2.2.2 Theoretical Foundation

Theoretical foundations of co-word analysis and its practical applications in science and technology studies (STS) were first developed and demonstrated by a group of french scientists Callon, Law, and Rip (1986). They have co-authored a book titled `Mapping the Dynamics of Science and Technology` which became a milestone work on co-word analysis. There, theoretical foundation of using the concepts co-occurring in the text to map the dynamics of science is based on Actor Network Theory (ANT). The assumption is that keywords, phrases or codified concepts reflects the social actor's, namely authors', cognition structure (Callon et.al., 1986). In other words, scientists build a complex world in field studies or in laboratories and enforce and disseminate them on papers (Latour, 1987; Callon et.al., 1983).

However, "they[scientists] are not only using texts[papers] to publish their world built in the lab but also using texts as a way to build a world and enroll others" (Qin, 1999: p. 137). In that perspective, concepts disseminated on the papers and scientists together form a heterogenous assemblage. In this case, scientific knowledge and scientists are mutually constitutive within the actor-network. For example, a scientist remains recognizable as long as he/she interacts appropriately with particular knowledge domain. "Overall, co-word analysis considers the dynamics of science as a result of actor strategies. Changes in the content of a subject area are the combined effect of a large number of individual strategies" (Qin, 1999: p. 138). In short, studying the papers is another way to map the structure and dynamics of a scientific field, where publications are not considered as discrete units, instead, each is built upon others in a relational manner (Turner and Rojouan, 1991; Qin, 1999).

2.2.3 Methodology

Co-word analyses progressed by a sequence of steps such as data selection, data pruning and information coding processes followed by statistical and algorithmic analyses of retrieved information. The details of the methodology is given in Chapter 5. Briefly, the first state is extracting keywords from each document in data set. Then a co-occurrence matrix of keywords is generated. Various features of resulting co-occurrence matrix is analyzed statistically or algorithmically based on research question at hand.

As different questions can be raised on interactions and relations in between keywords within a scientific field the co-occurrence matrix, or matrices in some longitudinal studies, is subjected to additional operations. Most uses of the method employ and adopt multivariate statistical techniques to discover and examine clusters of keywords that co-occur in the literature (Callon et.al., 1986; Courtail and Callon, 1991; Neff and Corley, 2009).

The keywords can be extracted from titles, abstracts, listed keywords of papers or from other parts of a publication. Keywords which appear together on the same publication are used while forming a cluster. A cluster, which is formed by one or more words, then is treated as representing a concept, a specific research theme, an issue, a method or a theoretical framework. In other words, a cluster of keywords is understood as a short description of a research theme, where structure of mutually connected clusters is considered to present a research field (Cahlik, 2000a). In the literature, network scientists have used different techniques to create clusters. Hierarchical clustering, agglomerative clustering, principal component analysis and factor analysis are amongst the most widely employed techniques (Rip and Courtial, 1984; Callon et.al., 1986; Tijssen and Vanraan, 1989; Turner and Rojouan, 1991; Qin, 1999; He, 1999; Neff and Corley, 2009).

Almost all of recent studies which employ co-word analysis do generate a strategic diagram[2] to see overall structure of the specific domain or a scientific field under examination. In order to derive a strategic diagram, centrality and density value of each cluster is determined. The centrality of a cluster implies how strong each keyword or phrase within the cluster is linked to other keywords or phrases in the other clusters, and the density of a cluster implies how strongly each keyword within the cluster is linked to each other. Then, each cluster is mapped on a strategic diagram based on its normalized centrality and density value. Resulting strategic diagram is a two dimensional Cartesian map, where usually horizontal axis denotes centrality and vertical axis denotes density of the specific field under examination. The origin of the axis is the intersection of median or mean of centrality and density values.

Thus, if a cluster has relatively high centrality and density, it is assumed to be central and developed area, subject, or topic within the field. If a cluster however has both a very low density and and a very low centrality, it is assumed to be peripheral and undeveloped. On the other hand, a cluster with high centrality but low density implies that although the subject is central to the field it is not developed enough, while a cluster with low centrality but high density implies that although the subject is very much developed, it has not been central or has not become mainstream so has a marginal importance to the field under examination.

2.2.4 Relevant Studies

Mark W. Neff and Elizabeth A. Corley (Neff and Corley, 2009) explore the evolution of ecology in between 1970 and 2005. They attempt to identify trends in the methods and subjects of ecology. They employ co-word analysis technique on a bibliometric data set of around 160.000 articles. They used titles of articles as unit of analysis. Compared to earlier studies at mapping the science, the study exemplifies one with largest in scale and it hints successfully the emerging trends and research priorities in the field. The researchers have also traced rapidly declining and emerging subjects which have allowed them to study evolutionary dynamics of the field. For that purpose, other than tracing most frequent words through out the time they have separately examined the clusters of words that have undergone rapid increase and decrease in prevalence. The authors have separated list of emerging words and list of vanishing words into two distinct set of keywords. Then they have formed clusters of emerging words in one case, and clusters of vanishing words in another case of co-word analysis. Having done so they have ignored relation of emerging and declining words with each other and with more frequent and persistent keywords. As a result, they fail to examine relations in between emerging or declining fields and their relations with mainstream subjects in the field.

Bangrae Lee and Yong-Il Jeong (Lee and Jeong, 2008) apply co-word analysis technique to establish "Strategic Diagram" of the robot technology in Korea. The study derives upon meta-data of around 100 projects on the technology as of 2001. They use list of keywords of each project to construct co-occurrence matrix. The authors adopt fully computational methods to extract most frequent words in Korean to be used at forming clusters. They fail to capture phrases due to lack of linguistic algorithms at detecting phrases out of texts written in Korean. On the other hand, the authors validate computationally generated clusters by conferring with experts in the field.

Woo Hyoung Lee (2008) attempts to identify emerging research themes within Information Security field. The study is based on 976 theses published in the field in SCI (Science Citation Index) database from 1993 to 2003. The author primarily extracts keywords from titles and abstracts. Out of 2,880 extracted keywords, only 223 keywords appearing 5 or more times are considered for actual study. The author finally detects 13 important research themes in the field.

A group of Czech researchers (Cahlik and Jirina, 2006) attempts to develop a model to simulate evolution of scientific fields using co-word analysis. In their model, they start with a snapshot of a field to develop an empirical co-occurrence matrix. Then the probability of a new tie in a subsequent period in between two keywords is determined by the frequencies in which both keywords have taken part already. The results show that strategic diagram developed for the successive period by simulation matches evolution of the scientific field, concluding that law of cumulative advantages holds for evolution of a scientific field. However, the study does not attempt or compare results of simulations for more than a subsequent period in a row with real data. Not having done so, they lack to address dynamics of declining or emerging themes in a field.

A research team in Netherlands exploits co-word analysis technique to study emergence of scientific discoveries and their impact on the meanings of words (Lucio-Arias and Leydesdorff, 2007). They use titles of patents in nanotubes field to extract words and then to construct semantic map of the specific field. In one of their recent study (Lucio-Arias and Leydesdorff, 2009b) they further imply that the technique may serve to discuss evolution of discursive knowledge.

Tomas Cahlik (Cahlik, 2000a) studies evolution of 'Water Resources' field by forming and tracing strategic maps over time. He further investigates to what extent a set words of same research theme has changed over time. He concludes that stage and intensity of research activity during the life span of a specific scientific field can also be traced by examining strategic maps. A typical life span is assumed to consists of 'start', 'expansion', 'maturity', 'depression' and 'obsolety' stages. He argues that in the 'start' and 'obsolety' stages the themes within the field commonly concentrated either at highly dense but not central quadrant or highly central but not any more dense quadrant. At the 'maturity' stage themes of field are rather concentrated either at the very central and dense quadrant or neither central nor dense quadrant. On the other hand, at the 'expansion' and 'depression' stage themes are observed to be dispersed in all four quadrants.

A group of African researchers employ the method examining titles of publications on AIDS/HIV studies. They examine relations of keywords within publications which study AIDS in Africa. Their analysis reveal that patterns of AIDS in Africa, observed from results of co-word analysis, is different compared to the cases in western or more industrialized countries (Onyancha and Ocholla, 2009).

Rodriguez et.al. (2007) perform co-word analysis to detect if there is a difference in underlying scientific structure of biotechnology field under different funding scheme. In other words, the researchers first form different sets of publications lead by similar or same funding regime. Then they compare and contrast strategic maps extracted from each set to examine impact of funding policies on the structure of the field.

Bhattacharya et. al. (2003) exploits the method to form intellectual structure at thin-film patents. They use the method to form conceptual themes formed upon keywords derived from the titles of patent documents. The study aims to decipher relation in between science and technology with the help of the method. Noyons and Vanraans (1994) have applied the same method to study science and technology relation in the field of optomechatronics and Callon et. al (1991) to study the relation in polymer chemistry.

Kavunenko et.al. (2005) exploits the method to compare semantic structure of social sciences and humanities, as seen in journals published in Ukraine, to the rest of world, as seen in the citation indexed journals of Web of Science database. Noyons (2001) applies a similar method to map science on science policy.

David and Jean-Phillipe (2008) exploits the method to detect hierarchical structure of any scientific field. Bailon-Moreno et.al. (2005) uses the method with a similar question in along with other statistical distributions of authors, countries, etc. to map structure of a specific field, namely the studies on surfactants within physical chemistry. Baldwin et.al. (2003) apply the method to map the literature of Geriatric Psychiatry in between 1980 to 2000. They use titles of papers in the field.

Stegmann and Grohmann (2003) attempt to generate new hypotheses on diagnosis of diseases. They apply co-word analysis on relevant sets of medical publications and then examine resulted strategic diagram where relations in between emerging themes have hinted them to formulate new sound hypothesis on diseases under study.

Earlier use of the technique is more common in biology related fields (DeLooze and Lemaire, 1997; Cambrosio et.al., 1993), at identifying and forecasting trends in technological inventions, tracing evolution of specific research area over time (Zitt, 1991; Lemarc et. al., 1991).

2.2.5 Summary and Discussions

The main problem of the method is the quality of keywords selected (Cahlik and Jirina, 2006; He, 1999; Leydesdorff, 1997; Whittaker et.al., 1989). Keyword quality deteriorates when not enough elaborate computerized keyword selection process is opted. For instance, a computerized keyword selection process may end up coding 'market' and 'markets' as separate keywords. Even advanced computational techniques may not be able to differentiate synonym words that are used in the texts. Another observed problem case is use of polysemous words. To overcome such problems either much advanced computational methods are employed or elaborate manual keyword selection processes are opted. In addition to polysemy and synonym usage, words may have different meanings in different contexts which further deters keyword selection or coding processes (Lucio-Arias and Leydesdorff, 2009a).

Vast majority of studies in the literature have dealt with very specific sub-fields (Neff and Corley, 2009). Focusing on a very specific sub-field allows to have a fine tuned clarification on the knowledge structure and evolution of a field (e.g., Law et. al, 1988), nevertheless it does not allow to elaborate on the trends at a larger scale covering multiple of sub-fields within a subject area.

A large body of studies in the literature show that particular locations of each cluster in the diagram and their movement within the diagram over time is a powerful method at observing evolutionary trends within a field. However, co-word analysis lacks to measure rich relational information in between clusters (Lee and Jeong, 2008). A relatively recent work by Woo Hyoung Lee (2008) incorporates network metrics to a limited extend. It measures and ranks only centrality measures of each cluster in the field of Information Security studies in Korea in between 1994 to 2003 in order to model detecting potential hub fields of research. The author computes degree, betweenness and closeness centrality of each identified cluster. He ranks them to discuss upon.

In this dissertation study, I entangle social network analysis and relevant parametric analysis on the network metrics to examine relational patterns more precisely, where relations in between network measures are examined and traced over time. The consideration of a network approach helps anticipate and present the orientation of a field to another. An approach in that direction is taken by a Spanish research group (Miguel et.al., 2008). They point to explanatory power of combining co-word analysis and social network analysis in order to map a field of science. However, their study lacks to exploit power of strategic diagram at interpreting importance of each emerging themes in a field.

The other widely used method for creation of maps of science is co-citation analysis. In co-citation analysis the target is again to discover clusters of research themes in a field. However, in this alternative method unit of analysis is articles instead of keywords. Then co-cited articles are used to form clusters. Each of such cluster is considered to represent a research theme in the field (Cahlik, 2000a). This method requires to be able to extract citation list of each article. That is it requires to collect set of publications which cites a document after its publications. Then co-cited papers will be used at formation of such clusters. It is observed that only a small portion of publications recieve citations degrading power of mapping a scientific field by co-citation analysis (Sternitzke and Bergmann, 2009). Besides, studies have shown that formation of list of citations is more subjective and varied compared to use of words and phrases (Lucio-Arias and Leydesdorff, 2009a). Another disadvantage of co-citation analysis is that it lacks mechanism of developing strategic diagram based on density and centrality parameters of a research theme.

There is a recent approach to overcome pitfalls of co-word analysis or co-citation analyses. For instance, a recent study by Eli M. Blatt (Blatt, 2009) applies a Latent Semantic Indexing (LSI) methodology borrowed from computer science to extract main themes in a scientific field and then to map each document regarding its content as of each main theme. LSI takes a bottom-up approach to derive basic themes in a field. That is, it is developed upon word frequencies in documents to extract keywords, whereas the alternative top-down approach develops upon a-priori keywords or phrases which is contained within the semantic space of a field. The author applies this well known content analysis technique from Computer Science to extract and scientific maps. It uses abstracts of papers retrieved from Web of Science in the field of Anthropology to form semantic space of the field and to map each article in that field. Although the method is promising at extracting major themes in a field decreasing problems of non-standard keyword usages, or synonymy and polysemy, the success of the method is very much depends on power of computational natural language processing tools and necessitates use of full text analysis for valid analysis. LSI "cannot as easily be conducted as co-word analysis relying solely on titles and abstracts" (Sternitzke and Bergmann, 2009: p. 114). Besides, the method is at its infancy stage at both mapping and evolution of growth or development in science.

2.3 Scientific Knowledge and Co-authorship Structure

As mentioned earlier, the literature on knowledge diffusion in scientific communities suggests a set of mechanisms on how knowledge is transferred across time and distance. A first set of studies emphasize the role of scientists, where knowledge is diffused by direct social contact with key academicians. The form of contact can be either in a form of master-apprenticeship relation that necessitates education and training as means of knowledge flow or co-authorship that necessitates scientific collaboration. This set of approaches are covered and discussed in detail in Chapter 3 and Chapter 4 respectively. A second set of studies emphasize the role of involuntary knowledge transfer, where knowledge is acquired by indirect channels via publications, etc. The primacy on the role of direct social contacts comprises relevant motivations behind the co-authorship networks, while a primacy on the dissemination of scientific knowledge comprises motivation behind the co-word analyses as discussed in Chapter 2.2.

2.3.1 A Composite Research Framework: Mutuality of knowledge and collaboration structure

Previous conceptual and methodological studies in the literature I have discussed in earlier chapters lead me to develop a composite framework in order to examine the structure and dynamics of a research field, where I can derive map of collaborations by researchers in the field, in parallel to a map of base knowledge supporting the research in the field. In other words, the approaches I have outlined earlier allows me to sketch out a map of subtopics and how they are related and to sketch out a second separate map of research teams doing research in the specialty. However, the literature is not elaborating on how they appear to be linked. There are only a few attempts which relate cognitive structure of a field and collaboration in between scientists in the field (Morris and Martens, 2008).

A sketch of methodological perspective of co-authorship studies (e.g., Mutshcke, 2003) would be (i) consider the authors, (ii) apply social network methods, and (iii) speculate over the network positions of the authors regarding their role at diffusing the knowledge. This outline considers neither cognitive structure of individuals nor the community as a whole. That is, it lacks to reflect fundamentals of a theoretical framework where mutuality of social structure and production or diffusion of knowledge in the community is primed.

The primacy of network position at knowledge diffusion is mostly coined by Burt's (1992) measure of structural holes. But it ignores the actual content that diffuses through the connection provided. In other terms, Burt's structural holes conception assumes that different, unconnected subgroups of researchers provide unique knowledge to the mediator, namely the broker, between them. This conception assumes that having occupied a strategically advantageous position in terms of access to knowledge, as well, the bridging is the most important network position. "However, there are more direct ways to establish the link between accessing a diversity of knowledge sources and the performance of the individual. ... In a relatively homogeneous research field, we expect that cognitive differences may drive the process of innovation. We expect that differences in the research profile of the ego and his alters may benefit the individual in addition to the already proven positive effect of a large and efficient social network." (Mike et.al, 2006: p. 23).

On co-word analysis side primacy is on strategic position of themes. It conceptualizes keywords or themes in a research field as actors, per se, developing upon the very idea of actor-network-theory or ANT (Callon, 1986; Law and Hassard, 1999), nevertheless, it fails to integrate direct or indirect impact of keywords as interactive non-human actors in a network of relations in between heterogeneous actors, where heterogeneity exists due to co-interaction of scientists and knowledge actants.

Some other scholars point the role of documents, instead of knowledge, themselves as actants and suggest to consider them in sociological studies on knowledge diffusion within scientific fields (e.g., Prior, 2008). Indeed, co-citation or citation analysis within the realm of scientometrics or informetrics have developed upon that conceptualization. In this dissertation study, when I attempt to relate cognitive structure and collaboration, documents act merely the role of a container for scientific knowledge and a collaboration space for the scientists.

2.3.2 Relevant Studies

There are a few studies in the literature which examines social network structure and cognitive structure of scientists simultaneously. Peter Mika in a series of studies (Mika, 2004; Mika, 2005) attempts to combine social network structure and social cognitive structure of Semantic Web research field. He mines Web data to form the social network structure of the research community. Various clustering algorithms are used to detect research sub-groups. The author additionally forms a bi-partite graph of the community, where each author is linked to one or more topics represented by 24 key terms. These key terms are determined qualitatively examining the studies in the field.

Noyon and Calero-Medina (2009) conduct a case study based on scientific activities of 21 selected faculty members in three Dutch universities of technology. They collect major publications of each faculty to form a publication portfolio of each one. They adopt natural language processing methods to extract keywords or noun phrases from the titles of the publications. They use this set of keywords to represent cognitive profile of each faculty. The cognitive profiles of individuals are then used as input to a similarity analysis in order to define the amount of research 'overlap' in between them. The overlaps are used to form cognitive similarity network of selected faculty members. They use this similarity network as a potential collaboration network. Their findings are suggested to serve develop research policies for case universities. Theoretical and methodological foundations of this case study is based on an earlier study by Calero et.al. (2006).

The study by Mutschke and Haase (2001) explicates in detail how existence of relationship between researchers' position in social structure of scientific networks and the innovativeness of themes they examine can be related. For instance, they posit that the researchers with highest degree centrality are likely to work on the more central research themes. The social structures in their research is derived mainly from co-authorship relations. Then the main focus of the study is the interaction of research themes (cognitive structure) and co-authorship networks (social structure) of a research field.

The authors employ co-word analysis and social network analysis to study socio-cognitive structure of a field. More particularly the authors investigate "whether the network positions of actors are associated with the types of themes they are researching" (Mutschke and Haase, 2001: p. 495). The authors estimate the relevance a scientist to a particular theme using the set of documents he/she has published. The authors first consider and estimate the relevance of each such document to a particular theme. Partial relevance of each of these documents are then summed up. The resulting summation is used as an indicator of the contribution the scientist has made to the theme. The estimate of that very contribution is used as a metric for the relevance of the scientist to the field[3].

Based on co-authorship centrality of each scientist in a field, the authors propose a scheme to categorize them. Namely, the authors with no collaborators are considered as *single fighters*, the ones who collaborate very rarely as *free riders*, the ones who collaborate but not yet very central as *social climbers*, and the ones who are the most central are categorized as *experts*.

The study which is conducted on the fields of sociology of youth and women concludes that the positions of actors in scientific social networks are associated with their choice of themes. Their longitudinal analysis over a period of 10 years (1988 - 1998) further suggests that *experts* of a field tend to select themes with a high degree of popularity whereas new ideas are most likely to be introduced and pursued by *social climbers*.

Another but rather early work by Doerfel and Barnett (1999) investigates semantic network, namely overall cognitive structure of, International Communication Association (ICA) in 1991. The authors examine to what extent cognitive map of the association in 1991 resembles affiliation network of the community? They extract cognitive map of the association conducting content analysis on the titles of the papers presented at the annual meeting in 1991. Then, they relate a network based on scientists common institutional affiliation and one based on their cognitive similarity. Theoretical framework that explains how they relate an affiliation network to one based on meaning stems from the literature on social influence process:

> This literature suggests that individuals' attitudes and beliefs are a function of the information received from socially proximate individuals. In this[their] case, attitudes toward communication research may be expressed by conference paper titles. Proximity is measured as shared memberships. ... Members of a social system converge on a common set of meanings as a result of joint interaction. That is, they are exposed to and influenced by the same information. In this case, membership in the same division or interest group results in the exposure of members to common information, either through social interaction or exposure to the same academic literature and conference presentations. As a result, conference paper titles would contain equivalent symbols. (Doerfel and Barnett, 1999: pp. 590-591).

Tijssen (1993) conducts an experiment to check perception of experts in a field on cognitive structure or knowledge structure of the field as a whole derived from computerized bibliometric analysis. More specifically, author compares and contrasts cognitive structure of a field solely driven from publications to its perception by a small set of experts in the field. The experiment demonstrates that although strategic map of Neural Network Research field developed upon co-word analysis where the keywords are retrieved by computerized methods has principal resemblance to joint mental map of 14 experts in the field, it is significantly different from perceptions of individual scientists in the field.

A relatively recent study by Calero-Medina and Noyons (2008) apply another hybrid approach by combining co-word analysis with citation analysis. The study further exemplifies potential of meta-network analysis at the study of knowledge diffusion. The authors attempt to trace development of a concept in management studies and its diffusion pattern over the years from its first occurrence in management literature. More specifically, the authors trace 'Absorptive Capacity'[4] concept. The bibliometric co-word analysis provide them to develop insight into the contents of the publications while citation network analysis enable them to recognize the main papers during the time period of their case. In other words, using co-word analysis along with citation analysis they are able to discover cluster of themes developed or gathered around 'Absorptive Capacity' concept and the most influential documents which have comprised the research frontiers of those clusters.

2.3.3 Discussions and Summary

There are few number of studies in the literature which address research questions that necessitates combining co-authorship patterns and knowledge map of a field. Although, most of these studies develop upon a very small size of data in very specific fields, they demonstrate the power of the method and its theoretical background at explaining how knowledge is diffused. It is seen that exposing patterns of collaborations of knowledge carriers and map of knowledge itself, interrelatedly, may overcome limitations of previous studies which solely focus either on co-authorship patterns or knowledge map.

For instance, Mika et.al. (2006) have attempted to examine how cognitive diversity of peripheral scientists is related to their scientific performance. Their findings suggests that cognitive diversity in the ego network of researchers is positively related to their performance, especially for those junior researchers yet at the periphery. The performance is measured by number of citations received. Alternatively, they have also used citations per publications as a measure of performance. The cognitive diversity is measured by the difference between the research interests of the ego and his or her connections, the alters. Novelty of the framework has allowed researchers to observe that it is possible that new ideas originate from the most peripheral actors (Mika et.al., 2006). However, as the boundary of a scientific network is always unclear and fuzzy, besides, as a peripheral actor may have many connections to actors outside of the community under investigation it is still very difficult to examine the role of the most peripheral actors.

This delineation difficulty faced by Mika et.al. (2006) does not stem from the framework, but rather by the size and scope of their case. Likewise other previous research by the lead author (Mika, 2004; Mika, 2005), the study develops upon a small set of manually selected keywords in a very specific and small community.

Another explanatory power of the method is exemplified by the research question: "whether the network positions of actors are associated with the types of themes they are researching" (Mutschke and Haase, 2001: p. 495). This very quest can be extended by examining co-evolution of key positions in collaboration network and positions of themes on the strategic map.

Extended co-word analysis, in a way, can be employed to derive cognitive structure of the whole community. However, it would derive cognitive structure based on publications only. It does not consider cognitive structure of individuals who disseminate and produce the actual publications. Tijssen (1993) implicitly addresses the validity of the method at reflecting the cognitive structure of the scientists in the field. The author interviews with a number of experts in the field to ask if the cognitive maps solely driven from publications employing co-word analysis reflect the cognitive map of the field. The author conclude that, having valid and proper keyword selection, map of the subjects in a field does reflect cognitive map of the whole community but it significantly differs from cognitive structure of individuals in the field (Tijssen, 1993).

The prospect of an hybrid approach may allow to address a set of questions comparing and contrasting cognitive structure of ego and the community. More specifically, for instance, cognitive resemblance of key scientists to whole community can be investigated in different fields or its evolution for a field over time. Having extracted a representation of cognitive maps of individuals have helped policy making study by Noyon and Calero-Medina (2009) at recommending potential collaborations in between scientist in a field. They have generated a potential collaboration network of Dutch scientists based on cognitive similarities in between them.

In summary, understanding the inter-connectivity of knowledge resources and researchers within a field via a network theoretic approach may help not only to better understand knowledge diffusion, but also anticipate potential dissemination paths of promising sub-fields. In this section, I have attempted to outline the necessity of a research framework which provides basis of a coherent empirical method which relates knowledge and social organization at diffusing knowledge via collaboration networks. Building upon discussions in Chapter 3 and Chapter 4, Chapter 5 attempts to epitomize details of the method.

Chapter 3

Knowledge Diffusion in Networks

Knowledge diffusion has been studied in a range of disciplines from statistical physics and computer science to sociology and management sciences. These knowledge diffusion scientists with very diverse backgrounds have studied various antecedents and consequences of knowledge transfer. This has lead to confusion of the concepts, inconsistencies at interpretation of research findings and sometimes irrelevant debates. For that reason, I will discuss relevant works in the literature clarifying: (a) what is the nature of knowledge that is being diffused; (b) what stage of a knowledge chain that is focused; (c) what mode of knowledge transfer that is assumed; (d) what unit of analysis that is taken; (e) what particular properties of knowledge actors or carriers that is considered or quested by studies; and (f) how social structure and nature of knowledge is related.

The discussion leads to me to develop a conceptual framework which contextualizes co-authorship studies those inquiring relationship in between collaboration patterns and diffusion of knowledge in the network.

3.1 Data, Information and Knowledge

Diffusion per se is a generic phenomenon which necessitates a material or a non-material transmittant in first place, a set of carriers, and a medium in which the carriers interact to share, exchange or diffuse the transmittant. A careful examination of the knowledge diffusion literature suggests the need for deliberation on the nature of transmittant that is exchanged, shared or transferred. More explicitly, it is necessary to differentiate between `data`, `information` and `knowledge`.

`Data` can be acquired or generated through any method of investigation, analysis or inquiry (Willke, 2007). In other words, data is created by observers through their theoretical frameworks and their technical methods. For instance, the large hadron collider at CERN creates data that had not existed before. Not only the technical setup influences the generation of data but also the 'mindmaps' in the head of researchers at CERN. The 'mindmaps' themselves are formed by theories, previous knowledge and experience as well as prejudices and social or policy structures.

Within a context of communication, data have to be coded or represented, such as, via texts, numerals or images. Uncoded data cannot be communicated and hence remain non existent. Representational data go through a filter and create `information`. The filter is a set of relevancies webbed by the inquiry on the data. In other terms, when data are bound in context of relevancies they become information (Polanyi, 2009).

`Knowledge`, in turn, is generated from information. That is, it is filtered through a second context of relevancies. However, this second stage of filtering is much more advanced and implicit. It is based upon meaningful patterns that are created through previous experiences which is accumulated in a system specific memory. Knowledge emerges from systematically processed information and is bound to individual or collective actions and praxis (Willke, 2007).

Nonaka and Takeuchi (1995), in their book on how organizations acquire knowledge, point out how knowledge and information is conflated within the literature. They discuss how knowledge is different from and similar to information describing "information is a flow of messages, while knowledge is created by that very flow of information, anchored in the beliefs and commitment of its holder" (Nonaka and Takeuchi, 1995: p. 58).

Knowledge itself is not homogenous but an heterogenous term. Among others, it can be classified as theoretical vs practical, individual vs organizational, implicit vs explicit knowledge. Scientists, being knowledge generation and dissemination practitioners, are actively taking part in transformation processes between `implicit` and `explicit` knowledge (Polanyi, 2009). 'Implicit' knowledge is partly unconscious 'know how' and can become 'explicit' knowledge when it is coded and explicated and transferred to others.

Table 3.1: Modes of knowledge generation via translation (Nonaka and Takeuchi, 1995).

`Transition`	To: Implicit Knowledge	To: **Explicit Knowledge**
From: Implicit Knowledge	*Socialization*	*Externalization*
From: Explicit Knowledge	*Internalization*	*Combination*

Nonaka and Takeuchi (1995) analyze the transformation processes between implicit and explicit knowledge. As tabulated in Table 3.1, they point out four intersections: *socialization*, *internalization*, *externalization*, and *combination*. Socialization accounts for the adoption of tacit knowledge through practice. Internalization is individually acquired and internalized knowledge. Externalization process accounts for translation of tacit knowledge into explicit knowledge. Combination process comprises of actions or processes of institutional, organizational or collective communication of explicit knowledge.

Any study on knowledge diffusion process in scientific communities highlights or probes a subset of processes of knowledge translation. For instance, in case analysis of this dissertation study, transitions to explicit knowledge is covered. There, use of published materials constraints the space for probations. It is limited by those transitions from either implicit or explicit knowledge to explicit knowledge.

3.2 Knowledge Chain

A part of the studies which are conducting empirical research on knowledge diffusion practices or theorizing about them, particularly those about highly knowledge driven sectors or communities, pay attention to underlying mechanism of knowledge process (Geisler, 2007; Chen and Hicks, 2004; Zollo and Winter, 2002; Nonaka and Takeuchi, 1995). Nonaka and Takeuchi (1995), i.e., further emphasize externalization of generated knowledge which enhances innovation:

> "When organizations innovate, they do not simply process information, from the outside in, in order to solve existing problems and adopt to a changing environment. They actually create new knowledge and information, from the inside out,..., to re-create their environment." (Nonaka and Takeuchi, 1995: p.56).

These conceptualizations approach knowledge process as a chain of knowledge creation, knowledge transfer and its social and technological implementations (Geisler, 2007; Nonaka and Takeuchi, 1995). At the knowledge creation stage the actors assemble knowledge acquired from all explicitly available sources or gained implicitly from their personal social interactions. This ring of knowledge chain also comprises translation of acquired and absorbed tacit and explicit knowledge into a diffusable form. The process of translation "includes verbalizing what they know, creating displays and visual formats, and establishing or following standards for codified content, so that the receivers of this knowledge downstream will be able to decode, understand, and use what they receive." (Geisler, 2007: p.86). The transferred knowledge is implemented either in a form of a tangible physical or digital product or in the form of organizational policies, procedures or any other activities and organizational practices.

Strategic management literature studies this chain of knowledge creation, transfer and implementation and frames it as a learning mechanism practiced by organizations. Scientists in the field thus approach knowledge diffusion in social networks by employing various learning mechanisms (Zollo and Winter, 2002). Zollo and Winter (2002) pinpoint and discuss three learning mechanisms: (1) experience accumulation, (2) knowledge articulation and (3) knowledge codification. The experience accumulation mechanism reflects the emergence of patterns and routines. In other words, it is a reification of tacit knowledge. The knowledge reification in relatively more complex environments are formalized by the mechanisms of knowledge articulation and knowledge codification. Articulation reflects exclusive share of knowledge through verbal communications, whereas knowledge codification takes place when it is implemented or applied via manuals, tools, or in any other technical media in order to facilitate knowledge diffusion. This learning mechanism is linked to the evolution of dynamic capabilities of firms such as re-engineering and process R&D. In return, dynamic capabilities of the firms are considered as stimuli of the evolution of organizational operating routines.

Although diffusion of scientific knowledge via publications can be best situated within knowledge codification stage of whole chain, it implicitly entails experience accumulation and knowledge creation activities and processes. The level of entanglement of above chain may be different from a discipline to another discipline. Nevertheless, diffusion of scientific knowledge leads scientists in all fields ubiquitously to engage in denser communications compared to many forms of information diffusion, where a mere social contact may be sufficient.

3.3 Modes of Knowledge Transfer

Literature suggests that, the conscious knowledge transfer process is regulated with different modes of organizing. Namely, they are (1) price mechanism of markets, (2) contractual arrangements within organizations, (3) informal know-how transfers via networks of knowledge carriers (Cantner and Graf, 2006). The price mechanism of markets exchanges codified or implemented form of knowledge. Licenses for patents, licenses for proprietary software, various consultancy services are all examples of knowledge transfer where codified knowledge is protected by intellectual property rights and priced by dynamics of markets. On the other extreme of the market, which forms second mode of knowledge transfer, knowledge diffusion takes place and coordinated within hierarchical structure of the organizations. As such, the researchers within a knowledge intensive institute or employees within a firm are contractually obliged to leave technology or process innovations to the employer (Cantner and Graf, 2006). The third mode of knowledge transfer is based on bilateral information exchange and sharing. This mode of knowledge transfer also comprises joint knowledge creation, dissemination and implementation activities. It is a common practice by scientists and researchers by various means such as via conferences, informal meetings, collaborations towards joint publications, etc.

Walter W. Powell (1990), in his work titled *Neither Market nor Hierarchy*, points to rise to networks as a viable form of economic organizations particularly in knowledge intensive industries. Powell's network driven modes of knowledge transfer is developed upon new forms of economic organizations. He outlines features of networks that differentiates it from markets and hierarchies. The normative characteristics of networks, in which knowledge is shared and diffused, are based on complementary strength, flexibility, reciprocity and mutual benefits of knowledge carriers. A set of follow up empirical studies principle conducted at biotechnology industry further show how networks become the actual medium and thus can foster knowledge diffusion enhancing firm level learning mechanisms (Powell et.al., 1996).

The autonomous and self organizing nature scientific practices towards knowledge creation and diffusion situates networks as most appropriate framework or mode of knowledge transfer. Knowledge is shared, transferred or diffused within networks formed either by individuals, groups or institutes.

3.4 Network Mode of Knowledge Transfer

Knowledge diffusion is most commonly examined by innovation studies. Many of these innovation oriented studies explore the relationship between social network structure and the process of innovation. The network structures are formed by patterns of interactions in between knowledge carriers or innovator entities either be individuals or/and organizations. The recurring and empirically validated claim suggests that understanding of this relation will better explain the role of different elements of network structure on the effectiveness of knowledge flows through such networks and will also help to anticipate effective and useful knowledge systems (Morrison and Rabelotti 2009; Ahuja, 2000). The unit of analysis changes from pervasive nature of links in the network to overall network topology.

3.4.1 The Nature of Flow: Information vs Knowledge

Deriving upon the observations and differentiations in between knowledge and information as discussed in Section 3.1, Section 3.2, and Section 3.3, we can posit that diffusion of scientific or technical knowledge requires a common knowledge base and commitment in between interacting actors rather than simpler information flow mechanisms. In that respect, an evidence of a mere social tie or communication in between actors is necessary to exchange information but might not be sufficient for flow of expertise. A critical review of findings from empirical studies in the literature supports this distinction.

Nature of transmittant of diffusion networks in rather earlier studies which are indifferent to such a distinction (i.e., Brown and Reingen, 1987) or elude this distinction (i.e., Abrahamson and Rosenkopf, 1997; Watts and Strogatz, 1998) exhibits characteristics of information. In these empirical researches, the network nodes or actors who have weak ties, but who rather connect different subgroups within the whole network, are primed to exhibit more significance for diffusion.

Brown and Reingen (1987) examine diffusion of rumor about products in between consumers and investigate the strength of social ties on the speed of rumor. They find that at macro level weak ties are speeding up dispersion of the rumor. Existence of a weak social tie is found to be necessary and sufficient for flow of rumors, like other form of information.

Abrahamson and Rosenkopf (1997), alternatively, run computer simulations to understand how innovations or epidemics might spread via social networks. Their findings again emphasize ‘strength of weak ties’ (Granovetter, 1973). However, although spread of innovations in different social settings might require dense social cognitive processes and interactions for the intake of the knowledge, their computer models underestimate or disregard network mode of knowledge transfer. Computational models, in general, presumes that a link in between two nodes of a network will lead flow of knowledge or information automatically.

On the other hand, a line of rather recent empirical studies which are conducted at knowledge intensive industries fail to acknowledge strategic position of weak ties (i.e., Morrison and Rabelloti, 2009; Fritsch and Kauffeld-Monz, 2009; Morrison, 2008). Morrison (2008) studies networks of firms in a successful Italian industrial district on furniture. The study shows that leader firms are the ones who bridge the region to other external districts acting as 'gatekeepers'. The study also shows that although these gatekeepers have interpersonal and firm level connection with local firms, yet they do communicate only generic information. They do not diffuse much of knowledge which they have acquired from their external ties into the region. It is interesting to note that "information sharing is rather diffused, whereas know-how exchanges are limited to few actors" (Morrison, 2008: p.828). The gatekeeper firms which have ties to external firms happened to have invested significantly more in R&D and human capital which lead them to be able to internalize knowledge acquired from external contacts and exchange it.

Morrison and Rabelloti (2009) further conducts research to examine whether and how knowledge and information diffuses differently. They study a wine producers cluster. Authors explore the structure of information network of firms formed by rather informal contacts by the members of the firms within the same cluster. They find out that informal interpersonal network diffuse information and it is structurally different than rather more professional and formal network which is purposefully formed to share and to exchange knowledge. The knowledge flows are restricted to a tightly connected community of local producers.

Comparing and contrasting studies by Singh (2004) and Fritsch and Kauffeld-Monz (2009) sheds further light on distinction in between information diffusion and knowledge diffusion. Both of theses studies do research on knowledge intensive R&D industries. In general, they examine primacy of network structure on the diffusion. But more specifically, they investigate role of network positions of individual firms on the flow of knowledge.

Fritsch and Kauffeld-Monz (2009) examine about 300 firms embedded in 16 different regional innovation clusters in Germany. The firms and the regional clusters are heterogeneous in terms of their knowledge base, along with other regional and firm level factors. They conclude that "contrary to Granovetter's thesis, 'the strength of weak ties', strong ties in between cohesive embedded firms are without any doubt more favorable concerning knowledge exchanges".

Singh (2004), likewise Fritsch and Kauffeld-Monz (2009), examine knowledge intensive industrial clusters. On the contrary, his empirical findings concludes supporting Granovetter's thesis. However, a critical review of the case reveals that firms subject to his study are rather homogenous: they reside within the same region and share very similar knowledge base and expertise. Thus, his reaffirmation of 'the strength of weak ties' holds for the collaboration network of rather homogeneous firms residing within the same region. Presumably, firms either having similar knowledge bases or aiming to build a common knowledge base opt to collaborate and exchange knowledge. Within that setting, it is posited that a broker firm which fills in a 'structural hole' (Burt, 1992) is more likely to diffuse knowledge within the region. It should be noted that Burt's 'structural hole' conception is developed upon Granovetter's (1973) 'the strength of weak ties' theorization.

Concluding remarks of the two studies are contradictory on the surface. However, an elaboration on the nature of flow shows that a network level homogeneity at the cognitive reference system of actors resolves or explains the contradiction. It is observed that diffusion of knowledge emulates the patterns or properties of information diffusion when majority of interacting actors share similar expertise and similar social settings. In other words, sharing similar expertise and social environment eases the transfer of demanding 'know-how' to the level of regular information flow.

Other than examining the strength of pervasive social ties as a variable at knowledge diffusion, the impact of overall network structure or the role of ego-network of individuals on knowledge diffusion is a frequently recurring theme in the literature. In other words, there are many other theoretical and empirical studies whose focus is on how an overall network structure or more often how a particular position of key actors in the network affect knowledge diffusion (Breschi et.al. 2009; Morrison and Rabelotti, 2009; Morrison, 2008; Cassi et.al., 2008; Fleming et.al., 2007; Cowan and Jonard, 2004; Spencer, 2003; Ahuja, 2000; Watts and Strogatz, 1998; Valente, 1995; Burt, 1992; Powell, 1990; Coleman 1988).

Nonetheless, these studies does not clarify the nature of transmittant. Lacking to make distinction in between information and knowledge they miss one of the major axis at making sense of divergence in between similar studies. Besides, lack of elaboration at explaining the stage of knowledge chain they focus, or undermining social settings of the knowledge carriers leads to ambiguity at discussions relating network structure and knowledge diffusion.

Relation in between knowledge diffusion and network structure, thus, can be classified by two different level of analysis: network level and node level. The most prevalent level of analyses are done at the node level. Both theoretical and empirical studies done at this level specifically focus on impact of structure of ego-network of actors on the knowledge transfer as a whole.

3.4.2 Ego Networks and Knowledge Diffusion

There are two major debating approach in the literature on the impact of ego networks on knowledge diffusion. They are attempting to hypothesize on network characteristics of egos and validate empirically optimal ego-networks which foster knowledge diffusion best. The first approach derives upon the Granovetter's (1973) 'strength of weak ties' and its re-conceptualization by Burt's (1992) 'structural holes' metaphor arguing importance of brokerage at knowledge transfer. The second approach is lead by by Coleman (1988). Coleman (1988) argues that being embedded in a cohesive subgroup is increasing the social capital of the ego as the major facilitator of knowledge transfer.

There are also some other yet less prominent line of theoretical discussions. For instance, another influential work, by Valente (1995), addresses and discusses several other network structural characteristics of individuals that may foster diffusion of innovations. The author in particular emphasizes impact of structural equivalence of egos on overall diffusion of innovations within the network. If two individuals have same ego networks, that is if two individuals maintain the same relations with the same others, they are considered as structurally equivalent (Scott, 2000). Thence a structurally equivalent pair might be embedded together in a cohesive group or together may broker different component of a whole network. However, Valente's (1995) line of discussions can be rather paralleled by social cohesion approach of Coleman (1988) at explaining effective knowledge diffusion.

Many earlier studies in the literature, which have examined whether social network of inventors itself is a significant mechanism for diffusion of information, have hinted empirical validity of Burt's (1992) 'structural holes' theory (Morrison and Rabelotti, 2009). That is, egos filling in structural holes are significantly more important at information diffusion. Later studies have started to apply the same framework for very knowledge intensive fields in order to discover or explore potential brokers even without an explicit discussion on the role of 'strength of weak ties' or 'structural roles'.

For example, Singh (2003) examines US patent data on manufacturing in between 1975 and 1995 to explore role of social networks of innovators on knowledge diffusion. The paper, in particular, examines role of indirect ties. The study considers backward patent citations along with innovators' cooccurence on the same patenting team to form one's ego network and to spot bridges. The empirically validated hypothesis of the paper emphasizes the role of brokers providing indirect connections in between scientists. The paper's concluding discussions are in line with Burt's (1992) and Gronovetter's (1978) conception on the role of brokers.

Recurrent empirical support for brokerage has lead many earlier studies take the 'structural hole' framework for granted (Ahuja, 2000). Ahuja (2000) is examining the role of structure of ego's network at diffusing knowledge. He forms network of firms in a cluster of chemical industry instead of individuals. Counter intuitively, the longitudinal network analysis of the study shows that structural holes have negative impact on knowledge diffusion, whereas dense direct ties in between a firm's collaborators enhances depth and breadth of collaborations thence knowledge diffusion. Later studies which also fail to demonstrate affirmative effect of weak ties attempt to explain it by opportunistic actions. They presume that actors filling in structural holes engages in opportunistic actions which degrades the diffusion of valuable information. An opportunistic action, for instance, can be withholding strategically important knowledge instead of giving it away.

Some other very recent works in the literature on knowledge diffusion within and across industrial clusters also challenge conventional assumption about the enabling role of bridges (Morrison, 2008; Morrison and Rabelotti, 2009). Morrison (2008) in his work he examines the role of 'gatekeeper' firms at transferring knowledge into their local industrial networks. His empirical study suggests that know-how acquired from external contacts are kept within the firm and diffused to local contacts in very generic forms. Instead it is observed that strong ties which have supported or enabled by contracts, via strategic partnerships or through dense collaboration on knowledge intensive areas enhance cohesiveness and embeddedness.

Those recent studies acknowledge Coleman (1988) by addressing importance of cohesion and embeddedness of ego within knowledge intensive areas both at fostering knowledge diffusion and at better exploiting knowledge flow:

> "The contradictory effects of connections between partners thus prompt two competing predictions with respect to the relationship between structural holes and innovation. Many structural holes in ego's network will increase ego's access to diverse information and, hence, enhance innovation output. Conversely, ego networks with fewer structural holes might promote trust generation and reduce opportunism, leading to more productive collaboration from the perspective of resource sharing." (Ahuja, 2000: p. 433).

The importance of trust which is formed by strong ties and overall cohesion of a network is gaining more empirical support by very recent studies. Fritsch and Kauffeld-Monz (2009) argue that contrary to 'strength of weak ties' approach strong ties are one of the most important prerequisites for transactions taking place within a knowledge exchange context. However, they cautiously point out that advantageous of strong ties are more often observed at emerging stage of an innovation network which “don’t rule out the argument of Granovetter. It simply shows the importance of the context when analysing the impact of certain network characteristics” (p.16).

3.4.3 Overall Network Structures and Knowledge Diffusion

A large number of attempts are describing in particular how the structure of a social network is influencing the flow of existing knowledge and thence the rate of new knowledge creation.

A very large number of studies from various fields suggest that structural properties effective systems exhibit a high clustering coefficient and low average distance (Cassi et.al. 2008). A high clustering coefficient implies dense local interactions which leads formation of cohesive subgroups or cliques and low average distance implies existence of bridges from one clique to other cliques (Cowan and Jonard, 2004). This structural property of social networks was first conceptualized by Watts and Strogatz (1998) as a `small-world` phenomenon. It is frequently observed that networks which exhibit such small worlds properties enable a high communication within the network and great out reach across boundaries of social cliques, accelerating the rates of knowledge creation and diffusion. These observations are supported either by conducting longitudinal studies (Cowan and Jonard, 2004) or by running simulations (Watts and Strogatz, 1998). While the study by Cowan and Jonard (2004) reconfirms efficiency of small world structures at diffusing speed of knowledge, it also points out and explains how heterogeneity and so expertise and speciality of smaller groups are kept in small worlds.

On the other hand, some recent studies in the literature question if evidences of a small worlds form always imply an efficient knowledge transfer. Fleming et al. (2007) extract co-authorship data from U.S. patent data for the years between 1975 and 2002. They observe existence of regional small-world structures throughout the period. Their longitudinal network data allow them to check if existence of such small worlds can be associated with the output of new patents over the years. Employing statistical models, they test and fail to associate that evidence of small-world structure enhances innovative productivity. But they do find that existence of a well connected giant component acts as a facilitator of new innovations. They have been able to detect the emergence and disappearance of larger connected components with shorter paths in patent collaboration networks. They have been able to observe that emergence of well connected giant component has resulted in increased innovation, while its decline has followed by a decline in number of innovations.

Some other recent follow up studies in the literature study innovative knowledge intensive industries to see what other form of networks can stimulate knowledge transfer, as well. Fritsch and Kauffeld-Monz (2009) suggest that highly cohesive, i.e. not fragmented, networks are very important both at knowledge creation and knowledge transfer.

Morrison and Rabelotti (2009) do research at winery clusters in Italy. More specifically, they are attempting to understand whether organizational properties of firms in the cluster such as their size, performance and knowledge base is also associated with their position within the knowledge diffusion networks:

> "In fact, knowledge flows are restricted to a tightly connected community of local producers, differing in terms of knowledge assets, innovation behavior and overall economic performance with respect to the rest of the firms in the cluster." (Morrison and Rabelotti, 2009: p. 983).

Their findings suggest that clusters with a diverse knowledge network structure perform better. The diversity of the these networks stem from heterogeneity of network properties such as betweenness and concentration of ties which leads to an overall a core-periphery network. They find that firms at connected cohesive core act best at knowledge transfer in between them and to the periphery, whereas firms at periphery are better at knowledge creation and innovation.

Trace of efficient core-periphery structures are also identified by Breschi et.al. (2009). They study knowledge networks formed during execution of European Union research framework programs (FP6). Their study however points existence of both the characteristics of a small world and a scale-free network. They have observed multiple connected clusters of research partners. Each of these clusters exhibits a core-periphery structure. The cores they have identified are usually occupied by very few but large organizations acting like stars or hubs. The hubs are viewed by other local medium or small sized firms as high-status partners. Because these stars are situated at privileged positions of the network and they preferentially form strong connections to the other stars elsewhere. The interconnection in between hubs exhibits a facilitating role for flows of information and ideas which of all are benefits to local partners in terms of knowledge assets and network resources (Breschi et.al., 2009).

This architecture is different from a typical small-world constellation, where each local cluster is exhibiting a scale-free network rather than a very cohesive subgroup. Besides, the bridges are the large organizations which occupy the core of the local cluster. SMEs in a cluster are remaining at the periphery and they are preferentially connecting to the star(s) in the core. This rather different yet efficient network architecture has not emerged endogenously but lead by policy interventions and funding regimes of European Union Commission (Breschi et.al., 2009).

Cassi et.al. (2008) in particular question the role of such policy interventions at building research network infrastructure in order to foster knowledge diffusion towards innovation in Europe. They examine the structure of resulting collaborative networks and observe how knowledge has been transferred between research, innovation and deployment activities. The paper enhances the observations which imply that devised research networks facilitates knowledge diffusion by providing social interaction links and by increasing number of research institutes within the network. The findings of the study also highlights importance of bridges, the ‘gate keepers’, and stars, the ‘hubs’, at the very network level mechanism of knowledge diffusion. The research illuminates how a hub in the network can complement knowledge diffusion mechanism. The hubs keep otherwise isolates or less connecteds remain connected to whole network. A hub node is characterized by both having a high degree centrality and a high betweenness centrality. They fulfill this role by maintaining bulk of the ties in the network. The bridges diffuse research findings in between institutes. The bridges in the paper are the organizations which do occur in both advanced research and development projects and also knowledge dissemination projects. The paper thus emphasizes the role of endogenously strengthened inter-network connectivity at accelerating innovation. The networks that are enforced by funding regimes and research policies increase deployment or embeddedness of actors which are necessary factors for innovation (Cassi et.al, 2008).

Earlier studies along with latest empirical findings suggest that the most knowledge-transfer-wise efficient form of a network structure can not be solely sought by its topological properties but by its regional, social and political contextualization. An earlier work by Spencer (2003) points in that direction suggesting that structural features of networks contribute to "the emergence of dominant designs and the competitiveness of countries' firms and industries" and in return "national institutional structures and firm-specific attributes influence the development of these knowledge-diffusion networks." (Spencer, 2003: p.428).

3.5 Properties of Knowledge Carriers

Although various channels of knowledge diffusion is studied and traced, e.g. citations, the literature in sociology emphasizes the fact that in many settings knowledge diffusion does actually take place when some sort of interpersonal social interaction exists (Singh, 2005; Burt, 1992; Granovetter, 1973). This premise has been a main denominator by majority of innovation studies at attempting to decipher either the overall optimal social network structures or social network position of key influential individuals. Valente (1995), along with common structural patterns exhibited by individuals' centrality, brokerage and structural equivalence in a network as discussed above, pays attention to heterogeneity of individuals' social characteristics as an influence on knowledge diffusion. This trend has lead a new research frontier in the field to study properties of knowledge carriers other than their network positions (Whittington, 2009; Fritsch and Kauffeld-Monz, 2009; Breschi and Lissoni, 2009; Azoulay and Zivin, 2006; Singh, 2005; Osterloh and Frey, 2000; Almeida and Kogut, 1999; Appleyard, 1996; Saxenian, 1996; Valente, 1995; Jaffe et.al., 1993). These researchers are pointing to additional factors which together influence how knowledge diffuses. Amongst many, the most accentuated factors are geographical locations, mobility, culture, institutional motivations, governmental and regional incentives and leadership.

3.5.1 Location

Azoulay and Zivin (2006) study magnitude of knowledge spillover generated by the influence of key scientists in physical sciences. They, in particular, try to identify the most prevalent means of knowledge diffusion channels. Their very extensive study suggests that co-authorship in between co-located scientists is one of the most significant channel of knowledge transfer. Furthermore, their findings suggest this overall impact of co-location is diminishing starting around in 1990s regardless of physical distance and other factors.

Rather an earlier study by Jaffe et.al (1993) points the concentration of knowledge and diffusion paths within certain regions. Although they explain that the impact of locality is faded over time, they don't attempt to explain why and how knowledge diffusion is localized. Annalee Saxanian (1996), in her book *Regional Advantage*, examines traces of institutional paths that have lead Silicon Valley in the west of USA and Boston area in the east into global innovation hubs. She points to the role and importance of personal ties that lead innovative regional networks. She details dynamics of social interactions which stimulates formation of interpersonal ties and which in return induces professional inter-organizational networks. These co-located inter-organizational networks are found to be the engine at developing regional competencies.

Singh (2005) also attempts to understand why co-location is important for better knowledge flows. It reconfirms these earlier studies explaining that pattern of interpersonal ties help to understand why knowledge flows are stronger within regional and organizational boundaries than across boundaries. He supports his findings showing that impact of co-location diminishes again when personal ties are sustained across regional and institutional boundaries.

The very recent study by Fritsch and Kauffeld-Monz (2009) reviews the literature on the importance of spatiality on the diffusion of information. Contrary to the earlier studies they examine what other subtle nature of interpersonal ties are causing the effect that knowledge spillovers often concentrated locally at its source of generation. They again observe existence of strong personal ties which transcend organizational and regional boundaries.

Another very recent work by Whittington et.al. (2009) examines effects geographical proximity together with network position of firms in knowledge intensive regions and regional clusters. They develop a set of hypothesis to empirically test whether network position of actors and their geographic proximity properties are interrelated and if they have independent influences on innovations. They conclude that network position of individual firms and their geographic proximity are having complementary and contingent interdependency on over all innovation efficiency. Their findings suggest that geographically co-located firms are becoming more efficient and so their centrality exists if they also co-embed in global networks. The other important finding of the study supports the observations that structural properties of global networks in return influence geographic proximity of firms (Whittington et.al., 2009).

3.5.2 Mobility

Almeida and Kogut (1999) observe even sub-regional differences while they trace knowledge diffusion within semiconductor industry in Silicon Valley. Their primary focus is to answer why knowledge spillover is more efficient within certain regions. They posit that the variation of knowledge diffusion from one region to another differs because of differences at institutional properties from one region to the other and differences between the structure of networks formed in between these institutions. They run in depth interviews with key scientists in the field. Their findings suggest that institutions by large depend on patent holding scientists at knowledge creation. They explain that network structural and institutional differences at knowledge diffusion are significantly shaped by the mobility of these inventors from one institution to another. They claim that mobility of scientists induce institutional ties which can explain structure of knowledge diffusion networks and the reason of conglomeration of certain innovations at certain regions.

A recent study by Breschi and Lissoni (2009) enhances these rather earlier empirical findings. Employing social network analysis methods, they measure contribution of mobile inventors at different fields to knowledge diffusion across boundaries of firms, cities and states. They claim that mobility of inventors which also shapes co-invention networks reduces the importance of being close geographically. They further hint why previous empirical studies fail to decipher why knowledge diffusion exhibit geographical locality:

> "[T]eams of inventors from different organizations are linked to each other by inventors that move across organizations and act as bridges across them. To the extent that such moving individuals do not relocate in space and remain within the same region, the resulting co-invention network will be also spatially localized. In other words, the most closely connected inventors will also tend to be spatially close to each other and this explains why knowledge flows measured by patent citations exhibit localization effects." (Breschi and Lissoni, 2009: (p.460).

3.5.3 Organizational Form, Culture, Motivation, and Trust

A branch of studies in the knowledge diffusion literature attempt to questions, such as, which organizational form, culture, or motivation is most conducive to knowledge generation and transfer (Osterloh and Frey, 2000; Valente and Davis,1999). Another focus in the literature is on properties of knowledge carrier individuals, e.g., their demographic profile, their ego network orientation, or their cultural differences. For instance, Appleyard (1996) recapitulates impact of cultural differences of carriers at her study on knowledge diffusion process in the semiconductor industry.

Valente and Davis (1999), on the other hand, study the role of opinion leader individuals at the speed of knowledge diffusion. Authors run computer simulations which emulate interaction patterns derived from interpersonal communications via help of standard social network analyses. Their opinion leaders are the individuals with high centrality in the community of science, who are presumably more influential at accelerating the process of diffusion. However, contrary to the standard network simulation mechanism, the opinion leaders are identified by nomination and consensus. A consensus about candidate opinion leaders are sought for their community-wide credibility and trustworthiness.

Osterloh and Frey (2000) point importance of diffusion of tacit knowledge at knowledge creation. They posit that diffusion of tacit knowledge is very much connected to motivation of individuals within an organization. They argue that organizational forms can be detrimental at providing channels of tacit knowledge diffusion if they lack a motivation management.

3.6 Social Structure vs Knowledge Diffusion

Review of literature reveals that knowledge diffusion issues are inherently tentative and are not easily surveyed or observed. Nonetheless, it shows that a theoretical framework which is based on duality or interplay in between social structure and knowledge can be employed to make sense of ambiguities and inconsistencies resulted from empirical studies. It is seen that social attributes of individuals or social settings of knowledge actors influence the knowledge diffusion processes. In return, it is further seen that nature of knowledge itself impacts organization of efficient social structures, namely, the network topologies.

It is seen that relevant studies from the literature on overall network structure, those I have discussed in this chapter, posit existence of a non-fragmented and rather cohesive network topology for efficient knowledge diffusion within the network. Although earlier studies have necessitated existence of 'small worlds', recent studies have found strong evidences that there might be other form of networks, e.g., a single densely connected core, which might act better or explain high speed of knowledge diffusion. The duality of knowledge-social structure framework suggest that this rather contradictory findings can be explained though when the nature of diffusion process is detailed. We see that while 'small world' information networks are good at explaining how informal information such as a rumor or a brand image is transferred to elsewhere in the network, existence of strong ties in between subgroups, or co-existence of structurally equivalent brokers in the networks are required to diffuse specialized and tacit knowledge.

In a similar manner, it is possible to employ an information-knowledge dichotomy to explain rather conflicting results on the ego network studies. Not surprisingly studies conducted at very knowledge intensive areas or in the fields where access to knowledge is difficult and requires being embedded in the network with strong ties support Coleman (1988), whereas line of studies which forms their network based on rather more informal social interactions support 'strength of weak ties' theory which was first coined by Granovetter (1973).

3.7 Contextualizing Knowledge Diffusion in Scientific Communities

3.7.1 Academia and Knowledge Diffusion

Compared to knowledge application activities of corporate R&D departments or knowledge management practices of organizations in large, academia is considered as the most prominent knowledge-intensive area, where academic research involves knowledge creation and dissemination in its purest form (Sousa and Hendriks, 2006).

Studies on academia within realm of knowledge diffusion literature either focus on academic institutes employing theories from organizational management theory (Geisler, 2007; Sousa and Hendriks, 2006) or they engage in discussions borrowing concepts and methodologies from community level social network studies (Davidson and Lamb, 2000). More specifically, studies or practices on management of academic research at organizational level, employs the knowledge-based theory of organizations (Grant, 1996). The knowledge based theory itself derives upon a resource-based view of the firms, where knowledge is the most important resource for competitiveness as "creating, acquiring, storing, and applying knowledge are all considered to be fundamental organizational activities" (Sousa and Hendriks, 2006: p.315) of academic units. Nevertheless, both of the approaches, either be at organizational level or community level, trace how knowledge created in academy is transferred to the industry.

Sorenson and Flemming (2004), e.g., study how publications on theoretical science help more rapid diffusion of knowledge at technological applications. Their theoretical framework is based on the conception that the norm of science compels discoverers to disseminate it to others, which in return proves valuable by accelerating the diffusion of knowledge following its discovery. A bulk of literature in that genre examine impact of means of communication itself as a facilitator of social networks of scientists which lead them to innovate and transfer knowledge to the industry. Majority of these studies examine the role of ICTs in academia which allow them to exchange knowledge (Davidson and Lamb, 2000). The paper by Chen and Hicks (2004), on the other hand, integrates various methodologies adopted from network science in order to detect scientific and technological frontiers by sensing that very knowledge transfer process in between pure science created by universities and its technological implementations by industry.

3.7.2 Diffusion of Knowledge in Co-authorship Networks

Review of literature reveal that knowledge diffusion issues are inherently tentative and are not easily surveyed or observed. It necessitates to elaborate on the set of issues I have outlined and discussed above to clarify my analysis framework while studying knowledge diffusion in co-authorship networks.

Co-authorship networks are formed intentionally and deliberately by scientists. The choice of co-authorship networks is not arbitrary. The autonomous and self organizing nature scientific practices towards knowledge creation and diffusion situates co-authorship networks as the most appropriate framework or mode of knowledge transfer. They are inherently different than other form of informal social networks. Scientist purposefully look for and select their co-authors in order to collaborate for a tangible research output or for the presentation of a scientific knowledge. In other words, this nature of collaboration via co-authorship implies that interactions do not emerge from unplanned and occasional contacts; rather they are structured form of knowledge exchange and sharing in between co-authors.

This very nature of co-authorship network leads me to differentiate in between knowledge and information, in first place. Thus, my discussions will follow the line of studies where exchange or transfer of knowledge is considered. That is, deriving upon publication data as solid indicator of knowledge dissemination, I will focus on knowledge transfer stage of a full knowledge chain.

Paralleling similar studies from the literature, I assume that knowledge transfer process via co-authorship is neither purely regulated by price mechanism of markets nor contractual arrangements within universities, but rather by informal self-organized network forms of knowledge carriers. Nevertheless, my assumption does not exclude indirect influence of market or institutional or national level policies on the incentives of scientists at forming scientific collaboration ties. In that respect, network theories to be employed or adopted necessitates me to pay more attention at contextualizing and clarifying my network approach.

A theoretical perspective which is based on mutuality of social structure and knowledge further necessitates to contextualize case studies. As an exemplary case, I consider knowledge diffusion in management discipline in Turkey. The nature of scientific collaboration I study requires a common knowledge background in between co-authors and a level of commitment for publication. Apart from their network properties, knowledge carriers of my case are sharing similar cultural values and are subject to similar institutional settings in terms of governance and academic policies up to late 2000's.

The primary source of data in my case consists bibliographic entries of scientific articles in Turkey. Along with practical reasons, I deliberately exclude citation data of each publication in my analyzes. Literature points out the limitations and shortcomings of studies which uses patent or citation data to examine knowledge transfer. The studies based on social networks formed by co-citations or co-patenting fail to specify network boundaries. In addition, these networks can capture only a fraction of social collaboration. Besides, particularly, in the case of citation data it is not possible to analyze the impact of social network structure on knowledge transfer (Fritsch and Kauffeld-Monz, 2009). Following relevant empirically supported theoretical discussions, I opt to form social networks based on national level co-authorship data to overcome those shortcomings.

In addition, I use titles of published materials uniformly and when necessary available keywords, abstracts, and source of publications to study relations in between collaboration structures and development of management knowledge. Use of published materials however constraints me to probe diffusion of management knowledge which are made explicit via bibliographic information. Although diffusion of scientific knowledge via publications can be best situated within knowledge codification stage of whole chain, it implicitly entails experience accumulation and knowledge creation activities and processes. I am not primarily engaging in examining the prior stage leading the knowledge to be codified in the form of a scientific paper and its social, organizational or technological implementation stage afterwards.

Chapter 4

Co-authorship Networks

Based on the literature on knowledge diffusion, we can summary a set of mechanisms on how knowledge is transferred across time and distance. A set of studies emphasize the role of key actors or scientists. Within this perspective knowledge is diffused often times by direct social contact in between academicians. There are various form of contacts which contextualize social means and media of knowledge diffusion in scientific communities. The first form of contact is in a form of master-apprenticeship relation, where education and training is necessitated as means of knowledge flow. A second set of studies emphasize the role of involuntary knowledge transfer, where knowledge is acquired by indirect channels via publications, etc. The third set of studies highlight the role of teamwork at knowledge sharing. Co-authorship is then a formal evidence of teamworks where knowledge is shared and reproduced by team members, namely, the co-authors. In this dissertation, I focus on such form of social contact at knowledge diffusion.

Co-authorship as a form of collaborative teamwork form of knowledge creation, codification and transfer is studied over the publications. Studying and analyzing co-authored publications has become the convention to measure research collaborations. Previous literature validates use of co-authorship networks in order to study collaboration in scientific communities:

> "Co-authorship is one of the most tangible and well documented forms of scientific collaboration. Almost every aspect of scientific

> collaboration networks can be reliably tracked by analyzing co-authorship networks by bibliometric methods." (Zitt et.al., 2000: p.257)

On the other hand, literature also suggests that collaboration in the form of co-authorship, per se, is a very complex phenomenon, where numerous factors from different levels continuously and contingently interact. These factors varies from very micro levels determined by individual decisions or influenced by individual characteristics to international level science policies outlined by bilateral or multilateral cooperation programs. These factors together influence micro-decisions taken by scientists consciously or unconsciously. The micro-decisions are reflected by regular patterns which shore up in macro forms of co-authorship network structures.

This chapter attempts to review literature on collaboration via co-authorship extensively and critically within the context of the dissertation work. It further contributes to an ongoing theoretical debate on the models of empirical co-authorship networks after its systematic and a relatively thorough review.

4.1 Co-authorship Studies

Research literature on co-authorship goes back to mid 1960's. By the end of 1970's it has become a new field of study by scientometricians. These early yet relatively comprehensive studies has attempted to combine statistical properties of co-authorships to its social implications. They have been looking at collaboration practices derived from bibliographic datasets. By early 2000's it has captured attention of network scientists. Newman's (2000) analyses has made the subject a hot topic for other scientists with diverse backgrounds from sociology to statistical physics and computer science. It is this stream of research which comprises the bulk of publications on the subject.

Most of influential publications however comes from scientist from statistical physics field. In general, they have conducted research for the sake of studying mathematical properties of the co-authorship networks. In that sense they approach co-authorship form of collaboration as a specific case of the more general complex social networks. Thence statistical parameters and methods to be applied on co-authorship data is relatively well developed and tested. However, most of these studies suffer from the extend and coverage of their cases. Besides they have focused more on steady state nature of co-authorship leaving out its evolving nature. Nevertheless, very recent publications in related top journals show sign of increasing propensity to examine dynamic properties of co-authorship.

The other and the most important deficiency of the literature is that it lacks thorough social, economical, organizational, and implications of well developed network metrics. There are few studies, and most of which are very recent publications, which address social implications of examined social network topologies, observed patterns and their evolution.

In the rest of the chapter, deriving upon studies in the literature on scientific co-authorship, first, I will discuss to what extent co-authorship represents and explains scientific collaboration. Scientific collaboration literature contains some other alternative approaches as well, such as, constructing science networks based on paper to paper citations data. We will compare and contrast co-authorship networks with citation networks in terms of their respective validity and power at exploring social dimension of knowledge diffusion.

The literature disseminates contradictory empirical results on co-authorship network properties and their social implications, which requires a finer scrutiny on the source, scope and time spans of bibliographic data used as well as unit of analyses. In Section 4.3 and Section 4.4, I attempt to classify source and scope of datasets used along with various levels of analyses.

In Section 4.5, I review co-authorship network analyses. The review is detailed in terms of variety of metrics adopted and their implications; the focus of ego level and overall network level perspectives; and topological models of the network structures and their corresponding mathematical models. In addition, I overview debating models in longitudinal studies which attempt to better explain how co-authorship networks grow or evolve over time.

A bulk of studies, principally published by scholars from various social science disciplines are particularly interested in exogenous and endogenous factors which influence co-authorship patterns or influenced by them. As of exogenous factors addressed in the literature, Section 4.7 briefs empirical and theoretical studies which examine globalization; advancement at information and communication technologies; historical, political and economical path dependencies and institutions; and inter-play in between academy, market and government policies, the phenomenon which is so called the triple helix. As of addressed endogenous factors, it briefs mobility of individuals; diversity of co-authoring teams; and their geographic proximity. Many of those studies use a subset of these factors regarding their impact on productivity estimated by number of publications produced. Some other studies, however, either quest or model correlation in between ego network of individuals and their productivity, or impact of network topology on productivity. I address, those productivity related studies in Section 4.6.

A relatively new stream of studies examine Web visibility of co-authorship or offer to exploit co-authorship data extracted from the Web as an alternative mean of studying scientific collaboration. Section 4.7.7 discusses this new track in the literature.

Finally, in Section 4.8, I attempt to reveal some of contradictory findings in the empirical studies in the literature and attempt to interpret and explain those discrepancies. The discussions demonstrate how proposed models from the literature is sensitive the selection of primary data. The discussions further emphasizes importance of appropriate selection of data that can represent social context of co-authorship practices.

4.2 Co-authorship and Collaboration

Scientific collaboration began to expand significantly in many fields and primarily in natural sciences since World War II (Wagner-Dobler, 2001). The increase in the number of collaborations then have become subject matter of many studies. A major branch of those collaboration studies has derived upon co-authorship data as a sole indicator of scientific collaboration. At the same it has been criticized that co-authorship based indicators should be handled with care as a source of evidence on actual and extend of scientific collaboration.

4.2.1 Limitations

Katz and Martin (1997), in their paper 'what is research collaboration?' discuss extend and limitations of co-authorship as a valid indicator of scientific collaboration. Although they conclude that co-authorship is yet the best partial indicator of collaboration in science, they point the fact that there are many form of scientific collaborations which do not consummate in a co-authored paper. For instance, internal technical papers or seminar presentations done within the institutes are very rarely published. In addition, co-authorship relations can be retrieved from only those articles submitted to conferences, workshops and journals which are indexed by currently available digital libraries.

Considering the fact that co-authorship is a formal and professional form of social interaction, it might lack to reveal or hint underlying informal communication when it exists. Zuccala (2006) states that although it is easy to access documents and "create bibliometric maps of the intellectual structure of scholarship, it can be problematic to assume that they reveal much about underlying informal communication." (Zuccala, 2006: p. 155).

The study conducted by MJ Kim (2005) reflects another limitation at the usage of available bibliographic data in empirical studies. His work exemplifies how researches conducted to trace international collaboration might be exposed to significant errors which stem from source of data. Majority of studies which examine international level co-authorship are conducting their empirical work based on international databases, more commonly the SCI database[5]. However, the extent of publications indexed with a database might change dramatically. MJ Kim in his study which is based on SCI database for the years 1995 to 2000, observe a dramatic decrease in the number of international level collaborations of Korean scientists contrary to general increase in the number of scientists in Korea, excellence of research infrastructure and increase at national level publications. Having a closer look at the data, he realizes that it has been caused by solely exclusion of an important number of Journals from the database after 1998 in which Korean scientists have been publishing (Kim, 2005).

The studies conducted in the field have also examined to what extend collaboration in science represented by co-authorship reflects patterns of other form of non-scientific social collaborations. For instance, Kretschmer and Gupta (1998) examine the scientific literature at the field of theoretical population genetics in between 1900 to 1980 to compare and contrast co-authorship patterns with other non-scientific yet social interactions. They particularly show that patterns of scientific collaboration formed upon co-authorship data reflects social network patterns observed at non-scientific populations.

4.2.2 Citing vs Co-authoring

A parallel stream of studies in scientific collaboration literature has grown on publication citations (White et.al., 2004; Li-Chun et.al., 2006). These studies on citation practices use citation counts and patterns of citations in their analyses. The citation practices and their implications have widely conducted for various disciplines. Studies by information scientists often adopt quantitative approaches to underline "the disparities between more and less prestigious authors or to characterize the rate at which knowledge becomes obsolete in different fields" (Bechner and Trowler, 2001: p. 114).

White et.al. (2004), on the other hand, claims that many authors within network science have conceded a social component in citation networks, assuming that citers and citees often have interpersonal as well as intellectual ties. However, authors' conclusion is based on their empirical study which is drawn from publication of an international special interest group of 16 researchers. Their findings are very biased and can not be generalized. It consists of a small group of scientists who already knows each other. This group of scientists are formed in order to study human development interactively, which increases the fact that they would cite each other.

Many other empirical and theoretical studies discuss that citation networks does not necessarily imply social connectedness (Scott, 2000; Wasserman and Faust, 2006):

> "Citation networks, the web, and Wikipedia cannot be considered social networks in the proper sense, although they do support communication and information transmission in social contexts." (Tomassini and Luthi, 2007: p. 751).

4.3 Data Sources, Scopes and Time Spans

Literature as a whole suggests that the validity and implications of empirical findings on co-authorship are bound very much by the selection of data source, its scope and time span of its bibliographic entries. It is also seen that scope and depth of majority of those case studies are in return shaped by availability and organization of data resources.

Almost all of the datasets of the empirical studies are extracted from electronic resources. It is possible to mention two slightly overlapping periods regarding the main mean of access to those electronic resources. While studies up to millennium are driven from offline data resources such as CD-ROMs or microfilms, after the years following the millennium remote access to online digital libraries has become the prevailing mean. This shift was lead by prominence of large bandwidth of Internet connections along with increase at size and coverage of digital resources and services, which also provide use of search engines as part of their services. The shift also coincides with fast grow in number of studies on co-authorship networks and relevant works.

Major digital resources are collecting data on international journals, proceedings, etc. There are also increasing propensity by countries to form national digital resources. Management of such country level or regional databases are mainly financed by public. They collect national level publications which may also cover part of international publications made by citizen scientists. While country level databases are rather extensive attempting to cover all national publications. International digital resources are more selective and they are usually narrowed by disciplinary sub-categories.

The nature of bibliographic data enables researches to access year information of a publication, which makes it easier to pick a time window to examine a set of co-authorship phenomena within that period or conduct periodization over several subsequent or overlapping durations. This has lead studies either to conduct a static analyses where bibliographic data of selected time window is cumulatively analyzed or run dynamic longitudinal analyses where changes over time within the picked time window is probed. Static analyses assume patterns of collaboration has reached a steady state (Tommassini and Luthi, 2007).

A great majority of longitudinal studies appear in last decade. However, the coverage extends back to early 1980's. This date coincides with the availability SCI database made available back to that time. These longitudinal studies usually cover 5 to 10 years of a subset of publications available in the data set. In these studies, the evolution of co-authorship measures over time is traced. In addition to that, many other studies examine and attempt to understand how a co-authorship network grows. In other words, they probe how new collaborations are formed in between existing scientists given their collaboration history.

To my knowledge, the longest study conducted backwards in time is covered by Roland Wagner-Dobler (2001). Nevertheless, he uses off-line databases and forms a small data set which covers subdisciplines only in mathematics, logic and physics. He examines rate of collaboration in these fields for the years from 1800 up to 1998.

4.4 Unit of Analyses

Unit of analysis of co-authorship studies can be classified into two categories: individual level studies and aggregation level analyses. At individual level each author is taken as the subject actor, whereas at aggregate levels authors' affiliation information is used for superpositions. These superpositions varies from clique of authors to departments, institutions, regions, or countries. Individual level analyses address a very large range of studies, i.e., from examining motivation of individuals co-located in the same department at participating to collaborations to examining impact of globalization on co-authorship patterns emerging in between individuals living and working in different countries.

At individual level, for instance, Lee and Wee (2007) examine social co-hesiveness and the level of social capital in a network formed by faculty members of the same university. They examine co-authorship at the National University of Singapore. Their finding hints explanatory power of co-authorship networks at identifying emergent communities of practice and mapping the structural dimension of the social capital along with detecting research networks. On the other end, Engels and Ruschenburgh (2006) study individual aspects of globalization in social sciences on expansion of international level co-authorship. Their empirical study, which is in particular supported by qualitative analyses of institutes in Germany and USA, hints increase of frequency of existing co-authorship patterns in between OECD countries. Their finding suggests that impact of globalization is contextualized by existing political and historical ties. It is seen that these ties are enhanced significantly by the help of globalization but it does not necessarily imply denationalization of co-authorship patterns.

Aggregate level analyses are becoming necessary because of complexity of collaboration via co-authorship:

> "Research collaboration and co-authorship in science is an interesting multi-faceted phenomenon. In order to understand and to interpret collaboration and co-authorship in a correct manner, co-operation must be studied at each level of aggregation in its specific way. Collaboration among individuals is at least in part subject to other motivations than collaboration between institutions and countries." (Zitt et.al.; 2000: p.273).

Levels of aggregation in the literature can be classified as institutional, national and international. The institutional level analyses (e.g., Chen and Huang, 2007; Mahlck and Persson, 2000) examine collaboration in between institutes derived from papers written by individuals from different institutes. That is, a collaboration in between two institutes assumed to exist if their members have collaborated. Most of these studies refer to or discuss network topological properties of inter-institute ties within a research context.

In a similar manner, country level aggregation is used to study international level co-authorship. Majority of studies at that level focus to understand why and when international research is opted. For instance, Glanzel (2000) runs country-wise comparisons to understand simply magnitude of involvement of individual nations in international collaborations. On the other hand, Wagner (2005) conducts a research on international studies to probe amplitude of overall growth, irrespective to any sociopolitical or politico-economical differences of countries. He takes two snapshots one in 1990 and the other in 2000 and examines change at level of collaboration in six fields, namely astrophysics, geophysics, mathematical logic, polymers, soil science, and virology. His research shows that international collaboration grew significantly in all the fields they have examined. More recent studies at that aggregation level then address the structure of growing networks. For example, Kim (2006) in particular examines scientifically peripheral countries at taking part in international collaborations. He observes different trends on the structure of collaboration networks for the years from 1970's up to 2000's. His findings, in contrast to Wagner (2005), emphasize impact of socio-political and technological contingencies at shaping patterns of collaborations.

Studies which construct international level aggregations usually do so to compare and contrast different geographic regions at international arena, or socio-political systems, or simply developing vs developed countries. Gaillard (1992), for example, compares and contrasts co-authorship strategies of individual scientists in developing countries with respect to observations from developed world. However, that very study is developed upon a very small set of data. A similar but more extensive follow up study by Melin et.al. (2000) compare patterns of co-authorship in Taiwan to developed Western countries to examine if they differ in the structure and if so whether it can be explained by cultural differences.

Zitt et.al. (2000) aggregates data on leading European union countries Germany, France and Britain from early 1980's towards the millennium 2000.

They find that given geographical and cultural proximity and size of the scientific community in these countries along with being in the same political union, the level of collaboration in between them remains low. British scientists are observed to co-author more often with scientists in former commonwealth states, while French scientists are collaborating more often with former French colonies and German more often with geographically adjacent countries. Their findings highlights dominance of historical, economic and linguistic affinities over geographical and political proximity at co-authoring patterns.

Aggregation level studies in general show that process and dynamics of national level collaborations are very different than international level collaborations (Leydesdorff and Wagner, 2008). Each nation has its own scientific communication system which is stimulated by national level policies and its institutions. Besides, other studies reveal that language, culture, and geopolitical location are shaping preferences in co-authorship towards emergence of national level patterns (Schubert and Glanzel, 2006).

4.5 Network Analyses

The very nature of co-authorship information defined by the relational data of co-authoring results in a literature wherein almost all of them employ social network analysis techniques to some degree. This enable researchers take two complementary approach in their study. In the first approach, usually rate of collaboration is taken as dependent variable and then its antecedents or consequences are examined in various contexts and scope with a corresponding unit of analysis. Thus, these approaches address factors which influence collaboration rates or cause emergence of a dominant pattern of collaboration. In return, they examine consequences of collaboration trends or emerging patterns as of observable scientific productivity or knowledge diffusion. Majority of studies discussed in Knowledge Diffusion Chapter 3, and in Sections 4.4, 4.7, 4.6, 4.7.2 takes this approach.

The second approach focus more significantly on the co-authorship network structures and relations in between network properties, structural models and network growth over time. Conceptual framework of these studies is formulated by Yin et.al. (2006):

> "The structure of the network affects the information available to individuals, and their opportunities to collaborate. The structure of the network also affects the overall flow of information, and the nature of the scientific community. ... Some network structures may promote diverse and creative work; other network structures may create separation and retard creativity." (Yin et.al.,2006: p. 1600).

This conceptual formulation enhances theoretical framework of this dissertation which is based mutuality of social structure and knowledge as discussed earlier in Section 1.3.

In this rather indigenous and context free approach there are four main branches of investigation. In the first one, which is the quest of rather earlier studies, the focus is on developing sound social network metrics or adopting the ones from complexity literature with their re-interpretations within scientific collaboration realm. While the second branch of studies delve more into ego-network analyses of key scientists, the third one develops a network level approach attempting to model overall network topology. The ego level analyses investigate node level local properties, such as looking at distribution of publication productivity of individual scientists, assortativity in between co-author scientists, or brokerage of key scientists. Network level analyses, however, investigate more global properties such as connectedness and fragmentation level of whole network, or attempt to discover clusters or other cohesive subgroups like cliques to investigate their structures or their structure related properties. The fourth major branch of studies combine local and global properties and trace them over time or attempt to model their change over time.

4.5.1 Metrics

Erdös number[6], an index, which is quite popular amongst mathematicians is presumably one of the most inspiring metric of scientific collaboration literature. Therefore it is not surprising that it is mentioned often times at the introduction sections in the scientometrics literature. Paul Erdös, a Hungarian mathematician travelled around the world collaborating with other mathematicians. In his life time, he was able to publish over 1400 papers with over 500 scientists. Erdös number of Paul Erdös' direct collaborators is one, it is two for the coauthors of his coauthors, and it goes on so. For instance, to our knowledge, Erdös number of one of the member of this dissertation committee is just two. Small numbers as such reflects tight interconnectedness of scientific community. However, the nature and structure of interconnectedness of scientific activity has very recently motivated many researchers both from social sciences and natural sciences to study the phenomena in a larger scale within realm of complex social networks.

Not surprisingly, scientists from statistical physics who work social complexity in general have contributed most at developing co-authorship network metrics and their empirical validations via case studies. MEJ Newman's works (2001a; 2001b) have lead a series of methodological research at soliciting and validating relevant statistical metrics. He demonstrates use of those metrics and their contextual parametrization to explain social phenomena in co-authorship networks. He worked on electronic databases of publications from various fields. Using a 5 year-long data, he contextualizes use of following network metrics, details of which are given in Section 5.2 and 5.2: number of authors; mean paper per author, authors per paper; distribution of number of collaborators; the size of giant component; average degrees of separation (the network diameter); degree centrality; betweenness centrality; and clustering coefficient. Subsequently these metrics are adopted not only to study structural properties, models and growth of overall co-authorship networks but also to study ego networks.

In addition to aforementioned metrics, Newman (2001c) studies connectedness of an author to her/his collaborators. For that reason he demonstrates two other metrics. In the first one, he measures the strength of collaboration in between a pair. To measure it, he considers number of papers they have co-authored and number of other co-authors they had while collaborating. Thus, a pair who collaborate very frequently with no other co-authors, would be considered a very connected duo. In the second metric, he attempts to measure importance of one's collaborators, in a way, to acquire knowledge from the network or transfer knowledge to a network. In this metric, he is able to spot one's bridging collaborator to whole network. Another metric he has developed later in a follow up study (Newman, 2004) is the degree assortativity of authors, which measures correlation between one's degree centrality to his collaborators. That is, it checks whether a given author collaborates with others' who have published more less similar number of papers with him or not.

Although MEJ Newman (2001a-c) was able to work on a large amount of data, the approach he has attempted was static (Barabasi et.al., 2002; Newman 2004; Tomassini et.al., 2007). Barabasi et.al (2002) together with some other researchers from various institutes have attempted to overcome Newman's (2001a-c) limitation by conducting a series of longitudinal analysis tracing evolution of those metrics over the years. Another branch of studies adopting similar metrics developed by Newman (2001a-c) examines ego networks and role of sub-groups within a discipline (e.g., Moody 2004, Hou et.al. 2008).

4.5.2 Structural Properties

Connectedness and Fragmentation

In a given network, measures such as number of components, density of whole network, size and ratio of giant component and average distance or degree of separation are adopted to probe connectedness or fragmentation of a scientific community.

Tomassini and Luthi (2007) in their in depth research attempt to discover how fragmentation occurs and what factors lead or shape the fragmentation in scientific communities. They observe that "a collaboration network is fragmented into many connected components, which may correspond to discipline boundaries, or geographical and location boundaries, or both. There are also human behaviors that may result in fragmentation such as researchers who almost never collaborate with others or groups of people who collaborate solely within the group (Tomassini and Luthi, 2007: p. 753)."

For instance, Newman (2001a) studies differences at degree of separation in between computer science, physics and biomedical fields. In his 5-year long time window he observes that science works better if it is less fragmented, where again scientific practice in general implies that connectedness in between researchers, which can be sensed by a small degree of separation, is necessary for productivity and can be reached by realization of collaboration.

Subgroups, Cliques and Invisible Colleges

Detection of key scientists who collaborate and lead a field has attracted many researchers in the literature (e.g., Moody, 2004). Computational methods and tools enable them to spot cohesive subgroups or cliques of scientists. Most of these studies however attempt to discover these highly interconnected group of scientists within a given boundary, such as, a particular institute, or a specific journal. Detection of cohesive groups across boundaries, so called invisible colleges, has also been addressed recently, where an invisible college is defined as:

> "a set of interacting scholars or scientists who share similar research interests concerning a subject specialty, who often produce publications relevant to this subject and who communicate both formally and informally with one another to work towards important goals in the subject, even though they may belong to geographically distant research affiliates." (Zuccala, 2006; p. 156).

Alesia Zuccala (2006) points impact of inter-disciplinary studies at establishing such invisible colleges of scientists which extends institutional and national boundaries. Hybrid problem areas in which involvement and collaboration of researchers from different backgrounds are needed have been found to stimulate formation of invisible colleges.

4.5.3 Network Models

The literature reveals a set of different yet recurring topologies of co-authorship networks, which are small-worlds, scale free networks and fragmented structures. Occurrence and prevalence of one over the other forms is determined by the nature and stage of the field under examination, as well as, depth and scope of the community covered in the study.

Small-world networks are detected when the whole network exhibits a very large clustering coefficient and a small average path length in between scientists (Newman, 2004; Moody, 2004; Barabasi et.al., 2002). A community where it has a multiple of cohesive research groups connected by a small number of bridging scientists reveal these small-world characteristics. Newman (2004) examines and compares, biology, physics and computer science fields. The overall network structures in all of these fields exhibit small-world characteristics. His research data covers publications in major US journals in respective fields.

Flemming and Marx (2006) examine co-authorship network of US patent inventors from 1975 to 1999. They fail to observe a small-world structure at individual inventors level. However, the structure of network formed at aggregate level in between firms reveal small-world characteristics. They find that increasing mobility of inventors in between companies has lead to formation of 'small world' network at aggregate level of innovator companies.

Yet both theoretical and empirical studies have shown that small-worlds models lodge the risk of shattering into a fragmented structure with many isolated components. The risk arises where there are a few number of key hubs or stars with no structural equivalent actors in the network. For instance, Yin et.al. (2006) in their study on structural study of COLLNET[7] identify that the network is not robust enough. They show that removal of three core actors from whole network dramatically changes connectedness of whole network resulting in many disconnected components.

Literature suggests that scale free networks on the other hand exhibit relatively more robust network structure in terms of connectedness of whole network in cases of node removals from the network. A node removal may correspond, for instance, exit of a scientist from the field. Scale free networks are characterized by a connected giant core component and a 'preferential attachment' model of link formation. Scale free networks are observed in the studies where coverage of scientists is diverse and/or coverage of data sets are extensive comprising of publications from a diverse set of journals or proceedings.

In preferential attachment model, chance for a scientist to form a new tie is proportional to his/her existing ties. In other words, it is seen that new authors prefer to collaborate with star authors suggesting that probability of having a new partnership in the future is proportional to one's number of existing published papers. James Moody (2004) in his study attempts to identify a structurally embedded groups who dominate a discipline, he observes their existence and examines their characteristics. These networks which accommodate cohesive and structurally embedded groups neither do support a preferential attachment model or a small-world phenomenon.

Scientific communities in their birth stages, or with very diverse research agenda, or with less propensity to collaborate do exhibit a very fragmented nature with very small isolated research groups or singleton scientists (Gossart and Ozman, 2009).

4.5.4 Network Growth and Evolution

A part of literature trace the growth of co-authorship networks over time. Degree distribution of authors at a given time window allows researchers to observe when the network under examination exhibits a scale free model, a small-worlds model, or other less salient collaboration forms. It is shown that while an exponential degree distribution implies a small-worlds model, power law distributions indicate scale free model, where network is growing with a preferential attachment mechanism (Barabasi et. al., 2002; Newman 2004; Tommassini and Luthi, 2007).

More often, the longitudinal studies explore and trace evolution of other node level or network level parameters over the years. For instance, Barabasi et.al. (2002) examine network level evolution at collaboration in mathematics and neuroscience in US reflected by journal publications. They find that both of the disciplines have a power law degree distribution. New entrants and existing authors prefer to collaborate with higher degree authors, where degree of an author is estimated by number of his/her publication in respective set of journals. They also observe that average degrees increase over time, while average node separations decrease over time. The other metrics they have examined are the clustering coefficient and the size of giant components. They find that clustering coefficients decay with time but giant component sizes increase with time. The increases of average node degrees along with decreases in node separation and clustering coefficient together suggest that scientists in field keep publishing but instead of keeping to collaborate with previous co-authors they form new ties picking new collaborators. As a result, a connected giant component increases over time. Furthermore, the power law degree distributions again along with decreasing clustering coefficient suggest that the connected giant components are comprising of collaborations formed around star authors but not by bridged small-worlds.

The study by Barabasi et.al. (2002) has two certain limitations (1) the study has a narrow time window covering only the years in between 1991 up to 1998, besides, (2) it covers only a subset of publications within explored time span. Thus, chosen samples to represent co-authorship in mathematics and neuroscience in US lack all of relevant data prior to 1991 and they miss out many other bibliographic data within the examination period. Tommassini and Luthi (2007) tackle these limitations in their analysis by studying co-authorship network of an emerging and a very specific sub-field. They study publications on genetic programming discipline by collecting co-authorship data retrieved from all of related journals in the field starting from its very first inception in 1986 up to the year 2007.

Findings of Tommassini and Luthi (2007) parallels Barabasi et.al. (2002) at recurring characteristics of co-authorship networks, such as, preferential attachment phenomenon, increase at average degree over the years, grow in number of authors and increase at the rate of collaboration over the years. Moreover, a rather complete data allow Tommassini and Luthi (2007) to detect two different regimes. For instance, they observe that growth of authors exhibits two different linear regimes, a very slow linear growth in between 1986 and 1996 and a steeper linear growth in between 1996 and 2007. On the other hand, corresponding growth in the number of collaborators exhibits two distinct regimes. In the first period, the growth in number of papers parallels growth in the number of authors, but in the second period it exhibits a quadratic nature.

They also find a periodic difference at formation and evolution of giant component. In the first period the network is fragmented which consists of many isolated small components. The birth of giant components happens around 1996 and it grows steadily afterwards. Additionally, the authors trace number of components over the years and size distribution of connected components. The size of a connected component is determined by the number of authors in the component. It is seen that size of components, similar to degree distribution of individual authors, fallow a power law distribution.

In contrast, cases examined by Barabasi et.al. (2002), degree distribution at genetic programming network of Tommassini and Luthi (2007) follows a distorted power law distribution which can be modeled as an exponentially truncated power law distribution. Besides, they observe an increase in clustering coefficient in the second period and an increase in node separation within the giant component.

Literature suggests that collaboration in a field as specific as genetic programming network studied by Tommassini and Luthi (2007) would reveal small-worlds characteristics (Newman, 2004). However, Tommassini and Luthi (2007) are not able to observe it concluding that network they study exhibits a scale-free network model. They fail to explain it why. The remark of a distorted power law distribution leaning to an exponential distribution along with an increase in clustering coefficient hints emergence of small-worlds in the network. Nevertheless, transformation into a small-worlds completes when a network exhibits a decreasing node separation, namely a decrease in average path length, as well. In their case, on the other hand, path length increases which inhibits transformation of the connected giant component into a small-worlds community structure.

Ausloos and Lambiotte (2007) as well seek to observe any periodical differences in their data. They apply a moving time window approach. That is, instead of adding data to the longitudinal analysis cumulatively over the years, they use sequences of an overlapping time window of 3 years. In other words they attempt to observe evolution of the network taking 3-years long overlapping snapshots, such as, 1995-1998, 1996-1999, 1997-2000, and so on. In that way, they examine change in the basic network features, such as, degree centrality of co-authorship network over ten years in between 1995 and 2005.

Longitudinal network research also address trends at collaboration rates, particularly, at interdisciplinary studies. For instance, Qin (1994) traces collaboration rates and development of interdisciplinary studies back from 1901 till 1991. However, findings of the study is not generalizable as author traces collaboration rates looking a small set of authors he has selected.

Evolution of collaboration overtime extending beyond sub-fields covering all publications at a national level have also been addressed. As an example, Kundra (1996), investigates collaboration trends in Indian medical sciences looking at rate of multi-author papers over the years between 1900 and 1945. The study fails to observe a strong trend at collaboration rate over that period. On the other side, Vilan Filho et.al. (2008) study the evolution of basic statistical properties of co-authorship and publication productivity of scientists in major Brazilian journals from 1972 to 2006. As another example, Yoshikane and Kageura (2004) study evolution of co-authorship networks of a set of engineering and chemistry sciences in Japan. Authors extract data from national level conference proceedings. They perform their network growth analysis from the perspective of ego, i.e., taking average values of observed characteristics of egos to explain whole network. Authors examine change in the number of total collaborators one has over time and change at inequality in terms of frequencies of collaboration in between ego and each of her/his collaborators. By observing link strength with each partner, thus, they examine the change of the variety of relations in ego networks. They adopt and develop a Gini index to measure inequality at link strengths over the whole network. They conclude that amount and rate of collaboration is growing steadily in Japan.

None of aforementioned national level network growth studies discusses factors peculiar to national contexts which might influence characteristics of collaboration or its growth and evolution.

4.6 Co-authorship and Productivity

Scientific productivity has been studied widely elsewhere, co-authorship network studies however specifically address impact of collaboration on individual productivity or its accumulation at various aggregate levels. Productivity oriented co-authorship studies focus to reveal significant factors which might influence number of publication output. These studies not necessarily driven from bibliographic data sets.

For instance, Lee and Bozeman (2005) run in depth surveys to examine interrelation between publication productivity and co-authorship. Their findings driven from around 500 scientists in USA reveal that at individual level the number of collaborators is not a significant indicator of publication productivity. On the other hand, they do find significant effects of research grants, citizenship of individuals, collaboration strategy, and the field of study on the publication productivity at individual level.

Yoshikane et.al. (2009), instead, take a diachronic approach to examine productivity of authors. They look at top tier journals in computer science in between 1991 to 2007. They probe newcomers in the field and their first co-authors. They quest whether prior productivity of a newcomer's co-authors has any positive impact on his/her productivity afterwards. In other words, if a newcomer starts publishing with a very seminal author would that have a positive influence on that newcomer's subsequent productivity. They fail to observe such a positive correlation. However, they do find a positive impact on newcomers' continuity in the field. That is, those newcomers who have entered to the field with a productive co-author, who is supposedly a mentor, keep publishing and remain in the academia.

Seglen and Aksnes (2000) examine if there is any significant correlation between research group size and productivity. Their research based on co-authorship network of Norwegian microbiology literature revels no such relation.

4.7 Exogenous and Endogenous Factors

Numerous factors, such as local, regional or country level contingencies; institutional policies; interaction of market, government and academy; geographic proximity in between scientists; globalization; advancement in information and communication technologies are major exogenous factors addressed in the literature. On the other hand, motivation; team diversity; self-organization; nature of scientific activity; peculiarities of a field are amongst major indigenous factors addressed in co-authorship studies.

4.7.1 National vs International Contexts

A large number of studies in the literature trace national or international collaboration rates over the years without addressing or explaining peculiarities. For instance, Vogel (1997) traces number of publications over the years and rate of international collaboration of Chilean physics in between 1987 and 1994. Doneto and De Oliveira (2009) does it recently to demonstrate contribution of Portuguese cancer research to the international publications over 1997-2006. Leta and Chaimovich (2002) examine growth of international publication rate of Brazilian scientists in between 1980 to 2000, while Farahat(2002) study co-authorship patterns in agricultural sciences only in Egypt.

Zhang and Guo (1997) examines multi-author and multi-institutional collaboration rate in China looking at national level publications in year 1993. Wang et.al. (2005) repeat an extended version of the study in China as reflected. Authors group type of co-authorship and compare them over a short period from 1997 to 2001. They examine only rate of co-authorship and perform comparisons in between groups of papers co-authored by authors (1) within the same institutes, (2) from different institutes, (3) within the same region, (4) from different regions, (5) where at least one of them are from a different country other than China. In a similar study, Godin and Ippersiel

(1996) compare inter-regional collaboration rate within a country to international collaborations. Their findings suggest that international collaboration rate is higher than regional collaboration for their cases. They explain it concluding that competition center in science is international rather than national.

Kim (1999) examines performance of Korean scientists and their contribution and visibility at international level co-authorship for the years 1994-1996. Akakendelva (2009), recently conducts a similar study to reveal international level contribution of Zambian scientists in between 2002-2007. Boshoff (2009), on the other hand, while examining international collaboration of Cameroonian scientists, he examines whether foreign collaborators are affiliated with institutions from previous colonial powers in order to explore impact of historical ties on co-authorship.

As discussed in Section 4.4 a number of studies in the field show that process and dynamics of national level collaborations are very different than international level collaborations. It is seen that while national contexts favor determination of exogenous factors on collaboration, at the global level collaboration takes place in a more self-organizing manner (Schubert and Glanzel, 2006). "The exception here is the European Union, where specific incentives exist to encourage formal international linkages among member countries (Schubert and Glanzel, 2006: p. 317)."

There are other follow up studies in the literature (e.g., Vidgen et.al., 2007; Mattson et.al., 2008) which in particular address this exceptional case of international co-authorship in Europe. It is seen that funding policy of European Commission regulates collaboration patterns, which mimic characteristics of a national level network. Earlier studies (e.g. Zitt et.al., 2000) conducted on major European states are suggesting a different picture, in which political systems, historical paths, colonial ties, economy, and language dominate over geographical proximity of European countries at determining recurring collaboration practices in between states.

It is also seen that there exist differing collaboration strategies in between individuals from developed countries compared to developing countries (Gaillard, 1992). Jacobsen (2009), examines international collaboration at the field of epidemiology. Author examines incentives of scientist regarding income level of their home countries. The study concludes that researchers from high income level countries participate to field studies at low income level countries. On the other side, authors from low level countries take part only in the field studies conducted in their home country.

Melin et.al. (2000) examine whether cultural homogeneity of Taiwanese scientists lead them to exhibit a collaboration structure different from international patterns practiced by developed western nations. They find no significant differences, instead they conclude that Taiwanese networks are well integrated to international level collaborations. Engels and Ruschenburgh (2006) explains such denationalization as an impact of globalization and communication technologies. Kim (2006) further elaborates on internationalization. He reports that globally connected collaboration network yet comprises of a core and a periphery.

Why and when international research is opted has been addressed by earlier studies, as well. In these earlier studies, however, the focus is rather on impact of common political regimes instead of globalization. Later transitional studies examine combined effects, while recent studies focus more on globalization related factors. A transitional study by Braun and Glanzel (1996), for example, examine international collaboration in east Europe, combining impact of former Soviet ties and recent westernization at international collaboration.

It is seen that following the collapse of bipolar global political system with advancement in ICT, in last two decades, lead an exponential increase in the number of addresses on internationally co-authored papers, whereas the number papers remained to grow linearly (Leydesdorff and Wagner, 2008). This observation reveals the fact that number of collaborators from different countries per paper has increased faster than actual number of internationally co-authored papers.

4.7.2 Subfield Studies

Disciplinary level analyses show that factors such as research methods, nature of science, availability of grants, policy decisions are all have bigger determining impact at degree of collaboration and patterns of collaboration at disciplinary level compared to other levels of analyses (de Granda-Orive et.al., 2009; Hou et.al., 2008; Durbach et.al., 2008; Yue and Liu, 2005; Newman, 2001).

Wagner (2005) conduct a research on international studies irrespective to any sociopolitical or politico-economical of countries. He takes two snapshots one in 1990 and the other in 2000 and examine change at level of collaboration in six fields, namely astrophysics, geophysics, mathematical logic, polymers, soil science, and virology. His research shows that international collaboration grew in all the fields they have examined at rates higher than the international average. The results of the study indicate the field specificity of rate of collaboration at international level. A subsequent study on the same set of data (Wagner and Leydesdorff, 2005) show that international collaboration in science at sub-field levels follows a slightly distorted power law distribution, whereas it follows a much more smooth power law distributions when data on all fields are aggregated to fit a model to international collaboration.

Yeung et.al. (2005) exemplifies this fact on their comparative study in the field of physics in USA. Pontille (2003) examines field of sociology both in USA and France to emphasize other factors such as particular institutional and historical contexts of field of studies, and the cognitive content. A relatively earlier study by Wolfgang Glanzel (2002) conducts a research which covers a wide range of fields for the years 1980 to 1998 supporting above findings.

Wagner-Dobler (2001) examines rate of collaboration in different fields for the years in between 1800 up to 1998. He shows that propensity to co-author exhibits a high level of heterogeneity from a discipline to another. The only salient pattern-wise feature he observes is the tendency to collaborate increases in areas where theoretical and applied research is needed to be combined.

4.7.3 Geographic Proximity

Cronin (2008) studies primacy of place to the extent to which co-authorship relationships are stimulated by physical collocation. The physical proximity level of her study is the common workplace. Her conclusions, which are based on ego network of very small set of authors, indicate primacy of inhabiting common workplace at forming co-authorship ties.

Fernanda and Daniela (2009), on the other hand, address the same problem for a spatially larger scope and in between research institutes. They conduct a case study where role of central regions such as state capital is examined. They observe pattern of co-authorship in between center and periphery to estimate impact of spatial centralization on the overall national level collaboration. They conclude the significance of proximity to the center for peripheral institutes at forming partnerships with the center.

Literature suggests at a global level geographical proximity has not been determining factor for individuals. However, it is seen that for inter-institutional collaboration geographic proximity becomes significant. Glanzel and Schubert (2005) demonstrate that inter-institutional collaboration are restricted to national or regional boundaries. They report that domestic inter-institutional collaboration, for instance, in Canada, Australia, and the UK decreases exponentially with the distance separating the collaborative institutional partners.

4.7.4 Motivation

A set of socio-anthropologically studies attempt to discover underlining motivations of individuals at taking incentives to collaborate with others or taking part at multi-authored papers. For instance, Hart (2000) runs an in depth survey to investigate personal motivations at taking part in multi-authored papers. He particularly emphasizes the importance of factors such as benefits of collaboration, working relationships, the division of labor, and name order assignment on the articles. In that direction, Laudel (2001) examines 57 German research groups to investigate how tasks of a paper co-authorship is organized. The findings of the result show that there is a division of labour between lead author and the other co-authors. While the leader's work requires the ability to create research problems and to integrate results, other group members do conduct experimental research and develop methodological-technical tools.

Wray (2002), on the other hand, studies epistemic significance of collaboration in the form of co-authorship. The author claims that the reason why collaboration has become a norm of research not only in natural sciences as well as in social sciences is because its nature enables individuals access to resources much easier, which in turn increases their awareness on epistemic goals of science more effectively than other non-collaborating scientists.

4.7.5 Size and Diversity of Teams

A set of studies focus on impact of team size and team diversity on publication productivity (Bordons et.al., 2005; Morris and Goldstein, 2007; Ausloos and Lambiotte, 2007; Barjak and Robinson, 2007). Morris and Goldstein (2007) develop a mathematical model to study characteristics of a team process including size of a team and knowledge diversity within a team. They aim to better examine how teams are created, how team level productivities are evolving and how inter-team collaboration can be simulated.

Bordons et.al. (2005) investigate correlation in between team size and productivity in Spain in the field of Mathematics for the years 1996 to 2001. They observe that although the number of publications increases with team size, overall productivity inclines to decrease as team size is getting bigger. They further observe that while large teams are observed to collaborate both at the national and at the international level, it is national collaboration that fosters interdisciplinary studies.

Ausloos and Lambiotte (2007) in particular aim to trace impact of knowledge speciality of individual authors on the subject of collaboration. In their study mathematical modeling is put to use to explain development of a field constituted by speciality of co-authors. Barjak and Robinson (2007), study performance of international co-authorship based on knowledge diversity of co-authors. Their findings suggest that authors drawn from different nation pools with medium level of diversity perform best. They further stress that maximal diversity does not lead to maximum performance.

Driving upon literature, it can be concluded that a 'medium' level of knowledge diversity and size of a team might lead to optimal productivity. The 'medium' is to be determined within a context, e.g., in what field collaboration is taking place, whether members are from the same institute or nation or the team is constituted internationally or in between different institutes.

4.7.6 Triple Helix and Academic Policies

Melin and Persson (1996) points the impact of science policy at tremendous increase at collaboration in the third quarter of 20^{th} century measured looking at co-authorship rates. Funding as one of academic policy instruments has frequently been discussed. The literature suggests that government policies governed indirectly by funding schemes sets research agendas which might foster research leading to formation of dense patterns of co-authorship and emerging invisible colleges of scientists from various institutes (Zuccala, 2006). Pao (1992), e.g., studies such impact of research funding on collaboration. Author's findings show that how funding leads to formation of a core group who exploits grants more often.

Complex nature of interacting and evolving factors in between academy and government plus industry has been addressed by a metaphor called triple helix. Researchers employs it, in general, while they attempt to unseal layers of interactions in between academy, industry and government agencies. Scholarly collaboration related triple helix studies, in particular, derive upon publications either as a mean of collaboration, or a by-product of collaborations in between academy, industry and governmental bodies. For instance, Belkhodja and Landry (2007) investigate why researchers from academia do collaborate with industry and government in Canada. Along with publication data, they run surveys to extract factors which cannot be driven from publications. Researcher's strategic positioning and publications, the setup of existing networks, research budget, university localization are among a set of factors they find significant. Leydesdorff and Sun (2009) examine triple helix in Japanese national context comparing it with Canada. They use only Japanese publication data for the years in between 1981 and 2004 to study and focus on network driven factors instead. Forming co-authorship networks of industry, university and government in Madrid, Olmeda-Gomez et.al. (2008) attempt to spot key actors of triple helix.

Butcher and Jeffrey (2005) examine industry university collaboration structure in the field of membrane use for water treatment over the years 1967 to 2001. They find the increasing interdisciplinary nature of collaborations. Another recent disciplinary level work by Abroma et.al. (2009), in particular, elaborates on collaboration in between industry and academy in Italy. Their findings suggest that industry and academy collaboration is most prevalent in applied physical sciences. The study reveal that although respective literature of scrutinized fields are increasingly multidisciplinary when conducted purely within academia, papers which are academy-industry collaboration do not show the same level of multi-disciplinarity.

Recurring findings in co-authorship studies inspires triple helix researchers to come up with policy proposals. For instance, recurrence of scale-free networks at co-authorship studies inspires policy suggestions towards development of matching ICT technologies which adapts to scale-free networks to optimize access to scientific knowledge (Chirita et.al., 2005; Heylighen, 2006). More recently, Nankani et.al. (2009) examine academic networks traced by co-authorship data and they propose new network driven measures which captures information fusion channels. The measures are particularly suggested to be employed by decision makers at taking specific strategic actions.

Examining industry university collaboration solely through co-authorship data has limitations, e.g., Lundberg et.al. (2006) in their study conducted in medical industry they find that out of around 500 funding medical companies one third of them have never co-authored a paper pertaining the fund. Another way of sensing and studying scholarly interactions within triple helix framework derives upon virtual networks extracted from Web hyperlinks (Kretschmer et.al., 2007).

4.7.7 Co-authorship and Visibility on the Web

Hildrun Kretschmer has lead a series of studies to investigate issues regarding co-authorship and its Web visibility (Kretschmer and Aguillo, 2004; Kretschmer et.al., 2006; Kretschmer and Kretschmer, 2006; Kretschmer et.al., 2007). These studies have addressed a range of questions including to what level the type of multi-authored papers influence the Web visibility (Kretschmer and Aguillo, 2004), to which extent structure of collaborations visible in the Web do evolve over time in the same way as bibliographic collaboration networks (Kretschmer and Aguillo, 2004), as well as, to what extent gender visibility on the Web can be observed regarding female contributions to the investigated case disciplines (Kretschmer et.al., 2006).

Kretschmer et.al. (2007) in their latest study on the subject detail quest to what extent actual co-authorship is reflected on the Web. They compare and contrast virtual collaboration networks formed solely using Web data with actual offline co-authorship networks. The empirical work covers collaborations in between institutions and individuals at several medical sciences. Their findings suggest that virtual collaboration estimated by existence of hyperlinks in between Web sites of institutions or individuals does not reflect actual collaboration structure. On the other hand, when they measure visibility of actual ties on the Web by checking occurrence of publications or citations to them on the Web, they do find strong similarities. They posit that using data from the Web can provide evidences of work in progress. In addition, collaborations which are sensed from the Web are not subject to normative constraints of peer review publishing (Kretschmer et.al., 2007). As such, Web visibility studies can enhance the exploration of scientific collaboration phenomenon.

In another empirical study Hildrun Kretschmer and Theo Kretschmer (Kretschmer and Kretschmer, 2006) show that forming whole network using visible connections on the Web results in a more centralized structure than the network formed by bibliographic data.

4.8 Summary and Discussions

Literature concludes that collaboration in the form of co-authorship, per se, is a very complex phenomenon, where numerous factors from different levels continuously and contingently interact. These factors varies from very micro levels determined by individual decisions or influenced by individual characteristics to international level science policies outlined by bilateral or multilateral cooperation programs. These factors together influence micro-decisions taken by scientists consciously or unconsciously. The micro-decisions are reflected by regular patterns which shore up in macro forms of co-authorship network structures.

However, most of these studies suffer from the extend and coverage of their cases. Besides they have focused more on steady state nature of co-authorship leaving out its evolving nature. Before concluding this chapter, I would like to attempt to reveal some of contradictory findings in the empirical studies in the literature and propose a conceptual framework in order to interpret and explain those discrepancies.

An extensive critical review of literature emphasizes importance of two major points of consideration while doing research in the field. The first one is clarifying context of co-authorship practice which is being scrutinized. The second one is alignment of research findings or their implications with scope, range and coverage of the data sources used. Although these two points are very well known research issues in any field, they are missed in a set of co-authorship studies leading inconsistencies in between similar works, as well as, limiting validity of results and discussions.

4.8.1 Context Dependency and Sensitivity to Primary Data

Isolating social, economical, institutional or other environmental settings in which collaboration activities take place leads to context independent generalizations. Although Bechner and Trowler's (2001) study addresses context dependency of co-authorship practices, yet, they miss the second point. They attempt to generalize their findings for all developed world. However, the cases they investigate consists of several top tier research institutes in the states and England, leaving out many other practices in these countries. Besides, their study suffers from a limited time window which increases the susceptibility to errors.

Tommassini and Luthi (2007) recognize the problem of having a narrow range of data in their research. They attempt to surmount the problem by applying a 3-4 years long sliding window on the years of observation. A sliding time window allow them to analyze active collaborations within the window over time. A sliding time window approach, to an extent, overcomes difficulties faced while conducting longitudinal studies. However, studies which are attempting to characterize structure of the whole network or attempt to fit a statistical model to degree distribution of the network still face problems arisen from range, scope and coverage of data sources.

There are two major competing models which characterize structures of co-authorship networks: the scale free models vs small-worlds. A closer examination of data might help to understand why network studies on inherently and contextually similar scientific fields sometimes report scale-free structure and some other times demonstrate small-worlds or fragmented structures. In that respect, I suggest to probe range of data, namely width of time window used, to collect publication data as a first aspect and scope and coverage of data as a second aspect. The scope and coverage of publications can vary, for instance, from a national journal on a very specific subject, let say Turkish Entomological Studies, to an international dataset, such as a collection of all social science citation indexed journals.

It is seen that a significant number of studies with a narrow time window either contains a connected major component with scale-free characteristics or very high degree of fragmentation without any major connected component irrespective to scope and coverage of data set. As time window gets wider, either a scale free network structure with a single giant connected component dominates the structure or a small-worlds structure with a multiple of densely connected sub-components within giant component shores up.

Networks constructed using bibliographic entries of a single journal or a set of journals on a specific subject shows high propensity to exhibit a small-worlds collaboration structure. This can be explained by a relatively narrow literature where significant number of publications are done by a number of research groups. Members affiliated with the same research group around a specific subject repeatedly co-author with each other. Besides, there are occasional collaborations in between scientists across research groups which establish ties or knowledge diffusion channels in between them leading to emergence of small-worlds characteristics for the whole collaboration structure for that very specific area or sub-discipline. On the other hand, when the set of bibliographic entries cover a large number of disciplines or a large number of scientists from very different institutes, resulting structure rather exhibits a major connected component in the center and pendants or isolates at the periphery.

There are also studies with very large time window. As time window gets very wide, the degree distribution of scientists in the network starts to exhibit a distorted power law distribution. A power law degree distribution repeatedly observed in the co-authorship studies and it parallels preferential attachment model of growth of co-authorship networks. Resulting distorted power law distributions in majority of studies with a wide time window exhibit a hook at the lower end of the distribution and a fat tail in the upper end.

For instance, the networks formed by James Moody (2004) have 36 years long time window covering years 1963-1999 with a distorted power law degree distribution as described above. However, he fails to fully explain the distortions he observes. It is possible to explain the hook at the lower end and the fat tail in the upper end as a result of having a wide time window. The very lower end of the distribution mainly reveals proportion of number of authors with 2 papers to authors with 1 paper, subsequently, proportion of authors with 3 papers to 2 papers. A hook at that end indicates that authors with 2 papers is not decaying exponentially and similarly an exponential decay from 2 papers 3 papers is not observable either compared to a smooth power law distribution. This can be explained again by the width of time window. A time window around 30 years or more allows enough time to observe authors' whole publication life cycle. Thus, it increases the chance of observing the second and third publications. In a similar manner, in the higher end of a distribution with a large time window number of authors with many publications accumulate resulting in a fat tail. In other words, having a large time window causes to count even idle or retired seminal authors still as active scientists.

These observations on studies with very large time windows or very short time windows hints the necessity to consider activity of scientists in a field. A very earlier paper by Derek de Solla Price and Süha Gürsey (1976) attempts to categorize authors in a field into different and distinct groups. They perform an author categorization in a yearly basis:

- Transients: Those who are observed to publish only at the year of categorization.
- Recruits: Those who publish at the year of categorization and observed to publish in subsequent years.
- Terminators: Those who had published earlier and who publish at the year of organization for the last time.
- Core continuants: Those who publishes every year including the year of categorization.
- Non-core publishing continuants: Those who had published earlier and who publish at the year of categorization.
- None-publishing continuants: Those who had published earlier and who did not publish at the year of categorization but observed to publish in subsequent years.

Wagner and Leydesdorff (2005) partially employ above categorization in order to explain deviation from an ideal preferential attachment model. They test preferential attachment model for international collaboration. They observe a hook at the lower end and a fat tail at the upper end and a linear downward slope in between of log-log plot of degree distribution. They presume that if they have considered only continuants to model degree distribution, it would yield to an ideal preferential attachment model with no hook at the lower end of the distribution and a fat tail at upper end of the distribution.

Chapter 5

Method and Data

The chapter introduces an empirical research framework which attempts to embody the theoretical framework of the study. Discussions in previous chapter have shown the primacy of duality and interplay in between underlying collaborative social structure and the diffusion of knowledge in scientific communities. In that respect, the chapter attempts to develop a rigorous method in order to accomplish explanatory power of aforementioned conceptual framework. Proposed methodological approach borrows and adopts existing relevant tools and models from previous body of knowledge and experience, as well as, it introduces new models, metrics and software tools.

5.1 Meta-Networks

The primary source of data for the study is publications produced by a scientific community. Bibliographies have long been the canonical form of data storage at recording information on scientific activities in a field or across fields. Bibliographic records capture summary information on the essence of a universal scientific activity which is knowledge dissemination by scientists.

In that perspective, a bibliographic entry reveals three different yet interrelated set of relations: (1) a social relation in between co-authors, (2) a semantic relation in between keywords or phrases used to describe the whole content of the work, (3) a cognitive structure which reveals cognitive relations established by very author(s) of a given paper. As such, an extended bibliographic data provides a rich set of relational data that goes beyond its mere count as a measure of productivity of a given scientific community.

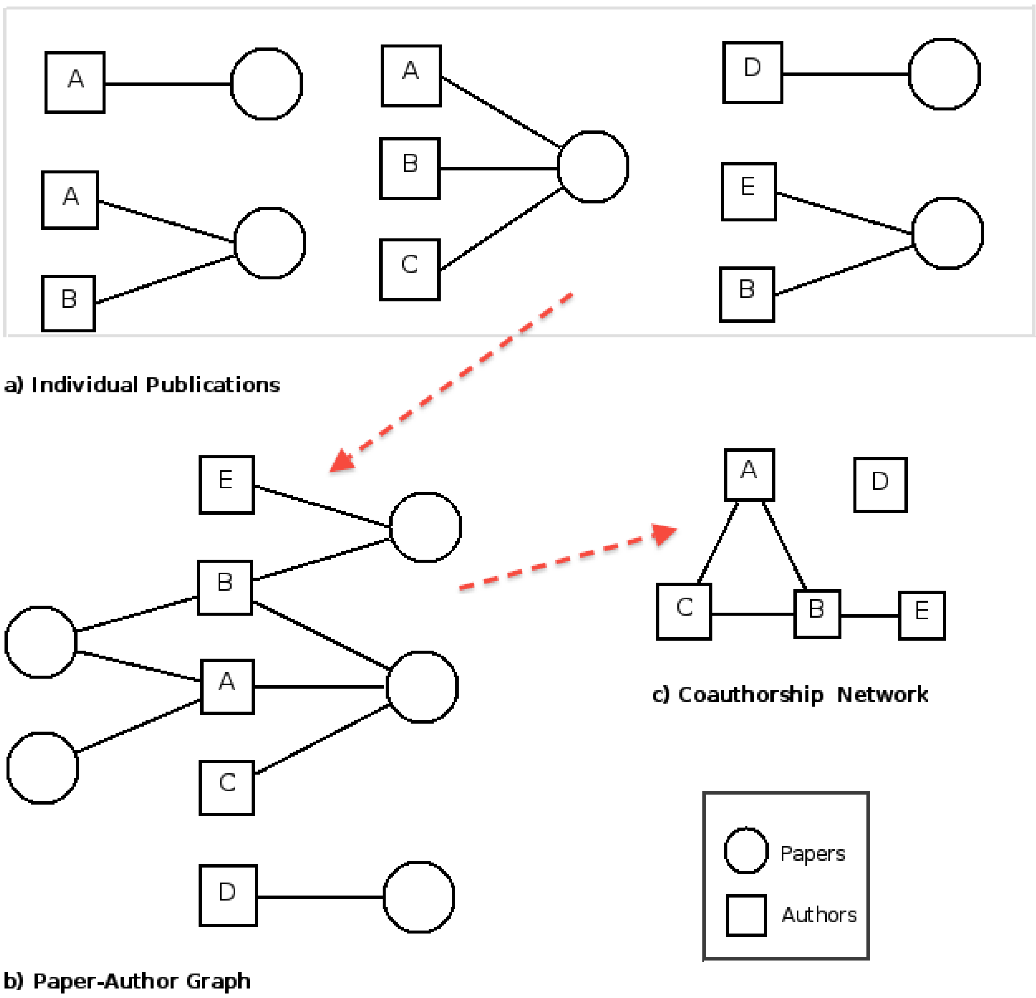
However, as previous chapters has outlined, only a large enough set of bibliographic entities and an integrated approach at examining the set of relations can reveal inherent and endogenous properties of a scientific community under examination. The empirical primacy of this dissertation drives upon a large set of data and an integrated methodological framework. Coverage, scope and size of the primary data of this dissertation is outlined in Chapter 7.1. Theoretically oriented power of this empirical research is thus gained by observing recurrent relations emerged from a representative set of data.

The three primary relations extracted from a set of bibliographic entities is represented by their corresponding network models. They are, namely, co-authorship network (AxA), knowledge network (KxK), and knowledge dissemination network (AxK). Previous studies on scientific communities or on knowledge diffusion in large have either focused on co-authorship relations or semantic relations. As it has been discussed in Chapter 2.3 there are a few number of studies which have integrated both set of relations. Additionally, in this research I integrate observed cognitive relations made by scientists by capturing it via knowledge dissemination network.

An illustrative process of forming relations extracted from a bibliographic entity is given in Figure 5.1. The figure demonstrates how co-authorship (AxA) relations are formed. Authorship information is one of the standard component of bibliographic entities. Establishing KxK and AxK relations, however, necessitates further data pre-processing in order to tokenize keywords of each title or paper. Once keywords of each bibliographic entry is tokenized, the process of KxK and AxK relation formation is same as Figure 5.1 illustration. The details on keyword extraction process of this study is discussed in Section 7.1.

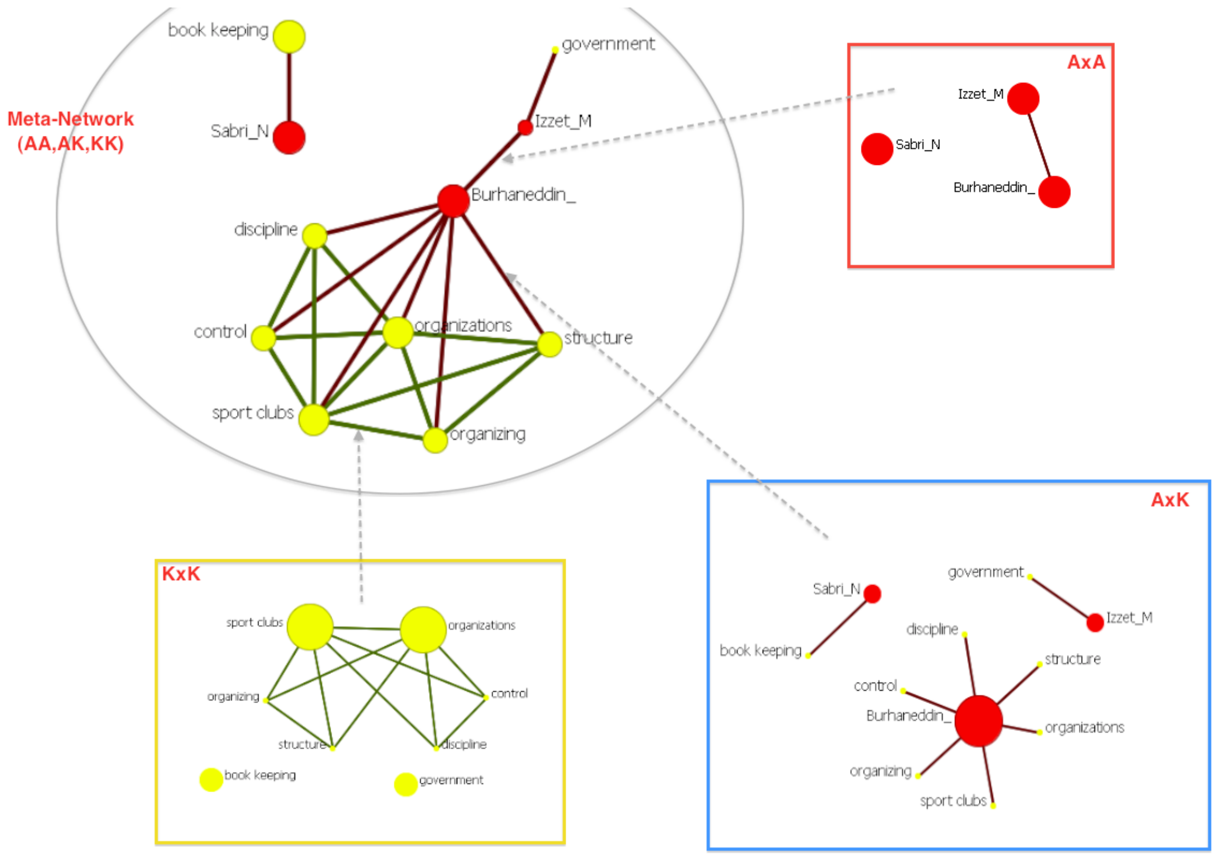
One of methodological contributions of this dissertation is adoption of Meta-Network perspective, which principally allows to observe and analyze

Figure 5.1: From bibliographic entries to network relations.



cascaded influences across different yet interrelated networks of relations. Meta-Networks have been introduced by a research team lead by network scientist Kathleen Carley[8] (Carley, 2001; Carley et.al. 2009, Carley, 2002).

Figure 5.2: An exemplary Meta-Network based on very first management related publications in Turkey:1922-1925*.



Explanatory power of an integrated Meta-Network perspective is visualized by Figure 5.2. The network of the three set of relations is based on bibliographic entries found in Turkish National Library data set[9]. The author nodes are scaled based on their 'cognitive distinctiveness' and keywords or phrases are scaled based on their 'eigenvector centrality'. The actual full set covers all scientific articles published throughout Turkish Republic until 1999.

The figure demonstrates that computationally processed and visually represented data reveals its overall structure when integrated via a Meta-Network. On the other hand the representation does not limit the researcher by its increased complexity, as it allows to focus a particular set of relations whenever it is necessary.

Analysis power of such a Meta-Network approach is demonstrated in the next Section5.2. The section introduces network models and metrics that is employed or introduced as part of this dissertation study.

5.2 Meta-Network Models and Parameters

The selection of network types as outlined above or introduction of new metrics are driven upon analysis and discussions of previous theoretical chapters. In this sections, each metric is introduced first by explaining what social phenomenon it is deemed to represent. A part of metrics are newly introduced or particularly adopted for this dissertation study. Mathematical representations and relevant details of such new or adopted metrics are given briefly. A complete summary of mathematical representations and relevant details along with further pointers on the full set of metrics are provided in Appendix B.

5.2.1 Individual Level SNA Metrics

Centrality Metrics

- **Degree Centrality:** Degree Centrality measures the relative number of direct connections an author might have in a network. The score tells the relative number of co-author a scientist had so far in the community (Wasserman and Faust, 1994).

- **Betweenness Centrality:** Betweenness measures one's connection to the other parts of a network other than one's direct connections (Freeman, 1979). It is another way of telling centrality of an author in the community. Betweenness of an author is computed by measuring the number of times that connections must pass through him or her which connects others in the network. The measure indicates the extent that an author acts as broker of indirect connections among all others in network. Mathematically, authors who occur on many shortest paths among other scientists have highest betweenness value. In other words, betweenness of an author is the fraction of shortest path that passes through him or her.

- **Closeness Centrality:** Closeness measures the average distances in terms of social connections from one person to another in a network. Within a community of science network it may help to reveal how long it takes a theme or knowledge to diffuse from one scientist to others in the network. Mathematically, high scoring individuals in closeness have the shortest paths to all others in the network.

  It should be noted that closeness is different from the betweenness. Closeness computes the shortest path initiated from a person aiming to reach as much as possible scientists in the community, whereas, betweenness measures the rate of being on such shortest paths.

- **Eigenvector Centrality:** It reflects a scientist's connections to other well-connected scientists. A scientist who connects to many isolated scientists in a community of science will have a much lower score in this measure then those that are connected to ones that have many connections themselves.

  Social network literature suggests that a person well-connected to well-connected people can diffuse knowledge much more quickly than one who only has connections to lesser important people in a network (Carley et.al., 2009; Bonacich , 1972).

The same metric is also applicable to compute eigenvector centrality of each piece of knowledge. Then it would measure the importance of a theme or concept represented by a keyword. Eigenvector centrality in this dissertation mainly served to generate combined tag clouds of concepts and scientists for each period in order to reveal important figures and themes in the period.

- **Knowledge Degree Centrality (KDD):** This metric is measured and interpreted according to an author's activity at disseminating knowledge. The metric is adopted from out degree centrality of Wasserman and Faust (1994).

  Let assume that an AK matrix holds frequencies of themes (keywords, or knowledge) disseminated by each scientist. Rows denote authors (A) in the community and columns denote keywords observed within titles of publications by the authors in the community. Then Knowledge Degree Centrality (KDD) of an author is computed as follows.

$$\begin{gathered} KDD_a = \frac{1}{n} \sum_{k=1}^{n} AK(a,k), \text{where} \\ n = \#\text{ of unique keywords observed.} \end{gathered} \tag{5.1}$$

  It should be noted that AK matrix is a rectangular and asymmetric matrix, representing a bi-modal relation between scientists and pieces of knowledge they have disseminated via observed publications.

Socio-Knowledge Metrics

Socio-knowledge metrics are used as mathematical instruments to make an estimate of embededness of authors in the scientific community as of observed collaboration ties and scope of disseminated knowledge. In other words, it combines social capital of an author and its expertise on knowledge space of the community.

- **Triad Count:** A triad is a relationship amongst three scientists. In mathematical terms, it is the count of co-authoring triples. Existing and prevalence of triads deemed to be relevant to network architecture which in term shapes the channels of knowledge diffusion (Scott, 2000; Geisler, 2007).

- **Clique Count:** The measure computes the number of distinct cliques to which each author belongs. A clique is defined as a group of three or more actors that have many connections to each other and relatively fewer connections to those in other groups. The measure reflects sub-structures in the collaboration network that contribute to a cohesive whole (Wasserman and Faust, 1994).

- **Clustering Coefficient (CC):** The clustering coefficient of an author is the density of his/her ego network which is the sub-graph induced by its immediate neighbors. Individual clustering coefficient estimates the intensity of one's ties with the others in the network. It estimates cohesiveness of ties between ego's immediate neighbors including the ego (Carley et.al., 2009).

- **Collaborator Exclusivity Index (CEI):** Collaborator Exclusivity Index is used to detect authors who have connections that are unique in the community. In other words, it is used to detect authors who collaborate with someone with whom no one else has collaborated so far.

  The metric is developed for this dissertation by adopting Knowledge Exclusivity Index given by Equation B.12. A person with a high number of pendants would have a high collaborator exclusivity value. A pendant in network terms is a node who is connected to the community through a single person. The Collaborator Exclusivity Index (CEI) for an author $a \in A$, where A represents set of authors in the community and AA is the corresponding adjacency matrix, then is defined as follows:

$$CEI_a = \sum_{j=1}^{|A|} AA(a,j) e^{(1-\sum(AA(:,j)))} \tag{5.2}$$

As a by product, this metric may be critical at assessing impact of a scientists who have 'external' ties. For instance, within a local community a scientist who have access to some other non-local scientist(s), with whom nobody else from other locals has a tie, may be critical at diffusing knowledge acquired during that very collaboration. However, it should be noted that in order to detect such an impact such unique collaborations should be visible within research data.

- **Socio-Knowledge Power (SKP):** The measure indicates strength of a scientist both in terms of one's access to other peer scientists and one's expertise in the field. In other words, it combines one's social capital and one's knowledge portfolio. The social capital in that sense is measured by co-authorship information. Diversity and frequency of concepts that appears on one's articles is used to form his/her knowledge portfolio.

  Let AA' represent normalized co-authorship matrix and AK' represent normalized knowledge dissemination network. Then SKP_a of an author a can be computed as follows:

$$\begin{aligned} M &= [AA'|AK'] \\ m &= |A| + |K| \\ SKP_a &= \frac{1}{m}\sum_{k=1}^{m} M(a,k) \end{aligned} \tag{5.3}$$

  Note that M is formed by concatenating normalized AA and AK relations.

Cognitive Activity Metrics

This set of metrics explores cognitive state of a scientist in comparison to others in the same community. It should be noted that the representation capacity of measures in the context of this study is limited. It can only reflect cognitive content derived from disseminated and encodable concepts from bibliographic entries relevant to respective scientists. It does not reflect full cognitive load of a scientist. For that reason, the measures are interpreted in a relative manner. For instance, cognitive distinctiveness of an author is read as relative to others.

- **Cognitive Distinctiveness (CD):** Cognitive Distinctiveness estimates the degree to which each pair of scientists has disseminated complementary knowledge, expressed as the percent of total knowledge disseminated within the community. In other words, it measures how distinct are two scientists based on the number of knowledge bits they hold oppositely (Carley, 2002).

- **Cognitive Similarity (CS):** Cognitive Similarity estimates the degree to which each pair of scientists have disseminated overlapping knowledge. In other words, it measures the degree of similarity between authors based on the number of knowledge bits they both have (Carley, 2002).

- **Cognitive Resemblance (CR):** Resemblance estimates the degree of resemblance between scientists based on the number of keywords they both have or both have not disseminated. In a way, it measures the degree to which each pair of author has the exact same knowledge (Carley, 2002).

- **Knowledge Exclusivity Index (KEI):** Detects scientists who have singular knowledge. KEI measures the extent that an author has disseminated on a field that is unique to the community. Having published on a subject nobody else have published, may point that the scientist acts as a solo novice knowledge source for the rest of the community he/she is in.

5.2.2 Co-authorship Network Level SNA Metrics

- **Count, Node:** Node count in a given a co-authorship network is the total of scientists in the network.
- **Cunt, Link:** Link count in a given network is total of co-authorship ties in between scientists in a network.
- **Count, Isolates:** Isolates count is the number of scientists who has not been observed to co-author.
- **Count, Components:** A component in a network is defined by maximally connected group (Wasserman and Faust, 1994). In other words, in a co-authorship network, a component is the set of authors who can reach to each other over either their direct ties or through ties of their co-authors. The metric estimates number of connected components in a co-authorship network.
- **Centralization, Degree:** Degree centralization measures graph level centralization of a co-authorship network based on total degree centrality of each author (Freeman, 1979). It averages degree centrality of each author normalized by largest degree centrality found in the network.
- **Centralization, Betweenness:** Network centralization based on the betweenness score for each author in the community. It averages betweenness centrality of each author normalized by largest degree centrality found in the network (Freeman, 1979).
- **Centralization, Closeness:** It estimates network centralization based on the closeness centrality of each author in his/her respective community. It averages closeness centrality of each author normalized by largest degree centrality found in the network (Freeman, 1979).

- **Clustering Coefficient:** Clustering Coefficient, measures the degree of clustering in a scientific community by averaging the clustering coefficient of each scientist. The clustering coefficient helps to explore local characteristics of a given socio-gram. It might help to understand how knowledge diffuses by means of research teams. A higher clustering coefficient for whole network deemed to support local knowledge diffusion. Besides, it is also a sign for a decentralized community structure (Watts and Strogatz, 1998).

- **Connectedness:** Connectedness for a $G(V, E)$ representing a network is equal to the fraction of all dyads, i, j, such that there exists a path from i to j in G (Krackhardt, 1994). It estimates ratio of reachability in a given community.

- **Average Distance:** It is simply the average shortest path length between authors in the network, excluding infinite distances. It measures the social distance in between scientists in a network.

- **Density :** Density measure is simply the ratio of the number of links versus the maximum possible links for a given co-authorship network. Density compares existing links to all possible links in a given network. It reflects the social level of cohesion (Wasserman and Faust, 1994).

  Interpreting density by itself alone may be misleading. It should be interpreted along with number of authors in the network and the growth stage of the community. For instance, a community at its early years may consist of a small number of interacting and collaborating scientists which would lead a large density of interaction for the socio-gram at the period. However, as community grows there may be speed increases in the number of scientists which would yield lower density values.

- **Diameter:** The metric measures the extent of collaboration distance in a given network. It is a measure of largest social distance in the network.

- **Transitivity:** It estimates extent of transitivity of collaboration ties.

It measures the percentage of edge pairs $\{(i, j), (j, k)\}$ in a co-authorship network such that (i, k) is also an edge in the network. In other words, it is the percentage of author pairs where author A has co-authored with author B and author B has co-authored with author C, which induced a co-authorship in between A and C.

5.2.3 Knowledge Network Level SNA Metrics

- **Density:** It is measured in the same way as in co-authorship networks, where author entities are replaced by knowledge entities. The measure explains intensity of cognitive links formed in between concepts in a field.

- **Diameter:** It is measured in the same way as in co-authorship networks, where author entities are replaced by knowledge entities. The metric measures the extent of furthest cognitive distance in a given field (Carley et.al, 2009).

- **Average Distance:** The measure is estimate for pairwise cognitive distances in between themes or concepts in a field, derived from keywords co-occurrences on the same paper.

5.2.4 Dissemination Network Level SNA Metrics

- **Knowledge Load:** Knowledge Load is the estimate for average number of knowledge per author in the network (Carley, 2002).

- **Knowledge Redundancy:** It is a normalized estimate for the number of scientists with the same knowledge (Carley, 2002).

- **Knowledge Diversity:** Knowledge Diversity is used to characterize a given scientific community in terms of how research subjects or knowledge items are non-uniformly distributed across scientists based on their knowledge dissemination pattern. In other words, it is the distribution of difference in research issues in a community.

The estimate is also known to be adopted from as the Herfindahl-Hirshman (Gini) index (Carley et.al., 2009). Within this dissertation research context it can be considered as Gini Index that is applied to distribution of knowledge dissemination among scientists in a community.

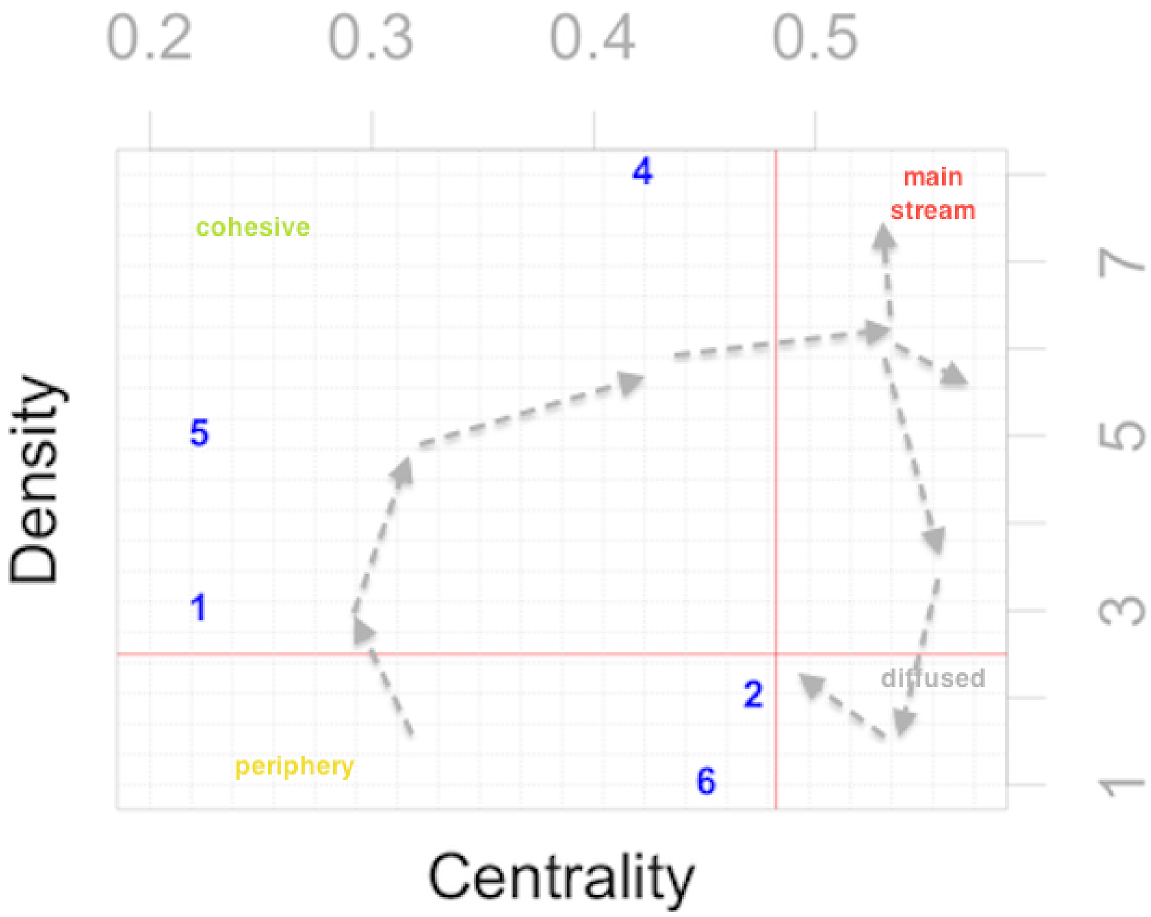
5.3 Co-word Analysis: Forming Strategic Diagrams

Relations established and observed by Knowledge Network (KxK) considers keywords as the atomic unit of analysis. However, it does not present or visualize rather abstracted semantic relations in between groups of keywords. Co-word analysis which is developed upon ANT theory provides such higher level abstractions. Theoretical background of co-word analysis along with relevant literature review is given in Chapter˜chp:Coword.

Co-word analysis produces strategic diagram of a field, in other terms, the strategic map of a scientific field. More precisely, given a set of bibliographic entries which is able to cover or represent knowledge produced in a specific field at a specific time, co-word analysis attempts to position cluster of themes within the field regarding each cluster's internal cohesiveness and its field level pervasiveness.

Figure 5.3 depicts strategic diagram of a hypothetical field. 'Density' is the vertical axis and 'Centrality' is the horizontal axis. 'Density' denotes cohesiveness of a cluster and 'Centrality' denotes its pervasiveness.

Figure 5.3: Strategic map of a hypothetical field.



5.3.1 Cluster Analysis

Conceptual clustering of themes are derived raw co-occurrence data, namely, KxK relations derived from bibliographic entities. In order to derive or form clusters of themes an equivalence index (E_{ij}) for each pair of themes is calculated (Neff and Corley, 2009; He, 1999; Law and Whittaker, 1992). The equivalence index (E_{ij}) measures strength and proximity of two themes (i, j) in the field based on their co-appearance in the same title. Equation 5.4 gives computation of strength in between given two themes (He, 1999):

$$
\begin{aligned}
E_{ij} &= \frac{CC_{ij}^2}{C_i x C_j}, \text{ where} \\
C_i &= \text{frequency of } i \text{ in the set,} \\
C_j &= \text{frequency of } j \text{ in the set,} \\
C_{ij} &= \text{co-occurrence frequency of } i \wedge j \text{ in the set.}
\end{aligned} \tag{5.4}
$$

Having computed equivalence of each pair of themes, all of themes are grouped into clusters. There are various clustering algorithms which can be applied to generate conceptual group of themes. Clustering methods, in general, attempts to end up with groups of themes, where sum of intra-cluster equivalence values of themes within the same cluster are maximized and sum of inter-cluster equivalence values in between themes from different clusters are minimized. However, there are two distinct approaches at the very process of clustering: a top-down clustering and a bottom-up clustering. The choice of one approach over the other may result in significant differences and interpretations given circumstances of research questions. In the top down approach, number of 'desired' clusters is predetermined and algorithms are forced to partition themes into that many clusters. On the other hand, in the bottom up approach, no number of clusters suppressed initially. The number of clusters emerges given distribution of proximity in between items.

In this dissertation study, Ward's clustering algorithm is opted (Gordon, 1999). The clustering method measures euclidian distances in between themes based on their mutual equivalence values. The choice of clustering is not arbitrary, given the exploratory nature of the case of this dissertation Ward's method is opted to be able to detect self-emerging number of theme clusters in different periods of time. For the analysis R Statistical Tool and Software (R) implementation of Ward's bottom-up agglomerative clustering algorithm is run.

5.3.2 Positioning Cluster of Themes on a Strategic Diagram

Centrality and density of each theme cluster (issue) is computed as suggested by classical co-word analysis. A theme cluster can be taken as a sub-field, as a particular research area, as a paradigm, as a specific framework or simply as a basic concept within the subject of a given study. It should be noted that on one hand a cluster may consist of a single theme, phrase or keyword given circumstances of its prominence emerged from the data set, and on the other hand it may include a large number of themes which are conceptually not very relevant with each other in the field. In most of the cases where there is a large number of themes, such an 'outliers' cluster shows up and usually they are positioned as peripheral.

Centrality of a theme is a measure which indicates how much a cluster or an issue which may be represented by the cluster as a whole is discussed within the field along with other issues. It is computed as follows (Neff and Corley, 2009):

$$C_{cluster} = \frac{\sum_{i=1,j=1}^{E_{ij}} E_{iw}}{n(N-n)}$$

where,

$C_{cluster}$ = Centrality of the cluster

E = Equivalence index of word pair link

i = First word in the pairing, internal to the cluster

w = Word in dataset, but not in the cluster

N = Total number of unique words used in titles within the period

n = Number of unique words in the cluster

(5.5)

Density of a theme is a measure which indicates how much a cluster or an issue is studied repeatedly around the themes or concepts positioned within the cluster. It is computed adopting the metric given in Neff and Corley (2009: p. 666):

$$D_{cluster} = \frac{\sum_{i=1,j=1}^{E_{ij}} E_{ij}}{n(n-1)/2}, \text{ when } n > 1;$$
$$= \sum_{i=1,j=1}^{E_{ij}} E_{ij}, \text{ when } n = 1.$$

where,

$D_{cluster}$ = Centrality of the cluster

E = Equivalence index of word pair link

i = First word in the pairing

j = Second word in the pairing

n = Number of unique words in the cluster

(5.6)

Note that, the measure in Equation 5.6 also accommodates a cluster with a single theme, which simply yields overall frequency of the word within the set.

There are various other centrality and density measures used and applied in the literature. The choice of centrality equation above is opted to have a correcting advantage for the significant variances of title lengths over time. The equation neutralizes distorting impact of titles with inflated number of keywords (Neff and Corley, 2009).

The arrows in Figure 5.3 shows trace of a normal science (Kuhn,1970) as discussed in earlier chapters. A cluster representing a theme emerges in the periphery, the lower left quadrant; develops internally as scientists interwove relevant concepts and the paradigm, the upper left quadrant; it becomes main stream and moves to the center, upper right quadrant; after a certain time the concepts of the 'paradigm' becomes omnipresent appearing in majority of other themes in the field, the bottom right quadrant.

It should be noted that Density and Centrality axis are placed by computing mean centrality and mean density in the field. The measures along with visualizations of clusters on the strategic map is accomplished by developing and coding a new co-word analysis package for R.

5.3.3 Network of Theme Clusters (Issues)

Given quality of keywords assigned or identified from titles, co-word analysis provides a powerful method at deriving conceptual abstractions and mapping them on a visually interpretable diagram. The method may further be exploited to trace development of a field over time for rather more micro-level exploratory studies.

However, conventional co-word analysis lacks to provide conceptual relations in between emerging or existing themes. The first set of articles from Turkish management literature further demonstrates this deficiency. Figure 5.4 shows the formation of clusters during the clustering analysis. Established clusters are mapped to the diagram given in Figure 5.5. As it is seen clusters 2,3,4 share the same spot having the same centrality and density values. Nevertheless, this visual co-habitantence does not imply their conceptual equivalence. Indeed, very nature of the conventional method does not claim any conceptual proximity based on their coordinates on the diagram.

As part of this dissertation study, conceptual network of theme clusters are established computationally. As it is visualized in top right corner of Figure 5.5, cluster 1 (C1) does not only remains in the periphery, but also no researcher at the time formed a cognitive relation in between it and the rest of the other themes at that period. Furthermore, it tells that cluster 2 (C2), which consists of `discipline` and `control` words (see Figure 5.4, is more prominent than the rest.

Figure 5.4: Dendogram of management related concepts observed in Turkey: 1922-1925.

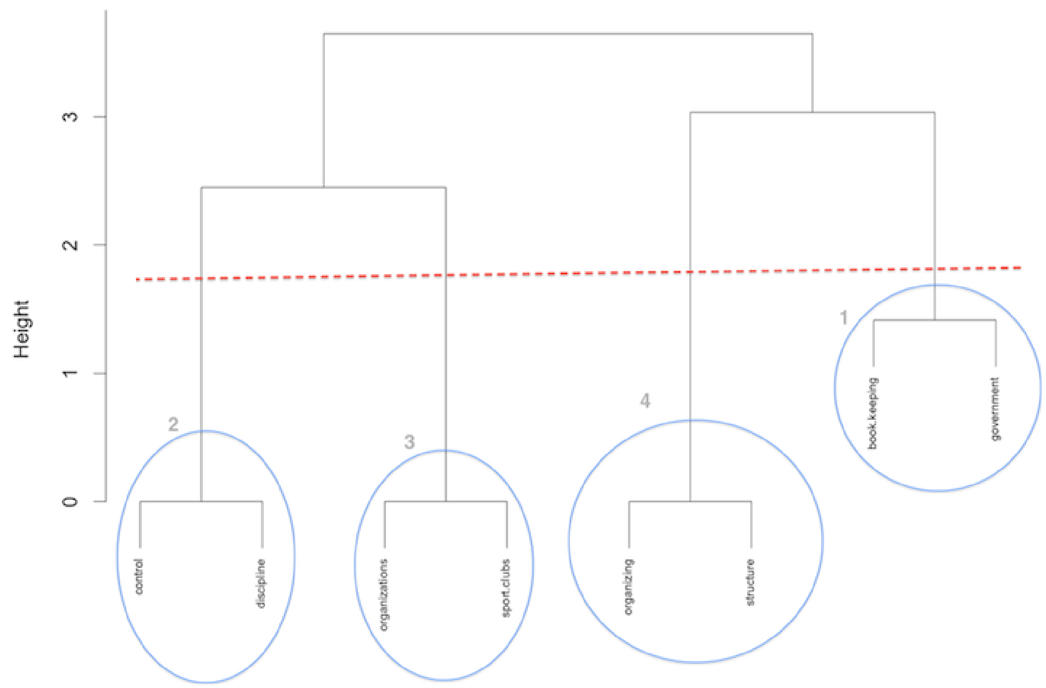
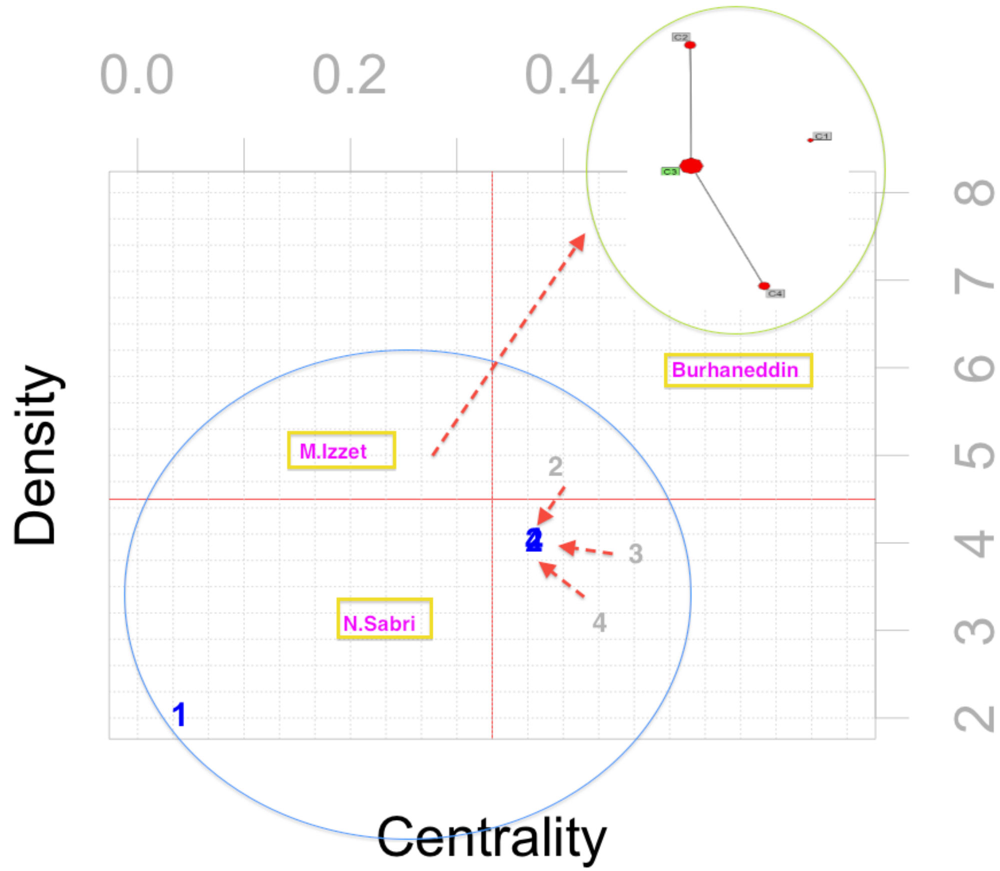


Figure 5.5: Field map of Management in Turkey: 1922 - 1925.



5.3.4 Mapping Scientists onto Strategic Diagram of their Respective Research Fields

Conventional strategic diagram is deficient in the sense that it isolates knowledge from its carriers. It does not constellate the knowledge generators regarding their contribution to different theme clusters. In other words, it does not hint what percent of a scientist's effort is towards main stream issues, or towards rather peripheral issues within that very field.

As part of this dissertation study, a new methodological model is developed to overcome aforementioned deficiency. The proposed novel method combines meta-network analysis and conceptual clusters of conventional co-word analysis. The method is simply re-generation of strategic map of the field as of authors in the field. Putting it differently, it develops a metric in order to find each author's Centrality and Density. In that sense, it parallels conventional strategic diagrams.

Equations 5.7 and Equation 5.8 are respective equations used to identify centrality and density of each author observed within a bibliographic set.

$$ASC_{author} = \sum_{\forall p \in P_a} \frac{1}{a_p} \left(\frac{\sum_{i=1,j=1}^{E_{ij}} (E_{iw}/C_{iw})}{n(N-n)} \right)$$

where,

$$\begin{aligned}
ASC_{author} &= \text{Centrality of the author} \\
P &= \text{Set of papers by the author} \\
E &= \text{Equivalence index of word pair link} \\
C_{ij} &= \text{co-occurrence frequency of } i \wedge j \text{ appearing on the same paper.} \\
N &= \text{Total number of unique words used in titles within the period} \\
p &= \text{current paper in the set} \\
a_p &= \text{Number of collaborators of current paper in the set} \\
i &= \text{First word in the pairing, internal to the cluster} \\
w &= \text{Word in dataset, but not in the cluster} \\
n &= \text{Number of unique words in the cluster}
\end{aligned} \tag{5.7}$$

In words, equations sums of contributions of each paper of an author to each issue in the field. It examines each paper of an author and checks distribution of keywords of that very across the clusters in the field. Using this cluster identification information each author collects back his or her own contribution to a cluster as of the very paper he or she has published. The metric further takes into consideration the number of authors on the same paper. On the other way around, the metric can be interpreted as distributing back the portion of each author's contribution to theme clusters, where the share is represented by a tuple, the centrality of the issue and density of the issue.

$$
\begin{aligned}
ASD_{author} &= \sum_{\forall p \in P_a} \frac{1}{a_p} (\frac{\sum_{i=1,j=1}^{E_{ij}} (E_{ij}/C_{ij})}{(n(n-1))/2}) \text{ for } n > 1 \\
&= \sum_{\forall p \in P_a} (\frac{1}{a_p} \sum_{i=1,j=1}^{E_{ij}} E_{ij}/C_{ij}) \text{ for } n = 1
\end{aligned}
$$

where,

$$
\begin{aligned}
ASD_{author} &= \text{Density of the author} \\
P &= \text{Set of papers by the author} \\
E &= \text{Equivalence index of word pair link} \\
C_{ij} &= \text{co-occurrence frequency of } i \wedge j \text{ appearing on the same paper.} \\
p &= \text{current paper in the set} \\
a_p &= \text{Number of collaborators of current paper in the set} \\
i &= \text{First word in the pairing} \\
j &= \text{Second word in the pairing} \\
n &= \text{Number of unique words in the cluster}
\end{aligned} \tag{5.8}
$$

Based on this new pair of metrics, the model finds position of the authors on the strategic map. The axis of author strategic maps are recomputed based on the average centrality of authors (ASC) and average density of authors (ASD). It should be noted that strategic map of scientists and the strategic map of the knowledge in the field are not necessarily the same two dimensional space. They are rather parallel and dual maps.

Figure 5.5 further shows distribution of authors to the quadrants on the strategic diagram based on their computed ASC and ASD coordinates. The model is exploited to combine and examine the interplay between individual level positions on the strategic diagram and cognitive state of individuals as of their dissemination activities in a field of science.

5.4 Periodization

As part of the dissertation case study, bibliographic entries of Turkish Management related fields are examined. In order to further examine varying social structure and knowledge diffusion channels methodologically periodization research is conducted.

Contrary to other studies elsewhere, basis of the periodization is not developed upon in depth analysis of management knowledge. Rather overall publication activity and collaboration network structure of the community is probed. Publication activities are examined in terms of trends in the number of publications relevant to management. For the social structure a set of social network metrics, such as rate and degree of collaboration, and transitivity is used.

The primacy, for periodization, on publication counts and rates along with basic network measures over knowledge content is based on three reasons. First, the case covers a very long time span and the case it self consists of sub-cases, where nature and content of the knowledge is observed to change dramatically. Second, in order to trace changes in the content the research needs to be initiated after manual inspection of each title for its keywords and then periodization, which is not very practical given the size of the data and subjectivity of content coding. Instead, keywords of the titles are extracted combining computing power and manual inspections with sliding time windows in parallel to periodization efforts. Third, co-authorship data extracted from the papers and year-wise number of publications along with collaboration characteristics provides a scientifically more sound basis for the study. The details of data cleaning and content coding is given in Chapter 7.1.

5.5 Over Time Analysis

Periodization enhances and allows individual and knowledge level analysis for a given period. Over time analysis, moreover, is used to examine and model relation in between structure and change of co-authorship network and level of diffusion over time. Continuous, year-wise, data is used to detect underlying diffusion mechanism in the community. The details of the descriptive, non-parametric tests, regression models as well as diffusion models which are employed or developed are given in Chapter 6. Empirical findings of the study based on the results and discussions are given in the same chapter.

5.6 Software Tools

Majority of meta-network analysis is conducted using ORA SNA Tool[10] and SNA packages from R[11]. Statistical tests and models are developed in R. The initial and differing format of data sets and the size of data along with advanced methodological tools targeted for the study necessitated to develop new software and programming scripts both in Python and R. A set of self-content software is developed in order to repeat, test and automate laborious data analysis and visualization which are by-product of this dissertation study. The set comprises of of data extraction, cleaning, encoding, analysis and visualizations tasks presented in this dissertation study.

5.7 Data

The research framework which is outlined in previous sections in this chapter which encompasses mutuality of knowledge in a scientific field and social collaboration at disseminating knowledge in the field via co-authorship networks is exemplified with a case. The case covers Turkish management academia.

Selection of case, nonetheless, allows me to make certain assumptions on the other social identities and social media in which scientific activity is realized. For instance, all national level socio-political, economical and historical factors applies to the community. Besides primary data covers almost entire period of Turkish Republic from 1923 up to 2008. The data set itself is homogenous, as it consists of scientific articles published at national level and disseminated within the country. Language of almost all titles in the set are in Turkish. Author or at least one of the co-authors of each paper is affiliated with a Turkish academic institute. Scope, coverage and time span of selected dataset relaxes certain limitations and drawbacks faced in earlier studies in the literature. The limitations on the plausibility of findings due to selection of datasets are covered and discussed in Chapter 4.

5.7.1 Data Sets

The source of primary data comprises of public records on scientific articles published in Turkey from 1922 to 2008, or from Turkey published in WoS spanning years from 1980 to 2008. The records on local publications have two separate sets as a consequence of institutional public policy changes. The first set is recorded and kept by Turkish National Library (MK), the second set is held by Turkish Academic Network and Information Center (ULAKBIM).

Turkish higher education institute has experienced a dramatic institutional change in 1981 (Onder et.al., 2008; Usdiken and Wasti, 2009). This change in long term starting in late 1990's has lead more strict policy developments and set of criteria at confirming scientificity of published articles. As a result, institutional change at assessment criteria regarding scientific content and its acceptance to public data sets has applied more strict rules. Consequently, it is seen that number of publications in public data sets starting in mid 1990's has decreased. Besides, task of keeping and publishing bibliographic information on journal articles in Turkey was relocated from MK to ULAKBIM. This has resulted in a gap in available data sets.

1. **Turkish National Library Dataset (MK), 1922 - 1999:** The primary source of data is a dataset which is published by Turkish National Library. The set covers bibliography of articles in the Republic periodicals. There are more than 566,000 articles published in 4,398 periodicals, which were published in Turkey between 1923 to 1999. Each entry in the set has a subject code. This subject codes are used to extract management related publications. There were two relevant subject codes: 'management' and 'management related studies'. Papers having either code was extracted from the complete set.

The initially extracted set comprised of around 16,000 papers. The set further examined and cleaned with the help of written programming script and laborious manual inspections. Duplicates, irrelevant papers, and entries with no title were extracted from the sub-set. Additionally items which lacks proper author information were filtered out. Finally, 12,484 papers found to be valid for further analysis.

2. **Turkish Academic Network and Information Center Dataset (ULAKBIM), 2002 - 2008:** The dataset was provided in a rather clean format. The papers which had management subject codes were extracted and further examined for relevancy and duplicates. In the end a set of 860 papers with proper author names remained valid for further analysis.

3. **Web of Science Dataset (WoS), 1980 - 2008:** In addition to national publications international publications were extracted from Web of Science. WoS[12] is a Web based interface developed by Institute for Scientific Information (ISI), which publishes Science Citation Index (SCI), Social Sciences Citation Index (SSCI) and the Arts and Humanities Citation Index (AHCI) papers. Articles address information was used to extract papers with at least one author affiliated with an organization in Turkey. Only journal and proceeding papers are used. List of journals and proceedings in the data set is used to identify journals which publishes management or management related papers. Articles from those journals extracted out for further analysis. Eventually, 281 items covering the years from 1980 to 2008 is found valid.

5.7.2 Data Coding Process

Formation of co-authorship relations (AxA) is based on co-authorship information available for each article. Authors full name is used. The process automatized and tested for correctness. Authors with same last name and overlapping first name(s) are further examined manually to decrease probability of making errors.

In order to encode each paper as of their keywords. Titles of papers are used uniformly for all sets. As it has been discussed in Chapter 2.2 use of titles has been reported to be the most robust and less error prone option for co-word analysis, given that there is a large number of items in the set.

In the literature, almost unanimously, extracting contents of the titles for content analysis is performed computationally. Computational extraction of keywords are further probed to filter out words under a certain threshold varying from 2 to 5. Out of remaining list of papers at most up to 250 most frequent words have been reported in other studies to be used to conduct actual analysis.

For this dissertation study, a semi-automated content coding scheme have been applied. A 5 year long moving time window is used:

1. Each title is split into words using programming scripts.
2. Frequencies of each word is examined manually.
3. Numbers, conjunctions, articles, and other content-wise noisy and uninformative words are eliminated.
4. Due to agglutinative[13] structure of Turkish words, list of unique nouns are sorted according to their initials.
5. Words with same root and same meaning are grouped content-wise using thesaurus like data structures.
6. List of unique names are further used to spot synonyms. Sets of such synonym words are also formed.
7. Whole titles and word lists are further examined to form list phrases which consists of more than one word.

Above process has been iterated over and over again until no further improvement was detectable. Having completed above process for each time window, list of words are normalized. The process above was conducted only for articles in Turkish. Non Turkish articles from local set were less than 20 in number and and they were coded manually in accordance same standard as above.

In order to test reliability of coding scheme full set was randomized and were sent to an independent referee. The referee were asked to content code each title manually. The referee have accomplished to content code 861 article titles (6.3 percent). The number was found large enough for robustness of reliability test of coding scheme.

Content codes are then compared. Two different inter-rater reliability method is employed: Percent Agreement (Riffe et.al., 1998) and Krippendorff's Alpha (Krippendorff, 2004). The choice of Percent agreement stems from its being most widely used method. However, literature suggests that although it is intuitively appealing and simple to calculate, it should be accompanied with a more robust method (White and Marsh, 2006). Krippendorff's Alpha is known to be the most conservative producing lower values compared to other methods; yet it remains valid with multiple coders, different sample sizes and missing data, in that sense, it is regarded and recommended (Hayes and Krippendorff, 2007).

Percent agreement measure has suggested 0.83 level of reliability for the coding scheme, which is over accepted 0.70 threshold (Riffe et.al., 1998) and Krippendorff's Alpha have produced 0.71 rate. Considering the very conservative nature of the second test and large sample size, test results significantly support coding scheme used. Besides, during the actual analysis keywords with 3 and more frequencies are used for the periods with large enough items, and keywords with 2 or more frequencies used for earlier periods where there were less number of items. Elimination of less frequent keywords is applied unanimously in the literature for error reduction.

Lastly, it should be noted that the nature of this study does not primarily focus on the very particular or specific content, it rather examines diffusion of 'uniquely tagged' knowledge in relation to co-authorship structure. This primary focus diminishes importance of possible errors made during content coding.

Chapter 6

Findings

The chapter details a set of cascaded and interrelated analysis on the exemplary case. It develops upon a theoretically and methodologically coherent and comprehensive research framework discussed in earlier chapters. Relevancy of findings presented in this chapter is discussed in the next chapter.

The first set of analysis in Section 6.1 provides overall publication productivity and collaboration trend in Turkish academia in 20^{th} century. The growing rate of collaboration in Turkey is modeled and characterized. The chapter follows by contextualizing the Turkish management academia within Turkey. Macro level collaboration and dissemination activities of management academia is used to identify periods with peculiar macro level characteristics.

The periodization is conducted in order to be able to detail advanced analysis within time intervals of each period. In each period, academia exhibits a relatively more similar characteristics as well as it is exposed to similar historical, political, demographical and economical settings. However, it should be noted that throughout the analysis, time window of each period is extended backward and forward in time in order to accommodate continuity. This adjustment is designed in parallel to discussions foreseen in Chapter 4. Shortly, it aims to overcome pitfalls that might stem from excluding transient phenomena of the period under exploration. Besides, continuum nature of knowledge transfer in fields of sciences and persistency of collaboration ties suggest such an adjustment.

The chapter additionally presents findings resulted from some auxiliary analysis conducted for certain periods. The auxiliary analyses consist of productivity, rate of collaboration and co-authorship distributions over time as well as study types employed in some random subset of papers, sectoral distribution of case analysis reported in them and overall publication trends in subfields of management in Turkey. This rich set of auxiliary analyses serves to contextualize the major focus of the dissertation, helps to identify periods, provides additional findings to enhance discussions, and hints to point further micro level research on the subject. In short, findings of these precursory analyses are seen to be instrumental at enhancing and supporting major findings of this exemplary case.

The chapter follows by exploring knowledge map of the field over time highlighting central concepts and their carriers, strategic map of issues, interaction of issues with each other and interdiscipliniarity of the field. These findings serve to characterize knowledge diffusion qualitatively and quantitatively over time and period-wise.

Next, topologies of the collaboration structure is explored. The findings help to demonstrate and present nature of fragmentation in the academia. Additionally, impact of geographic location on the fragmentation is highlighted. Network level comparisons are conducted. The major part of the analysis reveals findings on knowledge diffusion model in the network, as well as, it demonstrates actor level relations observed in between scientists' socio-knowledge properties and their typical strategies at picking issues in the field.

Further details on additional and auxiliary findings are annexed in the appendices.

6.1 Collaboration and Productivity Overall in Turkey

Aggregate trends in number of publications and co-authorship rate in Turkey is explored. All available bibliographic entries of the major data set which covers years from 1922 up to 1999 is used. The set includes almost all major and minor scientific fields that have produced national level publications within Turkey. The number of publications over the years is depicted in Figure 6.1. In total there are more than 566,000 articles published in 4,398 scientific periodicals. Year of important socio-political events are marked on Figure 6.1 and Figure 6.2.

Figure 6.1: Publication frequency trends in Turkey: 1922-1999.

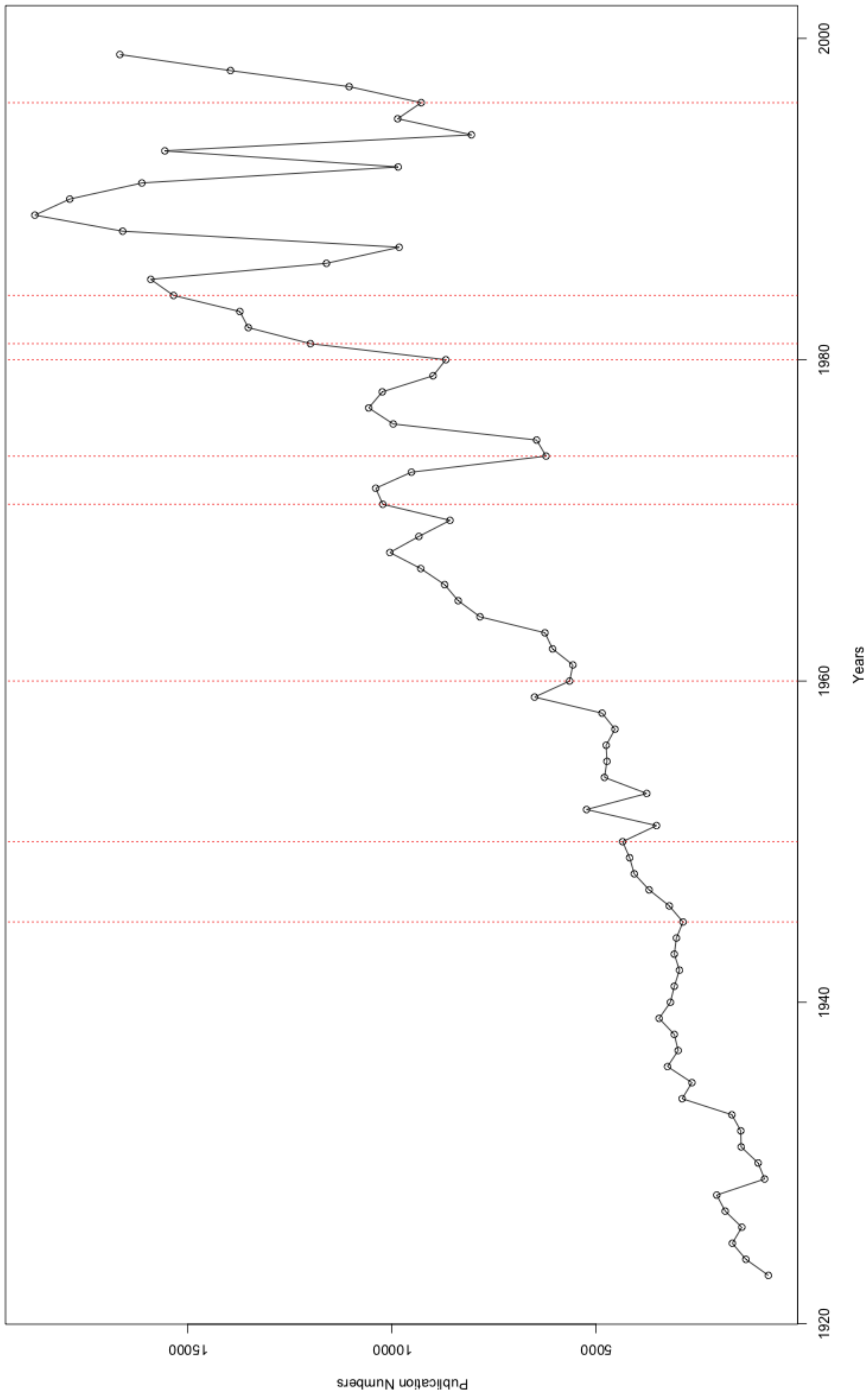
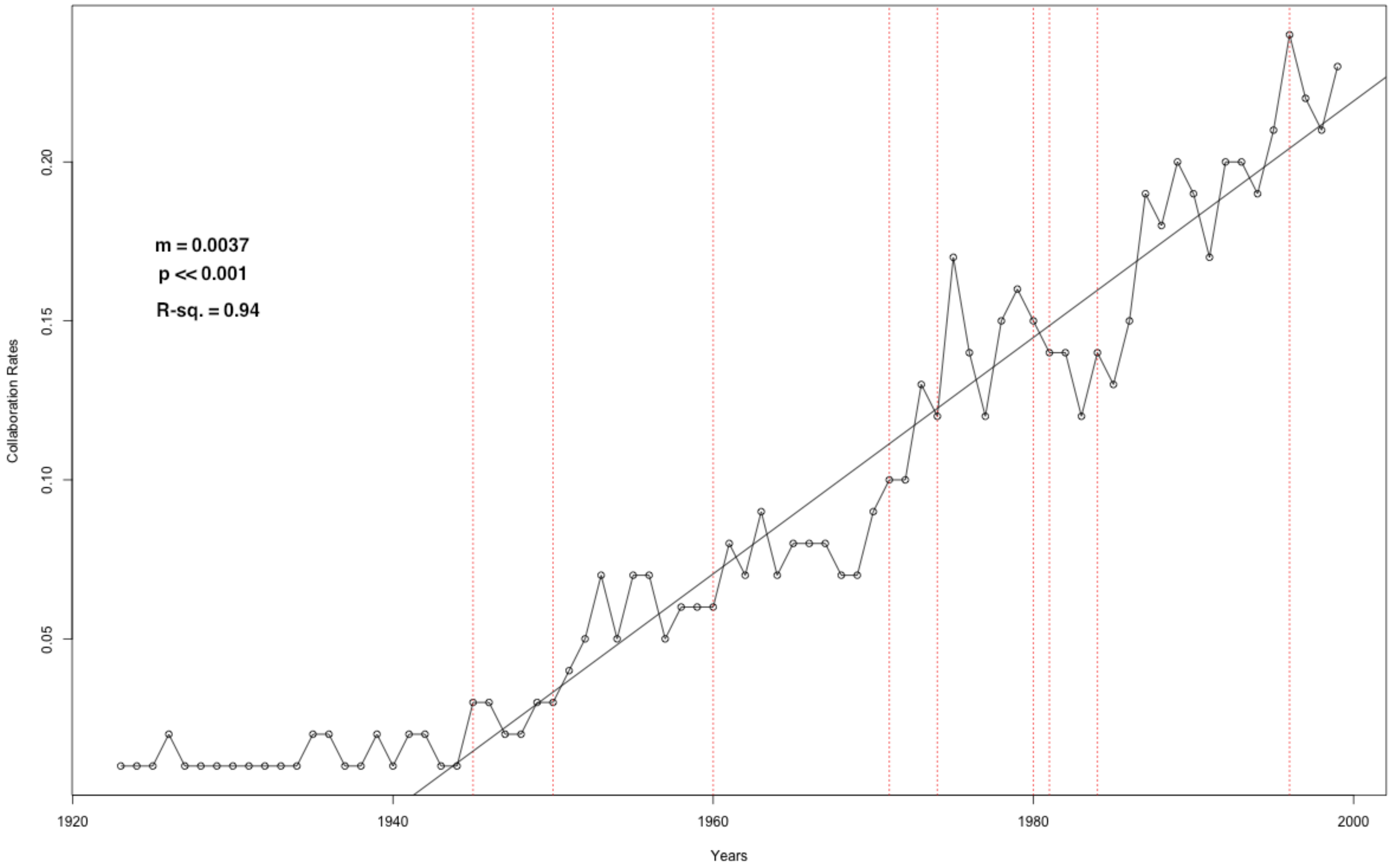


Figure 6.2: Rate of collaboration in Turkish academia: 1922-1999.



Rate of collaboration is further examined in order to characterize overall average trends in Turkey. Collaboration ties are focused as they provide both channels of knowledge diffusion and medium of individual level social interactions. A simple linear regression model is tested in order to check if rate of increase at the ratio of co-authored papers is significantly steady in Turkey. Following model is applied:

$$\begin{aligned} R_i &= mY_i + C \\ &\text{where,} \\ Y_i &= \textit{Year of publications} \\ R_i &= \frac{\textit{Number of co-authored papers in } Y_i}{\textit{Total number of papers in } Y_i} \end{aligned} \tag{6.1}$$

In words, the rate for each year gives the ratio of co-authored papers to total papers published in that year. The result of regression as well as fitted regression line is drawn in Figure 6.2. The test result shows that ratio of papers with 2 or more number of co-authors in Turkey from 1945 up to 1999 has experienced a statistically significant increase with a rate of 0.0037. Figure 6.3 to Figure 6.6 reveal that not only the rate of co-authored papers but also the size of teams have also increased. The distributions in the figures displays histograms representing number of collaborators over decades.

6.2 Periods in Turkish Management Academia

While examining the periods in Turkish management in addition to main data set the MK which covers journal articles published in Turkey from 1922 to 1999, a second data set which comprises of articles published in WoS is used. WoS entries spans from 1980 to 2008. The third data set is again articles published in Turkey which are retrieved from ULAKBIM dataset and covers years starting from 2002 up to 2008.

Figure 6.3: Team sizes in 20's and 30's.

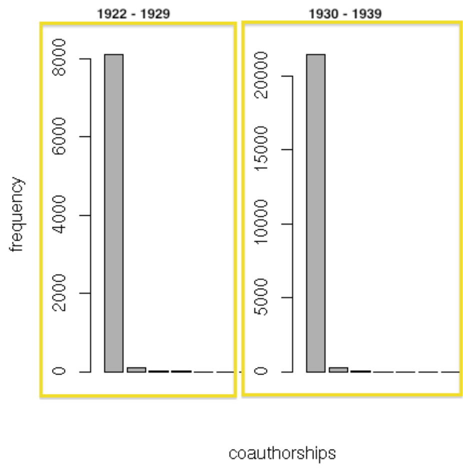


Figure 6.4: Team sizes in 40's and 50's.

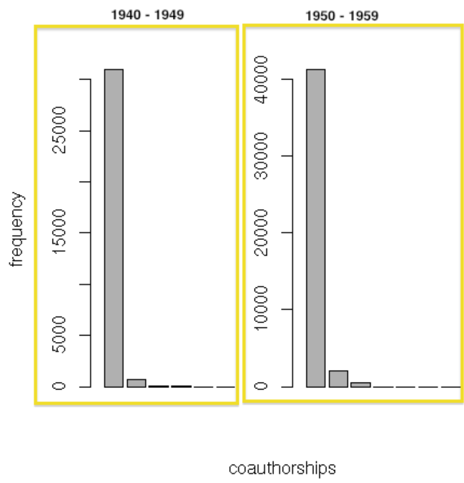


Figure 6.5: Team sizes in 60's and 70's.

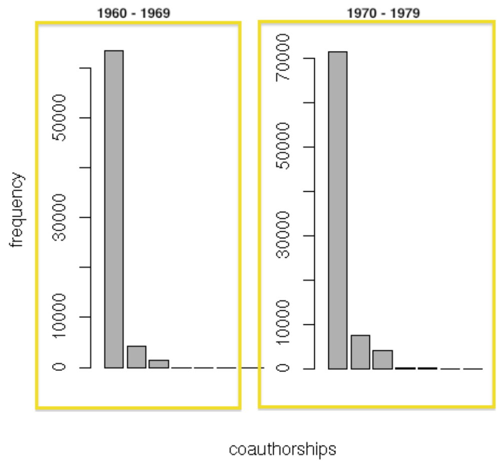


Figure 6.6: Team sizes in 80's and 90's.

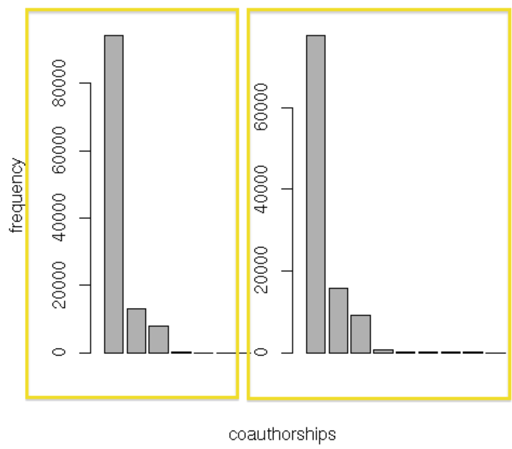


Figure 6.7: Publication frequency trends in Turkish management field: 1922-1999.

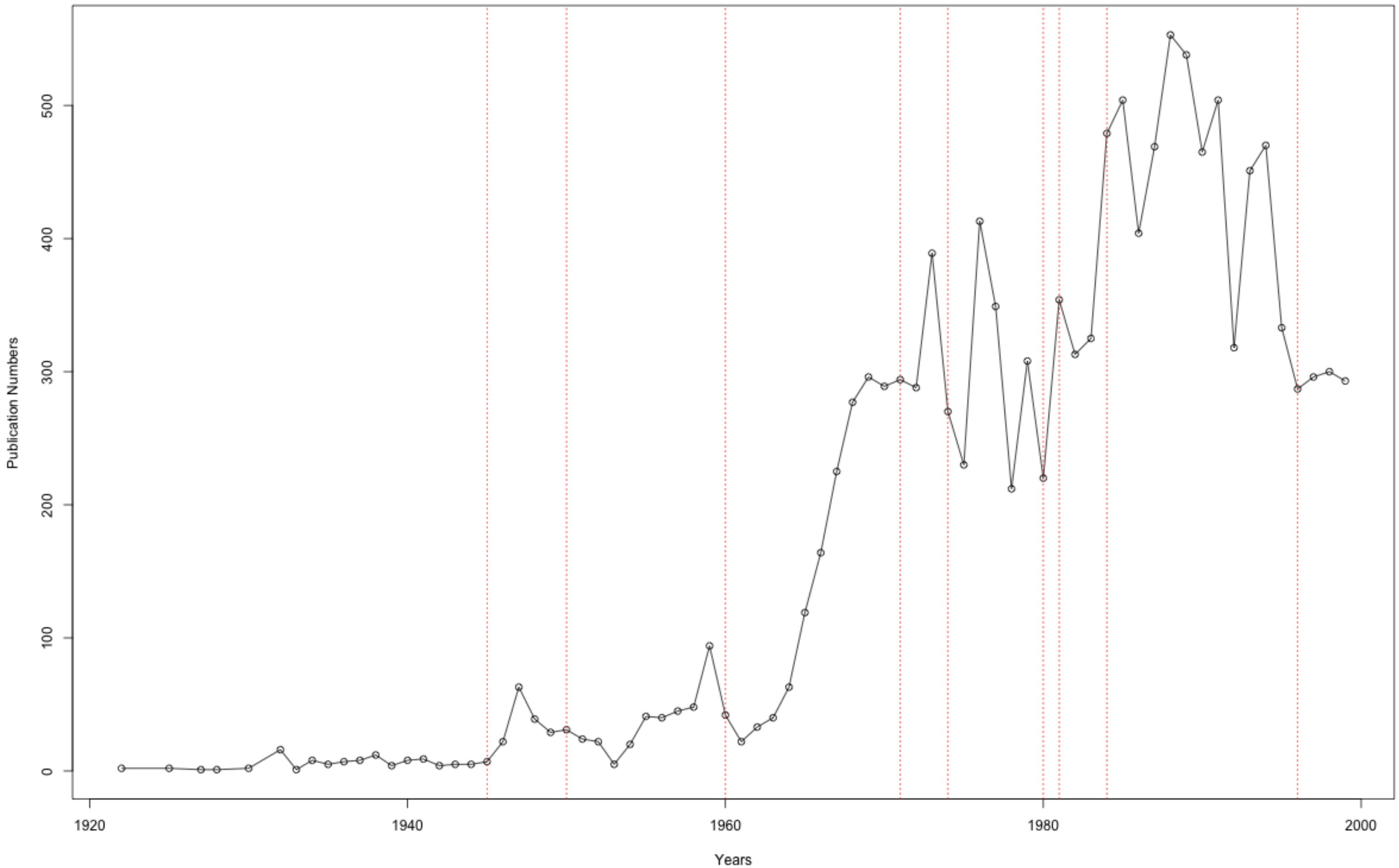


Figure 6.8: Rate of collaboration in Turkish management academia: 1922-1999.

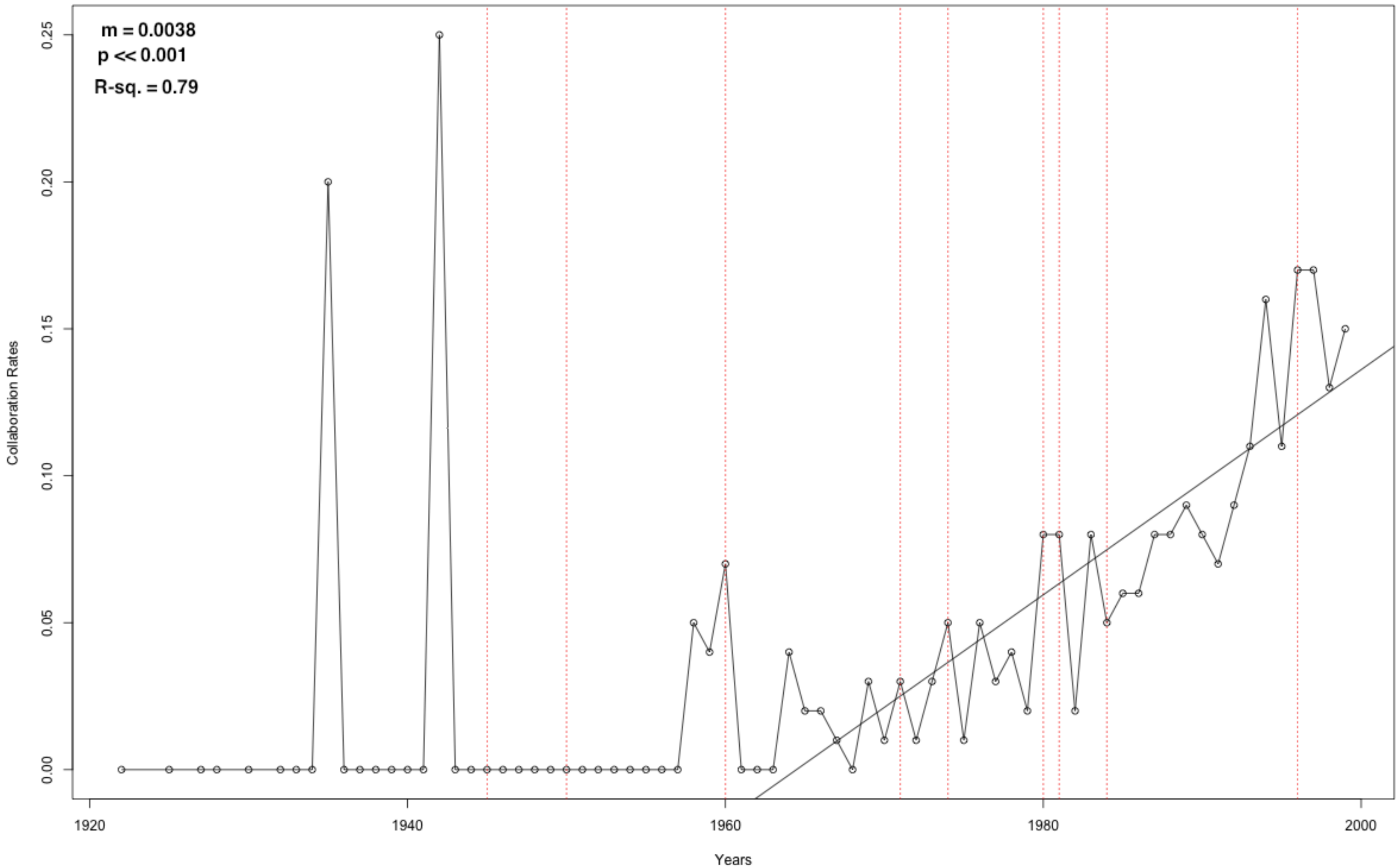


Figure 6.7 and Figure 6.8 together parallel Figure 6.1 and Figure 6.2 of previous section. They respectively, depict publication productivity and collaboration rate specifically in management field for the same years. Comparing the two set demonstrates that although trends in management related studies follow the national level pattern in all sciences, it further has its own peculiarities. It is observed that the number of papers in 70's is more unstable compared to number of overall papers. Second, not only rate of collaboration but also number of papers in the years following the military intervention in 1980 has decreased significantly.

Rate of collaboration in management is further characterized using the model given in Equation 6.1, it is seen that increase in the rate of collaboration is very slightly but not very significantly higher in management as a discipline compared to average rate in all sciences. The result of regression along with fitted line is drawn in Figure 6.8.

Figure 6.9 depicts distribution of team sizes in three different data sets. The ratio of co-authored papers in WoS papers surpasses single authored papers. This fact hints a very different mechanism and social form of collaboration at incentives to publish internationally. As a result dynamics of WoS is studied separately yet comparatively with local publications. The two local sets MK and ULAKBIM are further taken separately. The basis of separation is manifold: (i) there are larger team sizes in ULAKBIM compared to MK as seen in Figure 6.9; (ii) ULAKBIM set exhibits higher rate of collaboration, compare Figure 6.12 with Figure 6.8; (iii) there is a time-wise difference in between them; (iv) they comprise of two distinct datasets although there are a high number of authors occurring in both sets. As a result, knowledge space in ULAKBIM set and social structure that has produced it is considered as a separate period.

The main data set which is based on around 13,500 papers is very extensive and highly representative of management field in Turkey. The length of time duration and exhibited differentiable trends as seen in the figures necessitates further periodization within the set. Productivity, rate of collaboration and distribution of team sizes (Figure 6.13) together have provided basis of periodization as well as major global and national historical events

Figure 6.9: Distribution of team sizes in management fields and in different datasets.

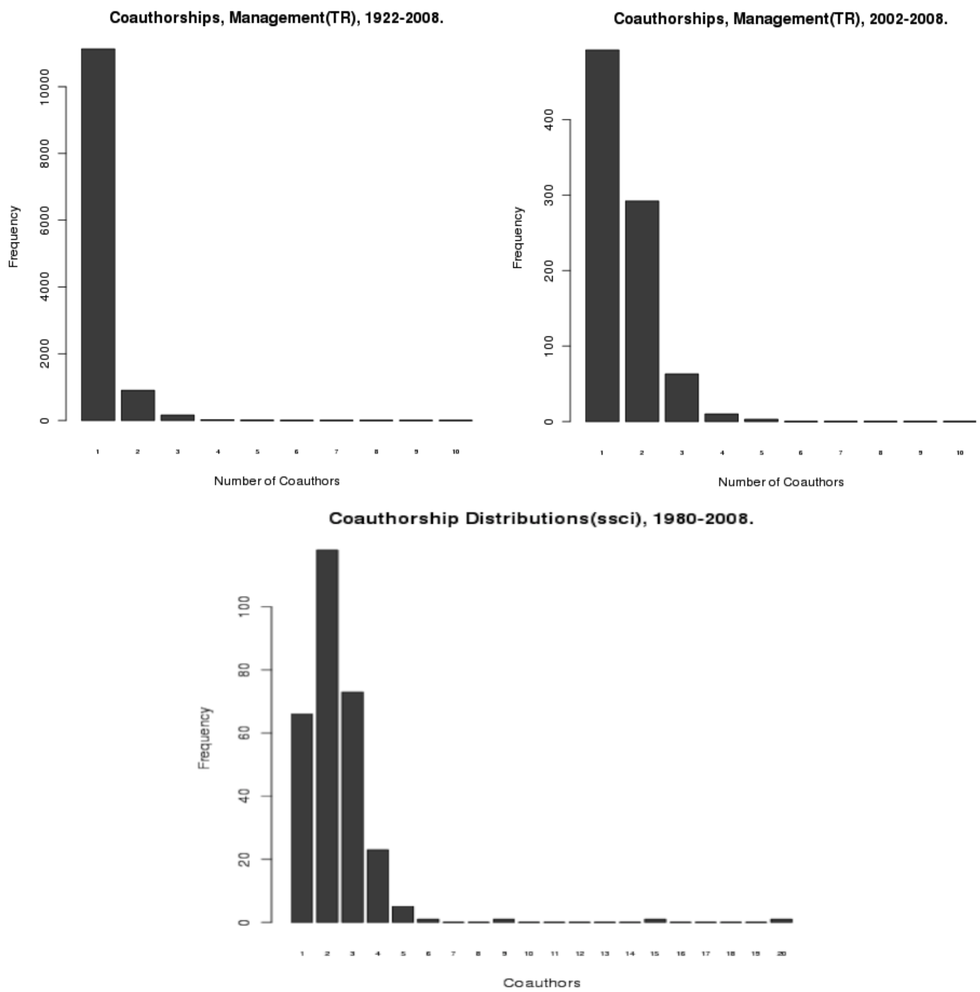


Figure 6.10: Publication frequency trends in WoS: 1980-2008.

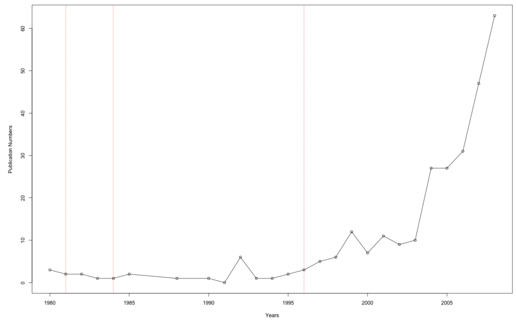


Figure 6.11: Rate of collaboration in WoS: 1980-2008.

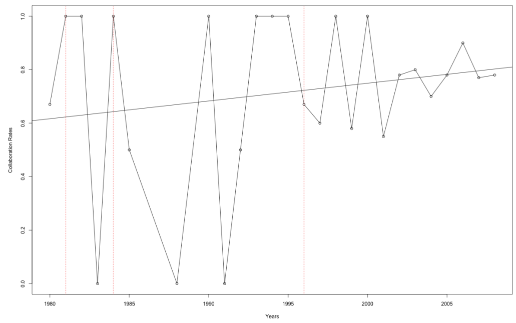


Figure 6.12: Rate of collaboration in ULAKBIM: 2002-2008.

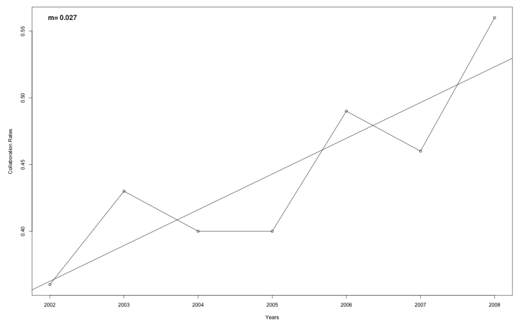
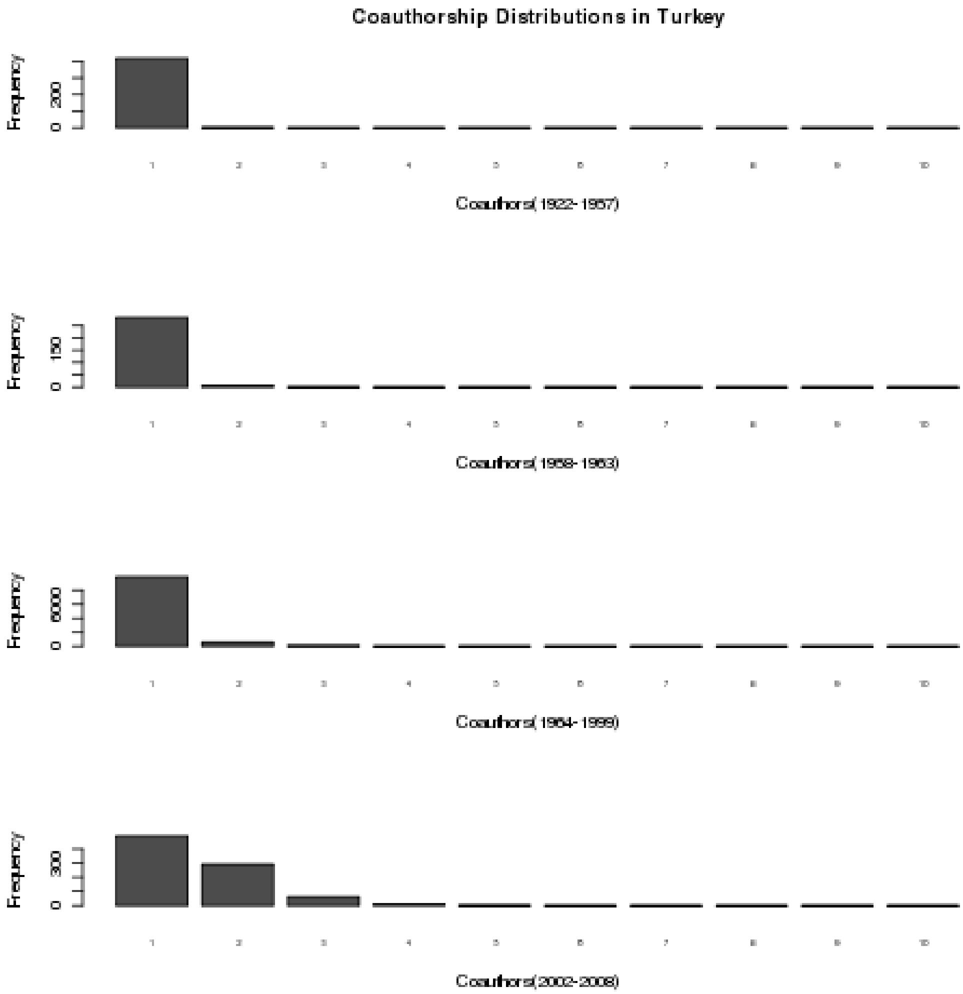


Figure 6.13: Distribution of team sizes in management fields in Turkey prior to 2000.



in 20^{th} century. There are 6 different observable regimes:

1. **Inceptive Years, 1922 ≈ 1945:** In the early period, there are hardly any year with more than 10 paper that can be annotated as a management related study or discussion. During the period almost all observed publications are single authored papers.

2. **Infancy Years, 1945 ≈ 1960:** In these years, there are significantly more number of papers compared to earlier years. This can be explained by influx of expat or immigrant management scientists to the country, as well as, by the global trends at establishment of the field as a discipline. Towards end of these years, we observe repeating co-authored papers.

3. **Growth Years, 1960 ≈ 1974:** In the growth years there is an exponential growth in the number of papers related to management discipline. Nevertheless, rate of collaboration is still low with a slower pace of growth.

4. **Years of Instability, 1974 ≈ 1984:** Years of instability reveals very unexpected characteristics compared natural growth of any scientific field (Kuhn, 1970; Merton, 1968). The growth in the number of publications looses its pace abruptly and it fluctuates from the years to years. However, if we have drawn an imaginary curve surpassing this period we would observe a continuum at the pace of growth in the field. On the other hand, Figure 6.8 reveals that growth in the rate of collaboration, in general, however keeps its intrinsic characteristics. Political and social instability in those same years such as hyper politicization of universities, military coup and national level centralization of university administration and finances may partly explain the discontinuity at productivity of the scientists in the period.

5. **Neo-growth Years, 1984 ≈ 1990:** The period resumes the rate of growth achieved in previous growth years. Rate of collaboration however exhibits a faster growth following global trends elsewhere.

6. **Post-growth Years, 1990 $\approx$ 2000:** In this period both total number of publications and growth rate seems to be decreased. On the other hand the rate of collaboration exhibits a further increase.

6.3 Knowledge Maps of Turkish Management Field

The first set of articles found in data set deals with organizational issues of sport clubs. The very first two article which appears in the set has the title read: *Kuluplerde Zapt ve Rabt* and *Kuluplerde Disiplin*. Both of the papers were written before 1925. The former can be translated as 'Governance and Control in Sport Clubs' while the latter 'Discipline in Sport Clubs'. However, not all articles examined in the study falls into realm of organization studies. Iterative probations on subsets of data has shown that it is possible to categorize them under: management, production, accounting, finance and marketing. The category of management covers all organizational issues from human resource development (HRM) to organizational behavior (OB). The category coding were performed in parallel to tokenization of keywords from the articles. Supervised semi-programmatic coding scheme as outlined in Section 7.1 were followed. An article is tagged by more then one category when it applies. The reliability of subfield classification is tested comparing actual codes and the control subset. The control subset consisted of 861 randomly selected articles. The manual categorization on the control subset was conducted by a faculty member in business administration department. An 0.92 agreement rate in between classifications is observed.

Figure 6.14 traces frequencies of publications in Turkey on management related subfields from 1922 up to 2008. It is seen that other then main field `accounting` dominates the field until the growth period of the main field. Since then `marketing` and `finance` seems to take over the role of major subfields. Figure 6.15 displays frequencies of papers as of the publications from Turkey in WoS. The figure shows that `marketing` has been dominating international publications as the major subfield.

Figure 6.14: Subfields in local studies: 1922-2008.

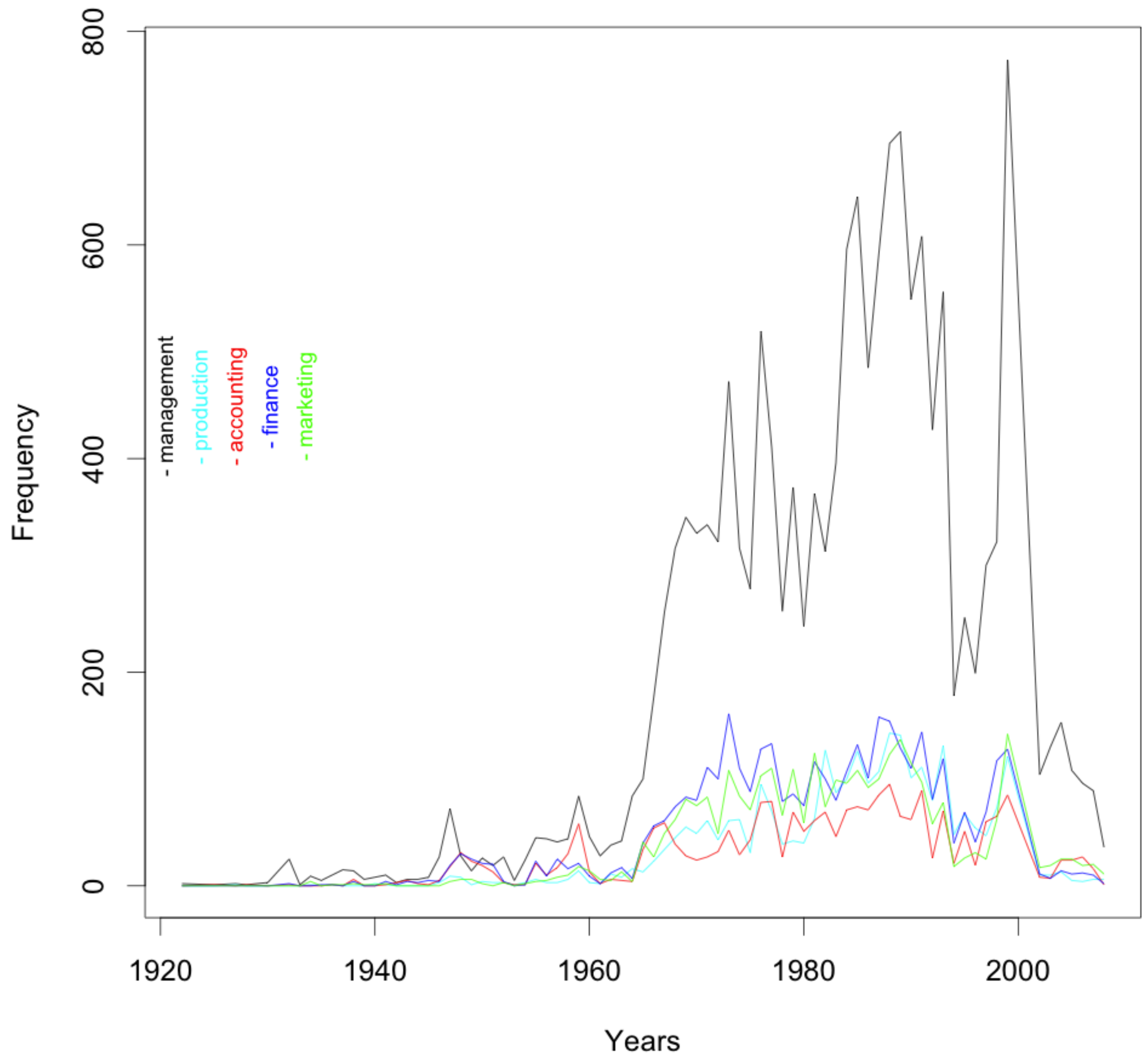


Figure 6.15: Subfields in WoS studies: 1980-2008.

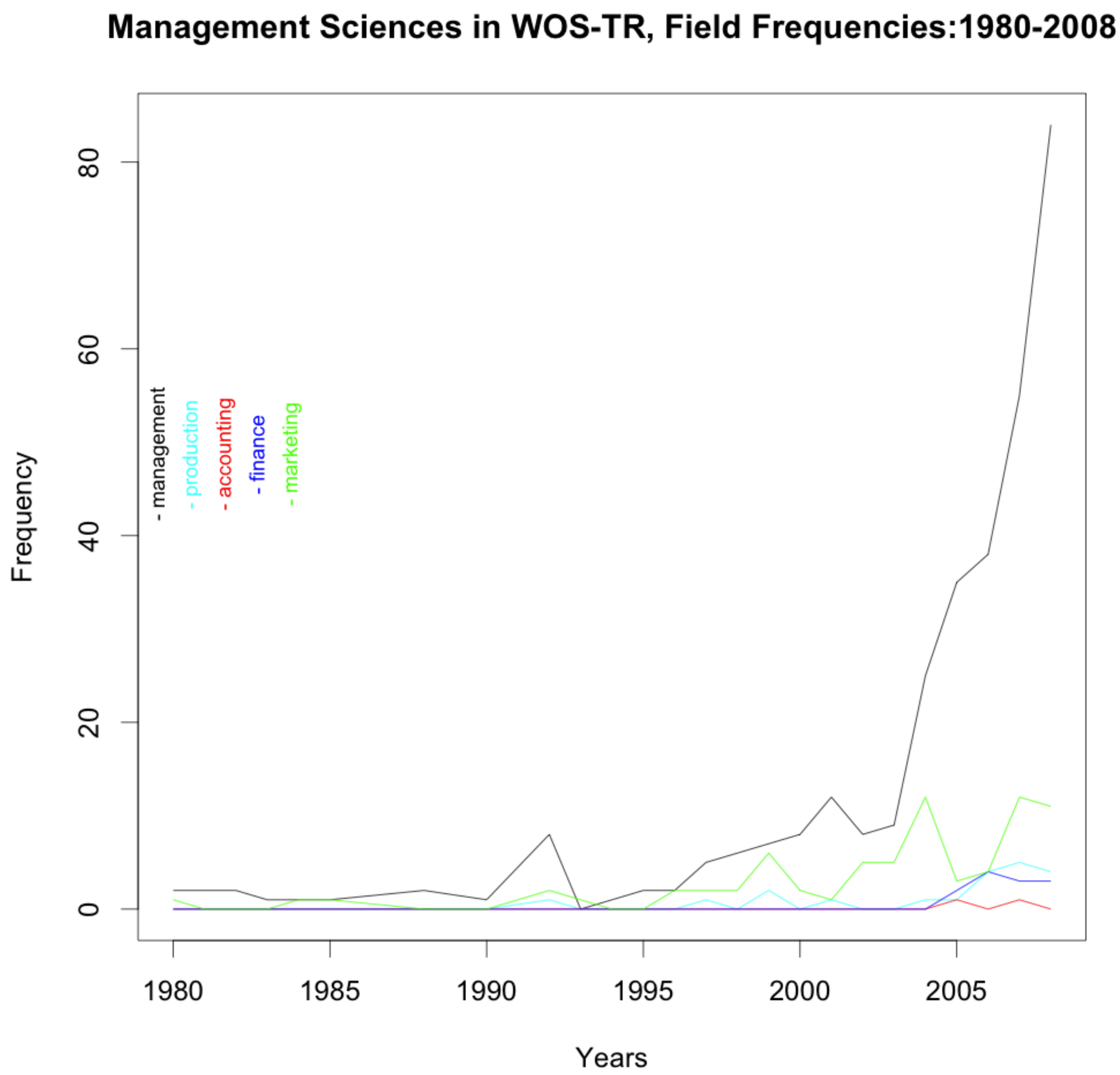


Figure 6.16 visualizes that over the time the field has become increasingly interdisciplinar. The figures are based on paper subject codes. The subject codes comes along with raw data. Subject code(s) of each article has been entered to the original database at the time of inclusion of an article. Of all subjects which were co-coded alongside management, the ones with 5 or higher frequencies are displayed in the graphs. Relative size of a subject node and width of its link represents its co-occurrence frequency with a management related study.

Figure 6.18 and Figure 6.19 are tag clouds of key authors and keywords in respective periods. The relative size of a tag represents its eigenvector centrality in the network of relations based on ties in between authors, in between keywords and in between authors and keywords. In mathematical terms, keywords and authors with large eigenvalues in AxA, KxK and AxK matrices are selected. They are positioned regarding to their co-occurrence in the bibliographic entries. In general, it is seen that at early stages of the field authors or the knowledge carriers are relatively more prominent. As field grows in Turkey from 1922 to 1999 the prominence of knowledge itself becomes much more dominant.

Figure 6.16: Increasing interdisciplinar influences on management:1922-1999.

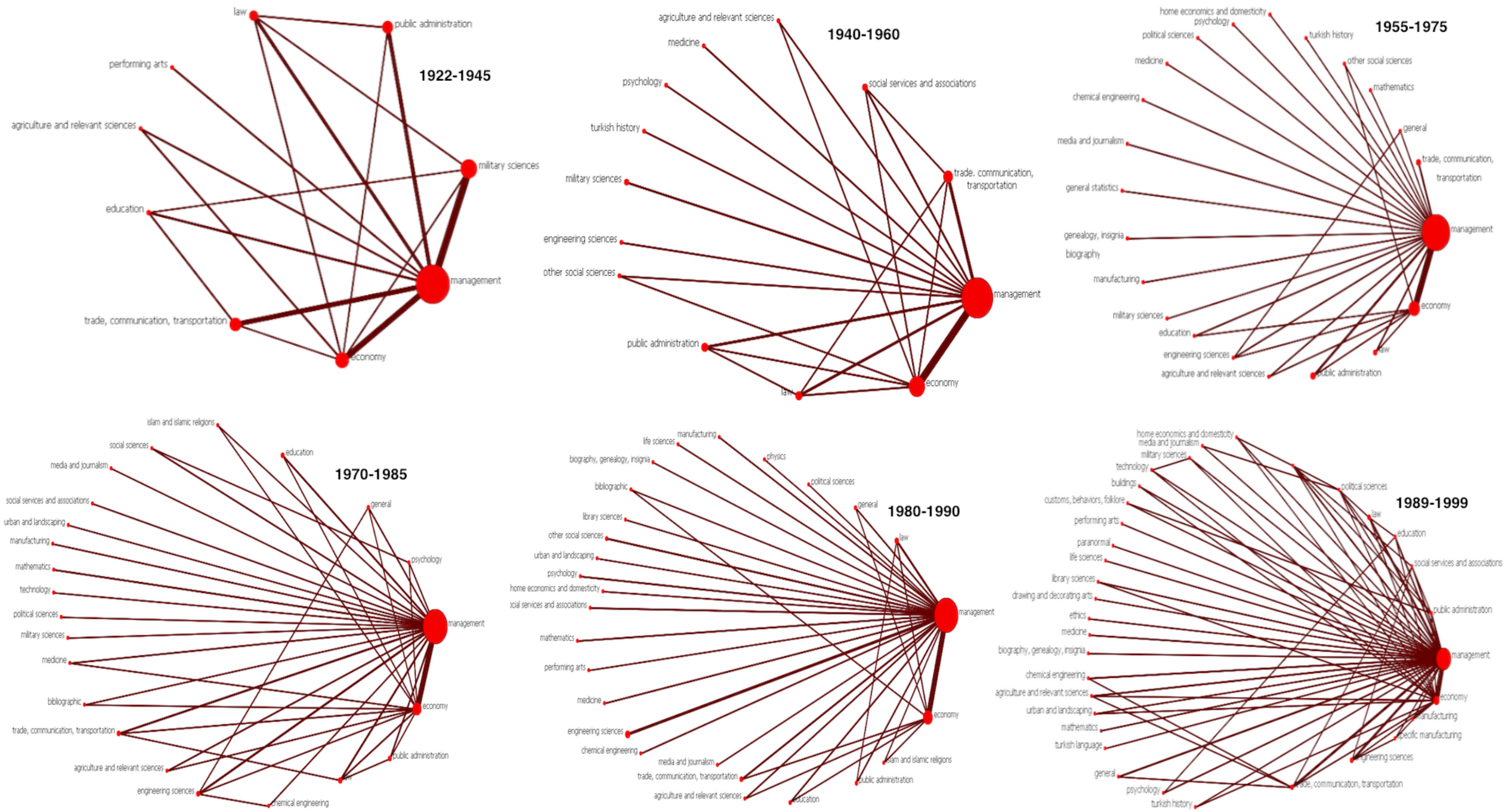
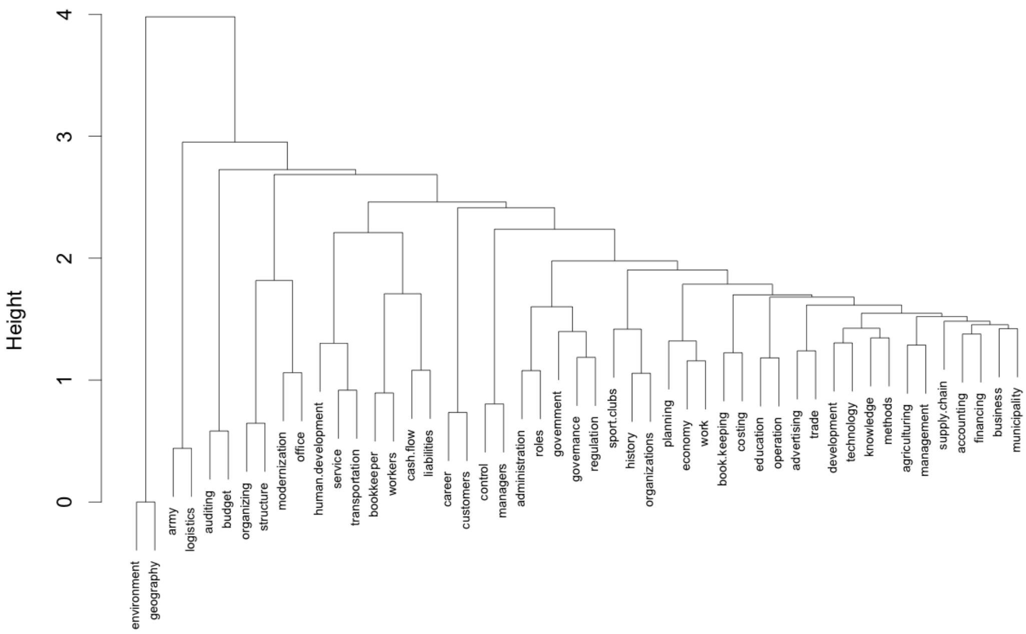


Figure 6.17: Dendogram of keywords: 1922-1945.



The tags derived from WoS however displays comparatively more scientists. A closer inspection by checking the names of some authors in the original set shows that prominence of these authors are put forward either due to their publications in new yet key subjects or their collaboration ties with popular authors. The choice of eigenvector centrality instead of other regular SNA centrality measures such as degree and betweenness has enabled to detect such subtle relations.

Figure 6.18: Clouds of central keywords and authors:1922-1999.

Figure 6.19: Clouds of central keywords in WoS (1980-2008) and in Turkey after millennium.

Keywords in WoS (1980 - 2008)

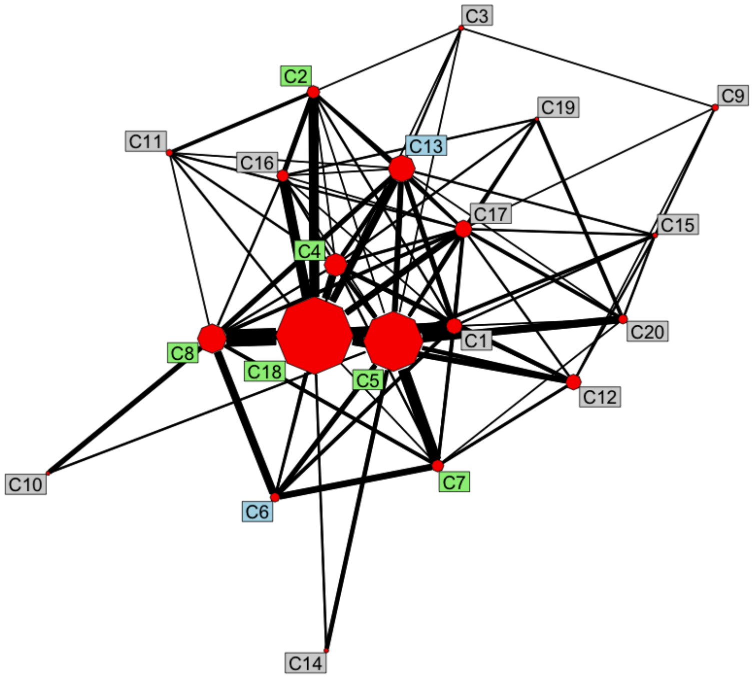
Keywords in Local Studies (2002-2008)

Although extraction and display of key concepts from the large dataset enables to trace the diffusion of main themes to some extent, it does not fully explain how these concepts are related to each other. In that respect, clustering analysis on keywords for each period is conducted. Figure 6.17 depicts the mutual proximity of concepts observed in years spanning 1922 to 1945. The figure is generated during the process of concept clustering. Proximity and depth of keyword groups on the dendogram represents their cohesiveness. It should be noted that cohesiveness here is induced by cognitive correlations made by the authors of the period. In other words, proximity of keywords and their depth on the dendogram graph is the visual representation of how keywords are clustered to form issues of the period. Thus each cluster represents a theme or an issue which consists of interrelated concepts by the scientists in the period. Namely an issue can be seen as a semantic representation by a set of keywords showing up relationally in the same cluster.

Having constructed clusters of semantically close keywords, each cluster's or issue's prevalence within semantic space of the period and its cohesiveness in between its own internal keywords are further identified. Prevalence is represented by centrality measure and cohesiveness is measured by density measure. Table 6.1 tabulates measured centrality, density and size of each cluster along with concepts which together form the issues in between 1922 to 1945. Each issue is then mapped onto the strategic diagram of the period.

For instance, the top leftmost diagram in Figure 6.21 shows the strategic map of the first period. It should be noted that to reduce the impact of random errors made during the semi-automated keyword extraction process, relatively very infrequent keywords are eliminated before the analysis. It is seen that in the first period logistics has been studied along with army organizations and it is the most central and recurrent issue in the period. Considering the fact that international political tensions of the period which has raised and ended with a world war, strategic map of the period captures prominence of the issue. It is further seen that transportation, service and human development keywords have co-occurred together in the titles. This strongly implies that human development issues have been studied within transportation services. On the other way around, the strategic diagram also shows that issue number 3, which consists of advertising and trade, was relatively a peripheral issue at the time.

Figure 6.20: Network of relations in between issues found in the period 1922-1945.



Strategic diagrams are research tool which are generated by co-word analysis. Although strategic diagram of any period has strong exploratory power to visualize map of the science at the time regarding prevalence and cohesiveness of issues addressed by scientists during the period, it lacks to demonstrate semantic relations formed in between issues. One of the methodological contribution of this dissertation is to extend co-word analysis in order to incorporate network of relations in between keyword clusters. For instance network of relations, in Figure 6.20 demonstrates the cognitive relations formed in between issues in the first period. The width of a link demonstrates relevance of issues. Size of an issue further represents aggregate frequency of keywords in the cluster. Furthermore, comparing strategic diagram of the period in Figure 6.21 and Figure 6.20 we observe that army logistics has been studied or discussed along with human resource development and book keeping issues.

The color codes on the issue network of Figure 6.20 represent quadrant of each respective issue. Comparing the network with its corresponding strategic diagram we observe that peripheral issues such as office modernization (C19) and organizing structure (C20) are studied more in army organizations (C5) then with sport clubs (C17).

Table 6.1: Management issues, 1922-1945.

ID	Centrality	Density	Size	Members
1	0.29	2.4	5	supply.chain; municipality; financing; business; accounting
2	0.36	19	2	roles; administration
3	0.06	8	2	trade; advertising
4	0.46	34	2	management; agriculturing
5	1.07	88	2	logistics; army
6	0.34	14	2	budget; auditing
7	0.41	18	2	costing; book.keeping
8	0.74	43	2	workers; bookkeeper
9	0.05	10	2	customers; career
10	0.09	6	2	liabilities; cash.flow
11	0.13	10	2	managers; control
12	0.15	3.83	4	technology; methods; knowledge; development
13	0.33	13.33	3	work; planning; economy
14	0.07	7	2	operation; education
15	0.17	8	2	geography; environment
16	0.21	6	3	regulation; government; governance
17	0.32	8.67	3	sport.clubs; organizations; history
18	0.9	38	3	transportation; service; human.development
19	0.14	6	2	office; modernization
20	0.24	14	2	structure; organizing

We see that moving from first period to the second period (1940-1960) accounting is studied more in relation to financing and it dominates the debate of the period. At the same period agriculturing is discussed with governmentally supported provincial or town cooperations which have been a major policy of the period. Yet, it is seen that compared to the first period of the republic the issue has lost its pace in subsequent periods and have found its position on the the third quadrant, the peripheral.

It is also observed that prominence of accounting left its spot for education, knowledge and training issues in the growth years. Inter-cluster relations (See, e.g. Appendix E) further reveals that these issues are rather discussed with themes in the peripheral rather than the other main stream issues such as manufacturing. In these years, issues relevant to manufacturing are rather more discussed with organizational history and automation. Training related issues seems to be evolved and sedimented within human development framework by late 90's.

The period which covers 70's and early 80's meets managerial leadership issue, while 90's is inflated with marketing and governance issues. Clouds, strategic maps and inter-issue networks together demonstrate dramatic changes in the management issues during late 70's onward compared to earlier periods. It is seen that focus on managers, socialization in work environment have become more and more centralized.

Figure 6.21: Strategic diagrams of issues in Turkey: 1922-1999.

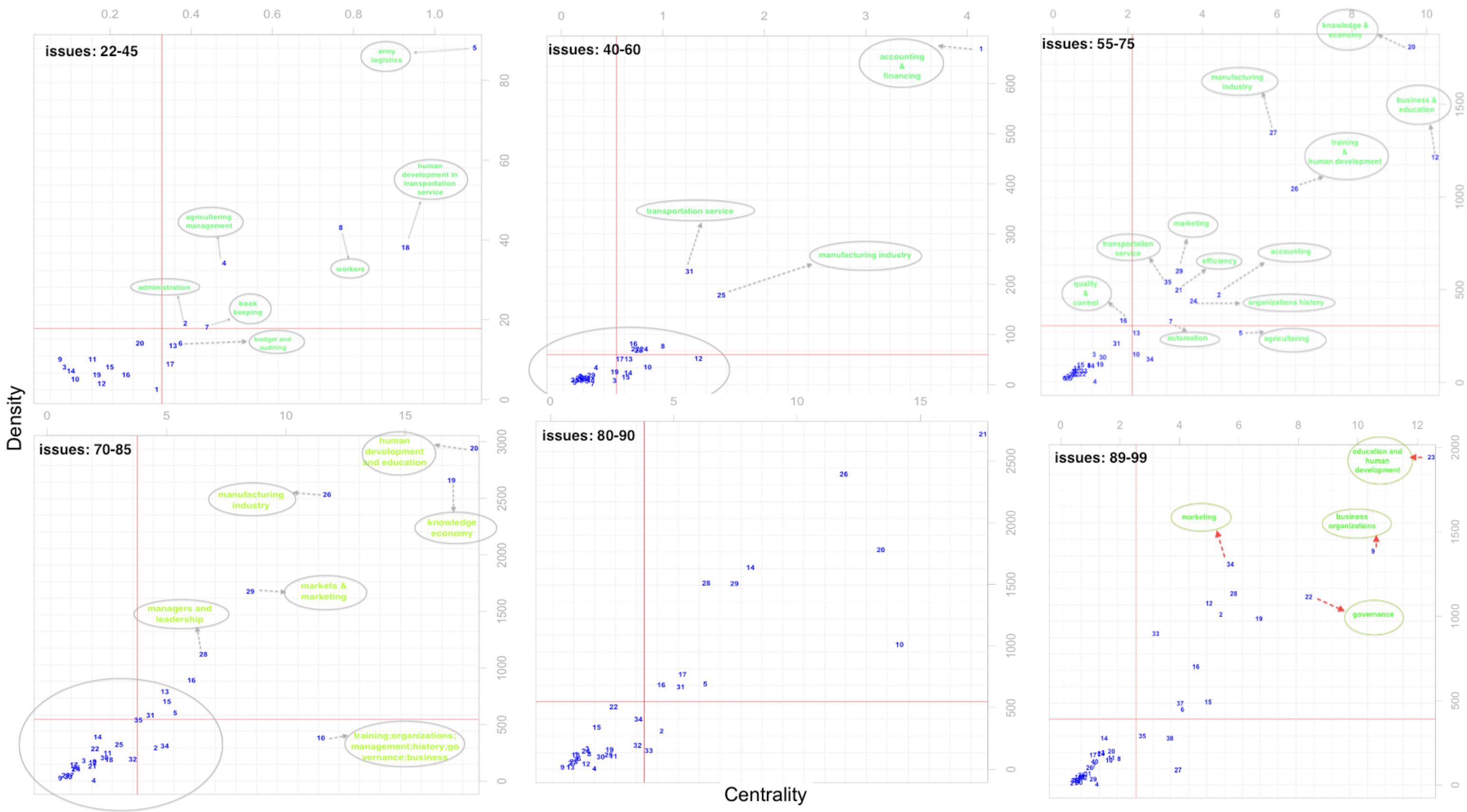
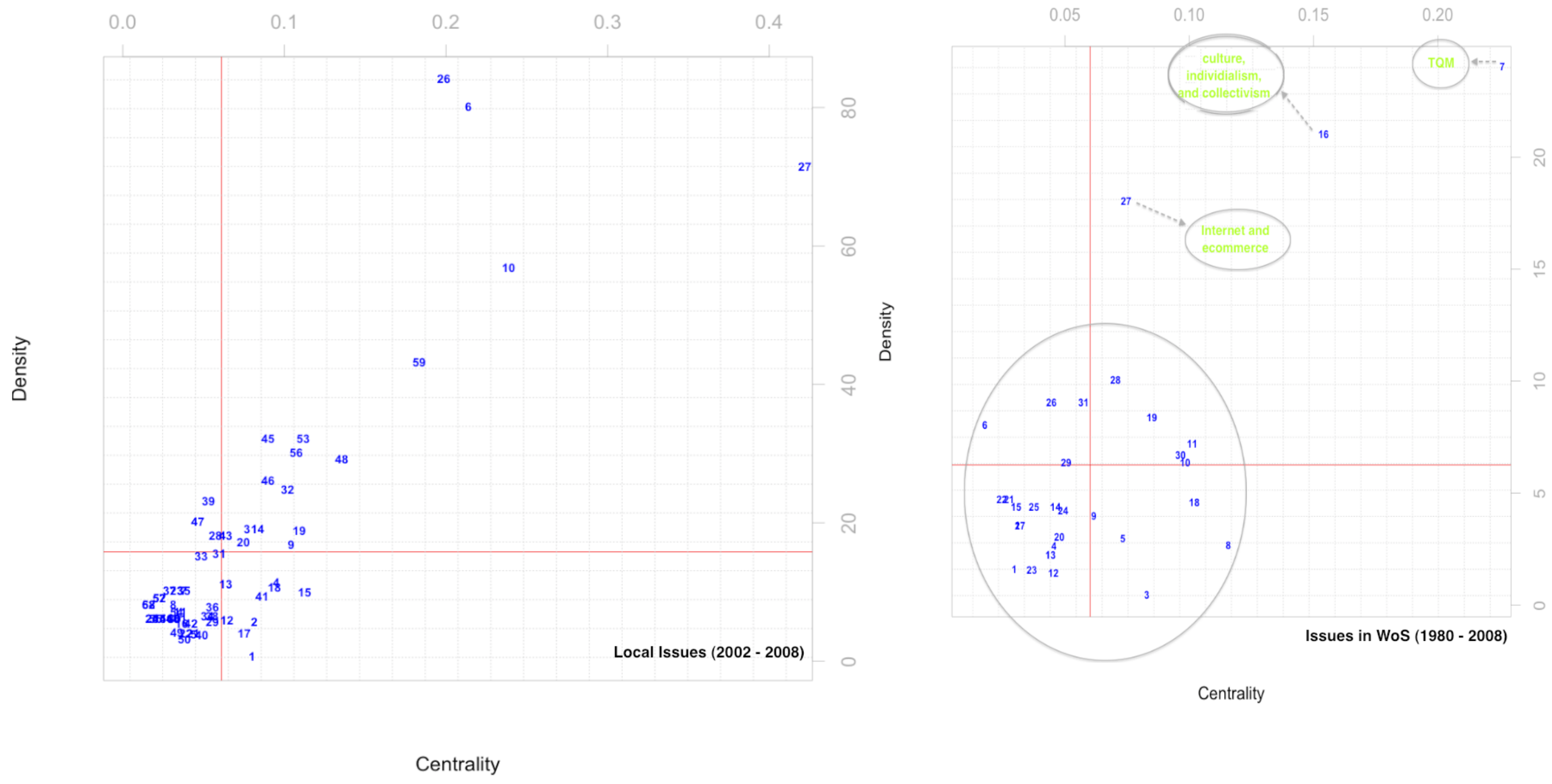


Figure 6.22: Strategic diagrams of issues in WoS (1980-2008) and in Turkey after millennium.



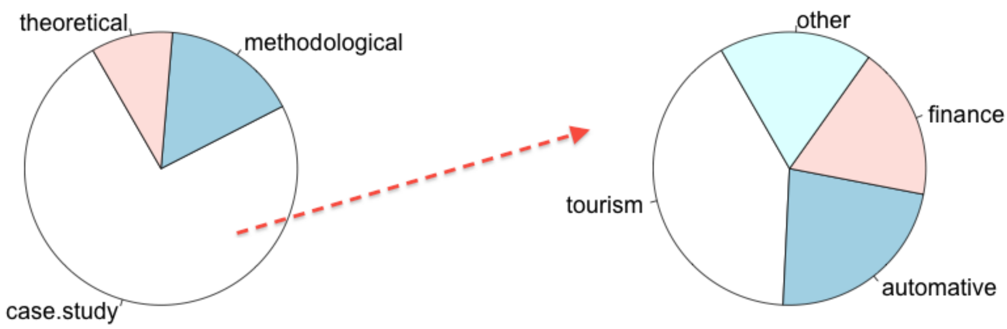
6.3.1 Case Studies and Research Types

The analyses in this section are auxiliary in the nature. It aims to enhance understanding on the nature of knowledge production and knowledge transfer qualitatively. Subjectivity of partial content coding performed in this very subsection limits the generalizability of its findings.

Characterization of productivity and extend of collaboration in previous sections of this chapter has revealed that in the period following millennium Turkish scientists have built an increasing attention in publishing at international journals. It is further seen that collaboration rate is much higher and overall number of multi-authored papers exceeds papers with a single author. Moreover, it is seen that knowledge diversity has increased very significantly. These findings lead the quest to examine nature of the study types published in international journals.

Out of 281 articles a random subset of 50 papers were selected and downloaded from WoS for further examination. When full paper versions were not available abstracts of those papers, keywords assigned by the authors as well as keywords tagged by the WoS database itself were used. Each paper content coded according to whether it primarily engages in a theoretical debate, or it discusses and tests or adopts a research methodology or it mainly performs sectoral case analysis. Around 9 papers were tagged by more than one category. The results are given in Figure 6.23.

Figure 6.23: Study types in WoS (1980-2008).



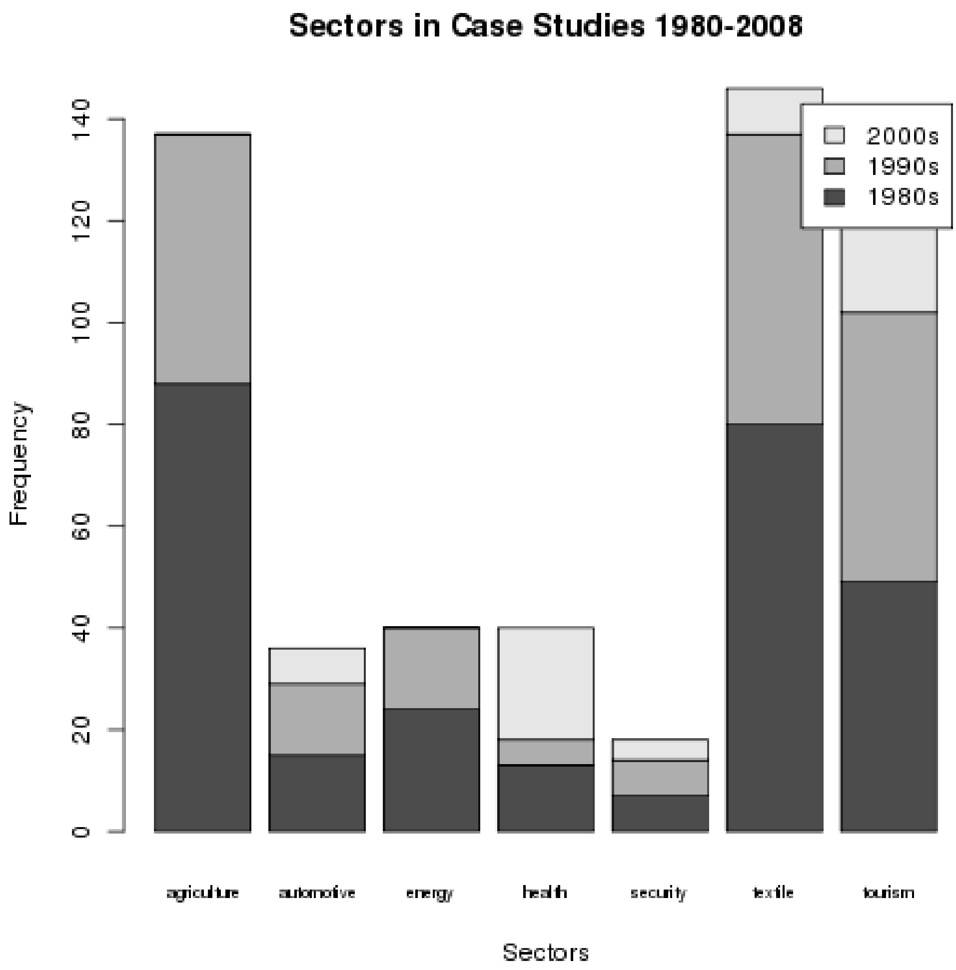
Given the significantly large amount of case studies, their sectoral distributions are identified. The three largest sector within the sample found to be tourism, automative and finance. Sectoral distributions of articles in local publications are explored for comparisons. Given the very large dataset of local publications, instead of a fully qualitative examination keyword searches were performed by written programming scripts. The full set of keywords derived earlier which covers all periods were inspected to determine a subset. The subset is used to detect sectoral distributions.

Sectoral distribution of articles in the period which parallels WoS period is given in Figure 6.24. The two figures together compares and contrasts sectoral distribution of case in analysis seen in WoS and in national publications. The figures prime the importance of audience. Organization of scientific practice around knowledge production and diffusion is seen to be influenced by the audience who will presumably be exposed to the very knowledge disseminated via the publications. Case papers which are published in WoS, expectedly targeting a global audience, have picked tourism, automative and banking as sectoral research fields. Comparatively, case analysis of local papers at the same time period have conducted research in textile, agriculture and tourism sectors respectively. Sectoral distribution of articles published earlier in Turkey from 1922 up to 1980's is given in Appendix K.

Among other things, figures in the appendices confirm that case oriented scientific activity in management discipline represents dominant national level industries. For instance, dominance of field studies in agriculture leaves its place to tourism starting in late 70s and early 80s. This indeed reflects social and economical changes which coincides with both in rapid increase in Turkish tourism and decay of agriculture industry in Turkey.

It is also seen that until 60's most of management theories or issues have been studied within security organizations such as military and police departments. Another interesting figure, which is not observable from the figures but can be seen by inspecting raw data, the very first set of management articles have been dealing on organizational issues that can be encountered in Turkish sport clubs such as BJK and GS, which have been founded in Istanbul, the major city of Turkish Republic.

Figure 6.24: Sectoral distribution of articles in local publications (1980 - 2008).



6.4 Collaboration Structure in Turkish Management Academia

The visualization of collaboration networks of the field over the periods is displayed in Figure 6.25 and Figure 6.26. The nodes represent authors. Varying node sizes represent productivity of the authors in their respective periods. The nodes are placed optimally by placing collaborators next to each other.

Figure 6.25 covers the years spanning from 1922 to 1999. The figure reveals an overall hyper-fragmentation of the academia throughout the time. Nevertheless, it hints slow yet a significant growth in the network level centralization towards formation of connected components. Collaborating teams are placed in the center and isolated to the periphery. Over the periods a visually recognizable thickness in the center and rings of smaller and smaller teams towards the rim of the network is observed. Examining each period separately, we observe that traces of core has first occurred in the third period. Nonetheless, in the years until mid 50's a no significant team of collaborators is observable. It should be noted that thick nodes in the first and second period represent seminal yet singleton authors. The period corresponding to 1980-1990 exhibit a slow down in the formation core connected component(s). Collaborating spots visualized slight dispersion. This can be explained by significant decrease in the rate of collaboration in these years as can be better observed in Figure 6.8.

Figure 6.26 depicts the overall collaboration structures sensed from local publications in last decade and international publications for last three decades. However, very large majority of papers which forms the latter network structure also come from the latest decade. This can be observed by the exponential growth in number of publications given in Figure 6.10. Both network structure exhibit a higher rate of co-authorship and higher frequency in number and size of collaborating teams compared to networks seen in Figure 6.26. Indeed, ULAKBIM network can be seen a natural growth and continuum of national level collaborations. In other words, it can be seen an evolution of the network seen in 1989-1999, where ties become much denser and frequency and size of the teams expanded significantly.

Figure 6.25: Co-authorship Networks in Turkey: 1922-1999.

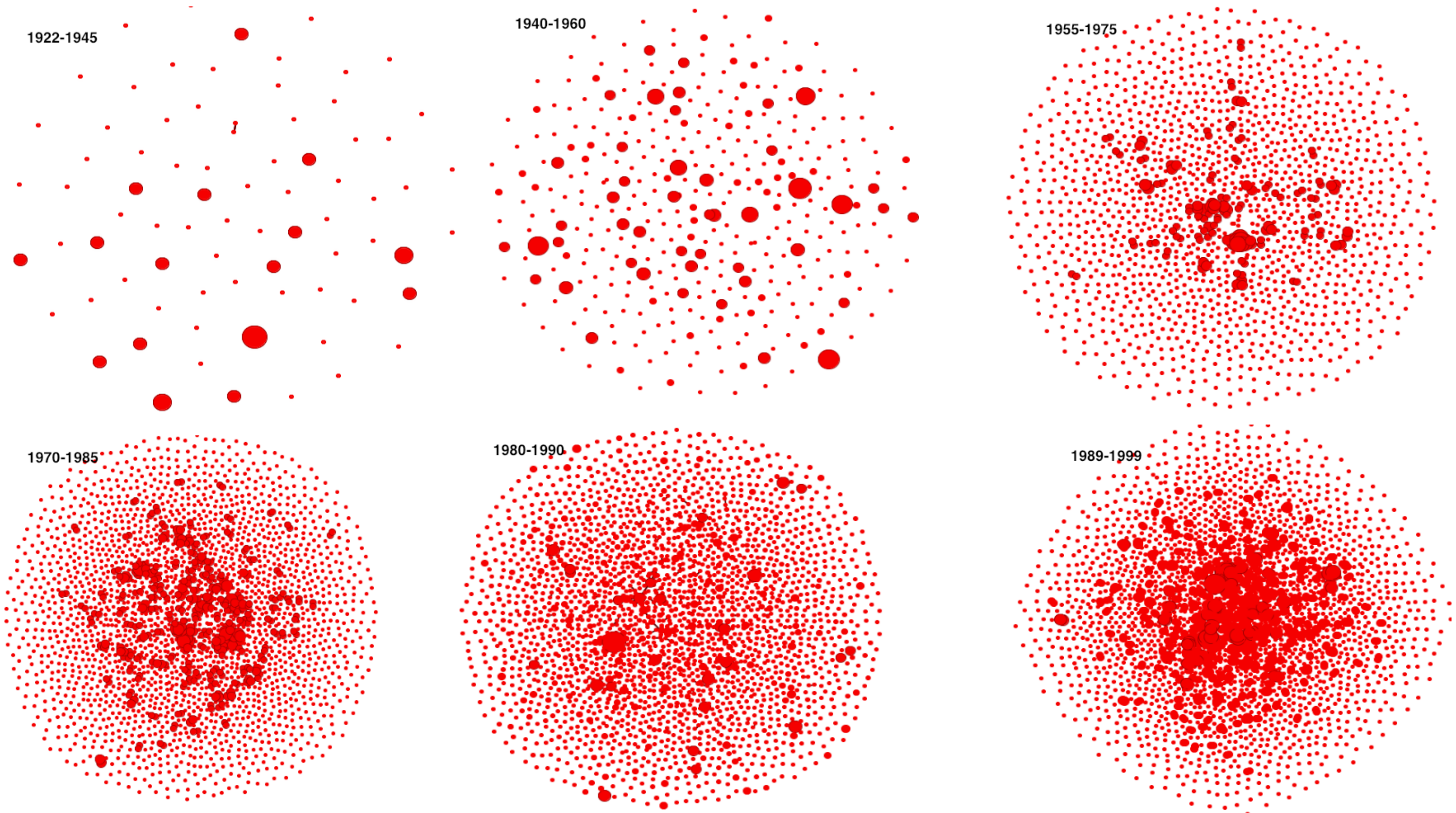
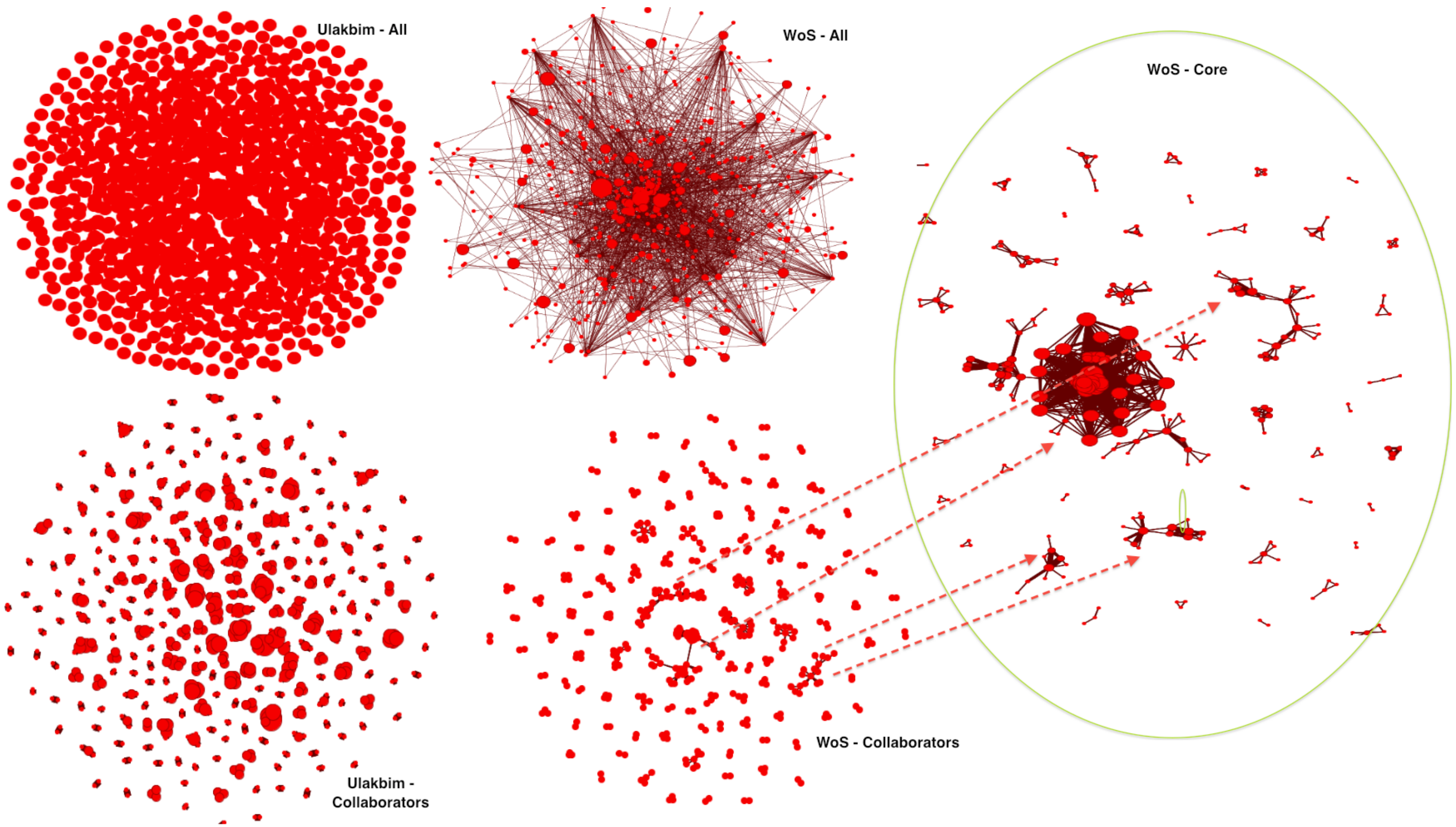


Figure 6.26: Co-authorship Networks ULAKBIM vs WoS



However, WoS network structure displays a qualitatively different structure. The network is not fully connected, yet there are candidate large connected components to occupy the center and become the main core. Overall, the network displays a collection of multiple connected components with an obvious largest core connected component candidate in the middle. The largest component with several other relatively larger components are pointed on Figure 6.26.

Figure 6.27 to Figure 6.32 displays collaborators in each period and zooms in to display network structure of major team or teams in respective periods. The nodes are color coded by geographical locations of the authors. It aims to decode locational distribution of each highlighted component. Authors with multiple location attributes are colored based on their latest location information. Colors are not mapped one-to-one for each city. That is, moving from one component to another, it is possible to see that the same color maybe used for multiple locations or the same location maybe colored by multiple colors.

In the very first period, there is only two pairs of collaborators. In the second period, the number of pairs doubles. Besides, a team of four scientists exists. In both of the networks it is seen that in pairs one of the members is more seminal than the other. Besides, names of the team members suggest that in majority of teams there is at least one scientist with a non-turkish name.

A closer inspection of major teams of subsequent periods from 1955-1975 to 1980-1990 reveals continuity of collaboration ties in some major components. For instance, the largest component in 1955-1975 keeps collaborating in 1970-1985 period. The component size and composition slightly changes. The component exhibits properties of a strongly embedded group, where almost each member seems to have collaborated at least once with most of the others. The component disappears in 1980's.

Figure 6.27: Collaborators: 1922-1960

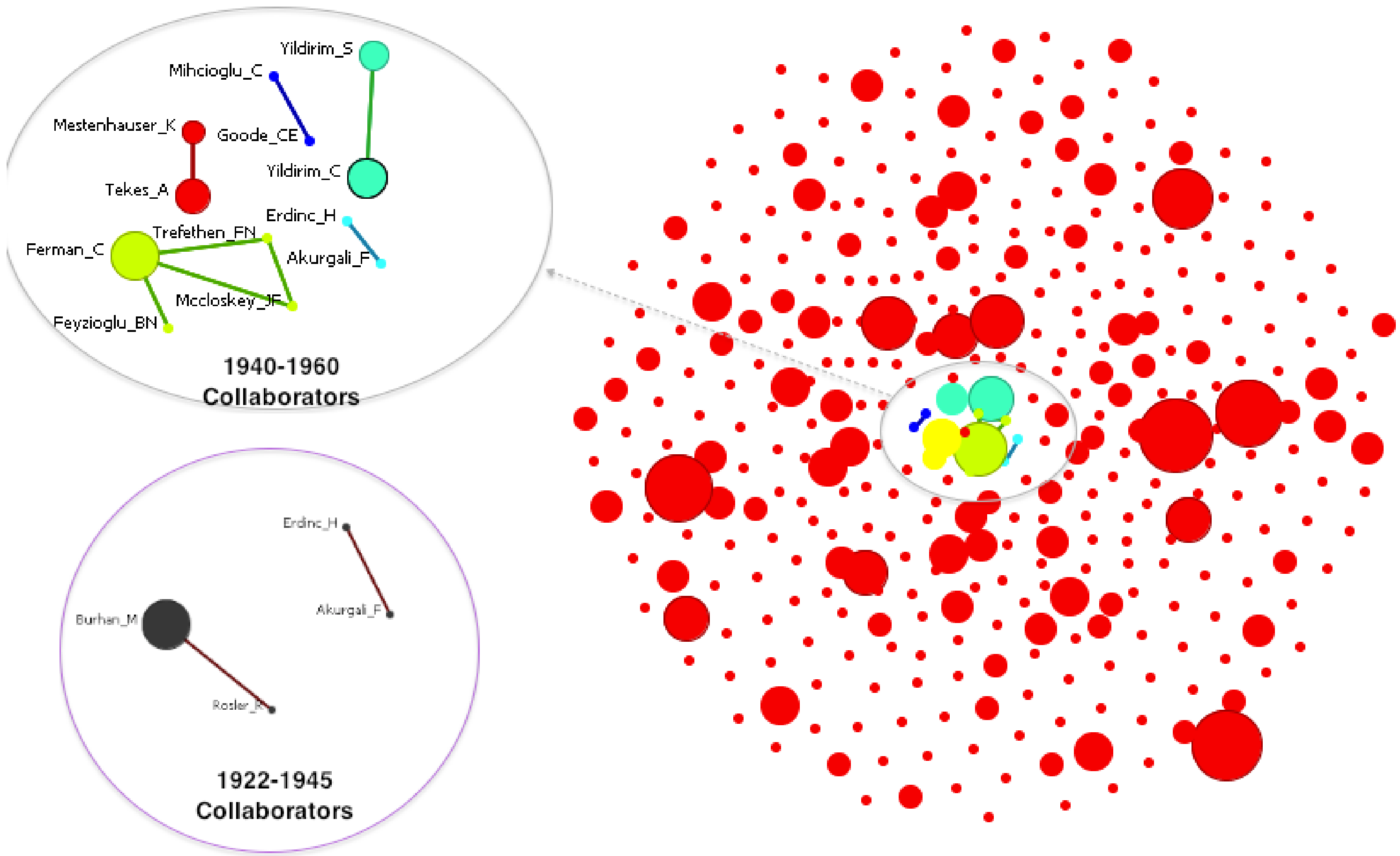


Figure 6.28: Collaborators and the core: 1955-1975

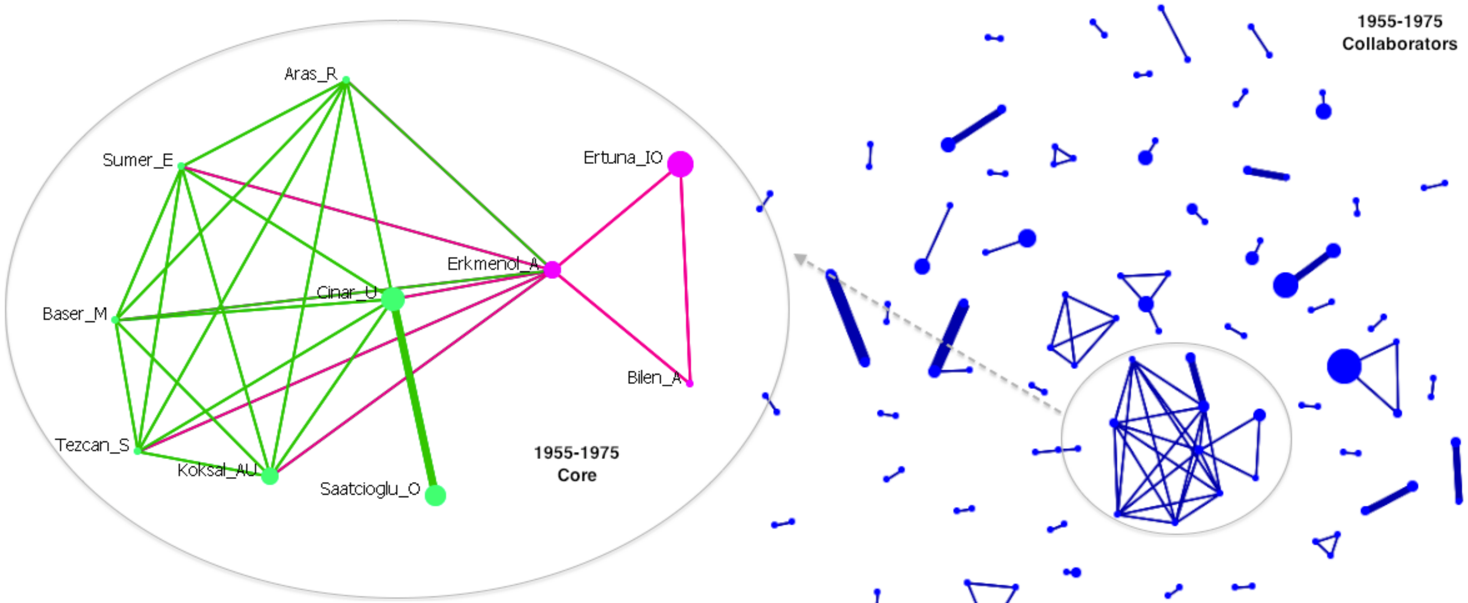


Figure 6.29: Collaborators and the components: 1970-1985

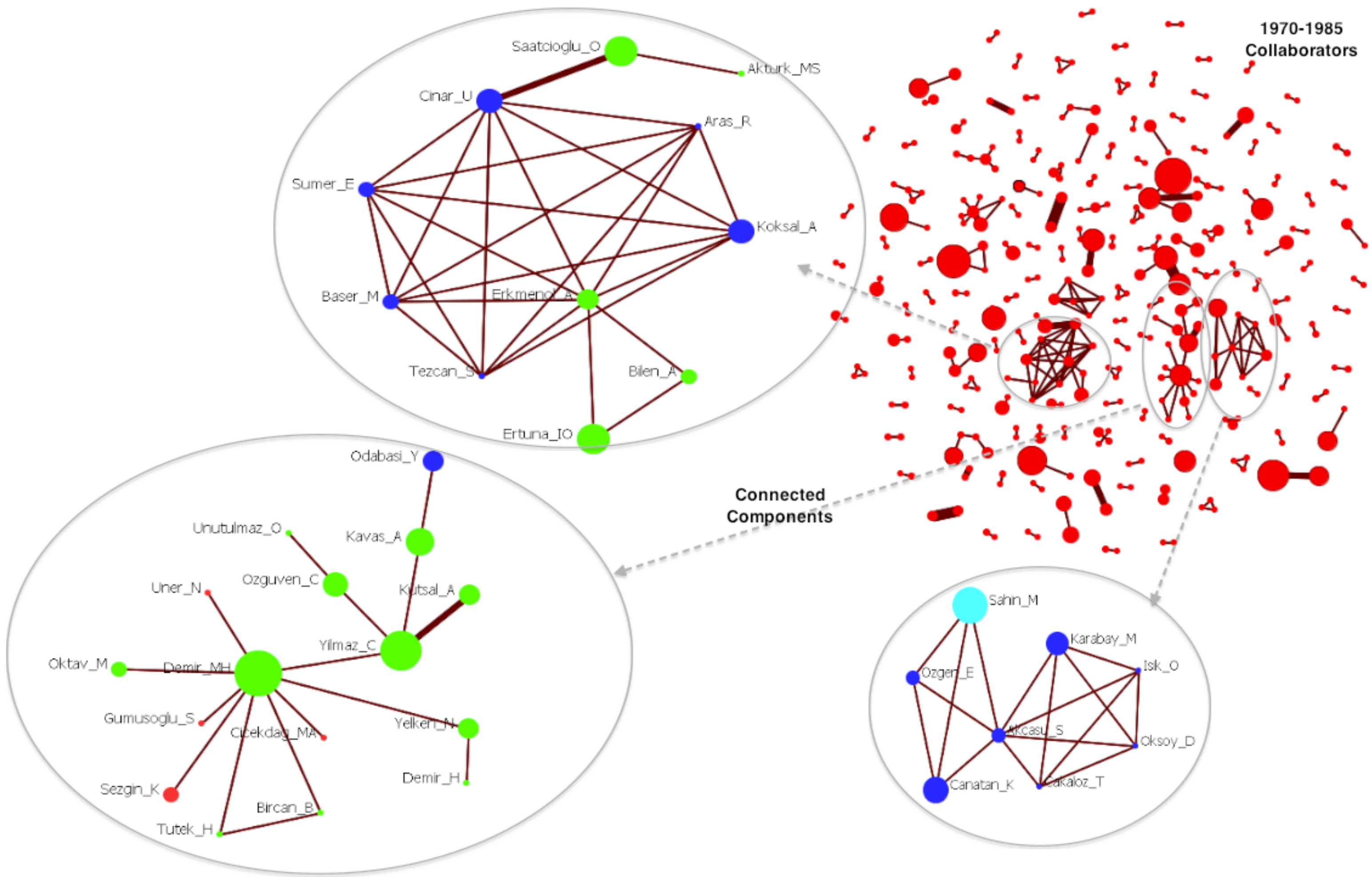


Figure 6.30: Collaborators and the core: 1980-1990

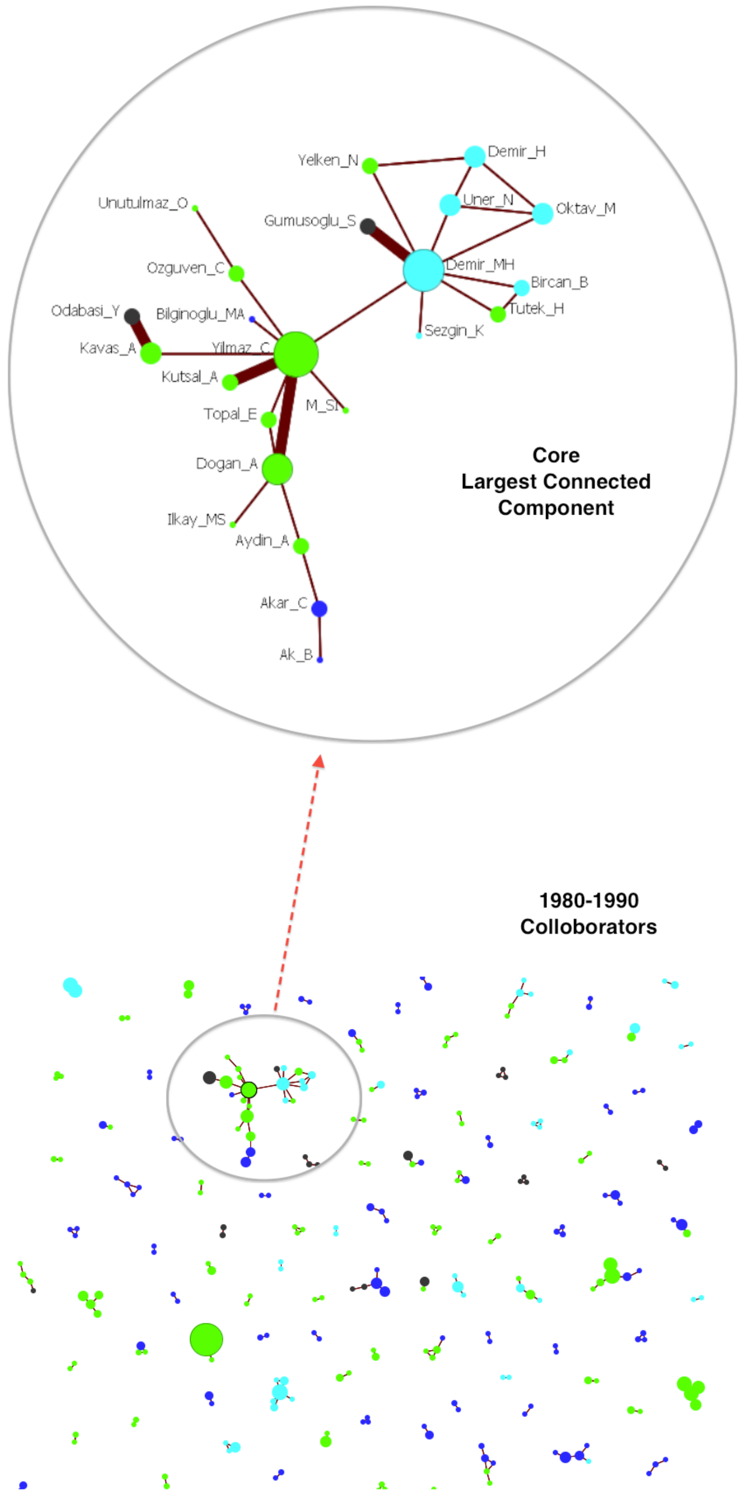


Figure 6.31: Collaborators and the components: 1989-1999

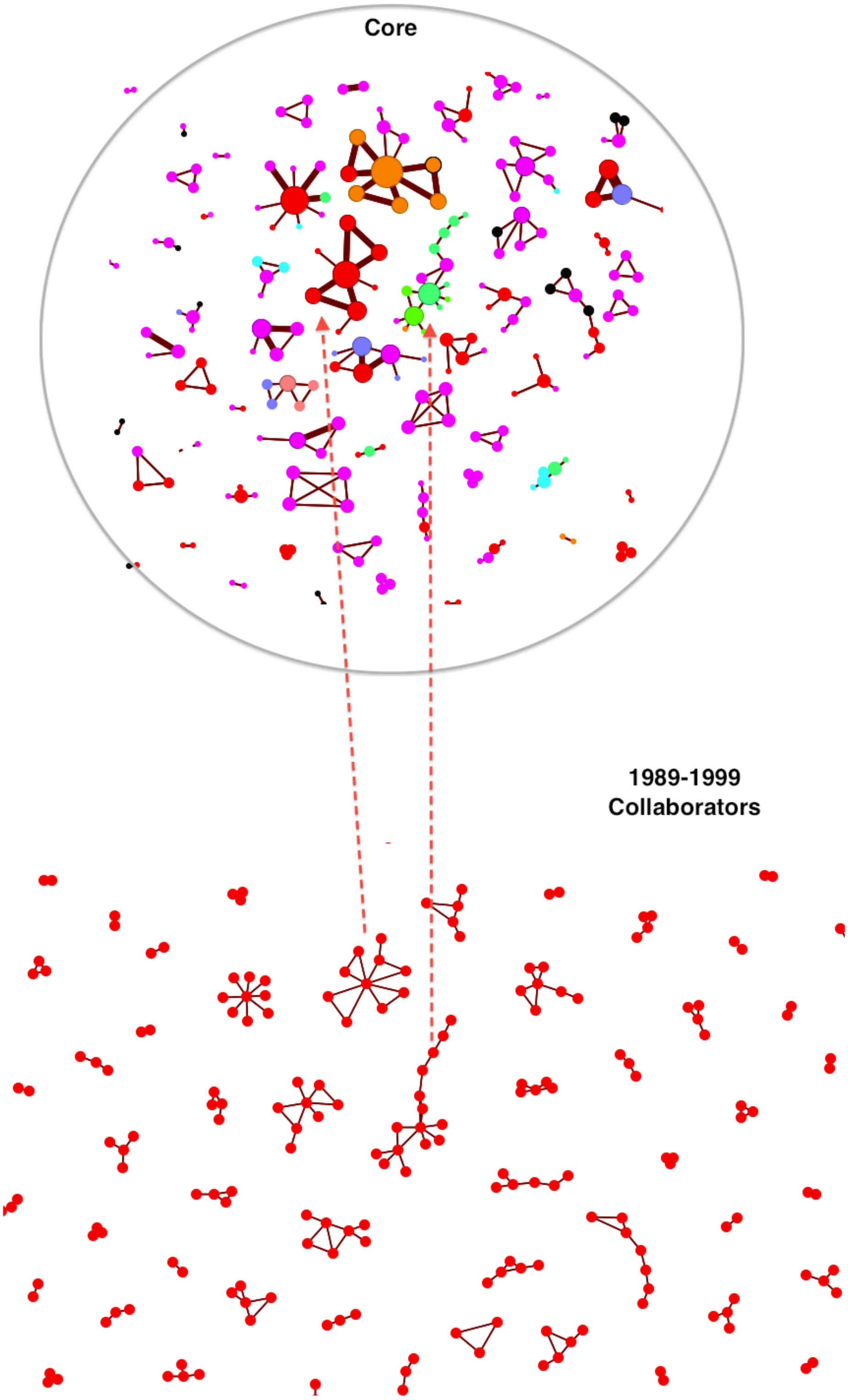


Figure 6.32: Collaborators: 2002-2008

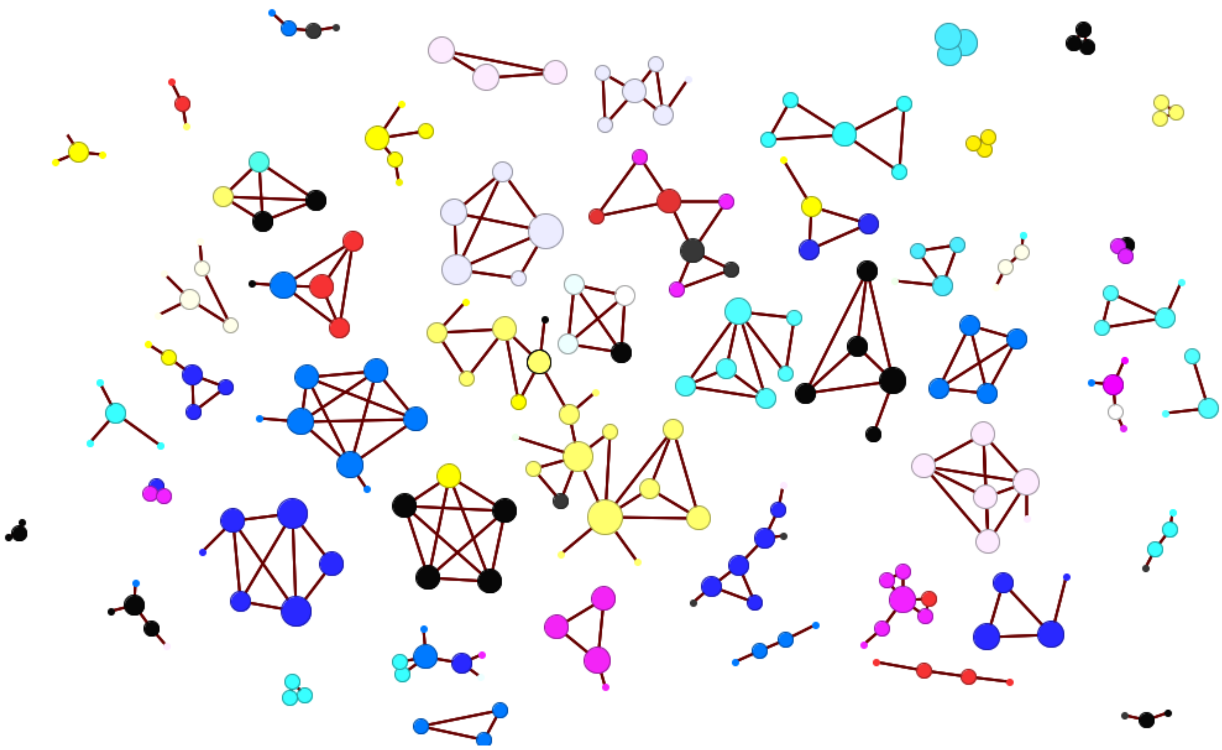
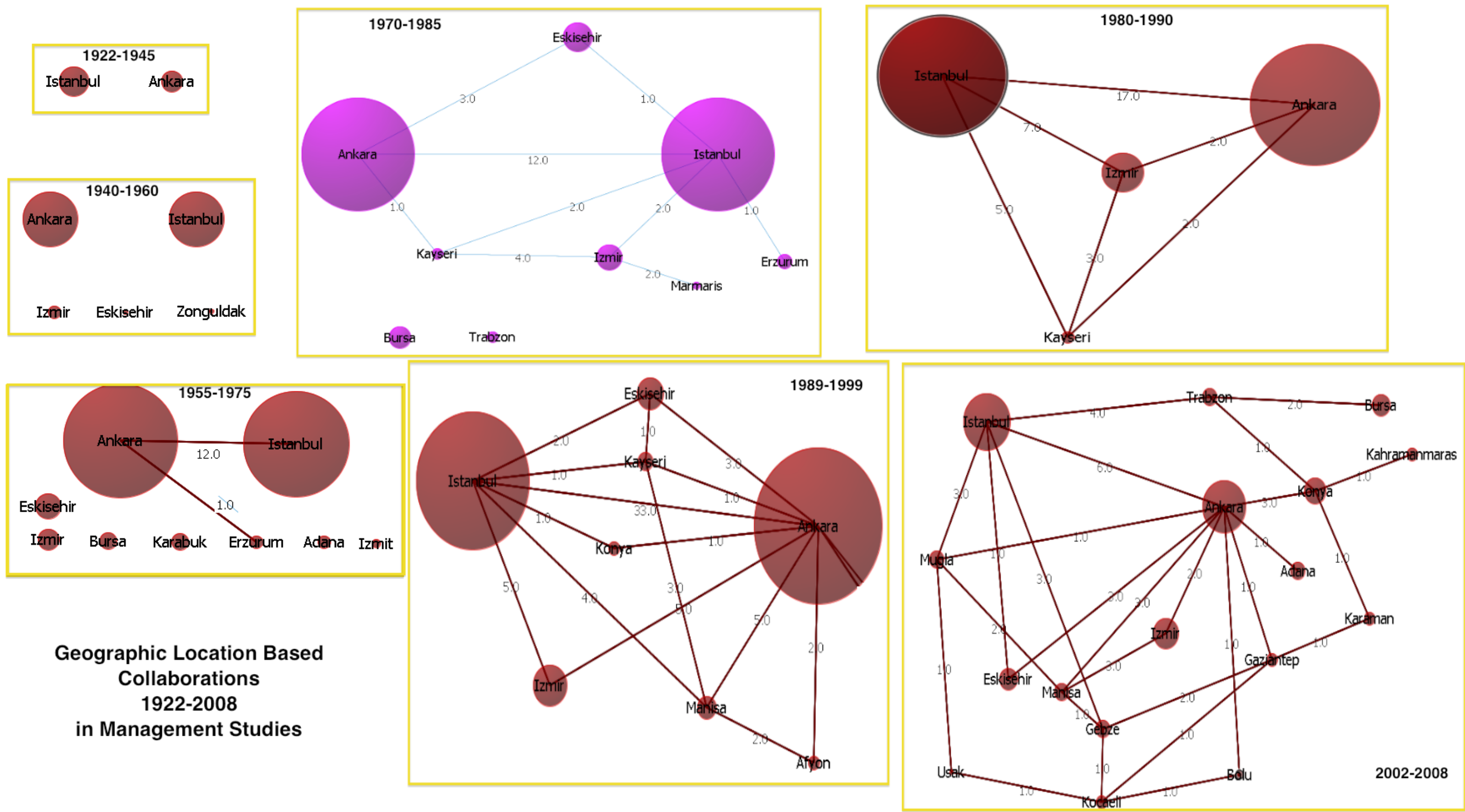


Figure 6.33: Geographic location and co-authorship in Turkey: 1922-2008



A second relatively large component persists in two subsequent periods. The component is displayed in the middle in Figure 6.29. Of three largest components in 1970-1985, it is the only largest component who survives to exist and even gets larger in 1980-1990 network structure. The component is highlighted both in Figure 6.29 and in Figure 6.30. It should be noted that, the component consists of two weekly connected sub-groups.

6.4.1 Geographical Location vs Collaborations in Turkey

Figure 6.33 displays inter-city collaboration networks for each period within Turkey. Nodes represent city names of the locations. Numbers on the edges between nodes represent number of co-authored papers in between scientists in geographically different locations. Nodes are scaled by aggregate number of publications from the represented location.

Dual dominance of Istanbul and Ankara is observable throughout the time until latest decade. The period following the millennium location based publication productivity is seen to be relatively decentralized. However, it is seen that until 1960's there is a location based isolation and academia fragmentation. The period which spans 1980-1990 has lost the pace of increasing inter-city co-authorship, but the pace is recovered significantly in subsequent periods.

6.5 Knowledge Dissemination and Co-authorship Structures Across Periods

Table 6.2 summarizes distribution of knowledge based on extracted knowledge dissemination relations (AxK). The first row the table indicates diversity in terms of accumulation of knowledge among scientists. Over the periods, the level of inequality at disseminating knowledge stagnates at higher values. This is another indication for low level of knowledge diffusion in the network of scientific collaboration.

On the other hand, knowledge load per author persistently increases until 90's. Load of knowledge is significantly higher for the part of the academia who publish in WoS. Knowledge load per author in WoS, on the average, almost doubles the knowledge load per author in local datasets. It is also seen that redundant number of authors decreases significantly in last two decades. Given increase in the number of authors, this can be explained best by increased discipliner diversification in the field.

Table 6.2: Knowledge Dissemination Networks (AxK).

AxK	22-45	40-60	55-75	70-85	80-90	89-00	02-08	WoS(1980-2008)
Knowledge Diversity	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99
Load Knowledge	3.67	4.12	5.36	5.68	5.79	5.45	3.62	8.15
Knowledge Redundancy	0.04	0.04	0.04	0.04	0.04	0.03	0.01	0.01

Table 6.3 gives major network level measures of the collaboration in the academia over time by periods. The last row estimates the ratio of authors who have collaborated at least once. The ratio doubles in local publications from 1990's to 2000's, yet it is far below the ratio compared to rate of collaborations in WoS. Albeit, local academia remains fragmented to the time of data collection.

Average distance and clustering coefficient measure together hints subtle formation of small world structures in last three decades. Visual analysis of core components in earlier section further enhances this phenomenon.

Transitivity values supports earlier findings regarding structure of collaborating teams. High transitivity values principally in WoS indicate that although the academia as a whole is fragmented and a large number of authors remain completely isolated, yet the ones who collaborate sharing their knowledge induce further collaborations in between their collaborators. This value, however, deeps down for the period following the military coup in 1980.

Table 6.3: Collaboration Networks (AxA).

AxA	22-45	40-60	55-75	70-85	80-90	89-00	02-08	WoS(1980-2008)
Density	0.0	0.0	0.0	0.0	0.0001	0.0002	0.0011	0.01
Link Count	4	16	194	520	636	996	1058	2830
Count Node	78	362	1507	2386	2438	2493	988	505
Diameter	78	362	1507	2386		2493	988	505
Average Distance	1	1.5	1.38	1.76	2.27	1.78	1.84	2.81
Clustering Coefficient	0.0	0.010	0.020	0.030	0.035	0.066	0.197	0.560
Transitivity	0.000	0.600	0.860	0.690	0.432	0.501	0.663	0.930
Total Degree	0.01	0.01	0.01			0.0054	0.0070	0.1000
Fragmentation	1	1	1	1	1	1	1	0.97
Isolate Count	74	350	1382	2028	1960	1791	321	37
Component Count	76	355	1435	2174	2153	2063	564	146
Total Connected	4	12	125	358	478	702	667	468
Ratio Connected	0.05	0.03	0.08	0.15	0.20	0.28	0.68	0.93

6.6 Socio-Knowledge Activities, Embeddedness and Cognitive Structures Across Periods

The proposed framework which incorporates mutuality and dialectics of knowledge and knowledge carriers or producers enables me to address and answer following exemplary case specific research questions of this dissertation:

1. To what extent patterns at individual level socio-knowledge centralities are distinguishable as of scientists' preferences on the strategic type of issue they pick to disseminate?

2. To what extent structurally embeddedness of individual scientists are distinguishable as of their preferences on the strategic type of issue they pick to disseminate?

3. To what extent relative cognitive structure of individual scientists are distinguishable as of their preferences on the strategic type of issue they pick to disseminate?

Type of an issue is defined by its location on strategic diagram of a given field, which is determined by prevalence and cohesiveness of the issue in the field. Individual scientists' social or knowledge centralities, embeddedness, and their relative cognitive states are computed within meta-network analysis framework. The relevant set of metrics which are given in Chapter 5 are used. In order to classify individuals' preferences on the type of issue they study and disseminate the model given by Equation 5.7 and Equation 5.8 are applied. The equations enable to classify scientists's preferences on the diagram by their partial contribution to pervasiveness and cohesiveness of issues they have engaged in.

Statistical tests are conducted for each individual property to determine if its distribution significantly differs on the quadrants of strategic diagram. Instead of regular parametric tests, Kruskal-Wallis test which is a nonparametric test is opted. It does not assume an underlying distribution for the test variables. Because, distribution of values of socio-cognitive properties of scientists does not necessarily follow a normal distribution. Besides, Kruskal-Wallis test allows to compare three or more groups of sample data (Hollander and Wolfe, 1973).

6.6.1 Socio-knowledge Centralities vs Strategic Quadrants

In order to probe distinguishing social centralities, `degree`, `betweenness` and `closeness` centrality values of individuals in their respective collaboration networks (AxA) are inspected. `Socio-Knowledge Power` (SKP), `Knowledge Dissemination Degree` (KDD) derived from Knowledge Dissemination Networks (AxK) are used to probe knowledge centrality of individuals.

Table 6.4 tabulates test results. Only statistically significant correlations are given. For instance, it is seen that distribution of `closeness` does not differ significantly on different quadrants. The quadrants which are populated with high values and low values are given.

Table 6.4: Socio-Knowledge Activity vs dissemination preferences.

	22-45	40-60	55-75	70-85	80-90	89-00	02-08	WoS(1980-2008)
High Quadrants ($p \ll 0.001$)								
Degree	-	-	-	-	-	-	-	Q1
Betweenness	-	-	-	-	Q1	-	-	Q1, Q3
SKP	Q1, Q2	Q1, Q4	Q1	Q1	Q1	Q1, Q4	Q1, Q4	-
KDD	Q1	-	Q1	Q1	Q1, Q4	Q1	Q1	-
Low Quadrants ($p \ll 0.001$)								
SKP	Q3	Q3	Q3	Q3	Q3	Q3, Q2	Q3, Q2	-
KDD	Q3	-	Q3	Q3, Q4	Q3	-	Q3, Q2	-

Of collaboration network centralities, it is seen that closeness of individuals to other members of the academia does not provide any implication or correlation on their decisions or choices of knowledge production process. However, it is seen that at international level publications centrality in the network is correlated on the preferences. High degree central and high betweenness central authors in WoS seen to populate the first quadrant. Besides, the ones with high betweenness are also observed to populate peripheral issues.

Of periods in local publication, it is seen that the ones with high betweenness centrality populate the first quadrant issues. Indeed, examining the structure of collaborators in the period given in Figure 6.30 further confirms this relation. There, it is seen that connected components exhibit rather chainlike structures than fully connected cliques. It means that a significant number of individuals who publish on mainstream issues are also accommodating chainlike components. A chainlike connection may facilitate indirect knowledge diffusion channels in between scientists.

The tabulated test results further explain that at international level publications, one's diversity in terms of knowledge items he/she have published is not correlated with his/her strategic choice of scientific endeavor. On the other hand, at national level publications it is other way around. The ones' with high socio-knowledge power (SKP) or knowledge dissemination degree (KDD) populates or may have manipulated mainstream issues. The ones with low SKP and KDD remains peripheral.

The results hints an important dichotomy in between socio-knowledge behavior at publishing internally and externally. In WoS high social central authors publish or do collectively set the mainstream issues. Internally, it is the influence of individuals' socially enhanced knowledge diversity (SKP) and individual's dissemination activity (KDD) which is correlated with issues populating the map of the field.

It is should be noted that, the direction of causality is not clear with identified correlations.

6.6.2 Embeddedness vs Strategic Quadrants

In order to probe whether there is any significant correlation in between one's cliquishness in the collaboration network and one's preferences regarding the strategic type of issues one publishes, a set of embeddedness relevant metrics are estimated. They are individuals `Clique Count`, number of `Triads` they partake, density of their ego-networks estimated by their `Clustering Coefficient` (CC) and their `Collaborator Exclusivity Index` (CEI). All of the metrics are estimated from individuals' respective AxA networks. Table 6.5 tabulates test results.

Table 6.5: Embeddedness vs dissemination preferences.

	22-45	40-60	55-75	70-85	80-90	89-00	02-08	WoS(1980-2008)
High Quadrants ($p \ll 0.001$)								
Cliques	-	-	-	-	-	-	Q1	Q1, Q2, Q3
CC	-	-	-	-	Q1	Q1	Q1	-
CEI	-	-	-	-	-	-	Q1	-
Triads	-	-	-	-	-	-	Q1	-
Low Quadrants ($p \ll 0.001$)								
Cliques	-	-	-	-	-	-	-	Q4
CC	-	-	-	-	Q3	Q3	-	-

It is seen that in international arena ones with highest clique counts are disseminating mainstream issues, while the ones with the lowest clique counts are disseminating relatively peripheral issues. A similar correlation is observed only in last decade at internal publications. Besides, significant correlation with ones CEI hints that isolated authors, when they form new ties, they preferentially attach with authors who publish mainstream issues.

Analysis of social structure in earlier section supports the fact that authors with dense ego-networks, estimated via their CC values, are playing important role at diffusing or shaping mainstream issues. Exemplary distributions of clique counts are given in Figure 6.34. Details for each period are given in the appendices.

6.6.3 Relative Cognitive Structure vs Strategic Quadrants

Authors AxK relations based `Knowledge Exclusivity Index` (KEI), `Cognitive Distinctiveness`, `Cognitive Similarity` and `Cognitive Resemblance` metrics are estimated. The results are given in Table 6.6.

Table 6.6: Relative cognitive structures vs dissemination preferences.

	22-45	40-60	55-75	70-85	80-90	89-00	02-08	WoS(1980-2008)
High Quadrants ($p \ll 0.001$)								
Distinctiveness	Q1, Q2	Q1, Q4, Q2	Q1	Q1	Q1	Q1	Q1	-
KEI	Q1, Q2	Q2	Q1	Q1	-	-	Q2	-
Similarity	Q3	Q4, Q3	Q1, Q4	Q1, Q4	Q4, Q1	Q4	Q3, Q4	-
Resemblance	-	Q3, Q2	Q3, Q2	Q3	Q3	-	-	-
Low Quadrants ($p \ll 0.001$)								
Distinctiveness	Q3	Q3	Q3	Q3	Q3	Q3	Q3	-
Similarity	Q1, Q2	Q2	Q2, Q3	Q2, Q3	Q3, Q2	Q2, Q3	Q2	-
Resemblance	-	Q1, Q4	Q1	Q1	Q1	-	-	-

Test results hint that individuals' cognitive state relative to other individuals in the network does not imply any correlations while publishing internationally. On the other side, relative cognitive state of individuals and their preferences at the choice of issues they pick to study and disseminate is very strongly correlated while publishing nationally.

While individuals with high cognitive distinctiveness dominate the first quadrant, the ones with low cognitive distinctiveness invariably populate the third quadrant. The ones in the third quadrant resemble to each other, but the ones in the first quadrant don't. Yet the ones in the first quadrant have high similarity as well. Presumably having common or overlapping issues with the rest but as well as owning unique knowledge keep individuals or makes individuals be at the first quadrant.

Figure 6.35 demonstrates a typical relation in between cognitive state of individuals with respect to the rest of the academia and their preferences at picking issues to publish. It is seen that in the period which spans from 1970 to 1985, the ones who publish mostly on mainstream or on hot topics have distinct knowledge compared to their peers in the network, they hold certain knowledge exclusively, they don't resemble the rest, but keep a level of similarity with the academia.

6.7 Knowledge Diffusion Models

Lastly, effect of overall collaboration structure on knowledge diffusion is modeled. Exploratory analysis in earlier section has hinted formation and influ-

Figure 6.34: Distribution of authors on quadrants by their socio-knowledge properties.

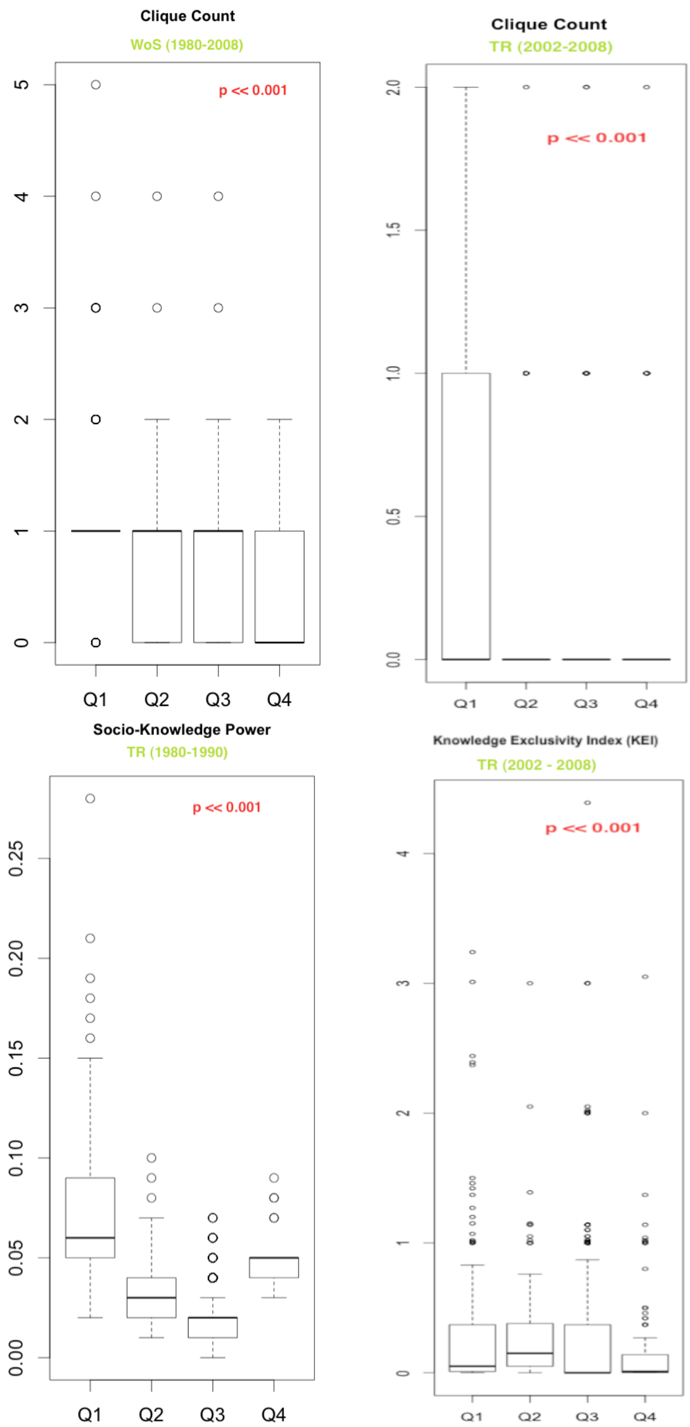
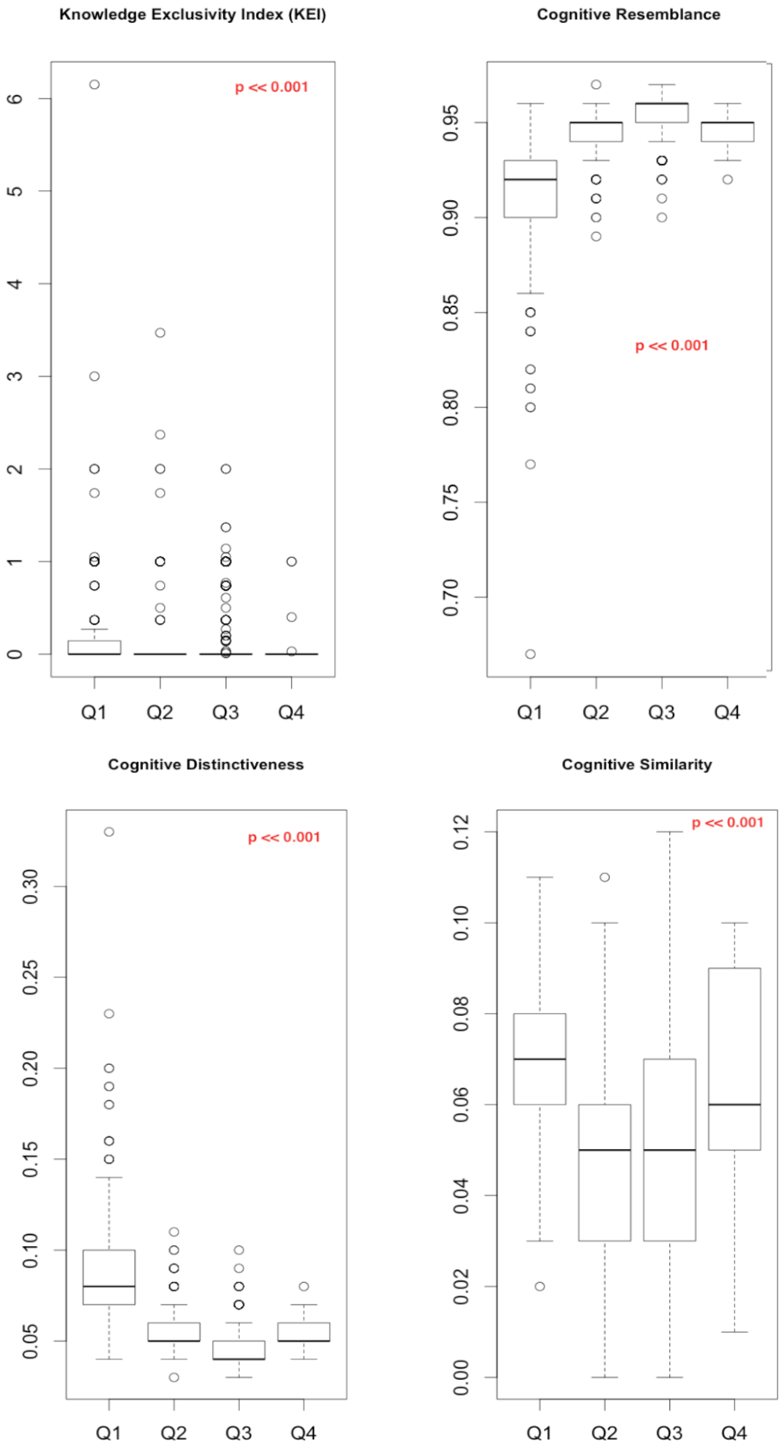


Figure 6.35: Relative cognitive structures vs distribution on quadrants: 1970-1985



ence of small-worlds like structure within national level (MK) co-authorships. On the other hand, prevalence of cliques formed by isolated yet strongly connected components have been observed at co-authorship patterns at international (WoS) publications. This led me to develop two separate diffusion models. The first one estimates to what extent emerging small world structures can explain the diffusion of knowledge; the second one estimates to what extent existence and prevalence of cohesive groups can explain the diffusion of knowledge. Each model is tested both in national (MK) and international level (WoS) co-authorships.

6.7.1 Small Worlds in Turkish Management Academia

Following the empirical conventions from the literature (Flemming et.al., 2007; Baum et.al., 2003; Kogut and Walker, 2001) small world regimes are traced by a variable which is calculated by dividing network level clustering coefficient by network level average distance. The variable is shown to reflect a small-world network structure where a large clustering coefficient and a low average density is typical (Watts and Strogatz, 1998). Both of the metrics that are used to compute the small world variable are normalized due to variations in the size of the networks.The details of the model is given in Equation 6.2:

$$\begin{gathered}Avg.Knowledge.Load(t) = \alpha SmallWorldliness(t) + C \\ \text{where,} \\ SmallWorldliness(t) = \frac{Avg.Clust.Coeff.(t)}{Avg.Dist.(t)}\end{gathered} \tag{6.2}$$

Avg.Knowledge.Load is the average number of distinct knowledge (keyword) per academician in the whole network. It is used as a measure of network level knowledge dispersion. The model is tested both for the co-authorship structures based on local publications covering the years 1945 up to 1999 and co-authorship structures based on publications in WoS covering the years from 1985 up to 2008. The variables for each year is computed using cumulated co-authorship ties and knowledge.

Early years in local publications are excluded from the analysis, because it is observed that in Turkish management academia for the years from 1922 up to 1944 there have been only a few number of co-authorships. On the other hand, observed number of publications in WoS is relatively very low for the years covering 1980 up to 1984, hence this early stage in WoS is excluded in longitudinal analysis. It should be noted that exclusions are done at year-wise probations of early stages of the networks, however the cumulative influence of activities in those early years are indirectly reflected in subsequent years which are considered for the probations.

Table 6.7: Small worlds and knowledge diffusion in local collaborations.

Coefficients	Estimate	Std.Err.	t-value
Const.	3.8***	0.07	57.9
SmallWorldliness	101.8***	5.4	18.8
Overall	F-sta:354.4, Adj.R^2 : 0.87, $p \ll 0.0001$)		

The results are tabulated in Table 6.7 and Table 6.8. It is clearly seen that while small world structures in local academia are significantly able to explain ($R^2 = 0.87$) dispersion of knowledge in the academia, it fails to be correlated with knowledge diffusion at international publications.

Table 6.8: Small worlds and knowledge diffusion in WoS collaborations.

Coefficients	Estimate	Std.Err.	t-value
Const.	5.9***	1.05	5.6
SmallWorldliness	-4.5	3.5	-1.3
Overall	F-sta:1.6, Adj.R^2 : 0.02, $p = 0.22$)		

6.7.2 Isolated Cohesive Groups in Turkish Management Academia

In a similar manner, cliquishness regime of a collaboration network is computed. Existence and increase in the number of connected components along with increase in the level of transitivity is deemed to indicate cohesiveness and embeddedness of cliques in a network (e.g., Fritsch and Kauffeld-Monz, 2009; Coleman, 1988). Effect of cliquishness of a given network is computed by multiplying average transitivity by average size of connected components in the network. The details of cliquishness model is given in Equation 6.3:

$$\begin{aligned} Avg.Knowledge.Load(t) &= \alpha Cliquishness(t) + C \\ &\text{where,} \\ Cliquishness(t) &= Avg.Comp.Size(t)\ x\ Avg.Transitivity(t) \\ Avg.Comp.Size(t) &= \frac{Number\ of\ Authors}{Number\ of\ Strongly\ Connected\ Components} \end{aligned} \tag{6.3}$$

It is seen that both number of authors and number of strongly connected components grow over the years in Turkish management academia. Average sizes of connected components are calculated in order to trace a normalized level of distribution of authors in densely connected groups for each year.

Table 6.9: Cliquishness and knowledge diffusion in WoS collaborations.

Coefficients	Estimate	Std.Err.	t-value
Const.	0.98*	0.43	2.23
Cliquishness	2.06***	0.23	9.08
Overall	F-sta:82.5, Adj.R^2 : 0.77, $p \ll 0.0001$)		

The test results are given in Table 6.9 and Table 6.10. The tabulated results show that embeddedness within connected components significantly explains knowledge diffusion across part of the academia publishing in WoS. On the other hand, the statistical significance of cliquishness at explaining knowledge diffusion within the country is lower. Besides, Table 6.7 and Table 6.10 together hint that small worlds structures in the academia are more powerful at explaining knowledge diffusion within the country compared to influence of the cliquishness in the academia.

Table 6.10: Cliquishness and knowledge diffusion in WoS collaborations.

Coefficients	Estimate	Std.Err.	t-value
Const.	3.89***	0.14	27.46
Cliquishness	1.64***	0.22	7.41
Overall	F-sta:54.9, Adj.R^2 : 0.49, $p \ll 0.0001$)		

6.8 List of Findings

Following are the list of significant findings from the exemplary case.

6.8.1 Publication productivity and rate of collaborations in Turkey across all fields

- In the years of the military coups, namely 1960, 1971 and 1980, or at the several years preceding those coup d'etats the level of productivities are observed to drop down from their earlier steady courses.
- A steady increase in the number of publications following immediately the years of military interventions is observed.
- The intervention in 1980, has propagated decaying rate of co-authorship rate in between scientists.
- Rate of collaboration in between scientists has increased linearly with a ratio of 0.0037 in a yearly basis.
- Size of co-authorship teams have increased steadily.

6.8.2 Productivity and Rate of Collaboration

- Management in Turkey exhibits its own peculiarities, e.g., not only rate of collaboration but also number of papers in the years following the military intervention in 1980 has decreased significantly.
- Rate of collaboration and size of teams are significantly higher among scientists publishing internationally.

- Rate of collaboration in between management scientists publishing locally has increased linearly with a ratio of 0.0038 in a yearly basis.

6.8.3 Knowledge Diffusion

- Development of management field in Turkey, exhibits deviations from the stages of a `normal science`. It hardly hints novel knowledge production within academia. The observation based on lack of issues which are found to become cohesive before becoming central. Almost all issues are exhibiting central or peripheral characteristics over the periods.

- An increasing diversity in the number of new issues and keywords as well as an increase in interdisciplinarity is observed over time.

- The results hints an important dichotomy in between socio-knowledge behavior at publishing internally and externally. In WoS high social central authors publish or do collectively set the mainstream issues. Internally, it is the influence of individuals' socially enhanced knowledge diversity (SKP) and individual's dissemination activity (KDD) which is correlated with issues populating the map of the field.

- It is seen that in international arena ones with highest clique counts are disseminating mainstream issues, while the ones with the lowest clique counts are disseminating relatively peripheral issues. A similar correlation is observed only in last decade at internal publications.

- It is seen that in local academia ones having high CEI are populating the first quadrant. The finding hints that isolated authors when form new ties they preferentially attach with authors who publish mainstream issues.

- The level of inequality at knowledge dissemination stagnates at higher values at all periods but drops within part of academia publishing internationally.

- High degree central and high betweenness central authors in WoS seen to populate main-stream issues rather than new emerging or peripheral issues. Yet it is still the ones with high betweenness who study peripheral issues.

- Knowledge diversity of scientists at WoS is not correlated with their strategic choice of scientific endeavor. On the other hand, at national level publications it is the other way around. The ones' with high socio-knowledge power (SKP) or knowledge dissemination degree (KDD) populates or may have manipulated mainstream issues. The ones with low SKP and KDD remains peripheral.

- The findings hint that authors with dense ego-networks, estimated via their CC values, are playing important role at diffusing or shaping mainstream issues locally for last several decades.

- The findings hint that individuals' cognitive state relative to other individuals in the network does not imply any correlations while publishing internationally. On the other side, relative cognitive state of individuals and their preferences at the choice of issues they pick to study and disseminate is very strongly correlated while publishing nationally.

- The socio-cognitive patterns of local academia hint that the ones who publish mostly on mainstream or on hot topics have distinct knowledge compared to their peers in the network, they hold certain knowledge exclusively, they don't resemble the rest, but they keep a level of similarity with the rest of the academia.

- Results from knowledge diffusion models hint that management knowledge within local studies is transferred following the patterns of information diffusion rather then pattern of knowledge transfer found elsewhere. On the other hand, cognitive demand of publishing in citation indexed journals may have given way to cohesive collaborating teams as mean of collaborative knowledge production and transfer.

6.8.4 Community Structure

- Community exhibits a hyper-fragmentation throughout the time. Nevertheless, trends hint a slow yet a significant growth in the network level centralization towards formation of multiple connected components.

- Geographic location of authors marks one of the major axis of academia fragmentation. Location based isolation and academia fragmentation has been very clear cut until 1960's. The period which spans 1980-1990 has lost the pace of increasing inter-city co-authorship, but the pace is recovered significantly in subsequent periods.

- Within studies dual dominance of Istanbul and Ankara is observable throughout the time until latest decade. The period following the millennium location based publication productivity is seen to be relatively decentralized.

- High transitivity values principally in WoS indicate that although the academia as a whole is fragmented and a large number of authors remain completely isolated, yet the ones who collaborate sharing their knowledge induce further collaborations in between their collaborators.

- It is seen that connected components within Turkey exhibit rather chainlike structures than fully connected cliques.

Chapter 7

Discussions

The chapter starts with a brief review of studies on Turkish academia and outlines rationale for the selection of the exemplary case. In the Section 7.2, it discusses the major findings from the exemplary case. Section 7.3 discusses relevant studies in the literature.

7.1 Selection of the Exemplary Case

Selection and elaboration on a particular field is bound up with the particular form of the community. Cultural variation of the community, historical factors, special terminology of the scientists in the community are among the factors which socially influence development of a field. Max Scheler classify these factors as 'structural identities' of the scientific community (Scheler, 1980). The choice of case and elaboration on data for this dissertation have fallowed the same line of endeavor. Further, it has attempted to link empirically social structure and diffusion of knowledge in the field. Of all types of social structures, specifically the primacy of the case is rather on collaboration structure within a community. As of field research, longitudinal analysis of Turkish management academia is preferred.

Selection of case, nonetheless, allows me to make certain assumptions on the other social identities and social media in which scientific activity is realized. For instance, all national level socio-political, economical and historical factors applies to the community. In addition, primary data covers almost entire period of Turkish Republic from 1923 up to 2008. The data set itself is homogenous, as it consists of scientific articles published at national level and disseminated within the country. Language of almost all titles in the set are in Turkish. Author or at least one of the co-authors of each paper is affiliated with a Turkish academic institute.

Arbitrarily any other field of science from Turkey could have been chosen to examine the interplay between collaboration structure and diffusion of knowledge. However, choice of management provides several advantageous over the others. First of all, nature of the field is very much prone to socio-economic factors of the country. In that respect, it allows me to observe to some extent impact of environmental factors on the internal structure of collaboration. Secondly, compared to any other discipline, management field is the only field which is partly covered by studies on Turkish academia. Nonetheless, it should be noted that those few number of studies on Turkish academia primarily focus on institutional properties and international influences on management education in Turkey (Usdiken and Wasti, 2009). Lastly, familiarity, background and expertise of dissertation committee on management field is of practical reasons.

This section briefly reviews studies on Turkish academia, those focusing on scientific networks, before detailing source of data used for the rest of analyses.

7.1.1 Studies on Academia in Turkey

Point of departure of almost all academic studies which focus Turkish academy is primarily the concern about low publication productivity of Turkish scientists in international journals. Majority of them solely provide statistical descriptive figures, while some other attempt to entail in investigating regulations and incentives which aims to foster or have resulted to deter publication productivity. There are only a few studies which engages in some other social and institutional aspect of academia in Turkey. Namely, they are (i) a set of papers that are repeatedly published or lead authored by Behlul Usdiken

(Usdiken and Wasti, 2009; Usdiken, 2007; Usdiken at.al. 2004; Usdiken, 2004a, Usdiken, 2004b; Usdiken and Cetin, 2001) which of all primarily examine institutionalization of management field and education in Turkey; (ii) a recent paper by Gossart and Ozman (2009), which examine structure of co-authorship in social sciences in Turkey in between 2000 and 2007; (iii) a recent paper by Ozel et.al. (2010) which primarily examine influence of gender differences on co-authorship patterns in Turkish social sciences in between 2002 and 2008.

Yurtsever and Gulgoz (1999) trace a set of researchers in chemistry and examines publication counts over the years in between 1986 to 1987, while Uzun (1996) studies publication efforts in Physics in Turkey in between 1990-1994. The author compares collaboration rates and publication productivity of Turkey regarding other Middle Eastern physicists from Egypt, Iran, Iraq, Jordan, Saudi Arabia and Syria. The empirical investigation is conducted by examining top tier international journals in the area. The study hints a propensity towards decreasing isolation and increasing collaboration not only for Turkey but also for other middle eastern countries. Uzun and Ozel (1996) have studied 187 papers from Turkey published in the journals on astronomy and astrophysics indexed in the Science Citation Index (SCI) for the period 1985-1994. They have also found that the fraction of multiple authored papers has increased over the years in the period. Uzun (1998) have further reported the number of papers from Turkey in social sciences published in WoS for the years 1987-1996. The study concludes that number of co-authors has increased, reflecting increased interaction among scientists.

Uzun (2002) examine the number of publications in WoS particularly on library and information sciences comparing Turkey to other developing countries and East European countries. He also applies co-word analysis based on the keywords in the titles and abstracts based on a a sample of 102 articles published in between 1996 and 1999. He concludes that bibliometrics is the most frequent topic followed by information retrieval, information need and information use. Al and Afzali (2006) also examine productivity in a similar field. The authors examine SSCI papers published in Information Science related journals. Their set consists of less than 100 papers covering 1967 to

2006. They simply trace total number of papers over time. A steady increase is observed. Al et.al. (2006) examine arts and humanities publications from Turkey found in WoS dataset for the years from 1975 up to 2003. They simply provide the number of publications over the years and its summary statistics such as authors per paper. Likewise, Gokceoglu, et.al. (2008) examine earth sciences publication in the same set for the years 1970-2005.

Gulgoz et.al. (2002) examine contributions from Turkey in social sciences found in WoS dataset for the years 1970-1999. They differently argue that national orientation creates obstacles for presence of articles authored by researchers from third world countries like Turkey. They further conclude that publication in scholarly journals constitute a small portion of publications of researchers from social sciences.

Uzun (2006) qualitatively examine new regulations and incentives taken by government to stimulate science and technology. Onder et.al. (2008) also examine impact of institutional changes in Turkey starting mid 1990's. They examine factors such as promotion policies, existence of foundation type universities, recruitment strategies, impact of funding and reward incentives. The study covers the years from 1973 to 2005 derives upon citation indexed publication productivity of scientists from Turkey.

Usdiken (2004b) examines penetration of 'Human Relations' concepts and as a new field in management education following changes at national level political and economical climate after the World War II (WWII) until mid 1960's. The empirical study develops upon content analysis conducted using 23 public presentations and curricula of educational institutes within the period. The study shows that diffusion of 'Human Relations' concepts have been much faster within the presentations compared to its codification within management curriculum.

The study further indicates that management scientists themselves have been the 'significant actors' at knowledge diffusion in Turkey compared to other arenas elsewhere (Engwall and Kipling, 2004). The study shows that Turkey like other Mediterranean countries has experienced strong U.S. influence (Kipling, et.al., 2004; Usdiken, 2004a). They further show that management scholars from USA or the ones trained in USA have acted as active knowledge carriers in Turkey. The authors further show that scientists from USA or the ones with USA orientation have exploited organizational and institutional transformations and adaptations which mimics American system (Usdiken, 1996; Usdiken, 2004b). Usdiken and Cetin (2001) and Usdiken et.al. (2004) additionally outlines German influence and concepts on managerial practice before WWII and discuss how immigrant scholars have acted as knowledge carriers in Turkey. This set of papers attempt to understand diffusion of knowledge from external communities into management field in Turkey (Usdiken, 2007).

The study by Gossart and Ozman (2009) compares co-authorship patterns found in social sciences. They compare national publications versus internationally indexed publications. The comparison is conducted measuring rate of collaborations and degree distributions. The study covers the years from 2000-2007 and concludes that there is two distinct publication regime and group of scientists who are isolated from each other.

The study by Ozel et.al. (2010) primarily finds that there is a gender difference at scientific collaboration patterns. In this study, we have shown that female-female ties in Turkish social sciences are significantly more persistent compared to same gender male ties and inter-gender ties.

7.2 Analysis of Major Findings from Exemplary Case

7.2.1 Productivity and Collaboration Overall in Turkish Academia

Figure 6.1 shows that although there is a steady growth in scientific productions in Turkey in last century until mid 1990's, there are occasional glitches as well as significantly decaying productivity years. Occasional yearly glitches may partly be attributed by factors such as under-representation of bibliographic records in respective years. However, a closer inspection of flatter valleys in the figure shows that those years correspond to periods in which important national level social and political events have taken place. For instance, interestingly, at the years of the military coups, namely 1960, 1971 and 1980, or at the several years preceding those coup d'etats the level of productivity drops down from its observed and rather steady course. The productivity is stagnated in between subsequent coup d'etats of 1971 and 1980. The social and political turmoil of the decade was further exposed to Turkish-Greek Cyprus conflict and military intervention by Turkey in 1974, the year where the scientific productivity further dips down.

A rather counter-intuitive recurrent pattern is the steady increase in number of publications following immediately the years of military interventions. Years following the intervention in 1980, additionally, exhibit decaying rate of co-authorship rate in between scientists. Figure 6.2 depicts that a steady decay is observable until mid 80's. The figures hint that further research is required to study these patterns, which is out of focus of this dissertation study.

Results show that science in Turkey has experienced an almost steady increase in the rate of collaborations starting from the years around World War II. This can be partly explained by the evolving nature of science in the 20^{th} century. Such a growing tendency towards collaboration is seen to occur universally by the advancement of knowledge in all fields and an increase in the quantitative studies (Acedo et.al., 2006). Elsewhere it is observed that advancement in the science has lead the need to use more complex methodologies which can be accomplished through collaboration (Moody, 2004).

It should be noted both in management subset and in the main dataset the number of papers diminishes towards late 90s significantly. This best can be explained by the decrease in the number of records in the set rather than decrease in the level of productivity. This fact has been addressed in Section 7.1, it is due to several reasons. First, academicians are inclined and promoted to publish rather in international journals. Second criterium to confirm a published article as a scientific paper and to include it in the set has allowed to include only peer reviewed journal articles. Third, there has been ambiguity among public offices at setting these criterium and fulfilling task of keeping and maintaining a dataset on national level articles until 2001. The inclination and incentives at publishing at international journals can be seen by the steep increase in the number of papers seen WoS dataset. It is given in Figure 6.10. The acceleration for management field takes off starting in mid 90's. The propensity of Turkish academicians to publish internationally has captured international attention as a phenomenon (e.g., Gokceoglu et.al., 2008; Onder et.al., 2008).

Americanization of management education, paradigms along with change in academic promotion policies which adopts *publish or perish* phenomenon and awards social sciences citation indexed (SSCI) publications have turned attention of Turkish scientists to publish at international and English journals. This factor may also further explain the decrease in the number of publications in the last period. Besides, comparing co-authorship distributions of papers from Turkey published in WoS database to other studies elsewhere which focus national contributions to WoS leads us to find out a significantly different distribution characteristics exhibited by Turkish academia. As it has been discussed in Chapter 4, studies elsewhere show that distribution of number of collaborators in scientific papers normally exhibit a power law distribution. For instance, in a power law regime, number of papers with two or more authors decay exponentially compared to single author papers. Nonetheless, presence of Turkish scientists within multi-authored papers show inclinations to take part or be embedded in teams to publish.

As it has been discussed in Chapter 4 the literature suggests that natural sciences compared to social sciences experience higher rate of collaboration. Management in Turkey exhibits almost an average rate of collaboration pattern compared to all other fields in Turkey. This can partly be investigated by examining level of interdisciplinarity of the field. The literature further suggests that interdisciplinarity and use of quantitative methods are among the motivations to collaborate in social sciences (Moody, 2004).

7.2.2 Development of Turkish Management Academia

Peculiarity of management field in Turkey, from 1922 to 1999, probed via number of publications and rate of collaborations show that although Kuhn's (1970) conception of structure of science can be applied to development of management sciences in Turkey, it lacks to explain discontinuities or deviations from the stages of a `normal science`. The figures and findings in previous chapter reveal that social, political and other national level settings may influence natural growth of a discipline causing discontinuities or sometimes deviations.

It is seen that ratio of co-authored papers in WoS publications surpasses single author publications which hints that form of collaboration and incentives to publish internationally is different than at publishing locally. Nevertheless, it is also seen that form of collaboration and incentives to publish locally is not uniform either. It is seen that size of co-authoring teams and rate of collaboration has increased significantly after the millennium. There is a jump at the rate of collaborations to a level of 20 percents. This can be explained largely by rather strict academic and scientific criteria and national policies regulated by central national authorities. National level science policies and appraisal procedures in academia has lead many scientists in the period seek to publish at peer reviewed periodicals which are rarer and more difficult. Presumably tighter control on the accreditation of periodicals for their scientific contents has left out many papers to be included in the bibliographic dataset. But same factors may have played at increase at the collaboration rate in between scientists aiming to be accredited academically.

The analysis on interdisciplinarity aspect of management field show that economy has constantly been the most influential field. That is a great many articles have dealt with a subject which addresses both management and economy issues. A set of other observations hint socio-political settings of peculiar periods. For instance, in the inceptive years it is seen that an important number of management studies have entangled with managerial or organizational issues in military institutes. Additionally, public administration, law, agriculture, trade and transportation relevant issues have been observed more recurrently. It can also be seen that starting from mid 50's engineering and manufacturing related issues becoming more and more influential. Psychology is entering to the picture in 60's and becoming more frequent over the decades. Ethics, on the other hand first occurs to be studied after the millennium. Islam and religion issues shows up in late 70's and 80's.

Examining emergence and prevalence of keywords via tag clouds reveals detailed peculiarity of the field over time. The tag clouds show that, in the first period, which covers WWII years and before back to early years of the republic, efficiency in army logistics, mining and transportation services are recurrent issues. In the second period, when presumably influence of german management scientists has become institutionalized, issues such as accounting, book keeping, planning, financing and machinery along with manufacturing becomes more prevalent. It is seen that issues have shifted towards more conventional management related issues. Army logistics has given way to accounting, for instance. Besides, change in concepts and paradigms may have replaced book keeping with more contemporary accounting concepts. In the subsequent period, manufacturing and mass production oriented issues are shoring up. Automation, tasks, industry and training are among them. In later two periods, which covers 70's up to late 90's, tag clouds show that business and marketing oriented concepts and issues are recurrently mentioned in the articles. In the years covering last decade, management literature seems to diversified embodying globalization relevant issues. In the local literature, for example, strategic management and organizations become the most central keywords. WoS literature which actually populated mostly by the articles published in early 2000 onward exhibits similar yet much contemporary management related set of keywords such as culture, ethics, behavior, multinationals, uncertainty, collectivism, individualism and competitive advantage.

A rather systematic view of the field via co-word analysis helps to understand to what extent knowledge is produced within the community. Besides, it helps to probe mainstream and peripheral issues overtime. An overview of major mainstream issues, those with high density and high centrality values on the strategic diagrams, reveals a set of underlying social, economical and scientific concerns for each period. In other words, it is seen that constellation of issues on their respective strategic diagrams reflect mainstream management science paradigms, stages in the mode and means of economic productions at national scale and relevant public and entrepreneurial concerns. For instance findings from previous chapter show that moving from first period (1922-1945) to the second period (1940-1960) accounting is studied more in relation to financing and it dominates the debate of the period. At the same period agriculturing is discussed with governmentally supported provincial or town cooperations which have been a major policy of the period. In later periods, it is further observed that prominence of accounting left its spot for education, knowledge and training issues. Training related issues seems to be evolved and sedimented within human development framework by late 90's. The period which covers 70's and early 80's meets managerial leadership issue, while 90's is inflated with marketing and governance issues.

Emergence of new concepts constantly on tag clouds and the increase in the interdisciplinary studies point that overall debate in Turkish management has enriched and diversified in latest decade. This is observed not only in citation indexed publications but also in local publications. Issues in local and international publications, to some degree, parallel each other. For example, while culture is addressed with organizational structures locally, it is discussed along with individualism and collectivism in international publications. However, both issues are related with consumption and consumer behavior issues (See Fig. I.4 and Fig. J.4 in appendices). Differently, while in local articles customer relationship management (CRM) or consumer behavior is discussed, internet and e-commerce as well as TQM have been the other major focus of international publications.

It is also seen that until 60's most of management theories or issues have been studied within security organizations such as military and police departments. Yet the very first set of management articles have been observed to address organizational issues that can be encountered in Turkish sport clubs.

7.2.3 Socio-Knowledge Structures in Turkish Management Academia

Review of literature has shown that cohesiveness or density of components in scientific networks foster collaboration and enhance knowledge generation and transfer mechanisms. Comparing evolution and change in the structure of connected components from Figure 6.30 to Figure 6.32 an increase in the cohesiveness of the components is observable. An increasing diversity in the number of new issues and keywords as observed in previous section descriptively observes and supports this correlation.

It is seen that until 1960's there is a location based isolation and fragmentation in academia. However, only the years following 1990's a significant number of inter-city collaboration occur. Examining collaboration networks of early periods in the academia, it is seen that expat scientists pioneered culture and practice of collaborations.

Examining knowledge dissemination relations (AxK), it is observed that over the periods, the level of inequality at disseminating knowledge stagnates at higher values. This provides another hint for low level of knowledge diffusion in the network of scientific collaboration. On the other hand, knowledge load per author persistently increases until 90's. Load of knowledge is significantly higher for the part of the academia who publish in WoS. Knowledge load per author in WoS, on the average, almost doubles the knowledge load per author in local datasets. It is also seen that redundant number of authors decreases significantly in last two decades. Given increase in the number of authors, this can be explained best by increased discipliner diversification in the field.

Although local academia remains fragmented, slight increases in average distance and clustering coefficient measure together hints subtle formation of small world structures in last three decades. Visual analysis of core components in earlier section further enhances this phenomenon. Transitivity values supports earlier findings regarding structure of collaborating teams. High transitivity values principally in WoS indicate that although the academia as a whole is fragmented and a large number of authors remain completely isolated, yet the ones who collaborate sharing their knowledge induce further collaborations in between their collaborators. This value, however, deeps down for the period following the military coup in 1980.

Of collaboration network centralities, it is seen that closeness of individuals to other members of the academia does not provide any implication or correlation on their decisions or choices of knowledge production process. However, it is seen that at international level publications centrality in the network is correlated on the preferences. High degree central and high betweenness central authors in WoS seen to populate the first quadrant. Besides, the ones with high betweenness are also observed to populate peripheral issues.

It is seen that the ones with high betweenness centrality populate the first quadrant issues invariably for most of the periods over entire time. Indeed, examining the structure of collaborators in the period given in Figure 6.30 further confirms this relation. There, it is seen that connected components exhibit rather chainlike structures than fully connected cliques. It means that a significant number of individuals who publish on mainstream issues are also accommodating chainlike components. A chainlike connection may facilitate indirect knowledge diffusion channels in between scientists.

Existence of chain-like components along with lower number of cliques in MK set hints existence inter-generational collaborators as major form of co-authorship in management academia. That is, chains are formed presumably by dyads from different generations. A further research examining this phenomenon may help understand significance of inter-generational collaboration at diffusing scientific knowledge.

It is seen international level publications, one's diversity in terms of knowledge items he/she have published is not correlated with his/her strategic choice of scientific endeavor. On the other hand, at national level publications it is other way around. The ones' with high socio-knowledge power (SKP) or knowledge dissemination degree (KDD) populates or may have manipulated mainstream issues. The ones with low SKP and KDD remains peripheral.

The results hints an important dichotomy in between socio-knowledge behavior at publishing internally and externally. In WoS high social central authors publish or do collectively set the mainstream issues. Internally, it is the influence of individuals' socially enhanced knowledge diversity (SKP) and individual's dissemination activity (KDD) which is correlated with issues populating the map of the field.

There are also certain peculiarities. It is seen that at early period of management field in Turkey, academicians with high KEI dominates the second quadrant. This phenomenon re-occurs in the latest period. Analysis in earlier sections has hinted that in the latest period local academia has enriched its knowledge depth. Both observance may correspond development or remake of a field where cohesiveness and commitment in early stages would naturally make the second quadrant more populated according to Kuhn's (1970) paradigm of a 'normal science'.

7.2.4 Small Worlds vs Isolated Cohesive Groups

Observed differences in the mechanisms of knowledge diffusion at internal collaborations compared to collaborations found in WoS are in parallel to the theoretical debate engaged in Chapter 3 and Chapter 4. There it is suggested that the nature of transmittance should be taken into consideration while studying effective network models of diffusion. Studies have shown that while in knowledge intensive networks cohesiveness and strong ties are diffusing knowledge better giving way to strongly connected cohesive networks or network parts as ideal form of knowledge diffusion, information or information like transmittances are diffused easily through weak ties. In that respect weak ties connecting different worlds have been observed to be efficient.

The findings of regression models given in Section 6.7.1 and Section 6.7.2 are inline with descriptive and visual analysis conducted and discussed earlier in this chapter. A closer inspection on the position of the issues on the strategic map (See Fig. 6.21 reveal that only very few issues in local management academia appear in the second quadrant. During normal course of development of a scientific field, which may require high cognitive demand and collaborating teams, issues seen to enter the diagram in the third quadrant. Then they mature and develop internally before moving up to to the first quadrant, where mainstream issues are found to be located. That is, during the developmental transition phase issues are observed to occupy the second quadrant.

Analyses have further shown that local academicians populated in the first quadrant are more active at knowledge transfer. These findings together may hint that management knowledge within local studies is transferred following the patterns of information diffusion rather then pattern of knowledge transfer found elsewhere. On the other hand, cognitive demand of publishing in citation indexed journals may have given way to cohesive collaborating teams as mean of collaborative knowledge production and transfer.

The theoretical discussion in Chapter 3 has suggested that in the networks where knowledge intensive work and commitment in existing ties is required, knowledge is diffused better in strongly connected components. In such cases, it is seen that occasional weak ties linking different parts of the network or teams may fail to transfer encoded knowledge or experience. The empirical findings parallel this framework. It has been observed that scientists who publish in WoS co-author repeatedly in triads or in cohesive larger team sizes.

7.2.5 Summary

Results from knowledge diffusion models hint that management knowledge within local studies is transferred following the patterns of information diffusion rather then pattern of knowledge transfer found elsewhere. On the other hand, cognitive demand of publishing in citation indexed journals have given way to cohesive collaborating teams as mean of collaborative knowledge production and transfer.

At ego levels, diffusion of knowledge is lead by certain type of academicians. Presumably they have also determined mainstream topics. These star egos exhibit a common cognitive structure relative to the rest of the academia: They have more social ties and pieces of knowledge compared to the rest. Knowledge they have is distinct compared to their peers in the network, they hold certain part of their knowledge exclusively, thus knowledge-wise they don't resemble the rest, but they keep a level of similarity with the rest of the academia. On the other hand, individuals who publish internationally are embedded in strongly connected components which fosters transfer of knowledge in between them.

7.3 Relevant Studies

The research questions I have attempted in the exemplary case are partly relevant to the key questions Chubin (1976) is raising in his review on the studies of research specialities which address (i) the social and intellectual properties of a specialty, (ii) the temporal and spatial dimensions of a specialty, (iii) growth, stabilization, and decline of a specialty. Such an approach has a focus on practices of science internally. Majority of these studies with internal focus exploit scientific publications data. Extensive use of large amount of bibliometric data on published materials, in return, has fostered various advanced quantitative methods such as co-word analysis, co-citation analysis and co-authorship analysis.

Although these bibliographic analyses might be incapable of capturing some of the nuances of traditional historical or ethnographic methods of studying science, they are acknowledged as powerful tools which might provide a perspective that has been eluded by other forms of inquiry (Neff and Corley, 2009). Amongst the three bibliometric analysis, co-authorship networks are mostly adopted to study collaboration structure of scientific communities, where network oriented questions, such as, accessibility, frequent channels of communication, strategic positioning, overall network topology, etc., have shown to be relevant and valid (Newman, 2001a; Newman, 2001b; Newman, 2001c, Newman, 2004). Cohesiveness of co-authorship ties, mean and distribution of number of collaborators, identification of research cliques are among most frequent research questions attempted so far (i.e., Newman, 2004 ; Moody, 2004).

In citation analysis or co-citation analysis focus is on influential documents in a field. The method isolates scientists and the very content of documents. This isolation provides a very limited perspective on communication in scientific fields, which can be supplemented by co-authorship analysis or content analysis (Chubin, 1976; Morris and Martens, 2009). For that reason, detailed discussions on paper citation network has been excluded from this study, principally, due to its limited representation of actual social structure. Although White et.al. (2004) claims that many authors within network science have conceded a social component in citation networks, assuming that citers and citees often have interpersonal as well as intellectual ties, the claim is based on an empirical study which is drawn from publication of an international special interest group of 16 researchers. This group of scientists are formed in order to study human development interactively, which increases the fact that they would cite each other.

Co-word analysis, on the other hand, is deemed to be powerful tool because it allows for the investigation of research priorities across an entire discipline (Callon et.al., 1983). As Callon, Law and Rip (1968) argue in their early work that laid out the theory of co-word analysis, it is an attempt to "pursue the qualitative by other means" (Neff and Corley, 2009: p.658). The technique is employed to track the comparative rise and fall of themes within different subfields and identify overarching trends in a way that would be prohibitively time consuming with traditional historical tools (Callon et.al., 1986). It is principally a content analysis technique which is based on co-occurrence of words or phrases in bibliometric entries such as titles, keywords lists and sometimes publication abstracts.

Those paying attention to interplay between communities, institutions and practices of science as a whole and the rest of the society treat total of scientific practices as a unit. Then, they examine impact of exogenous factors, which may be other non-academic institutions, mechanisms and governance structures on the practices of science. The interplay in between academia as a unit and the actors in the rest of the society is studied within so called 'triple-helix' framework (Etkowitz and Leydesdorff, 1996; Etkowitz and Leydesdorff, 2000), where relationship among academy, market and government is primed. Within triple helix perspective, dynamics of knowledge-based economy and stimulation of policy inputs by government agencies are both supportive institutional arrangements and externally differentiating factors on scientific practices (Leydesdorff and Meyer, 2003; Leydesdorff and Meyer, 2007). In this dissertation, those exogenous factors are not addressed. Rather internal dynamics of scientific practices is concerned, which also allows to exploit premise of bibliographic data and methods to examine extensively.

Most of existing bibliometric methods have adopted or have extended social network analysis framework. Adoption of social network analysis in the study of internal practices of science is not haphazard. It is observed that social connectivity is relevant to many aspects of research. In social studies of science, for instance, individual research fields have been considered as self-organized communities, therefore, they are also referred to as 'invisible colleges' (Mika et.al., 2006). Social network perspective enables to make 'invisible colleges' visible by constructing network of the research community using bibliographic data.

A network theory perspective is not strictly bound to studies on internal dynamics of science. An early study by Wolf (1986) brings social network analysis perspective into anthropology of business. Wolf studies relation among business corporations involved in international business activities. Accessibility to one another, channels of communication in between actors, contingency of ties, strategic positioning in the network, decision taking and the evolution of the network structure, among others, are enticed phenomena which are quested by network scientists. Wolf (1986), for instance, points that all organizations immersed in an international business system are not equally accessible to one another, and thus, relations among them can not be governed simply by free market mechanisms. Exchanges and communications in between corporations follow pathways through increasingly integrated sociocultural network that includes other kind of actors as well. He further points the nature of contingency in his case pointing that pathways of relations are precedented in attempts to reduce risks in an unstable organization environment, as such, they are tentative. Corporations strategically position themselves in the network in order to gain advantageous places relative to others. He adds that the network corporations is a continually evolving system, where actions of corporations themselves have an impact on that evolution.

Starting around 2000 several researchers from statistical physics began to construct large-scale networks using co-authorship data to examine scientific collaboration structures which provides patterns of knowledge diffusion (e.g., Newman, 2001a; Barabasi et.al., 2002). These studies have represented research in mathematics, neuroscience (Barabasi et al., 2002); biology, physics and computer science (Newman, 2001a). However, these studies are mainly focusing on statistical characteristics of the cases under examination and don't address how knowledge is diffused. Besides, majority of other studies examine static cumulative properties of co-authorship networks they have constructed. For instance, de Granda-Orive et.al. (2009) study co-authorship network in the field of smoking studies among different specialties at an international level. They work on science citation indexed articles in the period 1999-2003. They first identify sub-fields and then they compare production, visibility and centrality of authors regarding their speciality. They derive their conclusions from 500 papers they have selected.

Some other studies simply compare network metrics of different disciplines for specific regions or nations. For example, Durbach et.al. (2008) compare co-authorship networks of chemistry and mathematics. Authors collect internationally accredited or science citation indexed publications in the field with at least one author affiliated to a South African institution. Although they cover 15 years in between (1990-2005) they do static network analysis. The network metrics they examine are clustering-coefficient, network diameter and size of giant component along with other general publication statistics. Although each network they examine have a giant component, in general, they are comprised of isolated small groups. Yue and Liu (2005) more specifically study co-authorship in management sciences in China. Their research is based on bibliographic set of Chinese Journals Fulltext Database (CJFD). They attempt to find the leading cities in China as of publication productivity at management fields. Besides, they attempt to observe common age groups of senior researchers and new entrants. Their findings suggest that management scientists do start publishing at around age 30 and they become seniors around age 40 in China.

Bettencourt et.al. (2009), on the other hand, examine collaboration structure of specific fields in order to spot advent of a new scientific discovery. Their central hypothesis is that "the creation and spread of new discoveries through a scientific community creates qualitative, measurable changes in its social structure" (Bettencourt et.al., 2009: p. 212). They use bibliometric data to form collaboration structure via co-authorship relations. Their quantitative findings mimic process of scientific discovery as outlined by Kuhn (1970), where discovery takes root among a small community of practitioners, later on, leading to a large-scale reorganization of the social structure of collaboration in whole community.

In that respect, a Kuhnian perspective as outlined in *The Structure of Scientific Revolutions* (Kuhn, 1970) has been partly employed to trace stages and evolution of interplay between cognitive structure, representing the collective knowledge, and collaboration structure, representing the social structure. For a generalization of that formulation, we can assume that as a new concept diffuses in a community, it moves from the periphery to the center of knowledge map of the community. This phenomenon can be observed studying scientific dissertations by a community. Because, diffusion of a concept is reflected by its prevalence in scientific publications connotated with other themes in the field (Law et.al. 1988; Latour, 1987; Law and Whittaker, 1992). The movement of a theme from periphery to the center both stimulates and is achieved by social interaction of scientists in the field, which in return may lead to a large-scale reorganization of the structure of collaboration in whole community. Some recent studies attempting to detect research frontiers have employed such a perspective by solely observing changes at overall structure of co-authorship network of a scientific field. For instance, Bettencourt et.al (2009) have reported formation of a giant connected core of scientists over time as an indication of maturation of a development and maturation of a scientific field. However, the study fail to relate co-evolution of cognitive structure in a scientific field and collaboration structure in the field via explicit theoretical and empirical discussions.

There are a few new attempts in the literature that relate cognitive structures and collaboration (Mutschke and Haase, 2001; Mika et.al., 2006; Calero et.al., 2006; Noyon and Calero-Medina, 2009). However, they take very specific fields with few number of researchers to identify and classify research groups to come up with potential collaborations in between them within a research policy context. As such, they fail to demonstrate general characteristics or longitudinal evolution of a field. Hou et.al. (2008) incorporate content analyses and co-authorship network analysis. They perform clustering analysis on co-authorship data to capture collaborating sub-groups. After that they perform frequency analyses of words within the titles of the publications to associate them with different groups. Doing so they successfully identify the subjects collaborated in each respective group. Morris and Martens, in their aforementioned review, they suggest adopting co-authorship perspective and co-word analysis:

> "The two communicative approaches [co-authorship and co-word analysis] most relevant to scientific specialties, therefore, involve the study of communication among specialty members and the study of the content of specialty papers themselves. These two approaches may be termed the diffusionist approach, focusing on the communicative process, and the discursive approach, focusing on the communicative content." (Morris and Martens, 2009: p. 230)

This dissertation study have attempted going beyond mechanic amalgamation of techniques as implied by Morris and Martens (2009). It has primed to develop a theoretically grounded approach by contextualizing different analysis techniques systematically. The theoretical framework with the help of appropriated techniques has served to study knowledge diffusion and community structure of a scientific field overtime. Although focus of discussions has been on internal dynamics of scientific practices, the theoretical framework and the method does not constrain engaging in discussions considering external social, historical and institutional peculiarities.

Chapter 8

Conclusions

8.1 Overall Summary

Focus of this dissertation has been the interplay between knowledge and social structure. Contribution of this dissertation in this respect has been manyfold. It has proposed and has elaborated a framework which relates knowledge structure and the collaboration patterns into an integrated socio-knowledge analysis of any scientific community. It has adopted a longitudinal approach demonstrating how to trace knowledge diffusion within peculiarity of a national level socio-knowledge system. Proposed and demonstrated research framework is comprehensive and promising. It can be employed for future directions.

Theoretically it emphasizes mutual influence in between social structure and knowledge diffusion processes. The mutuality is elaborated within social network analysis research perspective that primes relational approach to social actions. The framework serves as a conceptual instrument. It is developed deriving upon a comprehensive and critical literature review on knowledge diffusion in science networks. Its primacy on social context dependency of data and knowledge has served as lenses to identify and discuss discrepancies and fallacies at empirical studies on co-authorship networks. It is shown that how peculiarities of social boundaries and limitations of datasets result in distortions on proposed network models and lead to inconsistencies in between findings of similar case studies.

The dissertation has developed an encompassing method which combines two powerful perspective. They are social network analysis oriented meta-network perspective, and co-word analysis oriented map of sciences. While the meta-network perspective enables to study co-authorship network, knowledge network and knowledge dissemination network of authors in a field simultaneously, strategic maps of a science that is formed by co-word analysis enables to visualize pervasiveness and cohesiveness of issues in the field in parallel to meta-networks. Rather than an eclectic use of existing methods, the proposed research framework has enhanced them with extensions and has integrated them coherently by a new model along with new or adopted social network analysis metrics. The novel model enables to map actors from co-authorship networks into strategic map of sciences generated by co-word analysis. The method further demonstrates how co-word analysis can be extended in the direction of network analysis enabling researchers to examine semantic relations in between concepts and issues emerged on the strategic map of science.

The longitudinal exemplary case, based on primary data enriches the understandings on social network aspects of research and knowledge diffusion. It demonstrates explanatory power of the theoretically induced research method. In depth analysis on the exemplary case traces how management related knowledge is diffused and what collaboration structure is exhibited by Turkish management scientists from 1920s until 2008.

8.2 Major Results

Empirical findings from knowledge diffusion literature as well as from exemplary case of this dissertation suggest the need for deliberation on the nature of knowledge that is exchanged, shared or transferred through social networks. More specifically, it is seen that it is necessary to differentiate in between information and knowledge nature of transmittance in the network. Within such a differentiation scheme while information is considered as a form of filtered data within a context of relevancies, knowledge is considered as a systematically processed information that is bound to individual or collective actions and praxis. Empirical findings elsewhere has shown that diffusion of rumor, perception of consumer brands, etc. follows patterns of information diffusion. On the contrary, cognitively demanding know-how or expertise knowledge such as found in biotechnology industry fallows patterns of knowledge diffusion in networks.

This dissertation study suggests that the nature of transmittance should be taken into consideration, also, while studying effective network models of diffusion. Studies have shown that while in knowledge intensive networks cohesiveness and strong ties are diffusing knowledge better giving way to strongly connected cohesive networks or network parts as ideal form of knowledge diffusion, information or information like transmittances are diffused easily through weak ties. In that respect weak ties connecting different worlds have been observed to be efficient.

This mutuality or interplay in between network structures and the nature of knowledge has been further instrumental at identifying and discussing discrepancies and fallacies at the empirical studies on co-authorship networks. It is seen that flow of information and flow of knowledge are correlated with differing ego level social interaction patterns. At ego levels, flow of information has been observed to prime brokerage at diffusion processes where Gronovetter's 'strength of weak ties' and Burt's 'structural holes' are in action. On the other hand, flow of knowledge has been observed to prime embeddedness in cohesive subgroups which is assumed to increase social capital of the ego as the major facilitator of knowledge creation and transfer.

Furthermore, at overall network levels, an information vs knowledge dichotomy has been instrumental to understand why in some cases small-worlds emerge as network level predominant pattern of interaction, while in some other cases a tightly connected whole or isolated yet strongly connected components emerge. Empirical findings elsewhere has shown that flow of information is accompanied with small-worlds patterns, whereas flow of knowledge is observed along with tightly connected whole or components.

In relation to nature of knowledge that is diffused, overall network level patterns or emerging structure of ego networks are consistent. It is, again, seen that cognitively demanding knowledge requires or diffuses best when ties are strong, namely when interactions are frequent or dense. However, it is also observed a knowledge vs information dichotomy maybe fuzzy when knowledge 'behaves' like information in the networks. That is, diffusion of knowledge may emulate the patterns or properties of regular information flow, which eases the transfer of demanding 'know-how' in certain cases. For instance, when individuals share very similar expertise and social settings exchange of knowledge may follow patterns of information diffusion.

Empirical findings of the study are in align with elaborated conceptual framework which primes mutuality of knowledge and social structure. Observed differences in the mechanisms of knowledge diffusion at internal collaborations compared to collaborations found in WoS are in parallels the empirical conclusions above. Results from knowledge diffusion models which have been tested hint that management knowledge within local studies is transferred following the patterns of information diffusion rather then pattern of knowledge transfer found elsewhere. On the other hand, cognitive demand of publishing in citation indexed journals have given way to cohesive collaborating teams as mean of collaborative knowledge production and transfer.

Results from co-word analyses as well as analysis on ego level socio-knowledge activities support this observation. A closer inspection on the position of the issues on the strategic map of the field over time have revealed that only very few issues in local management academia follow normal course of development of a scientific field, which would require high cognitive demand and densely collaborating teams. Ego level socio-knowledge analyses have further shown that local academicians populating the first quadrant are more active at knowledge transfer. They individually exhibit high socio-knowledge capital. But in general academicians publishing locally have either no or few number of collaborators. In contrast, it has been observed that scientists who publish in WoS co-author repeatedly in triads or in cohesive larger team sizes.

Proposed novel model which enables to reveal 'strategic' preferences of scientists at picking issues to publish is promising. It may provide new perspectives at the study of individual level knowledge dissemination practices. The model has enabled to observe that certain type of academicians within Turkey has lead diffusion of knowledge. For instance, presumably mainstream topics in the academia is set by them. They exhibit a common knowledge structure relative to the rest of the academia. They have more social ties and pieces of knowledge compared to the rest. Knowledge they have is distinct compared to their peers in the network, they hold certain part of their knowledge exclusively, thus knowledge-wise they don't resemble the rest, but they keep a level of similarity with the rest of the academia. On the contrary, it is observed that authors who publish internationally are embedded in cliques or cohesive groups. Moreover, rate of collaboration at international publications are observed to be significantly higher than local publications. Besides, contrary to local publication practices, mainstream issues are not correlated with star authors who hold strong socio-knowledge capital but correlated with authors who are embedded in cohesive collaborating groups.

8.3 Future Directions

Current framework can be used to repeat similar analysis for any of other disciplines such as medicine, physics, history, engineering sciences, etc. Peculiarities of each area can be compared and contrasted within a national level context. Instead, development and evolution of sub-areas within a discipline can be traced and compared. The methodological framework of this dissertation enables to examine micro-level semantic relations in between issues or concepts within an area, which are established by academicians. Given availability of reliable data a similar analysis can be conducted to make international comparisons. International comparisons may help to understand collaboration structure related knowledge diffusion patterns in different national and regional systems.

Proposed framework can be further elaborated, adopted or extended around a multitude of new research questions employing both qualitative and quantitative methods:

- **Policy Making:** Rich empirical evidences acquired from co-authorship patterns, socio-cognitive structures and knowledge diffusion mechanisms within the community may be used to develop field specific multi-agent simulation models. Such simulation models can be employed to conduct contextualized policy experiments at national, regional or even institutional levels. Devised experiments may hint potential future collaborations in a field or promising and emerging future areas within the field, which of all may help to develop empirically supported research policies.

- **Public vs Private/Foundation Type Universities:** Starting from mid 1980's Turkey have increasingly experienced a dichotomy at institutional structures at higher education. Academicians in new foundation type universities have been exposed to different working conditions and publication policies. Impact of changes at institutional affiliations of individual academicians on overall collaboration trends as well as on knowledge dissemination activities in Turkey has not been addressed in that respect. The framework of this dissertation can be employed and adopted to study it.

- **Institutional and Geographic Mobility and Knowledge Diffusion:** Literature suggests that geographic distance is not important and importance of geographic distance is diminishing by advancement of communication. However a critical examination of findings suggest that this diminishing factor is not automatic and it is conditioned by the strength of personal ties. That is, ease of communication does not automatically form new collaborations but it rather helps persistence and sustainable interpersonal ties. Tracing mobility of authors, in that respect, in terms of its influence on knowledge transfer within a given community may further shed light to understand dynamics and evolution of contextualized scientific activities.

- **Productivity:** Community level or individual level productivity in a field can be characterized. For instance, at the individual levels one's network position, relative cognitive structure, geographic location, institutional affiliation or other socio-knowledge properties can be probed at characterizing productivity of individuals and its evolution overtime.

- **Characterizing Individual Enrollment in the Community:** Having a very large time span of scientific activities in a field enables to characterize and categorize individual enrollment levels in a community. Categorization scheme proposed by Price and Gürsey (1976), as it has been discussed in Chapter 4 can be employed. The scheme may further be used in a knowledge diffusion context, for instance, in order to probe specific influence of transients and recruits in the field.

- **Publication Life Cycle:** Having a very large time span of scientific activities in a field further enables to probe if scientists in a field reveal a recurring cycle of publication productivity. Attempts to characterize publication productivity of scientists can be conducted in different levels which may vary from overall community level to sub-groups of authors within the community who exhibit similar socio-cognitive attributes. Such a characterization may help to explore knowledge diffusion mechanisms at micro levels as well as may help to enrich dynamics of scientific activities in a discipline.

- **Community Boundary and Knowledge Diffusion Mechanisms:** Proposed diffusion model can be further improved by incorporating influence of socio-demographic variables which may help to detect influence of individuals at the 'boundary' of probed community. Besides, auxiliary analysis on collaboration structures which are entangled with knowledge diffusion mechanisms may be employed. For example, current findings hint that a detailed probation on size and numbers of connected components as well as their structure within Turkish management academia is promising at elaborating the field specific knowledge diffusion mechanisms. Findings further hint a differing influence of 'external' collaborators. Those 'external' authors are observed majorly at more knowledge intensive collaborations which have produced publications in WoS. This further points to a necessity to address influence of individuals at the boundary zone of the community. The dissertation introduces or adopts a set of relevant and coherent social network analysis metrics, such as, collaborator exclusivity index, cognitive distinctiveness, etc, which can be employed to study boundary phenomena at knowledge creation, transfer as well as knowledge brokerage processes.

Focus of this dissertation has been academia. However, developed framework is applicable to other form of communities and organizations where a network mechanism of social interaction is one of primary mean of knowledge transfer. For instance, meta networks can be extended to incorporate task allocations and resources in an organization along with individuals and expertise within the organization to study team dynamics stimulating knowledge diffusion and productivity.

Appendix A

Glossary of Abbreviations

ANT Actor Network Theory

AxA Co-authorship Network

AxK Knowledge Dissemination Network

ASC Author Strategic Centrality

ASD Author Strategic Density

CC Clustering Coefficient

CD Cognitive Distinctiveness

CEI Collaborator Exclusivity Index

CR Cognitive Resemblance

CS Cognitive Similarity

DNA Dynamic Network Analysis

HHI Herfindahl-Hirscmann Index

KDC Knowledge Degree Centrality

KEI Collaborator Exclusivity Index

KxK Knowledge Network

LSA Latent Semantic Analysis

LSI Latent Semantic Indexing

MK Milli Kütüphane (Turkish National Library) Data Set

R R Statistical Tool and Software

SCI Science Citation Index

SNA Social Network Analysis

SSCI Social Science Citation Index

STS Science and Technology Studies

TCE Transaction Cost Economics

ULAKBIM Turkish Academic Network and Information Center Data Set

WoS Web of Science

Appendix B

Details of Metrics and Parameters Employed

B.1 Individual Level SNA Metrics

B.1.1 Centrality Metrics

- **Degree Centrality:** The equation is based on Wasserman and Faust (1994: pp. 196-199). The entries in the matrix holds frequency of collaboration in between author i and author$j$. Then diagonal *A(i,i)* holds an authors total number of publication. Note that the diagonal is excluded from the computation below.

$$AA_i = \frac{1}{2(n-1)} \sum_{i=1}^{n} \sum_{\substack{j=1 \\ i \neq j}}^{n} AA(i,j) \tag{B.1}$$

AA co-authorship Adjacency matrix.

- **Betweenness Centrality:** Betweenness is computed as follows (Carley et.al., 2009):

  Let $G = (V, E)$ be the graph representation for a co-authorship network. Let $n = |V|$, and fix an author $v \in V$.

For $(u, w) \in VxV$, let $n_G(u, w0$ be the number of shortest paths (geodesics) in G from u to w. If $(u, w) \in E$, then set $n_G(u, w) = 1$:

$$\begin{aligned} S = \{(u, w) \in VxV | d_G(u, w) = d_G(u, v) + d_G(u, w)\} \\ between = \sum_{(u,w) \in S} n_G(u, v) n_G(v, w) / n_G(u, w) \\ v_{betweenness} = \frac{between}{(n-1)(n-2)/2} \end{aligned} \tag{B.2}$$

- **Closeness Centrality:** Let $G = (V, E)$ be the graph representation for a co-authorship network. Then the total distance from a person $v \in V$ to others and then the closeness centrality of that person in the network is computed as follows (Freeman, 1979; Carley et.al., 2009):

$$\begin{aligned} dist_v = \sum_{i \in V} d_G(v, i), where \\ d_G(v, i) \text{ is the shortest path from } v \text{ to } i \\ Closeness_v = (|V| - 1)/dist_v \end{aligned} \tag{B.3}$$

  In above equation if some entity , i is not reachable from v then its distance to v is set to a very large number ($> |V|$).

- **Eigenvector Centrality:** Whenever necessary ORA Network Analysis Software is used to calculate the measure. The software calculates the eigenvector of the largest positive eigenvalue of the adjacency matrix representation of a co-authorship network. It uses a Jacobi method, as suggested by P. Bonacich (1972), to compute the eigenvalues and vectors.

- **Knowledge Degree Centrality (KDD):** Let assume that an AK matrix holds frequencies of themes (keywords, or knowledge) disseminated by each scientist. Rows denote authors (A) in the community and columns denote keywords observed within titles of publications by the authors in the community. Then Knowledge Degree Centrality (KDD) of an author is computed as follows.

$$KDD_a = \frac{1}{n}\sum_{k=1}^{n} AK(a,k), \text{where}$$
$$n = \# \text{ of unique keywords observed.} \tag{B.4}$$

It should be noted that AK matrix is a rectangular and asymmetric matrix, representing a bi-modal relation between scientists and pieces of knowledge they have disseminated via observed publications. The metric is adopted from out degree centrality of Wasserman and Faust (1994).

Socio-Knowledge Metrics

- **Triad Count:** Let A represent set of scientists in the community and squared and symmetric matrix AA represent co-authorship in between them:

$$\begin{aligned} Triad(i,i) =& 0, \forall i \in A; \\ Triad(i,j)_{i \neq j} =& card\{k | k \neq i, k \neq j, \\ & AA(i,j) \wedge AA(i,k) \wedge \mathring{A}(k,j)\}; \\ Triad\ Count_a =& \sum_{j=1}^{|A|} Triad(a,j). \end{aligned} \tag{B.5}$$

- **Clique Count:**

  The clique detection algorithm employed by ORA SNA Tool is used. The software implements Bron-Kerbosch maximal clique algorithm (Bron and Kerbosch, 1973).

- **Clustering Coefficient (CC):** Let $G = (V, E)$ be the graph representation of a co-authorship network, kept in AA matrix. Then let G_v be the ego-network of author v:

$$CC_v = density(G_v) \tag{B.6}$$

Note that density of any graph G representing a socio-gram is given by Equation B.17.

- **Collaborator Exclusivity Index (CEI):**

  The metric is developed for this dissertation by adopting Knowledge Exclusivity Index given by Equation B.12. A person with a high number of pendants would have a high collaborator exclusivity value. A pendant in network terms is a node who is connected to the community through a single person. The Collaborator Exclusivity Index (CEI) for an author $a \in A$, where A represents set of authors in the community and AA is the corresponding adjacency matrix, then is defined as follows:

$$CEI_a = \sum_{j=1}^{|A|} AA(a,j) e^{(1-\sum(AA(:,j)))} \tag{B.7}$$

- **Socio-Knowledge Power (SKP):**

  Let AA' represent normalized co-authorship matrix and AK' represent normalized knowledge dissemination network. Then SKP_a of an author a can be computed as follows:

$$\begin{aligned} M &= [AA'|AK'] \\ m &= |A| + |K| \\ SKP_a &= \frac{1}{m} \sum_{k=1}^{m} M(a,k) \end{aligned} \tag{B.8}$$

  Note that M is formed by concatenating normalized AA and AK relations.

Cognitive Activity Metrics

- **Cognitive Distinctiveness (CD):** It measures how distinct are two scientists based on the number of knowledge bits they hold oppositely (Carley, 2002).

$$CR_{i,j} = \frac{\sum_{k=1}^{|K|} (AK_{i,k} \neg AK_{j,k}^T) + (\neg AK_{i,k} AK_{j,k}^T)}{|K|} \qquad CR_{i,i} = 0 \tag{B.9}$$

  As it can be seen from the equation, the measure in effect is the exclusive-OR of scientists knowledge vectors.

- **Cognitive Similarity (CS):** It measures the degree of similarity between authors based on the number of knowledge bits they both have (Carley, 2002):

$$CS_{i,j} = \frac{\sum_{k=1}^{|K|} (AK_{i,k} AK_{j,k}^T)}{\sum_{k=1}^{|K|} (AK_{i,k} + AK_{j,k})} \qquad CR_{i,i} = 1 \tag{B.10}$$

  Note that similarity value is normalized by the total of knowledge they both hold, which is the union of knowledge they both have.

- **Cognitive Resemblance (CR):** Cognitive Resemblance of author i and author j is computed as follows (Carley, 2002):

$$CR_{i,j} = \frac{\sum_{k=1}^{|K|} (AK_{i,k} AK_{j,k}^T) + (\neg AK_{i,k} \neg AK_{j,k}^T)}{|K|} \qquad CR_{i,i} = 1 \tag{B.11}$$

  Note that each value is normalized by the number of knowledge pieces in a community represented by set K. Having cognitive resemblance of each dyad in the community, then cognitive resemblance of an author to whole community is measured by averaging his/her dyadic cognitive resemblance.

- **Knowledge Exclusivity Index (KEI):**

  Knowledge dissemination network which is represented by bi-modal AK matrix is used to compute the measure (Carley et.al., 2009; Ashworth, 2003):

$$KEI_a = \sum_{j=1}^{|K|} AK(a,j)e^{(1-\sum(AK(:,j)))} \tag{B.12}$$

  Note that A represents set of authors and K represents set of keywords (knowledge) disseminated by the authors.

B.2 Co-authorship Network Level SNA Metrics

- **Count, Components:** The metric estimates number of connected components in a co-authorship network. ORA SNA Tool is used to compute number of connected components in a network (Carley et.al., 2009).

- **Centralization, Degree:** Degree centralization measures graph level centralization of a co-authorship network based on total degree centrality of each author (Freeman, 1979):

$$\begin{aligned} Degree\ Centralization &= \frac{\sum_{1\le i\le n} \bar{d} - \bar{d}_i}{n-2}, \text{ where} \\ d_i &= Total\ Degree\ Centrality\ of\ Author\ i, \\ \bar{d}_i &= max\{(d_i|1 \le i \le n)\}. \end{aligned} \tag{B.13}$$

The measure is a normalized summary metric on the size of collaborators that an average scientist have in a given community.

- **Centralization, Betweenness:** It averages betweenness centrality of each author normalized by largest degree centrality found in the network (Freeman, 1979). For a given community represented by $G(V, E)$, it is computed as follows:

$$\begin{aligned} Betweenness\ Centralization &= \frac{\sum_{1 \le i \le n} \bar{d} - \bar{d}_i}{(n-1)} \\ d_i &= Betweenness\ Centrality\ of\ Author\ i, \\ n &= |V| \\ \bar{d}_i &= max\{(d_i | 1 \le i \le n)\}. \end{aligned} \tag{B.14}$$

- **Centralization, Closeness:** For a given community represented by $G(V, E)$, it is computed as follows (Freeman, 1979):

$$\begin{aligned} Closeness\ Centralization &= \frac{\sum_{1 \le i \le n} \bar{d} - \bar{d}_i}{(n-2)(n-1)/(2n-3)} \\ d_i &= Closeness\ Centrality\ of\ Author\ i, \\ n &= |V| \\ \bar{d}_i &= max\{(d_i | 1 \le i \le n)\}. \end{aligned} \tag{B.15}$$

- **Clustering Coefficient:** The clustering coefficient of a scientist v, CC_v, in a network represented by $G(V, E)$ is given by Equation B.6. Then Clustering Coefficient of the whole network is computed as (Watts and Strogatz, 1998):

$$CC_G = \frac{\sum_{v \in V} CC_v}{|V|} \tag{B.16}$$

- **Connectedness:** Connectedness for a $G(V, E)$ representing a network is equal to the fraction of all dyads, i, j, such that there exists a path from i to j in G (Krackhardt, 1994). It estimates ratio of reachability in a given community.

- **Density :** Let $G = (V, E)$ be the graph representation of a co-authorship network and let AA be the adjacency matrix for the network of dimension nxn (Wasserman and Faust, 1994):

$$Density_{AA} = \sum_{\substack{j=1,i=1 \\ i \neq j}}^{n,n} AA(i,j) \tag{B.17}$$

- **Diameter:** It is measured by taking the maximum shortest path length between any two authors in a co-authorship network represented by a graph $G = (V, E)$:

$$Diameter_G = max\{d_G(i,j)|i,j \in V\}. \tag{B.18}$$

- **Transitivity:** Let $G(E, V)$ be graph representation of a co-authorship network, then, Transitivity is defined as follows (Carley et.al., 2009):

$$\begin{aligned} I =& \{(i,j,k) \in V^3 | i \neq j \neq k\}. \\ Potential =& \{(i,j,k) \in I | (i,j) \in E \wedge (j,k) \in E\} \\ Complete =& \{(i,j,k) \in Potential | (i,k) \in E\} \\ Transitivity =& \frac{|Complete|}{|Potential|} \end{aligned} \tag{B.19}$$

For example, each triad in a network would contribute 3 pairs to Transitivity. Given that a network consists of only a single triad, then there would also be only 3 pairs that exist in the network, which then would yield 1 as the ideal Transitivity for the network.

B.3 Dissemination Network Level SNA Metrics

- **Knowledge Load:** Given a knowledge dissemination network AK with $|A|$ authors and $|K|$ unique keywords, Load is computed as follows (Carley, 2002):

$$Load = \frac{\sum_{i=1,j=1}^{|A|,|K|} AK(i,j)}{|A|} \tag{B.20}$$

- **Knowledge Diversity:** Given a knowledge dissemination pattern represented by a matrix $|AK|$ Knowledge Diversity is computed as follows (Borgatti, 2003):

$$\begin{aligned} w_k &= \sum_{i=1}^{|A|} AK(i,k), \forall (1 \leq k \leq |K|), \\ W &= \sum_{k=1}^{|K|} w_k, \\ Knowledge\ Diversity &= 1 - \sum_{k=1}^{|K|} (w_k/W)^2. \end{aligned} \tag{B.21}$$

- **Knowledge Redundancy:** Given a knowledge dissemination pattern represented by a matrix $|AK|$, where the entries in the matrix are made binary. Knowledge Redundancy is computed as follows (Carley et.al., 2009; Carley, 2002):

$$\begin{aligned} Knowledge\ Redundancy &= \frac{\sum_{j=1}^{|K|} d_j}{|K|}, \\ where, \\ d_j &= max(0, (\sum_{i=1}^{|A|} AK(i,j)) - 1) \end{aligned} \tag{B.22}$$

Appendix C

Socio-Knowledge Details of Management Field: 1922-1945

Figure C.1: Knowledge and scientists cloud: 1922-1945.

Figure C.2: Interdisciplinary scope of management field: 1922-1945.

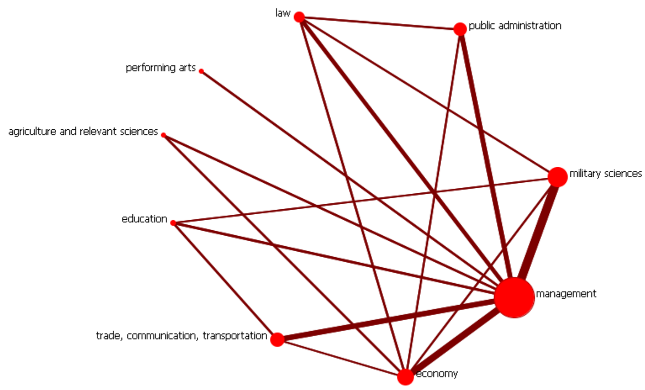


Figure C.3: Dendogram of keywords: 1922-1945.

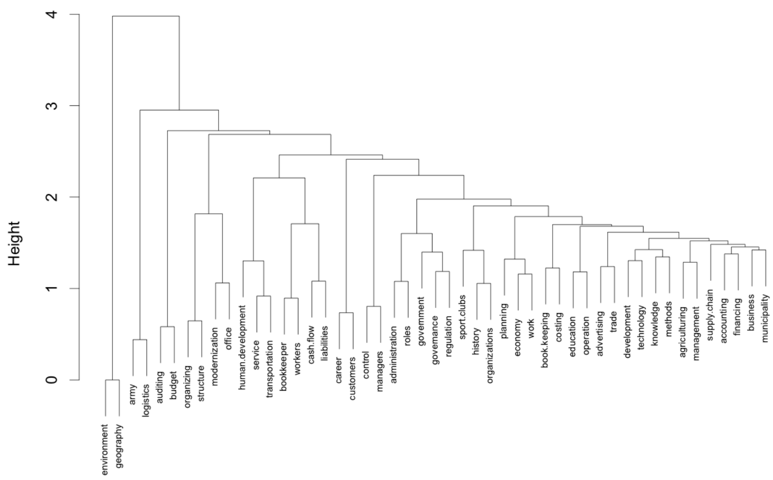


Table C.1: Management issues, 1922-1945.

ID	Centrality	Density	Size	Members
1	0.29	2.4	5	supply.chain; municipality; financing; business; accounting
2	0.36	19	2	roles; administration
3	0.06	8	2	trade; advertising
4	0.46	34	2	management; agriculturing
5	1.07	88	2	logistics; army
6	0.34	14	2	budget; auditing
7	0.41	18	2	costing; book.keeping
8	0.74	43	2	workers; bookkeeper
9	0.05	10	2	customers; career
10	0.09	6	2	liabilities; cash.flow
11	0.13	10	2	managers; control
12	0.15	3.83	4	technology; methods; knowledge; development
13	0.33	13.33	3	work; planning; economy
14	0.07	7	2	operation; education
15	0.17	8	2	geography; environment
16	0.21	6	3	regulation; government; governance
17	0.32	8.67	3	sport.clubs; organizations; history
18	0.9	38	3	transportation; service; human.development
19	0.14	6	2	office; modernization
20	0.24	14	2	structure; organizing

Figure C.4: Strategic diagram of published issues in Management: 1922-1945.

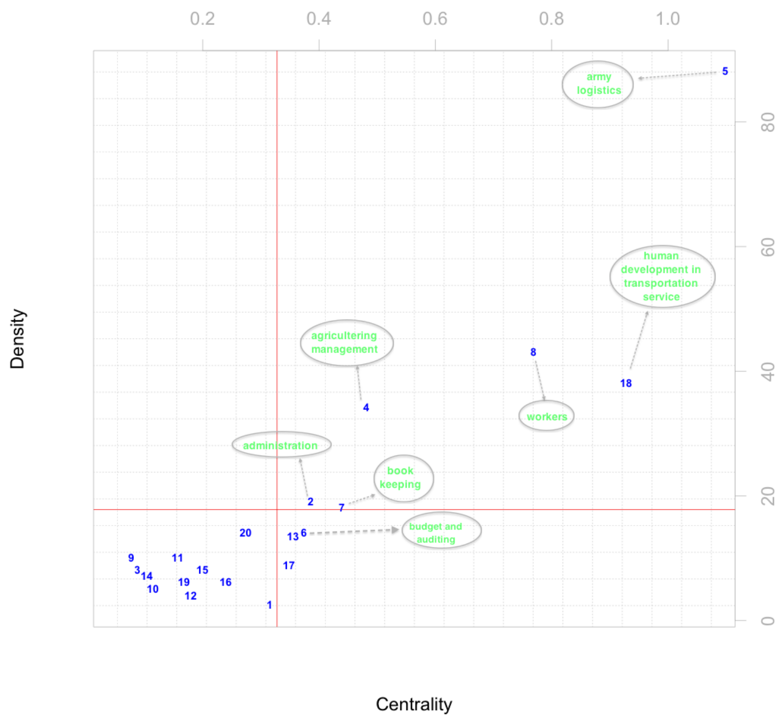


Figure C.5: Cognitive relation of themes: 1922-1945.

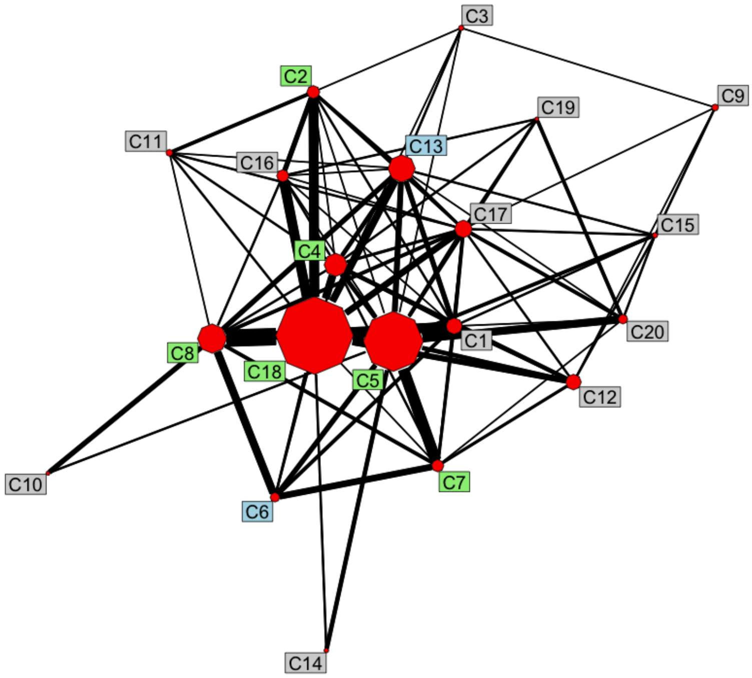


Figure C.6: Collaboration network, overall: 1922-1945.

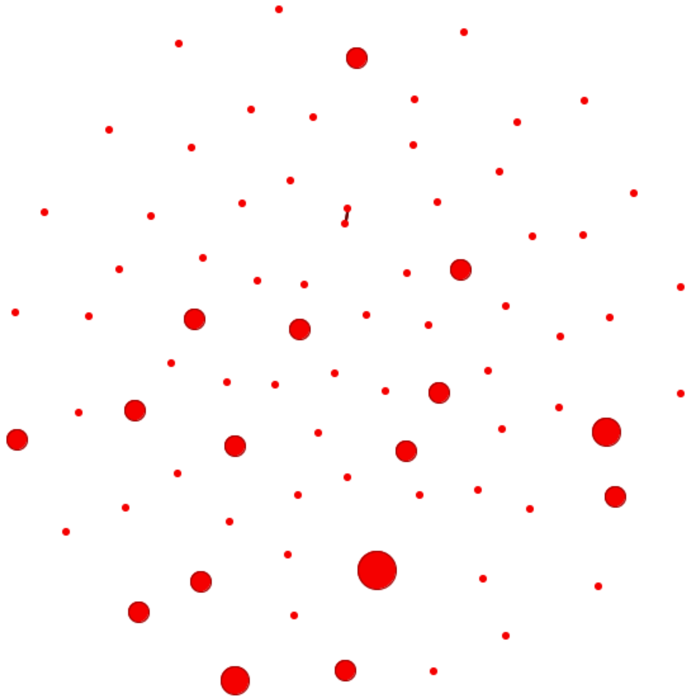


Figure C.7: Collaboration network, the collaborators: 1922-1945.

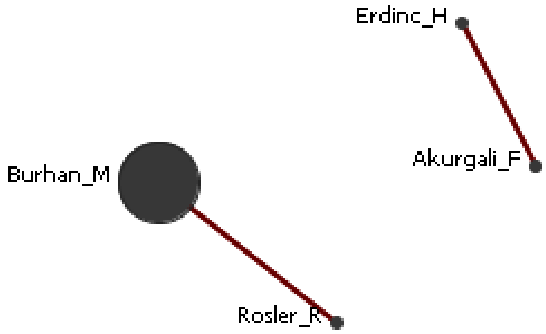


Figure C.8: Geographic locations of collaborators: 1922-1945.

Figure C.9: Socio-Knowledge centrality of scientists' in respective quadrants of management fields: 1922-1945.

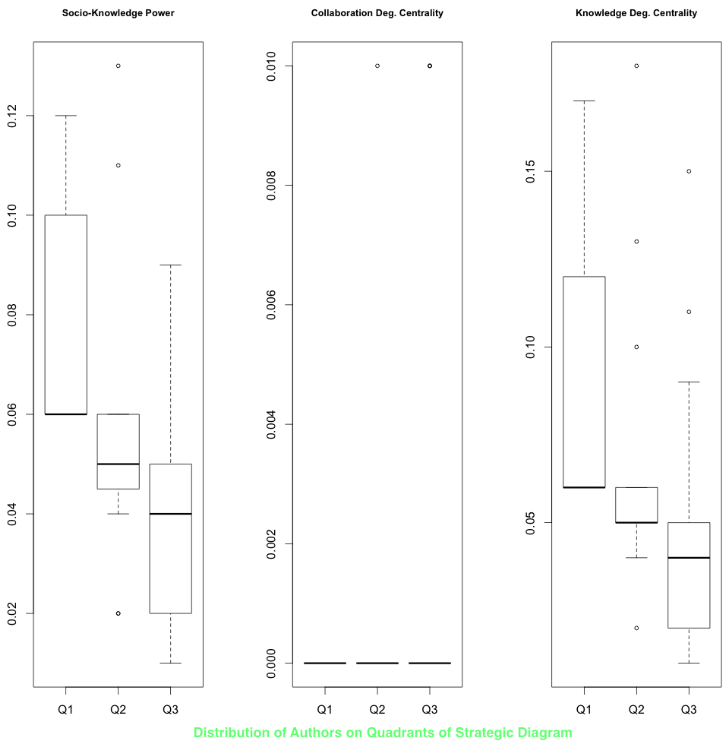
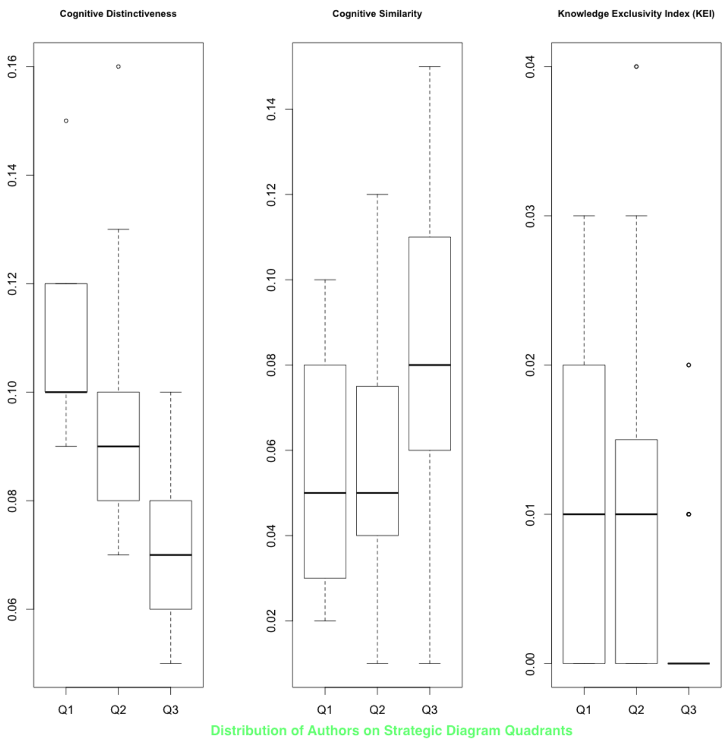


Figure C.10: Cognitive attributes of scientists' in respective quadrants of management fields: 1922-1945.



Appendix D

Socio-Knowledge Details of Management in Turkey: 1940-1960

Figure D.1: Knowledge and scientists cloud: 1940-1960.

Figure D.2: Interdisciplinary scope of management field: 1940-1960.

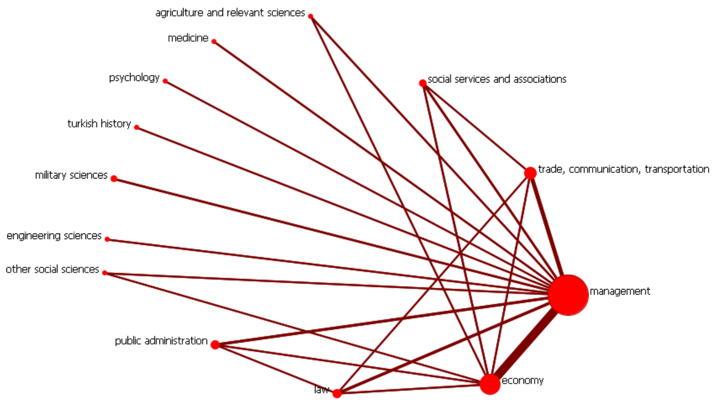


Table D.1: Management issues, 1940-1960.

ID	Centrality	Density	Size	Members
1	4.04	668	2	financing, accounting
2	0.1	16	2	practices, activity
3	0.43	7.48	7	roles, modernization, markets, finance, economy, development, advertising
4	0.25	33	2	cooperative enterprise, agriculturing
5	0.16	6.6	5	values, inventory, equity, change, amortization
6	0.1	14	2	navy, army
7	0.21	0.68	26	working condition, wages, time, reporting, printing, policies, office, municipality, methods, maritime, labor, insurance, hotels, government, export, expenses, control, communication, capacity, budget, benefits, automotive, auditing
8	0.91	76	3	technology, machinery, automation
9	0.04	3.33	3	international, cooperation, behavior
10	0.74	33.5	4	taxing, merchants, laws, book keeping
11	0.18	7.33	3	production, decision making, bookkeeper
12	1.24	50.67	4	trade, success, management, business
13	0.55	50	2	teaching, career
14	0.54	22.33	4	work climate, work, rationalization, community
15	0.52	14.33	4	standards, profit, factory, costing
16	0.6	80	2	logistics, distribution
17	0.46	50	2	knowledge, education
18	0.06	7	2	labor force, efficiency
19	0.41	24.67	3	workers, labor unions, employer
20	0.07	12	2	human capital, expertise
21	0.13	12	2	managers, governance
22	0.61	70	2	organizations, history
23	0.02	8	2	recruitment, HRM
24	0.7	70	2	training, human development
25	1.46	177	2	manufacturing, industry
26	0.11	13	2	psychology, measures
27	0.17	10	3	socialization, police, mining
28	0.65	67	2	structure, organizing
29	0.18	18	2	target management, planning
30	0.09	9	2	supply chain, procurement
31	1.15	225	2	transportation, service

Figure D.3: Strategic diagram of published issues in management: 1940-1960.

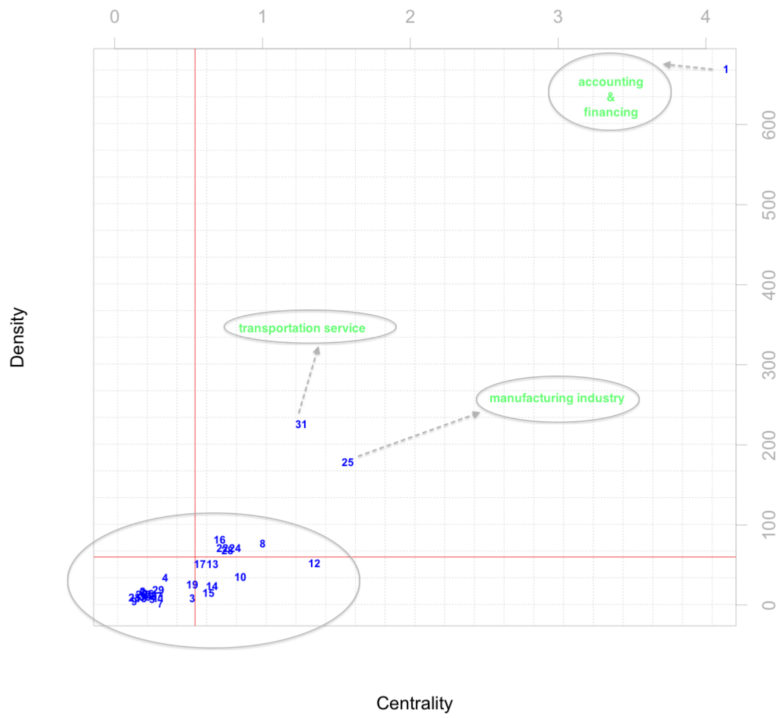


Figure D.4: Strategic diagram of published issues in management, lower quadrants: 1940-1960.

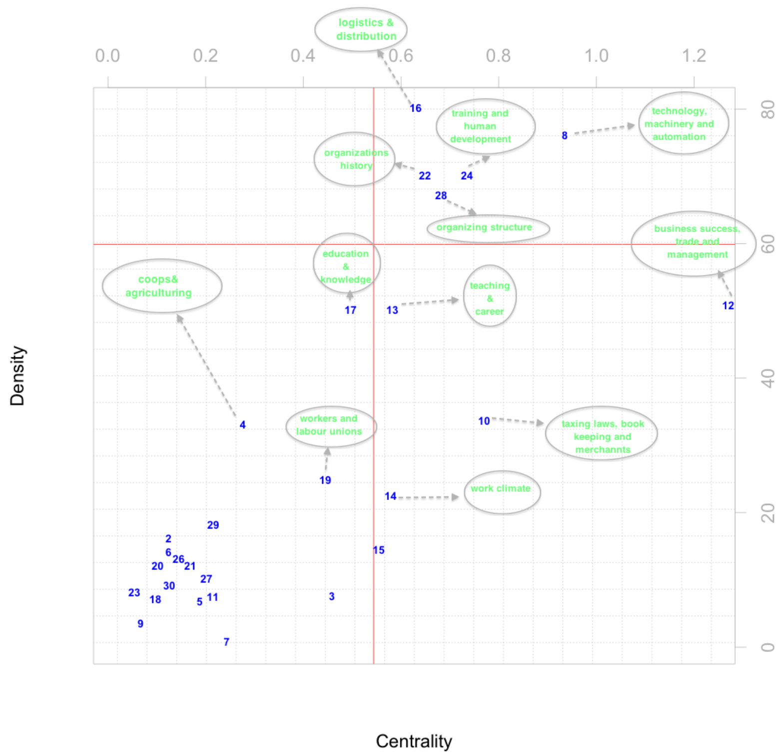


Figure D.5: Cognitive relation of themes: 1940-1960.

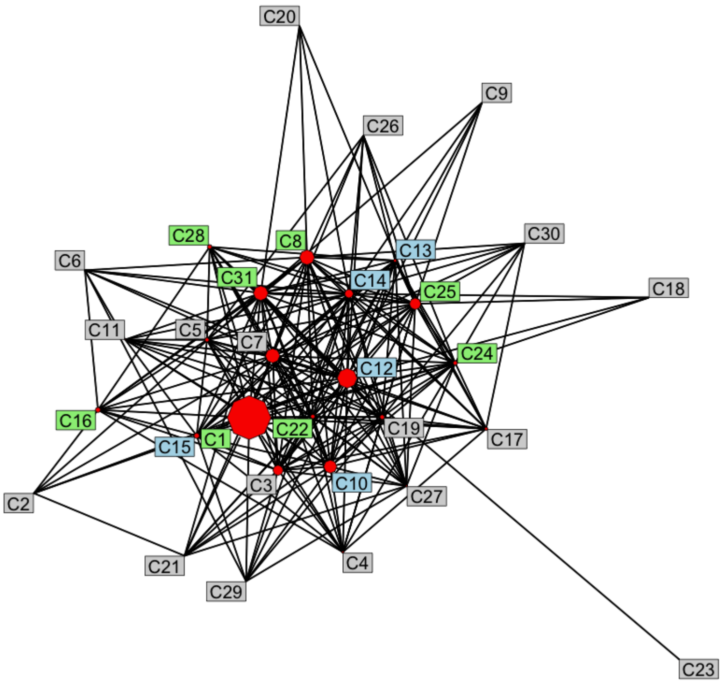


Figure D.6: Collaboration network, overall: 1940-1960.

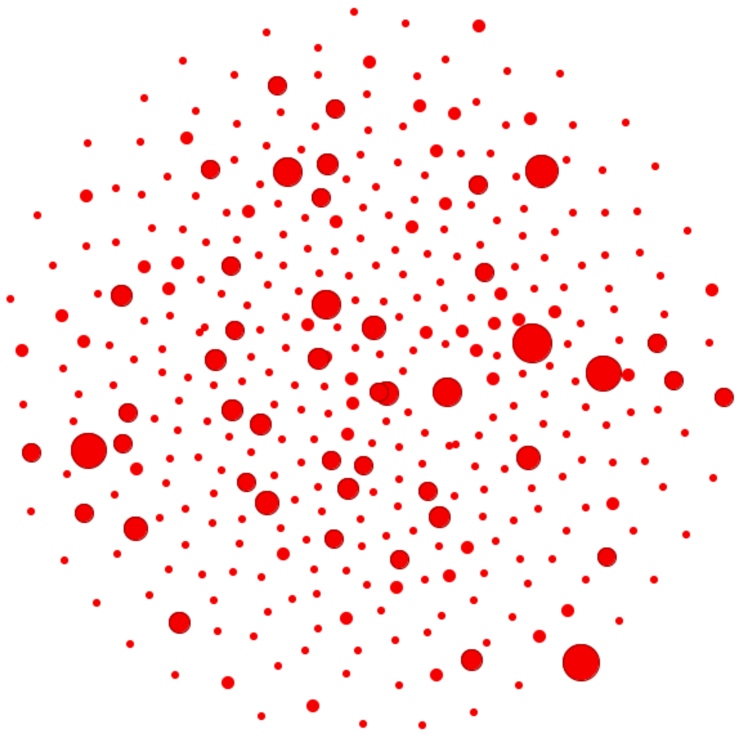


Figure D.7: Collaboration network, the collaborators: 1940-1960.

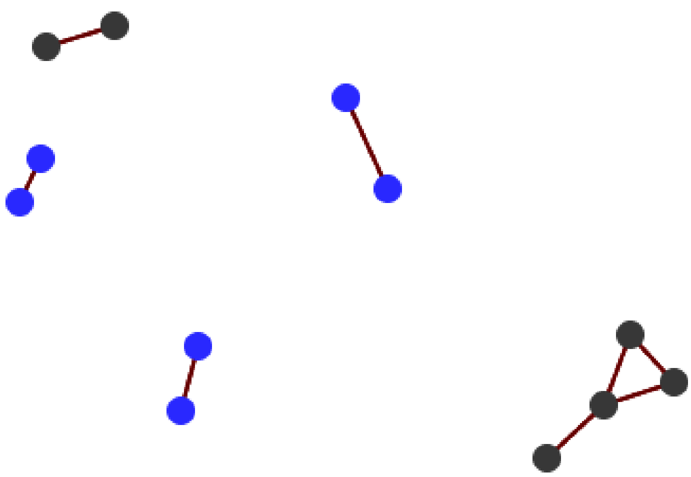


Figure D.8: Collaboration network, the core collaborators: 1940-1960.

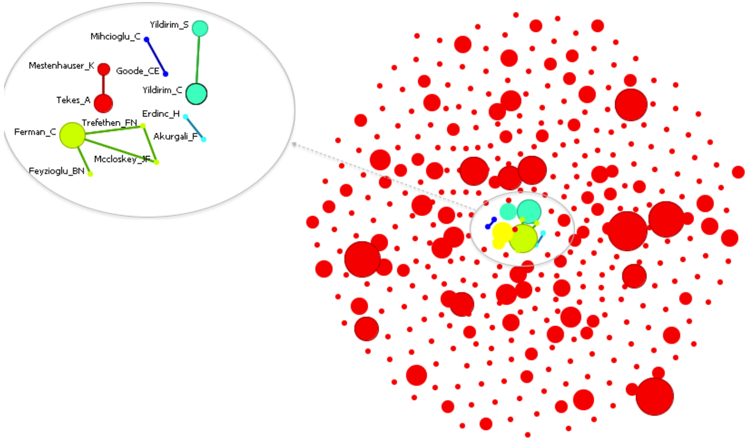


Figure D.9: Geographic locations of collaborators: 1940-1960.

Figure D.10: Socio-Knowledge centrality of scientists' in respective quadrants of management fields: 1940-1960.

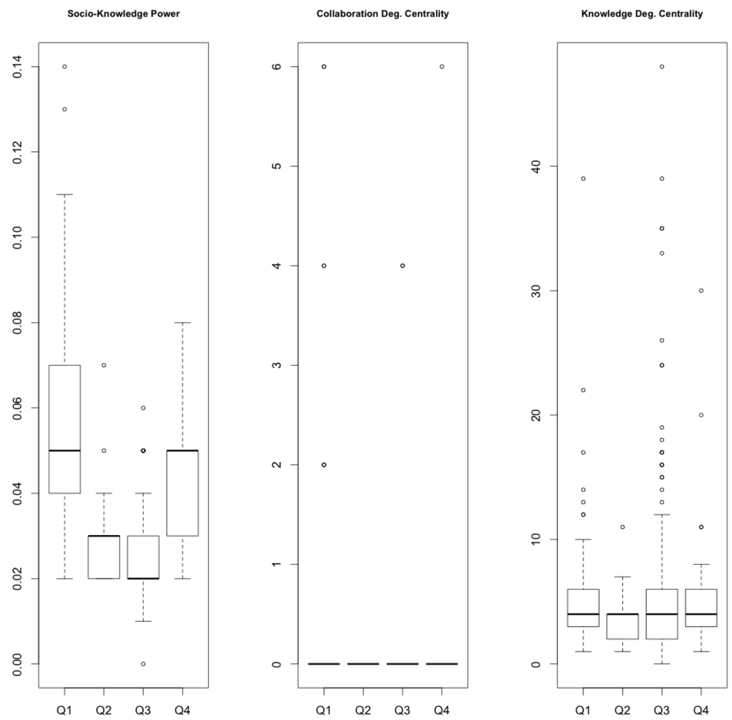
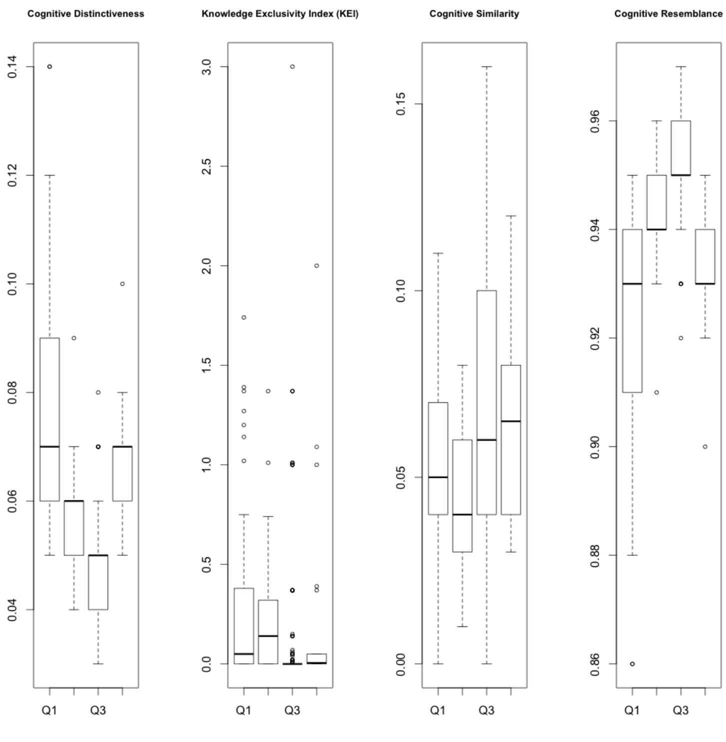


Figure D.11: Cognitive attributes of scientists' in respective quadrants of management fields: 1940-1960.



Appendix E

Socio-Knowledge Details of Management in Turkey: 1955-1975

Figure E.1: Knowledge and scientists cloud: 1955-1975.

Figure E.2: Interdisciplinary scope of management field: 1955-1975.

Table E.1: Management issues, 1955-1975.

ID	Centrality	Density	Size	Members
1	4.04	668	2	financing, accounting
2	0.1	16	2	practices, activity
3	0.43	7.48	7	roles, modernization, markets, finance, economy, development, advertising
4	0.25	33	2	cooperative enterprise, agriculturing
5	0.16	6.6	5	values, inventory, equity, change, amortization
6	0.1	14	2	navy, army
7	0.21	0.68	26	... budget, benefits, automotive, auditing...
8	0.91	76	3	technology, machinery, automation
9	0.04	3.33	3	international, cooperation, behavior
10	0.74	33.5	4	taxing, merchants, laws, book keeping
11	0.18	7.33	3	production, decision making, bookkeeper
12	1.24	50.67	4	trade, success, management, business
13	0.55	50	2	teaching, career
14	0.54	22.33	4	work climate, work, rationalization, community
15	0.52	14.33	4	standards, profit, factory, costing
16	0.6	80	2	logistics, distribution
17	0.46	50	2	knowledge, education
18	0.06	7	2	labor force, efficiency
19	0.41	24.67	3	workers, labor unions, employer
20	0.07	12	2	human capital, expertise
21	0.13	12	2	managers, governance
22	0.61	70	2	organizations, history
23	0.02	8	2	recruitment, HRM
24	0.7	70	2	training, human development
25	1.46	177	2	manufacturing, industry
26	0.11	13	2	psychology, measures
27	0.17	10	3	socialization, police, mining
28	0.65	67	2	structure, organizing
29	0.18	18	2	target management, planning
30	0.09	9	2	supply chain, procurement
31	1.15	225	2	transportation, service

Figure E.3: Strategic diagram of published issues in management: 1955-1975.

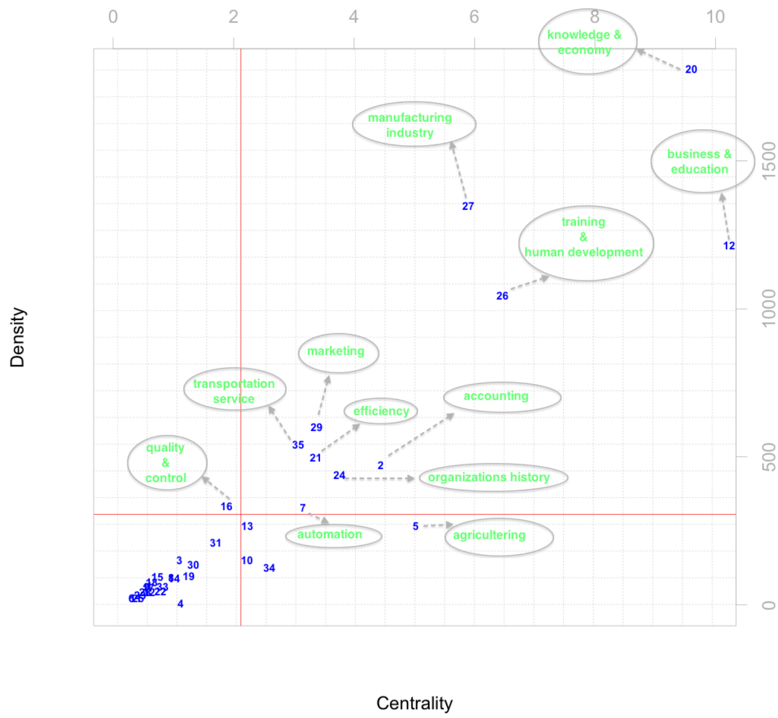


Figure E.4: Cognitive relation of themes: 1955-1975.

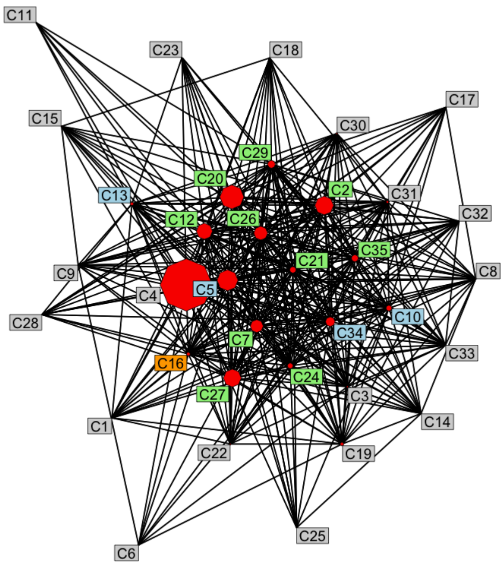


Figure E.5: Collaboration network, overall: 1955-1975.

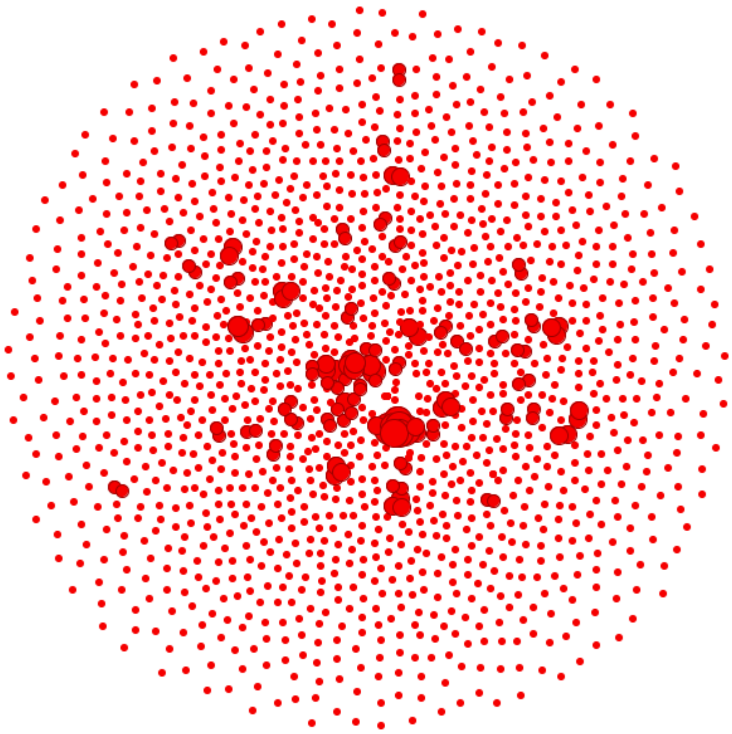


Figure E.6: Collaboration network, the collaborators: 1955-1975.

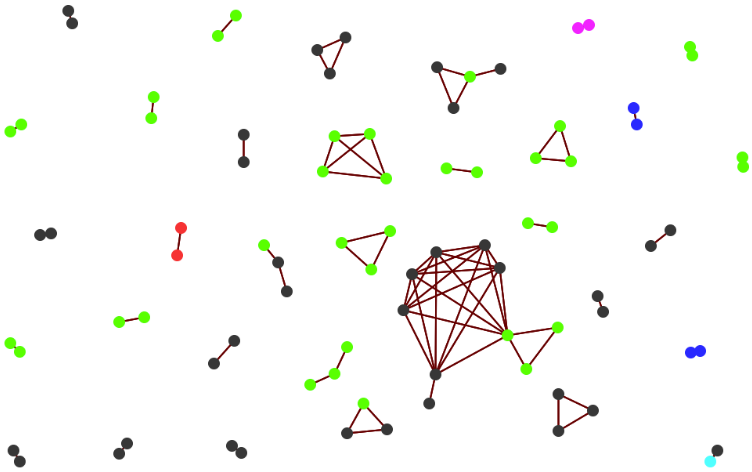


Figure E.7: Collaboration network, the core collaborators: 1955-1975.

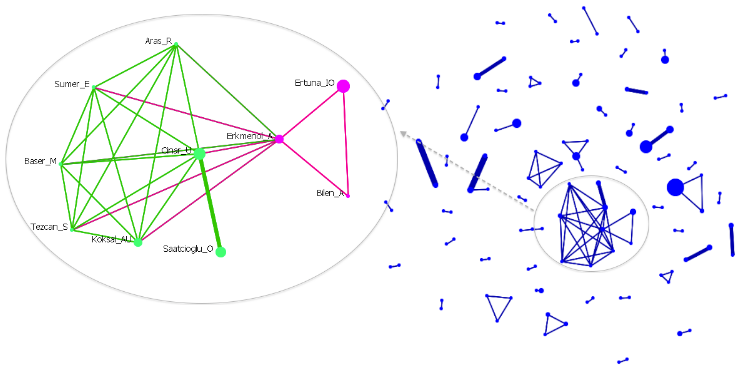


Figure E.8: Geographic locations of collaborators: 1955-1975.

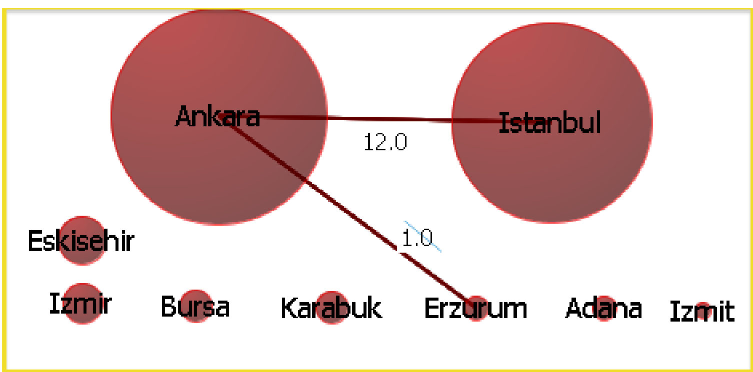


Figure E.9: Socio-Knowledge centrality of scientists' in respective quadrants of management fields: 1955-1975.

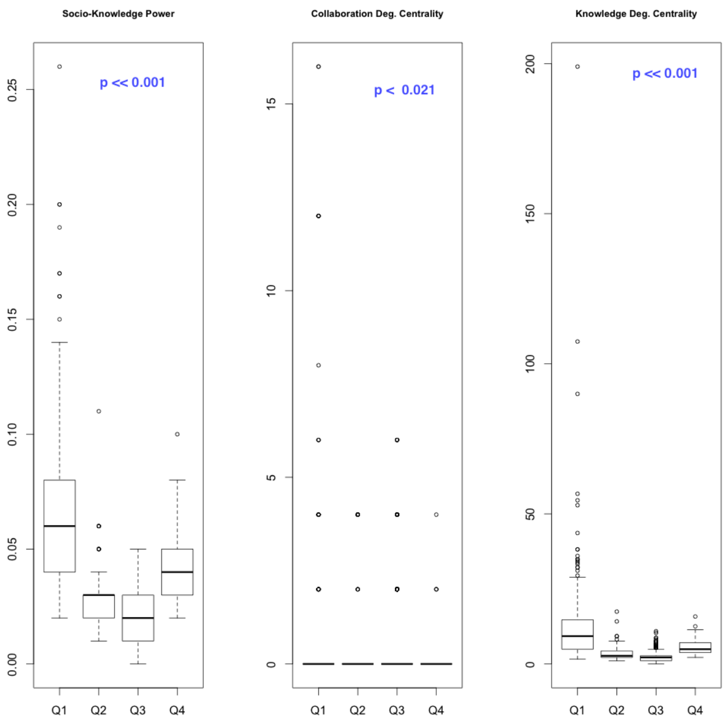
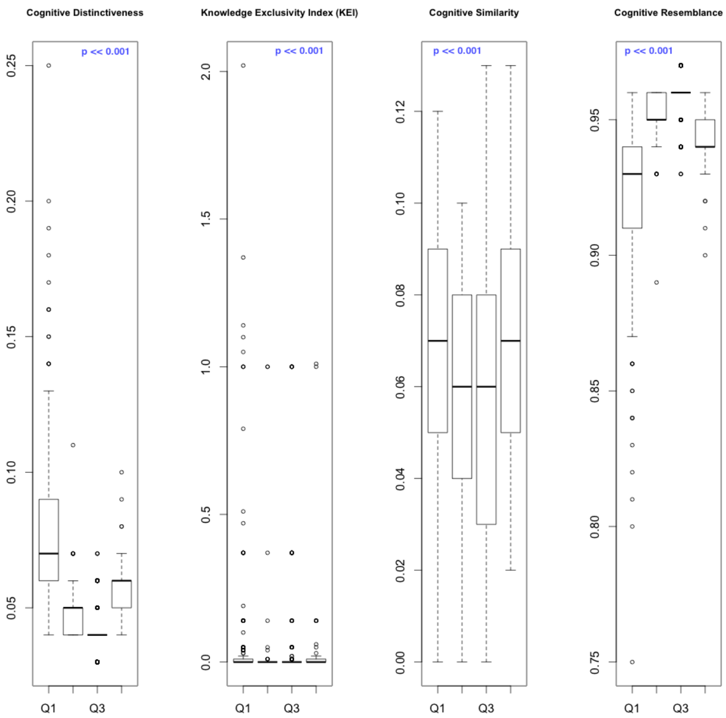


Figure E.10: Cognitive attributes of scientists' in respective quadrants of management fields: 1955-1975.



Appendix F

Socio-Knowledge Details of Management in Turkey: 1970-1985

Figure F.1: Knowledge and scientists cloud: 1970-1985.

Figure F.2: Interdisciplinary scope of management field: 1970-1985.

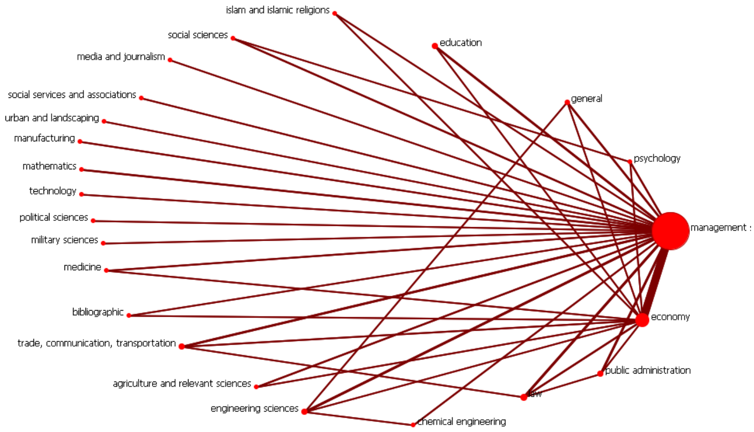


Table F.1: Management issues, 1970-1985.

ID	Centrality	Density	Size	Members
1	0.76	124	2	responsibility;accountability
2	4.14	291.33	3	values;taxing;accounting
3	1.13	176	2	practices;activity
4	1.54	1.33	107	*...all other themes*
5	4.96	598.33	3	technology;machinery;automation
6	0.88	113	2	financial.statement;balance.sheets
7	0.68	98	2	motivation;behavior
8	1.58	168	2	target.management;book.keeping
9	0.14	24	2	cost.accounting;break.even
10	10.97	378.73	6	training;organizations;management;history;governance;business
11	2.04	242	2	teaching;career
12	1.41	159	2	innovation;change
13	4.43	787	3	ict;computerization
14	1.62	384	2	consumption;consumers
15	4.52	699	2	quality;control
16	5.55	887	2	financing;costing
17	0.63	138	2	pr;crm
18	2.1	183	3	storage;logistics;distribution
19	16.44	2655	2	knowledge;economy
20	17.4	2937	2	human.development;education
21	1.4	128	2	knowledge.management;electronics
22	1.51	280	2	products;ergonomy
23	0.28	48	2	human.capital;expertise
24	0.72	100	2	teams;group
25	2.51	319	2	workers;hrm
26	11.23	2527	2	manufacturing;industry
27	0.46	46	2	power;labor.force
28	6.05	1118	2	managers;leadership
29	8.02	1672	2	markets;marketing
30	1.91	203	2	work.assesment;measures
31	3.83	576	2	structure;organizing
32	3.09	191	3	production.management;production;planning
33	0.39	34	2	supply.chain;procurement
34	4.43	308	3	work;tasks;project.management
35	3.33	534	2	transportation;service

Figure F.3: Strategic diagram of published issues in management: 1970-1985.

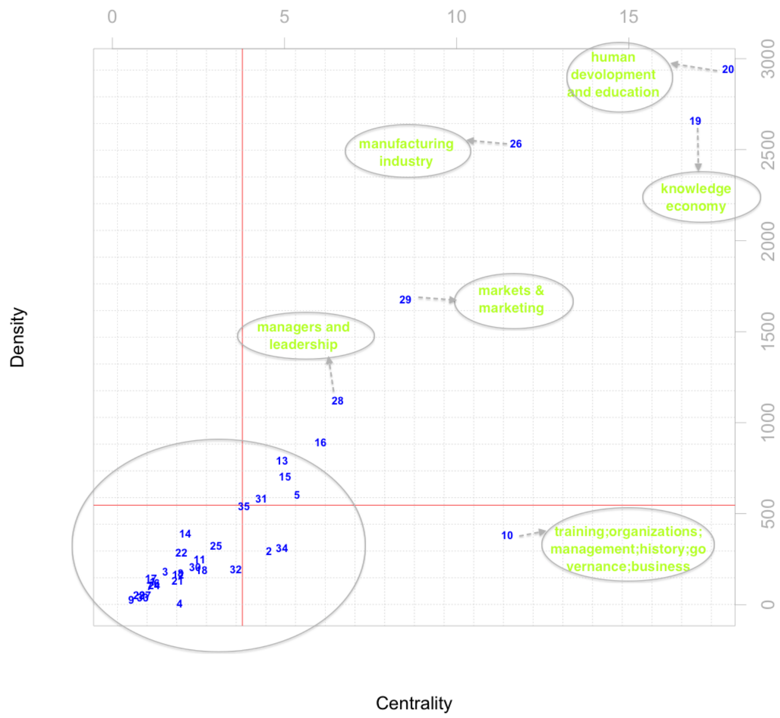


Figure F.4: Strategic diagram of published issues in management, peripheral quadrants: 1970-1985.

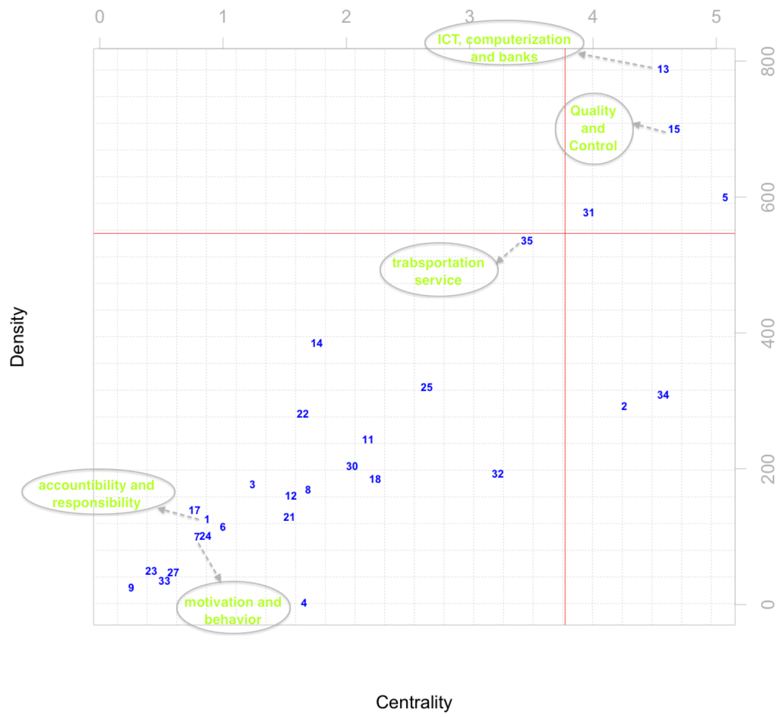


Figure F.5: Cognitive relation of themes: 1970-1985.

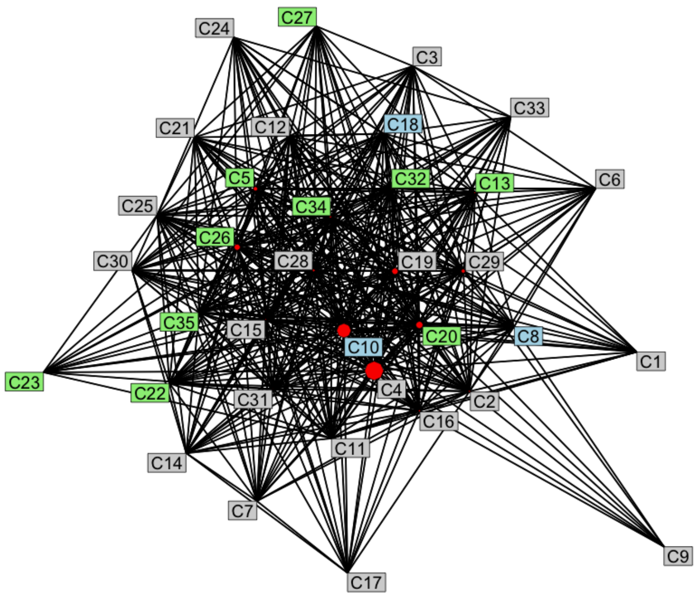


Figure F.6: Collaboration network, overall: 1970-1985.

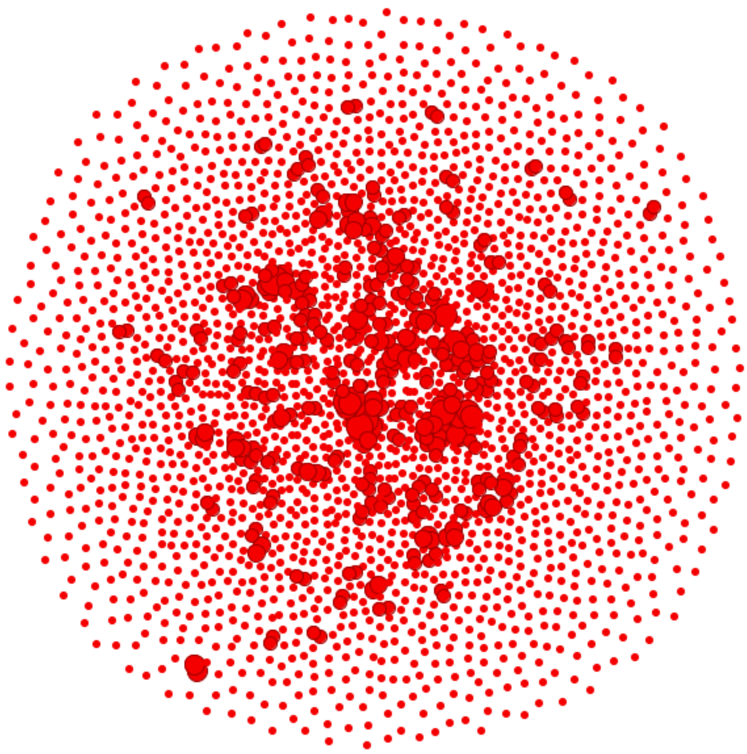


Figure F.7: Collaboration network, the collaborators: 1970-1985.

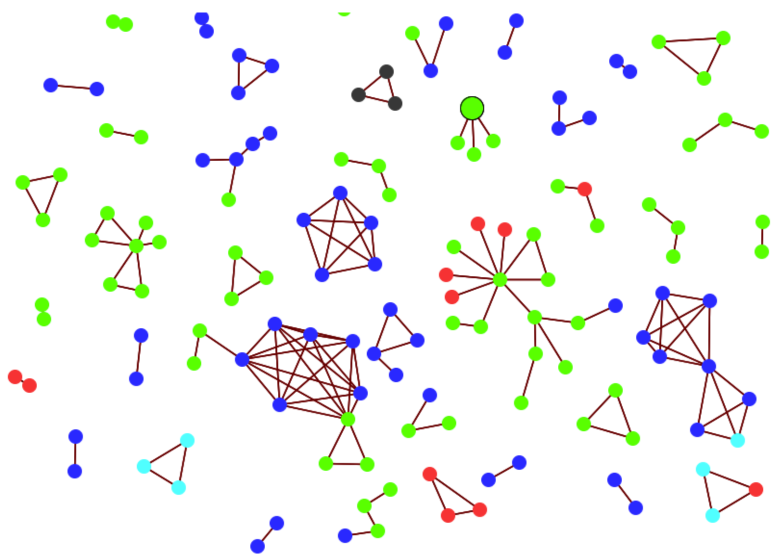


Figure F.8: Collaboration network, the core collaborators: 1970-1985.

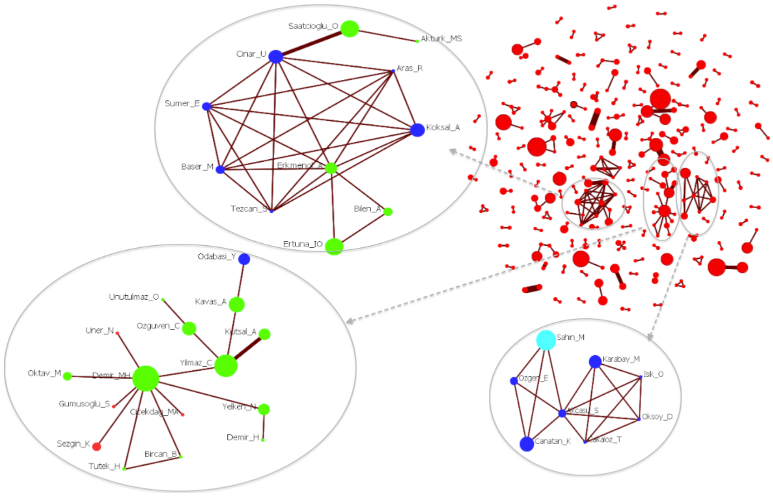


Figure F.9: Geographic locations of collaborators: 1970-1985.

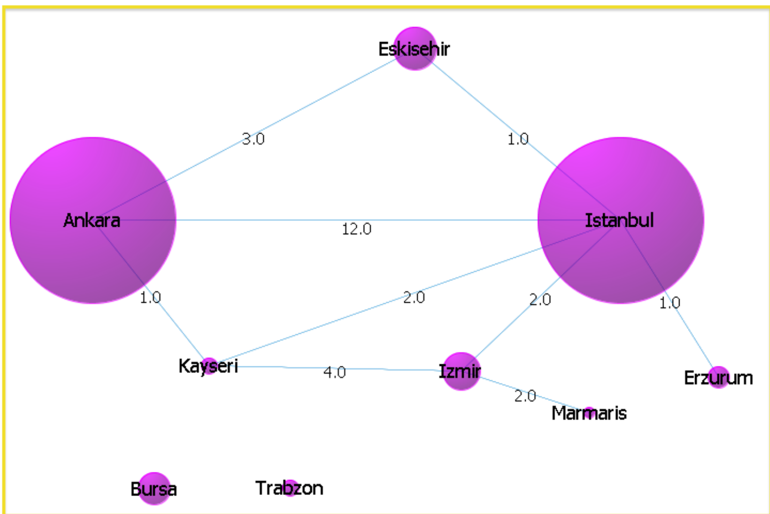


Figure F.10: Knowledge dissemination and social degree centrality of scientists' in respective quadrants of management fields: 1970-1985.

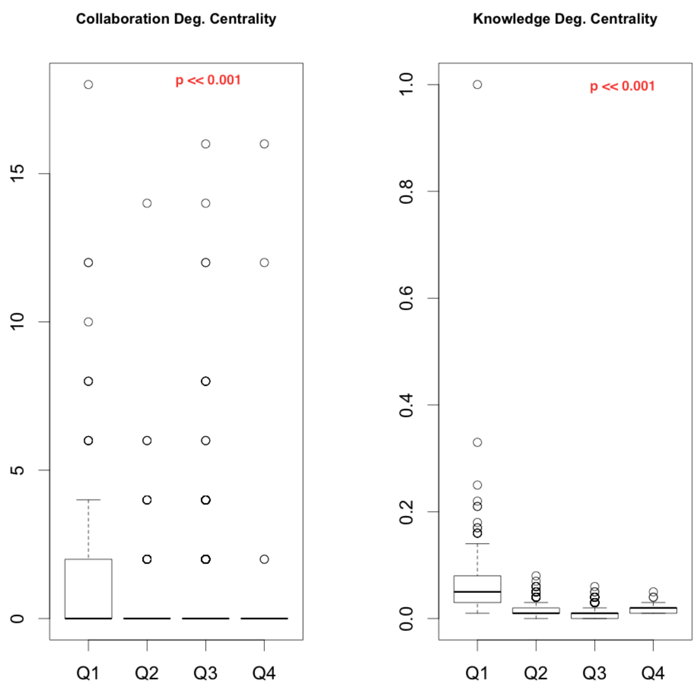


Figure F.11: Socio-knowledge power and cliquishness of scientists' in respective quadrants of management fields: 1970-1985.

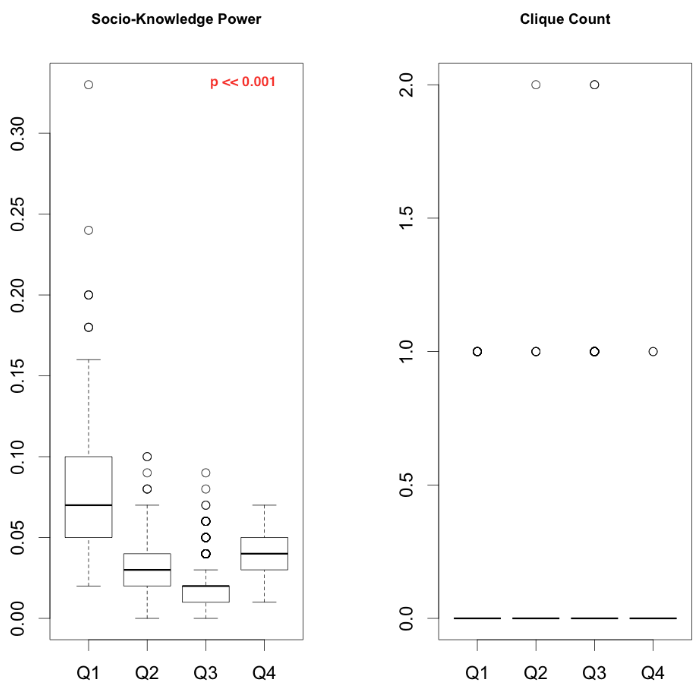


Figure F.12: Knowledge exclusivity and resemblance of scientists' in respective quadrants of management fields: 1970-1985.

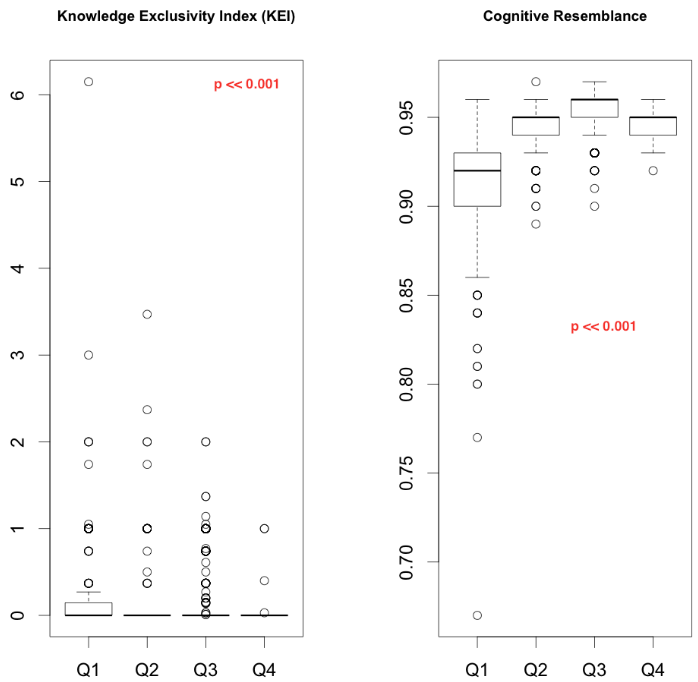
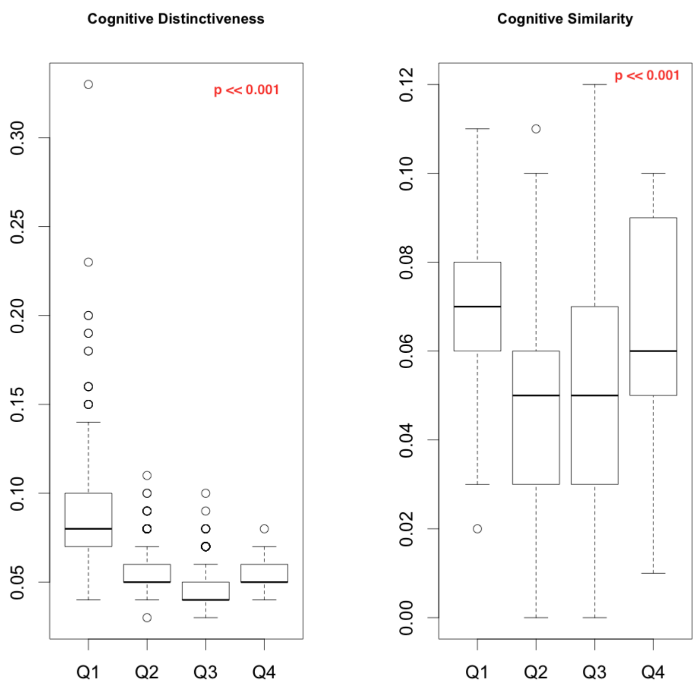


Figure F.13: Knowledge distinctiveness and similarity of scientists' in respective quadrants of management fields: 1970-1985



Appendix G

Socio-Knowledge Details of Management in Turkey: 1980-1990

Figure G.1: Knowledge and scientists cloud: 1980-1990.

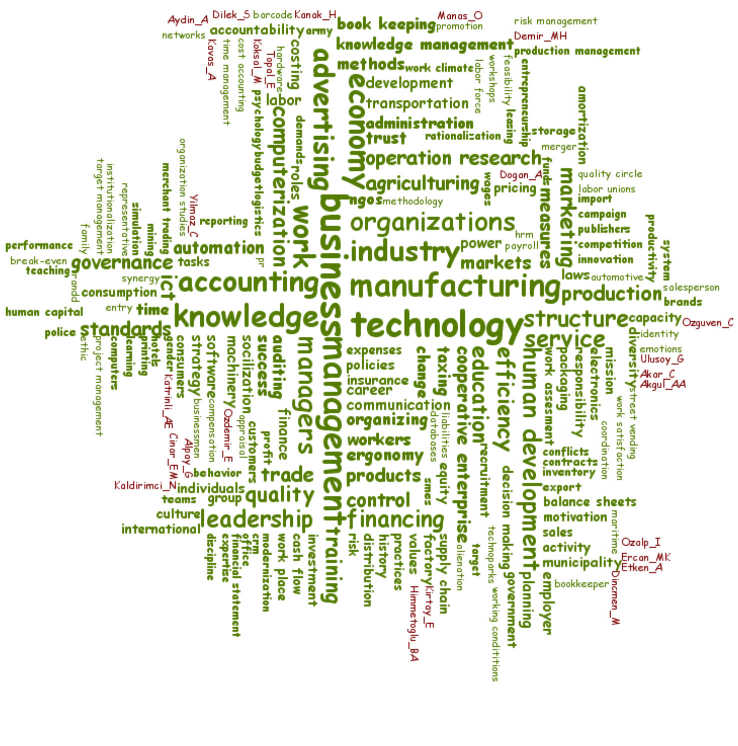


Figure G.2: Interdisciplinary scope of management field: 1980-1990.

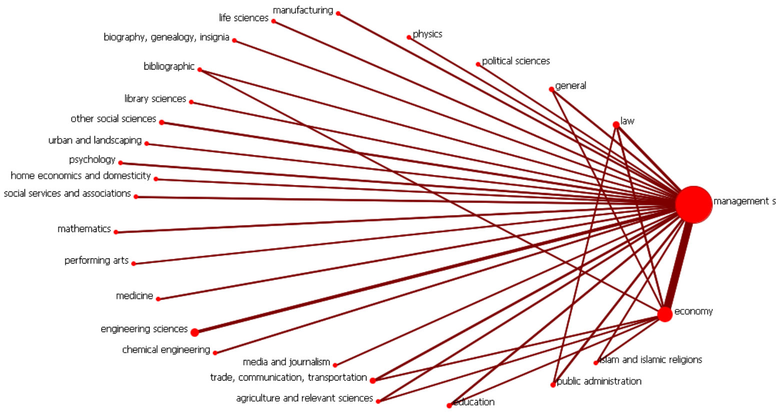


Table G.1: Management issues, 1980-1990.

ID	Centrality	Density	Size	Members
1	0.65	116	2	responsibility;accountability
2	4.11	307.33	3	values;taxing;accounting
3	1.1	164	2	practices;activity
4	1.38	1.18	106	workshops;working.conditions;work.satisfaction;work.place;work.climate ...
5	5.88	689	3	technology;machinery;automation
6	0.76	81	2	financial.statement;balance.sheets
7	0.64	75	2	motivation;behavior
8	1.18	122	2	target.management;book.keeping
9	0.09	12	2	cost.accounting;break.even
10	13.67	1009	3	organizations;management;business
11	2.06	99.67	3	training;teaching;career
12	0.96	40.67	4	recruitment;innovation;entrepreneurship;change
13	0.32	13.17	4	laws;labor;funds;compensation
14	7.63	1631.67	3	knowledge;ict;computerization
15	1.39	336	2	consumption;consumers
16	4.01	679	2	quality;control
17	4.86	763	2	financing;costing
18	0.54	113	2	pr;crm
19	1.91	157	3	storage;logistics;distribution
20	12.91	1777	2	governance;economy
21	17.05	2712	2	human.development;education
22	2.08	503	2	products;ergonomy
23	0.47	60	2	human.capital;expertise
24	0.95	143	2	teams;group
25	1.88	113	3	workers;trust;hrm
26	11.41	2390	2	manufacturing;industry
27	0.41	47	2	power;labor.force
28	5.83	1506	2	managers;leadership
29	6.98	1503	2	markets;marketing
30	1.55	98	3	work.assesment;wages;measures
31	4.8	666	2	structure;organizing
32	3.04	190.33	3	production.management;production;planning
33	3.5	145.83	4	work;tasks;reporting;project.management
34	3.08	403	2	transportation;service

Figure G.3: Strategic diagram of published issues in management: 1980-1990.

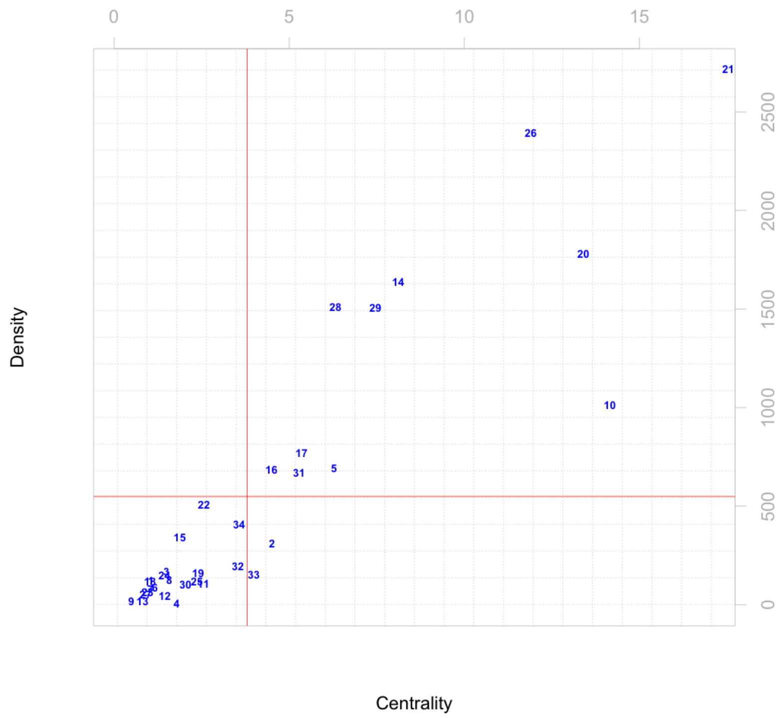


Figure G.4: Strategic diagram of published issues in management, peripheral quadrants: 1980-1990.

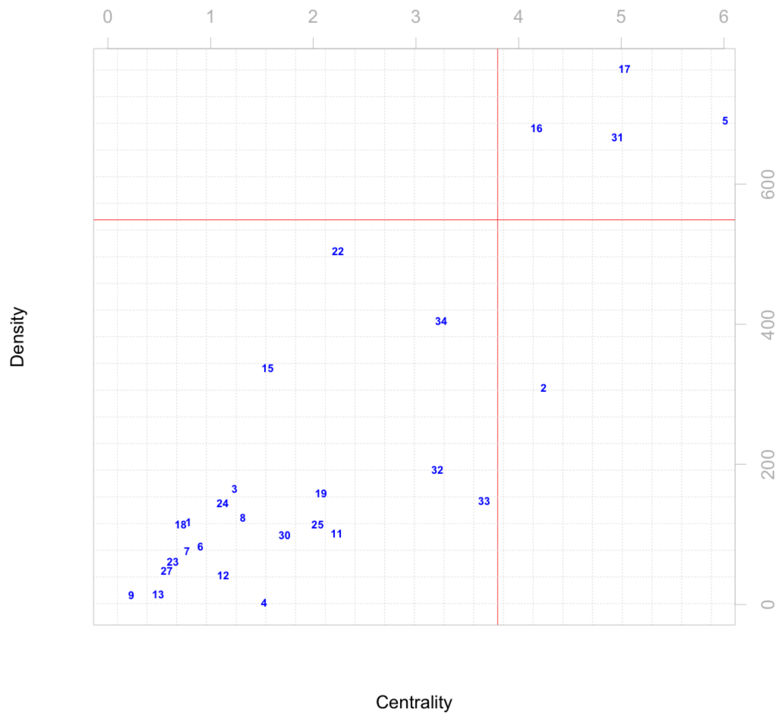


Figure G.5: Cognitive relation of themes: 1980-1990.

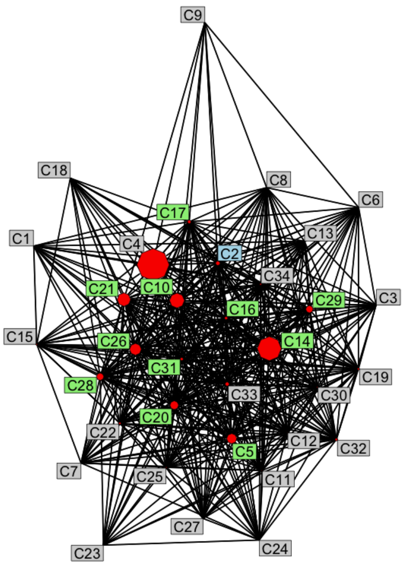


Figure G.6: Collaboration network, overall: 1980-1990.

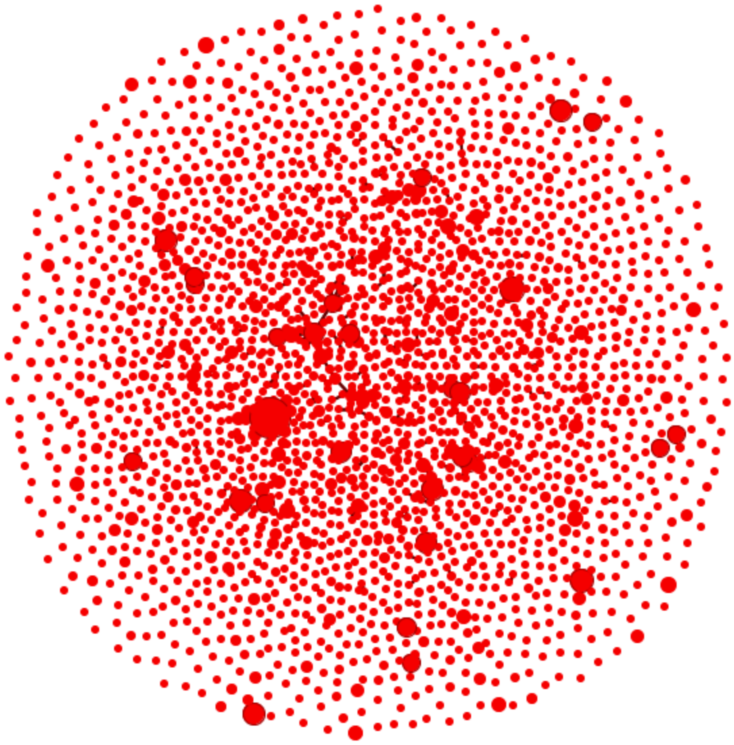


Figure G.7: Collaboration network, the collaborators: 1980-1990.

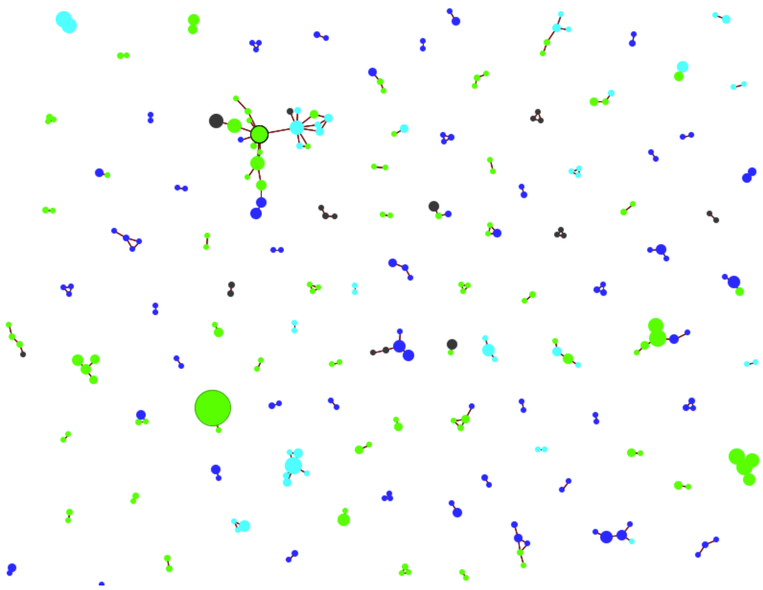


Figure G.8: Collaboration network, the core collaborators: 1980-1990.

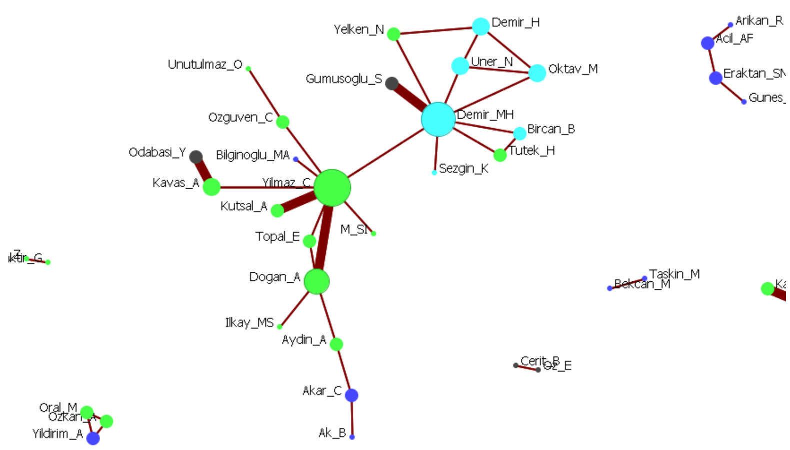


Figure G.9: Geographic locations of collaborators: 1980-1990.

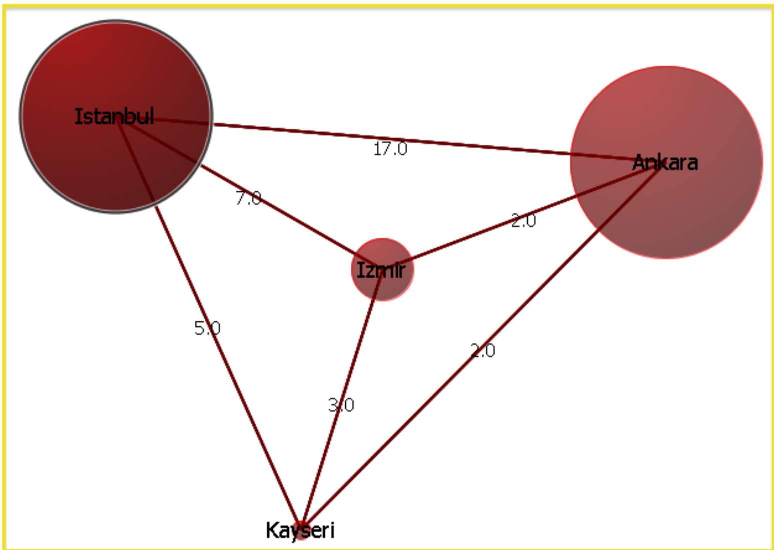


Figure G.10: Collaboration degree and betweenness of scientists' in respective quadrants of management fields: 1980-1990.

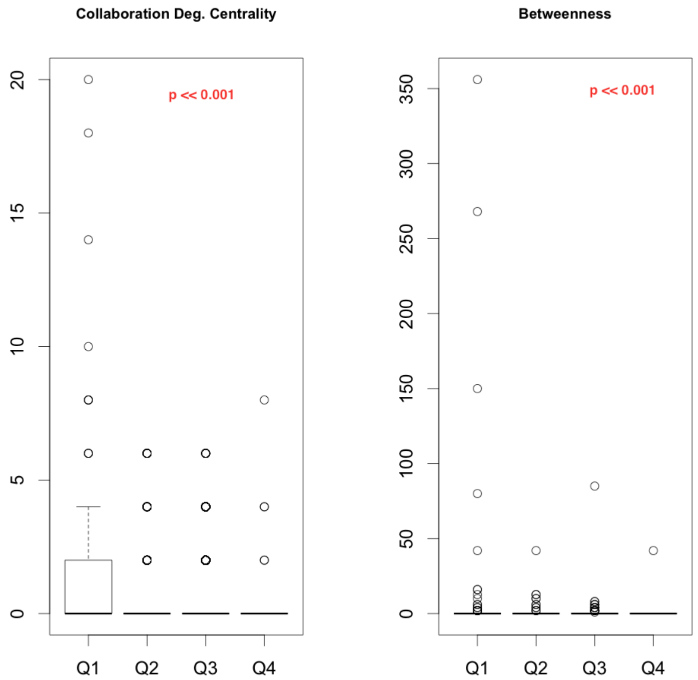


Figure G.11: Socio-knowledge power and knowledge dissemination degree centrality of scientists' in respective quadrants of management fields: 1980-1990.

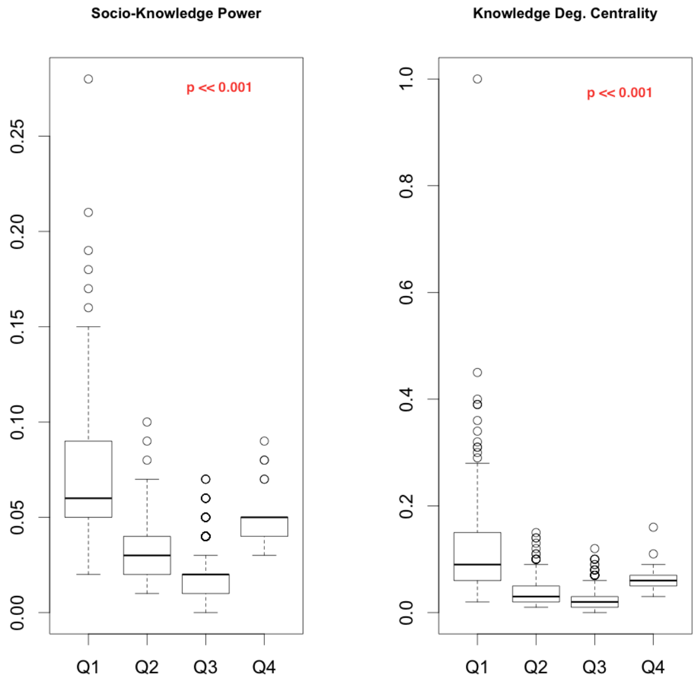


Figure G.12: Knowledge exclusivity and resemblance of scientists' in respective quadrants of management fields: 1980-1990.

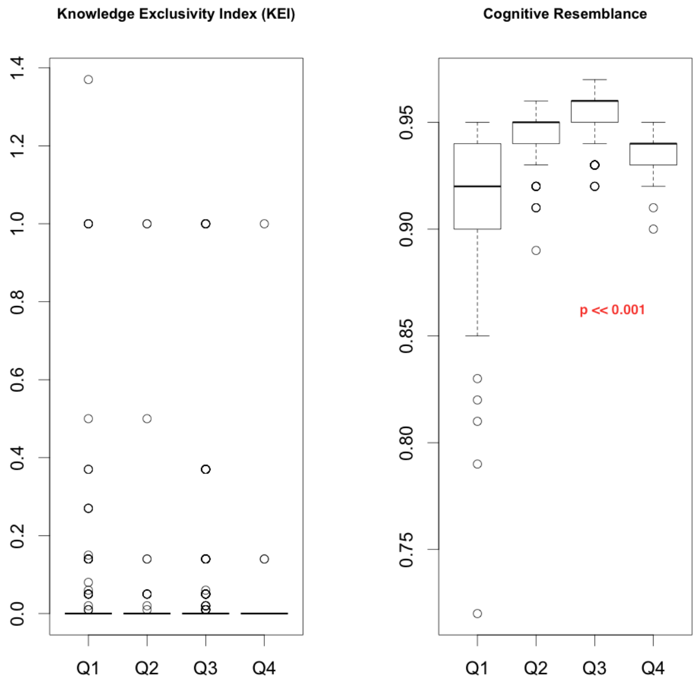
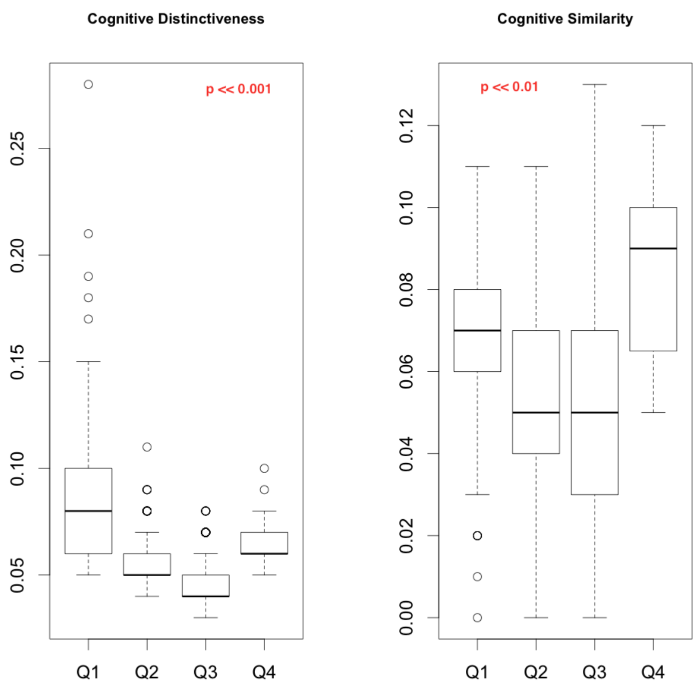


Figure G.13: Knowledge distinctiveness and similarity of scientists' in respective quadrants of management fields: 1980-1990



Appendix H

Socio-Knowledge Details of Management in Turkey: 1989-2000

Figure H.1: Knowledge and scientists cloud: 1989-2000.

Figure H.2: Interdisciplinary scope of management field: 1989-2000.

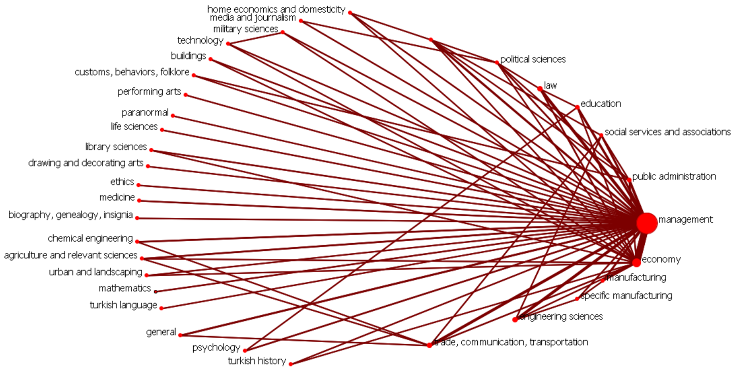


Table H.1: Management issues, 1989-2000.

ID	Centrality	Density	Size	Members
1	1	176	2	responsibility;accountability
2	5.11	1007	2	taxing;accounting
3	1.15	188	2	practices;activity
4	0.94	0.8	101	... *all other words*
5	0.46	44	3	sponsorship;campaign;advertising
6	3.81	443.67	3	technology;machinery;automation
7	0.85	111	2	financial.statement;balance.sheets
8	1.68	152.33	3	target.management;planning;book.keeping
9	10.23	1381	2	organizations;business
10	1.28	144	2	ethic;career
11	1.37	158	2	innovation;change
12	4.65	1072.67	3	knowledge;ict;computerization
13	0.21	23	2	conflicts;conflict.management
14	1.12	272	2	consumption;consumers
15	4.62	487.33	3	standards;quality;control
16	4.21	697	2	financing;costing
17	0.75	174	2	pr;crm
18	0.25	45	2	customers;customer.satisfaction
19	6.33	981	2	efficiency;development
20	1.37	197	2	logistics;distribution
21	0.1	10	2	religion;diversity
22	8	1110	2	governance;economy
23	12.13	1937	2	human.development;education
24	1.02	183	2	products;ergonomy
25	0.37	56	2	human.capital;expertise
26	0.63	100	2	teams;group
27	3.61	85.43	7	workers;training;trade;teaching;merchant.trading;management;hrm
28	5.48	1130	2	manufacturing;industry
29	0.75	30.67	4	work.satisfaction;socilization;motivation;insurance
30	0.28	13	3	storage;simulation;inventory
31	0.56	65	2	laws;labor
32	0.43	38	2	power;labor.force
33	2.86	892	2	managers;leadership
34	5.37	1304	2	markets;marketing
35	2.41	287	2	service;municipality
36	0.12	22	2	synergy;operation.research
37	3.68	479	2	structure;organizing
38	3.33	274.67	3	work;tasks;project.management
39	0.18	25	2	risk.management;risk
40	0.81	137	2	time.management;time
41	0.37	44	2	work.assesment;wages

Figure H.3: Strategic diagram of published issues in management: 1989-2000.

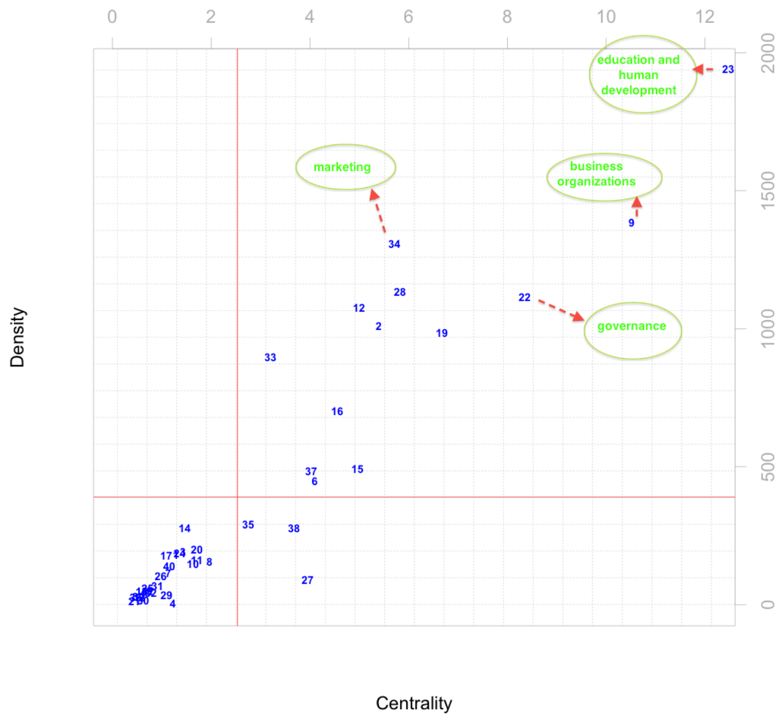


Figure H.4: Cognitive relation of themes: 1989-2000.

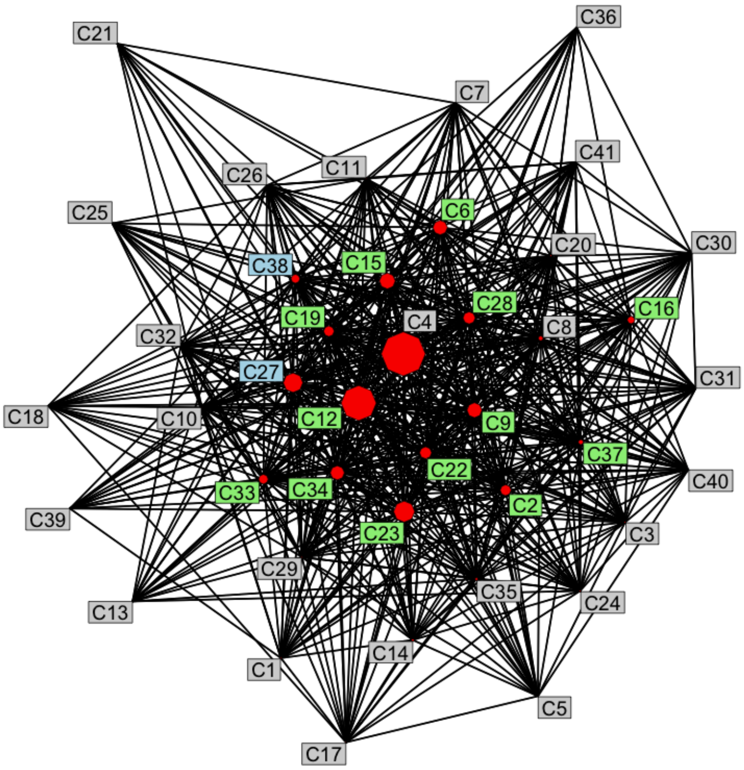


Figure H.5: Collaboration network, overall: 1989-2000.

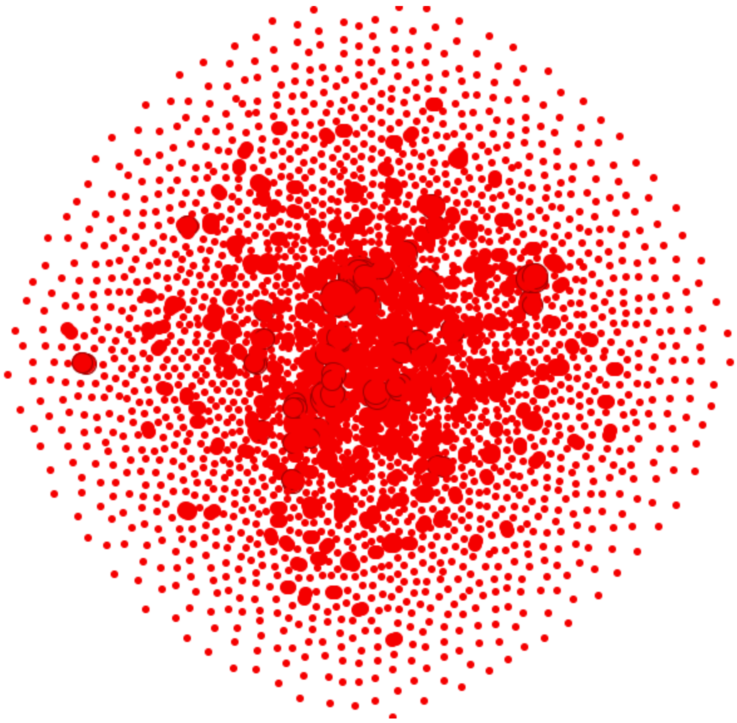


Figure H.6: Collaboration network, the collaborators: 1989-2000.

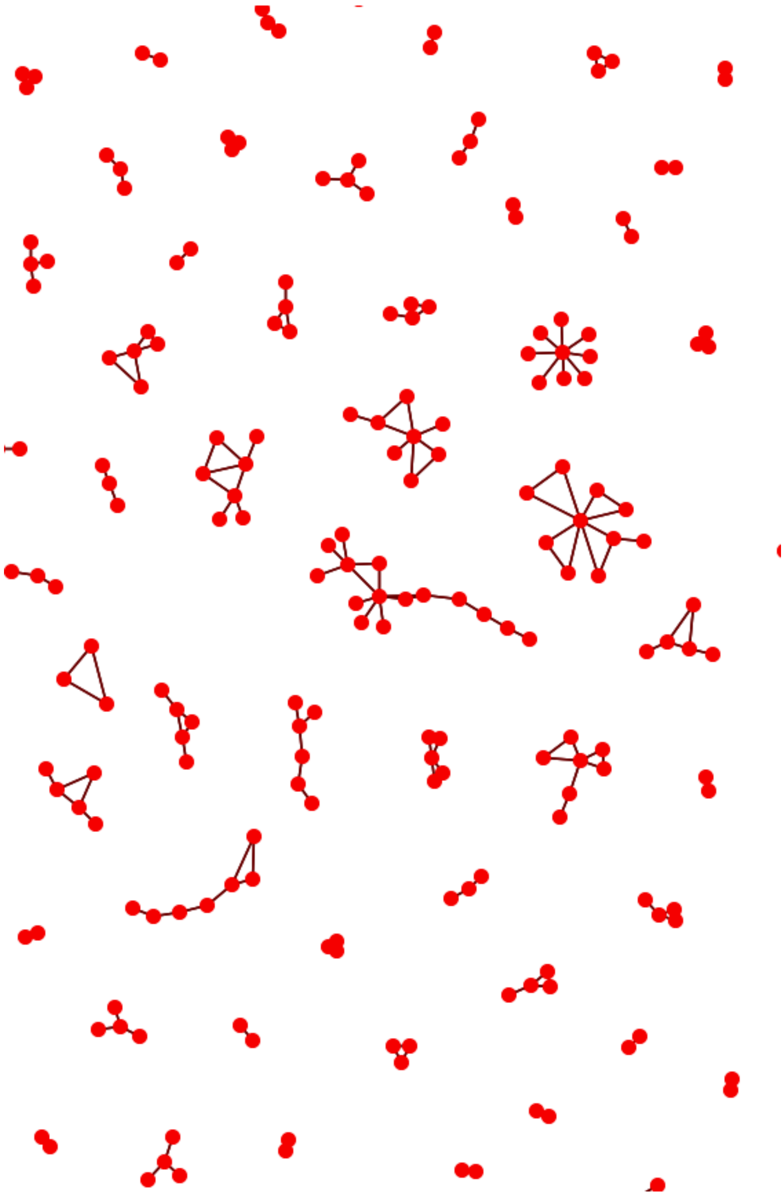


Figure H.7: Collaboration network, the core collaborators: 1989-2000.

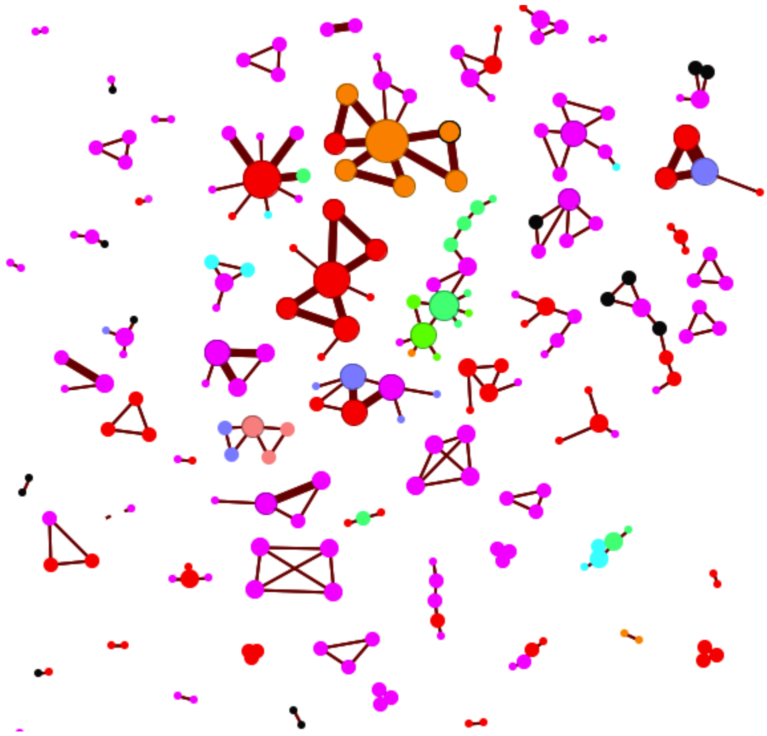


Figure H.8: Geographic locations of collaborators: 1989-2000.

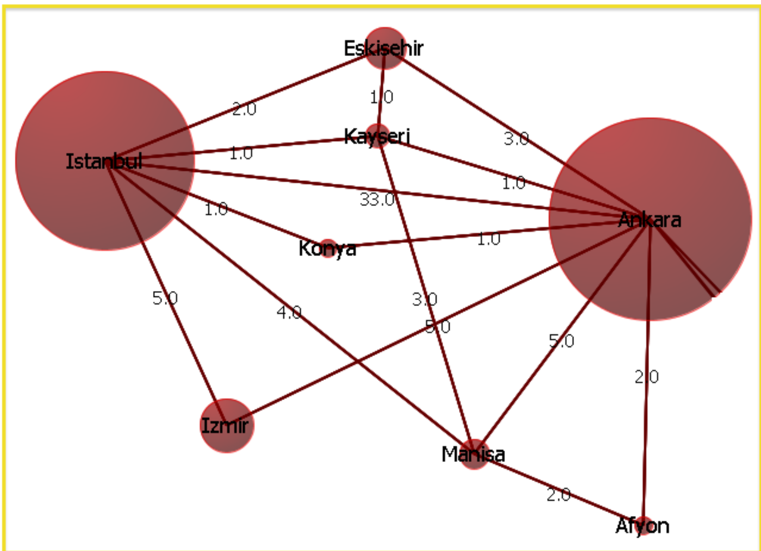


Figure H.9: Collaboration degree, betweenness and CEI of scientists' in respective quadrants of management fields: 1989-2000.

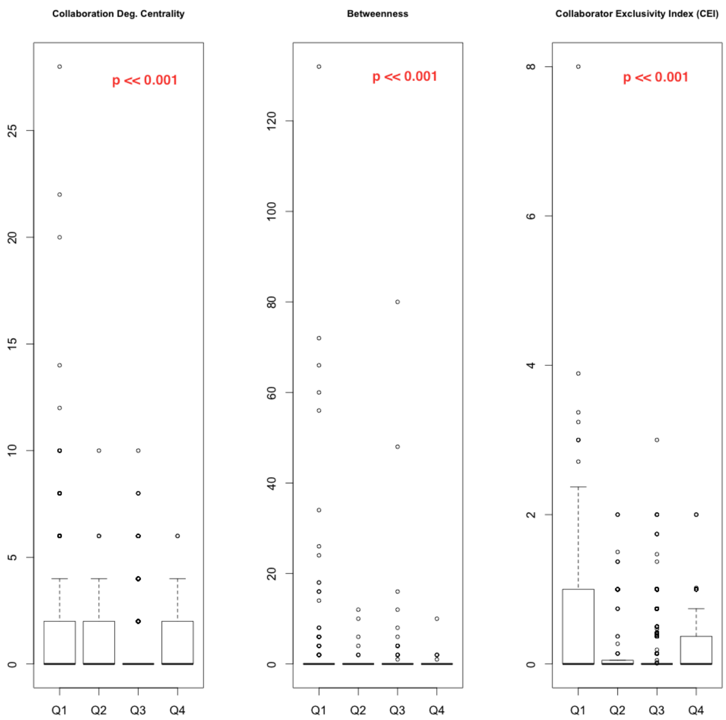


Figure H.10: Socio-knowledge power and knowledge dissemination degree centrality of scientists' in respective quadrants of management fields: 1989-2000.

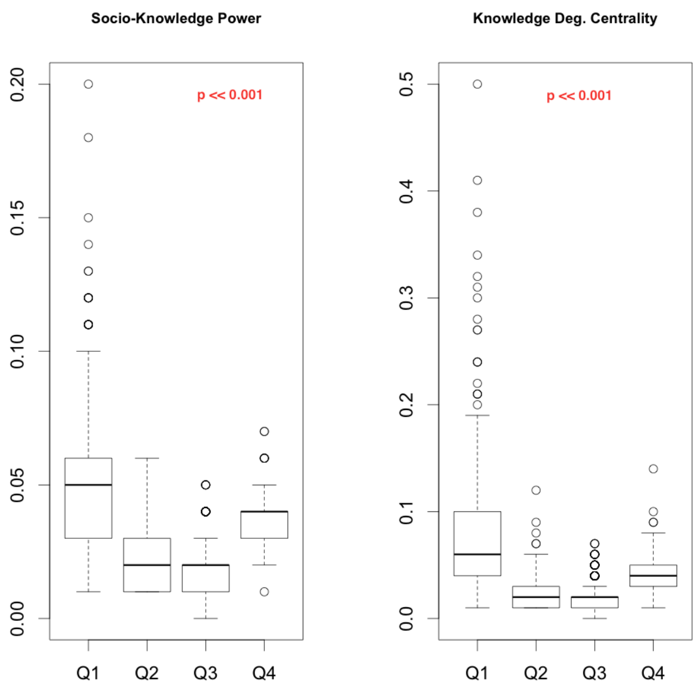


Figure H.11: Knowledge distinctiveness, similarity and exclusivity of scientists' in respective quadrants of management fields: 1989-2000.

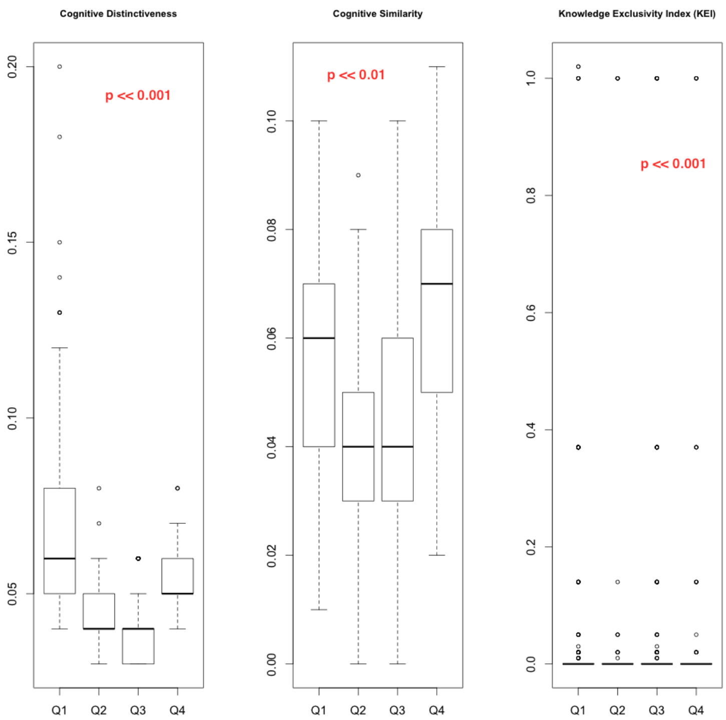
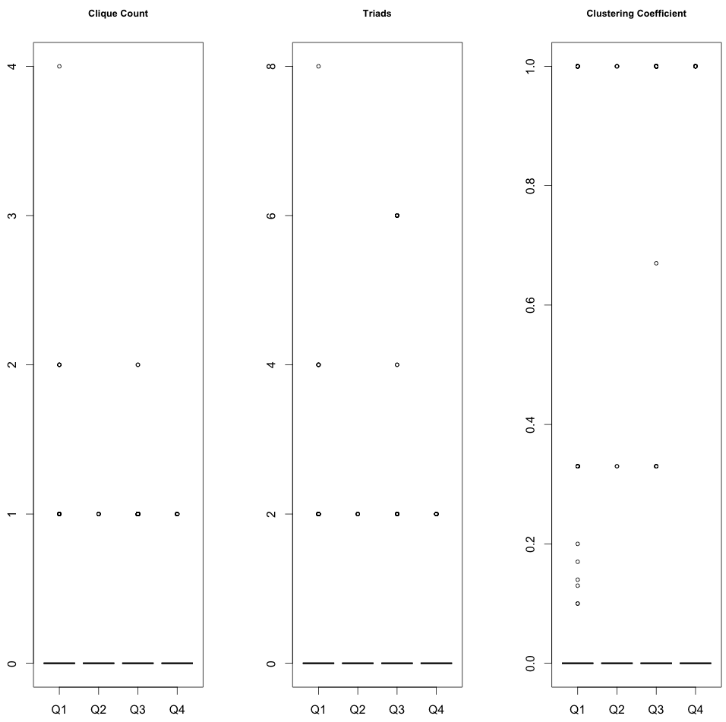


Figure H.12: Embeddedness of scientists' in respective quadrants of management fields: 1989-2000



Appendix I

Socio-Knowledge Details of Management in Turkey: 2002-2008

Figure I.1: Knowledge and scientists cloud: 2002-2008.

Table I.1: Management issues, 2002-2008.

ID	Centrality	Density	Size	Members
1	0.07	0.55	59	unemployment;trust;trend.analysis; ... ;absenteeism
2	0.07	5.58	9	taxation; standards; regulations; quantitative; policy; management; education; auditing; accounting
3	0.07	19	2	eu;adaptation
4	0.09	11.2	6	technology;management.accounting;ict;erp;computerization;adoption
5	0.03	3.7	5	organizational;image;consumption;brands;advertising
6	0.2	80	2	decision.making;ahp
7	0.03	10	2	partnership;alliance
8	0.02	8	2	work.place;appraisal
9	0.09	16.67	3	social.structure;empowerment;attachment
10	0.23	56.67	3	consumers;consumer.research;behavior
11	0.02	7	2	board.of.directors;benefits
12	0.05	5.8	5	promotion;product;pricing;costing;brand.equity
13	0.05	11	2	values;brand.loyalty
14	0.07	19	2	national;brand.positioning
15	0.1	9.83	4	performance;investment;emotional.intelligence;capital.structure
16	0.02	5.33	3	time.management;careerism;career.management
17	0.06	3.9	5	services;ngos;furnishings.sector;consultancy;communication
18	0.08	10.5	4	schumpeterian;randd;innovation;competition
19	0.1	18.67	3	work;family;conflicts
20	0.06	17	2	discipline;control
21	0.03	3.83	4	social.networks;social;mediation;cooperation
22	0.03	3.83	4	sustainability;risk.taking;growth;corporate.citizenship
23	0.02	10	2	enron;corruption
24	0.01	6	2	cost.management;cost.accounting
25	0.01	6	2	turmoil;crises.management
26	0.19	84	2	customer.satisfaction;crm
27	0.41	71.33	3	structure;organizations;culture
28	0.05	18	2	loyalty;customers
29	0.04	5.5	4	practices;organization.design;knowledge.diffusion;design
30	0.02	6	3	society;regional;development
31	0.05	15.33	3	glass.ceiling;gender;discrimination
32	0.09	24.67	3	supply.chain;logistics;distribution.channels
33	0.04	15	2	history;double.entry.bookkeeping
34	0.04	6.33	3	self.efficacy;participation;downsizing
35	0.03	10	2	segmentation;durable.goods
36	0.04	7.67	4	surplus;performance.measures;market;economy
37	0.02	10	2	productivity;efficiency
38	0.04	6.33	3	organization.climate;justice;emotions
39	0.04	23	2	norm.cadre;employee.recruitment
40	0.04	3.67	4	uncertainty;fuzzy.topsis;flexibility;entry
41	0.07	9.17	4	production;geography;family.business;environment
42	0.03	5.33	3	structuration;institutionalization;going.public
43	0.05	18	2	ownership;governance
44	0.02	6	2	labor.force;hierarchy
45	0.08	32	2	scorecard;hrm
46	0.08	26	2	office.management;human.capital
47	0.03	20	2	training;human.development
48	0.12	29	2	personality;identity
49	0.02	4	3	socialization;orientation;jit
50	0.03	3	5	vision;social.capital;politics;municipalities;labor
51	0.02	6	2	manufacturing.sector;labor.market
52	0.01	9	2	organizing;labor.unions
53	0.1	32	2	transformational.leadership;leadership
54	0.02	7	2	target.cost.management;life.cycle
55	0.01	6	2	methods;management.science
56	0.1	30	2	product.positioning;market.research
57	0.01	9	2	postmodern;market.segmentation
58	0	8	2	paradigms;organization.studies
59	0.17	43	2	workers;perceptions
60	0.02	6	2	theory.of.constraints;procurement
61	0.02	6	2	trading;strengths
62	0	8	2	vertical.analysis;uniform.accounting

Figure I.2: Strategic diagram of published issues in management: 2002-2008.

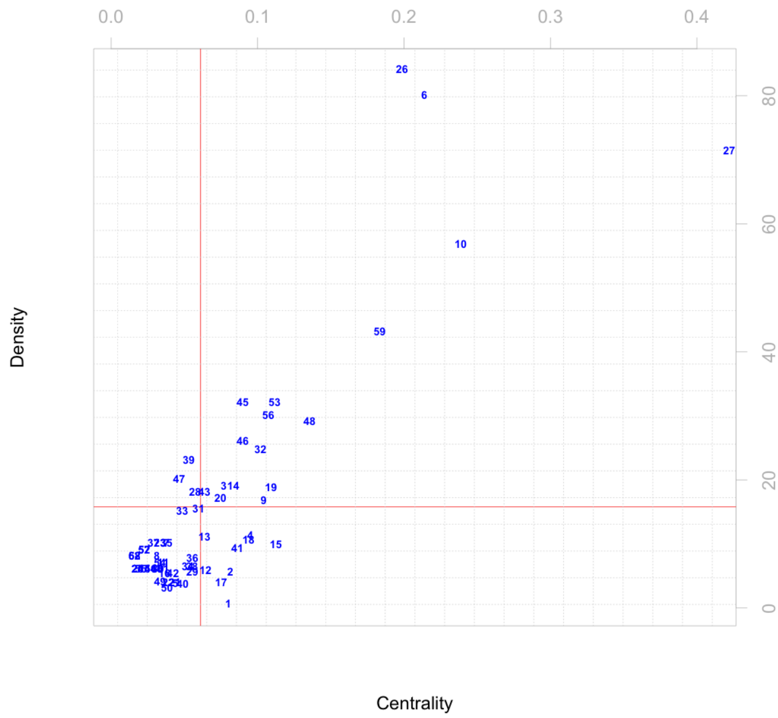


Figure I.3: Strategic diagram of published issues in management, emergence of cohesive groups : 2002-2008.

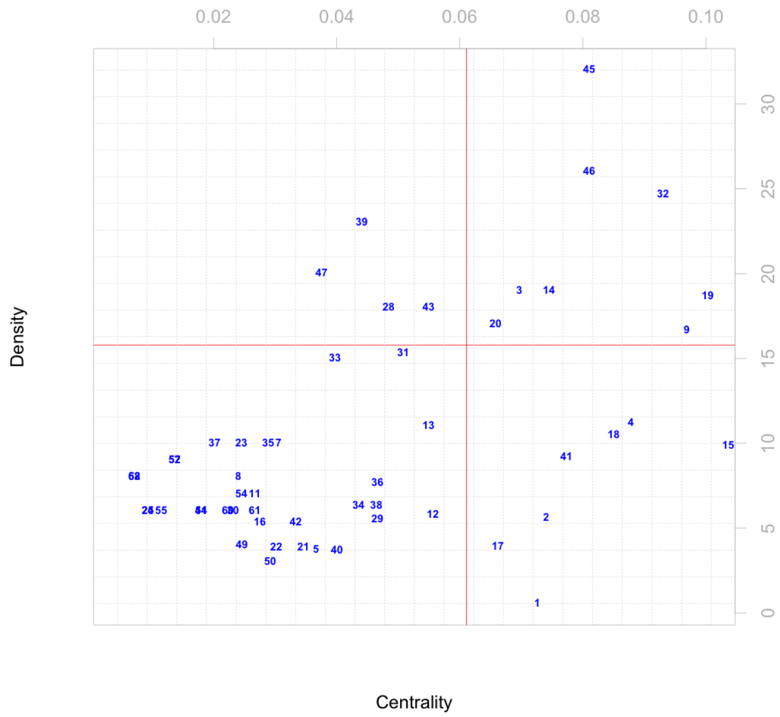


Figure I.4: Cognitive relation of themes: 2002-2008.

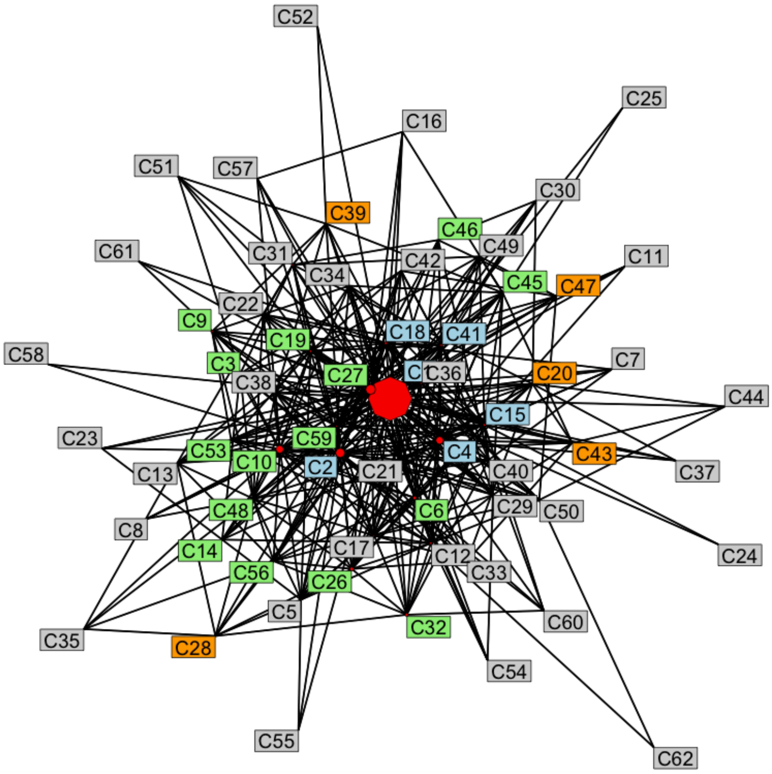


Figure I.5: Collaboration network, overall: 2002-2008.

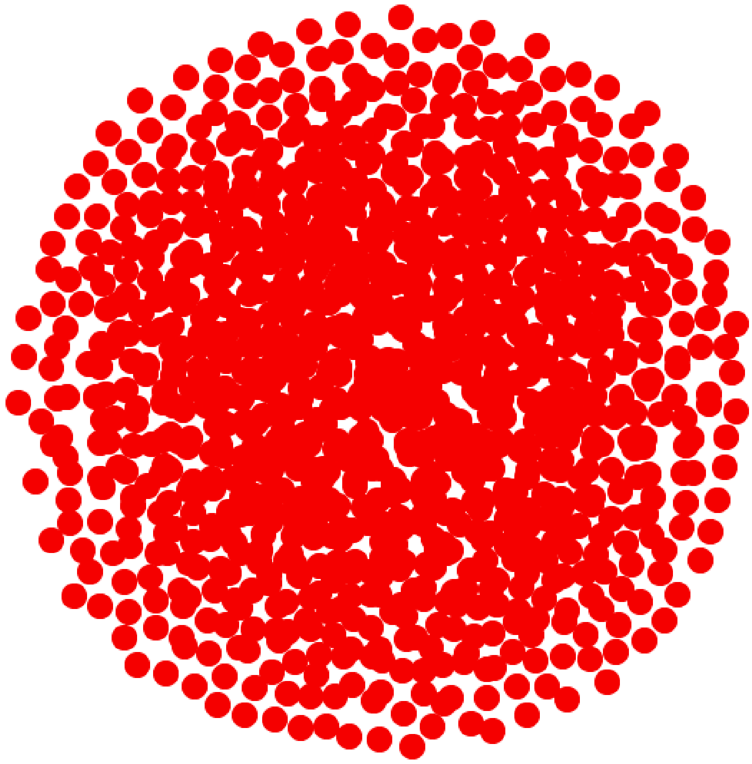


Figure I.6: Collaboration network, the collaborators: 2002-2008.

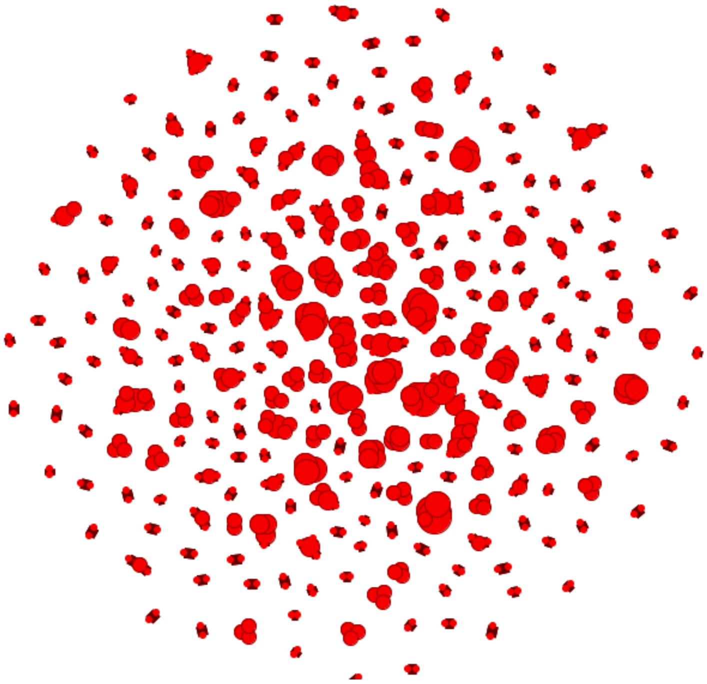


Figure I.7: Collaboration network, the core collaborators: 2002-2008.

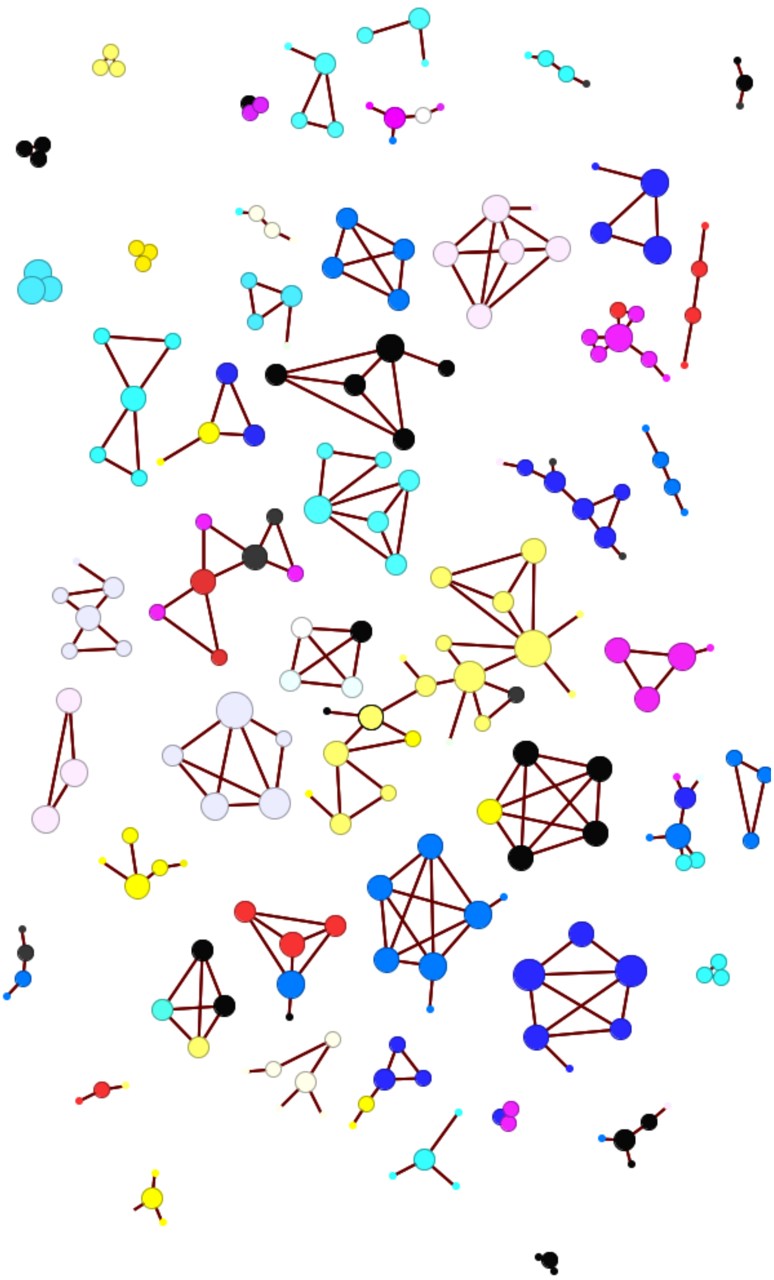


Figure I.8: Geographic locations of collaborators: 2002-2008.

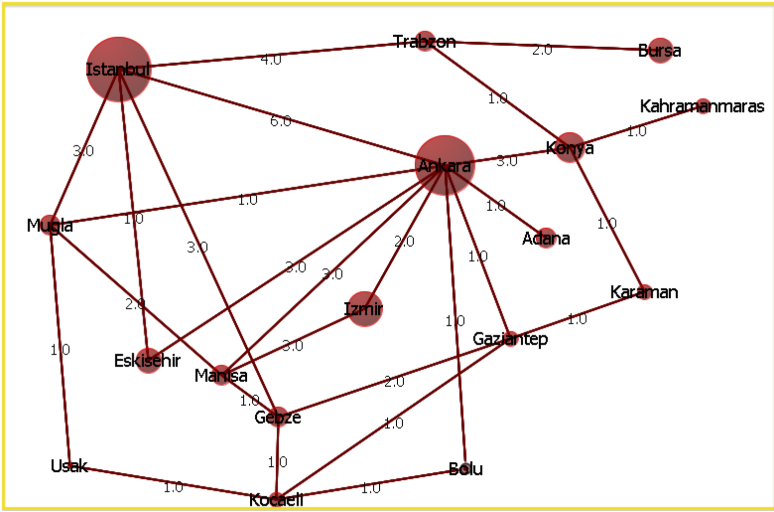


Figure I.9: Collaboration degree, betweenness and CEI of scientists' in respective quadrants of management fields: 2002-2008.

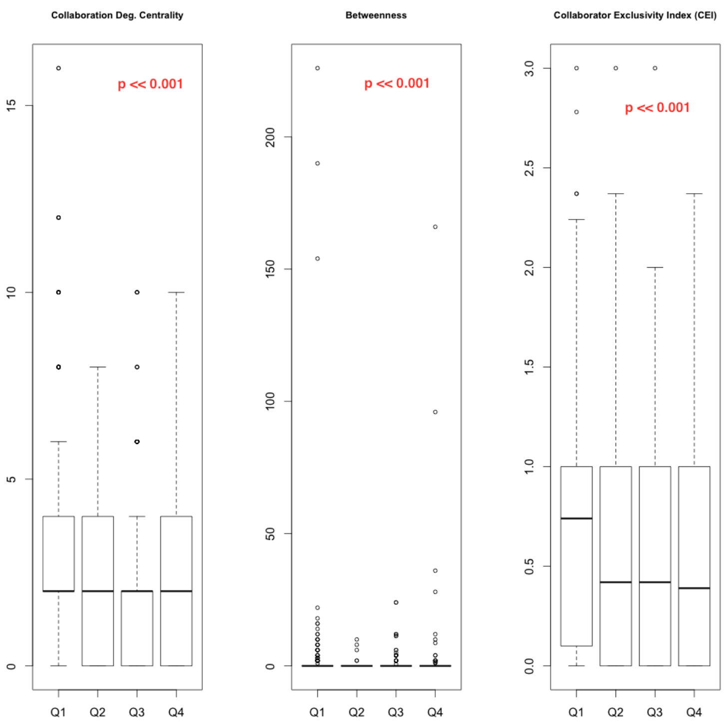


Figure I.10: Socio-knowledge power and knowledge dissemination degree centrality of scientists' in respective quadrants of management fields: 2002-2008.

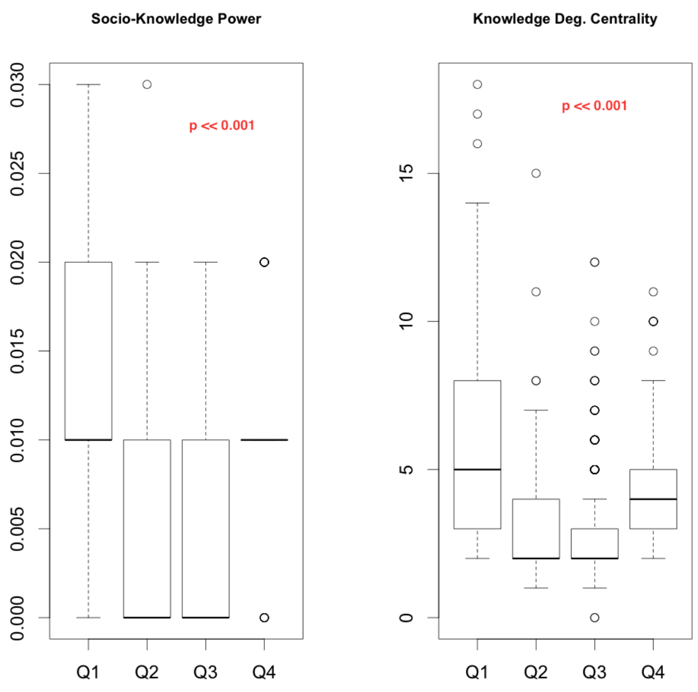


Figure I.11: Knowledge distinctiveness, similarity and exclusivity of scientists' in respective quadrants of management fields: 2002-2008.

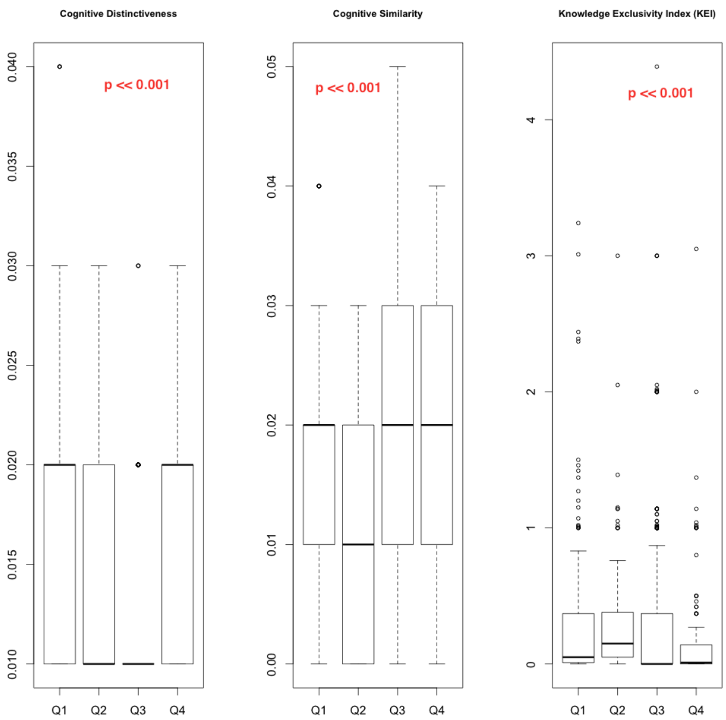
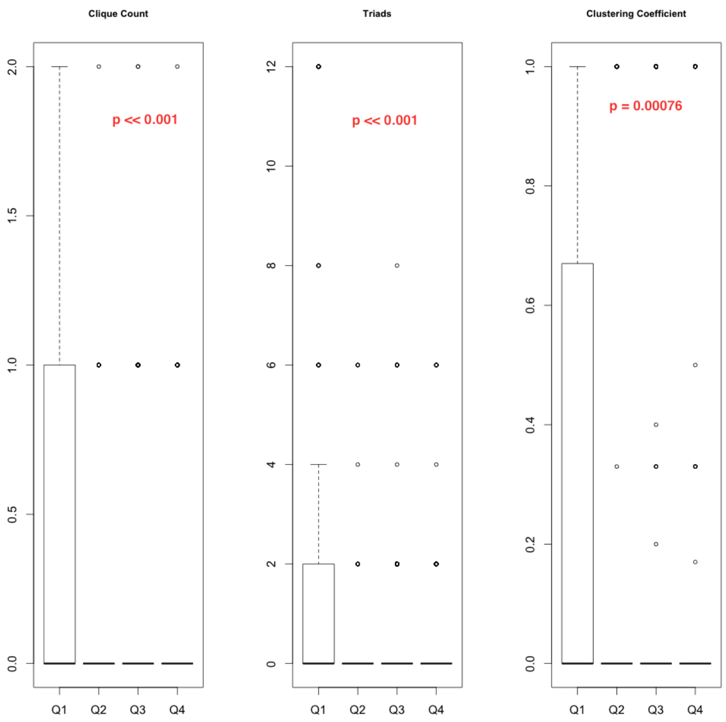


Figure I.12: Embeddedness of scientists' in respective quadrants of management fields: 2002-2008



Appendix J

Socio-Knowledge Details of Management from Turkey in WoS : 1980-2008

Figure J.1: Knowledge and scientists cloud: 1980-2008w.

Table J.1: Management issues, 1980-2008w.

ID	Centrality	Density	Size	Members
1	0.02	1.57	8	science, regulation, public.policy, management.research, germany, egovernment, biotechnology.sector, academics
2	0.03	3.5	4	transaction.cost, emerging.markets, bargaining.power, acquisition
3	0.08	0.42	103	workplace, value, usa, uncertainty, textile.industry, technology, team, systems, system.dynamics, supply.chain.management, success, strategy, strategic.management, standards, stability, social.capital, smes, scale, satisfaction, role, resource.management, quality, public.organizations, public.administration, productivity, policy, perspective, performance, perception, patterns, partnerships, outsourcing, organizational.learning, organizational.behavior, networks, negotiation, multinational.corporations, modernization, materialism, marketing, market, manufacturing, management, logistics, leadership, justice, joint.ventures, inventory.management, institutions, institutional.perspective, innovation, impact, identity, ict, higher.education, government, governance, globalization, gender, game.theory, forms, flexibility, firm, feedback, family.business, experience, eu, ethics, environment, entrepreneurship, empowerment, empiric, emotional.intelligence, efficiency, education, economies, dynamics, dimensionality, diffusion, developing.countries, determinants, decision.making, culture, cross.culture, crisis, cooperation, continuous.improvement, contingency, contextualization, context, consumption, consumer, constructs, conflict.management, complexity, company.law, change, business, bureaucracy, banks, agency.problems, administration
4	0.04	2.6	6	shareholder.value, promotion, product.innovation, market.entry, art, advertising
5	0.07	2.93	6	R&D, leader.member.exchange, job.satisfaction, framework, citizenship, ambiguity
6	0.01	8	2	management.education, americanization
7	0.22	24	2	TQM, technology.adoption
8	0.11	2.64	11	work, service, self.efficacy, personality, organizations, opportunities, internationalization, conservatism, beliefs, behavior, attitudes
9	0.06	3.93	6	size, ownership, mechanisms, managers, corporate.governance, board.composition
10	0.09	6.33	6	trust, power, marketing.channels, dependence, commitment, buyer.supplier.relationships
11	0.1	7.17	4	market.orientation, learning, competency, capability
12	0.04	1.38	11	product, price, market.research, international.research, information, consumer.research, consumer.behavior, competition, cognition, choice, career.choice
13	0.04	2.2	5	subsidiary, politics, development, decentralization, centralization
14	0.04	4.33	3	wealth, earnings, china
15	0.02	4.33	3	interorganizational.relations, embeddedness, collaboration
16	0.15	21	2	individualism, collectivism
17	0.03	3.5	4	structure, hierarchy, corruption, collusion
18	0.1	4.53	6	resource.based.theory, orientation, knowledge, evolution, competitive.advantage, communication
19	0.08	8.33	3	stress, family, conflict
20	0.04	3	5	validation, self, meaning, corporate.social.responsibility, consumer.culture
21	0.02	4.67	3	postmodern, history, consumer.ethnography
22	0.02	4.67	3	service.quality, healthcare.sector, consumer.perceptions
23	0.03	1.52	6	systems.thinking, paradigm, metaphor, large.corporations, customer, creativity
24	0.04	4.17	4	turnover, profitability, management.practices, customer.satisfaction
25	0.03	4.33	3	practice, knowledge.management, discipline
26	0.04	9	4	rhetoric, discourse, consequences, antecedents
27	0.07	18	2	internet, ecommerce
28	0.06	10	2	transformation, emerging.economies
29	0.04	6.33	3	turkey, integrated.management.model, foresight
30	0.09	6.67	3	product.development, populations, organizational.research
31	0.05	9	2	top.management, succession

Figure J.2: Strategic diagram of published issues in management: 1980-2008w.

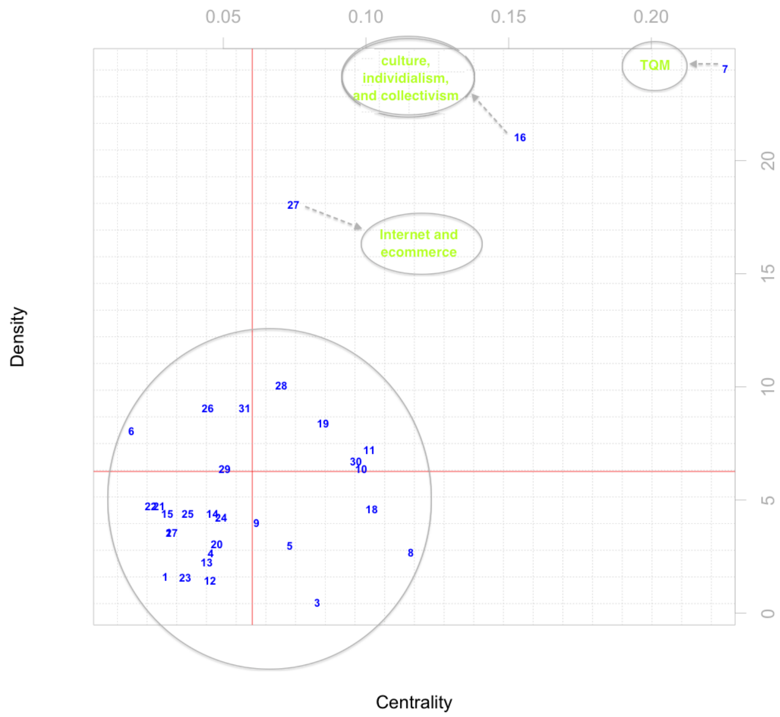


Figure J.3: Strategic diagram of published issues in management, emergence of cohesive issues: 1980-2008w.

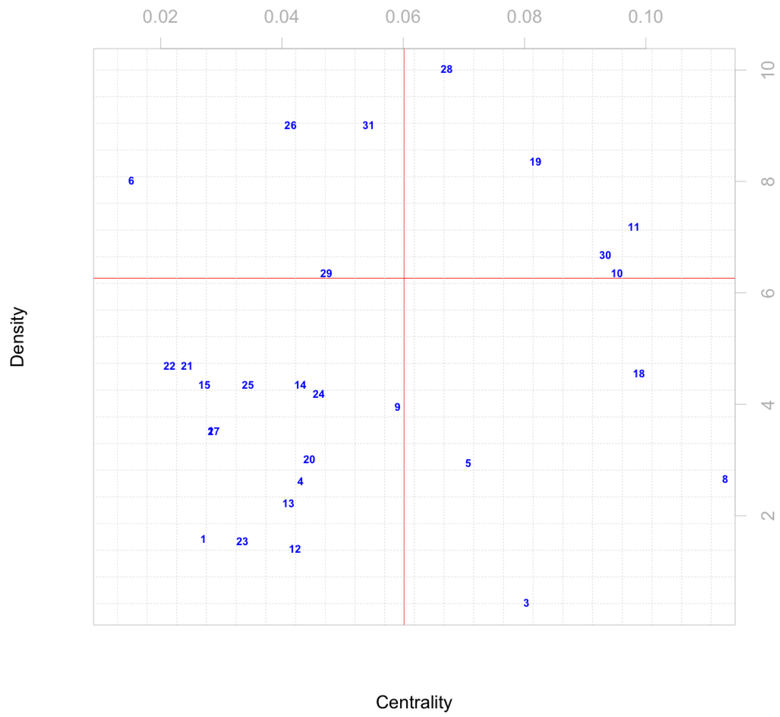


Figure J.4: Cognitive relation of themes: 1980-2008w.

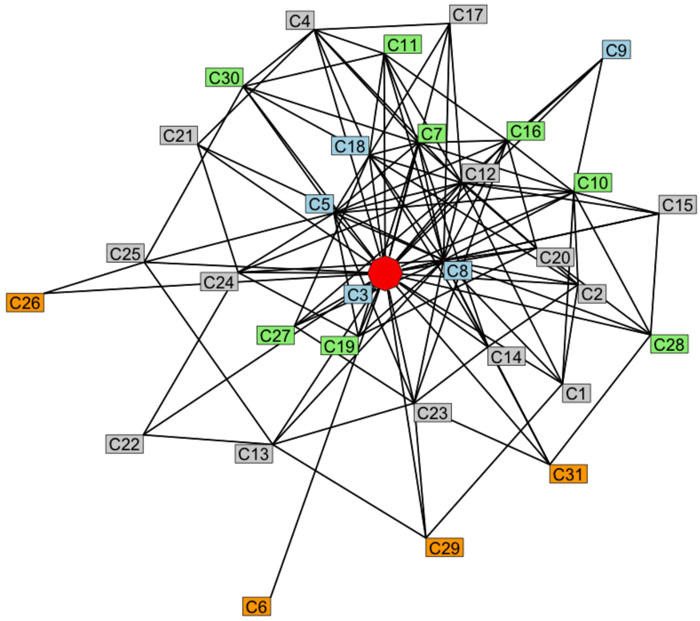


Figure J.5: Collaboration network, overall: 1980-2008w.

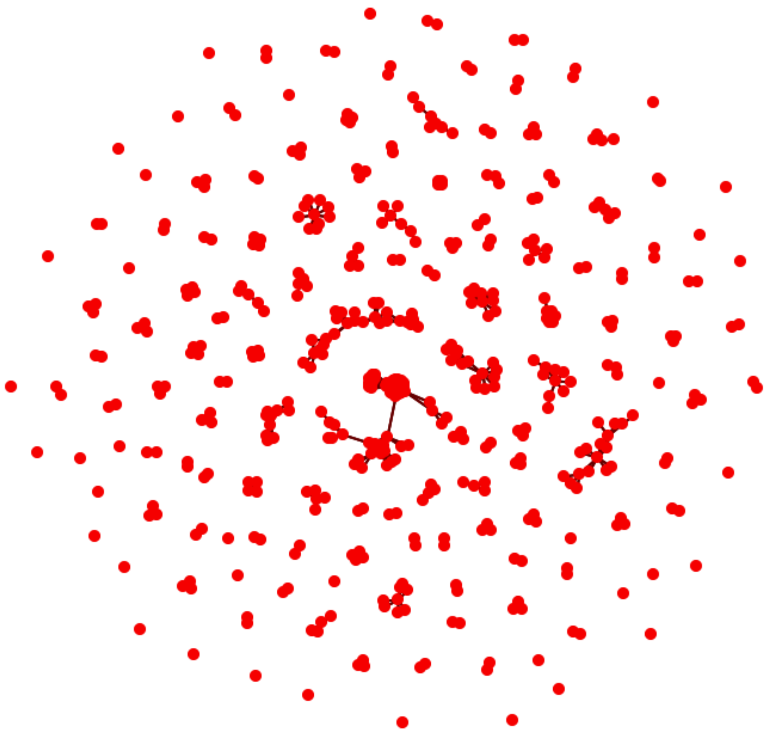


Figure J.6: Collaboration network, the collaborators: 1980-2008w.

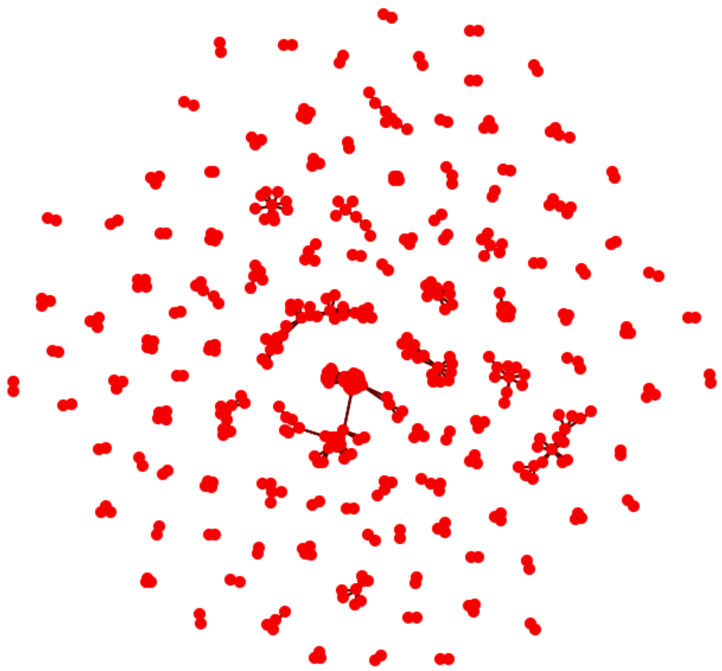


Figure J.7: Collaboration network, the core collaborators: 1980-2008w.

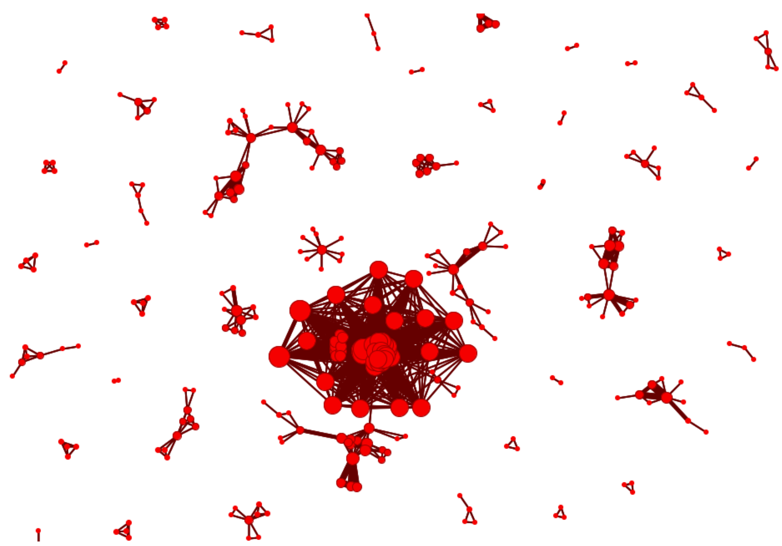


Figure J.8: Collaboration network, the giant connected cormponent: 1980-2008w.

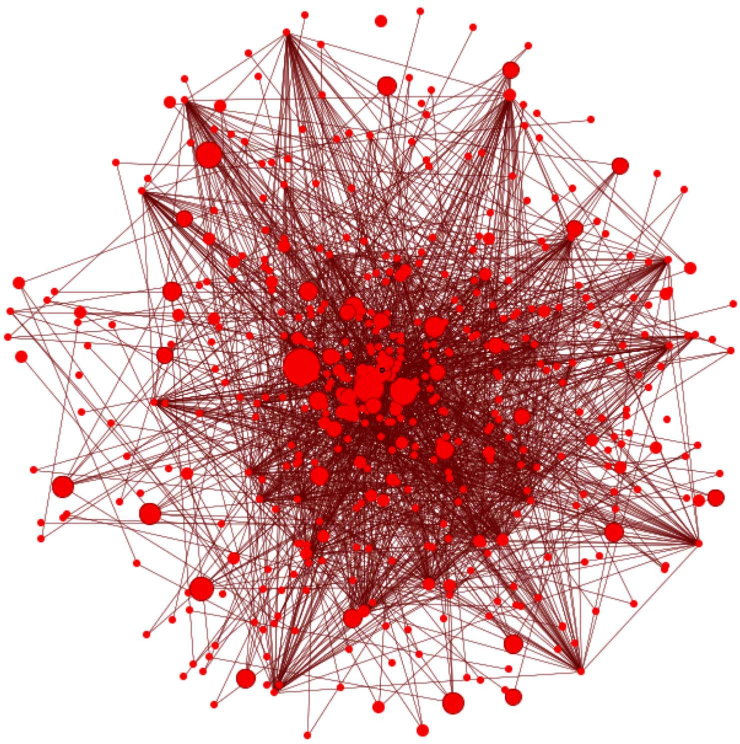


Figure J.9: Socio-knowledge power and clique number of scientists' in respective quadrants of management fields: 1980-2008w.

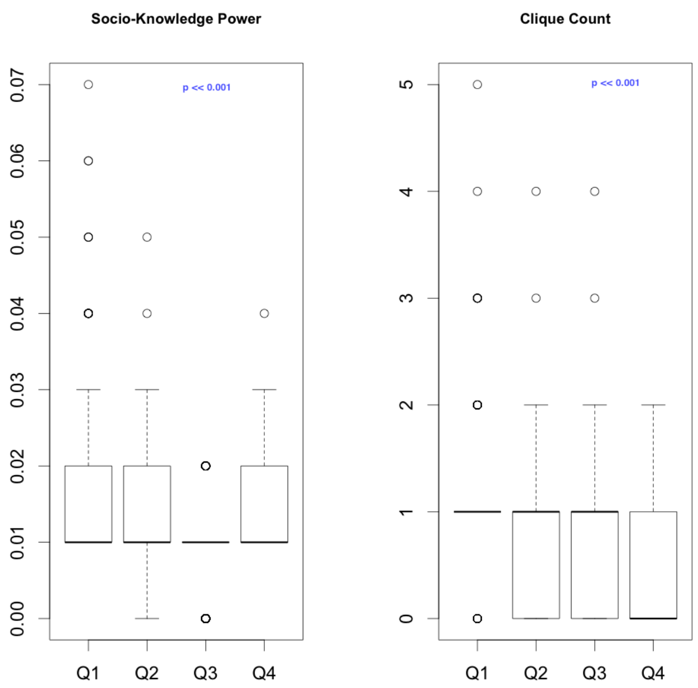
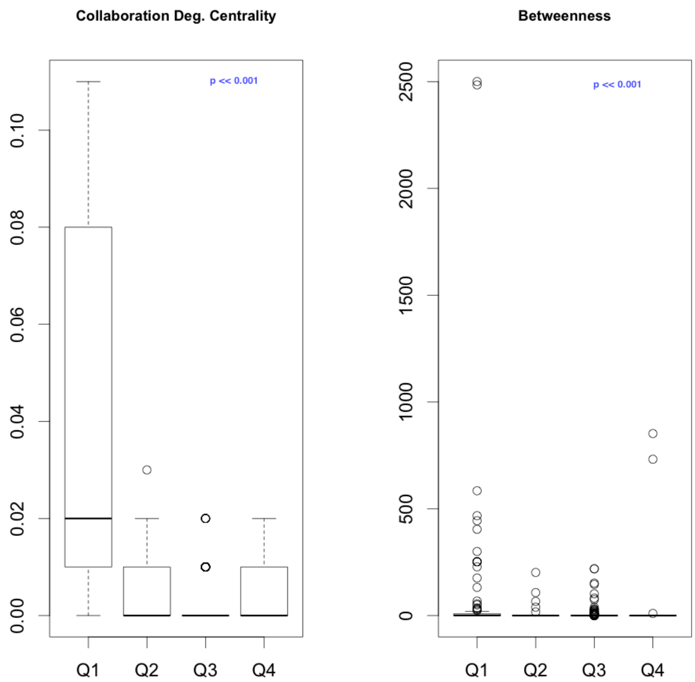


Figure J.10: Collaboration degree centrality, betweenness of scientists' in respective quadrants of management fields: 1980-2008w.



Appendix K

Sectoral Distribution of Case Studies in Turkey: 1922-1999

```
Key Entities: Authors who have published in WOS Dataset.
Periods:
    - wos-1990-c: Covers years 1980-1990
    - wos-1999-c: Covers years 1980-1999
    - wos-2008-c: Covers years 1980-2008

* In-the-Know (total degree centrality)
  - The Total Degree Centrality of an author is the normalized
    sum of its total degree.

      Input network(s): Coauthorship Network

      Rank wos-1990-c                         wos-1999-c
      ---- ------ ------------------------ ------ -----------
      1    0.1579 Yavas_U                  0.1096 Ger_G
      2    0.1053 Heper_M                  0.0685 Belk_R
      3    0.1053 Pai_S                    0.0685 Askegaard_S
      4    0.1053 Kim_C                    0.0685 Yavas_U
      5    0.1053 Salancik_G               0.0548 Kaynak_E
```

```
6    0.1053 Leblebici_H                0.0411 Heper_M
7    0.1053 Kaynak_E                   0.0411 Demir_E
8    0.1053 Borak_E                    0.0411 Kasapoglu_A
9    0.0526 Ger_G                      0.0411 Sugur_N
10   0.0526 Belk_R                     0.0411 Nichols_T

Rank wos-2008-c
---- ------ --------------
1    0.1071 Fu_P
2    0.1071 Howel_J
3    0.1071 Prieto_L
4    0.1071 Peng_T
5    0.1071 Koopman_P
6    0.0833 Kabasakal_H
7    0.0813 Bodur_M
8    0.0794 Grachev_M
9    0.0794 Chen_YJ
10   0.0794 Den hartog_DN


* Number of Cliques (clique count)
  - The number of distinct cliques to which each author belongs.

    Input network(s): Coauthorship Network

    Rank wos-1990-c                         wos-1999-c
    ---- ------ ------------------------ ------ --------------
    1    1.0000 Heper_M                  3.0000 Ger_G
    2    1.0000 Pai_S                    2.0000 Belk_R
    3    1.0000 Kim_C                    2.0000 Askegaard_S
    4    1.0000 Kaynak_E                 2.0000 Yavas_U
    5    1.0000 Borak_E                  2.0000 Kaynak_E
    6    1.0000 Yavas_U                  1.0000 Heper_M
```

7	0.0000	Salancik_G	1.0000	Pai_S
8	0.0000		1.0000	Kim_C
9	0.0000		1.0000	Lascu_D
10	0.0000		1.0000	Christensen_A

Rank	wos-2008-c	
1	5.0000	Yilmaz_C
2	4.0000	Aksoy_L
3	4.0000	Kaynak_E
4	4.0000	Tatoglu_E
5	3.0000	Ger_G
6	3.0000	Wasti_S
7	3.0000	Akgun_A
8	3.0000	Yavas_U
9	3.0000	Keiningham_T
10	3.0000	Pauwels_K

* Most Knowledge (row degree centrality)
  - The Knowledge Centrality of an author is his/her normalized out-degree in AxK.

  Input network(s): Knowledge Dissemination Network

Rank	wos-1990-c		wos-1999-c	
1	0.2941	Leblebici_H	0.2647	Ger_G
2	0.2353	Salancik_G	0.0735	Leblebici_H
3	0.2059	Yavas_U	0.0735	Askegaard_S
4	0.1176	Ger_G	0.0735	Yavas_U
5	0.1176	Belk_R	0.0662	Belk_R
6	0.1176	Rountree_D	0.0662	Liker_J
7	0.0882	Heper_M	0.0662	Wasti_S

```
8    0.0882 Pai_S                     0.0662 Bac_M
9    0.0882 Kim_C                     0.0662 Harcar_T
10   0.0882 Bodur_M                   0.0662 Kumcu_E

Rank wos-2008-c
---- -----------
1    0.0977 Yilmaz_C
2    0.0836 Ger_G
3    0.0680 Wasti_S
4    0.0680 Keskin_H
5    0.0666 Usdiken_B
6    0.0552 Akgun_A
7    0.0552 Byrne_JC
8    0.0524 Ozsomer_A
9    0.0510 Karatepe_OM
10   0.0467 Harmancioglu_N


* Leader of Strong Clique (eigenvector centrality)
  - Calculates the principal eigenvector of the network.
    An author is central to the extent that his/her co-authors are
    central.

      Input network(s): Coauthorship Network

      Rank wos-1990-c                        wos-1999-c
      ---- ------ ------------------------- ------ -------------
      1    1.0000 Heper_M                   1.0000 Heper_M
      2    1.0000 Pai_S                     1.0000 Salancik_G
      3    1.0000 Kim_C                     1.0000 Leblebici_H
      4    1.0000 Salancik_G                1.0000 Ger_G
      5    1.0000 Leblebici_H               1.0000 Bodur_M
      6    1.0000 Ger_G                     1.0000 Cavusgil_S
```

```
7    1.0000 Belk_R                    1.0000 Kozan_M
8    1.0000 Bodur_M                   1.0000 Ergin_C
9    1.0000 Cavusgil_S                1.0000 Liker_J
10   1.0000 Yavas_U                   1.0000 Wasti_S

Rank wos-2008-c
---- ------ ----------
1    1.0000 Heper_M
2    1.0000 Salancik_G
3    1.0000 Leblebici_H
4    1.0000 Ger_G
5    1.0000 Aksoy_L
6    1.0000 Fern_E
7    1.0000 Mandrik_C
8    1.0000 Bao_Y
9    1.0000 Musso_JA
10   1.0000 Weare_C
```

* Acts as a Hub (hub centrality)
  - An author is hub-central to the extent that his/her out-links are to authors that have many in-links.

```
Input network(s): Coauthorship Network

Rank wos-1990-c                       wos-1999-c
---- ------ ------------------------- ------ -------------
1    1.0000 Heper_M                   1.0000 Heper_M
2    1.0000 Pai_S                     1.0000 Ger_G
3    1.0000 Kim_C                     1.0000 Yavas_U
4    1.0000 Yavas_U                   1.0000 Harcar_T
5    0.8546 Kaynak_E                  1.0000 Kumcu_E
6    0.8546 Borak_E                   1.0000 Kumcu_M
```

```
7    0.4608 Rountree_D                 1.0000 Sertel_M
8    0.0000                            1.0000 Adaman_F
9    0.0000                            1.0000 Zenginobuz_E
10   0.0000                            1.0000 Johnson_J
```

```
Rank wos-2008-c
---- ------ ----------------
1    1.0000 Heper_M
2    1.0000 Ger_G
3    1.0000 Aksoy_L
4    1.0000 Fern_E
5    1.0000 Mandrik_C
6    1.0000 Bao_Y
7    1.0000 Musso_JA
8    1.0000 Weare_C
9    1.0000 Loges_WE
10   1.0000 Oztas_N
```

```
* Potentially Influential (betweenness centrality)
  - The Betweenness Centrality of an author v in a network is defined as:
    across all author pairs that have a shortest path containing v,
    the percentage that pass through v.

      Input network(s): Coauthorship Network

      Rank wos-1990-c                        wos-1999-c
      ---- ------ ------------------------ ------ -------------
      1    0.0117 Yavas_U                  0.0053 Yavas_U
      2    0.0000                          0.0038 Kaynak_E
      3    0.0000                          0.0029 Ger_G
      4    0.0000                          0.0021 Askegaard_S
      5    0.0000                          0.0008 Heper_M
```

```
6    0.0000                                 0.0004 Belk_R
7    0.0000                                 0.0000
8    0.0000                                 0.0000
9    0.0000                                 0.0000
10   0.0000                                 0.0000

Rank wos-2008-c
---- ------ -------------
1    0.0099 Cavusgil_S
2    0.0098 Bodur_M
3    0.0034 Griffith_DA
4    0.0029 Seggie_SH
5    0.0023 Kabasakal_H
6    0.0018 Kaynak_E
7    0.0018 Harmancioglu_N
8    0.0016 Yavas_U
9    0.0012 Asugman_G
10   0.0010 Tatoglu_E


* Connects Groups (high betweenness and low degree)
  - The ratio of betweenness to degree centrality;
    higher scores mean that an author is a potential
    boundary spanner.

    Input network(s): Coauthorship Network

    Rank wos-1990-c                             wos-1999-c
    ---- ------ ------------------------- ------ -----------
    1    1.0000 Yavas_U                         0.3413 Yavas_U
    2    0.0000                                 0.3047 Kaynak_E
    3    0.0000                                 0.1341 Askegaard_S
    4    0.0000                                 0.1143 Ger_G
```

```
5    0.0000                           0.0813 Heper_M
6    0.0000                           0.0244 Belk_R
7    0.0000                           0.0000
8    0.0000                           0.0000
9    0.0000                           0.0000
10   0.0000                           0.0000
```

```
Rank wos-2008-c
---- ------ ---------------
1    0.2176 Cavusgil_S
2    0.1168 Seggie_SH
3    0.0816 Griffith_DA
4    0.0718 Asugman_G
5    0.0580 Bodur_M
6    0.0496 Kaynak_E
7    0.0485 Xu_S
8    0.0387 Yavas_U
9    0.0250 Harmancioglu_N
10   0.0218 Karatepe_OM
```

* Specialization - knowledge (relatively unique)
  - Detects authors who have published on matters that comparatively few other authors have published.

Input network(s): Knowledge Dissemination Network

```
Rank wos-1990-c                       wos-1999-c
---- ------ ------------------------- ------ --------------
1    0.1454 Leblebici_H               0.0781 Ger_G
2    0.0866 Salancik_G                0.0321 Ersoy_M
3    0.0588 Erden_D                   0.0320 Leblebici_H
4    0.0518 Yavas_U                   0.0293 Bac_M
```

5	0.0433	Rountree_D	0.0221	Alexander_M
6	0.0339	Ger_G	0.0173	Salancik_G
7	0.0339	Belk_R	0.0163	Berk_E
8	0.0325	Bodur_M	0.0163	Moinzadeh_K
9	0.0325	Cavusgil_S	0.0157	Nakip_M
10	0.0294	Kurtulus_K	0.0147	Erden_D

Rank	wos-2008-c	
1	0.0158	Akdogu_E
2	0.0113	Yuksel_A
3	0.0105	Ger_G
4	0.0092	Kirdar_MG
5	0.0089	Bac_M
6	0.0072	Sandikci_O
7	0.0064	Usdiken_B
8	0.0063	Ozgener_S
9	0.0062	Tansel_A
10	0.0058	Aycan_Z

* Complete Exclusivity - knowledge (complete exclusivity)
  - Detects authors who have published on matters that no other author has.

Input network(s): Knowledge Dissemination Network

Rank	wos-1990-c		wos-1999-c	
1	0.0588	Leblebici_H	0.0588	Ger_G
2	0.0588	Erden_D	0.0294	Ersoy_M
3	0.0294	Kurtulus_K	0.0221	Alexander_M
4	0.0294	Usdiken_B	0.0147	Leblebici_H

5	0.0000	0.0147	Nakip_M
6	0.0000	0.0147	Bac_M
7	0.0000	0.0147	Erden_D
8	0.0000	0.0074	Berkman_U
9	0.0000	0.0074	Kurtulus_K
10	0.0000	0.0074	Usdiken_B

Rank	wos-2008-c	
1	0.0156	Akdogu_E
2	0.0113	Yuksel_A
3	0.0085	Kirdar_MG
4	0.0071	Bac_M
5	0.0057	Tansel_A
6	0.0057	Aycan_Z
7	0.0057	Parkan_B
8	0.0057	Ozgener_S
9	0.0042	Ger_G
10	0.0042	Uz_A

Appendix L

Key Authors in WoS Database: 1980-2008

Figure L.1: Sectoral distribution of case studies: 1922-1959

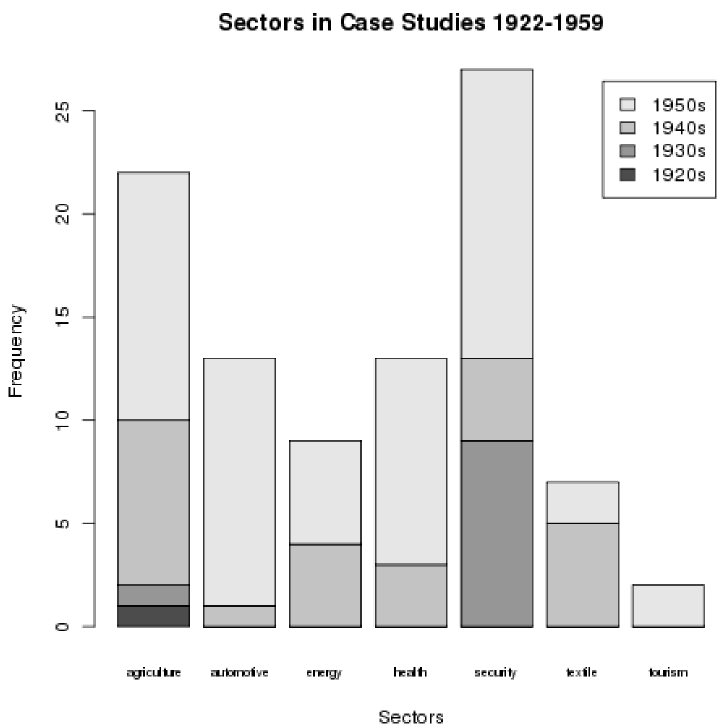


Figure L.2: Sectoral distribution of case studies: 1940-1969

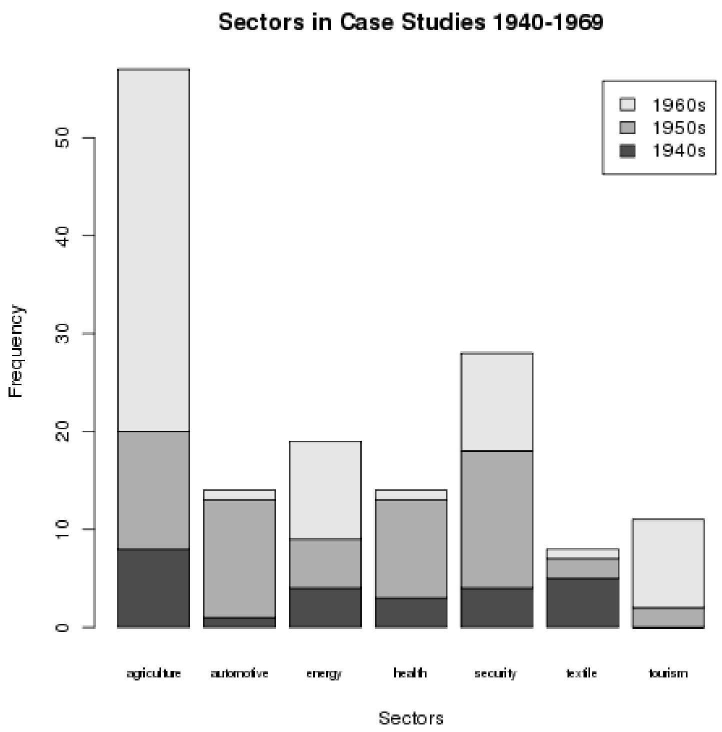


Figure L.3: Sectoral distribution of case studies: 1960-1989

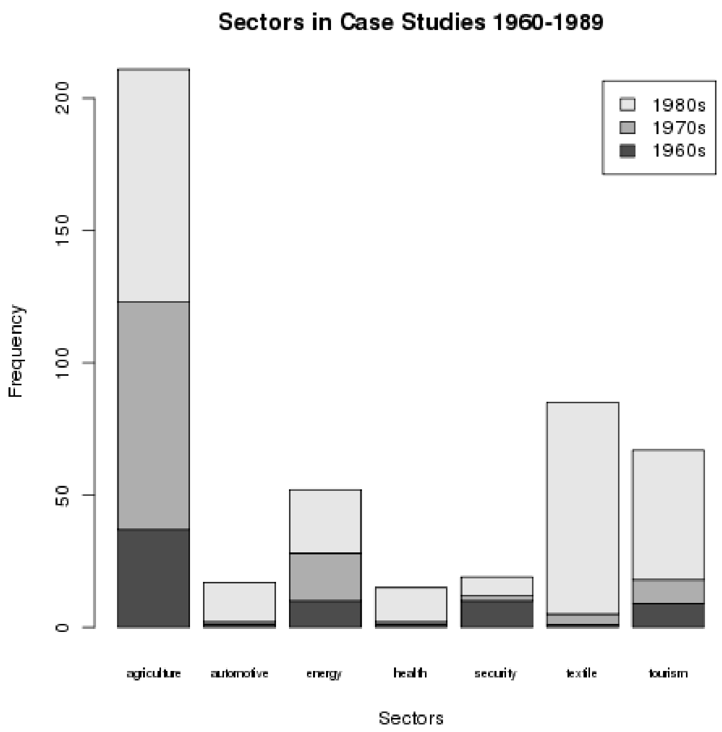
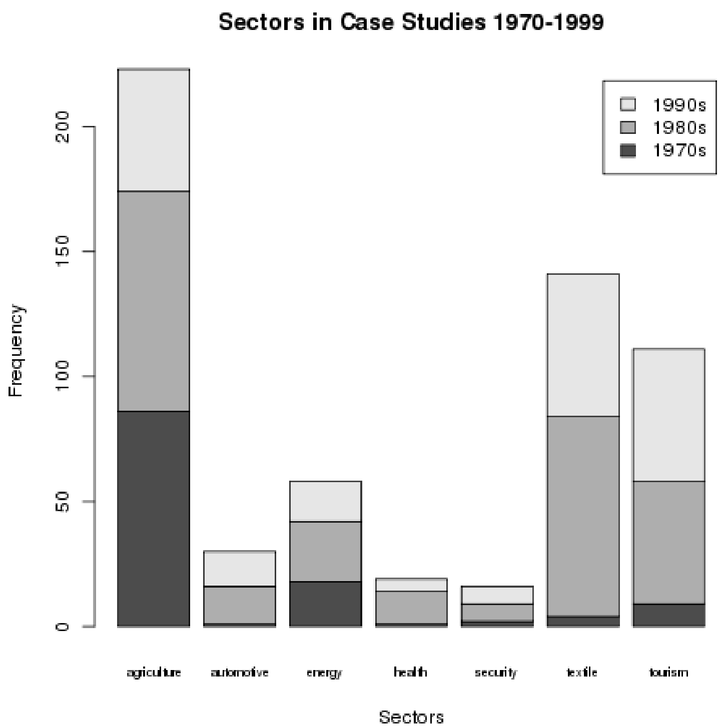


Figure L.4: Sectoral distribution of case studies: 1970-1999



Appendix M

Key Authors in National Level Publications: 1922 -2008

```
Key Entities: Authors who have published in Turkey.
Periods:
 - tr-1930-c: Covers years 1923-1930
 - tr-1940-c: Covers years up to 1940
 - tr-1950-c: Covers years up to 1950
 - tr-1960-c: Covers years up to 1960
 - tr-1970-c: Covers years up to 1970
 - tr-1980-c: Covers years up to 1980

* In-the-Know (total degree centrality)
  - The Total Degree Centrality of an author is his/her
    total degree normalized.

      Input network(s): Coauthorship Network

      Rank tr-1930-c                           tr-1940-c
      ---- ------ ------------------------- ------ --------------
      1    0.0000 Nuri_O                    0.0185 Burhan_M
      2    0.0000 Senih_H                   0.0185 Rosler_R
```

3	0.0000	Izzet_M	0.0000	Nuri_O
4	0.0000	Sabri_N	0.0000	Nadi_Y
5	0.0000	Zekeriya_S	0.0000	Cemal_
6	0.0000	Burhaneddin_	0.0000	Sevket_
7	-	-	0.0000	Naci_
8	-	-	0.0000	S._
9	-	-	0.0000	C._
10	-	-	0.0000	Ismail_T

Rank	tr-1950-c		tr-1960-c	
1	0.0053	Burhan_M	0.0073	Ferman_C
2	0.0053	Rosler_R	0.0073	Yildirim_C
3	0.0053	Erdinc_H	0.0073	Yildirim_S
4	0.0053	Akurgali_F	0.0049	Mccloskey_JF
5	0.0000	Kurtbek_S	0.0049	Trefethen_FN
6	0.0000	Nuri_O	0.0049	Tekes_A
7	0.0000	Nadi_Y	0.0049	Mestenhauser_K
8	0.0000	Peker_K	0.0024	Mihcioglu_C
9	0.0000	Ruma_S	0.0024	Goode_CE
10	0.0000	Kokturk_N	0.0024	Feyzioglu_BN

Rank	tr-1970-c		tr-1980-c	
1	0.0026	Ferman_C	0.0036	Cinar_U
2	0.0026	Yildirim_C	0.0036	Erkmenol_A
3	0.0026	Yildirim_S	0.0031	Yavas_U
4	0.0026	Lilienstern_VR	0.0031	Akcasu_S
5	0.0026	Neumann_J	0.0027	Koksal_AU
6	0.0026	Ruhle_H	0.0027	Sumer_E
7	0.0026	Hermann_A	0.0027	Tezcan_S
8	0.0017	Hiscox_C	0.0027	Baser_M
9	0.0017	Luyendyk_WR	0.0027	Aras_R

```
10   0.0017 Chappel_LS                 0.0018 Tatar_T

Rank tr-1990-c                         tr-1999-c
---- ------ ------------------------- ------ ----------
1    0.0024 Demir_MH                   0.0026 Ozalp_I
2    0.0024 Yilmaz_C                   0.0024 Yilmaz_C
3    0.0019 Cinar_U                    0.0019 Ozgen_H
4    0.0019 Erkmenol_A                 0.0017 Demir_MH
5    0.0017 Ozalp_I                    0.0017 Bozkurt_Y
6    0.0017 Yavas_U                    0.0014 Cinar_U
7    0.0017 Akcasu_S                   0.0014 Erkmenol_A
8    0.0014 Koksal_AU                  0.0012 Yavas_U
9    0.0014 Baser_M                    0.0012 Akcasu_S
10   0.0014 Sumer_E                    0.0010 Katrinli_AE


Rank tr-2008-c
---- -------- ---------
1    0.0024   Yilmaz_C
2    0.0024   Ozgen_H
3    0.0023   Ozalp_I
4    0.0017   Demir_MH
5    0.0015   Bozkurt_Y
6    0.0012   Ceylan_A
7    0.0012   Dogan_A
8    0.0012   Ersoy_A
9    0.0012   Cinar_U
10   0.0012   Erkmenol_A


* Number of Cliques (clique count)
  - The number of distinct cliques to which each author belongs.
```

Input network(s): Coauthorship Network

Rank	tr-1930-c		tr-1940-c	
1	0.0000	Nuri_O	0.0000	Nuri_O
2	0.0000	Senih_H	0.0000	Nadi_Y
3	0.0000	Izzet_M	0.0000	Cemal_
4	0.0000	Sabri_N	0.0000	Sevket_
5	0.0000	Zekeriya_S	0.0000	Naci_
6	0.0000	Burhaneddin_	0.0000	S._
7	-	-	0.0000	C._
8	-	-	0.0000	Ismail_T
9	-	-	0.0000	Ali_M
10	-	-	0.0000	Cemal_L

Rank	tr-1950-c		tr-1960-c	
1	0.0000	Kurtbek_S	1.0000	Mccloskey_JF
2	0.0000	Nuri_O	1.0000	Ferman_C
3	0.0000	Nadi_Y	1.0000	Trefethen_FN
4	0.0000	Peker_K	0.0000	Schmalenbach_E
5	0.0000	Ruma_S	0.0000	Tarkan_F
6	0.0000	Kokturk_N	0.0000	Edey_HC
7	0.0000	Egeli_MH	0.0000	Hamilton_W
8	0.0000	Kandan_S	0.0000	Mihcioglu_C
9	0.0000	Alicli_S	0.0000	Goode_CE
10	0.0000	Kiper_C	0.0000	Feyzioglu_BN

Rank	tr-1970-c		tr-1980-c	
1	1.0000	Hiscox_C	2.0000	Yavas_U
2	1.0000	Luyendyk_WR	2.0000	Erkmenol_A
3	1.0000	Chappel_LS	2.0000	Akcasu_S

```
4    1.0000 Mccloskey_JF                1.0000 Tatar_T
5    1.0000 Ferman_C                    1.0000 Cinar_U
6    1.0000 Trefethen_FN                1.0000 Hiscox_C
7    1.0000 Ergun_T                     1.0000 Luyendyk_WR
8    1.0000 Tokcan_C                    1.0000 Chappel_LS
9    1.0000 Oge_U                       1.0000 Kirac_C
10   1.0000 Lilienstern_VR              1.0000 Mccloskey_JF

Rank tr-1990-c                          tr-1999-c
---- ------ ------------------------- ------ ------------
1    2.0000 Ozalp_I                     4.0000 Ozalp_I
2    2.0000 Yavas_U                     2.0000 Yilmaz_C
3    2.0000 Demir_MH                    2.0000 Gulerman_A
4    2.0000 Oktav_M                     2.0000 Yavas_U
5    2.0000 Uner_N                      2.0000 Demir_MH
6    2.0000 Erkmenol_A                  2.0000 Oktav_M
7    2.0000 Akcasu_S                    2.0000 Uner_N
8    1.0000 Tatar_T                     2.0000 Erkmenol_A
9    1.0000 Cinar_U                     2.0000 Sarikaya_H
10   1.0000 Hiscox_C                    2.0000 Ozmen_ONT

Rank tr-2008-c
---- -------- --------------------------------------
1    4.0000   Ozalp_I
2    3.0000   Celik_A
3    3.0000   Arbak_Y
4    2.0000   Ceylan_A
5    2.0000   Dogan_A
6    2.0000   Demir_Y
7    2.0000   Ozturk_E
8    2.0000   Donmez_A
9    2.0000   Ersoy_A
10   2.0000   Yilmaz_C
```

* Most Knowledge (row degree centrality)
  - The Knowledge Centrality of an author is his/her normalized out-degree in AxK.

Input network(s): Knowledge Dissemination Network

Rank	tr-1930-c		tr-1940-c	
1	0.4211	Burhaneddin_	0.2206	Burhan_M
2	0.2632	Nuri_O	0.2059	Apaydin_H
3	0.2105	Senih_H	0.1765	S._
4	0.1053	Zekeriya_S	0.1471	Gurgen_R
5	0.0526	Izzet_M	0.1324	Pasin_S
6	0.0526	Sabri_N	0.1176	Burhaneddin_
7	-	-	0.1029	Kadri_
8	-	-	0.0882	Naci_
9	-	-	0.0882	Hamdi_Y
10	-	-	0.0882	Kadri_M

Rank	tr-1950-c		tr-1960-c	
1	0.3707	Sahinbas_S	0.3333	Sahinbas_S
2	0.2241	Ozelmas_E	0.2708	Tosun_K
3	0.2069	Tumen_L	0.2708	Ervardar_F
4	0.1897	S._N	0.2431	Durukal_HS
5	0.1724	Arkun_OF	0.2431	Arkun_OF
6	0.1638	Kiper_C	0.2292	Ferman_C
7	0.1552	Balkanli_A	0.2083	Hicsasmaz_M
8	0.1552	Aybar_S	0.1806	Ozelmas_E
9	0.1466	Dincer_C	0.1667	Balkanli_A
10	0.1379	Bayman_ON	0.1667	Tumen_L

Rank	tr-1970-c		tr-1980-c	
1	1.0000	Tosun_K	1.0000	Tosun_K
2	0.6493	Kilkis_Y	0.3121	Kilkis_Y
3	0.5829	Ervardar_F	0.2456	Ervardar_F
4	0.5118	Sahinbas_S	0.2144	Kurtulus_K
5	0.3886	Karayalcin_I	0.1723	Arikan_T
6	0.2986	Uyguner_M	0.1696	Karayalcin_I
7	0.2796	Podol_R	0.1655	Askun_IC
8	0.2464	Arkun_OF	0.1533	Sahinbas_S
9	0.2227	Kazgan_H	0.1479	Uyguner_M
10	0.2085	Buktas_M	0.1425	Eren_E

Rank	tr-1990-c		tr-1999-c	
1	1.0000	Tosun_K	1.0000	Tosun_K
2	0.2995	Kilkis_Y	0.2995	Kilkis_Y
3	0.2944	Ozok_AF	0.2944	Ozok_AF
4	0.2348	Kurtulus_K	0.2348	Kurtulus_K
5	0.2335	Ervardar_F	0.2335	Ervardar_F
6	0.2005	Askun_IC	0.2069	Ozalp_I
7	0.2005	Eren_E	0.2018	Eren_E
8	0.1662	Karayalcin_I	0.2005	Askun_IC
9	0.1612	Arikan_T	0.1739	Gulerman_A
10	0.1561	Gulerman_A	0.1662	Karayalcin_I

Rank	tr-2008-c	
1	1.0000	Tosun_K
2	0.2995	Kilkis_Y
3	0.2944	Ozok_AF
4	0.2373	Kurtulus_K
5	0.2335	Ervardar_F

```
6    0.2069   Ozalp_I
7    0.2043   Eren_E
8    0.2005   Askun_IC
9    0.1739   Gulerman_A
10   0.1662   Karayalcin_I


* Leader of Strong Clique (eigenvector centrality)
  - Calculates the principal eigenvector of the network.
    An author is central to the extent that his/her co-authors
    are central.

      Input network(s): Coauthorship Network

      Rank tr-1930-c                          tr-1940-c
      ---- ------ ------------------------- ------ ----------
      1    0.0000 Nuri_O                      1.0000 Burhan_M
      2    0.0000 Senih_H                     1.0000 Rosler_R
      3    0.0000 Izzet_M                     0.0000 Nuri_O
      4    0.0000 Sabri_N                     0.0000 Nadi_Y
      5    0.0000 Zekeriya_S                  0.0000 Cemal_
      6    0.0000 Burhaneddin_                0.0000 Sevket_
      7    -      -                           0.0000 Naci_
      8    -      -                           0.0000 S._
      9    -      -                           0.0000 C._
      10   -      -                           0.0000 Ismail_T

      Rank tr-1950-c                          tr-1960-c
      ---- ------ ------------------------- ------ ------------
      1    1.0000 Burhan_M                    1.0000 Ferman_C
      2    1.0000 Rosler_R                    1.0000 Mihcioglu_C
      3    1.0000 Erdinc_H                    1.0000 Goode_CE
      4    1.0000 Akurgali_F                  1.0000 Burhan_M
```

5	0.0000	Kurtbek_S	1.0000	Rosler_R
6	0.0000	Nuri_O	1.0000	Erdinc_H
7	0.0000	Nadi_Y	1.0000	Akurgali_F
8	0.0000	Peker_K	1.0000	Yildirim_C
9	0.0000	Ruma_S	1.0000	Tekes_A
10	0.0000	Kokturk_N	1.0000	Yildirim_S

Rank	tr-1970-c		tr-1980-c	
1	1.0000	Kizilkaya_O	1.0000	Tatar_T
2	1.0000	Hiscox_C	1.0000	Kizilkaya_O
3	1.0000	Luyendyk_WR	1.0000	Kazgan_H
4	1.0000	Chappel_LS	1.0000	Askun_IC
5	1.0000	Unver_O	1.0000	Cinar_U
6	1.0000	Sen_S	1.0000	Hiscox_C
7	1.0000	Archer_SH	1.0000	Luyendyk_WR
8	1.0000	D'ambrosio_CA	1.0000	Chappel_LS
9	1.0000	Weston_JF	1.0000	Sen_S
10	1.0000	Brigham_FE	1.0000	Aktan_F

Rank	tr-1990-c		tr-1999-c	
1	1.0000	Ozok_AF	1.0000	Senturk_O
2	1.0000	Serarslan_MN	1.0000	Mahmutoglu_Y
3	1.0000	Koksal_S	1.0000	Goktan_E
4	1.0000	Tatar_T	1.0000	Serarslan_MN
5	1.0000	Ozalp_I	1.0000	Tek_OB
6	1.0000	Cakici_L	1.0000	Ozer_PS
7	1.0000	Kizilkaya_O	1.0000	Suer_I
8	1.0000	Kazgan_H	1.0000	Senol_N
9	1.0000	Askun_IC	1.0000	Unusan_C
10	1.0000	Bozkurt_R	1.0000	Karatepe_OM

Rank	tr-2008-c	
1	1.0000	Unsal_A
2	1.0000	Demirel_N
3	1.0000	Yardimcioglu_M
4	1.0000	Oskay_C
5	1.0000	Kubar_Y
6	1.0000	Aldemir_S
7	1.0000	Sumer_FE
8	1.0000	Satir_C
9	1.0000	Kurt_S
10	1.0000	Berber_M

* Acts as a Hub (hub centrality)
  - An author is hub-central to the extent that his/her out-links are to authors that have many in-links.

Input network(s): Coauthorship Network

Rank	tr-1930-c		tr-1940-c	
1	0.0000	Nuri_O	0.0000	Nuri_O
2	0.0000	Senih_H	0.0000	Nadi_Y
3	0.0000	Izzet_M	0.0000	Cemal_
4	0.0000	Sabri_N	0.0000	Sevket_
5	0.0000	Zekeriya_S	0.0000	Naci_
6	0.0000	Burhaneddin_	0.0000	S._
7	-	-	0.0000	C._
8	-	-	0.0000	Ismail_T
9	-	-	0.0000	Ali_M
10	-	-	0.0000	Cemal_L

Rank tr-1950-c tr-1960-c

1	0.0000	Kurtbek_S	1.0000	Ferman_C
2	0.0000	Nuri_O	0.8546	Mccloskey_JF
3	0.0000	Nadi_Y	0.8546	Trefethen_FN
4	0.0000	Peker_K	0.4608	Feyzioglu_BN
5	0.0000	Ruma_S	0.0000	Schmalenbach_E
6	0.0000	Kokturk_N	0.0000	Tarkan_F
7	0.0000	Egeli_MH	0.0000	Edey_HC
8	0.0000	Kandan_S	0.0000	Hamilton_W
9	0.0000	Alicli_S	0.0000	Mihcioglu_C
10	0.0000	Kiper_C	0.0000	Goode_CE

Rank	tr-1970-c		tr-1980-c	
1	1.0000	Hiscox_C	1.0000	Tatar_T
2	1.0000	Luyendyk_WR	1.0000	Cinar_U
3	1.0000	Chappel_LS	1.0000	Hiscox_C
4	1.0000	Ferman_C	1.0000	Luyendyk_WR
5	1.0000	Ergun_T	1.0000	Chappel_LS
6	1.0000	Tokcan_C	1.0000	Kirac_C
7	1.0000	Oge_U	1.0000	Aksan_Z
8	1.0000	Lilienstern_VR	1.0000	Ferman_C
9	1.0000	Neumann_J	1.0000	Eraktan_SN
10	1.0000	Ruhle_H	1.0000	Inan_HI

Rank	tr-1990-c		tr-1999-c	
1	1.0000	Ozok_AF	1.0000	Goktan_E
2	1.0000	Tatar_T	1.0000	Serarslan_MN
3	1.0000	Ozalp_I	1.0000	Ozer_PS
4	1.0000	Cinar_U	1.0000	Senol_N
5	1.0000	Hiscox_C	1.0000	Unusan_C
6	1.0000	Luyendyk_WR	1.0000	Karatepe_OM

```
7    1.0000 Chappel_LS                 1.0000 Ayhan_DY
8    1.0000 Katrinli_AE                1.0000 Tatoglu_E
9    1.0000 Alpay_G                    1.0000 Yilmaz_C
10   1.0000 Mavis_F                    1.0000 Tatar_T

Rank tr-2008-c
---- -------- ------------------------------------
1    1.0000   Unsal_A
2    1.0000   Barisik_S
3    1.0000   Cevik_EI
4    1.0000   Bayraktutan_Y
5    1.0000   Ceylan_A
6    1.0000   Ercis_A
7    1.0000   Erdem_MS
8    1.0000   Erkan_G
9    1.0000   Sezgin_M
10   1.0000   Bardakci_A

* Potentially Influential (betweenness centrality)
  - The Betweenness Centrality of author v in a network is
    defined as: across all author pairs that have a shortest
    path containing v, the percentage that pass through v.

    Input network(s): Coauthorship Network

    Rank tr-1930-c                         tr-1940-c
    ---- ------ ------------------------- ------ ----------
    1    0.0000 Nuri_O                     0.0000 Nuri_O
    2    0.0000 Senih_H                    0.0000 Nadi_Y
    3    0.0000 Izzet_M                    0.0000 Cemal_
    4    0.0000 Sabri_N                    0.0000 Sevket_
    5    0.0000 Zekeriya_S                 0.0000 Naci_
    6    0.0000 Burhaneddin_               0.0000 S._
```

7	-	-	0.0000	C._
8	-	-	0.0000	Ismail_T
9	-	-	0.0000	Ali_M
10	-	-	0.0000	Cemal_L

Rank	tr-1950-c		tr-1960-c	
1	0.0000	Kurtbek_S	0.0000	Ferman_C
2	0.0000	Nuri_O	0.0000	Schmalenbach_E
3	0.0000	Nadi_Y	0.0000	Tarkan_F
4	0.0000	Peker_K	0.0000	Edey_HC
5	0.0000	Ruma_S	0.0000	Hamilton_W
6	0.0000	Kokturk_N	0.0000	Mccloskey_JF
7	0.0000	Egeli_MH	0.0000	Trefethen_FN
8	0.0000	Kandan_S	0.0000	Mihcioglu_C
9	0.0000	Alicli_S	0.0000	Goode_CE
10	0.0000	Kiper_C	0.0000	Feyzioglu_BN

Rank	tr-1970-c		tr-1980-c	
1	0.0000	Ferman_C	0.0000	Erkmenol_A
2	0.0000	Kizilkaya_O	0.0000	Yavas_U
3	0.0000	Miller_FB	0.0000	Akcasu_S
4	0.0000	Kazgan_H	0.0000	Cinar_U
5	0.0000	Neng_E	0.0000	Acil_AF
6	0.0000	Ozturkcu_N	0.0000	Ferman_C
7	0.0000	Nis'el_S	0.0000	Ozbasar_S
8	0.0000	Roos_NP	0.0000	Demir_MH
9	0.0000	Etzioni_A	0.0000	Dogu_I
10	0.0000	Thompson_VA	0.0000	Yucel_G

Rank	tr-1990-c		tr-1999-c	

```
1    0.0000 Yilmaz_C                  0.0000 Yilmaz_C
2    0.0000 Demir_MH                  0.0000 Demir_MH
3    0.0000 Dogan_A                   0.0000 Dogan_A
4    0.0000 Aydin_A                   0.0000 Tutek_H
5    0.0000 Ozguven_C                 0.0000 Oncu_S
6    0.0000 Kavas_A                   0.0000 Ecevit_Z
7    0.0000 Akar_C                    0.0000 Ay_C
8    0.0000 Cinar_U                   0.0000 Ozkan_A
9    0.0000 Erkmenol_A                0.0000 Kavas_A
10   0.0000 Yavas_U                   0.0000 Aydin_A

Rank tr-2008-c
---- -------- ----------------------------------------
1    0.0000   Yilmaz_C
2    0.0000   Demir_MH
3    0.0000   Dogan_A
4    0.0000   Tutek_H
5    0.0000   Oncu_S
6    0.0000   Ecevit_Z
7    0.0000   Ay_C
8    0.0000   Ozkan_A
9    0.0000   Aydin_A
10   0.0000   Keskin_H


* Connects Groups (high betweenness and low degree)
  - The ratio of betweenness to degree centrality;
    higher scores mean that a author is a potential
    boundary spanner.

    Input network(s): Coauthorship Network

    Rank tr-1930-c                     tr-1940-c
```

1	0.0000	Nuri_O	0.0000	Nuri_O
2	0.0000	Senih_H	0.0000	Nadi_Y
3	0.0000	Izzet_M	0.0000	Cemal_
4	0.0000	Sabri_N	0.0000	Sevket_
5	0.0000	Zekeriya_S	0.0000	Naci_
6	0.0000	Burhaneddin_	0.0000	S._
7	-	-	0.0000	C._
8	-	-	0.0000	Ismail_T
9	-	-	0.0000	Ali_M
10	-	-	0.0000	Cemal_L

Rank	tr-1950-c		tr-1960-c	
1	0.0000	Kurtbek_S	1.0000	Ferman_C
2	0.0000	Nuri_O	0.0000	Schmalenbach_E
3	0.0000	Nadi_Y	0.0000	Tarkan_F
4	0.0000	Peker_K	0.0000	Edey_HC
5	0.0000	Ruma_S	0.0000	Hamilton_W
6	0.0000	Kokturk_N	0.0000	Mccloskey_JF
7	0.0000	Egeli_MH	0.0000	Trefethen_FN
8	0.0000	Kandan_S	0.0000	Mihcioglu_C
9	0.0000	Alicli_S	0.0000	Goode_CE
10	0.0000	Kiper_C	0.0000	Feyzioglu_BN

Rank	tr-1970-c		tr-1980-c	
1	1.0000	Ferman_C	0.1690	Yavas_U
2	0.0000	Kizilkaya_O	0.1593	Erkmenol_A
3	0.0000	Miller_FB	0.1560	Akcasu_S
4	0.0000	Kazgan_H	0.0910	Acil_AF
5	0.0000	Neng_E	0.0910	Cinar_U
6	0.0000	Ozturkcu_N	0.0607	Ferman_C

```
7    0.0000 Nis'el_S                 0.0455 Demir_MH
8    0.0000 Roos_NP                  0.0455 Dogu_I
9    0.0000 Etzioni_A                0.0455 Yucel_G
10   0.0000 Thompson_VA              0.0455 Akbulut_T

Rank tr-1990-c                       tr-1999-c
---- ------ ------------------------ ------ ------------------------
1    0.1317 Aydin_A                  0.0784 Ay_C
2    0.1198 Yilmaz_C                 0.0724 Tutek_H
3    0.0991 Dogan_A                  0.0679 Ecevit_Z
4    0.0979 Demir_MH                 0.0650 Dogan_A
5    0.0690 Ozguven_C                0.0648 Yilmaz_C
6    0.0690 Akar_C                   0.0640 Demir_MH
7    0.0460 Kavas_A                  0.0536 Aydin_A
8    0.0209 Yelken_N                 0.0536 Unal_AN
9    0.0188 Saatcioglu_O             0.0523 Ozkan_A
10   0.0139 Oktav_M                  0.0515 Oncu_S

Rank tr-2008-c
---- -------- ---------------------------------------
1    0.0553   Ecevit_Z
2    0.0521   Aydin_A
3    0.0486   Tutek_H
4    0.0461   Ay_C
5    0.0433   Dogan_A
6    0.0429   Yilmaz_C
7    0.0420   Demir_MH
8    0.0355   Unal_AN
9    0.0347   Ozkan_A
10   0.0343   Oncu_S
```

```
* Specialization - knowledge (relatively unique)
  - Detects authors who have published on matters that
```

comparatively few other authors have published.

Input network(s): Knowledge Dissemination Network

Rank	tr-1930-c		tr-1940-c	
1	0.2493	Burhaneddin_	0.0672	Apaydin_H
2	0.2105	Senih_H	0.0588	Ekrem_A
3	0.1966	Nuri_O	0.0344	Burhaneddin_
4	0.1053	Zekeriya_S	0.0316	Gurgen_R
5	0.0526	Izzet_M	0.0314	Yazir_MH
6	0.0526	Sabri_N	0.0257	Burhan_M
7	-	-	0.0228	Nuri_O
8	-	-	0.0228	Senih_H
9	-	-	0.0221	Somer_LO
10	-	-	0.0201	Gasson_HN

Rank	tr-1950-c		tr-1960-c	
1	0.0205	Ete_M	0.0208	Ozcicekci_B
2	0.0204	Gunel_S	0.0139	Burhaneddin_
3	0.0193	Kiper_C	0.0104	Ete_M
4	0.0173	Burhaneddin_	0.0104	Demirozu_O
5	0.0172	Kalkandelen_AH	0.0095	Bayman_ON
6	0.0124	Bayman_ON	0.0095	Gunel_S
7	0.0121	Dincer_C	0.0095	Tumay_T
8	0.0098	Yazir_MH	0.0095	Basar_M
9	0.0098	Gasson_HN	0.0095	Ustundal_M
10	0.0091	Nuri_O	0.0095	Guvenal_N

Rank	tr-1970-c		tr-1980-c	
1	0.0077	Gulerman_A	0.0070	Tosun_K

2	0.0073	Tosun_K	0.0048	Ekin_DB
3	0.0058	Demirozu_O	0.0047	Eren_E
4	0.0058	Bayraktar_B	0.0047	Demirozu_O
5	0.0058	Ete_M	0.0046	Korkmaz_HF
6	0.0058	Uyguner_M	0.0046	Gulerman_A
7	0.0057	Kilkis_Y	0.0046	Ete_M
8	0.0054	Ozcicekci_B	0.0046	Uyguner_M
9	0.0051	Ervardar_F	0.0046	Ozcicekci_B
10	0.0051	Burhaneddin_	0.0046	Erimcag_HC

Rank	tr-1990-c		tr-1999-c	
1	0.0049	Tosun_K	0.0041	Demirozu_O
2	0.0044	Demirozu_O	0.0041	Gulerman_A
3	0.0043	Gulerman_A	0.0041	Korkmaz_HF
4	0.0043	Korkmaz_HF	0.0041	Fidaner_C
5	0.0043	Fidaner_C	0.0041	Nuri_O
6	0.0043	Ercis_A	0.0041	Ismail_T
7	0.0043	Ete_M	0.0041	Bodur_M
8	0.0043	Uyguner_M	0.0041	Segundo_KD
9	0.0043	Altintas_M	0.0041	Adives_I
10	0.0043	Sahin_M	0.0041	Ileri_SN

Rank	tr-2008-c	
1	0.0074	Unsal_P
2	0.0051	Samiloglu_F
3	0.0051	Tasci_D
4	0.0051	Cosar_N
5	0.0051	Akinci_Z
6	0.0047	Ozturk_MB
7	0.0040	Ozturk_L
8	0.0035	Ozdevecioglu_M

9	0.0035	Karacaoglu_K
10	0.0034	Toksari_M

* Complete Exclusivity - knowledge (complete exclusivity)
  - Detects authors who have published on matters that no other author has.

Input network(s): Knowledge Dissemination Network

Rank	tr-1930-c		tr-1940-c	
1	0.2105	Senih_H	0.0588	Ekrem_A
2	0.2105	Burhaneddin_	0.0588	Apaydin_H
3	0.1579	Nuri_O	0.0294	Gurgen_R
4	0.1053	Zekeriya_S	0.0294	Yazir_MH
5	0.0526	Izzet_M	0.0294	Burhaneddin_
6	0.0526	Sabri_N	0.0147	Nuri_O
7	-	-	0.0147	Ismail_T
8	-	-	0.0147	Gasson_HN
9	-	-	0.0147	Senih_H
10	-	-	0.0147	Teksen_H

Rank	tr-1950-c		tr-1960-c	
1	0.0172	Gunel_S	0.0208	Ozcicekci_B
2	0.0172	Kalkandelen_AH	0.0139	Burhaneddin_
3	0.0172	Ete_M	0.0069	Nuri_O
4	0.0172	Burhaneddin_	0.0069	Tuna_O
5	0.0086	Nuri_O	0.0069	Sari_N
6	0.0086	Kiper_C	0.0069	Gunel_S
7	0.0086	Dincer_C	0.0069	Kop_KK

8	0.0086	Tuna_O	0.0069	Durukal_HS
9	0.0086	Ulubay_F	0.0069	Ismail_T
10	0.0086	Sari_N	0.0069	Ocal_O

Rank	tr-1970-c		tr-1980-c	
1	0.0051	Gulerman_A	0.0046	Gursakal_N
2	0.0051	Nuri_O	0.0046	Burat_K
3	0.0051	Kilkis_Y	0.0046	Gulerman_A
4	0.0051	Tosun_K	0.0046	Korkmaz_HF
5	0.0051	Koseer_O	0.0046	Nuri_O
6	0.0051	Karahan_O	0.0046	Tosun_K
7	0.0051	Ismail_T	0.0046	Delevi_M
8	0.0051	Dikel_M	0.0046	Sahin_M
9	0.0051	Ozcicekci_B	0.0046	Ismail_T
10	0.0051	Senih_H	0.0046	Dikel_M

Rank	tr-1990-c		tr-1999-c	
1	0.0043	Altintas_M	0.0041	Gulerman_A
2	0.0043	Sahin_M	0.0041	Fidaner_C
3	0.0043	Burat_K	0.0041	Korkmaz_HF
4	0.0043	Gulerman_A	0.0041	Nuri_O
5	0.0043	Saatcioglu_O	0.0041	Ismail_T
6	0.0043	Fidaner_C	0.0041	Bodur_M
7	0.0043	Korkmaz_HF	0.0041	Segundo_KD
8	0.0043	Ulusoy_H	0.0041	Adives_I
9	0.0043	Nuri_O	0.0041	Ileri_SN
10	0.0043	Ercis_A	0.0041	Ete_M

Rank	tr-2008-c	

1	0.0068	Unsal_P
2	0.0051	Tasci_D
3	0.0051	Samiloglu_F
4	0.0051	Cosar_N
5	0.0051	Akinci_Z
6	0.0034	Cetin_M
7	0.0034	Toksari_M
8	0.0034	Batirel_OF
9	0.0034	Ozturk_MB
10	0.0034	Oguzlar_A

Appendix N

Key Concepts in Turkish Management Field: 1922-2008

```
Key Entities: Knowledge in Turkish management academia.

Periods: 1922 to 1999, Cumulative

* Dominant Knowledge (total degree centrality)
  - The Total Degree Centrality of a knowledge is the normalized
    value of its degree centrality.

      Input: all networks (AxK, KxK)

      Rank tr-1930-c                        tr-1940-c
      ---- ------ ------------------------- ------ ----------
      1    0.4762 organizations             0.8783 service
      2    0.3810 organizing                0.6321 army
      3    0.3810 structure                 0.5850 logistics
      4    0.3333 sport clubs               0.4395 transportation
      5    0.2143 security sector           0.3783 management
      6    0.2143 modernization             0.2450 administration
      7    0.2143 army                      0.2072 organizations
```

8	0.2143	service	0.1925	government
9	0.1667	models	0.1832	workers
10	0.1667	accounting	0.1633	human development
11	0.1667	knowledge	0.1580	book keeping
12	0.1667	methods	0.1507	supply chain
13	0.1667	discipline	0.1454	structure
14	0.1667	control	0.1182	development
15	0.1429	management	0.1036	roles
16	0.1429	agriculturing	0.1016	economy
17	0.0714	municipality	0.0963	organizing
18	0.0238	government	0.0943	methods
19	0.0238	book keeping	0.0817	accounting
20	-	-	0.0817	control

Rank	tr-1940-c		tr-1950-c	
1	0.8783	service	0.7703	financing
2	0.6321	army	0.7434	accounting
3	0.5850	logistics	0.4654	service
4	0.4395	transportation	0.4129	work
5	0.3783	management	0.3597	workers
6	0.2450	administration	0.2852	management
7	0.2072	organizations	0.2781	business
8	0.1925	government	0.2647	book keeping
9	0.1832	workers	0.2642	logistics
10	0.1633	human development	0.2272	army
11	0.1580	book keeping	0.2050	economy
12	0.1507	supply chain	0.1994	manufacturing
13	0.1454	structure	0.1989	structure
14	0.1182	development	0.1955	organizing
15	0.1036	roles	0.1941	organizations
16	0.1016	economy	0.1763	transportation
17	0.0963	organizing	0.1691	industry

18	0.0943	methods	0.1590	taxing
19	0.0817	accounting	0.1321	bookkeeper
20	0.0817	control	0.1138	government

Rank	tr-1950-c		tr-1960-c	
1	0.7703	financing	0.7303	accounting
2	0.7434	accounting	0.6048	financing
3	0.4654	service	0.3879	service
4	0.4129	work	0.3314	business
5	0.3597	workers	0.2846	management
6	0.2852	management	0.2769	work
7	0.2781	business	0.2450	economy
8	0.2647	book keeping	0.2353	book keeping
9	0.2642	logistics	0.2179	technology
10	0.2272	army	0.2159	manufacturing
11	0.2050	economy	0.2046	transportation
12	0.1994	manufacturing	0.1942	workers
13	0.1989	structure	0.1867	logistics
14	0.1955	organizing	0.1825	industry
15	0.1941	organizations	0.1669	human development
16	0.1763	transportation	0.1655	organizations
17	0.1691	industry	0.1378	trade
18	0.1590	taxing	0.1271	costing
19	0.1321	bookkeeper	0.1161	taxing
20	0.1138	government	0.1115	army

Rank	tr-1960-c		tr-1970-c	
1	0.7303	accounting	0.5925	management
2	0.6048	financing	0.5086	business
3	0.3879	service	0.4785	accounting
4	0.3314	business	0.4062	financing

5	0.2846	management	0.3963	economy
6	0.2769	work	0.3275	work
7	0.2450	economy	0.3003	human development
8	0.2353	book keeping	0.2990	service
9	0.2179	technology	0.2904	manufacturing
10	0.2159	manufacturing	0.2686	industry
11	0.2046	transportation	0.2504	organizations
12	0.1942	workers	0.2406	technology
13	0.1867	logistics	0.2269	workers
14	0.1825	industry	0.2180	trade
15	0.1669	human development	0.1755	training
16	0.1655	organizations	0.1695	knowledge
17	0.1378	trade	0.1686	book keeping
18	0.1271	costing	0.1431	efficiency
19	0.1161	taxing	0.1321	transportation
20	0.1115	army	0.1201	control

Rank	tr-1970-c		tr-1980-c	
1	0.5925	management	0.6489	management
2	0.5086	business	0.6251	business
3	0.4785	accounting	0.5124	economy
4	0.4062	financing	0.4094	human development
5	0.3963	economy	0.3441	accounting
6	0.3275	work	0.2981	knowledge
7	0.3003	human development	0.2723	manufacturing
8	0.2990	service	0.2594	work
9	0.2904	manufacturing	0.2534	industry
10	0.2686	industry	0.2506	financing
11	0.2504	organizations	0.2491	organizations
12	0.2406	technology	0.2354	education
13	0.2269	workers	0.2126	trade
14	0.2180	trade	0.2029	technology

15	0.1755	training	0.1875	service
16	0.1695	knowledge	0.1747	marketing
17	0.1686	book keeping	0.1653	workers
18	0.1431	efficiency	0.1604	markets
19	0.1321	transportation	0.1565	efficiency
20	0.1201	control	0.1539	managers

Rank	tr-1990-c		tr-1999-c	
1	0.5458	business	0.4940	business
2	0.4934	management	0.4899	management
3	0.4452	economy	0.4109	human development
4	0.4210	human development	0.3941	economy
5	0.3040	accounting	0.2888	education
6	0.3015	manufacturing	0.2879	accounting
7	0.2958	education	0.2611	manufacturing
8	0.2821	knowledge	0.2466	work
9	0.2767	industry	0.2408	industry
10	0.2568	work	0.2368	knowledge
11	0.2379	technology	0.2350	technology
12	0.2243	organizations	0.2272	efficiency
13	0.2054	financing	0.2261	organizations
14	0.1848	marketing	0.1976	financing
15	0.1786	markets	0.1871	marketing
16	0.1763	efficiency	0.1820	markets
17	0.1725	trade	0.1660	managers
18	0.1654	managers	0.1570	tqm
19	0.1504	service	0.1453	service
20	0.1416	governance	0.1382	trade

Rank	tr-2008-c	
1	0.4888	business

2	0.4738	management
3	0.4161	human development
4	0.3891	economy
5	0.2983	education
6	0.2944	accounting
7	0.2633	manufacturing
8	0.2483	work
9	0.2470	organizations
10	0.2424	knowledge
11	0.2409	technology
12	0.2405	industry
13	0.2211	efficiency
14	0.2003	financing
15	0.1872	marketing
16	0.1789	markets
17	0.1778	managers
18	0.1586	tqm
19	0.1443	governance
20	0.1427	service

* Most Available (column degree centrality)
  - The In Degree Centrality of a knowledge is its normalized in-degree.

Input network(s): Knowledge Dissemination Network(AxK)

Rank	tr-1930-c		tr-1940-c	
1	0.3333	organizing	0.5818	service
2	0.3333	structure	0.3636	army
3	0.3333	organizations	0.3455	management
4	0.3333	sport clubs	0.3273	logistics
5	0.1667	security sector	0.2545	transportation

6	0.1667	modernization	0.1636	administration
7	0.1667	army	0.1273	workers
8	0.1667	models	0.1091	human development
9	0.1667	accounting	0.1091	government
10	0.1667	knowledge	0.1091	organizations
11	0.1667	methods	0.0909	book keeping
12	0.1667	government	0.0909	supply chain
13	0.1667	book keeping	0.0727	structure
14	0.1667	municipality	0.0727	economy
15	0.1667	service	0.0727	methods
16	0.1667	discipline	0.0545	organizing
17	0.1667	control	0.0545	municipality
18	0.0000	management	0.0545	technology
19	0.0000	agriculturing	0.0545	career
20	-	-	0.0545	accounting

Rank	tr-1950-c		tr-1960-c	
1	0.4894	financing	0.5426	accounting
2	0.4894	accounting	0.4088	financing
3	0.3032	service	0.2822	service
4	0.2979	work	0.2214	business
5	0.2394	workers	0.2165	management
6	0.2234	management	0.1922	work
7	0.1649	business	0.1752	economy
8	0.1436	economy	0.1509	book keeping
9	0.1436	book keeping	0.1484	transportation
10	0.1383	logistics	0.1387	workers
11	0.1330	army	0.1192	logistics
12	0.1064	organizations	0.1192	manufacturing
13	0.1011	organizing	0.1192	technology
14	0.1011	manufacturing	0.1071	human development
15	0.1011	transportation	0.1071	organizations

16	0.1011 taxing	0.0998 industry
17	0.0957 structure	0.0949 trade
18	0.0851 industry	0.0852 taxing
19	0.0798 bookkeeper	0.0730 army
20	0.0745 methods	0.0681 government

Rank	tr-1970-c	tr-1980-c
1	0.4560 management	0.6091 management
2	0.3480 business	0.5532 business
3	0.3472 accounting	0.4654 economy
4	0.2815 economy	0.3478 human development
5	0.2746 financing	0.3181 accounting
6	0.2168 work	0.2649 knowledge
7	0.1986 service	0.2343 manufacturing
8	0.1908 human development	0.2303 work
9	0.1779 manufacturing	0.2209 financing
10	0.1693 organizations	0.2205 organizations
11	0.1658 trade	0.2178 industry
12	0.1649 industry	0.2063 trade
13	0.1580 workers	0.1983 education
14	0.1416 technology	0.1717 technology
15	0.1192 knowledge	0.1677 service
16	0.1131 training	0.1517 marketing
17	0.1079 book keeping	0.1517 workers
18	0.0915 efficiency	0.1411 markets
19	0.0907 transportation	0.1406 efficiency
20	0.0812 control	0.1344 managers

Rank	tr-1990-c	tr-1999-c
1	0.4957 business	0.4591 management
2	0.4617 management	0.4511 business

3	0.4080	economy	0.3673	human development
4	0.3714	human development	0.3617	economy
5	0.2849	accounting	0.2701	accounting
6	0.2704	manufacturing	0.2561	education
7	0.2591	education	0.2360	manufacturing
8	0.2496	knowledge	0.2258	work
9	0.2482	industry	0.2177	industry
10	0.2333	work	0.2123	efficiency
11	0.2109	technology	0.2115	technology
12	0.2028	organizations	0.2094	knowledge
13	0.1872	financing	0.2061	organizations
14	0.1676	marketing	0.1812	financing
15	0.1657	trade	0.1719	marketing
16	0.1624	markets	0.1674	markets
17	0.1617	efficiency	0.1508	managers
18	0.1456	managers	0.1487	quality
19	0.1376	service	0.1337	service
20	0.1227	workers	0.1319	trade

Rank	tr-2008-c	
1	0.4058	management
2	0.3975	business
3	0.3249	human development
4	0.3198	economy
5	0.2561	accounting
6	0.2305	education
7	0.2103	manufacturing
8	0.2045	organizations
9	0.2042	work
10	0.1918	industry
11	0.1915	technology
12	0.1885	efficiency

13	0.1854	knowledge
14	0.1656	financing
15	0.1547	marketing
16	0.1475	markets
17	0.1457	managers
18	0.1400	quality
19	0.1178	service
20	0.1163	trade

* Most Connecting (betweenness centrality)
  - The Betweenness Centrality of a knowledge k in a network is defined as: across all node pairs that have a shortest containing k, the percentage that pass through k.

Input network(s): Knowledge Network(KxK)

Rank	tr-1930-c		tr-1940-c	
1	0.2418	organizations	0.2753	service
2	0.0784	organizing	0.2430	logistics
3	0.0784	structure	0.1792	army
4	0.0719	service	0.1114	management
5	0.0327	sport clubs	0.0606	organizations
6	0.0000	security sector	0.0570	advertising
7	0.0000	modernization	0.0375	methods
8	0.0000	army	0.0369	transportation
9	0.0000	models	0.0339	book keeping
10	0.0000	accounting	0.0318	administration
11	0.0000	knowledge	0.0304	government
12	0.0000	methods	0.0289	career
13	0.0000	government	0.0205	operation
14	0.0000	book keeping	0.0166	accounting
15	0.0000	municipality	0.0163	technology

16	0.0000	discipline	0.0147	economy
17	0.0000	control	0.0143	structure
18	0.0000	management	0.0126	development
19	0.0000	agriculturing	0.0123	control
20	-	-	0.0096	education

Rank	tr-1950-c		tr-1960-c	
1	0.1958	work	0.1058	work
2	0.1069	service	0.0982	service
3	0.0913	accounting	0.0667	economy
4	0.0901	financing	0.0649	accounting
5	0.0706	organizations	0.0616	financing
6	0.0596	management	0.0548	trade
7	0.0581	workers	0.0462	management
8	0.0540	economy	0.0378	workers
9	0.0511	logistics	0.0374	business
10	0.0452	book keeping	0.0373	manufacturing
11	0.0434	army	0.0360	transportation
12	0.0296	manufacturing	0.0346	technology
13	0.0294	technology	0.0344	logistics
14	0.0205	methods	0.0339	industry
15	0.0193	transportation	0.0297	career
16	0.0191	industry	0.0269	organizations
17	0.0176	career	0.0182	book keeping
18	0.0176	business	0.0177	control
19	0.0175	knowledge	0.0174	army
20	0.0151	structure	0.0122	agriculturing

Rank	tr-1970-c		tr-1980-c	
1	0.0952	economy	0.0689	economy
2	0.0588	business	0.0483	business

3	0.0586	service	0.0433	management
4	0.0577	work	0.0429	knowledge
5	0.0450	trade	0.0348	work
6	0.0405	management	0.0331	service
7	0.0350	knowledge	0.0304	accounting
8	0.0342	financing	0.0298	manufacturing
9	0.0328	organizations	0.0269	trade
10	0.0288	accounting	0.0266	industry
11	0.0282	manufacturing	0.0262	organizations
12	0.0258	workers	0.0251	efficiency
13	0.0249	efficiency	0.0212	human development
14	0.0249	technology	0.0211	financing
15	0.0246	industry	0.0202	technology
16	0.0203	transportation	0.0192	education
17	0.0197	methods	0.0173	workers
18	0.0194	productivity	0.0164	structure
19	0.0181	logistics	0.0151	marketing
20	0.0178	career	0.0143	methods

Rank	tr-1990-c		tr-1999-c	
1	0.0478	economy	0.0438	economy
2	0.0369	business	0.0379	business
3	0.0362	accounting	0.0376	work
4	0.0353	knowledge	0.0322	organizations
5	0.0337	work	0.0317	management
6	0.0330	management	0.0272	accounting
7	0.0306	service	0.0250	service
8	0.0266	manufacturing	0.0239	knowledge
9	0.0262	industry	0.0226	technology
10	0.0245	organizations	0.0219	manufacturing
11	0.0228	education	0.0215	industry
12	0.0215	technology	0.0205	managers

```
13   0.0213 human development          0.0188 education
14   0.0192 trade                      0.0185 human development
15   0.0188 structure                  0.0167 efficiency
16   0.0184 financing                  0.0161 marketing
17   0.0132 efficiency                 0.0148 markets
18   0.0131 governance                 0.0145 structure
19   0.0129 methods                    0.0142 trade
20   0.0129 marketing                  0.0141 financing

Rank tr-2008-c
---- ------------------------------
1    0.0929   organizations
2    0.0564   accounting
3    0.0546   strategic management
4    0.0388   work
5    0.0381   decision making
6    0.0373   performance
7    0.0359   managers
8    0.0298   behavior
9    0.0297   financing
10   0.0266   costing
11   0.0262   quality
12   0.0256   consumers
13   0.0253   economy
14   0.0235   culture
15   0.0231   crm
16   0.0227   technology
17   0.0225   production
18   0.0208   education
19   0.0200   hrm
20   0.0190   leadership
```

Appendix O

Key Management Concepts in WoS: 1922-2008

Key Entities: Knowledge in Turkish management academia as of publications from WOS.

Periods: wos-1990-c, wos-1999-c, wos-2008-c

* Dominant Knowledge (total degree centrality)
  - The Total Degree Centrality of a knowledge is the normalized value of its degree centrality.

Input: all networks(AxK, KxK)

Rank	wos-1990-c		wos-1999-c	
1	0.1512	developing countries	0.2180	consumption
2	0.1395	consumption	0.1541	developing countries
3	0.1163	environment	0.1221	performance
4	0.1163	information	0.1134	culture
5	0.1163	uncertainty	0.1076	determinants
6	0.1163	banks	0.1047	decision making

7	0.1163 decision making	0.1017 technology
8	0.0930 culture	0.0930 marketing
9	0.0930 cross culture	0.0930 competitive advantage
10	0.0930 materialism	0.0785 hierarchy
11	0.0930 diffusion	0.0756 management
12	0.0930 management	0.0756 manufacturing
13	0.0930 education	0.0698 materialism
14	0.0930 knowledge	0.0698 firm
15	0.0814 bureaucracy	0.0581 bureaucracy
16	0.0814 public administration	0.0552 environment
17	0.0814 regime types	0.0552 experience
18	0.0814 retailing institutions	0.0552 trade
19	0.0814 supermarket patronage	0.0552 growth
20	0.0698 stability	0.0552 behavior

Rank	wos-2008-c
1	0.4924 performance
2	0.2574 culture
3	0.2355 behavior
4	0.1859 management
5	0.1561 firm
6	0.1352 strategy
7	0.1227 technology
8	0.1217 environment
9	0.1206 ethics
10	0.1164 decision making
11	0.1117 consumption
12	0.1081 competitive advantage
13	0.1044 tqm
14	0.0982 organizations
15	0.0961 leadership
16	0.0898 consequences

17	0.0851	antecedents
18	0.0841	determinants
19	0.0841	marketing
20	0.0825	governance

* Most Disseminated (in degree centrality)
  - The In Degree Centrality of a knowledge is its normalized in-degree.

Input network(s): Knowledge Dissemination Network(AxK)

Rank	wos-1990-c		wos-1999-c	
1	0.2500	developing countries	0.2568	consumption
2	0.2000	consumption	0.2027	developing count.
3	0.1500	bureaucracy	0.1081	marketing
4	0.1500	public administration	0.1081	performance
5	0.1500	regime types	0.0946	culture
6	0.1500	retailing institutions	0.0946	technology
7	0.1500	supermarket patronage	0.0811	bureaucracy
8	0.1000	environment	0.0811	decision making
9	0.1000	information	0.0811	firm
10	0.1000	uncertainty	0.0676	contextualization
11	0.1000	banks	0.0676	determinants
12	0.1000	decision making	0.0676	ethics
13	0.1000	stability	0.0676	business
14	0.1000	interorganizational excha	0.0676	education
15	0.1000	administration	0.0541	public adm.
16	0.1000	culture	0.0541	materialism
17	0.1000	cross culture	0.0541	management
18	0.1000	materialism	0.0541	competitive adv.
19	0.1000	firm	0.0541	manufacturing
20	0.1000	marketing	0.0541	knowledge

Rank	wos-2008-c	
1	0.3545	performance
2	0.2673	culture
3	0.2158	behavior
4	0.1505	leadership
5	0.1188	tqm
6	0.1089	collectivism
7	0.1069	management
8	0.1030	corporate social responsi
9	0.1030	individualism
10	0.0990	value
11	0.0911	self
12	0.0832	consumption
13	0.0812	ethics
14	0.0812	strategy
15	0.0812	firm
16	0.0812	technology
17	0.0812	charismatic leadership
18	0.0772	decision making
19	0.0693	environment
20	0.0634	consequences

* Most Connecting (betweenness centrality)
  - The Betweenness Centrality of a knowledge k in a network is defined as: across all node pairs that have a shortest path containing k, the percentage that pass through k.

Input network(s): Knowledge Network(KxK)

Rank wos-1990-c wos-1999-c

1	0.0076	developing countries	0.3488	marketing
2	0.0057	consumption	0.3169	consumption
3	0.0000	bureaucracy	0.2124	performance
4	0.0000	public administration	0.1265	management
5	0.0000	regime types	0.1248	culture
6	0.0000	environment	0.1164	developing count.
7	0.0000	information	0.1037	decision making
8	0.0000	uncertainty	0.0928	firm
9	0.0000	banks	0.0893	technology
10	0.0000	decision making	0.0697	determinants
11	0.0000	stability	0.0626	hierarchy
12	0.0000	interorganizational ex.	0.0491	structure
13	0.0000	administration	0.0452	competitive adv.
14	0.0000	culture	0.0432	manufacturing
15	0.0000	cross culture	0.0371	modernization
16	0.0000	materialism	0.0371	globalization
17	0.0000	firm	0.0371	education
18	0.0000	marketing	0.0371	knowledge
19	0.0000	research orientation	0.0311	bureaucracy
20	0.0000	retailing institutions	0.0250	contextualization

Rank	wos-2008-c	
1	0.2120	performance
2	0.0825	culture
3	0.0690	behavior
4	0.0683	consumption
5	0.0637	management
6	0.0533	firm
7	0.0511	decision making
8	0.0500	tqm
9	0.0437	technology

```
10   0.0394 environment
11   0.0315 strategy
12   0.0311 governance
13   0.0289 developing countries
14   0.0281 ethics
15   0.0268 quality
16   0.0254 marketing
17   0.0239 market
18   0.0230 competitive advantage
19   0.0225 institutional perspective
20   0.0194 competition
```

Notes

[1]Extensive details on social network theory, methods and applications are outlined and discussed in Scott (2000), Wasserman and Faust (1994) and Carrington et.al. (2006)

[2]For details on the methodology see Chapter **??**.

[3]For the details on computations see Mutschke and Haase (2001) pp. 494-497

[4]The term or concept refers to "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Calero-Medina and Noyons, 2008: p. 273).

[5]The Web of Science (WoS), `http://www.isiknowledge.com/`

[6]See http://www.oakland.edu/enp/

[7]COLLNET (abbreviation of collaboration network) is a global interdisciplinary research network founded in 2000, which studies various aspect of collaboration networks

[8]See `http://www.casos.cs.cmu.edu/`.

[9]However it should be noted that the co-authorship link between two authors, in this example, is manipulated artificially for the explanatory reason.

[10]`http://www.casos.cs.cmu.edu/projects/ora/`

[11]`http://www.r-project.org/`

[12]See `http://www.isiknowledge.com/`

[13]Agglutinative means that words and sentences are made by adding suffixes to a root-word.

Bibliography

Abrahamson, E. and L. Rosenkopf (1997). Social network effects on the extent of innovation diffusion: A computer simulation. *Organization Science 8*(3), 289–309.

Abramo, G., C. A. D'Angelo, F. Di Costa, and M. Solazzi (2009). University-industry collaboration in Italy: A bibliometric examination. *Technovation 29*(6-7), 498–507.

Acedo, F., B. Carmen, C. Casanueva, and J. Galan (2006). Co-authorship in management and organizational studies: An empirical and network analysis. *Journal of Management Studies 43*(5), 957–984.

Ahuja, G. (2000). Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative Science Quarterly 45*(3), 425–455.

Akakandelwa, A. (2009). Author Collaboration and Productivity at the University of Zambia, 2002-2007. *African Journal of Library Archives and Information Science 19*(1), 13–23.

Al, U. and M. Afzali (2006). Iran ve türkiye'nin dünya bilgibilim literatürüne katkıları: Karşılaştırmalı bir çalışma. *Bilgi Dünyası 7*(2), 181–201.

Al, U., M. Sahiner, and Y. Tonta (2006). Arts and humanities literature: Bibliometric characteristics of contributions by Turkish authors. *Journal of the American Society for Information Science and Technology 57*(8), 1011–1022.

Almeida, P. and B. Kogut (1999). Localization of knowledge and the mobility of engineers in regional networks. *Management Science 45*(7), 905–917.

Appleyard, M. (1996). How does knowledge flow? Interfirm patterns in the semiconductor industry. *Strategic Management Journal 17*(Sp. Iss. SI), 137–154.

Ashworth, M. J. (2003). Identifying key contributors to performance in organizations: The case for knowledge-based measure. In *Proceedings of the First Annual Conference of the North American Association for Computational Social and Organizational Science.*

Ausloos, M. and R. Lambiotte (2007). Drastic events make evolving networks. *European Physical Journal B 57*(1), 89–94.

Azoulay, P. and J. G. Zivin (2006). Peer effects in the workplace: Evidence from professional transitions for the superstars of medicine. Presented at Conference on “Universities, Innovation and Economic Growth”, November 16-17, 2006, Cleveland, USA. Organized by Federal Reserve Bank of Cleveland.

Bailon-Moreno, R., E. Jurado-Alameda, R. Ruiz-Banos, and J. Courtial (2005). Analysis of the field of physical chemistry of surfactants with the Unified Scienctometric Model. Fit of relational and activity indicators. *Scientometrics 63*(2), 259–276.

Baldwin, C., J. Hughes, T. Hope, R. Jacoby, and S. Ziebland (2003). Ethics and dementia: mapping the literature by bibliometric analysis. *International Journal of Geriatric Psychiatry 18*(1), 41–54.

Barabasi, A. L. and R. Albert (1999). Emergence of scaling in random networks. *Science 286*, 509–512.

Barabasi, A. L., H. Jeong, Z. Neda, E. Ravasz, A. Schubert, and T. Vicsek (2002). Evolution of the social network of scientific collaborations. *Physica A: Statistical Mechanics and its Applications 311*(3-4), 590–614.

Barjak, F. and S. Robinson (2007). International collaboration, mobility and team diversity in the life sciences: Impact on research performance. In TorresSalinas, D and Moed, HF (Ed.), *Proceedings of ISSI 2007: 11th*

International Conference of the International Society for Scientometrics and Informetrics, Vols I and II, pp. 63–73. 11th International Conference of the International-Society-for-Scientrometrics-and-Informetrics, Madrid, SPAIN, JUN 25-27, 2007.

Barnes, J. (1954). Class and committees in a norwegian island parish. *Human Relations 7*, 39–58.

Baum, J. A. C., A. Shipilov, and T. Rowley (2003). Where do small worlds come from? *Industrial and Corporate Change 12*, 697–725.

Belkhodja, O. and R. Landry (2007). "The Triple-Helix collaboration: Why do researchers collaborate with industry and the government? What are the factors that influence the perceived barriers?". *Scientometrics 70*(2), 301–332.

Bettencourt, L. M. A., D. I. Kaiser, and J. Kaur (2009). Scientific discovery and topological transitions in collaboration networks. *Journal of Informetrics 3*(3), 210–221.

Bhattacharya, S. and P. Basu (1998). Mapping a research area at the micro level using co-word analysis. *Scientometrics 43*(3), 359–372.

Bhattacharya, S., H. Kretschmer, and M. Meyer (2003). Characterizing intellectual spaces between science and technology. *Scientometrics 58*(2), 369–390.

Blatt, E. M. (2009). Differentiating, describing, and visualizing scientific space: A novel approach to the analysis of published scientific abstracts. *Scientometrics 80*(2), 385–406.

Bonacich, P. (1972). Factoring and weighting approaches to clique identification. *Journal of Mathematical Sociology 2*, 113–120.

Bordons, M., M. Fernandez, F. Morillo, and I. Gomez (2005). Are there research teams in a "little science" discipline such as mathematics? In

Ingwersen, P and Larsen, B (Ed.), *ISSI 2005: Proceedings of the 10th International Conference of the International Society for Scientometrics and Informetrics, Vols 1 and 2*, pp. 305–309. 10th International Conference of the International-Society-for-Scientometrics-and-Informetrics, Stockholm, SWEDEN, JUL 24-28, 2005.

Borgatti, S. (2003). The key player problem. In *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers*.

Borgatti, S. P. and M. G. Everett (1999). Models of core/periphery structures. *Social Networks 21*, 375–395.

Borner, K., C. Chen, and K. Boyack (2003). Visualizing knowledge domains. *Annual Review of Information Science and Technology 37*, 179–255.

Boshoff, N. (2009). Neo-colonialism and research collaboration in Central Africa. *Scientometrics 81*(2), 413–434.

Bourdieu, P. (1998). *Practical Reason: On the Theory of Action*. Stanford University Press.

Braun, T. and W. Glanzel (1996). International collaboration: Will it be keeping alive east European research? *Scientometrics 36*(2), 247–254.

Breschi, S., L. Cassi, F. Malerba, and N. S. Vonortas (2009). Networked research: European policy intervention in ICTs. *Technology Analysis & Strategic Management 21*(7), 833–857.

Breschi, S. and F. Lissoni (2009). Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows. *Journal of Economic Geography 9*(4), 439–468.

Bron, C. and J. Kerbosch (1973). Algorithm 457: Finding all cliques of an undirected graph. *Communications of ACM 16*(9), 575–577.

Brown, J. and P. Reingen (1987). Social Ties and Word-of-Mouth Referral Behavior. *Journal of Consumer Research 14*(3), 350–362.

Burt, R. S. (1992). *Structural Holes: The Social Structure of Competition.* Cambridge: Harvard University Press.

Butcher, J. and P. Jeffrey (2005). The use of bibliometric indicators to explore industry-academia collaboration trends over time in the field of membrane use for water treatment. *Technovation 25*(11), 1273–1280.

Butts, C. T. (2009). Revisiting the foundation of network analysis. *Science 325*, 414–416.

Cahlik, T. (2000a). Comparison of the maps of science. *Scientometrics 49*(3), 373–387.

Cahlik, T. (2000b). Search for fundamental articles in economics. *Scientometrics 49*(3), 389–402.

Cahlik, T. and M. Jirina (2006). Law of cumulative advantages in the evolution of scientific fields. *Scientometrics 66*(3), 441–449.

Calero, C., R. Buter, C. Valdes, and E. Noyons (2006). How to identify research groups using publication analysis: an example in the field of nanotechnology. *Scientometrics 66*(2), 365–376.

Calero-Medina, C. and E. C. M. Noyons (2008). Combining mapping and citation network analysis for a better understanding of the scientific development: The case of the absorptive capacity field. *Journal of Informetrics 2*(4), 272–279.

Callon, M. (1986). *Power, Action and Belief: A New Sociology of Knowledge? Sociological Review Monograph*, Volume 32, Chapter Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of Saint Brieuc Bay, pp. 196 – 233. London: Routledge and Kegan Paul.

Callon, M., J. Courtial, and F. Laville (1991). Co-word analysis as a tool for describing the network of interactions between basic and technological research - The case of polymer chemistry. *Scientometrics 22*(1), 155–205.

Callon, M., J. Courtial, W. Turner, and S. Bauin (1983). From translation to network - The co-word analysis. *Scientometrics 5*(1), 78.

Callon, M., J. Law, and A. Rip (1986). *Mapping the dynamics of science and technology: Sociology of science in the real world*. London: The Macmillian Press Ltd.

Cambrosio, A., C. Limoges, J. Courtial, and F. Laville (1993). Historical scientometrics - Mapping over 70 years of biological safety research with co-word analysis. *Scientometrics 27*(2), 119–143.

Cantner, U. and H. Graf (2006). The network of innovators in Jena: An application of social network analysis. *Research Policy 35*(4), 463–480.

Carley, K. (1990). Group stability: A socio-cognitive approach. *Advances in Group Processes 7*, 1–44.

Carley, K. (1991). A theory of group stability. *American Sociological Review 56*, 331–354.

Carley, K. (1999). On the evolution of social and organizational networks. *Research in the Sociology of Organizations 16*, 3–30.

Carley, K. (2003). *Dynamic network analysis: Worshop summary and papers*, pp. 133–145. Washington D.C.: The National Academies Press.

Carley, K. and L. Gasser (1999). *Distributed Artificial Intelligence*, Chapter Computational Organization Theory, pp. 299–331. MIT Press.

Carley, K. M. (2002). Summary of key metwork measures for characterizing organizational architectures. CMU.

Carley, K. M., J. Reminga, J. Storrick, and M. De Reno (2009). Ora user's guide 2009. Technical report, Institute for Software Research, School of Computer Science, Carnegie Mellon University.

Carrington, P. J., J. Scott, and S. Wasserman (2006). *Models and Methods in Social Network Analysis*. Cambridge University Press.

Cassi, L., N. Corrocher, F. Malerba, and N. Vonortas (2008). Research networks as infrastructure for knowledge diffusion in european regions. *Economics of Innovation and New Technology 17*(7-8), 663–676.

Chavalarias, D. and J.-P. Cointet (2008). Bottom-up scientific field detection for dynamical and hierarchical science mapping, methodology and case study. *Scientometrics 75*(1), 37–50.

Chen, C. and D. Hicks (2004). Tracing knowledge diffusion. *Scientometrics 59*(2), 199–211.

Chirita, P. A., A. Damian, W. Nejdl, and W. Siberski (2005). Search strategies for scientific collaboration networks. In *P2PIR '05: Proceedings of the 2005 ACM workshop on Information retrieval in peer-to-peer networks*, New York, NY, pp. 33–40. ACM. Enter text here.

Chubin, D. (1976). The conceptualization of scientific specialties. *Sociological Quarterly 17*(4), 448–476.

Coleman, J. (1988). Social capital in the creation of human-capital. *American Journal of Sociology 94*(Suppl. S), S95–S120.

Collins, R. (1998). *The Sociology of Philosophies: A Global Theory of Intellectual Change*. Harvard University Press.

Courtial, J. and M. Callon (1991). Indicators for the identification of strategic themes within a research-program. *Scientometrics 21*(3), 447–458. International Conf On Output Indicators For Evaluation Of The Impact Of European Community Research Program, Paris, France, Jun 14-15, 1990.

Courtial, J., M. Callon, and A. Sigogneau (1993). The use of patent titles for identifying the topics of invention and forecasting trends. *Scientometrics 26*(2), 231–242.

Cowan, R. and N. Jonard (2004). Network structure and the diffusion of knowledge. *Journal of Economic Dynamics and Control 28*(8), 1557 – 1575.

Cronin, B. (2008). On the epistemic significance of place. *Journal of the American Society for Information Science and Technology 59*(6), 1002–1006.

Cross, R., S. P. Borgatti, and A. Parker (2002). Making invisible workvisible: Using social network analysis to support strategic collaboration. *California Management Review 49*(4), 25–65.

Davidson, E. and R. Lamb (2000). Examining socio-technical networks in scientific academia/industry collaboration. In H. M. Chung (Ed.), *Proceedings of Americas Conference on Information Systems*, Long Beach, CA., pp. 1625–1631. Association for Information Systems.

de Nooy, W. (2003). Fields and networks: correspondence analysis and social network analysis in the framework of field theory. *Poetics 31*, 305–327.

Debruin, R. and H. Moed (1993). Delimitation of scientific subfields using cognitive words from corporate addresses in scientific publications. *Scientometrics 26*(1), 65–80. European Workshop on Scientometric Methods of Research Evaluation in the Sciences, Social Sciences and Technology, Potsdam, Germany, Apr 13-17, 1991.

DeLooze, M. and J. Lemarie (1997). Corpus relevance through co-word analysis: An application to plant proteins. *Scientometrics 39*(3), 267–280.

Doerfel, M. and G. Barnett (1999). Application semantic network analysis of the International Communication Association. *Human Communication Research 25*(4), 589–603. 47th Annual Meeting of the International-Communication-Association, Montreal, Canada, May 22, 1997.

Donato, H. and C. F. De Oliveira (2009). Bibliometry of cancer in Portugal. *ACTA Medica Portuguesa 22*(1), 41–50.

Durbach, I. N., D. Naidoo, and J. Mouton (2008). Co-authorship networks in South African chemistry and mathematics. *South African Journal of Science 104*(11-12), 487–492.

Durkheim, E. (1974). *Sociology and Philosophy.* New York: Free Press.

Emirbayer, M. (1997). Manifesto for a eelational sociology. *American Journal of Sociology 103*(2), 281–317.

Engels, A. and T. Ruschenburg (2006). The expansion of spaces of communication: on science globalization, its scope, its mechanisms and its theories. *Soziale Welt-Zeitschrift für Sozialwissenschaftliche Forschung und Praxis 57*(1), 5+.

Engwall, L. and M. Kipping (2004). Introduction: The dissemination of management knowledge. *Management Learning 35*(3), 243–253.

Erdos, P. and A. Renyi (1959). On random graphs i. *Pub. Math. 6*, 290–297.

Etzkowitz, H. and L. Leydesdorff (1996). A triple helix of academic-industry-government relations: Development models beyond 'capitalism versus socialism'. *Current Science 70*(8), 690–693.

Etzkowitz, H. and L. Leydesdorff (2000). The dynamics of innovation: From national systems and "Mode 2" to a triple helix of university-industry-government relations. *Research Policy 29*(2), 109–123.

Farahat, H. (2002). Authorship patterns in agricultural sciences in Egypt. *Scientometrics 55*(2), 157–170.

Fleming, L., C. King, III, and A. I. Juda (2007). Small worlds and regional innovation. *Organization Science 18*(6), 938–954.

Fleming, L. and M. Marx (2006). Managing innovation in small worlds. *MIT Sloan Management Review 48*(1), 8+.

Freeman, L. (1979). Centrality in social networks i: Conceptual clarification. *Social Networks 1*, 215–239.

Freeman, L. (2004). *The Development of Social Network Analysis.* Vancouver, BC Canada: Empirical Press.

Fritsch, M. and M. Kauffeld-Monz (2009). The impact of network structure on knowledge transfer: An application of social network analysis in the context of regional innovation networks. *The Annals of Regional Science 43*. (forthcoming).

Gaillard, J. (1992). Use of publication lists to study scientific production and strategies of sceintists in developing countries. *Scientometrics 23*(1), 57–73. International Conf on Science Indicators for Developing Countries, Paris, France, Oct 15-19, 1990.

Geisler, E. (2007). A typology of knowledge management: strategic groups and role behavior in organizations. *Journal of Knowledge Management 11*(1).

Glanzel, W. (2000). Science in Scandinavia: A bibliometric approach. *Scientometrics 48*(2), 121–150. 4th Nordic Workshop in Bibliometrics, Copenhagen, Denmark, AUG 27-28, 1999.

Glanzel, W. (2002). Coauthorship patterns and trends in the sciences (1980-1998): A bibliometric study with implications for database indexing and search strategies. *Library Trends 50*(3), 461–473.

Glanzel, W. and A. Schubert (2005). *Handbook of Quantitative Science and Technology Research*, Chapter Analysing scientific networks through co-authorship, pp. 257–276. Kluwer Academic Publishers.

Godin, B. and M. Ippersiel (1996). Scientific collaboration at the regional level: The case of a small country. *Scientometrics 36*(1), 59–68.

Gokceoglu, C., A. I. Okay, and E. Sezer (2008). International earth science literature from Turkey - 1970-2005: Trends and possible causes. *Scientometrics 74*(3), 409–423.

Gordon, A. D. (1999). *Classification*. London: Chapman and Hall.

Gossart, C. and M. Oezman (2009). Co-authorship networks in social sciences: The case of Turkey. *Scientometrics 78*(2), 323–345. Enter text here.

Granovetter, M. S. (1973). The Strength of Weak Ties. *American Journal of Sociology 78*(6), 1360–1380.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal* (Winter Special Issue), 109–122.

Gulgoz, S., O. Yedekcioglu, and E. Yurtsever (2002). Turkey's output in social science publications: 1970-1999. *Scientometrics 55*(1), 103–121.

Hart, R. (2000). Co-authorship in the academic library literature: A survey of attitudes and behaviors. *Journal of Academic Librarianship 26*(5), 339–345.

Hayes, A. F. and K. Krippendorff (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures 1*(1), 77–89.

He, Q. (1999). Knowledge discovery through co-word analysis. *Library Trends 48*(1), 133–159.

He, Q. (2000). Mapping the dynamics in artificial intelligence through co-word analysis. In Kraft, Dh (Ed.), *ASIS 2000: Proceedings of The 63rd ASIS Annual Meeting, Vol 37, 2000*, Volume 37 of *Proceedings of the ASIS Annual Meetings*, pp. 219–226. 63rd Annual Meeting of the American-Society-for-Information-Science, Chicago, Il, Nov 12-16, 2000.

Heylighen (2006). Analysis of network structures to support scientific collaboration. Proposal submitted to the Belgian Fund for Scientific Research.

Hollander, M. and D. A. Wolfe (1973). *Nonparametric Statistical Methods.* New York: John Wiley and Sons.

Hou, H., H. Kretschmer, and Z. Liu (2008). The structure of scientific collaboration networks in scientometrics. *Scientometrics 75*(2), 189–202.

Ignacio de Granda-Orive, J., S. Villanueva-Serrano, R. Aleixandre-Benavent, J. Carlos Valderrama-Zurian, A. Alonso-Arroyo, F. Garcia Rio, C. A.

Jimenez Ruiz, S. Solano Reina, and J. M. Martinez Albiach (2009). World-wide collaboration among medical specialties in smoking research: production, collaboration, visibility and influence. *Research Evaluation 18*(1), 3–12.

Jacobsen, K. H. (2009). Patterns of co-authorship in international epidemiology. *Journal of Epidemiology and Community Health 63*(8), 665–669.

Jaffe, A., B. Trajtenberg, and R. Henderson (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics 108*(3), 577–598.

Jones, C., W. S. Hesterly, and S. P. Borgatti (1997). A general theory of network governance: Exchange conditions and social mechanisms. *The Academy of Management Review 22*(4), 911–945.

Katz, J. and B. Martin (1997). What is research collaboration? *Research Policy 26*(1), 1–18.

Kavunenko, L., V. Khorevin, and K. Luzan (2005). Comparative analysis of journals on social sciences and humanities in Ukraine and the world. *Scientometrics 66*(1), 123–132. 8th International Conference on Science and Technology Indicators, Leiden, Netherlands, Sep 23-25, 2004.

Kim, K. (2006). Measuring international research collaboration of peripheral countries: Taking the context into consideration. *Scientometrics 66*(2), 231–240.

Kim, M. (1999). Korean international co-authorship in science 1994-1996. *Journal of Information Science 25*(5), 403–412.

Kim, M. (2005). Korean science and international collaboration, 1995-2000. *Scientometrics 63*(2), 321–339.

Kipping, M., B. Üsdiken, and N. Puig (2004). Imitation, tension, and hybridization: Multiple "Americanizations" of management education in Mediterranean Europe. *Journal of Management Inquiry 13*(2), 98–108.

Annual Meeting of the Academy-of-Management, SEATTLE, WA, AUG, 2003.

Kogut, B. and G. Walker (2001). The small world of germany and the durability of national networks. *American Sociological Review 66*, 317–335.

Krackhardt, D. (1994). *Computational Organization Theory*, Chapter Graph theoretical dimensions of informal organizations, pp. 89–111. Hillsdale, NJ: Lawrence Erlbaum and Associates.

Kretschmer, H. and I. Aguillo (2004). Visibility of collaboration on the Web. *Scientometrics 61*(3), 405–426.

Kretschmer, H. and B. Gupta (1998). Collaboration patterns in theoretical population genetics. *Scientometrics 43*(3), 455–462.

Kretschmer, H., U. Hoffmann, and T. Kretschmer (2006). Collaboration structures between German immunology institutions, and gender visibility, as reflected in the Web. *Research Evaluation 15*(2), 117–126. 10th International Conference of the International-Society-for-Scientometrics-and-Informetrics, Stockholm, SWEDEN, JUL 24-28, 2005.

Kretschmer, H. and T. Kretschmer (2006). Application of a new centrality measure for social network analysis to Bibliometric and webometric data. In *2006 1st International Conference on Digital Information Management*, pp. 199–204. 1st International Conference on Digital Information Management, Bangalore, INDIA, DEC 06-08, 2006.

Kretschmer, H., U. Kretschmer, and T. Kretschmer (2007). Reflection of co-authorship networks in the Web: Web hyperlinks versus Web visibility rates. *Scientometrics 70*(2), 519–540.

Krichel, T. and N. Bakkalbasi (2006). A social network analysis of research collaboration in the economics community. In *Proceedings of International Workshop on Webometrics, Informetrics and Scientometrics & seventh COLLNET meeting*, Nancy, France.

Krippendorff, K. (2004). Reliability in content analysis: Some common misconceptions and recommendations. *Human Communication Research 30*, 411–433.

Kuhn, T. S. (1970). *The structure of scientific revolutions.* Chicago: University of Chicago Press.

Kuhn, T. S. (2000). *The road since structure: Philosophical essays 1970-1983, with an autobiographical interview*, Chapter Afterword, pp. 224–252. Chicago: University of Chicago Press.

Kundra, R. (1996). Investigation of collaborative research trends in Indian medical sciences: 1900-1945. *Scientometrics 36*(1), 69–80.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society.* Cambridge, Ma: Harvard University Press.

Laudel, G. (2001). Collaboration, creativity and rewards: why and how scientists collaborate. *International Journal of Technology Management 22*(7-8), 762–781.

Law, J., S. Bauin, J. Courtial, and J. Whittaker (1988). Policy and the mapping of scientific change - A co-word analysis of research into environmental acidification. *Scientometrics 14*(3-4), 251–264.

Law, J. and J. Hassard (1999). *Actor-Network Theory and After.* Oxford: Blackwell.

Law, J. and J. Whittaker (1992). Mapping acidification research - A test of the co-word method. *Scientometrics 23*(3), 417–461.

Lee, B. and Y.-I. Jeong (2008). Mapping Korea's national R&D domain of robot technology by using the co-word analysis. *Scientometrics 77*(1), 3–19.

Lee, C. K. and J. F. Wee (2007). Social network analysis of four departments in the National University of Singapore. In Hawemdeh, S (Ed.), *Creating*

Collaborative Advantage Through Knowledge and Innovation, Volume 5 of *Series on Innovation and Knowledge Management*, pp. 119–134. 3rd International Conference on Knowledge Management, London, England, 2006.

Lee, S. and B. Bozeman (2005). The impact of research collaboration on scientific productivity. *Social Studies of Science 35*(5), 673–702.

Lee, W. H. (2008). How to identify emerging research fields using scientometrics: An example in the field of Information Security. *Scientometrics 76*(3), 503–525.

Lemarc, M., J. Courtial, E. Senkovska, J. Petard, and Y. Py (1991). The dynamics of research in the psychology of work from 1973 To 1987 - From the study of companies to the study of professions. *Scientometrics 21*(1), 69–86.

Lemarie, S., M. de Looze, and V. Mangematin (2000). Strategies of European SMEs in biotechnology: The role of size, technology and market. *Scientometrics 47*(3), 541–560.

Leta, J. and H. Chaimovich (2002). Recognition and international collaboration: the Brazilian case. *Scientometrics 53*(3), 325–335.

Leydesdorff, L. (1992). A validation-study of leximappe. *Scientometrics 25*(2), 295–312.

Leydesdorff, L. (1997). Why words and co-words cannot map the development of the sciences. *Journal of the American Society For Information Science 48*(5), 418–427.

Leydesdorff, L. and M. Meyer (2003). The triple helix of university-industry-government relations. *Scientometrics 58*(2), 191–203.

Leydesdorff, L. and M. Meyer (2007). The scientometrics of a triple helix of university-industry-government relations - (Introduction to the topical issue). *Scientometrics 70*(2), 207–222.

Leydesdorff, L. and Y. Sun (2009). National and International Dimensions of the Triple Helix in Japan: University-Industry-Government Versus International Coauthorship Relations. *Journal of the American Society for Information Science and Technology 60*(4), 778–788.

Leydesdorff, L. and C. S. Wagner (2008). International collaboration in science and the formation of a core group. *Journal of Informetrics 2*(4), 317–325.

Li-chun, Y., H. Kretschmer, R. A. Hanneman, and L. Ze-yuan (2006). Connection and stratification in research collaboration: An analysis of the COLLNET network. *Information Processing and Management 42*(6), 1599–1613.

Lucio-Arias, D. and L. Leydesdorff (2007). Knowledge emergence in scientific communication: from "fullerenes" to "nanotubes". *Scientometrics 70*(3), 603–632.

Lucio-Arias, D. and L. Leydesdorff (2009a). An indicator of research front activity: Measuring intellectual organization as uncertainty reduction in document sets. *Journal of the American Society for Information Science and Technology 60*(12), 2488–2498.

Lucio-Arias, D. and L. Leydesdorff (2009b). The dynamics of exchanges and references among scientific texts, and the autopoiesis of discursive knowledge. *Journal of Informetrics 3*(3), 261–271.

Lundberg, J., G. Tomson, I. Lundkvist, J. Skar, and M. Brommels (2006). Collaboration uncovered: Exploring the adequacy of measuring university-industry collaboration through co-authorship and funding. *Scientometrics 69*(3), 575–589.

Mahlck, P. and O. Persson (2000). Socio-bibliometric mapping of intra-departmental networks. *Scientometrics 49*(1), 81–91.

Mannheim, K. (1968). *Ideology and utopia : An introduction to the sociology of knowledge*. London: Routledge and Kegan Paul.

Mattsson, P., P. Laget, A. Nilsson, and C.-J. Sundberg (2008). Intra-EU vs. extra-EU scientific co-publication patterns in EU. *Scientometrics 75*(3), 555–574.

Melin, G., R. Danell, and O. Persson (2000). A bibliometric mapping of the scientific landscape on Taiwan. *Issues and Studies 36*(5), 61–82.

Melin, G. and O. Persson (1996). Studying research collaboration using co-authorships. *Scientometrics 36*(3), 363–377.

Merton, R. K. (1968). *Social Theory and Social Structure*. New York: Free Press.

Miguel, S., L. Caprile, and I. Jorquera-Vidal (2008). Co-term and social networks analysis for the generation of subject maps. *Profesional de la Informacion 17*(6), 637–646.

Mika, P. (2004). Social networks and the Semantic Web. In Zhong, N and Tirri, H and Yao, Yy and Zhou, L and Liu, J and Cercone, N (Ed.), *IEEE/WIC/ACM International Conference on Web Intelligence (WI 2004), Proceedings*, pp. 285–291. ieee/wic/acm International Conference on Web Intelligence, Beijing, Peoples R China, Sep 20-24, 2004.

Mika, P. (2005). Social networks and the Semantic Web: The next challenge. *IEEE Intelligent Systems 20*(1), 82–85.

Mika, P., T. Elfring, and P. Groenewegen (2006). Application of semantic technology for social network analysis in the sciences. *Scientometrics 68*(1), 3–27.

Milgram, S. (1967). The small world problem. *Psychology Today 22*, 61–67.

Moody, J. (2004). The structure of a social science collaboration network: Disciplinary cohesion from 1963 to 1999. *American Sociological Review 69*(2), 213–238.

Moreno, J. and H. Jennings (1938). Statistics of social configurations. *Sociometry 1*, 342–374.

Morillo, F. and D. De Filippe (2009). Decentralization of scientific activity. The major role of central regions: the case of Madrid. *Revista Espanola de Documentacion Cientifica 32*(3), 29–50.

Morris, S. A. and M. L. Goldstein (2007). Manifestation of research teams in journal literature: A growth model of papers, coauthorship, weak ties, authors, collaboration, and Lotka's law. *Journal of the American Society for Information Science and Technology 58*(12), 1764–1782.

Morris, S. A. and B. Van der Veer Martens (2008). Mapping research specialties. *Annual Review of Information Science And Technology 42*, 213–295.

Morrison, A. (2008). Gatekeepers of knowledge within industrial districts: Who they are, how they interact. *Regional Studies 42*(6), 817–835.

Morrison, A. and R. Rabellotti (2009). Knowledge and Information Networks in an Italian Wine Cluster. *European Planning Studies 17*(7), 983–1006.

Mutschke, P. (2003). Mining networks and central entities in digital libraries. A graph theoretic approach applied to co-author networks. In Berthold, Mr and Lenz, Hj and Bradley, E and Kruse, R and Borgelt, C (Ed.), *Advances In Intelligent Data Analysis V*, Volume 2810 of *Lecture Notes In Computer Science*, pp. 155–166. 5th International Symposium on Intelligent Data Analysis, Berlin, Germany, Aug 28-30, 2003.

Mutschke, P. and A. Haase (2001). Collaboration and cognitive structures in social science research fields. Towards socio-cognitive analysis in information systems. *Scientometrics 52*(3), 487–502. 2nd Berlin Workshop on Scientometrics and Informatics/Collaboration in Science and in Technology, Berlin, Germany, Sep 01-04, 2000.

Nankani, E., S. Simoff, S. Denize, and L. Young (2009). Supporting Strategic Decision Making in an Enterprise University Through Detecting Patterns of Academic Collaboration. In Yang, J and Ginige, A and Mayr, HC and Kutsche, RD (Ed.), *Information Systems: Modeling, Development and Integration, UNISCON 2009*, Volume 20 of *Lecture Notes in Business*

Information Processing, pp. 496–507. 3rd International United Information Systems Conference (UNISCON 2009), Sydney, AUSTRALIA, APR 21-24, 2009.

Neff, M. W. and E. A. Corley (2009). 35 years and 160,000 articles: A bibliometric exploration of the evolution of ecology. *Scientometrics 80*(3), 657–682.

Newman, M. (2001a). Scientific collaboration networks. I. Network construction and fundamental results. *Physical Review E 64*(016131), 1–8.

Newman, M. (2001b). Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality. *Physical Review E 64*(016132), 1–10.

Newman, M. (2001c). The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences of The United States of America 98*(2), 404–409.

Newman, M. (2003). The structure and function of complex networks. *SIAM Review*.

Newman, M. (2004). Coauthorship networks and patterns of scientific collaboration. *Proceedings of the National Academy of Sciences of The United States of America 101*(Suppl. 1), 5200–5205.

Nonaka, I. and H. Takeuchi (1995). *The Knowledge-Creating Company.* Oxford University Press.

Noyons, E. (2001). Bibliometric mapping of science in a science policy context. *Scientometrics 50*(1), 83–98.

Noyons, E. and A. Vanraan (1994). Bibliometric cartography of scientific and technological developments of an research-and-development field - The case of optomechatronics. *Scientometrics 30*(1), 157–173. 4th International Conference on Bibliometrics, Informetrics and Scientometrics, in Memory of Derek John de Solla Price (1922-1983), Berlin, Germany, Sep 11-15, 1993.

Noyons, E. C. M. and C. Calero-Medina (2009). Applying bibliometric mapping in a high level science policy context. *Scientometrics 79*(2), 261–275.

Olmeda-Gomez, C., A. Perianes-Rodriguez, M. Antonia Ovalle-Perandones, and F. Moya-Anegon (2008). Comparative analysis of university-government-enterprise co-authorship networks in three scientific domains in the region of Madrid. *Information Research - An International Electronic Journal 13*(3).

Onder, C., M. Sevkli, T. Altinok, and C. Tavukcuoglu (2008). Institutional change and scientific research: A preliminary bibliometric analysis of institutional influences on Turkey's recent social science publications. *Scientometrics 76*(3), 543–560.

Onyancha, O. B. and D. N. Ocholla (2009). Is Hiv/aids in Africa distinct? What an we learn from an analysis of the literature? *Scientometrics 79*(2), 277–296.

Osterloh, M. and B. Frey (2000). Motivation, knowledge transfer, and organizational forms. *Organization Sceince 11*(5), 538–550. Enter text here.

Ozel, B., H. Kretschmer, and T. Kretschmer (2010). Gendered co-authorship pair distribution patterns. COLLNET Journal (at review process).

Pao, M. (1992). Global and local collaborators - A study of scientific collaboration. *Information Processing & Management 28*(1), 99–109.

Polanyi, M. (2009). *The Tacit Dimension.* The University of Chicago Press.

Pontille, D. (2003). Authorship practices and institutional contexts in sociology: Elements for a comparison of the United States and France. *Science Technology and Human Values 28*(2), 217–243.

Powell, W. (1990). Neither market nor hierarchy - Network forms of organization. *Research in Organizational Behavior 12*, 295–336.

Powell, W., K. Koput, and L. SmithDoerr (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly 41*(1), 116–145. 1994 SCOR Winter Conference, Stanford, CA, 1994.

Price, D. and S. Gursey (1976). Studies in scientometrics. Part 1. Transience and continuance in scientific authorship. In *International Forum on Information and Documentation*, pp. 17–24.

Prior, L. (2008). Repositioning documents in social research. *Sociology-The Journal of the British Sociological Association 42*(5), 821–836. ESA Workshop on Improving the Quality of Qualitative Research, Kristiansand, Norway, Jun, 2007.

Qin, J. (1994). An investigation of research collaboration in the sciences through the philosophical transactions 1901-1991. *Scientometrics 29*(2), 219–238.

Riffe, D., S. Lacy, and F. G. Fico (1998). *Analyzing Media Messages: Using Quantitative Content Analysis in Research.* Mahwah, NJ: Lawrence Erlbaum.

Rip, A. and J. Courtial (1984). Co-word maps of biotechnology - An example of cognitive scientometrics. *Scientometrics 6*(6), 381–400.

Rodriguez, V., F. Janssens, K. Debackere, and B. De Moor (2007). Do material transfer agreements affect the choice of research agendas? The case of biotechnology in Belgium. *Scientometrics 71*(2), 239–269.

Saxenian, A. (1996). *Regional Adventage.* Harvard University Press.

Scheler, M. (1980). *Problems of a Sociology of Knowledge.* Routledge.

Schubert, A. and W. Glanzel (2006). Cross-national preference in coauthorship, references and citations. *Scientometrics 69*(2), 409–428.

Scott, J. (2000). *Social Network Analysis: A Handbook* (2 ed.). Sage.

Seglen, P. and D. Aksnes (2000). Scientific productivity and group size: A bibliometric analysis of Norwegian microbiological research. *Scientometrics 49*(1), 125–143.

Segre, S. (2004). A durkeimian network theory. *Journal of Classical Sociology 4*(215-235).

Singh, J. (2003). Social networks as drivers of knowledge diffusion. Technical report, Harvard University.

Singh, J. (2005). Collaborative networks as determinants of knowledge diffusion patterns. *Management Science 51*(5), 756–770.

Slaughter, S. and G. Rhoades (1993). Changes in intellectual property statutes and policies at a public university: Revising the terms of professional labor. *Higher Education 26*(3), 287–312.

Sorenson, O. and L. Fleming (2004). Science and the diffusion of knowledge. *Research Policy 33*(10), 1615–1634.

Sousa, C. and P. Hendriks (2006). The diving bell and the butterfly - The need for grounded theory in developing a knowledge-based view of organizations. *Organizational Research Methods 9*(3), 315–338.

Spencer, J. (2003). Global gatekeeping, representation, and network structure: a longitudinal analysis of regional and global knowledge-diffusion networks. *Journal of International Business Studies 34*(5), 428–442.

Stegmann, J. and G. Grohmann (2003). Hypothesis generation guided by co-word clustering. *Scientometrics 56*(1), 111–135.

Sternitzke, C. and I. Bergmann (2009). Similarity measures for document mapping: A comparative study on the level of an individual scientist. *Scientometrics 78*(1), 113–130.

Tijssen, R. (1993). A scientometric cognitive study of neural-network research - Expert mental maps versus bibliometric maps. *Scientometrics 28*(1), 111–136.

Tijssen, R. and A. Vanraan (1989). Mapping co-word structures - A comparison of multidimensional-scaling and Leximappe. *Scientometrics 15*(3-4), 283–295.

Tomassini, M. and L. Luthi (2007). Empirical analysis of the evolution of a scientific collaboration network. *Physica A - Statistical Mechanics and its Applications 385*(2), 750–764.

Turner, W. and F. Rojouan (1991). Evaluating input output relationships in a regional research network using co-word analysis. *Scientometrics 22*(1), 139–154.

Üsdiken, B. (1996). Importing theories of management and organization: The case of turkish academia. *International Studies of Management and Organization 26*, 33–46.

Üsdiken, B. (2004a). Americanization of European management education in historical and comparative perspective - A symposium. *Journal Of Management Inquiry 13*(2), 87–89.

Üsdiken, B. (2004b). Exporting managerial knowledge to the outpost - Penetration of 'human relations' into Turkish academia, 1950-1965. *Management Learning 35*(3), 255–270. 3rd International Conference on Critical Management Studies, Lancaster, ENGLAND, JUL 07-09, 2003.

Üsdiken, B. (2007). Commentary: Management education between logics and locations. *Scandinavian Journal Of Management 23*(1), 84–94.

Üsdiken, B. and D. Cetin (2001). From betriebswirtschaftslehre to human relations: Turkish management literature before and after the Second World War. *Business History 43*(2), 99+.

Üsdiken, B., A. Kieser, and P. Kjaer (2004). Academy, economy and polity: Betriebswirtschaftslehre in Germany, Denmark and Turkey before 1945. *Business History 46*(3), 381+.

Üsdiken, B. and V. Pasadeos (1995). Organization analysis in north america and europe: A comparison of co-citation networks. *Organization Studies 16*(3), 503–527.

Üsdiken, B. and S. A. Wasti (2009). Preaching, Teaching and Researching at the Periphery: Academic Management Literature in Turkey, 1970-1999. *Organization Studies 30*(10), 1063–1082.

Uzun, A. (1996). A bibliometric analysis of physics publications from Middle Eastern countries. *Scientometrics 36*(2), 259–269.

Uzun, A. (1998). A scientometric profile of social sciences research in Turkey. *International Information and Library Review 30*(3), 169–184.

Uzun, A. (2002). Library and information science research in developing countries and Eastern European countries: A brief bibliometric perspective. *International Information and Library Review 34*(1), 21–33.

Uzun, A. (2006). Science and technology policy in Turkey. National strategies for innovation and change during the 1983-2003 period and beyond. *Scientometrics 66*(3), 551–559.

Uzun, A. and M. Ozel (1996). Publication patterns of Turkish astronomers. *Scientometrics 37*(1), 159–169.

Uzzi, B. (1997). Social structure and competition in interfirm networks. *Administrative Science Quarterly 42*(1), 35–67.

Valente, T. and R. Davis (1999). Accelerating the diffusion of innovations using opinion leaders. *Annals of the American Academy of Political and Social Science 566*, 55–67.

Valente, T. W. (1995). *Network Models of the Diffusion of Innovations.* Hampton Press.

Vanraan, A. and R. Tijssen (1993). The neural net of neural network research - An exercise in bibliometric mapping. *Scientometrics 26*(1), 169–192.

European Workshop On Scientometric Methods Of Research Evaluation In The Sciences, Social Sciences And Technology, Potsdam, Germany, Apr 13-17, 1991.

Vidgen, R., S. Henneberg, and P. Naude (2007). What sort of community is the European Conference on Information Systems? A social network analysis 1993-2005. *European Journal of Information Systems 16*(1), 5–19.

Vilan Filho, J. L., H. B. de Souza, and S. Mueller (2008). Articles from Brazilian scientific journals in information areas: evolution of production and multiple authorship. *Perspectivas em Ciencia da Informacao 13*(2), 2–17.

Vogel, E. (1997). Impact factor and international collaboration in Chilean physics: 1987-1994. *Scientometrics 38*(2), 253–263.

Wagner, C. (2005). Six case studies of international collaboration in science. *Scientometrics 62*(1), 3–26.

Wagner, C. S. and L. Leydesdorff (2005). Network structure, self-organization, and the growth of international collaboration in science. *Research Policy 34*(10), 1608–1618.

Wagner-Dobler, R. (2001). Continuity and discontinuity of collaboration behaviour since 1800 - from a bibliometric point of view. *Scientometrics 52*(3), 503–517. 2nd Berlin Workshop on Scientometrics and Informatics/Collaboration in Science and in Technology, BERLIN, GERMANY, SEP 01-04, 2000.

Wang, Y., Y. Wu, Y. Pan, Z. Ma, and R. Rousseau (2005). Scientific collaboration in China as reflected in co-authorship. *Scientometrics 62*(2), 183–198.

Wasserman, S. and K. Faust (1994). *Social Network Analysis.* Structural Analysis in the Social Sciences. Cambridge University Press.

Watts, D. J. and S. H. Strogatz (1998). Collective dynamics of 'small-world' networks. *Nature 393*(6684), 440–442.

Wellman, B. (1988). *Social Structures a Network Approach*, Chapter Structural analysis: from method and metaphor to theory and substance, pp. 19–61. Cambridge University Press.

White, H., B. Wellman, and N. Nazer (2004). Does citation reflect social structure?: Longitudinal evidence from the 'Globenet' interdisciplinary research group. *Journal of the American Society for Information Science and Technology 55*(2), 111–126.

White, M. D. and E. E. Marsh (2006). Content analysis: A flexible methodology. *Library Trends 55*(1), 22–45.

Whittaker, J., J. Courtial, and J. Law (1989). Creativity and conformity in science - Titles, keywords and co-word analysis. *Social Studies of Science 19*(3), 473–496.

Whittington, K. B., J. Owen-Smith, and W. W. Powell (2009). Networks, Propinquity, and Innovation in Knowledge-intensive Industries. *Administrative Science Quarterly 54*(1), 90–122.

Willke, H. (2007). *Smart Governance: Governing the Global Knowledge Society*. The University of Chicago Press.

Wolfe, A. W. (1986). The multinational corporation as a form of sociocultural integration above the level of the state. *Anthroplogy and International Business. Studies in Third World Series 28*, 163–192.

Wray, K. (2002). The epistemic significance of collaborative research. *Philosophy of Science 69*(1), 150–168.

Yeung, Y., T. Liu, and P. Ng (2005). A social network analysis of research collaboration in physics education. *American Journal of Physics 73*(2), 145–150.

Yoshikane, F. and K. Kageura (2004). Comparative analysis of coauthorship networks of different domains: The growth and change of networks. *Scientometrics 60*(3), 433–444. 9th International Conference on Scientometrics and Informatics, Beijing, PEOPLES R CHINA, AUG, 2003.

Yoshikane, F., T. Nozawa, S. Shibui, and T. Suzuki (2009). An analysis of the connection between researchers' productivity and their co-authors' past attributions, including the importance in collaboration networks. *Scientometrics 79*(2), 435–449.

Yue, C. and Z. Liu (2005). An analysis of co-authorship of management science in China. In Ingwersen, P and Larsen, B (Ed.), *ISSI 2005: Proceedings of the 10th International Conference of the International Society for Scientometrics and Informetrics, Vols 1 and 2*, pp. 733–739. 10th International Conference of the International-Society-for-Scientometrics-and-Informetrics, Stockholm, SWEDEN, JUL 24-28, 2005.

Yurtsever, E. and S. Gulgoz (1999). The increase in the rate of publications originating from Turkey. *Scientometrics 46*(2), 321–336.

Zhang, H. and H. Guo (1997). Scientific research collaboration in China. *Scientometrics 38*(2), 309–319.

Zitt, M. (1991). A simple method for dynamic scientometrics using lexical analysis. *Scientometrics 22*(1), 229–252.

Zitt, M., E. Bassecoulard, and Y. Okubo (2000). Shadows of the past in international cooperation: Collaboration profiles of the top five producers of science. *Scientometrics 47*(3), 627–657.

Zollo, M. and S. Winter (2002). Deliberate learning and the evolution of dynamic capabilities. *Organization Science 13*(3), 339–351.

Zuccala, A. (2006). Modeling the invisible college. *Journal of the American Society for Information Science and Technology 57*(2), 152–168.