Networks in Economics

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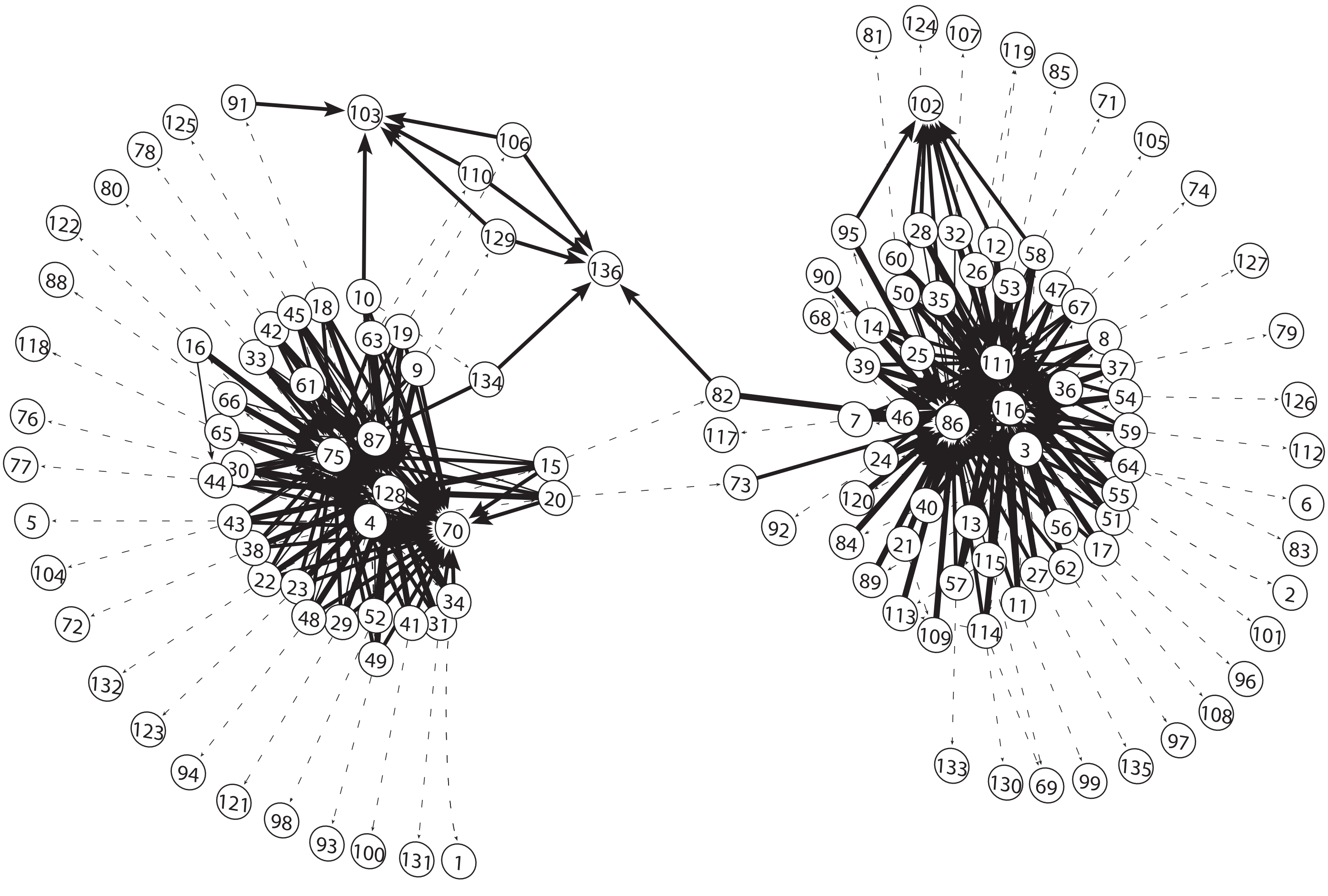

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To Anika, Christine and Sebastian

To My Parents

Preface

No large project can be accomplished without many supporters. Thank you to all colleagues, Ph.D. students and students at Darmstadt University of Technology, University of Mannheim and Universitat Autònoma de Barcelona for discussing economic topics, having lunch and proof reading my work.

I am especially grateful to my advisor at University of Frankfurt, Prof. Dr. Horst Entorf, who supported me throughout the last years. Moreover, I am also obliged to my co-supervisor Prof. Dr. Carsten Helm for comments and ameliorations.

Special thanks go to my family for their support during the last years. In particular, my children have strongly facilitated this work by totally disregarding it.

Jochen Möbert
Darmstadt, 17 April 2008

Content

Chapter 1

Introduction

1.1 Scientific Motivation for Network Research

The topic of this dissertation “Networks in Economics” is special. Classical economic themes in microeconomic as well as macroeconomics are either concerned with individuals interacting through anonymous markets or with the results of the interaction. In recent decades as well as centuries, given the lack of data and computing facilities this was a very rational and successful approach. Often these classical models are implicitly solved by the introduction of an abstract concept. The Walrasian auctioneer who clears the market by matching supply and demand is certainly the most popular example. An abstract concept allows to focus on final outcomes such as prices and quantities but turn a blind eye on social processes. Hence, we can regard these models as benchmark cases. In some circumstances the benchmark describes actual outcomes fairly well whereas in others more information is necessary to get a deeper understanding of observed processes and outcomes.

Economists are aware of these shortcomings and have considered much more elaborate models in recent years. For instance, the microfoundation of macroeconomics, agent-based models, models taking into account the heterogeneity of agents, social interaction models, among others broaden our view and may enhance our understanding. All modern researchers are always eager to improve standard models through the incorporation of additional pieces of information. The question comes up, when the process of more detailed models will come to a stop? Implicitly, this question asks “What is at the centre of all economic research?” For many economists a natural answer is that the atomistic subject of economics is either an individual, an institution or the interplay between both.[1] Economic network analysis exactly investigates the relationship of these atomistic subjects to each other and the importance of these relationships for economic outcomes. Henceforth, economic network analysis may not be on the agenda of today's economists but might pave the way for a new way of thinking among economists.

1.2 Dissertation Progress

The interest in economic network analysis arose while I was writing my master's thesis "Development of Bubbles: Theory and a case study of the 'Neuer Markt' ". Information on future stock market developments often contains no information which is based on any form of economic reasoning. Unfounded speculation can be self-perpetuating if naive investors or other financial market participants react on each other, i.e. take long positions if a peer group of each investor purchases shares. This processes can be very dynamic and, therefore, no reliable models forecasting the burst of stock market bubbles exist.

The idea arises that a successful forecast model might catch the social networks of important financial market participants. Hence, during the first years of working on my dissertation, I planned to reveal and investigate the social networks of financial analysts. In the aftermath of the burst of the bubble the disappointed small investors often adjudged them guilty. Beyond doubt, their forecasts were overconfident, however, beforehand bearish financial analysts performed poorly when the stock market indices continuously hit new all-time-highs. They lost their jobs and overconfident analysts were encouraged to continue their misinterpretations of the market situation.

At the outset of my dissertation, I contacted the 'Society of Investment Professionals in Germany'[2] an organisation representing "more than 1,100 individual members representing over 400 investment firms, banks, asset managers, consultants and counselling businesses"[3] and proposed to survey the behaviour and social networks of its members. In a first step, the research idea was presented to the managing director who supported my research scheme. Unfortunately, the DVFA-board of directors turned down the project. I continued this line of research by directly contacting banks. However, the analysts always denied to answer questions on the structure of their social networks. Consequently, the project was closed.

[1] In very recent years, economists have also started to explore the influence of neuroscientific processes on decision-making. These researchers might probably define the atomistic subject of economics quite differently.

[2] 'Deutsche Vereinigung für Finanzanalyse und Asset Management' (DVFA) located in Frankfurt am Main.

[3] *http://www.dvfa.de/home_engl/dok/35307.php* downloaded on May 25, 2007.

Subsequently, the idea arose to survey groups for which the information gathering is less difficult. I planned to evaluate social networks in school classes and their influence on marks or test scores. Managing such a project needs a large amount of resources and administrative work. Pupils as well as parents, teachers, and administrative staff have to be contacted to organize such a project. Accordingly, this approach seemed not feasible due to the large workload. To reduce the burden of work I was looking for existing data sets containing social network information. After reading several journal articles which tackle school classes and are based on original surveys I discovered an article in which pupils had been asked "who is your friend in class?". This information was used to investigate whether more intelligent pupils have more or less friends than less intelligent pupils. I contacted the author of the article and asked him whether the data is still available and whether it is possible to exploit the network information. Unfortunately, the originally available network information was aggregated such that the network information was lost and the project was not continued.

Last but not least, I tried to explore the characteristics of a game-theoretical model which explains typical properties of empirical network data such as the small-world property and power law distributions. Unfortunately, the model was complicated, or to put it in another way, my capabilities as well as the available computational capacity were not strong enough to find equilibria and efficient networks. To put it succinctly, the problem of this project was that the analysis of a multiplicative utility function tremendously increases the number of solutions such that a brief description seems difficult. However, the failure of this project induced me to evaluate an alternative welfare measure on social network models. The results of this work are shown in Chapter 2.

In 2006 and within a few weeks, two network data sets were available to me. First, the Hoppenstedt corporation provides me with a large corporate governance data set containing ownership structures of German companies. This unique data set is analysed in Chapter 3. Second, the DFG-project "Metaanalysis of Empirical Studies on Deterrence" allowed a scientometric network study on criminologists as shown in Chapter 5. The first data set was processed by Patrick Tydecks who used it to write his diploma thesis. The second data set was arranged by my colleague Thomas Rupp. Hence, both researchers are coauthors of mine whereas the chapters are written by myself.

Finally, in 2007 Immanuel Pahlke and Florian Gattung established an additional network data set which is analysed in Chapter 4. It contains information on the board of director network among DAX corporations and examines the impact of the network structure on executive remuneration. This chapter was written by myself together with both students and my supervisor Prof. Horst Entorf. The dissertation concludes with a supplement in Chapter 6.

Chapter 2

Jefficiency vs. Efficiency in Social Network Models

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2.1 Introduction

Measuring the welfare of a group of people or a society is at the heart of economics. There are several measures of welfare in the literature. The standard concept among the welfarist functions is a Benthamite welfare function which sums up the values of individual utility functions (cf. Bentham 1789). The counterpart to Bentham's concept is the minimax criterion described by Rawls (1971), which implies under weak assumptions an egalitarian outcome. Both are extreme positions of moral philosophy while more pragmatic concepts are less frequently debated. Traditionally, the success of the utilitarian as well as the egalitarian welfare function has not been emphasized by applied researchers, but ideologists and theorists used the concepts. Authors in the former category have made consumer-orientated use of it, whilst the latter have focused on academic research.

Until now, the standard measure in the social network literature has been the utilitarian welfare function. This welfare function is defined such that the term efficiency and utilitarian concept are used synonymously. In social network papers it might be challenging to prove which network structures are the efficient ones. For instance, in Bala and Goyal (2000) and Calvó-Armengol (2004) some difficulties are implicitly mentioned since the authors restrict some of their results related to the efficiency criterion to specific functions and values and not to a general solution.[1] Additionally, the calculation of the efficient set might be constrained by slow computer processors. However, the optimal utilitarian outcome is in many situations still one of the less complicated concepts and this is generally true in many other fields of economics where proofs and the computational task are less demanding. Hence, it can be argued that the use of this concept in social network papers[2] is motivated by mathematical simplicity.

The attractiveness of the utilitarian welfare function is closely related to the way utility functions are specified. The first contributions to the social network literature have not derived their utility functions from observing the behavior of humans but from the experience that fully-fledged solutions are often obtained out of linearly specified utility functions, while the detection of actually more realistic, but also more complicated, specifications of utility functions are much more involved. Therefore, instead of having realistic but irresolvable models economists prefer simple models conveying some simple messages.

Many researchers who use the utilitarian welfare concept often express their discomfort regarding its social implications. However, they continue to use it since they claim it is better to appraise the efficiency using the utilitarian concept than to completely disregard the welfare problem. Rawls (1971), Sen (1979), among others pointing out that the utilitarian concept abstracts from distributional issues.[3] It only maximizes the sum of all utilities and allows for arbitrary utility distributions across a set of players. Hence, this criterion can be inappropriate for advising non-economists and it can be an important reason for the lack of communication between theorists and applied researchers (cf. Slesnick 1998). Accordingly, proposals of policy advisors based on the utilitarian criterion might be attacked by politicians and decision-makers. In this contribution a different welfare criterion is proposed and results are compared with the utilitarian concept. Thereby, it is shown that the mathematical ease is obtainable in social network models if both welfare and utility functions are specified in a more realistic way.

Carayol, Roux, and Yildizoglu (2005) propose the use of an algorithm to approximate the set of efficient networks. This idea might be a promising one. Of course, one shortcoming of an approximation is the lack of beauty. While beauty has a value for itself, it also enhances

[1] In the case of the job-contact network model invented by Calvó-Armengol (2004) it is not the deterministic but the expected sum of utilities that is maximized.

[2] As well as in other subfields of economics.

[3] Note that given a utilitarian concept a uniform distribution of goods is welfare maximizing if each utility function increases with consumption and is concave.

our intuitive understanding for outcomes. Another shortcoming of an approximation is that an algorithm might produce misleading results. Carayol, Roux, and Yildizoglu (2005) show that for the co-author network formation model introduced by Jackson and Wolinsky (1996) the algorithm used is exact at least for small networks. However, it is not able to catch the structure of the symmetric connection model. Even worse, it seems that the degree of exactness depends in a nonlinear way on the number of players. The algorithm fails sometimes for small and very stylized network models such that for large and complex networks the precision of the algorithm could be low. The findings of Carayol, Roux, and Yildizoglu (2005) imply that a lot of additional research seems to be necessary for the application of the algorithm. The usage of algorithms might be especially helpful if applications of social network methods to large networks or whole economies are considered.

Welfare functions maximizing either the allocation efficiency or try to accomplish a uniform distribution are less interesting from a pragmatic point of view than welfare measures which take into account both properties. An example of such a welfare function is the product of utilities proposed by Nash (1950), also called 'Nash product'. This product is only one member of the constant elasticity of substitution class where the inequality aversion parameter is positive and finite. In this class of welfare criterions it is chosen because it exhibits favorable properties discussed below. The Nash product is also called multiplicative social welfare function and is maximized if the product of all utilities is maximal.[4]

[4]Game theorists working in the field of bargaining models are familiar with the Nash product, which is often defined as the product of player's utilities above their reservation utilities. Nash's (1950) seminal contribution to the bargaining literature demonstrated that the maximization of this product has decent properties in the context of bargaining among agents.

Researchers such as Kaneko and Nakamura (1979) as well as Hanany (2001) used the Nash product as a mean of measuring social welfare and showed its normative implications. In this paper I follow them and take the position of a social planner who uses the Nash product to evaluate the welfare properties of social networks. In the social network literature Nash is associated with some equilibrium concepts. The multiplicative welfare function is called the "jefficiency" criterion to avoid confusion with, for instance, the Pairwise-Nash equilibrium concept and where the j emphasizes that the Nash product takes into account some form of justice. Accordingly, a network which maximizes this criterion is called "jefficient". Having introduced the notation in Chapter 2.2, in Chapter 2.3 some properties of the efficiency and the jefficiency measure are compared. Moreover, some simple results of well-known social network formation models are shown. In Chapter 2.4 the application and comparison of the efficiency and jefficiency criterion and derive the jefficient networks of the original symmetric connection model as well as the "simple multiplicative symmetric connection model" is continued. Chapter 2.5 concludes by illustrating that in many situations multiplicative utility functions have attractive properties that are complementary to the jefficiency criterion.

2.2 Notation

Let $\mathcal{N} = \{1, ..., N\}$ be the finite set of players and the individual player is denoted by i. We assume throughout the paper $N \geq 3$. We denote the utilitarian welfare concept by $W = \sum_{i=1}^{N} u_i$ where $u_i \in \mathbb{R}$ is the utility level for each player i. The utility of each player i is derived from the position of i in a network g such that u_i is a short form for $u_i(g)$. The jefficiency criterion is defined by $J = \prod_{i=1}^{N} u_i$ where $u_i > 0$ for all i.[5] Otherwise, J is not defined. This assumption is necessary because without this assumption negative utility functions might be multiplied by each other and yield positive outcomes. This contradicts the aim of a social planner.[6] Given a utility distribution the mean utility level is abbreviated by $\overline{u}$. Utility vectors of dimension N are denoted by u and v respectively. The link between player i and j is denoted by ij and a set of links $g = \{ij, ik, \dots\}$ describes a whole network structure. If ij is formed, then ji also exists which implies that we consider undirected unweighted networks. Different networks are distinguished by a subscript g_c for $c = 1, 2$. Some considered network structures are the star g_S and the regular network of degree k $g_{R,k}$. In a star formation one player, the center, has links to every other player, while the other players, the peripheral players, have links to the star only. In

[5] Notice that taking the logarithm of J result in $\log(J) = \sum_{i=1}^{N} \log(u_i)$ which simplifies the comparison of both concepts.

[6] An alternative specification might be to multiply positive utility functions and divide the absolute value of negative utility levels, i.e. $J = \left(\prod_i u_i\right) / \left(\prod_j |u_j|\right)$ where $u_i > 0$ and $u_j < 0$. However, this definition is not applicable for zero utility levels.

a regular network each player has the same number of links. An example for a regular network is the complete network $g_{R,N-1}$ also denoted by g_N where each player i forms $N-1$ links. Also, the empty network is a regular network. Another frequently debated network formation is the line where $g_L = \{i_1i_2, i_2i_3, \ldots, i_Ni_{N-1}\}$. Additional notation which is needed to describe the results of other papers is introduced below.

2.3 Efficiency vs. Jefficiency

As is known, J and W are related to each other via the class of CES-functions.[7] The general form of these functions is

$$CES(\rho) = \begin{cases} \frac{1}{1-\rho} \sum_{i=1}^{N} [u_i]^{1-\rho} & \text{for } \rho \neq 1 \\ \prod_{i=1}^{N} u_i & \text{for } \rho = 1 \end{cases} \tag{2.1}$$

where ρ indicates the aversion towards inequality. If $\rho = 0$, the Benthamite social welfare function W is attained, and for $\rho = 1$ the CES-functions are completed by the Nash social welfare function.[8]

Lemma 1 (Transferable Utility) *Maximizing J in a transferable utility world requires the maximization of W in a first step. Subsequently, utility is redistributed such that each player obtains the same utility level.*

Proof: To maximize J we want to produce the maximum amount of utility units among the set of players. This implies maximizing W. Subsequently, each player gets the same utility level since $\log(\bar{u}) \geq \overline{\log(u)}$ where $\overline{\log(u)} = N^{-1} [\log(u_1) + \log(u_2) + \cdots + \log(u_N)]$ where log is the natural logarithm. $\square$

In a transferable utility world the production of utilities is separated from the distribution of utilities. Hence, a higher amount of total utility enables a Pareto improvement. After W is maximized the maximization of J requires to distribute all utility units equally among the player set. The reason for this is that $\prod_{i=1}^{N} \overline{u} > \prod_{i=1}^{N} u_i$ if at least one individual utility level $u_i \neq \overline{u}$ where $\sum_{i=1}^{N} u_i = N\overline{u}$ and $\overline{u}$ indicates that all players have the same utility level. Generally, if

[7] CES is the abbreviation for "constant elasticity of substitution".

[8] In general, the larger ρ is, the higher a social planner's inequality aversion. To show that for $\rho = 1$ the CES-class is completed by $\prod_{i=1}^{N} u_i$ can be shown by l'Hospital's rule if $\rho \to 1$.

a strictly concave function such as the logarithm is considered then the functional value of the mean is always larger than the mean value of all functional values.

The more realistic and therefore more interesting case is the nontransferable utility world. In such an economy, the maximization of J simultaneously takes also into account the allocation and the distribution of utilities. Therefore, we face a trade-off between the production of utilities and the degree of inequality in a society. Intuitively, multiplying all utility functions of the whole player set implies that each player's utility has not only a direct but also an indirect effect on the social welfare function. These externalities are preserved if we rewrite J as

$$J = \exp\left(\sum_{i=1}^{N} log(u_i)\right) \tag{2.2}$$

It is readily seen that the maximization of J yields the same outcome as maximizing $log(J) = \sum_{i=1}^{N} log(u_i)$. Here, it is not the utility sum which is maximized, but the sum of logarithmised utilities. The concave log function scales down the welfare weight of high utility levels relative to low levels. This implies that the indirect effects each player produces and which are initially contained in J are transformed into the concavity of the logarithm function. Therefore, the maximization of J weights both production efficiency and some form of equity. A Taylor approximation of $log(J)$ around the mean $\overline{u}$ enhances our understanding of the relationship between both welfare issues. It also enhances the comparison of the jefficiency property and the standard welfare property.

Proposition 1

$$\log(J) = N\left[\log(\bar{u}) + \sum_{d=2}^{D=\infty}\sum_{i=1}^{N}(-1)^{d+1}\frac{1}{dN}\left(\frac{u_i - \bar{u}}{\bar{u}}\right)^d\right] \tag{2.3}$$

where we call $\frac{1}{N}\sum_{i=1}^{N}(\frac{u_i-\bar{u}}{\bar{u}})^d$ *the* $\bar{u}$*-standardized dth-moment.*

Proof: Using the Taylor-series we can write $log(u_i) = \sum_{d=0}^{\infty} \frac{\log^{(d)}(\bar{u})}{d!}(u_i - \bar{u})^d$ where $\log^{(d)}(\bar{u}) = \frac{\partial^d log(\bar{u})}{\partial\ \bar{u}^d}$, i.e. the dth derivation with respect to $\bar{u}$. This can be rewritten as $log(u_i) = \log(\bar{u}) + \frac{u_i-\bar{u}}{\bar{u}} + \sum_{d=2}^{\infty} \frac{\log^{(d)}(\bar{u})}{d!}(u_i - \bar{u})^d$. Let $\log^{(d)}(\bar{u}) = (-1)^{d+1}\frac{(d-1)!}{\bar{u}^d}$ and summing over each player in the player set yields the above formula in Equation 2.3. □

We call the double sum the D-series and say J is approximated up to order $D \leq \infty$. If we also rewrite $W = N\overline{u}$, then the first right-hand term of J can be compared to W. Maximizing $N\overline{u}$ yields the same economic outcome as the maximization of $Nlog(\overline{u})$. Therefore, if the individual utilities are close to the mean, then the D-series is close to zero and the maximization of J and W yields similar results. However, J also takes into account the distribution of the utilities. Thus, if the utility levels of the players are spread across a larger range, then J yields different results than W. Taking the exponential on both sides of Equation 2.3 might be helpful in separating the jefficiency criterion into an allocation part and another part capturing the degree of inequality.

$$J = \bar{u}^N + \exp\left[\sum_{d=2}^{D=\infty}\sum_{i=1}^{N}(-1)^{d+1}\frac{1}{d}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d\right] \tag{2.4}$$

Let us call $\bar{u}^N$ the allocation addend and $J-\bar{u}^N$ the distributional addend. Then the fractions $\frac{\bar{u}^N}{J}$ and $\frac{J-\bar{u}^N}{J}$ characterize how important efficiency and inequality are in a specific situation. As a matter of course, the Taylor approximation is valid for other values than $\bar{u}$. If other values are chosen, then the partition into an efficiency part and an inequality part varies. However, the choice of $\bar{u}$ seems attractive because given this choice the inequality part can be interpreted as $\bar{u}$-standardized dth-moment.

If we consider the Taylor approximation up to degree $D = 4$ then

$$\log(J) \approx N\left[\log(\bar{u}) - \frac{1}{2N}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^2 + \frac{1}{3N}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^3 - \frac{1}{4N}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^4\right] \tag{2.5}$$

follows. This equation shows that $\log(J)$ is decreased, ceteris paribus, if the $\bar{u}$-standardized variance and the $\bar{u}$-standardized kurtosis of the utility distribution are increased. Furthermore, $\log(J)$ is higher for right-skewed utility distributions than for left-skewed distributions, ceteris paribus. We apply a simple example to illustrate the preference for right-skewed relative to left-skewed utility distributions. Let us consider a three-player world and let us suppose that in case α the utility levels are $u_1 = 2, u_2 = 2, u_3 = 5$ and in case β the utility levels are $u_1 = 1, u_2 = 4, u_3 = 4$. Note, in both cases the average utility level $\bar{u}$ equals three.[9] Let the skewness be $S^{case} = \frac{1}{3}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^3$ then $S^\alpha = 6 > -6 = S^\beta$. Therefore, we can conclude that $\log(J^\alpha) > \log(J^\beta)$. The message illustrated by the example holds for general $D \leq \infty$. Thereby, right-skewed utility distributions increase J and left-skewed utility distributions reduce J, ceteris paribus. Formally, this is true because under the assumptions of a constant mean and a mirror-inverted form of utilities all even d-terms are identical and all odd d-terms are positive in case α and negative in case β.

It is important to note that the Taylor-Approximation is only reasonable if the double sum $\sum_{d=2}^{\infty}\sum_{i=1}^{N}(-1)^{d+1}\frac{1}{d}\frac{1}{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d$ converges towards zero for large d. Otherwise, the alternating elements of the sum diverge and the value of J might heavily depend on the order of the approximation or, otherwise stated, the approximation introduced in Equation 2.3 is not applicable.

[9] Furthermore, convergence is guaranteed since $\max[u_i] < 2\bar{u}$ in both cases. See Remark 1.

Remark 1 *The approximation given in Equation 2.3 converges if and only if $u_i \leq 2\bar{u}$ for each player i.*

Proof[10]: First, the sufficient condition implies that $u_i \leq 2\bar{u}$ implies convergence. To prove this statement split the D-series in Equation 2.3 into a double-sum containing only even d addends (the D^{even}-part) and in another double-sum containing only odd d addends (the D^{odd}-part) . If each double-sum converges then the D-series converges. The following inequality

$$\left|(-1)^{d+1}\frac{1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d\right| > \left|(-1)^{d+3}\frac{1}{d+2}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2}\right| \tag{2.6}$$

holds for d even as well as for d odd.[11] If d is odd then distinguish case (1) where $\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d > 0$ from case (2) where $\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d < 0$. Under case (2) the D^{odd}-part as well as the D^{even}-part are smaller zero but both converge towards zero such that the D-series converges. Under case (1) the D^{even}-part is smaller zero whereas the D^{odd}-part is greater zero whereas again both converge towards zero and Leibnitz's convergence criterion is applicable.[12] Second, the necessary condition implies that convergence induces $u_i < 2\bar{u}$. Given Inequality 2.6 then each individual term $\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d$ must converge. Let $m = \left\{\left|\frac{u_j-\bar{u}}{\bar{u}}\right| \mid \left|\frac{u_j-\bar{u}}{\bar{u}}\right| \geq \left|\frac{u_i-\bar{u}}{\bar{u}}\right| \ \forall i \in \mathcal{N}\right\}$. Then, for player j it must hold that $\left|(-1)^{d+1}\frac{1}{d}m^d\right| > \left|(-1)^{d+3}\frac{1}{d+2}m^{d+2}\right|$. This can be rewritten as $\sqrt{\frac{d+2}{d}} > m$ and should hold for all $d \geq 2$ such that $1 > m = \frac{u_j-\bar{u}}{\bar{u}}$ implies $u_j < 2\bar{u}$ holds for player j and, therefore, for each player $i \in \mathcal{N}$. □

Another helpful remark simplifies some considerations regarding different network characteristics.

Remark 2 *The right term of* $\log(J)$ *in Proposition 1*

$$\sum_{d=2}^{D=\infty}\sum_{i=1}^{N}(-1)^{d+1}\frac{1}{d}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d \tag{2.7}$$

is not greater zero if the series converge.

[10]Notice throughout the whole paper I assumed that $u_i > 0$ for all i such that $\bar{u} > 0$. Hence, multiplying an inequality by $\bar{u}$ cannot turn the greater-than sign into a smaller-than sign.

[11]The Appendix contains further details.

[12]The Leibnitz Theorem has the following content: Let $\sum_{n=1}^{\infty} a_n$ be an alternating series and let $\{|a_n|\}_{n=1}^{\infty}$ be a decreasing null sequence. Then, the series $\sum_{n=1}^{\infty} a_n$ converges.

Proof: Independent of the order of D we find to every odd addend of order $d+1$ an even addend of order d. Thus, it suffices to show that

$$-\frac{1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}+\frac{1}{d+1}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}\leq 0 \tag{2.8}$$

holds. This inequality can be written as

$$\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}\leq\frac{d+1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d} \tag{2.9}$$

The inequality is true because $1<\frac{d+1}{d}$ for each d and $\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}\leq\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}$ holds because $\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}\leq\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}$ for each player i which is true by the convergence of the series. □

Both welfare criteria J and W are also related to each other under specific circumstances. While it is difficult to show fully-fledged results for the general model it is possible to discover some structure under special circumstances which are discussed below.

Lemma 2 (Dominant Order) *Suppose there are two networks g_x for $x=1,2$. If $u_i(g_1)>u_i(g_2)$ for each player i then it holds that both $W(g_1)>W(g_2)$ and $J(g_1)>J(g_2)$.*

The proof is straightforward and omitted.

Lemma 3 (Non-Dominant Order) *Suppose there are two networks g_x for $x=1,2$. Suppose S_1 and S_2 is a partition of the player set $\mathcal{N}$ where $N_1=|S_1|$ and $N_2=|S_2|$.[13] Let $u_i(g_1)>u_i(g_2)$ for all $i\in S_1$ and $u_j(g_1)<u_j(g_2)$ for all $j\in S_2$. Let $J_m(g_x)=\prod_{i=1}^{N_m}u_i(g_x)$ and $W_m(g_x)=\sum_{i=1}^{N_m}u_i(g_x)$ for $m=1,2$. Then $J(g_x)=J_1(g_x)J_2(g_x)$ and $W(g_x)=W_1(g_x)+W_2(g_x)$ for $x=1,2$. Furthermore, we assume $W_1(g_1)-W_1(g_2)>W_2(g_2)-W_2(g_1)$ which implies that network g_1 is efficient because $W(g_1)>W(g_2)$. However, it might hold that network g_2 is jefficient, i.e. $J(g_1)<J(g_2)$.*

Proof: Suppose a player $j\in S_2$ exists such that $u_j(g_1)=\varepsilon$ where $\varepsilon>0$. This small value may have only a small impact on $W(g_1)$ such that $W(g_1)>W(g_2)$ holds but $J(g_1)$ can be arbitrarily close to zero such that $J(g_2)>J(g_1)$. □

[13]Notice, the bars stand for the cardinality of the partition.

The proof of the last Remark illustrates how strong the utility level of a single player can influence the social welfare. The last two remarks can also be applied to general models in non-network models. The next two results take into account specific network formations.

Lemma 4 (Regular Networks) *If players are homogenous, then (i) the efficient network among the set of regular networks is also the jefficient network among the set of regular networks and (ii) if an efficient network is regular then this network is also the jefficient network.*

Proof: (i) If players are homogenous and all players have the same position in the network then $W = \sum_{i=1}^{N} u_i(g) = Nu_i(g)$ and $J = \prod_{i=1}^{N} u_i(g) = [u_i(g)]^N$ where $u_i(g) = \bar{u}$ for each player i. This implies that for both criteria we look for that regular network which produces the maximal utility sum for any player i since all players are identical. (ii) Lemma 1 implies that in a transferable utility world we first maximize W and then distribute the utility sum equally across all players. However, if the utilitarian welfare function is maximized such that all players get the same utility, the second step can be omitted and Lemma 1 is also applicable to the nontransferable utility world. □

Lemma 4 is applicable to the one-way flow model in Bala and Goyal (2000). In the one-way flow model information which spreads through networks can only flow to the player who bears the costs for the existing links. There, the efficient network is either the empty network or the cycle.[14] Of course, the empty network is only efficient if the costs of forming links are too high. Otherwise, the cycle is the efficient network where every player forms one link and gets the whole information set available in the set. Given Lemma 4, we know that the cycle is also the jefficient network. The same line of reasoning holds for the co-author model explained in Jackson and Wolinsky (1996). If the number of players is even, then the efficient network in the co-author model is the one where each component is formed by two players only. The reason for this result is that each player gains the maximum amount of utility relative to the number of links. If a further link is added to one player, then the utility of indirectly connected players shrinks more than the direct links add to the players who form the link. Thence, social welfare is reduced. Given Lemma 4, we can conclude that the jefficient network is also the network containing components of pairs of players only.

Another frequently investigated network formation is the star network. There, the central player is connected to $N-1$ players while the periphery players are only connected to the center. Let us assume a convergent series as defined above and denote the utilities of both groups of players

[14] Bala and Goyal (2000) used the notion wheel, while in graph theory the standard term is cycle.

by u_c for the central player and u_p for the periphery players, then

$$\log(J) = N \log\left[\frac{(N-1)u_p + u_c}{N}\right] + \sum_{d=2}^{D=\infty} \frac{(-1)^{d+1}}{d} \left\{ \frac{(N-1)(u_p - u_c)^d \left[1 + (N-1)^{d-1}(-1)^d\right]}{\left[(N-1)u_p + u_c\right]^d} \right\}$$

which given a fixed number of players depends only on u_p and u_c. It is immediately seen that $\log(J)$ reduces to $N\log(u_i)$ if and only if $u_p = u_c$ under the assumptions stated. If $u_p \neq u_c$, then all even d-terms are negative. The odd d-terms are negative if $u_p > u_c$ because from this point onwards, as described above, a left-skewed utility distribution is evaluated and the d-terms are positive if $u_p < u_c$.

The J-star formula can also be reinterpreted in the following way. In a sense, it relates an inequality measure to the total utility sum. Thus, we can rewrite

Lemma 5 (Star Networks) *In star network formations it holds that*

$$\log(J) = N \log\left(\frac{W}{N}\right) + \sum_{d=2}^{D=\infty} \frac{(-1)^{d+1}}{d} \left(\frac{\Gamma}{W}\right)^d (N-1)\left[1 + (N-1)^{d-1}(-1)^d\right]$$

where $\Gamma = u_p - u_c$ *and* $W = (N-1)u_p + u_c$.

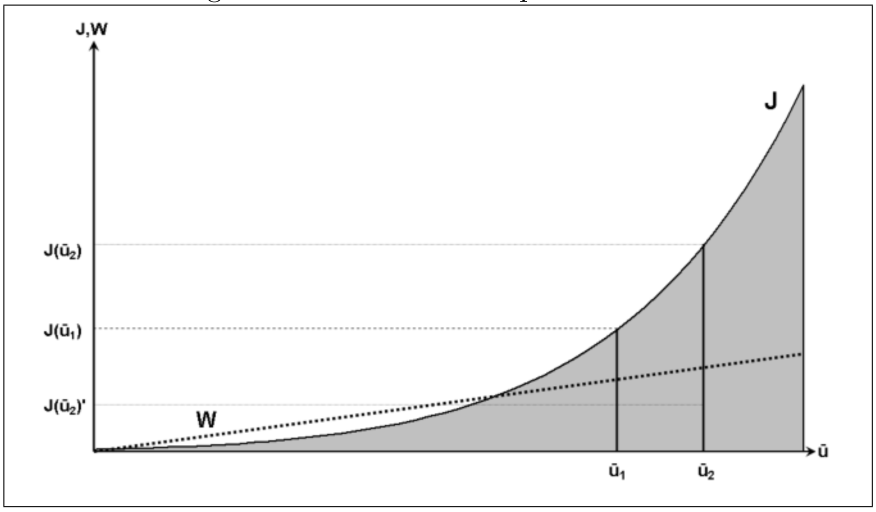
The proof requires simply replacing and solving the above equations to the original formula. Γ can be interpreted as an inequality measure while W is the sum of all utilities. It also holds that $\Gamma < W$. This inequality holds since $u_p - u_c < (N-1)u_p + u_c$ which implies $0 < (N-2)u_p + 2u_c$. This formula and its interpretation is transferable to any network where only two different utility levels arise.

Remark 3 *In a star network the Taylor-approximation converges if* $u_c < 2u_p$.

Proof: The standard condition for convergence is $u_i < 2\bar{u}$ for each player i. In the star network $u_i < 2N^{-1}\left[(N-1)u_p + u_c\right]$ for $i = p, c$ must hold. This inequality is always fulfilled for the peripheral players because $-2u_c < (N-2)u_p$. For the central player the inequality can be rewritten as $(N-2)u_c < (2N-2)u_p$. For large N this reduces to $u_c < 2u_p$ and if a smaller number of players forms the star then the inequality is a slightly less restrictive. □

A basic feature of J and W can also be characterized graphically. Figure 2.1 shows the functions $W(\bar{u})$ and $J(\bar{u})$.[15] Of course, the dotted line representing W is a linear function of $\bar{u}$ while J depends not only on $\bar{u}$, but also on the distribution of utilities. Therefore, the mapping represented by the grey field in Figure 2.1 shows the possible values the jefficiency criterion might take in dependence of $\bar{u}$. The maximum J is reached where the utility distribution degenerates to $u_i = \bar{u}$ for all player i. The minimum is reached if there exists at least one player i such that $u_i = \varepsilon > 0$. The arguments also suggest that for each $\bar{u}_2 > \bar{u}_1$ it is possible to find a utility distribution such that $J(\bar{u}_2) \leq J(\bar{u}_1)$ where the inequality is strict if $\bar{u}_1 > 0$.

Figure 2.1: J and W in dependence of $\bar{u}$



Own Source: Comparison of $J(\bar{u})$ and $W(\bar{u})$ where W is a monotonic continuously increasing linear function of $\bar{u}$ and J is a non-linear correspondence of $\bar{u}$. For each $J(\bar{u}_2) > J(\bar{u}_1)$ we can find a utility distribution $J(\bar{u}_2)' < J(\bar{u}_1)$.

[15] Notice, it is meaningless to compare the absolute value of different social welfare functions. Therefore, do not assume that $J \lesseqgtr W$.

Before the jefficiency criterion J is applied to a network model a final result is proven.

Remark 4 *Performing a mean preserving spread such that the convergence of the D-series is still maintained reduces J.*

The proof is appended.

For a symmetric utility distribution the outcome is immediately proven since all even d-parts are decreased by a mean preserving spread and odd d-terms are zero for any symmetric utility distributions.

2.4 Jefficiency in the Symmetric Connection Model

A (Multiplicative) Symmetric Connection Model
Jackson and Wolinsky (1996) introduced one of the simplest network formation models available, where each player derives utility from direct and indirect links where more distant links contribute less. Costs arise only for direct links. In this model only the empty network, the star, and the complete network are among the class of efficient networks. If we look for the jefficient networks, we discover a much richer set of networks.

Proposition 2 *The set of jefficient networks of the symmetric connection model is different from the set of efficient networks.*

Proof: For $N = 4$ there are eleven possible network formations in the symmetric connection model. Four out of these networks, for example g_0, have at least one player who is not connected to anyone else. Therefore, the jefficiency measure of these networks is zero. The following networks are left: $g_{R,1}, g_L, g = \{12, 13, 23, 24\}, g_S, g_{R,2}, g_{N-ij}$, and g_N where g_{N-ij} describes any network where $2^{-1}[N(N-1)] - 1$ links are formed. Let $c = \delta$, then in all networks where one player has only direct, and no indirect, links $J = 0$. Only J_L and $J_{R,2}$ are greater than zero and if $c = \delta$, then $J_L > J_{R,2}$. □

A general solution for N is quite demanding. Given Gauss' fundamental theorem of algebra, we conjecture that the set of jefficient network depends on the number of players.[16]

Conjecture 1 *In the symmetric connection model the set of jefficient networks increases with the number of players in a network.*

It seems reasonable that this conjecture is true in many cases and it is applicable to any additive separable utility function.[17] For instance, many utility functions in social network models are additively separable, i.e. $u_i = f_1(.) + f_2(.)$. If a utility function has this property, then the calculation of J requires the maximization of

$$J = \prod_{i=1}^{N} u_i = \prod_{i=1}^{N} [f_1(.) + f_2(.)] \tag{2.11}$$

In a simple environment such as a regular network it follows that $J = [f_1(.) + f_2(.)]^N$. Thus, even for a regular network which has only a few players the maximization of the jefficiency criterion might be complex. In network formations where players have different utility levels the calculation of J is much harder. This complexity with respect to finding the optimal J can be avoided if utility functions exhibit multiplicative separability only, i.e. if the utility function is modelled without any additive component.

Multiplicative separable utility functions make it easier to find the jefficient network. Taking the logartihm of J and the multiplicative separable utility functions shows that finding the jefficient network is as simple as finding the efficient network of utility functions which contain only additive components and have no multiplicative separable structure. Playing around with utility and welfare functions is pointless from an economic point of view. However, in many disciplines related to the social network literature – such as computer science, graph theory, Markov chain theory, neural networks, etc. – multiplicative structures are used to describe existing network outcomes. Intuitively, many economic phenomena such as critical mass effects in 'network economics'[18], the development of bubbles in financial markets, the development of customs and culture, social interaction effects, and others might be easier to model if multiplicative structures are assumed. Hence, the introduction of the jefficiency criterion as an appropriate social welfare

[16] Gauss' proof shows that in a polynomial of degree d there are d possible solutions. Some of the solutions might be complex and some of them might have multiplicity greater than one.

[17] A utility function is 'additive separability' if the function contains a 'plus'. In particular, if utility and disutility are separated by a 'plus'.

[18] Distinguish the general economic sub-discipline of social network research from 'network economics' which is a research field in industrial economics. Both fields are related to each other but researchers do not cite each other and both fields are different scientific markets.

function and the introduction of utility functions exhibiting multiplicative structures has three advantages. First, the maximization of the jefficiency is relatively simple, second, if the jefficiency criterion is used as a social welfare function an inequality measure is used which has some desirable properties, and third and most importantly, in many situations multiplicative utility functions describe social network effects in a more realistic way. In the following paragraphs, it is shown how simple the calculation of the jefficient network can be. The symmetric connection model is used to construct a utility function which enables a simple derivation of the set of jefficient networks.

The result in Proposition 2 shows that the set of jefficient networks may have a greater cardinality than the set of efficient networks in the symmetric connection model. Above it was proven that J is maximal if both equity and the production of utility is taken into account. Hence, the set of jefficient networks may contain at least some regular networks where each player has the same utility level and some minimal connected networks where the number of links and therefore the costs of forming links is minimized, and possibly also some mixture of both network structures may be jefficient.

In Möbert (2006) we defined the class of all symmetric connection models – the SCM(W)-class – grounded on the utilitarian efficiency criterion[19] and showed that the structure of the proof of the corresponding proposition in Jackson and Wolinsky (1996) can be used as a basis for the derivation of a whole class of symmetric connection models. Here a network formation model which is closely related to the SCM(W)-class is defined. This model is called "simple multiplicative symmetric connection model".[20] The idea of this network formation model is based on the (original) symmetric connection model mentioned above. The "simple multiplicative symmetric connection model" has the following utility function

$$u_i = \delta^{\sum_{e=1}^{\infty} \frac{l_e}{e}} c^{-l_1} \tag{2.12}$$

where l_e indicates the number of links of distance e of player i to all other players, δ is the utility of direct respectively indirect links and c are the costs of forming direct links.[21]

Proposition 3 *The jefficient network is*
(a) the complete network if $c < \delta^{0.5}$
(b) the star if $\delta^{0.5} < c < \delta^{0.5+0.25N}$

[19]We call this class the SCM(W)-class which means the class of symmetric connection models based on the utilitarian welfare criterion.

[20]In accordance to the "simple additive symmetric connection model" introduced in Möbert (2006).

[21]It is possible to show that the maximization of J leads to a simple result which is similar to both the maximization of W in the original and in the "simple additive symmetric connection model".

(c) the empty network if $c > \delta^{0.5+0.25N}$.

Proof: (a) If direct links are more valuable than indirect links, then $\frac{\delta}{c} > \delta^{0.5}$ which implies that the fully connected network g_N is formed if $c < \delta^{0.5}$. (b) Let us call the upper bound of a connected component with m players and $k \geq m-1$ links $J_U = (\frac{\delta}{c})^{2k}(\delta^{0.5})^{[m(m-1)-2k]}$. The jefficiency measure of the star is $J_S = (\frac{\delta}{c})^{2(m-1)}(\delta^{0.5})^{(m-2)(m-1)}$. Since $J_S \geq J_U$ for $\delta^{0.5} < c$ the star is jefficient among the set of connected components. (c) The star is just restricted by the emtpy network g_0 which is jefficient if $1 > (\frac{\delta}{c})^{2(m-1)}(\delta^{0.5})^{(m-2)(m-1)}$ which can be reduced to $c > \delta^{0.5+0.25m}$. □

2.5 Conclusion

In this paper a well-known welfare measure is applied to social network models which takes into account both allocation efficiency and has a positive risk-aversion against inequal utility distributions, the Nash product, to social network formation models. The Nash product is here also called jefficiency criterion which is a combination of the words '**j**ustice' and 'efficiency'. Several relationships between the Benthamite standard efficiency criterion and the jefficiency criterion is derived. In particular, a Taylor approximation is used to deduce a formula which improves our understanding of the jefficiency criterion relative to the utilitarian welfare measure. Furthermore, it is argued that a main reason for the application of the derivation of efficient outcomes is easier to perform if utility functions are linearly specified. By means of an example, it is shown that replacing the efficiency criterion by the jefficiency criterion leads to a larger variety of network structures in the symmetric connection model. However, the results of the "simple multiplicative symmetric connection model" demonstrated that multiplicative utility functions[22] may lead to simple welfare outcomes if welfare is measured by the jefficiency criterion. Hence, the evaluation of multiplicative specified utility functions with respect to the jefficiency criterion might be a natural choice both from a computational point of view to get relatively simple results and from a normative point of view since the jefficiency criterion introduces some form of inequality aversion into the social network literature.

The main advantage of the use of multiplicative utility functions, however, might be that multiplicative utility functions exhibit characteristics which can explain some features of really existing social networks. For instance, physicists such as Albert, Jeong, and Barabasi (1999)

[22]We call utility functions 'additive' if they exhibit 'additive seperability' properties, and 'multiplicative' if they ehibit 'multiplicative separability' properties.

have shown that a general characteristic of networks is that the distributions of links obeys the power-law or similar distributions. This kind of link distribution characterized by fat tails is also found in social networks. For instance, Goyal, van der Leij, and Moraga-González (2006) discovered that the real existing co-author network of economists also exhibits fat tails in the period 1970 to 2000. Mitzenmacher (2003) has shown that one necessity for the derivation of such distributions is the introduction of multiplicative structures. Economists who search for network formation models describing reality in an appropriate way might, therefore, prefer the modelling of multiplicative utility functions instead of the linear functions used often in today's specifications. Also in research fields which are closely related to the social network literature such as random graph theory and Markov chain theory many important results possess multiplicative structures.[23]

[23]Intuitively, multiplicative utility functions are directly justifiable by the simple observation that the survival of humans require the availability of several goods like air, water, food, etc. Without any of these resources humankind is unable to survive. Hence, if only one of these resources is unavailable to some players, then the utility levels of players in social network theories should be zero, and not above zero as in additively specified utility functions. Of course, this statement holds not only for the social network literature but for many game theoretical models (cf. Sen 1999).

2.6 Appendix

Extended Proof (Remark 1)[24]**:** First, prove the sufficient condition, i.e. $u_i \leq 2\bar{u}$ implies convergence. Split the D-series into two parts such that

$$\begin{aligned}\sum_{d=2}^{D=\infty}\sum_{i=1}^{N}(-1)^{d+1}\frac{1}{d}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d &= \\ \sum_{d\in d^e}\sum_{i=1}^{N}(-1)^{d+1}\frac{1}{d}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d &+ \sum_{d\in d^o}\sum_{i=1}^{N}(-1)^{d+1}\frac{1}{d}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d \\ &= D^{even}+D^{odd}\end{aligned} \tag{2.13}$$

where d^e and d^o is the set of even and odd numbers. If D^{even} and D^{odd} converges then the D-series itself converges. Each addend of the D^{even}-part is smaller than zero since $(-1)^{d+1} < 0$ whereas all other terms in the D^{even}-part are larger than zero. Show that

$$(-1)^{d+1}\frac{1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d < (-1)^{d+3}\frac{1}{d+2}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2}$$

which can be rewritten as

$$\frac{d+2}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d > \sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2} \tag{2.15}$$

which is true since $\frac{d+2}{d} > 1$ for each d and if $u_i < 2\bar{u}$ then each element $\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d > \left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2}$ for each d. Additionally, we have to show that not only the sequence $(.)^d$ but also the series converges. It is to show that $\sum_{r=1}^{\infty}(1-\varepsilon)^r$ converges for any $\varepsilon > 0$. Let $z = \sum_{r=1}^{\infty}(1-\varepsilon)^r$ then it holds that $z(1-\varepsilon)^{-1} = 1 + z$ such that $z = \varepsilon(1-\varepsilon)^{-1}$. Hence, D^{even} converges. To prove the convergence of the D^{odd}-part two cases must be distinguished. In case (1) $\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d > 0$ and this implies that

$$(-1)^{d+1}\frac{1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d > (-1)^{d+3}\frac{1}{d+2}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2}$$

which implies Equation 2.15. Hence, the D^{odd}-part converges. In case (2) $\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d < 0$ and then convergence requires that

$$(-1)^{d+1}\frac{1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^d < (-1)^{d+3}\frac{1}{d+2}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2}$$

[24]Notice throughout the whole paper $u_i > 0$ for all i such that $\bar{u} > 0$. Hence, multiplying an inequality by $\bar{u}$ cannot turn the greater-than sign into a smaller-than sign.

holds. This can be rewritten as

$$\frac{d+2}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}<\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2}$$

which is also true. Hence, each part converges irrespective of whether d is even or odd and irrespective of whether case (1) or (2) is considered. All conditions can be summarized in the following inequality.

$$\left|(-1)^{d+1}\frac{1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}\right|>\left|(-1)^{d+3}\frac{1}{d+2}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+2}\right|$$

which is the starting point for Remark 1. □

Proof (Remark 4): We have to show that $J > J^{MPS}$ where MPS is the abbreviation for 'mean preserving spread'. Let N^+, N^- and $\overline{N}$ be a partition on the player set. If $i \in N^+$ then $v_i > u_i \geq \bar{u}$, if $i \in N^-$ then $v_i < u_i \leq \bar{u}$, and if $i \in \overline{N}$ then $v_i = u_i$.[25] Therefore, the utility vector v defines our mean preserving spread of u. Independent of the order of D, we find for every odd addend of order $d+1$ an even addend of order d (see Remark 2) and $N\log(\bar{u})$ is constant for each mean preserving spread. Therefore, it is sufficient to show that

$$-\frac{1}{d}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}+\frac{1}{d+1}\sum_{i=1}^{N}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}>-\frac{1}{d}\sum_{i=1}^{N}\left(\frac{v_i-\bar{u}}{\bar{u}}\right)^{d}+\frac{1}{d+1}\sum_{i=1}^{N}\left(\frac{v_i-\bar{u}}{\bar{u}}\right)^{d+1}$$

We can eliminate all players who are not affected by the mean preserving spread.

$$-\sum_{i\in N\setminus\bar{N}}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}+\frac{d}{d+1}\sum_{i\in N\setminus\bar{N}}\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}>-\sum_{i\in N\setminus\bar{N}}\left(\frac{v_i-\bar{u}}{\bar{u}}\right)^{d}+\frac{d}{d+1}\sum_{i\in N\setminus\bar{N}}\left(\frac{v_i-\bar{u}}{\bar{u}}\right)^{d+1}$$

The last inequality can be written as

$$\sum_{i\in N\setminus\bar{N}}\left[\left(\frac{v_i-\bar{u}}{\bar{u}}\right)^{d}-\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}\right]>\frac{d}{d+1}\sum_{i\in N\setminus\bar{N}}\left[\left(\frac{v_i-\bar{u}}{\bar{u}}\right)^{d+1}-\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}\right]$$

Let us define $v_i = p + u_i$ for $i \in N^+$ where $p > 0$ and $v_i = -n + u_i$ for $i \in N^-$ where $n > 0$ then

$$\sum_{i\in N^+}\left[\left(\frac{p+u_i-\bar{u}}{\bar{u}}\right)^{d}-\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}\right]+\sum_{i\in N^-}\left[\left(\frac{-n+u_i-\bar{u}}{\bar{u}}\right)^{d}-\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d}\right]$$

$$>\frac{d}{d+1}\left\{\sum_{i\in N^+}\left[\left(\frac{p+u_i-\bar{u}}{\bar{u}}\right)^{d+1}-\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}\right]+\sum_{i\in N^-}\left[\left(\frac{-n+u_i-\bar{u}}{\bar{u}}\right)^{d+1}-\left(\frac{u_i-\bar{u}}{\bar{u}}\right)^{d+1}\right]\right\}$$

[25] The restrictions $v_i > u_i \geq \bar{u}$ for $i \in N^+$ and $v_i < u_i \leq \bar{u}$ for $i \in N^-$ is without loss of generality.

This inequality should hold for any natural number $d \geq 2$. Therefore, we can eliminate the first fraction on the right-hand side.

$$\sum_{i \in N^+} \left[\left(\frac{p + u_i - \bar{u}}{\bar{u}} \right)^d - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^d \right] + \sum_{i \in N^-} \left[\left(\frac{-n + u_i - \bar{u}}{\bar{u}} \right)^d - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^d \right] \tag{2.23}$$
$$> \sum_{i \in N^+} \left[\left(\frac{p + u_i - \bar{u}}{\bar{u}} \right)^{d+1} - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^{d+1} \right] + \sum_{i \in N^-} \left[\left(\frac{-n + u_i - \bar{u}}{\bar{u}} \right)^{d+1} - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^{d+1} \right]$$

Given convergence of the Taylor-series, the inequality holds since

$$\left(\frac{p + u_i - \bar{u}}{\bar{u}} \right)^d - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^d > \left(\frac{p + u_i - \bar{u}}{\bar{u}} \right)^{d+1} - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^{d+1}$$

for each player $i \in N^+$, and

$$\left(\frac{-n + u_i - \bar{u}}{\bar{u}} \right)^d - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^d > 0 > \left(\frac{-n + u_i - \bar{u}}{\bar{u}} \right)^{d+1} - \left(\frac{u_i - \bar{u}}{\bar{u}} \right)^{d+1}$$

for each player $i \in N^-$. Hence, inequality (2.23) is fulfilled and a mean preserving spread reduces the jefficiency criterion J. □

Chapter 3

Power and Ownership Structures among German Companies

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3.1 Introduction

Germany's corporate control system has at least three dimensions, i.e. the supervisory board, voting control at general assemblies (cf. Becht and Boehmer (2003)), and ownership stakes.[1] All three are closely related, but due to several specialities in German corporate law the impact of each dimension on the power of a company can be different. Ownership structures are an important source of power because they can separate cash flows and voting power (cf. Bebchuk et al. (2000), among others). In this work we identify the most powerful companies with respect to ownership stakes. The identification is important since, in Germany in particular, powerful companies might be large shareholders and such blockholders can have both a beneficial and detrimental influence.[2] Large shareholders can misuse their power in takeover proposals. A

[1] Cf. also Goergen et al. (2004) who provide a review of German corporate governance system.

[2] Agency costs might harm whereas increased monitoring efforts can create efficiency, evidence for the latter argument evidence is found by Yafeh and Yosha (2003), Gorton and Schmid (2000) and mixed results are found by Del Guercio and Hawkins (1999)).

blockholder of both the absorbing company and the acquiring company profits if a firm is sold below its value whereas minority shareholders of the acquired company are exploited. Such blockholder strategies which expropriate minority shareholders are often described by the term 'tunneling' in the corporate governance literature (cf. Bertrand et al. (2002)). Franks and Mayer (2001) analysed tunneling effects among German companies in 1990 and found little evidence that tunneling was an important issue. However, the misuse of tunneling effects is documented in several other cases. Attig et al. (2003) compile a data set on Canadian stock corporations and find evidence for the misuse of power which the ultimate owners of pyramids hold. They argue that ultimate owners maximize profits at the expense of minority shareholders and companies which have a high distance to the ultimate owners. Meoli et al. (2006) elaborate the Telecom Italia case where minority shareholders are expropriated by specific network and dual-class structures and Atanasov (2005) documents the malpractice of tunneling during the mass privatization in Bulgaria. There is also some evidence that tunneling effects played a role during the financial downturn in the Asian crisis (cf. Johnson et al. (2000), Lemmon and Lins (2003)).[3] Given these cases and the globalised financial markets detrimental consequences of block ownership can be seen as an issue in Germany as well.

In this article we exploit the large data sources available to get a micro-picture of a large part of the German corporate landscape which provides the basis for thorough investigations in the future. To put into practice such a micro-macro perspective a network approach is an appropriate method. It offers both a local micro-perspective since each company and its shareholders can be analysed alone as well as offering a bird's-eye macro-view due to the interconnectedness of all firms. Furthermore and particularly, the interaction between the micro and macro level can be investigated. Network science offers a variety of ideal tools for the development of real micro-based macroeconomics. The network perspective was already implicitly postulated in the literature on corporate control. La Porta et al. (1999) argued "For most countries, this [network perspective[4]] is the only way to understand the relationship between ownership and control"[5] (cf. also Faccio and Lang (2002), Chapelle and Szafarz (2005), among others). A large network data set is analysed and thereby extends the literature on company networks. Our aim is the identification of the most powerful companies and measure the power of companies by centrality concepts. These statistics have proven successful in the social network literature. Accordingly, this contribution is based on the network literature and the vast corporate governance literature.

[3] Edwards and Weichenrieder (2004) provides us with an econometric method to distinguish detrimental and beneficial effects of large shareholders.

[4] Authors' note.

[5] "Our principal contribution is to find wherever possible the identities of the ultimate owners of capital and of voting rights in firms, so when shares in a firm are owned by another company, we examine the ownership of that company, and so on. For most countries, this is the only way to understand the relationship between ownership and control. These data enable us to address, in a comparative perspective, four broad questions... ." La Porta et al. (1999), p. 472.

In addition to the identification of powerful companies our analysis sheds some light on the 'Deutschland AG'. Due to its particularities, the German case is intensively debated in the corporate governance literature. Many statements are based on a small data base which concentrates especially on large companies such as listed stock corporations or the largest one hundred companies.[6] The German ownership structure called 'Deutschland AG' was (or still is) interwoven and isolated relative to Anglo-Saxon markets that corporate control was implicitly exerted by the national companies themselves. Hence, legitimate ownership rights were disregarded and corporate control from outsiders, such as international shareholders as well as other stakeholders, was limited. This corporate network restrained non-national firms from gaining a foothold in the German company system and specific ownership structures among major companies hindered hostile takeovers.

In recent years, it has been discussed that the corporate ownership structure is subject to change in Germany. Due to the globalization and tax abatements on capital gains realized by sale, many blockholders diversified their investment portfolio by adding international companies and cutting down national holdings. In particular, bank and insurance companies have changed their investment portfolios. Therefore, long-term relationships often existing for decades, especially between banks and industrial companies, were broken.[7] These often mentioned breakups of bank-industry links being formed during the period of industrialisation (cf. Franks et al. (2005) and Fohlin (2005) who provide us with insights into the historical development of financial linkages in Germany), are the origin of statements such as "Is Deutschland AG kaputt?"[8] However, such analyses define the 'Deutschland AG' as a sub sample of all important German companies whereas all important ones might be of interest. Hence, the dissolution process observed may be nonexistent in the basic population. Our data set instead contains many more companies than other studies and may be more informative. Furthermore, the dissolution process observed among large national firms might be replaced by linkages to international connections. Becht and Röell (1999) have documented that companies from many countries in continental Europe have large voting blocks. Possibly, the dissolution among national firms is being replaced by new financial linkages among European corporations.[9]

[6]For instance, the equity stakes of the largest one hundred companies are investigated in biennial reports of the German Monopolkommission. Publications of Höpner and Krempel (2004) are often based on this data set.

[7]For simplicity, all non-financial companies are called industrial companies.

[8]The Economist, Dec 5th 2002, print edition.

[9]Besides a higher degree of internationalisation, concentration within an industry might also be an alternative explanation for the dissolution process among large companies. Brisk competition might force cooperation among firms. Hence, links are broken across an industry whereas the interlocking within main markets of companies is intensified. Allen and Phillips (2000) found a positive impact on operating performance in research intensive industries if blockholdings are combined with product market relationship between purchasing and target firm. Also Fee et al. (2006) investigates the impact of financial linkages among trading partners. They find that equity stakes between customers and suppliers increase the time span of trade relationships. Given these findings, it will be interesting to investigate whether the ownership structure is intensive within industries. However, the answers to these questions are left to future research.

Before we start our network analysis, we will review important contributions to the company network literature in Chapter 3.2. Subsequently, in Chapter 3.3 the data set is described. In Chapter 3.4 the most central corporations are identified by the application of standard network concepts. Furthermore, in a subchapter to Chapter 3.4 firm characteristics are used to explain the centrality vector in an econometric model. Hence, we can identify the industries and the firm characteristics being related to a high or low centrality. Chapter 3.5 concludes. For many readers the Appendix might also be of interest. Many network structures of large German companies are shown there.

3.2 Company Network Literature

The network literature on the 'Deutschland AG' and financial interlocking of firms is neither very detailed nor exhaustive. However, there are some important contributions which are first steps towards a deeper understanding of corporate ownership structures. These network articles, mainly written by social scientists are briefly reviewed here. In order to focus in on important contributions papers dealing with the German company network are reviewed. Moreover, contributions concerned with firm networks from other countries or with interlocking directorates in Germany are mentioned in passing.[10] From a methodological point of view, it is also important to mention that the reviewed papers as well as the present work are based on simple network statistics. The start of the network literature is often traced back to Moreno (1934) - incidentally, at the same time Berle and Means (1932) initiated the discussion on separation of ownership and control. Hence, today after seven decades of research, there are much more elaborated network concepts than the ones applied. However, many authors stick to well-known but also well-established network statistics due to their simplicity.

A large network study with respect to size was performed by Kogut and Walker (2001), who used data from the Frankfurter Allgemeine Zeitung GmbH.[11] They investigated how the German ownership network influences merger and acquisition activities from 1993 to 1997. Their firm sample incorporates the largest five hundred non-financial companies, the 25 largest banks, and the 25 largest insurers in 1993. After the selection of this sample the 684 owners of these 550 firms were ascertained. Finally, a binary network of zeros and ones among companies was arranged. The ones represent all direct links if the equity stake of a shareholder was above 5 percent. Hence, this network formation process ignores all blockholders below 5 percent and equally weighted all stakes above 5 percent. They therefore ignore a large part of small shareholders as shown in the next chapter, where our network data set is analysed. The M&A data base includes

[10] An overview of large company networks in six different countries is given in Windolf (2002).
[11] The editor of one of Germany's large business newspapers 'Frankfurter Allgemeine Zeitung'.

101 acquisitions which take place among the 550 companies from 1994 to 1997. By means of simulation the authors showed that randomly rewiring company holdings affects the German corporate system only slightly.[12] If, for instance, one hundred links are rewired then the average path length only dropped about 20% and the cluster coefficients about 30%. These findings are in line with small world networks and indicate the intrinsic stability of the corporation network. Furthermore, it is argued that mergers and acquisitions maintained the structure of the German company network since very central companies seem to be more active in acquiring firms than the average company in the sample. Therefore, their findings challenge the thesis on the dissolution of the 'Deutschland AG'.

Heinze (2004) investigated the change of interlocking directorates instead of the financial interlocking of the 'Deutschland AG' from 1989 to 2001. He described the different control structures by means of descriptive network statistics and also concentrated on large German companies. Furthermore, he asserts that both the financial network and the personal network of executive and supervisory board members are tightly knit and both networks co-evolved historically. In the twelve year span, many links in the network structure were diluted. But many local network structures such as cliques and core-periphery structures were unaffected. Furthermore, the financial companies are still the most central players. We are not convinced that financial and personal networks co-evolve similarly. Of course, shareholders can affect board elections. However, German laws establish special rules affecting board composition which dilute the power of shareholders. From a theoretical point of view, both types of links can be seen as substitutes of a common goal national companies share. While globalization and German tax policy boost incentives to abolish equity stakes, members of executive and control boards might be willing to strengthen the 'Deutschland AG' by maintaining or intensifying personal relationships.

Höpner and Krempel (2004) visualized the German company network for 1996 and 2000. The data base includes the one hundred largest companies and is provided by the German Monopolies Commission,[13] which publishes an official report about the competitive position of German corporations every second year. Inspection by eye reveals that the network density shrinks because several links were severed between financial and industrial companies. In addition, links between financial companies are diluted. As mentioned above, these observations contrast with the stability argument of Kogut and Walker (2001).

In an early study, Pappi et al. (1987) analyse the financial interlocking as well as interlocking directorates of the largest 325 German companies in 1976. The 205 industrial companies were

[12] The rewiring procedure picks company u that severs an existing link to company v and forms a new one to company w (see Watts and Strogatz (1999) for details).

[13] The German name is 'Monopolkommission'.

chosen due to the highest turnover level of all companies in 1976. The largest banks are identified by their balance sheet total and the largest insurers were chosen due to a ranking of earned premiums. Each company unit is sectioned into one of ten blocks which are defined by means of a cluster analysis. Subsequently, relationships among the blocks are investigated by analysing personal and financial linkages. Their analysis underpins the power of large German banks in former decades.

Recently, the focus among network researchers turned to the analysis of the historical evolvement of company networks. For instance, Windolf (2005) compares the development of U.S. and German firms between 1896 and 1938. His research suggests that the difference between both countries found today is caused by different developments in the 20th century. Whereas the financial interlocking is quite similar, the interlocking among members of the supervisory board was much more concentrated in Germany than in the U.S.

3.3 The Data Base

The data base used for the analysis is the Hoppenstedt Konzernstrukturdatenbank[14]. The data bank is one of Germany's major data banks containing ownership structures of more than 250,000 companies. This data source often abbreviated KSD was also used by Becht and Böhmer (1997), Kammerath (1999), Köke (1999), Becht and Böhmer (2001, 2003), among others.[15] and is also one primary source of the German monopolies commission. [16] The KSD contains self-reported information as well as actively collected information pieces via professional data managers.

The data collection process started on 20th May 2006 and was completed by 20th June 2006. This process can be separated into four steps. First, we picked all German companies with a turnover of at least one billion euro. This sample includes only single company units but no parent companies which are just holdings or have a turnover below one billion euro. This core sample contains 597 industrial companies.[17] Second, we gathered all direct and indirect ownership relationships among this core sample. Due to definitional issues, the revenues of financial companies are not termed turnover. The turnover criterion was also chosen by Pappi et al. (1987), however, for the financial companies, we adopted, due to better data availability,

[14]The data bank is available at www.hoppenstedt-konzernstrukturen.de

[15]See Table 2 in Goergen et al. (2004) for further references.

[16]Furthermore, the sometimes mentioned data source "Wer gehört zu wem?" (which means "who owns whom?") of the Commerzbank is based on the KSD.

[17]Financial companies are not part of this core sample since by definition financial companies have no balance sheet item called turnover.

a different approach from these authors. The third step was the identification of all direct and indirect parent companies from the first chosen sample of 597 units. These direct and indirect links can be conveniently depicted in Network Figures as shown in the Appendix. Also, Kogut and Walker (2001) used such network data but took into account only the direct parent companies. We also include the parent companies of the parent companies up to distance six, where the term 'distance' in network terminology is defined as the number of links between two companies and offers therefore a much deeper view than earlier work on Germany's corporate structure. This third step extended the total sample to 2784 companies, which also contained all major German financial companies. Fourth and finally, all shareholder relationships among all firms were compiled. Our network data set is very different from previous work on company structures performed by economists where the focus is mostly on the position of a single company. For instance, La Porta et al. (1999) provide us with a description of the ownership structure of Allianz and DaimlerChrysler.[18] This limited micro-perspective instead of a network view makes the application of network tools unappealing or even impossible.

The close relationship among Allianz, Dresdner Bank, and Münchner Rück is the classical paradigm of interwoven German companies (cf. La Porta et al. (1999)). In a certain manner, the financial linkages among these three corporations enabled them to bypass German stock corporation law[19] and, correspondingly, hostile takeovers and, more importantly, corporate control of outsiders were virtually impossible even if those firms and executives performed poorly. Even today, Allianz and Münchner Rück are important blockholder of each other. The Allianz holds 9.4% of the Münchner Rück whereas the Münchner Rück holds 4.9% of all Allianz shares. Otherwise the Allianz corporation has a dispersed ownership structure. Due to its simple structure the Allianz network is omitted in the company Network Figures shown in the Appendix. However, the ego-centered company networks of Aldi, AMB Generali, AXA, BMW, Commerzbank, DaimlerChrysler, Ergo concern, Metro, Deutsche Post, Deutsche Telekom, and Volkswagen are depicted in Network Figure 5 to 15 in the Appendix.

The final data set contains industrial and financial companies, state enterprises, partnerships, and individuals. Our data set also offers an international perspective on the German company network since not only national firms but also foreign firms are taken into account. The number of foreign firms amounts to 824 or 29.53% of the sample size. The number of companies from each country relative to the total number of companies in the network is reported in Table 3.1. Apparently, large economies such as US, UK, Japan, etc. make up the largest number of foreign

[18] Throughout the paper we use reasonable abbreviations for company names. In particular, legal forms of companies are never mentioned in the text. The legends of network figures shown in the Appendix contain full company names. For instance, BMW is called 'Bayerische Motoren Werke AG' in Network Figure 8.

[19] A member of the control board in corporation A cannot be member of the executive board of corporation B if an executive member of corporation B is a member of the control board of corporation A, §100(2)Nr.3 AktG (Prohibition of cross interlocks).

Table 3.1: Country Ranking

Country	%-share	Country	%-share	Country	%-share
Germany	70.47	Cayman Islands	0.32	Bahrain	0.04
US	4.71	Norway	0.32	Cyprus	0.04
United Kingdom	3.23	Bermuda	0.25	Czech Republic	0.04
Italy	3.20	Canada	0.18	Ireland	0.04
France	3.09	UA Emirates	0.14	Iran	0.04
The Netherlands	2.91	Russia	0.14	Libya	0.04
Japan	2.73	Denmark	0.11	Monaco	0.04
Swiss	1.98	South Africa	0.11	Mexico	0.04
Luxembourg	1.36	Finland	0.07	Portugal	0.04
Austria	1.19	Hong Kong	0.07	T&C Islands	0.04
Belgium	0.93	Kuwait	0.07	Virgin Islands	0.04
Sweden	0.93	Korea	0.04		
Spain	0.54	Saudi Arabia	0.04	Total	100.0
Australia	0.40	Netherlands Antilles	0.04		

Data Source: Hoppenstedt Konzernstruktur Datenbank (KSD). The total number of companies is 2784. UAE abbreviates United Arab Emirates. Official country name of Ireland is 'The Republic of Ireland', and T&C Islands full name is 'Turks and Caicos Islands'.

firms related to the German company network. Interestingly, firms based in tax havens such as the Cayman Islands and Bermuda have a similarly large number of relationships comparable with companies located in Spain and Canada.

Another important firm characteristic is the legal form of companies. Legal forms of different countries are not completely comparable. However, the different types of companies were allocated to different groups in keeping with Table 3.9, as shown in the Appendix. Given this assignment, most companies in our sample are limited companies as documented in Table 3.2. Expectedly, a large share of private and public limited companies is found. A high number of individuals and state enterprises is also included into the German company network. This finding is often exposed as one major difference in the shareholder structure of Anglo-Saxon and German companies as well as other companies located in continental Europe. According to Burkart et al. (2003), the large number of family-owned German corporations is caused by weak minority shareholder protection which is often attributed to the poor German corporate governance system. Even after recent changes no stronger market-oriented governance system is assumed (cf. Terberger (2003), Goergen (2004), among others). Hence, the importance of family blockholders will continue to be a feature in the future. Moreover, the number of individuals in our network may underrate their power since individuals and families are often ultimate owners of firms. Faccio and Lang (2002) find that Western European firms are either family controlled or have dispersed ownership structures. Their comparison of ultimate owners across countries

Table 3.2: Legal Forms of Companies in our Sample

Legal Form	Group	Legal Form in Germany	#Obs	%-share
Private Limited Company	Ltd.-Group	GmbH	1023	36.75
Public Limited Company	Inc.-Group	AG	690	24.78
Partnership	Partner-Group	KG/OHG	303	10.88
Others	Other-Group		69	2.48
Foundations		Stiftung	35	1.26
Cooperatives		e.G.	26	0.93
Civil Law Association		GbR	4	0.14
Association		e.V.	4	0.14
Private Individuals			368	13.22
State Enterprises			102	3.66
Missing Observations			229	8.23
Sum			2784	100.00

Data Source: Hoppenstedt KSD - data bank access is provided via www.konzernstrukturen.de. Abbreviations are listed in Table 3.2. #Obs signify the number of observations.

unveils the exceptional position of family firms in Germany. For instance, for publicly traded firms the ultimate owner is a family in about two-thirds of cases and about nine out of ten unlisted German firms are family-owned.

For generations shareholders of large German corporations have been well-known families. For instance, the Quandt family holds a large share in BMW and the Piëch family and Porsche family are still among the large blockholders of VW (compare Network Figures 8 and 15). The figures show that these families are not only represented by one company protecting rights of a whole family but that there are quite complex holding structures in which several individuals of each family are involved. Interestingly, individuals are sometimes only indirect blockholders of the automobile corporations since limited companies typically in complete individual ownership lie in between. For instance, Johanna Quandt is the sole owner of Johanna Quandt GmbH & Co. KG which holds 14.21% of all BMW shares. Often the impact of family ownership on firm performance and corporate control is debated. On the one hand family ownership might facilitate a thorough development of a company, on the other hand block ownership might hinder effective corporate control. Recently, Villalonga and Amit (2006) analysed the impact of family ownership on firm performance and found mixed results for US firms. Nowak et al. (2006) as well as Maury (2005) report a positive relationship between operating performance and family-ownership.

State enterprises are also involved in many German companies. Again, Network Figure 15 of VW exemplarily shows a state-firm relationship. The Hannoversche Beteiligungs mbH is a large shareholder of Volkswagen and is owned by the Bundesland Lower Saxony[20]. Similarly, the German state is still engaged in the DAX companies Deutsche Post and Deutsche Telekom imaged in Network Figures 13 and 14. The vast majority of 'state enterprises' are owned by medium-sized and large cities which are often connected to public utility companies as well as local saving banks.[21] Interestingly, in their cross-country comparison La Porta et al. (1999) and La Porta et al. (2002) argue that both a relatively high number of family-owned firms and a large influence of government entities indicate insufficient shareholder rights. For Germany, the low degree of shareholder protection relative to Anglo-Saxon countries is often reported and details about German corporate law - briefly discussed in the following paragraph - point out this fact.

3.3.1 Descriptive Network Statistics

A network consists of vertices and arcs between the vertices. In a company network the vertices are the companies themselves and arcs represent the ownership structures among these companies, where the arrows point from the companies to their shareholders. In total, our company network exhibits 3711 arcs and consists of 192 components, where companies of two different network components are neither directly nor indirectly connected.[22] Weights are attached to each arc to capture the different shares being held and the power exerted by owners. However, for the sake of clarity links in network figures shown in the Appendix are categorized into three classes. The first class summarizes small equity stakes below 10%, the second class contains equity stakes lying in the right open interval from 10% to 50%, and the third class contains equity stakes at or above 50%. In the network figures the three classes have different line widths. For instance, in Network Figure 15 an arc with a weight of 15.46 goes from Volkswagen to the Porsche corporation which indicates that Porsche holds 15.46% of all Volkswagen shares.[23]

[20]Lower Saxony is one out of 16 German states.

[21]Also, the German banking industry has specific regulations. Almost all cities and communities are owners of small saving banks - called Sparkassen - which all together are larger with respect to standard bank characteristics than most listed German competitors.

[22]In fact, the 192 components are weak components which take into account all companies being connected to each other independent of the direction of the arrows (strong components distinguish the direction of the arrows). See de Nooy et al. (2005) for details.

[23]In all Network Figures links are classified into three groups where thicker lines stand for higher equity stakes among the firms. The thinnest lines represent equity stakes up to 10%, medium lines represent stakes from 10% up to 50%, and the thickest lines represent equity stakes from 50% to 100%.

The mode weight in the complete network shown in Network Figure 1 is 100% whereas the mean value is 45.5% and the median is 27.7%. The mode weight is observed in about one third of all links. Obviously, holdings often completely own their subsidiaries. Means and medians of previous studies are both about 50% - an overview of several other Germany-related studies is documented in Becht and Boehmer (2003) as well as Goergen et al. (2004). Differences between previous studies and our median can be attributed to our larger data base, to different sample periods, or both. Other often observable link weights are equity holdings of about 10%, 20%, 50%, 75%, and about only a few percent as illustrated in Figure 3.1(a) and (b). Regarding block ownership, our findings are in accordance with previous studies, e.g. La Porta et al. (1998), who found strong concentrations in ownership structure in nearly all countries. Concentrated ownership structure is also induced by Gemany's Companies Act[24]. Germans stock corporation law gives (minority) shareholders specific rights.

For instance, individual discharges of each member of the supervisory board - instead of contemporaneous discharge of all members - is enforceable by shareholders holding 10% of the voting equity (§120(1) AktG - see also §137 AktG). Similarly, an investor requires at least 20% of the voting equity (§122 AktG) to enforce extraordinary general meetings. At least 50% of all votes are necessary to enforce decisions at general assemblies (§133 AktG). Also, the appointment of auditors scrutinising the formation process, the increase of capital, or capital reduction (§142 AktG) as well as raising a claim against board members or directors (§147 AktG) explicitly requires an ordinary majority. A qualified interest enables shareholders to amend corporate statues (§ 179 AktG) and to increase in registered capital (§182 AktG). Hence, it is obvious that chosen blockholder stakes are not randomly assigned between firms but are chosen to foster or block specific rules.

Figure 3.1(c) shows the distribution of incoming arcs (indegree) and the distribution of outgoing arcs (outdegree) of all companies in our network. Both functions are quite similar. The linearity in the log-log diagram indicates that there are a few central companies with many links and many firms who just have a small number of equity stakes.[25] Subfigure 3.1(d) shows the mean and the difference Δ of 66 cross-holdings in the total network.[26] Mean and difference are always calculated for each cross-holding. One cross-holding between Allianz and Münchner R¨uck was mentioned above and another exists between 'Kölnische Verwaltungs-Aktiengesellschaft f¨ur Versicherungswerte' and the AXA concern as shown in Network Figure 7. Most cross-holdings such as the Allianz-M¨unchner R¨uck link have capital weights below 10% in both directions,

[24]The German company act is called Aktiengesetz and is commonly abbreviated by AktG.

[25]Mathematically, the linearity is reproducible by power law or lognormal distributions. Barabási and Albert (1999) show that many network data sets exhibit power laws. For a general discussion of the characteristics of these distributions and how human behaviour can produce such distributions read Mitzenmacher (2003).

[26]Cross-holdings are defined as direct cross-holdings whereas Köke (1999) uses a broader definition which also takes into account circles of large distances.

therefore, both the difference and the mean of cross-holdings are small. The second cross-holding in Network Figure 7 has values of 25.631% and 23.02%. Hence, the mean is in the 20% interval whereas the difference lies in the 10% interval in Figure 3.1(d).

3.3.2 MAN-Analysis

One powerful mean to analyse the networks is the triad MAN-classification scheme proposed by Holland and Leinhardt (1970). This descriptive statistic is a simple count mechanism which picks all possible combinations of triads[27] among all nodes - in our case there are $\binom{2784}{3} = 3,592,429,984$ triads. After each combination the existing links among the nodes are observed. There are sixteen possible combinations depicted in Figure 6.1 in Chapter 6 representing the MAN-classification scheme. M represents the number of mutual dyads, A asymmetric dyads, and N null dyads in a triad. In addition, for some triads a letter is added to indicate the direction of the arrows in a triad where D abbreviates down, U up, T transitive, and C cycle.

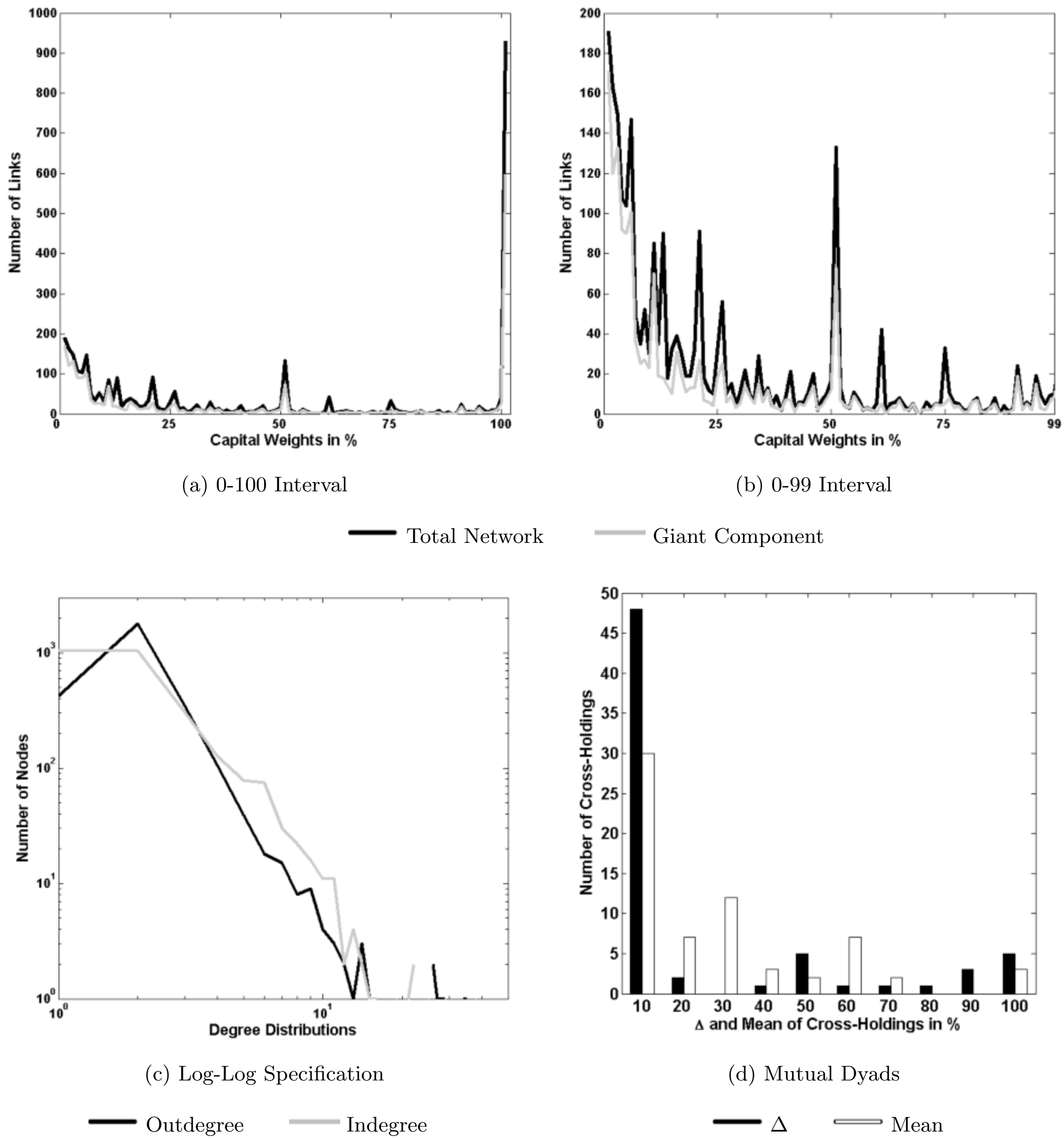
The MAN-classification scheme measures micro network formations and, contemporaneously, provides access to a macro perspective. All 16 possible triad formations observed in the company network are summarized in Table 3.3. For instance, 003 triads - the triads which contains three null dyads, i.e. no links at all - are found much more often than expected, whereas 012 triads are less often observed than expected. Thereby, the term ‘expected’ refers to a random network where each link has the same probability to be present. Table 6.1 in Chapter 6 shows the probabilities to observe certain triad formations in a random network. Our results indicate that the network formation process underlies a non-random process. In total, 003 triads and 012 triads are less often observed than expected. This indicates that certain network formations - those where more than one arc is involved - are likely to emerge. One such triad involving more than one arc contains mutual links, i.e. cross-holdings. The MAN-classification scheme reports a very high relative number of 102 triads as indicated by the ratio of observed to expected triads (O/E ratio in Table 3.3). Hence, we can conclude that firms have a high incentive for cross-holdings. This micro network structure is often seen as a classical form of ownership concentration. The reciprocal relationship can hinder the exercise of corporate control if the reciprocal voting power is large enough and managers are reluctant to explicitly control each other. Given the relative high number of mutual links it is also not surprising that we observe more 201, 120D, 120U, and 120C triads than expected. However, the absolute number of these triads is fairly low such that these formations are of minor importance.

Other often debated shareholder structures are pyramids, also called trees and forests.[28] Due to the low absolute number of cross-holdings and due to many asymmetric dyads, tree structures should be likely to emerge. La Porta et al. (1999) as well as Faccio and Lang (2002) report the tree structures as a prevalent company structure in many developed countries. To compare the

[27] In network terminology, triads are networks among three nodes and dyads are networks among two nodes.

[28] In the corporate governance literature these structures are called pyramids, whereas the graph theoretical notion is tree or forest. Hence, we also use to the last notions. Cf. Godsil and Royle (2001).

Figure 3.1: Characteristics of Arcs and Nodes



(a) 0-100 Interval

(b) 0-99 Interval

(c) Log-Log Specification

(d) Mutual Dyads

Data Source: Hoppenstedt KSD. Figure (a) is the distribution of link weights in the $[0, 100]$ interval and Figure (b) the corresponding $[0, 99]$ interval. Figure (c) shows the indegree and outdegree distribution of nodes. Figure (d) reports the difference of capital weights (ΔCapital Weights) for all mutual links. Each value at the abscissa is the upper threshold of a 10%-interval. For example, there are 48 links for which $W_{AB} - W_{BA} < 10\%$ where 10% is the upper threshold of the $[0, 10)$ interval and W_{AB} is the weight from vertex A to vertex B. Personally liable partners are excluded in Figure (d).

relevance of tree structures found in previous results with our data set, we can rely on the 021D and 021U triads. They represent small local trees probably embedded in large forests and also hint at the degree of centrality among nodes. The number of 021D and 021U triads is large in absolute as well as relative terms. Both triad types are observed more often than expected.[29] Hence, our statistics confirm well-known results but condenses company information in simple macro measures. Given the high number of 021D and 021U triads and the overall impression of the total German company network indicates that forests are an important structure in our data base. The emergence of these forests is often interpreted as evidence for the balance of power in company networks. Correspondingly, corporate control is exercised in the opposite direction of the arcs. Firms and subsidiaries are (partly) controlled by parent companies or other shareholders whereas the arrows tend to the controlling unit. Such forests are well documented by La Porta et al. (1999) and enhance the control of many companies by an ultimate owner. The pyramids enable the ultimate owner to control companies he is indirectly connected to even if he is only a minority shareholder. For instance, in Network Figure 8 the shareholders of BMW are shown. Via the Dresdner Bank the Allianz Corporation has direct as well as indirect influence at BMW's general assembly. This line of argument may explain why large equity stakes of 60% and 75% are less often observed in the giant component (compare Figure 3.1b) than in the total network. Possibly, corporate control via forests is easier to exert in a larger network component than in smaller ones. Hence, shareholdings and forests may be substitutes.

Additional ownership structures mentioned by Windolf and Beyer (1996) are circles and (nearly) complete cliques. Also, Kogut and Walker (2001) argued that the German corporate network consists of closely knit clusters and brokers filling structural holes between these clusters. As described above, the brokers might be ultimate owners or other central companies which hold pivotal positions in the pyramids. However, the evidence for the existence of circles such as 030C triads is weak. Although the O/E-ratio of 030C triads is large, the number of observed triads is low. In contrast, there is a large number of 021C triads, which confirms that circles are often found in triad formations. Yet, the expected number of 021C triads in a random network is even larger, such that the existence of circles in triads can be interpreted as a statistical artefact. Similarly, 210 and 300 triads representing clusters and (nearly) complete cliques are infrequently observed. Hence, it is reasonable to conclude that the impact of circles, cliques, and clusters on the overall structure is moderate and at least for our data set it seems implausible to call circles or cliques a basic ownership structure. In contrast, network patterns discussed in mainstream economics journals focusing on trees and cross-holdings are prevalent.

[29] An overall test of independence has a χ^2-value of $6 \cdot 10^8$ and, accordingly, clearly refutes the notion that the network is formed by accident.

Table 3.3: Observed and Expected Number of Isomorphic Triads

MAN-Type	Observed	Expected	O/E ratio
003	3,582,363,243	3,582,129,437.72	1.0000653
012	9,821,853	10,288,226.42	0.95
102	227,396	2,462.40	92.35
021D	6,307	2,462.40	2.56
021U	5,872	2,462.40	2.38
021C	4,179	4,924.80	0.85
030T	473	2.36	200.42
111U	385	2.36	163.14
111D	157	2.36	66.53
201	75	0.00	dbz
030C	12	0.79	15.19
120D	11	0.00	dbz
120U	9	0.00	dbz
120C	8	0.00	dbz
210	4	0.00	dbz
300	0	0.00	dbz
Sum	3,592,429,984	3,592,429,984	

Data Source: Hoppenstedt KSD. MAN-Types are defined by Holland and Leinhardt (1970). M counts the mutual dyads, A the asymmetric dyads, and N the null dyads in a triad. In addition, D down, U up, T transitive, and C cycle indicate the direction of links in asymmetric dyads. Confer also Chapter 6.2. The 'O/E ratio' is the ratio of observed number of triad types in our data set relative to the expected number of triad types in a random network model. dbz abbreviates 'division by zero'.

3.3.3 Sub-Networks

Until now, we have concentrated on information regarding the full company network. The data description is completed by turning to the analysis of subnetworks which only take into account capital linkages and related firms above certain weight thresholds. Table 3.4 summarizes different network measures for the full network and sub-networks. Each of the three sub-networks is reduced to links with weights above 24%, 49%, or 74%. In all sub-networks the disproportionate number of 021U triads emerge again, whereas the 021D triads are less frequently observed than in a random network having the same number of vertices and arcs. These findings also suggest that the balance of power is funnelled[30] into a small number of companies which are the nodes pointed to by the arrows in the 021U triads. These companies might be the brokers mentioned in Kogut and Walker (2001) or the apex of the pyramids mentioned in La Porta et al. (2002), Claessens (2000), Attig et al. (2003), among others, which are able to coordinate different developments in their subsidiaries and, hence, occupy a strategic position which allows control of local parts of the network. Again, in all four networks 021C triads are less often observed than expected. This underpins the fact that circles are formed incidentally and cannot be seen as a power enhancing mean.

Another important feature can be read off Table 3.4. The number of components increases when financial linkages below the three thresholds 24%, 49%, and 74% are ignored. The number of large components above fifty nodes decreases continuously, whereas the number of components having more than five or twenty nodes first increases if we take no account of financial links below 24% but then also declines if further thresholds are considered. The giant component in the total network contains 1626 nodes and 2271 arcs. The distribution of capital weights in the giant component is similar to the distribution in the total network. Except as already mentioned, blockholdings of about 60% and 75% are found relatively seldom in the giant component, whereas in the other components these values are relatively often observed. Unsurprisingly, the giant component is quickly decomposed into smaller pieces if low weighted links are disregarded.

The giant components of all sub-networks are shown in Network Figures 2 to 4. The giant component of the sub-network containing only equity stakes above 24% consists almost completely of energy companies such as E.ON, RAG, Vattenfall[31], and others. Additionally, many public utilities are part of this sub-network. The giant component of the second sub-network containing only equity stakes above 49% is mainly a Siemens-Bosch network - one of Germany's large technology companies - and the giant component of the 74% sub-network is

[30]This notion is introduced into the network literature by Newman (2001b). It implies that all geodesic paths from one vertex to all others in a network component typically go through a very small number of adjacent vertices.

[31]Vattenfall is a Swedish company.

Table 3.4: Importance of Capital Weights for Company Sub-Networks

Threshold	0%	24%	49%	74%
Companies	2784	2061	1867	1585
Arcs	3711	1771	1445	1152
021D-Triads	6307^+	223^-	43^-	1^-
021U-Triads	5872^+	2207^+	1898^+	1009^+
021C-Triads	4179^-	1054^-	696^-	493^-
Components	192	373	433	437
Component(Companies>5)	66	107	97	83
Component(Companies>20)	8	20	10	3
Component(Companies>50)	3	2	0	0
Companies in Giant Component	1626	117	40	28
Arcs in Giant Component	2271	122	40	27

Data Source: Hoppenstedt KSD. The full network has a threshold of 0%. A sub-network includes all links with weights above the threshold level. 021D-triads counts the number of triads with zero mutual, two asymmetric, one null dyad, and D indicates that both arrows point to one link, i.e. there is one shareholder with two different equity stakes (U=up, C=cycle). $^+(^-)$ indicates whether the observed number of triads is above (below) the expected number of triads. Component(Companies>K) counts the number of network components containing more than K companies, where the number of network components is the number of totally disconnected network parts.

an Aldi network where the Siepmann Stiftung is the center of a star. Network Figure 5 shows the complete Aldi network in which other foundations, personal liable partners, etc. are also included.

3.4 Important Companies

3.4.1 Central Nodes in the Global Network

Here we continue the explorative analysis of the previous Chapter and identify the power of each corporation. The power is measured by a standard network measures the indegree closeness centrality. The indegeree closeness centrality $InClos$[32]of company i is defined as

$$InClos_i = \frac{|NC_i|}{|AC|} \frac{|NC_i|}{\sum_{j \in NC_i} d(i,j)} \tag{3.1}$$

where NC_i is the set of companies which are part of the network component i belongs to, AC is the set of all companies, the bars indicate cardinality of a set, i.e. $|AC| = 2784$ for our data set, and $d(i,j)$ is the distance, i.e. the length of the shortest path, between companies i and j in the same network component.[33] Companies which are closely connected to others can impact upon these companies since we take into account indegrees only. In contrast, a company which has no other equity stakes has an indegree closeness centrality of zero. It is reasonable to assume that companies with a larger InClos_i value are more powerful than companies having a smaller centrality.[34] The closeness centrality is readily calculated and can therefore enhance the literature on company concentration (cf. Claessens et al. (2000), Faccio and Lang (2002), Attig et al. (2003), Chapelle and Szafarz (2005), among others).[35]

Unfortunately, as nearly all centrality measures also the indegree closeness centrality is not well-grounded on economic reasoning.[36] To the best of our knowledge, only Bonacich's (1987) power index of company i defined as $\sum_{j=1}^{n} \sum_{k=0}^{+\infty} g_{ij}^{k}$ where j indicates all other $n-1$ companies, $0 < g_{ij} \leq 1$ shows that company i holds directly or indirectly $g\%$ of all shares from company j, and k is the path of length.[37] Ballester et al. (2006) have shown that the power index can be interpreted as the result of a Nash equilibrium if a quadratic utility function is supposed. However, for our purposes the applicability of the power index is unsuitable. For instance, investors holding 75% of a company have similar control rights than investors who are the only

[32]Notice, that this formula deviates from the standard closeness centrality since our network consists of several components. The standard centrality definition is extended by the the first fraction which controls for the number of nodes in each network component.

[33]See Kosch¨utzki et al. (2005) for definitions and more advanced centrality statistics.

[34]The article by Freeman (1979) is a standard reference, although he was not the first to propose centrality concepts. Compare, for instance, Beauchamp (1965) and Sabidussi (1966).

[35]Interestingly, without mentioning the term 'network', Chapelle and Szafarz (2005) use network techniques by applying matrix algebra to calculate ultimate owners. Note that, mathematically the notions 'network' and 'matrix' are synonyms.

[36]Borgatti (2003) discusses problems in applied work which arises due to the lack of a theoretical foundation.

[37]In the original work the power index also includes a scaling factor. For brevity, we omit it.

shareholder of a company. However, the power index measure implies that a 100%-holding is much more powerful where this difference in power increases with k. Even more questionable is the usefulness of the index if we compare a 100%-holding with a 10%-holding.

In the network literature, there is a whole spade of centrality measures which try to identify very important or powerful vertices. We have chosen the indegree closeness centrality because it ignores any weights and only takes into account whether there is an ownership stake or not. This choice is at least partly in accordance with definitions of the largest shareholder in the literature. For example, Shleifer and Vishny (1997) propose to define investors holding at least 10% as large shareholders. Lech (2002) proposes a somewhat higher threshold around 25%. As shown above, companies holding stakes above these thresholds also have special rights which allow to control the management more effectively. Hence, the regulations laid down in the German shareholder act might also suggest a similar definition.

In addition, even a non-blockholder holding only a few percent or per mille of all shares of a company might be powerful. Since an investor planning an acquisition of a company might either face an opponent trying to hinder the investor activities or in the opposite case enables the investor to purchase these shares in an OTC transaction without revealing information to the market and, thereby, the stock market price is not boosted. Therefore, the definition of the indegree closeness centrality might be an appropriate indicator for the power of companies. A more sophisticated centrality measure might be preferable, however, so far it is unavailable.[38]

In Table 3.5 possibly important nodes are ranked by the indegree closeness centrality of nodes. Two different rankings are shown. The full sample ranking includes all observations whereas the reduced sample ranking focuses on parent companies only and thereby, focuses on companies and discounts subsidiaries as well as state entities and individuals. The indegree statistic measures only the number of links to a company, i.e. counts the number of equity stakes a company has in other companies. As in previous studies, many insurance companies are among the most central companies. In particular, corporations such as Allianz, M¨unchner Ruck, and Ergo as well as many subsidiaries of these companies are found. For instance, Allianz Subalpina[39] is a 98.003% subsidiary of RAS Riunione Adriatica di Sicurtà S.p.A. which is a 76.34% subsidiary of the Allianz concern. Similarly, D.A.S., Hamburg-Mannheimer SV, and Victoria Versicherung are all part of the Ergo concern. For details, see the Ergo network imaged in Network Figure 11. Other frequently found industries are banks, energy suppliers, wholesale and retail firms.

[38]Furthermore, game theoretical power measures such as the Shapley-Shubik or the Banzhaf index exhibit undesirable features. Compare Prigge (2007).

[39]This company holds rank 24 in the indegree closeness centrality column. The registered name is 'Allianz Subalpina Società di assicurazioni e riassicurazioni', based in Turin.

Among the banks there are large German banks but there are also many foreign competitors from Italy such as UniCredito, the parent company of the Bayerische Hypo- und Vereinsbank, and Mediobanca. Details about the investment bank Mediobanca, its ownership structure, its power in Italia, and its recent role in the hostile take over of Telecom Italia is provided by Kruse (2005) and Meoli et al. (2006). Japanese banks such as Japan Trustee Services Bank, The Mitsubishi Trust & Banking Corporation, and Sumitomo Mitsui Banking Corporation can also be found. Japanese banks tend to cluster in local company networks called keiretsus (cf. Lincoln et al. (1996) and Lincoln and Gerlach (2004)).[40] The Japanes banks have a high number of linkages among firms but are not among the most central companies. In contrast, Italian banks and insurance companies exhibit a high closeness centrality and, therefore, might be more influential on the German economy than companies from other countries.

The national energy market is dominated by E.ON, EnBW, RWE, and Vattenfall[41]. All local-operating German energy companies have to use the power grid of these four companies covering the whole German state. Each of the four big energy players covers a certain geographical area and much smaller competitors operating on a local basis have to use the power grid of one of these companies. Therefore, the big four energy companies are at least within their industry relatively powerful and except Vattenfall is not listed among the top 30 in the reduced sample ranking in Table 3.5. Parts of their ownership structure is shown in Network Figure 2 which stresses the strong interconnectedness among many energy companies as well as their close relationships to public utilities and cities.

Table 3.5 contains also foundations called Markus Stiftung and Luks Stiftung. Both are part of the Aldi concern which are one of Germany's and Europe's largest retailers.[42] The beautiful Network Figure 5 for Aldi is an isolated network component in the total network. Additional information about the Aldi network can also be found in Network Figure 4, i.e. the giant component of the total network where links below 74% are eliminated. The owners of both companies are the brothers Karl and Theo Albrecht and are the richest Germans.[43] Accordingly, the entity 'Familie Albrecht' is also related to this company network.

Finally, the French state - Republik Frankreich - is one of the entities exhibiting a high closeness centrality in the full sample ranking. It is well known that the French state is a large blockholder in large French companies. However, we were quite surprised to learn that this entity is found

[40] Miyajima and Kuroki (2005) show that Japanese firms can be separated into two groups after the banking crisis in the nineties. The less efficient companies are still strongly connected with banks, whereas the more prosperous corporations exhibit a higher tendency to break these links.

[41] Vattenfall is a Swedish company.

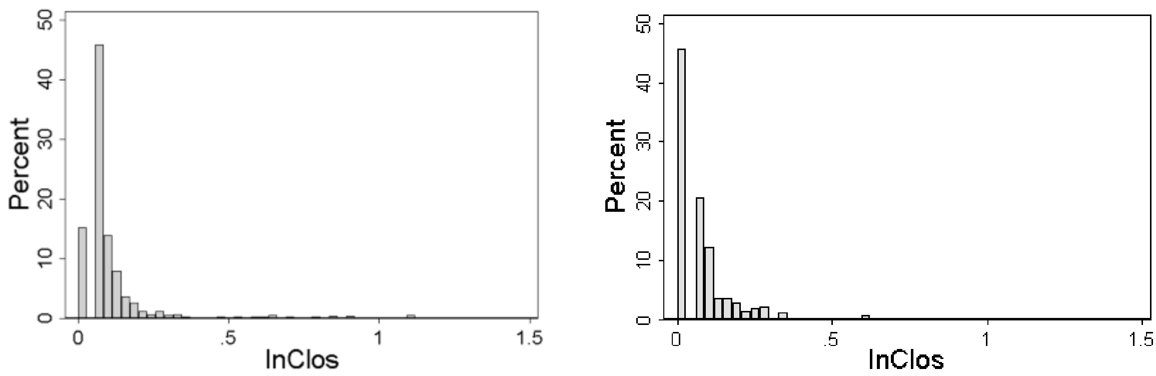
[42] Actually, there are two concerns Aldi Nord and Aldi S¨ud.

[43] Their wealth is estimated at approx. 18.5 and 15.5 billion USD. See Forbes Special Report 'The World's Billionaires' 03.10.2005.

to play a central role in the German company network, too. Among the direct links, only a 50% holding of the 'Stiftung Centre Culturel Franco-Allemand de Karlsruhe' and a 49.02% holding of the 'Internationale Mosel' are reported. Both participations are rather unimportant for the overall network. Industrial relations between German and French companies are probably essential since the French state directly impinges on EADS, France Télécom, Gaz de France, and Renault. More importantly, there are several indirect relations to financial corporations. The French state holds a 77.69% stake at GAN, and this company is a shareholder of the Italian Mediobanca, which is also among the most central banks. Mediobanca has, as shown in Network Figure 9, a strategic cross-holding with the Commerzbank and, as shown in Network Figure 6, is also an indirect shareholder of the AMB Generali Holding via Assicurazioni Genarali. Finally, there is a seven-distance relationship with the AXA Konzern which contributes to the high centrality the French state exhibits in the German company network. The following seven-distance path is imaged in Network Figure 7.

> AXA Konzern AG ⟶ AXA S.A. ⟶ Les Ateliers de Construction du Nord de la France S.A. ⟶ Eurazeo SA ⟶ Crédit Agricole S.A. ⟶ Assurances Générales de France S.A. ⟶ C.D.C. Cásse des Dépôts et Consignations ⟶ Republik Frankreich

Figure 3.2: Distribution of Indegree Closeness Centrality



(a) Full Sample (b) Reduced Sample

Own Source. InClos is the variable name of indegree closeness centrality. The abscissa is restricted to values below 1.5. As shown in Table 3.5, there are only two centrality values above this threshold. All indegree closeness centrality statistics are multiplied by 10^{-2}.

3.4.2 Analysing the Centrality Concept

In this subchapter we identify several factors which are related to the centrality of all firms.[44] The relationship of the left-hand-side variable InClos, measuring the indegree closeness centrality of firms and covariates, is based on two samples. The first sample includes variables which are observed for all companies, i.e. 2784 observations are available. The second sample - also called reduced sample - has a larger number of covariates but reduces the non-missing observations to 987. Figure 3.2 shows the distribution of InClos for both samples.

Hypotheses

Table 3.6 describes 24 right-hand side variables included in the estimation below. The Sign-column shows expected signs for each explanatory variable. For members of the giant component (NET_MoG) we expect a positive sign since nodes of larger network components typically exhibit higher indegree closeness centrality. In contrast, we expect a negative sign for

[44]Heinze (2004) applied the same methodology we adopted here to explain the centrality of interlocking directorates. However, we have some doubt about the validity of this method. The independence assumption prerequisite for the application of standard econometric methods is violated in the case of network data (see Gill and Swartz (2004)). Fortunately, if our doubts are unfounded, then results are viable and if our doubts are justified, then many results published in well-known journals may be error-prone since to the best of our knowledge the interdependencies among companies are always ignored. The issue of interdependence among observations is especially important since most studies focus on large companies which are often closely related in one form or another form.

Table 3.5: Most Central Companies and Entities

Rank	Full Sample Ranking #Obs: 2784 Company/Entity	10^{-2} Indegree Closeness	Reduced Sample Ranking #Obs: 275 Company/Entity	10^{-2} Indegree Closeness
1	Allianz AG	3.28	Allianz AG	3.28
2	Münchener Rück AG	3.1	Münchener Rück AG	3.11
3	Familie Albrecht	1.66	Bayer. Hypo- und Vereinsbank AG	1.04
4	Republik Frankreich	1.62	COMMERZBANK AG	.95
5	UniCredito Italiano SpA	1.44	E.ON AG	.88
6	Fondazione Cassa di Risparmio di Torino	1.35	Coca-Cola Erfrischungsgetränke AG	.74
7	AVIVA Plc	1.35	KARSTADT QUELLE AG	.65
8	Fondazione Cassa di Risparmio Verona[1)]	1.30	RWE AG	.60
9	Markus Stiftung	1.26	DEUTSCHE BANK AG	.59
10	Barclays PLC	1.24	Norddeutsche Landesbank	.49
11	The Capital Group Companies Inc.	1.23	Siemens AG	.46
12	Capital Research & Management[2)]	1.23	EnBW AG	.43
13	Lukas Stiftung	1.22	ThyssenKrupp AG	.39
14	Assicurazioni Generali SpA	1.21	Landesbank Baden-Württemberg	.34
15	Ergo Versicherungsgruppe AG	1.16	Franz Haniel & Cie. GmbH	.33
16	RAS Riunione Adriatica di Sicurtà SpA	1.14	SHB AG[11)]	.32
17	Mediobanca Banca dCF SpA[3)]	1.11	EDEKA ZENTRALE AG & Co. KG	.32
18	Victoria Versicherung AG	1.11	Deutsche Lufthansa AG	.29
19	Hamburg-Mannheimer SV AG	1.11	Deutsche Bahn AG	.28
20	Fondazione Cassamarca[5)]	1.11	Robert Bosch GmbH	.27
21	RB Vita SpA	1.11	DaimlerChrysler AG	.27
22	Europäische Reiseversicherung AG	1.11	REWE-ZENTRALFINANZ e.G.	.27
23	Carimonte Holding SpA	1.11	RAG AG	.22
24	Allianz Subalpina[8)]	1.11	VOLKSWAGEN AG	.22
25	D.A.S. AG[9)]	1.11	MAN AG	.21
26	Fidelity Investments Ltd	1.10	Deutsche Telekom AG	.21
27	Legal & General Group PLC	1.10	Deutsche BP AG	.20
28	D.A.S. AG[10)]	1.10	Salzgitter AG	.19
29	KarstadtQuelle Lebensversicherung AG	1.10	ExxonMobil GmbH[12)]	.19
30	DKV Deutsche Krankenversicherung AG	1.10	Bayerische Landesbank	.19

Own Source: Full company names are provided to simplify identification of companies. #Obs signifies the number of observations. 1) – 12) full names are provided in Table 3.8 in the Appendix. Note 9) and 10) have identical abbreviations but different full names. Further abbreviation: SV=Sachversicherung (property insurance). Translations: Lebensversicherung=life insurance, Krankenversicherung=health insurance, Reiseversicherung=travel insurance, Familie=family, Stiftung=foundation, Europäische=European, Republik Frankreich=France. The international company name of Münchner Rück is Munich Re Group. In the reduced sample ranking, several firms of the EDEKA association have a closeness centrality of approximately 0.25 and are among the top 30. However, we exclude them since EDEKA Zentral is already considered in the ranking.

firms having a turnover above 1 billion euro. These companies are often only operational entities controlled by holdings and other shareholders who are not involved in day-to-day management decisions but have a great impact on firm strategies. We also expect that large firms are more central than smaller ones. Hence, positive signs are allocated to incorporated and listed companies (LF_Inc, List) as well as to companies having high balance-sheet totals (ACC_Tot). All other legal forms may have a negative impact upon the indegree closeness centrality since they indicate smaller firms, personally liable partners, or states entities. A legal form indicator variable for missing observations is also included to check whether important information may be contained there.

The results of Table 3.5 suggests positive coefficients for French, Italian, and Japanese companies. Companies from the United Kingdom and the United States outnumber all other countries, but only little evidence for a high centrality of UK or US firms is found. Therefore, negative signs are assumed. The centrality measure in Figure 3.2 implies that most firms are unimportant for the whole network, whereas only a few are powerful. Since most vertices represent German companies, a negative sign for the indicator variable COU_Ger is expectable.

Banks and insurance companies were found to be central corporations in Germany (cf. Höpner and Krempel (2004)). The public utility companies described above might also be powerful. Hence, positive signs are expected for the first three industries mentioned in Table 3.6. Other industries may be less involved in the corporate company network. In contrast to these industries, negative signs for the manufacturing industry and trade industry are in accordance with our expectations. We also assume a positive sign for the regressor variable Multi since firms offering various products may have stronger incentives to be interwoven with many other companies. Finally, higher profits as well as strong equity positions measured by ACC_Pro and ACC_Equ should both positively affect the probability of acquiring other firms or expand a business and are likely to increase the centrality of a company.[45]

[45]Notice, for all variable groups the reference group always contains all other companies.

Econometric Models
In Table 3.7 results of the least squares regression are reported where we regress the indegree closeness centrality on firm characteristics (see Table 3.6 for variable names). Table 3.7 contains two Sub-Tables 7A and Sub-Table 7B. The first table reports coefficients and p-values of full-sample regressions, i.e. only firm characteristics being observed for all 2784 companies in the network are included. Equation 3.2 shows the estimation of column OLS_{A1}.

$$InClos = \beta_0 + \beta_1 NET + \beta_2 LF + \beta_3 IND + \beta_4 COU + \beta_5 Multi + \beta_6 List + u \tag{3.2}$$

where variable names in capitals indicate vectors (containing all variables of each variable group). NET represents network variables, LF legal form variables, IND industry variables, COU country variables, Multi indicates whether a firm is active in several different industry sectors, List indicates listed companies and u is the error term. Sub-Table 7B contains also coefficients of accounting variables ACC being observed for 987 German companies. Hence, the estimation results shown in column OLS_{B1} are based on Equation 3.2 where the country vector COU is excluded but equity capital, balance sheet total, and annual net profit are inserted. Using the full variable set in columns $OLS_{\cdot 1}$ – the dot in the subscript here is used to indicate that the statement holds for both the full sample and the reduced sample – is appropriate due to the low degree of multicollinearity being found among indicator variables. In contrast, the correlations among accounting variables themselves are large enough to affect estimation results, as shown below.[46]

In the second column of each Sub-Table we report the results of a stepwise regression which repeatedly decrements all insignificant variables until 5%-significant variables having coefficients above 0.05 in absolute value are left. One disadvantage of our approach is that the indicator variables only measure average effects for each group. Hence, the centrality difference between banks and insurers in France is the same as between banks and insurers in Italy. Furthermore, the distribution of centrality shown in Figure 3.2 indicates a nonlinear relationship similar to a hyperbola. Therefore, we can assume that indegree closeness centrality increases more sharply if an already fairly central company adds a power-enhancing characteristic than if a peripheral company adds the same characteristic. A simple solution to take into account this form of nonlinearity is a semi-log specification in a linear model. However, this specification is not applicable due to company centralities of zero. Instead, nonlinear least squares is applied to

[46] The correlations mentioned are ρ(ACC_Tot,ACC_Pro)=0.386, ρ(ACC_Tot,ACC_Equ)=0.411, ρ(ACC_Equ,ACC_Pro)=0.767.

Table 3.6: Covariates available for the Explanation of Indegree Closeness Centrality

Category (abbr.)	Variable	Description	Sign
Network	NET_MoG	Indicates firms being a member of the giant component	+
(NET)	NET_597	Indicates firms having a turnover above 1 bill. Euro	−
Legal Form	LF_Inc	Indicates incorporated companies	+
(LF)	LF_Ltd	Indicates limited companies	−
	LF_Par	Indicates partnerships	−
	LF_PP	Indicates personally liable partners	−
	LF_Sta	Indicates state enterprises/state entities	−
	LF_Mis	Indicator variables for missing observations	+ −
Industry	IND_Ins	Indicates insurance companies	+
(IND)	IND_Ban	Indicates banks	+
	IND_Uti	Indicates public utility companies	+
	IND_Man	Indicates manufacturing companies	−
	IND_Tra	Indicates wholesale and retail companies	+ −
Country	COU_Ger	Indicates German firms or entities	−
(COU)	COU_Fra	Indicates French firms or entities	+
	COU_Ita	Indicates Italian firms or entities	+
	COU_Jap	Indicates Japanese firms or entities	+
	COU_UK	Indicates British firms or entities	−
	COU_USA	Indicates U.S. firms or entities	−
Conglomerate	Multi	Indicates firms being active in a main industry and at least five sub-industries	+
Listed	List	Indicates firms having positive market capitalization	+
Accounting	ACC_Tot	Balance sheet total	+
(ACC)	ACC_Pro	Annual net profit	+
	ACC_Equ	Equity Capital	+

Own Source: All variables of the first six categories (from the Network-category up to the Listed-category) are indicator variables and are observed for the whole sample - 2784 companies. The variables of the Accounting category is observed for 987 companies.

Equation 3.3 and Equation 3.4.

$$InClos = \exp(\beta_0 + \beta_1 NET\_597 + \beta_2 IND\_Ins + \beta_3 IND\_Ban + \beta_4 COU\_Fra + \beta_5 COU\_Ita + \beta_6 COU\_Jap + \beta_7 List) + \epsilon_A \quad (3.3)$$

$$InClos = \exp(\beta_0 + \beta_1 NET\_597 + \beta_2 IND\_Ins + \beta_3 IND\_Uti + \beta_4 ACC\_Equ + \beta_5 ACC\_Tot) + \epsilon_B \quad (3.4)$$

where all variables are scalars, $exp(.)$ indicates the exponential function, and ϵ_A and ϵ_B are error terms. Regression results of Equation 3.3 are given in column NLS_A whereas column NLS_B reports results of Equation 3.4. In each estimation only significant variables left in the linear stepwise regression are used as regressors in the nonlinear estimation.

Regression Results

The ordinary least squares regressions in columns $\text{OLS}_{\cdot 1}$ and $\text{OLS}_{\cdot 2}$ are discussed first. In particular, the accounting variables may be endogenous such that we would like to account for this problem. However, the available data set contains no reasonable instruments since all additional variables such as number of employees, further balance sheet information, and others may directly affect the dependent variable as well as the endogenous one. The network variables are statistically and economically significant and have the expected signs. Firms being a member of the giant component have a higher centrality, whereas industrial enterprises having large turnovers above one billion euro tend to have smaller centrality measures than average firms. Four out of five legal form variables confirm our expectations. Contrary to expectations, LF_Inc has a negative sign. In regression A, the coefficient is statistically insignificant whereas it is highly significant in the reduced-sample regression. This slight difference might be caused by correlation between List and LF_Inc of 0.388 in regression A and 0.517 in regression B. This line of argument is also underpinned by the observation that List is an important variable in the full-sample regression A and not included in column $\text{OLS}_{\text{B}2}$ and NLS_{B}. In regression B no coefficient is available for LF_PP since accounting information excludes private individuals. The variable LF_Mis indicates the missing observations. In regression A no important influence is measured whereas in B the coefficients are statistically significant. However, in the first regression 131 observations are labelled as a missing variable, whereas only two are left in the reduced sample.

Among the coefficients of industry variables the largest values are observed for insurance companies. This confirms our results from the previous Sub-Chapter where these companies are among the most central companies. At first sight, the results for banks are mixed. In the full-sample regression significant positive coefficients are found, however, no higher centrality can be reported in the reduced-sample regression. This is substantiated by the fact that banks have higher balance sheet totals than non-banks. Excluding the variable ACC_Tot and inserting the bank indicator variable results in a 1%-significant coefficient of 0.185.[47] Therefore, we confirm the result of Pappi et al. (1987) and Höpner and Krempel (2004), i.e. that banks are still among the most powerful German companies. Expectations are also confirmed with respect to other industry variables. However, only IND_Man is significant at the 5% level in column OLS_{B1}. All other coefficients have the assumed sign but are insignificant.

Similarly, the signs and sizes of country variable coefficients in the full-sample regression correspond to expectations for France, Italy, and Japan. The strongest impact is found for Italy. The coefficient for the United States is negative, as assumed, but insignificant. For the United Kingdom and Germany results are not in accordance with expectations. In fact, for Germany the coefficient is also significant but the overall impact on closeness centrality is relatively small.

Two of the three accounting information have the expected sign such that a higher equity and a higher balance sheet total increases the centrality of the firm. In interpreting the coefficients take into account that ACC_Equ is measured in million euros whereas ACC_Tot is measured in billion euros. Hence, given the coefficients of 0.007 and 0.400 in OLS_{B2} the equity variable seems to be more important. Company earnings seem of little relevance in determining the power of firms.

Finally, we found a positive and significant relationship for the variables Multi and List. But a strong influence can only be measured for List in regression A, whereas Multi is dropped in the stepwise regressions $OLS_{\cdot 2}$. Hence, not only large but also listed companies are more central.

The coefficients of nonlinear least squares estimation strengthen the results of the OLS regression. All results with respect to sign and magnitude are confirmed. To compare the magnitudes of characteristics on centrality the coefficients must be plugged into Equation 3.3 and Equation 3.4. Then the fitted centrality for Italian banks is approximately $\exp(-2.093+0.399+1.319) = 0.687$, whereas the centrality based on coefficients in OLS_{A2} is 0.606. French insurance companies using the results reported in column NLS_A is $\exp(-2.093 + 0.842 + 0.547) = 0.495$, which is close to closeness centrality based on coefficients in OLS_{A2} is 0.506.[48] Hence, our results seem quite robust to the nonlinear specification.

[47] The corresponding p-value is 0.008.

[48] The last value rests upon the following equation 0.114+0.248+0.144=0.506.

Table 3.7: (Non-)Linear Least Squares Estimation

Table 3.7 contains several regression results. In each estimation the dependent Variable is InClos, the indegree closeness centrality. The Table is split into two Sub-Tables 7A and 7B. The regression results shown in the first Sub-Table are based on the full sample, whereas the regression results in the second Sub-Table is based on 987 observations. However, the reduced sample includes also accounting information of German companies. The first two columns of each Sub-Table are estimated by ordinary least squares, whereas the last column reports results of nonlinear least squares estimation.

*Sub-Table 7*A

	Full Sample		
Variable	OLS_{A1}	OLS_{A2}	NLS_{A}
Network Variables			
NET_MoG	0.043**		
	(0.000)		
NET_597	-0.100**	-0.084**	-1.120**
	(0.000)	(0.000)	(0.000)
Legal Form Variables			
LF_Inc	-0.046		
	(0.127)		
LF_Ltd	-0.076**		
	(0.009)		
LF_Par	-0.068*		
	(0.021)		
LF_PP	-0.078**		
	(0.009)		
LF_Sta	-0.061^{+}		
	(0.068)		
LF_Mis	-0.006		
	(0.871)		
Industry Variables			
IND_Ins	0.229**	0.248**	0.842**
	(0.000)	(0.000)	(0.000)
IND_Ban	0.054*	0.066**	0.399**
	(0.029)	(0.007)	(0.000)
IND_Uti	0.007		
	(0.524)		

*Sub-Table 7*B

	Reduced Sample		
Variable	OLS_{B1}	OLS_{B2}	NLS_{B}
Network Variables			
NET_MoG	-0.017		
	(0.136)		
NET_597	-0.048*	-0.058**	-0.527**
	(0.015)	(0.003)	(0.001)
Legal Form Variables			
LF_Inc	-0.094*		
	(0.012)		
LF_Ltd	-0.111**		
	(0.002)		
LF_Par	-0.094*		
	(0.011)		
LF_PP			
LF_Sta	-0.162*		
	(0.028)		
LF_Mis	-0.036		
	(0.661)		
Industry Variables			
IND_Ins	2.830**	2.929**	2.947**
	(0.000)	(0.000)	(0.000)
IND_Ban	0.107		
	(0.123)		
IND_Uti	0.120*	0.139**	1.082**
	(0.015)	(0.009)	(0.000)

Sub-Table 7A continued

IND_Man	-0.005		
	(0.526)		
IND_Tra	0.005		
	(0.599)		
Country Variables			
COU_Ger	0.029**		
	(0.005)		
COU_Fra	0.134**	0.144**	0.547**
	(0.000)	(0.000)	(0.000)
COU_Ita	0.417**	0.426**	1.319**
	(0.000)	(0.000)	(0.000)
COU_Jap	0.096**	0.096**	0.433**
	(0.000)	(0.000)	(0.000)
COU_UK	0.044		
	(0.111)		
COU_USA	-0.019		
	(0.279)		
Other Variables			
Multi	0.051^{+}		
	(0.081)		
List	0.048^{+}	0.069**	0.443**
	(0.050)	(0.005)	(0.000)
Constant	0.134**	0.114**	-2.093**
	(0.000)	(0.000)	(0.000)
R^2	0.279	0.257	0.466[1)]
#Obs	2784	2784	2784

Sub-Table 7B continued

IND_Man	-0.038*		
	(0.012)		
IND_Tra	-0.008		
	(0.656)		
Accounting Variables			
ACC_Pro	-0.030		
	(0.329)		
ACC_Equ	0.010**	0.007**	0.011**
	(0.007)	(0.001)	(0.000)
ACC_Tot	0.256**	0.400*	1.106**
	(0.007)	(0.012)	(0.000)
Other Variables			
Multi	0.056**		
	(0.001)		
List	0.014		
	(0.538)		
Constant	0.182**	0.101**	-2.109**
	(0.000)	(0.000)	(0.000)
R^2	0.870	0.849	0.839[1)]
#Obs	275	275	275

Data Source: Hoppenstedt KSD and Hoppenstedt Annual Data Information (www.bilanzen.de). p-values in parenthesis. 1%, 5%, 10% significance levels are labelled by **, *, $^{+}$. All except the accounting variables ACC_Pro, ACC_Tot, and ACC_Equ are indicator variables. ACC_Pro and ACC_Equ is measured in million Euros whereas ACC_Tot is measured in billion Euros. [1)] R^2 is not the standard goodness-of-fit since the nonlinear least squares regression contains no intercept.

3.5 Conclusions

Until now, researchers investigating ownership structures have been content with analysing small local company settings. There is a vast literature on patterns called pyramids or cross-holdings. However, these descriptions represent nothing else than local network formations and are, of course, embedded in larger network structures. Future analyses of ownership structures will be enhanced by complex and comprehensive network tools. For instance, network statistics might offer informative variables such as centrality measures, distance to ultimate owners, etc. These variables might lead to new insights on the impact of ownership structures on firm performance. Network analysis is attractive for empirical researchers given the huge data availability in coming years. Detailed data sets make it possible to track firm policies in greater detail, taking into account firm-specific environments and dependence structures of companies. Following the adoption of network methods, the German as well as the global corporate control system can be analysed and theories on corporate control and governance can be tested econometrically.

In this article we demonstrate that the global description of company networks is possible by analysing ownership structures among German companies in 2006. The financial linkages of a huge unique data set containing 2784 single companies were constructed and described. Several statistics were applied to discover general features of the company network. From our point of view, one major highlight is the MAN-classification scheme, offering a micro-macro perspective which simplifies both specific firm analysis as well as country-specific or global analyses of ownership structures. After the description of certain structural properties a centrality measure, the indegree closeness centrality, was calculated for all vertices. Finally, the explanation of the centrality vector was performed by applying standard econometric techniques.

Our results show that most central German companies are still banks and insurance companies. Given previous results of Agarwal and Elston (2001) as well as Dittmann et al. (2005) showing that bank-controlled firms have not been able to outperform in the past, regression results might be interpreted as an undesirable network characteristic. Another interesting result is the high degree of internationalisation detected in the company network. Today, large German firms are multinational corporations themselves or are often strongly connected to other non-German multinationals. It is reasonable to assume that this fact is a major difference to earlier networks. We found that the UK and US firms in the German company network outnumber firms of other nations, although most Anglo-Saxon firms are less central than firms from other nations. In particular, Italian corporations, but also French and Japanese companies, occupy central positions in the German corporate system. The results of the MAN-classification scheme (cf. Chapter 6.2) indicate that especially cross-holdings and pyramids are the most common triad formations in the German company network. Other formations such as circles, which are found relatively often in absolute terms, are formed incidentally and are less often observed than in a random network. The importance of pyramids is also underpinned by the observation that in the giant network component containing 1626 vertices the number of financial linkages with weights of about 60% and 75% is small, whereas in the total network there are many more capital weights of similar importance.

This paper can be seen as a first step towards an even deeper knowledge of the 'Deutschland AG'. The present work can be extended in several ways. First, the KSD data bank contains approximately 250,000 ownership links such that the complete 'Deutschland AG' may differ from Network Figure 1. Second, it is also interesting to identify whether and how such network structures affect profitability. In particular, if this network data set is available for different points in time, a panel study can reveal insightful results.

3.6 Appendix

Table 3.8: Full Company Names abbreviated in Table 3.5

Footnote	Company
1)	Fondazione Cassa di Risparmio Verona, Vicenza, Belluno e Ancona
2)	Capital Research & Management Company
3)	Mediobanca Banca di Credito Finanziario S.p.A.
4)	The Mitsubishi Trust & Banking Corporation (Mitsubishi Shintaku Ginko)
5)	Fondazione Cassamarca - Cassa di Risparmio della Marca Trivigniana
6)	Fidelity Management & Research Company
7)	The Dai-Ichi Kangyo Bank, Ltd. (Dai-Ichi Kangyo Ginko)
8)	Allianz Subalpina Società di assicurazioni e riassicurazioni
9)	Deutscher Automobil Schutz Allgemeine Rechtsschutz-Versicherungs-AG
10)	D.A.S. Deutscher Automobil Schutz Versicherungs-AG
11)	SHB Stuttgarter Finanz- und Beteiligungs AG
12)	ExxonMobil Central Europe Holding GmbH

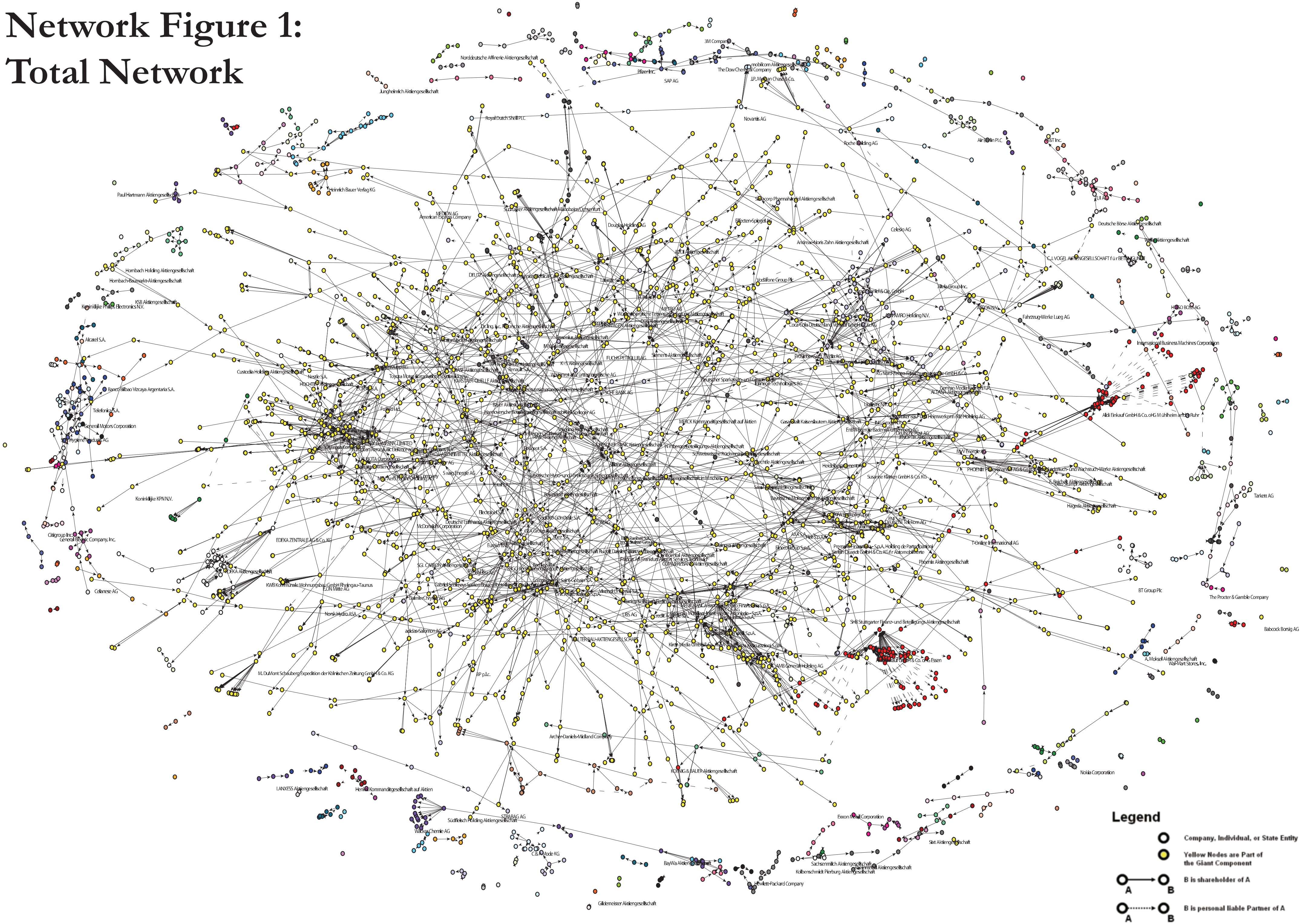
Own Source.

Table 3.9: Legal Forms of Companies in our Sample

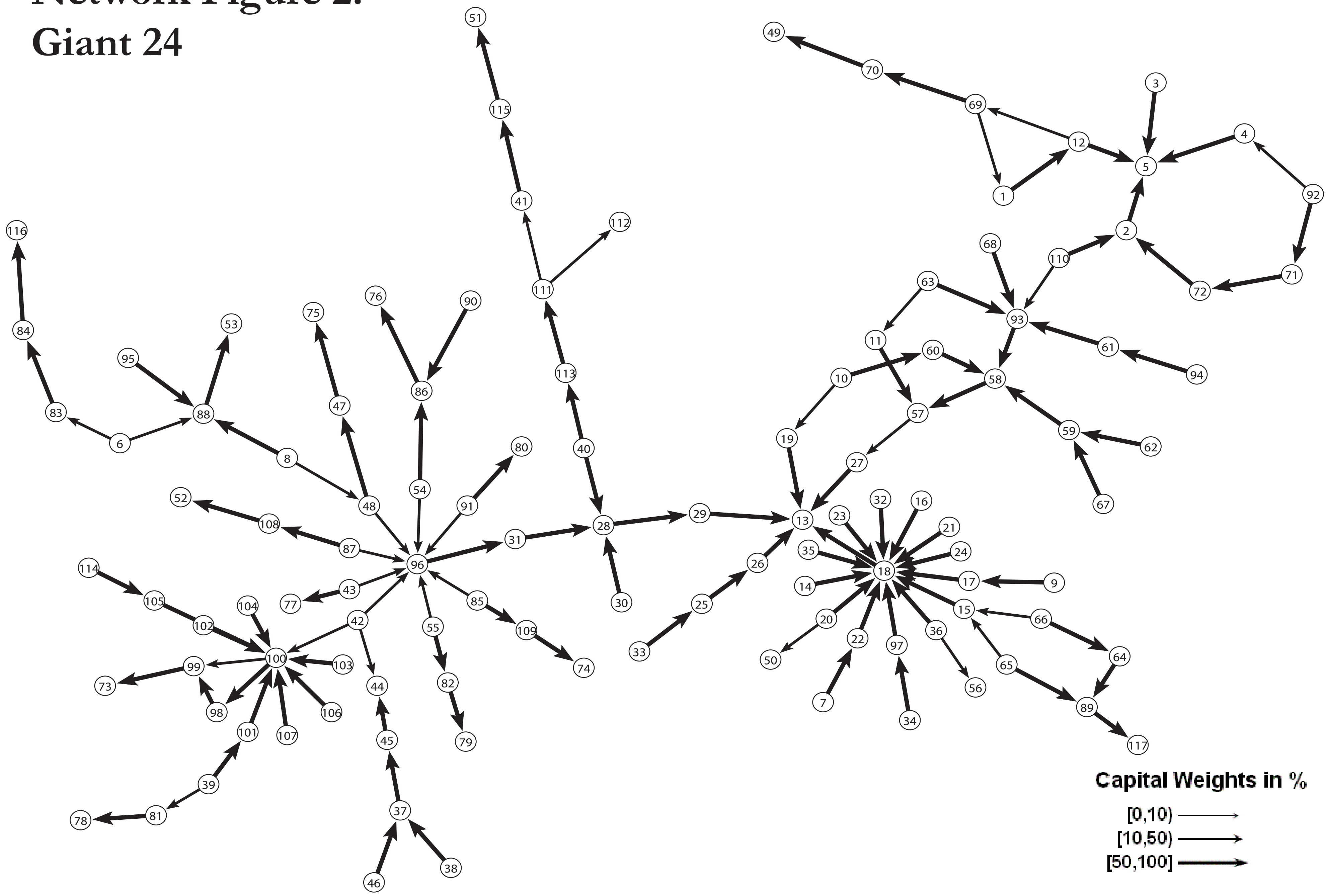
Abbreviation	Countries	Local Name	Group	#Obs
A/S	Denmark	Aktieslskab	Inc.	9
AB	Sweden	Aktiebolag	Inc.	15
AG	Germany	Aktiengesellschaft	Inc.	374
AG & Co KG	Germany		Inc.	16
ASA	Norway	Allmennaksjeselskap	Inc.	2
BV	The Netherlands	Besloten Vennootshap met beperkte aansprakelijkheid	Ltd.	44
CV	The Netherlands	Commanditaire Vennootschap	Partner	2
e.G.	Germany	eingetragene Genossenschaft	Other	26
e.V.	Germany	eingetragener Verein	Other	4
Foundation	Anglo-Saxon		Other	1
GbR	Germany	Gesellschaft des bürgerlichen Rechts	Other	4
GmbH	Germany	Gesellschaft mit beschränkter Haftung	Ltd.	816
GmbH & Co. KG	Germany		Partner	213
GmbH & Co. oHG	Germany		Partner	16
KG	Germany	Kommanditgesellschaft	Partner	43
KGaA	Germany	Kommanditgesellschaft auf Aktien	Inc.	7
LLC	USA	Limited Liability Company	Partner	22
LLP	USA, UK	Limited liability partnership	Partner	3
LP	USA	Limited Partnership	Ltd.	16
Ltd.	UK	Limited	Ltd.	133
NV	Belgium	Naamloze Vennootschap	Inc.	37
	The Netherlands	Naamloze Vennootschap	Inc.	
oHG	Germany	offene Handelsgesellschaft	Partner	4
PLC	UK	Public company limited by shares	Inc.	31
SA	Belgium	Société Anonyme	Inc.	120
	Brazil	Sociedade Anônima	Inc.	
	France	Société Anonyme	Inc.	
	Luxembourg	Société Anonyme	Inc.	
	Portugal	Sociedade Anônima	Inc.	
	Spain	Sociedad Anónima	Inc.	
SARL	France	Societe a responsabilite limitee	Ltd.	14
	Luxembourg	Societe a responsabilite limitee	Ltd.	
SAS	France	Société par Actions Simplifiée	Inc.	7
SCA	France	Société en commandite par actions	Inc.	4
SPA	Italy	Societa per azioni	Inc.	68
Stiftung	Germany	Stiftung	Other	34

Own Source: #Obs signifies the number of observations in the data set.

Network Figure 1: Total Network



Network Figure 2:
Giant 24

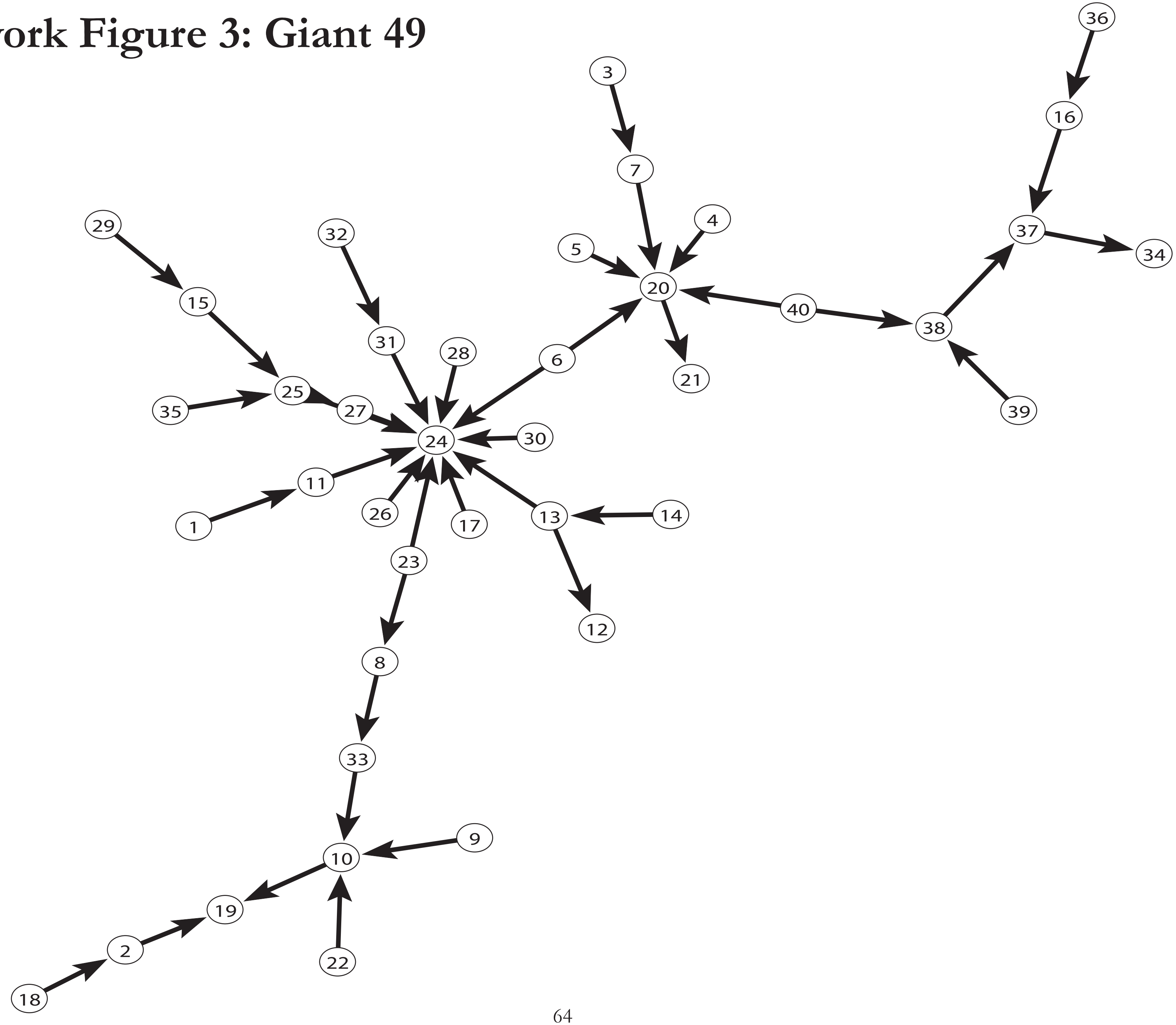


Giant 24

This is the Giant Component of the Complete Network where all links below 24% are deleted.

1 Aktien-Gesellschaft der Dillinger Hüttenwerke
2 ARBED S.A.
3 Arcelor Eisenhüttenstadt GmbH
4 Arcelor Germany Holding GmbH
5 Arcelor S.A.
6 Bayerngas GmbH
7 BKB AG
8 citiworks AG
9 CONTIGAS Deutsche Energie-AG
10 Degussa AG
11 Deutsche Steinkohle AG
12 DHS - Dillinger Hütte Saarstahl AG
13 E.ON AG
14 E.ON Avacon AG
15 E.ON Bayern AG
16 E.ON edis AG
17 E.ON Energie 26. Beteiligungs-GmbH
18 E.ON Energie AG
19 E.ON Finanzanlagen GmbH
20 E.ON Hanse AG
21 E.ON Kernkraft GmbH
22 E.ON Kraftwerke GmbH
23 E.ON Mitte AG
24 E.ON Netz GmbH
25 E.ON Nordic AB
26 E.ON Nordic Holding GmbH
27 E.ON RAG-Beteiligungsgesellschaft mbH
28 E.ON Ruhrgas AG
29 E.ON Ruhrgas Holding GmbH
30 E.ON Ruhrgas International AG
31 E.ON Ruhrgas Thüga Holding GmbH
32 E.ON Sales & Trading GmbH
33 E.ON Sverige AB
34 E.ON Thüringer Energie AG
35 E.ON Wasserkraft GmbH
36 E.ON Westfalen Weser AG
37 EEG - Erdgas Erdöl GmbH
38 EEG - Erdgas Transport GmbH
39 EnergieSüdwest AG
40 Erdgasversorgungsgesell. Thür.-Sa. mbH (EVG)
41 EWE AG
42 Gasag Berliner Gaswerke AG
43 Gasanstalt Kaiserslautern AG
44 Gaz de France Berliner Investissements SAS
45 Gaz de France Deutschland GmbH
46 Gaz de France Produktion Expl. Deutschland GmbH
47 HEAG AG
48 HEAG Südhessische Energie AG (HSE)
49 Jean Lang
50 Kreise
51 Landeselektrizitätsverband Oldenburg
52 Landeshauptstadt Hannover
53 Landeshauptstadt München
54 Mainova AG
55 N-ERGIE AG
56 Öffentliche Gebietskörperschaften
57 RAG AG
58 RAG Beteiligungs-GmbH
59 RAG Coal International AG
60 RAG Projektgesellschaft mbh
61 RAG Saarberg GmbH
62 RAG Trading GmbH
63 RAG Verkauf GmbH
64 Regensburger Badebetriebe GmbH
65 Regensburger Energie- und Wasserversorgung AG
66 Rewag Regensburger Ener.- und Wass. AG & Co KG
67 Rütgers GmbH
68 Saar Ferngas AG
69 Saarstahl AG
70 SHS - Struktur-Holding-Stahl GmbH & Co. KGaA
71 SIDARSTEEL N.V.
72 SIDMAR N.V.
73 Staat Schweden
74 Stadt Chemnitz
75 Stadt Darmstadt
76 Stadt Frankfurt am Main
77 Stadt Kaiserslautern
78 Stadt Landau
79 Stadt Nürnberg
80 Stadt Zweibrücken
81 Stadtholding Landau in der Pfalz GmbH
82 Städtische Werke Nürnberg GmbH
83 Stadtwerke Augsburg Energie GmbH
84 Stadtwerke Augsburg Holding GmbH
85 Stadtwerke Chemnitz AG
86 Stadtwerke Frankfurt am Main Holding GmbH
87 Stadtwerke Hannover AG
88 Stadtwerke München GmbH
89 Stadtwerke Regensburg GmbH
90 Stadtwerke Strom-/Wärmeversorgungsgesell. mbH
91 Stadtwerke Zweibrücken GmbH
92 Stahlwerke Bremen GmbH
93 STEAG AG
94 STEAG Saar Energie AG
95 SWM Versorgungs GmbH
96 Thüga AG
97 Thüringer Energie-Beteiligungsgesellschaft mbH
98 Vattenfall (Deutschland) GmbH
99 Vattenfall AB
100 Vattenfall Europe AG
101 Vattenfall Europe Berlin AG & Co. KG
102 Vattenfall Europe Berlin Verwaltungs-AG
103 Vattenfall Europe Generation AG & Co. KG
104 Vattenfall Europe Generation Verwaltungs-AG
105 Vattenfall Europe Hamburg AG
106 Vattenfall Europe Sales GmbH
107 Vattenfall Europe Transmission GmbH
108 Versorgungs- und Verkehrsgesellschaft Hannover mbH
109 Versorgungs- und Verkehrshold. GmbH Chemnitz (VVHC)
110 Verwaltungsgesellschaft RAG-Beteiligung mbH
111 VNG - Verbundnetz Gas AG
112 VNG Verbundnetz Gas Verwaltungs- und Bet.-GmbH
113 VNG-Erdgascommerz GmbH
114 WEMAG AG
115 Weser-Ems-Energiebeteiligungen GmbH
116 Stadt Augsburg
117 Stadt Regensburg

Network Figure 3: Giant 49

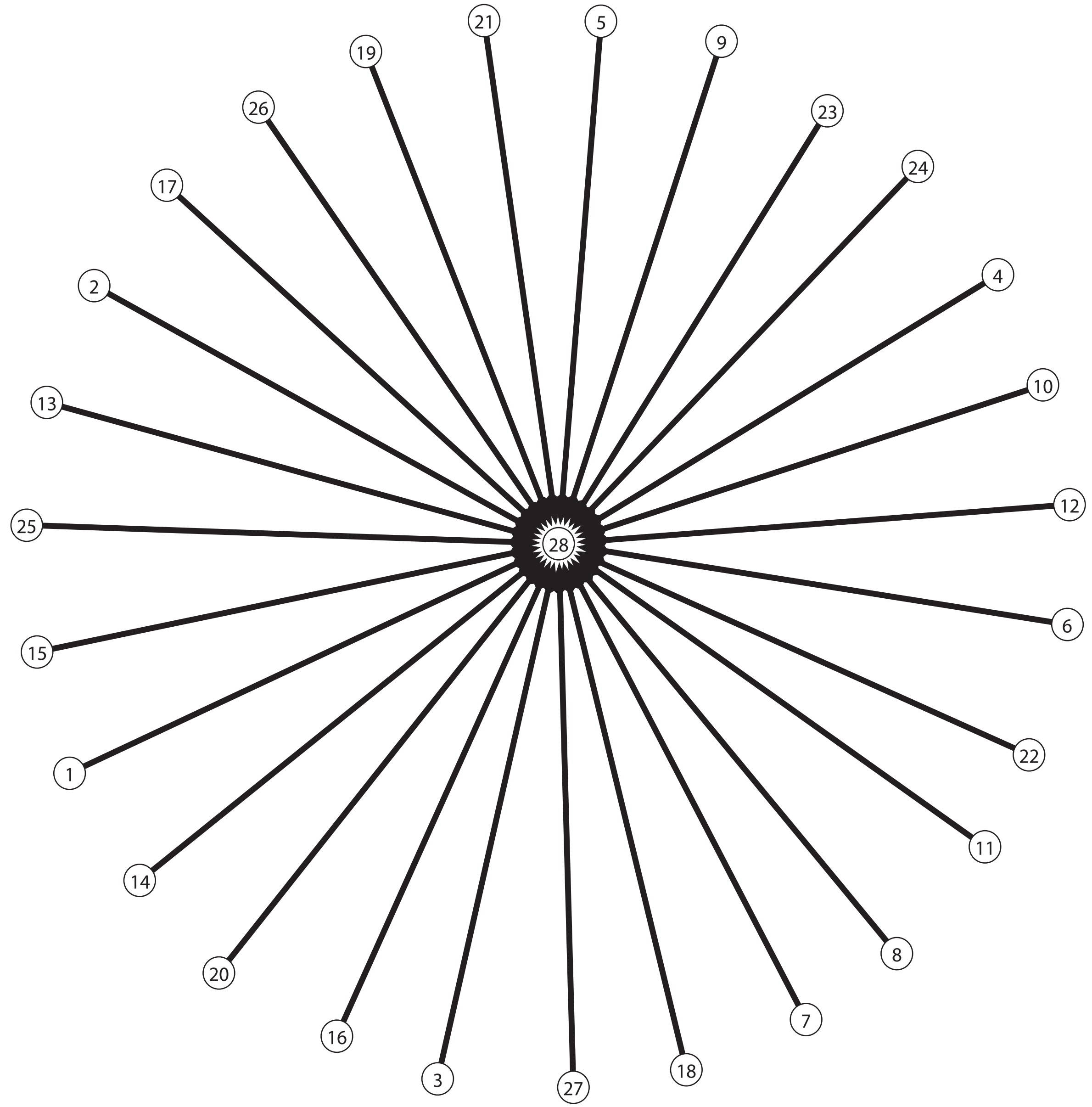


Giant 49

This is the Giant Component of the Complete Network where all links below 49% are deleted.

1 A. Friedr. Flender Aktiengesellschaft
2 Automobiles Peugeot S.A.
3 BBT Thermotechnik GmbH
4 Blaupunkt GmbH
5 Bosch Rexroth Aktiengesellschaft
6 BSH Bosch und Siemens Hausger舩e GmbH
7 Buderus Aktiengesellschaft
8 Faurecia Automotive GmbH
9 Faurecia Autositze GmbH & Co. KG
10 Faurecia S.A.
11 Flender Holding GmbH
12 Fujitsu Ltd.
13 Fujitsu Siemens Computers (Holding) B.V.
14 Fujitsu Siemens Computers GmbH
15 Kabel- und Drahtwerke Aktiengesellschaft
16 Luftschiffbau Zeppelin GmbH
17 Osram GmbH
18 PEUGEOT DEUTSCHLAND GMBH
19 Peugeot S.A.
20 Robert Bosch GmbH
21 Robert Bosch Stiftung GmbH
22 S.I.P. Verwaltungsgesellschaft mbH
23 SAS Autosystemtechnik Verwaltungs GmbH
24 Siemens Aktiengesellschaft
25 Siemens Aktiengesellschaft ｮsterreich
26 Siemens Beteiligungen Management GmbH
27 Siemens Beteiligungsverwaltung GmbH & Co. OHG
28 Siemens Business Services Beteiligungs-GmbH
29 Siemens Business Services GmbH
30 Siemens Business Services GmbH & Co. OHG
31 Siemens Real Estate GmbH & Co. OHG
32 Siemens Real Estate Management GmbH
33 Sommer Allibert S.A.
34 Stadt Friedrichshafen
35 VVK Vers.-Verm.- und Verkehrs-Kontor GmbH
36 ZEPPELIN GmbH
37 Zeppelin-Stiftung
38 ZF FRIEDRICHSHAFEN Aktiengesellschaft
39 ZF Getriebe GmbH
40 ZF Lenksysteme GmbH

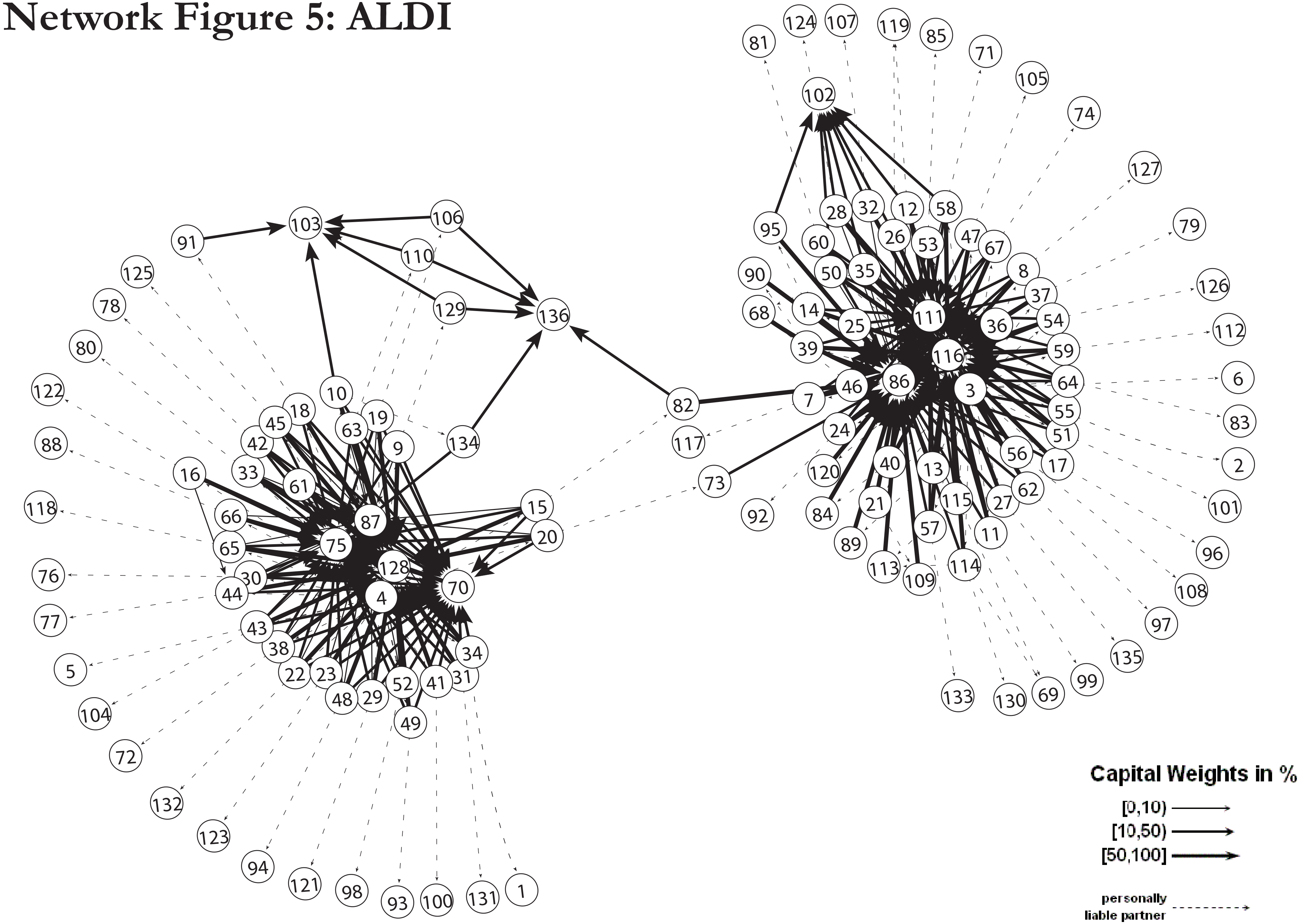
Network Figure 4: Giant 74



This is the Giant Component of the Complete Network where all links below 74% are deleted.

1 Aldi GmbH & Co. KG Adelsdorf
2 Aldi GmbH & Co. KG Altenstadt
3 Aldi GmbH & Co. KG Bingen am Rhein
4 Aldi GmbH & Co. KG Bous
5 Aldi GmbH & Co. KG Donaueschingen
6 Aldi GmbH & Co. KG Ebersberg
7 Aldi GmbH & Co. KG Eichenau
8 Aldi GmbH & Co. KG Geisenfeld
9 Aldi GmbH & Co. KG Helmstadt
10 Aldi GmbH & Co. KG Kerpen
11 Aldi GmbH & Co. KG Ketsch
12 Aldi GmbH & Co. KG Kirchheim an d. Weinstr.
13 Aldi GmbH & Co. KG Langenfeld L. (Rheinland)
14 Aldi GmbH & Co. KG Langenselbold
15 Aldi GmbH & Co. KG Mahlberg
16 Aldi GmbH & Co. KG Mönchengladbach
17 Aldi GmbH & Co. KG Montabaur
18 Aldi GmbH & Co. KG Mörfelden-Walldorf
19 Aldi GmbH & Co. KG Mühlheim an der Ruhr
20 Aldi GmbH & Co. KG Murr
21 Aldi GmbH & Co. KG Rastatt
22 Aldi GmbH & Co. KG Rheinberg
23 Aldi GmbH & Co. KG Sankt Augustin
24 Aldi GmbH & Co. KG Wittlich
25 Aldi GmbH & Co. KG Aichtal
26 ALDI GmbH & Co. KG Regenstauf
27 Aldi GmbH & Co. KG Roth
28 Siepmann Stiftung

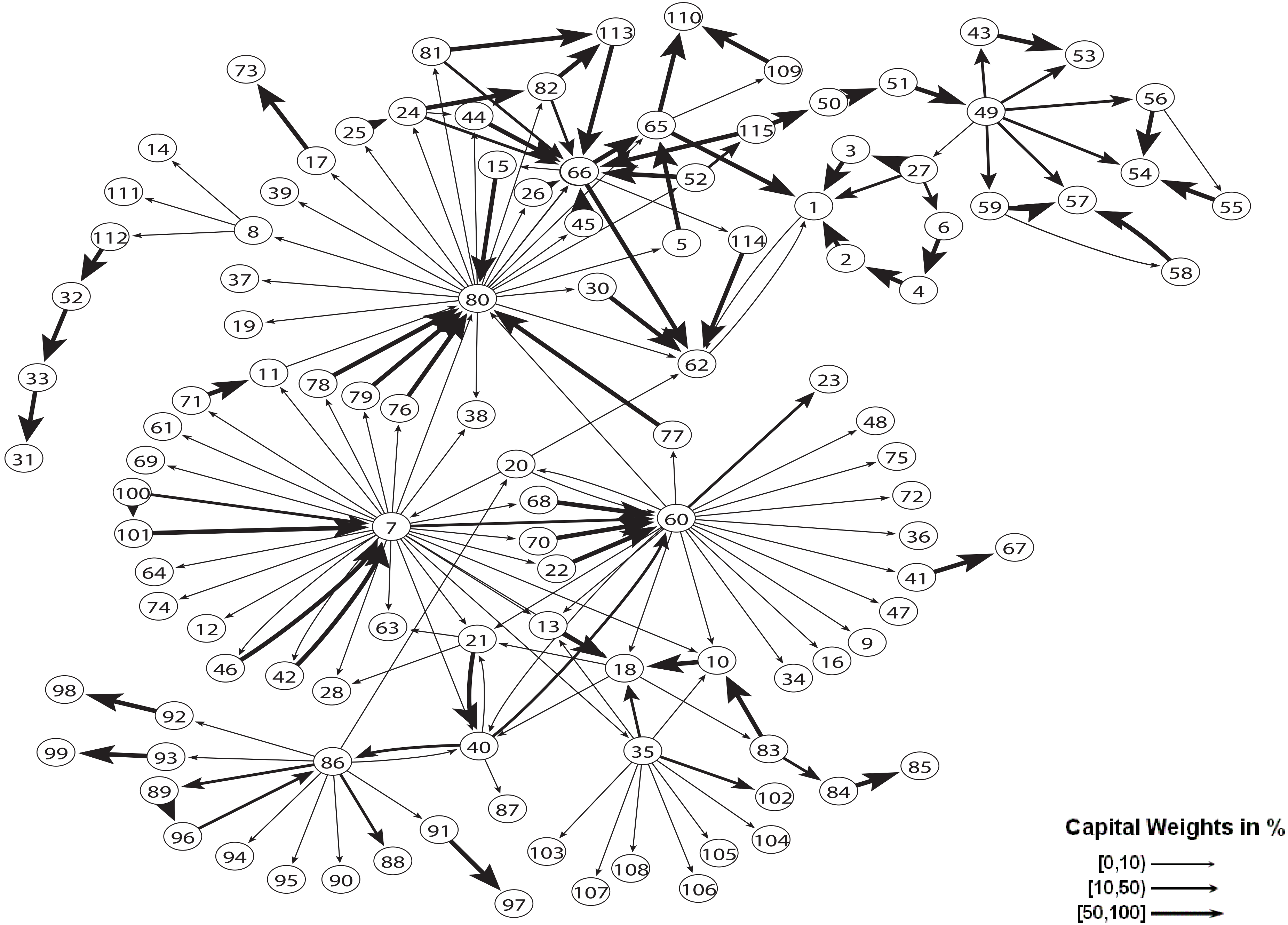
Network Figure 5: ALDI



ALDI

1 A. Dold GmbH
2 Albers GmbH
3 Aldi Einkauf GmbH & Co. oHG Essen
4 Aldi Einkauf GmbH & Co. oHG Mühlheim an der Ruhr
5 Aldi Einkauf GmbH Duisburg
6 Aldi Einkauf GmbH Herten
7 ALDI Gesellschaft & Co. KG Großbeeren
8 ALDI GmbH & Co. Beucha KG
9 Aldi GmbH & Co. KG Adelsdorf
10 Aldi GmbH & Co. KG Altenstadt
11 Aldi GmbH & Co. KG Bad Laasphe
12 Aldi GmbH & Co. KG Bargteheide
13 ALDI GmbH & Co. KG Berlin
14 ALDI GmbH & Co. KG Beverstedt
15 Aldi GmbH & Co. KG Bingen am Rhein
16 Aldi GmbH & Co. KG Bous
17 ALDI GmbH & Co. KG Datteln
18 Aldi GmbH & Co. KG Donaueschingen
19 Aldi GmbH & Co. KG Ebersberg
20 Aldi GmbH & Co. KG Eichenau
21 ALDI GmbH & Co. KG Essen
22 Aldi GmbH & Co. KG Geisenfeld
23 Aldi GmbH & Co. KG Helmstadt
24 ALDI GmbH & Co. KG Herten
25 Aldi GmbH & Co. KG Hesel
26 Aldi GmbH & Co. KG Horst
27 ALDI GmbH & Co. KG Hoyerswerder
28 ALDI GmbH & Co. KG Jarmen
29 Aldi GmbH & Co. KG Kerpen
30 Aldi GmbH & Co. KG Ketsch
31 Aldi GmbH & Co. KG Kirchheim an der Weinstraße
32 ALDI GmbH & Co. KG Könnern
33 Aldi GmbH & Co. KG Langenfeld Langenfeld (Rheinland)
34 Aldi GmbH & Co. KG Langenselbold
35 ALDI GmbH & Co. KG Langenwetzendorf
36 Aldi GmbH & Co. KG Lehrte
37 ALDI GmbH & Co. KG Lingen (Ems)
38 Aldi GmbH & Co. KG Mahlberg
39 ALDI GmbH & Co. KG Meitzendorf
40 ALDI GmbH & Co. KG Mittenwalde
41 Aldi GmbH & Co. KG Mönchengladbach
42 Aldi GmbH & Co. KG Montabaur
43 Aldi GmbH & Co. KG Mörfelden-Walldorf
44 Aldi GmbH & Co. KG Mühlheim an der Ruhr
45 Aldi GmbH & Co. KG Murr
46 ALDI GmbH & Co. KG Nohra
47 Aldi GmbH & Co. KG Radevormwald
48 Aldi GmbH & Co. KG Rastatt
49 Aldi GmbH & Co. KG Rheinberg
50 Aldi GmbH & Co. KG Rinteln
51 Aldi GmbH & Co. KG Salzgitter
52 Aldi GmbH & Co. KG Sankt Augustin
53 ALDI GmbH & Co. KG Scharbeutz
54 Aldi GmbH & Co. KG Schloß Holte-Stukenbrock
55 ALDI GmbH & Co. KG Schwelm
56 ALDI GmbH & Co. KG Seefeld
57 ALDI GmbH & Co. KG Seevetal
58 ALDI GmbH & Co. KG Werl
59 ALDI GmbH & Co. KG Weyhe
60 ALDI GmbH & Co. KG Wilsdruff
61 Aldi GmbH & Co. KG Wittlich
62 ALDI GmbH & Co. KG Wittstock
63 Aldi GmbH & Co. Kommanditgesellschaft Aichtal
64 Aldi GmbH & Co. Kommanditgesellschaft Greven
65 ALDI GmbH & Co. Kommanditgesellschaft Regenstauf
66 Aldi GmbH & Co. Kommanditgesellschaft Roth
67 Aldi GmbH u. Co. KG Notdorf
68 Berger GmbH
69 Berthold Albrecht
70 Billen GmbH
71 Brehm GmbH
72 Bröker GmbH
73 Burgard GmbH
74 Buttkus GmbH
75 Carolus-Stiftung
76 Daniel GmbH
77 David GmbH
78 Delschen GmbH
79 Diekhaus GmbH
80 Drees GmbH
81 Ebel GmbH
82 Eck GmbH
83 Eden GmbH
84 Ekrot GmbH
85 Elsner GmbH
86 Familie Albrecht
87 Fenten Gesellschaft mit beschränkter Haftung
88 Feucht GmbH
89 Frank Schröder GmbH
90 Gerdes GmbH
91 Goetsch GmbH
92 Günther GmbH
93 Hahn GmbH
94 Hake GmbH
95 Heckl GmbH
96 Heußinger GmbH
97 Hirtz GmbH
98 Hoffmann Beteiligungsgesellschaft mbH
99 Holger Schmidt GmbH
100 Holger Schneider GmbH
101 Iders GmbH
102 Jakobus-Stiftung
103 Karl Albrecht
104 Kehl GmbH
105 Kenzler GmbH
106 Kießl GmbH
107 Langenstroeher GmbH
108 Larberg GmbH
109 Lessner GmbH
110 Liebisch GmbH
111 Lukas Stiftung
112 Markhoff GmbH
113 Markus Kaffee GmbH
114 Markus Kaffee GmbH & Co. KG Herten
115 Markus Kaffee GmbH & Co. KG Weyhe
116 Markus Stiftung
117 Michalek GmbH
118 Müller GmbH
119 Neubold GmbH
120 Noack GmbH
121 Otte GmbH
122 Penkert GmbH
123 Polossek GmbH
124 Reitzig GmbH
125 Robinson GmbH
126 Roettgen GmbH
127 Sander GmbH
128 Siepmann Stiftung
129 Steinbrenner GmbH
130 Theo Albrecht jun.
131 Thull GmbH
132 Thunig GmbH
133 Tölle GmbH
134 Vollmer GmbH
135 Weiland GmbH
136 Oertel-Stiftung

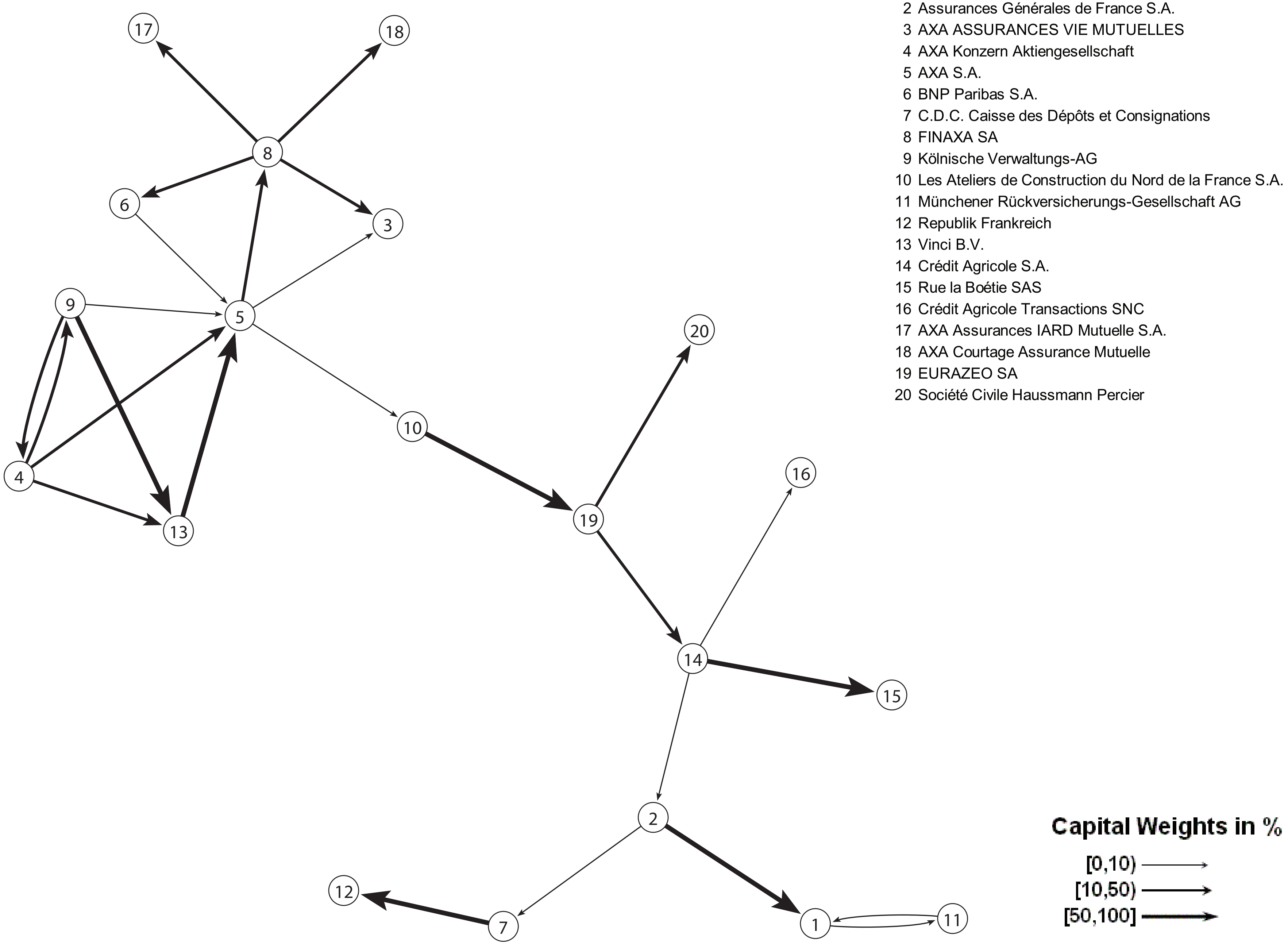
Network Figure 6: AMB Generali



AMB Generali

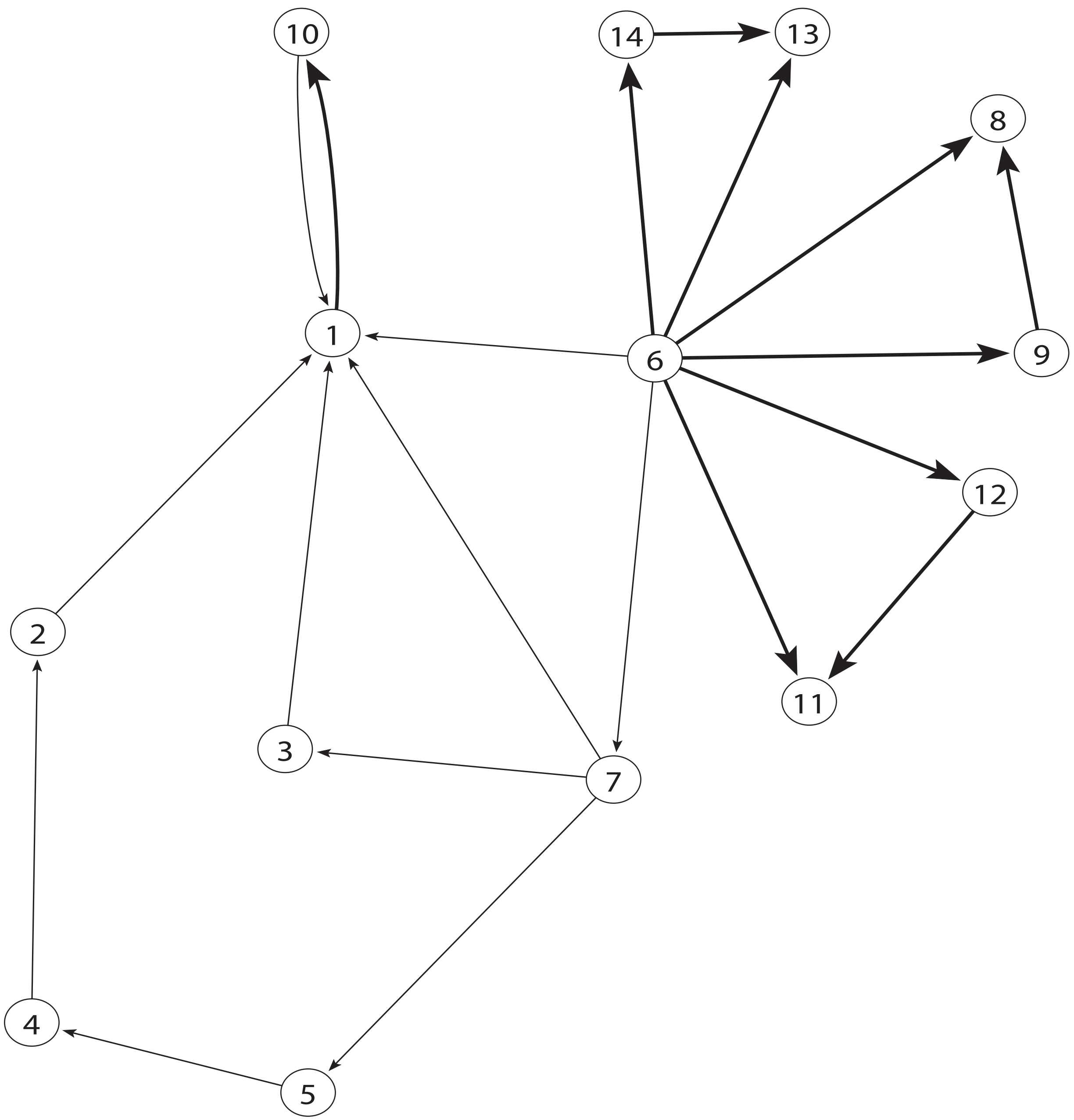
1 Allianz Aktiengesellschaft
2 Allianz Deutschland AG
3 Allianz Finanzbeteiligungs GmbH
4 Allianz Lebensversicherungs-Aktiengesellschaft
5 Allianz Subalpina Società di assicurazioni e riassicurazioni
6 Asopos Vermögensverwaltungsgesellschaft
7 Assicurazioni Generali S.p.A.
8 AVIVA Plc.
9 B and B Investissement S.C. Immobilière
10 Banca di Roma S.p.A.
11 Banca d'Italia S.p.A.
12 Banca Mediosim Banca della Rete S.p.A.
13 Banco di Sicilia S.p.A.
14 Barclays PLC
15 Bayerische Hypo- und Vereinsbank Aktiengesellschaft
16 Caisse Centrale des Assurances Mutuelles A.S.M.
17 Capital Research & Management Company
18 Capitalia S.p.A.
19 Carimonte Holding S.p.A.
20 COMMERZBANK Aktiengesellschaft
21 Compagnia di Assicurazione di Milano S.p.A.
22 Compass S.p.A.
23 Consortium S.r.l.
24 D.A.S. Deutscher Automobil Schutz Allgemeine R.-V. AG
25 D.A.S. Deutscher Automobil Schutz Versicherungs-AG
26 DKV Deutsche Krankenversicherung Aktiengesellschaft
27 DRESDNER BANK Aktiengesellschaft
28 EFFE Finanziaria S.p.A.
29 ERGO Versicherungsgruppe Aktiengesellschaft
30 Europäische Reiseversicherung Aktiengesellschaft
31 Fidelity International Limited
32 Fidelity Investments International
33 Fidelity Investments International Limited
34 Financière du Perguet S.A.S.
35 FinecoGroup S.p.A.
36 FINSAI INTERNATIONAL S.A.
37 Fondazione Cassa di Risparmio di Torino
38 Fondazione Cassa di Risparmio Verona. Vicenza. B. e A.
39 Fondazione Cassamarca -Cassa di Risparmio della M. T.
40 Fondiaria - SAI S.p.A.
41 GAN S.A.
42 Generali Vita S.p.A.
43 Grisfonta AG
44 Hamburg-Mannheimer Sachversicherungs-AG
45 Hamburg-Mannheimer Versicherungs-Aktiengesellschaft
46 Ina Vita S.p.A.
47 Italcementi Fabbriche Riunite Cemento S.p.A.
48 Italmobiliare S.p.A.
49 KARSTADT QUELLE Aktiengesellschaft
50 KARSTADT QUELLE Kunden-Service GmbH
51 KARSTADT QUELLE Service GmbH
52 KarstadtQuelle Lebensversicherung Aktiengesellschaft
53 Leo Herl
54 Madeleine Schickedanz
55 Madeleine Schickedanz Vermögensverwaltungs B. GmbH
56 Madeleine Schickedanz Vermögensverw. GmbH & Co. KG
57 Martin Dedi
58 Martin Dedi Vermögensverwaltungs Beteiligungs GmbH
59 Martin Dedi Vermögensverwaltungs GmbH & Co. KG
60 MEDIOBANCA Banca di Credito Finanziario S.p.A.
61 Merrill Lynch Investments Managers Group Ltd.
62 Münchener Rückversicherungs-Gesellschaft AG
63 Novara Vita S.p.A.
64 Po Vita Compagnia di Assicurazioni S.p.A.
65 RAS Riunione Adriatica di Sicurtà S.p.A.
66 RB Vita S.p.A.
67 Republik Frankreich
68 Sade Finanziaria S.p.A.
69 SIAT - Società Italiana Assicurazioni e Riassicurazioni - p.A.
70 Società per Amministrazioni Fiduciarie SPAFID S.p.A.
71 Società per la Bonifica dei Terreni F. e per le I. A. - S.p.A.
72 Société der Participation Financière Italmobiliare S.A.
73 The Capital Group Companies Inc.
74 The Lawrence Re Ireland Ltd.
75 Tradinglab Banca S.p.A.
76 Unicredit Banca d'Impresa S.p.A.
77 Unicredit Banca Mobiliare S.p.A.
78 Unicredit Banca S.p.A.
79 Unicredit Private Banking S.p.A.
80 UniCredito Italiano S.p.A.
81 VICTORIA Lebensversicherung Aktiengesellschaft
82 VICTORIA Versicherung Aktiengesellschaft
83 Roma Vita S.p.A.
84 Toro Assicurazioni S.p.A.
85 DE AGOSTINI S.p.A.
86 Premafin Finanziaria - S.p.A. Holding de Partecipazioni
87 Finadin - S.p.A. Finanziaria di Investimenti
88 Compagnia Fiduciaria Nazionale S.p.A.
89 Banca del Gottardo S.A.
90 Sinergia Terza S.p.A.
91 Canoe Securities S.A.
92 Hike Securities S.A.
93 Limbo Invest S.A.
94 Immobiliare Costruzioni IM.CO. S.p.A.
95 SAIFIN - SAI Finanziaria S.p.A.
96 Schweizerische LV. - und Rentenanstalt
97 Giulia Maria Ligresti
98 Jonella Ligresti
99 Gioacchino Paolo Ligresti
100 AMB Generali Holding AG
101 Generali Beteiligungs-GmbH
102 F. Mandori
103 M. Ardesi
104 Familie Schickedanz
105 Putnam Investments. LLC
106 Soc. Reale Mutua di Assicurazioni
107 C. Gestioni
108 A. Spaggiari
109 Crédit Industriel d'Alsace et de Lorraine S.A.
110 Crédit Industriel et Commercial (CIC)
111 Legal & General Group PLC
112 Fidelity Investments Ltd.
113 ERGO Achte Beteiligungsgesellschaft mbH
114 MR ERGO Beteiligungen GmbH
115 KarstadtQuelle Finanz Service GmbH

Network Figure 7: AXA



1 Allianz Aktiengesellschaft
2 Assurances Générales de France S.A.
3 AXA ASSURANCES VIE MUTUELLES
4 AXA Konzern Aktiengesellschaft
5 AXA S.A.
6 BNP Paribas S.A.
7 C.D.C. Caisse des Dépôts et Consignations
8 FINAXA SA
9 Kölnische Verwaltungs-AG
10 Les Ateliers de Construction du Nord de la France S.A.
11 Münchener Rückversicherungs-Gesellschaft AG
12 Republik Frankreich
13 Vinci B.V.
14 Crédit Agricole S.A.
15 Rue la Boétie SAS
16 Crédit Agricole Transactions SNC
17 AXA Assurances IARD Mutuelle S.A.
18 AXA Courtage Assurance Mutuelle
19 EURAZEO SA
20 Société Civile Haussmann Percier

Network Figure 8: BMW

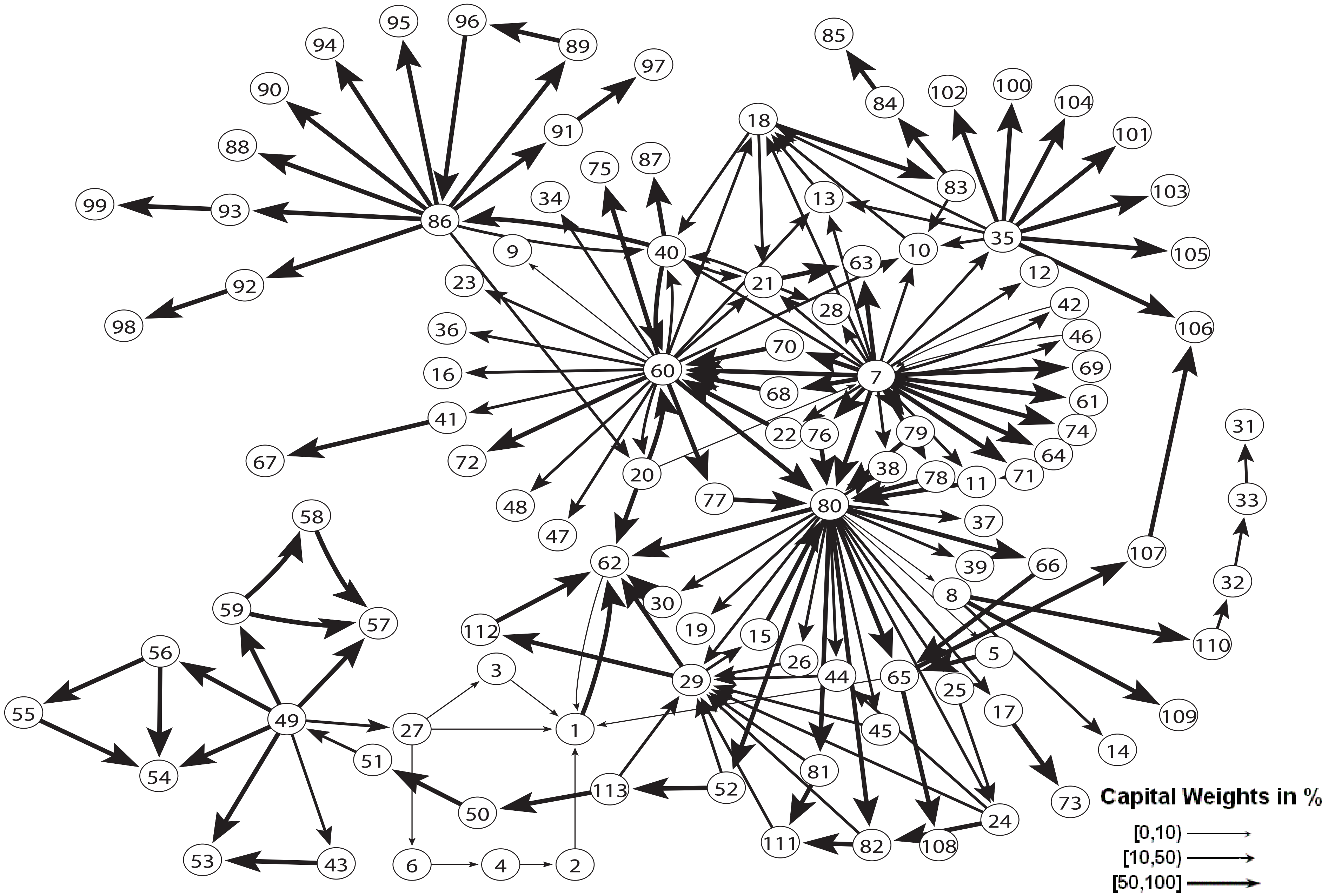


1 Allianz AG
2 Allianz Deutschland AG
3 Allianz Finanzbeteiligungs GmbH
4 Allianz Lebensversicherungs-AG
5 Asopos Vermögensverwaltungsgesellschaft
6 Bayerische Motoren Werke AG
7 DRESDNER BANK AG
8 Johanna Quandt
9 Johanna Quandt GmbH & Co. KG für Automobilwerte
10 Münchener Rückversicherungs-Gesellschaft AG
11 Stefan Quandt
12 Stefan Quandt GmbH & Co. KG für Automobilwerte
13 Susanne Klatten
14 Susanne Klatten GmbH & Co. KG für Automobilwerte

Capital Weights in %

[0,10)
[10,50)
[50,100]

Network Figure 9: Commerzbank



Commerzbank

1 Allianz AG
2 Allianz Deutschland AG
3 Allianz Finanzbeteiligungs GmbH
4 Allianz Lebensversicherungs-AG
5 Allianz Subalpina Società di assicurazioni e riassicurazioni
6 Asopos Vermögensverwaltungsgesellschaft
7 Assicurazioni Generali S.p.A.
8 AVIVA Plc.
9 B and B Investissement S.C. Immobilière
10 Banca di Roma S.p.A.
11 Banca d'Italia S.p.A.
12 Banca Mediosim Banca della Rete S.p.A.
13 Banco di Sicilia S.p.A.
14 Barclays PLC
15 Bayerische Hypo- und Vereinsbank AG
16 Caisse Centrale des Assurances Mutuelles A. S. M.
17 Capital Research & Management Company
18 Capitalia S.p.A.
19 Carimonte Holding S.p.A.
20 COMMERZBANK AG
21 Compagnia di Assicurazione di Milano S.p.A.
22 Compass S.p.A.
23 Consortium S.r.l.
24 D.A.S. Deutscher Automobil Schutz Allgemeine RV-AG
25 D.A.S. Deutscher Automobil Schutz Versicherungs-AG
26 DKV Deutsche Krankenversicherung AG
27 DRESDNER BANK AG
28 EFFE Finanziaria S.p.A.
29 ERGO Versicherungsgruppe AG
30 Europäische Reiseversicherung AG
31 Fidelity International Limited
32 Fidelity Investments International
33 Fidelity Investments International Limited
34 Financière du Perguet S.A.S.
35 FinecoGroup S.p.A.
36 FINSAI INTERNATIONAL S.A.
37 Fondazione Cassa di Risparmio di Torino
38 Fondazione Cassa di Risparmio Verona. Vicenza. B. e A.
39 Fondazione Cassamarca -Cassa di Risparmio della M. T.
40 Fondiaria - SAI S.p.A.
41 GAN S.A.
42 Generali Vita S.p.A.
43 Grisfonta AG
44 Hamburg-Mannheimer Sachversicherungs-AG
45 Hamburg-Mannheimer Versicherungs-AG
46 Ina Vita S.p.A.
47 Italcementi Fabbriche Riunite Cemento S.p.A.
48 Italmobiliare S.p.A.
49 KARSTADT QUELLE AG
50 KARSTADT QUELLE Kunden-Service GmbH
51 KARSTADT QUELLE Service GmbH
52 KarstadtQuelle Lebensversicherung AG
53 Leo Herl
54 Madeleine Schickedanz
55 Madeleine Schickedanz Vermögensverw. Beteil. GmbH
56 Madeleine Schickedanz Vermögensverw. GmbH & Co. KG
57 Martin Dedi
58 Martin Dedi Vermögensverwaltungs Beteiligungs GmbH
59 Martin Dedi Vermögensverwaltungs GmbH & Co. KG
60 MEDIOBANCA Banca di Credito Finanziario S.p.A.
61 Merrill Lynch Investments Managers Group Ltd.
62 Münchener Rückversicherungs-Gesellschaft AG
63 Novara Vita S.p.A.
64 Po Vita Compagnia di Assicurazioni S.p.A.
65 RAS Riunione Adriatica di Sicurtà S.p.A.
66 RB Vita S.p.A.
67 Republik Frankreich
68 Sade Finanziaria S.p.A.
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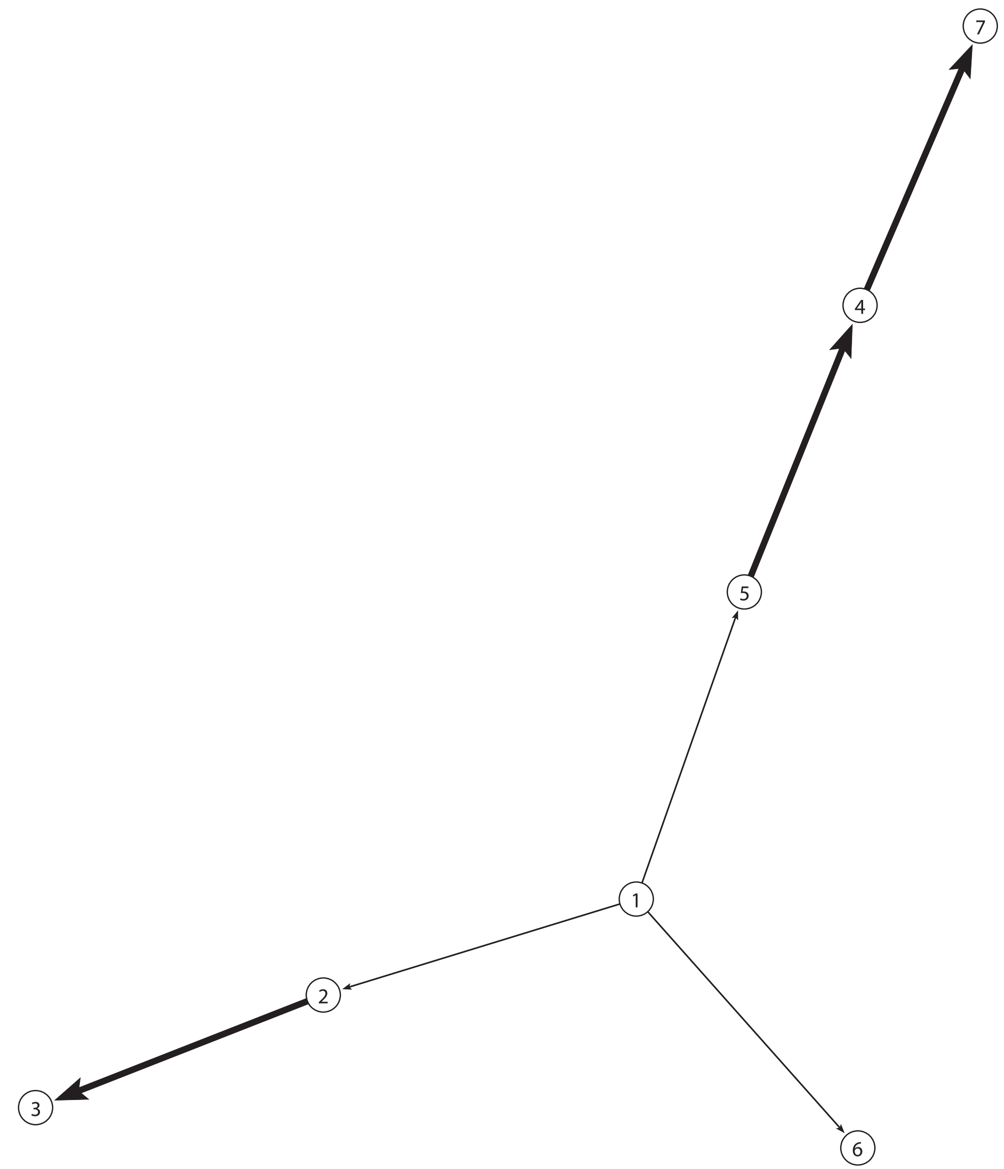
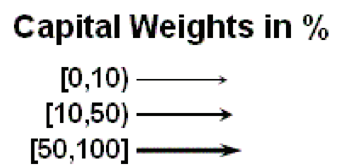
74 The Lawrence Re Ireland Ltd.
75 Tradinglab Banca S.p.A.
76 Unicredit Banca d'Impresa S.p.A.
77 Unicredit Banca Mobiliare S.p.A.
78 Unicredit Banca S.p.A.
79 Unicredit Private Banking S.p.A.
80 UniCredito Italiano S.p.A.
81 VICTORIA Lebensversicherung AG
82 VICTORIA Versicherung AG
83 Roma Vita S.p.A.
84 Toro Assicurazioni S.p.A.
85 DE AGOSTINI S.p.A.
86 Premafin Finanziaria - S.p.A. Holding de Partecipazioni
87 Finadin - S.p.A. Finanziaria di Investimenti
88 Compagnia Fiduciaria Nazionale S.p.A.
89 Banca del Gottardo S.A.
90 Sinergia Terza S.p.A.
91 Canoe Securities S.A.
92 Hike Securities S.A.
93 Limbo Invest S.A.
94 Immobiliare Costruzioni IM.CO. S.p.A.
95 SAIFIN - SAI Finanziaria S.p.A.
96 Schweizerische LV- und Rentenanstalt
97 Giulia Maria Ligresti
98 Jonella Ligresti
99 Gioacchino Paolo Ligresti
100 F. Mandori
101 M. Ardesi
102 Familie Schickedanz
103 Putnam Investments. LLC
104 Soc. Reale Mutua di Assicurazioni
105 C. Gestioni
106 A. Spaggiari
107 Crédit Industriel d'Alsace et de Lorraine S.A.
108 Crédit Industriel et Commercial (CIC)
109 Legal & General Group PLC
110 Fidelity Investments Ltd.
111 ERGO Achte Beteiligungsgesellschaft mbH
112 MR ERGO Beteiligungen GmbH
113 KarstadtQuelle Finanz Service GmbH

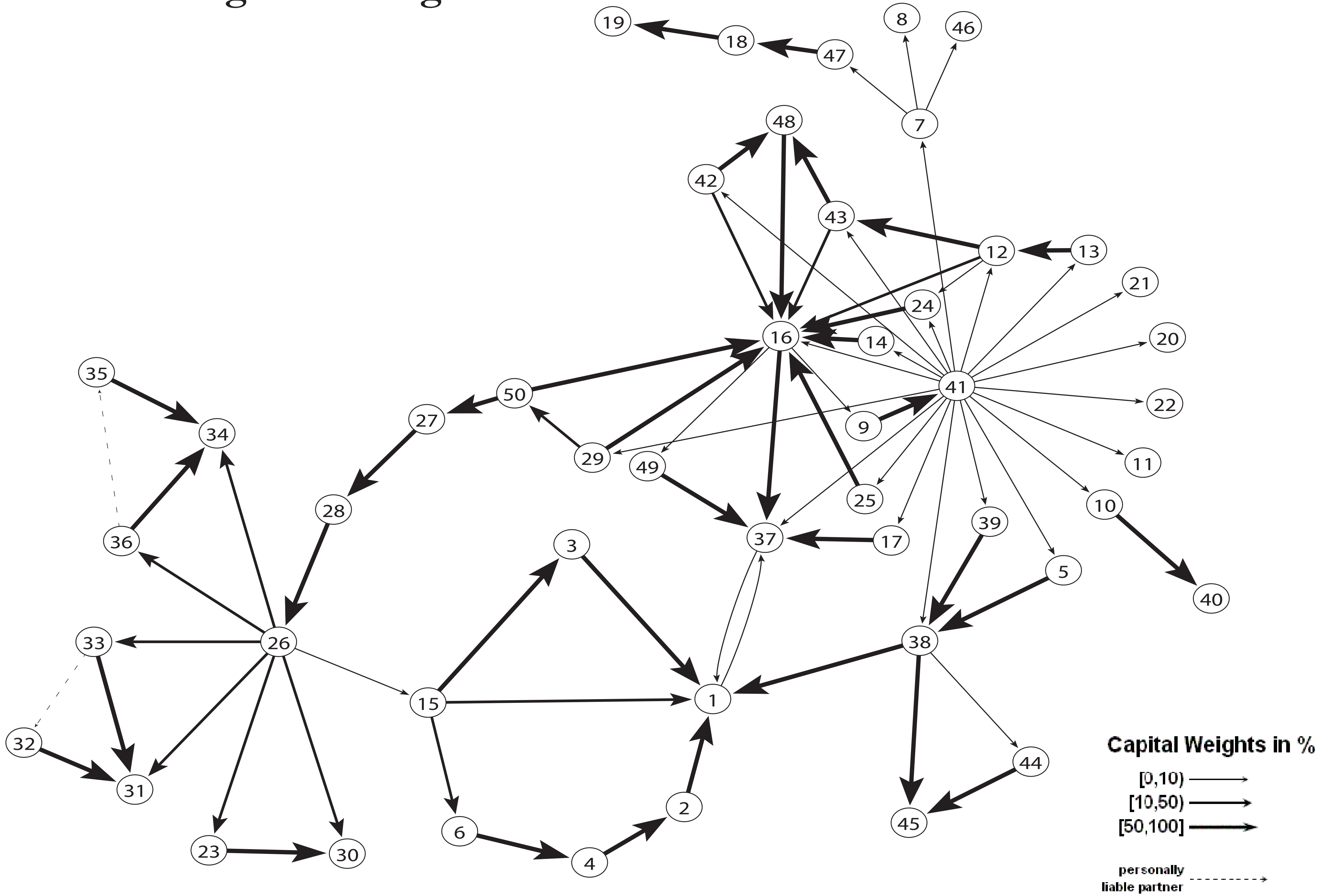
Network Figure 10: DaimlerChrysler



1 DaimlerChrysler AG
2 DB Value GmbH
3 Deutsche Bank AG
4 Dubai Holding Ltd.
5 Dubai International Capital Ltd.
6 Emirat Kuwait
7 Mohammed bin Rashid AL Maktoum



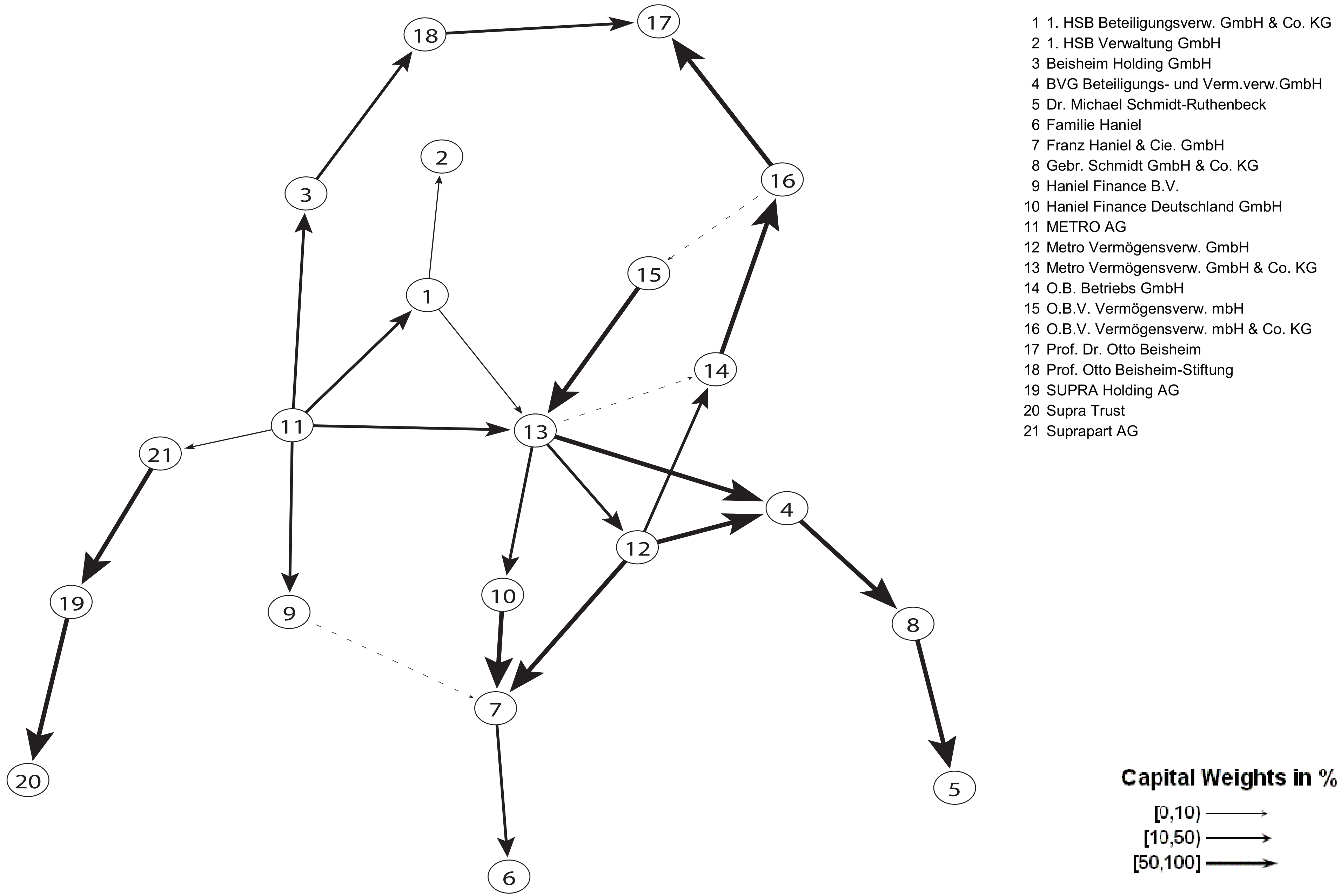
Network Figure 11: Ergo



Ergo

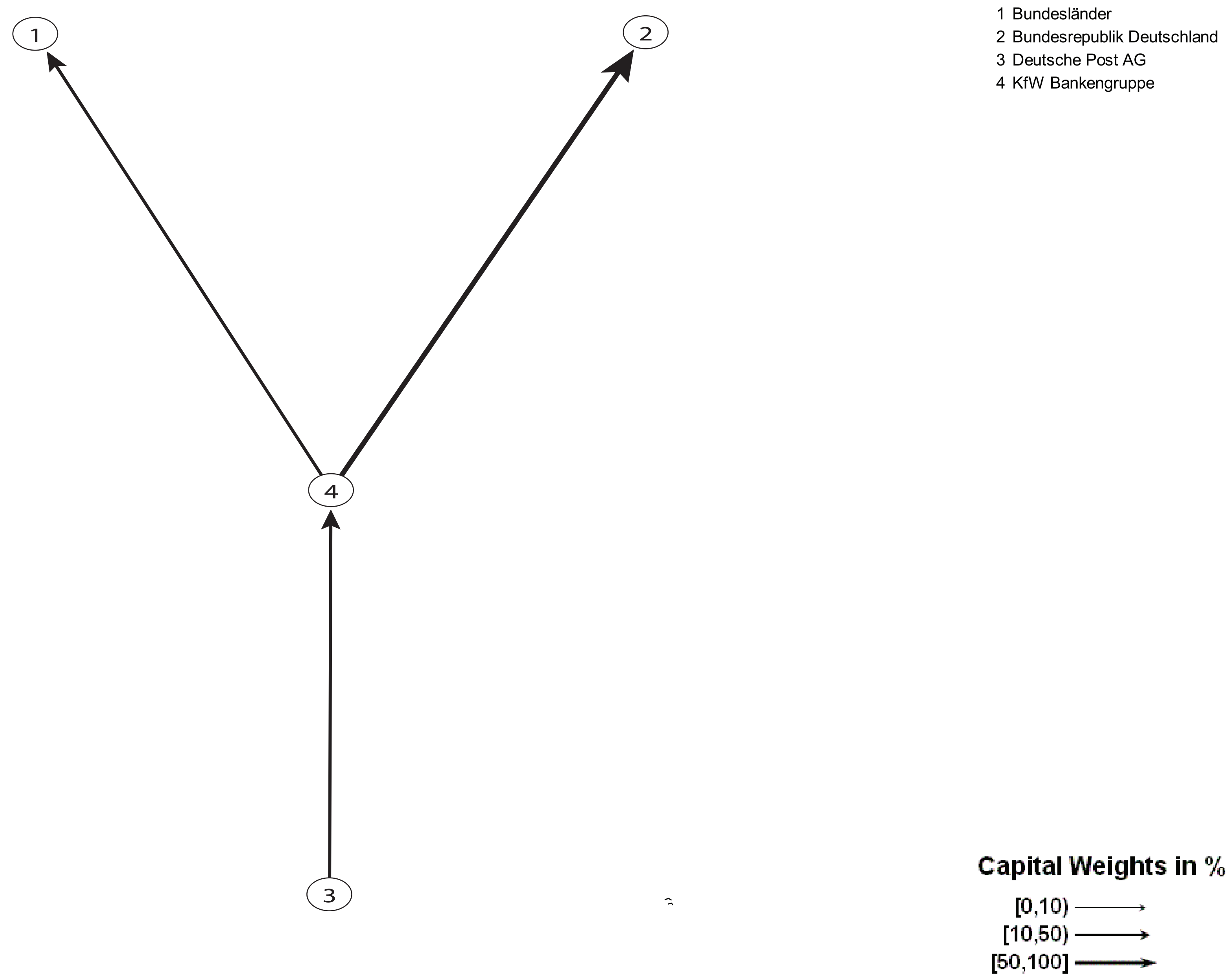
1 Allianz AG
2 Allianz Deutschland AG
3 Allianz Finanzbeteiligungs GmbH
4 Allianz Lebensversicherungs-AG
5 Allianz Subalpina Società di assicurazioni e riassicurazioni
6 Asopos Vermögensverwaltungsgesellschaft
7 AVIVA Plc.
8 Barclays PLC
9 Bayerische Hypo- und Vereinsbank AG
10 Capital Research & Management Company
11 Carimonte Holding S.p.A.
12 D.A.S. Deutscher Automobil Schutz Allgemeine Rechtsschutz-Versi
13 D.A.S. Deutscher Automobil Schutz Versicherungs-AG
14 DKV Deutsche Krankenversicherung AG
15 DRESDNER BANK AG
16 ERGO Versicherungsgruppe AG
17 Europäische Reiseversicherung AG
18 Fidelity Investments International
19 Fidelity Investments International Limited
20 Fondazione Cassa di Risparmio di Torino
21 Fondazione Cassa di Risparmio Verona, Vicenza, Belluno e Ancona
22 Fondazione Cassamarca -Cassa di Risparmio della Marca Trivignian
23 Grisfonta AG
24 Hamburg-Mannheimer Sachversicherungs-AG
25 Hamburg-Mannheimer Versicherungs-AG
26 KARSTADT QUELLE AG
27 KARSTADT QUELLE Kunden-Service GmbH
28 KARSTADT QUELLE Service GmbH
29 KarstadtQuelle Lebensversicherung AG
30 Leo Herl
31 Madeleine Schickedanz
32 Madeleine Schickedanz Vermögensverwaltungs Beteiligungs GmbH
33 Madeleine Schickedanz Vermögensverwaltungs GmbH & Co. KG
34 Martin Dedi
35 Martin Dedi Vermögensverwaltungs Beteiligungs GmbH
36 Martin Dedi Vermögensverwaltungs GmbH & Co. KG
37 Münchener Rückversicherungs-Gesellschaft AG in München
38 RAS Riunione Adriatica di Sicurtà S.p.A.
39 RB Vita S.p.A.
40 The Capital Group Companies Inc.
41 UniCredito Italiano S.p.A.
42 VICTORIA Lebensversicherung AG
43 VICTORIA Versicherung AG
44 Crédit Industriel d'Alsace et de Lorraine S.A.
45 Crédit Industriel et Commercial (CIC)
46 Legal & General Group PLC
47 Fidelity Investments Ltd.
48 ERGO Achte Beteiligungsgesellschaft mbH
49 MR ERGO Beteiligungen GmbH
50 KarstadtQuelle Finanz Service GmbH

Network Figure 12: Metro

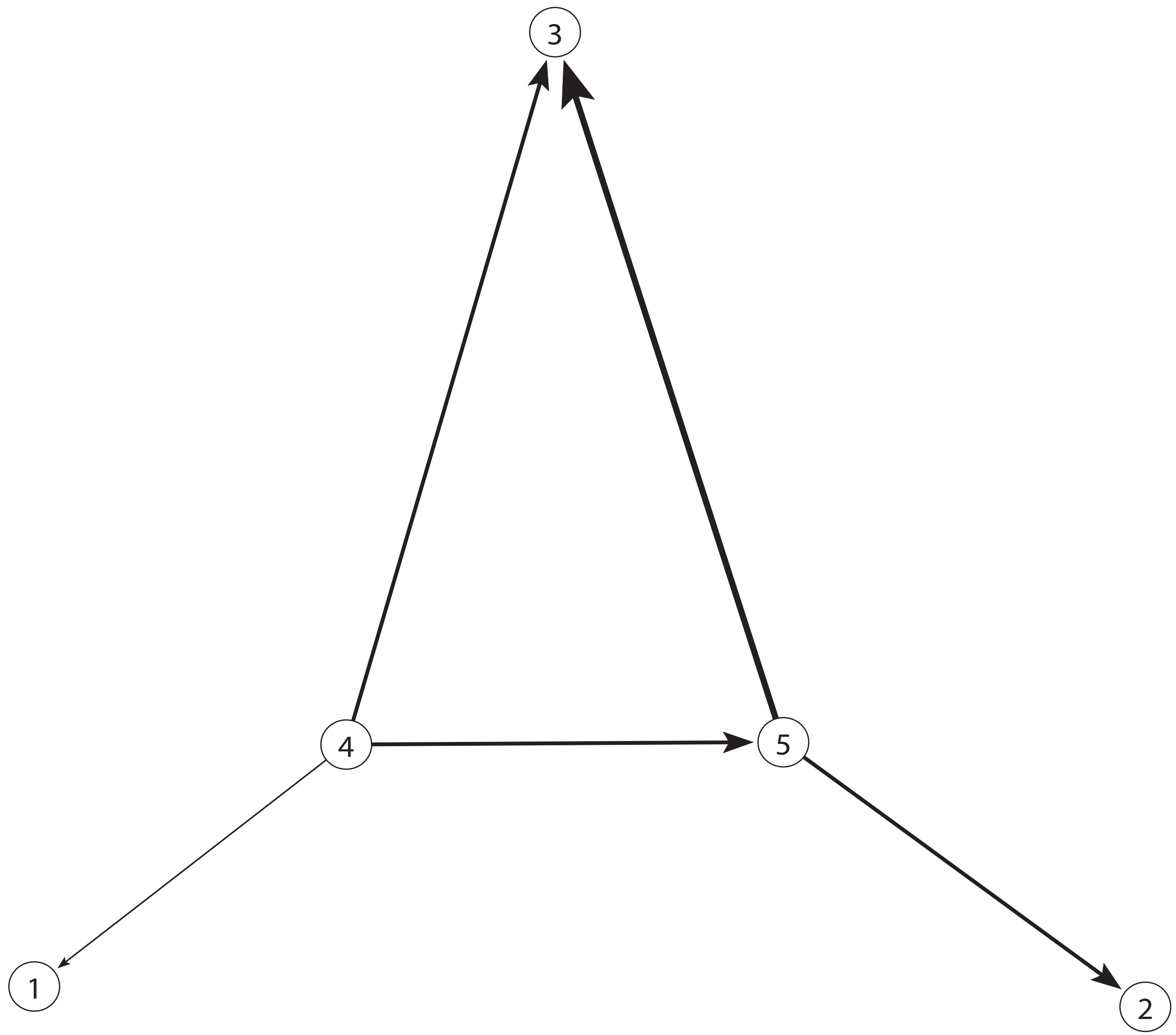


1 1. HSB Beteiligungsverw. GmbH & Co. KG
2 1. HSB Verwaltung GmbH
3 Beisheim Holding GmbH
4 BVG Beteiligungs- und Verm.verw.GmbH
5 Dr. Michael Schmidt-Ruthenbeck
6 Familie Haniel
7 Franz Haniel & Cie. GmbH
8 Gebr. Schmidt GmbH & Co. KG
9 Haniel Finance B.V.
10 Haniel Finance Deutschland GmbH
11 METRO AG
12 Metro Vermögensverw. GmbH
13 Metro Vermögensverw. GmbH & Co. KG
14 O.B. Betriebs GmbH
15 O.B.V. Vermögensverw. mbH
16 O.B.V. Vermögensverw. mbH & Co. KG
17 Prof. Dr. Otto Beisheim
18 Prof. Otto Beisheim-Stiftung
19 SUPRA Holding AG
20 Supra Trust
21 Suprapart AG

Network Figure 13: Deutsche Post



Network Figure 14: Deutsche Telekom

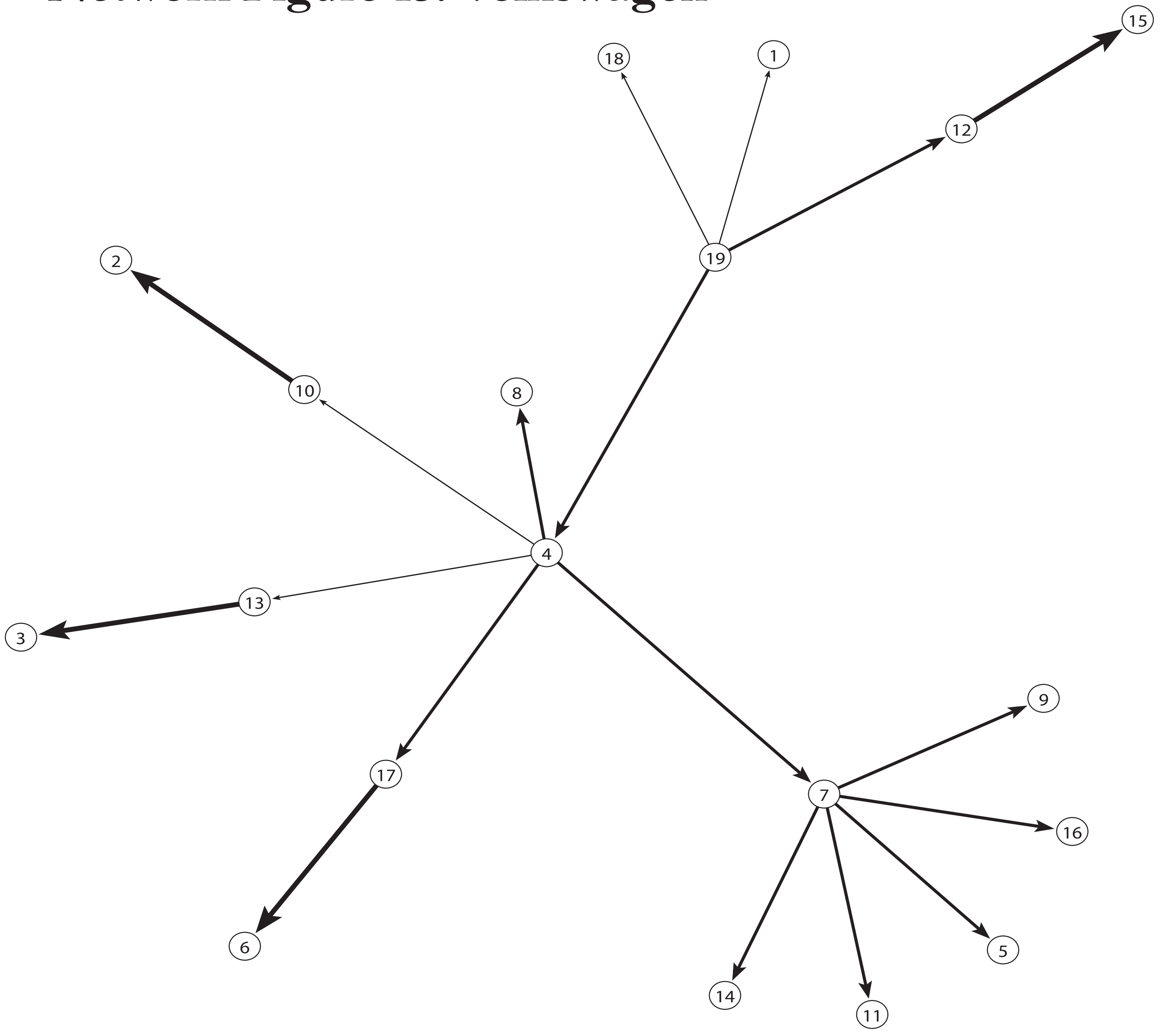


1 Blackstone Group L.P.
2 Bundesländer
3 Bundesrepublik Deutschland
4 Deutsche Telekom AG
5 KfW Bankengruppe

Capital Weights in %

[0,10)
[10,50)
[50,100]

Network Figure 15: Volkswagen



1 Brandes Investment Partners Inc.
2 Dr. Ferdinand Piëch
3 Dr. Hans-Michel Piëch
4 Dr. Ing. h.c. F. Porsche Aktiengesellschaft
5 Dr. Wolfgang Porsche
6 Familie Porsche
7 Familie Porsche Beteiligung GmbH
8 Familien Porsche-Daxer-Piëch Beteiligung GmbH
9 Ferdinand Alexander Porsche
10 Ferdinand Piëch GmbH
11 Gerhard Porsche
12 Hannoversche Beteiligungsgesellschaft mbH
13 Hans-Michel Piëch GmbH
14 Hans-Peter Porsche
15 Land Niedersachsen
16 Louise Daxer-Piëch
17 Porsche GmbH
18 The Capital Group Companies Inc.
19 Volkswagen Aktiengesellschaft

Capital Weights in %

[0,10) →
[10,50) →
[50,100] →

Chapter 4

DAX-Executive Remuneration and the Supervisory Board Network of Executives

Main Author: Jochen Möbert
Coauthors: Horst Entorf, Florian Gattung, Immanuel Pahlke

4.1 Introduction

What is an appropriate remuneration level of top managers? Is it justified that DAX-executives earn several million euros each year? Currently, this corporate governance topic is often discussed in Germany. On the one side high executive remuneration can be a result of surpassing company profits. On the other side they might represent the absence of control and the misuse of power. Often circumstantial evidence is available for both lines of arguments. Union representatives hint at the already high remuneration packages and regard them as unjustified. Executives may argue that the increases are a result of the positive economic development of their companies. Additionally, they also point to the large remuneration packages in Anglo-Saxon countries.

In recent years, executive remuneration of all DAX-companies rose continuously. Such changes in the executive pay need the approval of the supervisory board members. Many members of DAX-supervisory boards also hold executive positions of other DAX-companies. Hence, executives decide on the remuneration level of other executives.

In this contribution, the linkages of companies due to these executives being also members of supervisory boards at other companies are examined. In particular, the network resulting out of all personal linkages is shown for all DAX-companies. Subsequently, hypotheses are tested shedding some light on the relationship of executive remuneration and this social network of executives. This paper is also innovative regarding the application of panel regressions controlling for unobserved heterogeneity. However, before the data set is investigated a literature review is provided in Chapter 4.2. Chapter 4.3 establishes hypotheses and shows results of a descriptive analysis. Chapter 4.4 tests the hypotheses and contains the main findings. Chapter 4.5 concludes and provides proposals regarding amendments.

4.2 Executive Remuneration Literature

The corporate governance literature covering executive remuneration is fairly large and complex. This review is focussed on contributions examining the network of board members. Incidentally, other important non-network articles dealing with executive pay and the structures of management boards are quoted. The population for this review are articles examining the situation in Germany or the U.S. There are fundamental differences between the U.S. and the German corporate governance system. U.S. companies are governed by one entity such that a management board is a one-tier board. In contrast, a two-tier management board is enshrined in the German shareholder act. The executive board steers the company whereas the supervisory board is obliged to approve or veto executive proposals on important company decisions. Although the U.S. system is different, it is worthwhile to take into account the U.S. literature due to its extent and quality. Moreover, many questions which are debated in the U.S. literature might also be enlightening for the German system.

The articles being closest to ours are Larcker et al. (2005) and Guedj and Barnea (2007). Both articles examine whether board networks impact on executive remuneration. Larcker et al. (2005) study the impact of social networks on CEO remuneration by exploiting a huge cross-sectional data base of 22,074 directors and 3,114 U.S. firms. They find that director links between insiders and outsiders which are close to each other increase CEO remuneration. Guedj and Barnea (2007) use two-way fixed effect estimators since a large U.S. panel data set is analysed including

1500 S&P firms between 1996 and 2004. In accordance with Larcker et al., a significant impact of network statistics - similar measures are applied here - on executive remuneration is found.

The results of these studies reveal that indirect network effects might be important to understand economic outcomes. The study outset of most non-network studies makes it impossible to take indirect connections into account. This difference might explain the small impact of personal relationships on executive remuneration being found in non-network analyses. For instance, Hallock (1997, 1999) investigates CEO interlocks of 773 large U.S. firms in 1992. A small positive relationship between CEO interlocks and remuneration was found. The interlocks are only a small subset of the complete director network such that only a small effect of these sub-networks on executive remuneration is measured. Similarly, the analysis performed by Core, Holthausen and Larcker (1999) also reveals no strong influence of CEO interlocks on executive remuneration.

Miczaika and Witt (2004) use Pearson correlation coefficients to test whether executive remuneration is influenced by the number of personal interlocks among DAX and MDAX companies in 2002. No positive relationship was found. Other German studies using executive remuneration as dependent variable are Schmid (1997), Kaserer and Wagner (2004), among others. However, they are not focussed on network relationships, interlocks or other personal relationships. Hence, for the German corporate governance literature our work is a novel contribution.

From a methodological point of view, the network research in Germany is less developed than the U.S. literature on networks. However, for more than a decade a group of sociologists have performed descriptive analyses on German company networks. Accordingly, there are several interesting results regarding the development of supervisory board networks. Beyer (1996) shows the high interconnectedness of large German companies in 1992. Around 80% of all companies are directly or indirectly connected with each other. These figures are confirmed by Windolf and Nollert (2001). Banks and insurers exhibit most links and take up central positions in the German network. Heinze (2002) compares the network structure in 1989 with 2001 and finds structurally fairly stable networks. Kengelbach and Roos (2006) continue the research of Heinze (2002) and report an increasing number of network links from 2001 to 2004.

Table 4.1: Descriptive Statistics of Non-Network Variables

Variable	Year	Mean	Median	Std. Err.	Maximum	Minimum
AER	2001	1.16	1.08	0.55	2.94	0.20
	2003	1.47	1.29	0.72	3.73	0.62
	2005	1.77	1.64	0.67	3.83	0.90
EBT	2001	0.87	0.64	1.48	4.41	-2.50
	2003	0.97	0.72	1.61	5.54	-2.15
	2005	2.53	1.70	2.17	7.88	-1.92

Average executive renumeration (AER) is measured in Mio. euro und earnings before taxes (EBT) in billion euro. Executive renumeration in 2005 without chief executive officer. Data source: Executive renumeration: DSW, 2003, 2005, 2006. EBT is taken out of annual reports.

4.3 The Data Base

The analysis of executive remuneration and the network of supervisory board focuses on 30 companies being part of Germany's blue chip index DAX in 2003.[1] Companies such as 'Hypo Real Estate' and 'Deutsche Postbank' are not studied since they were listed in the stock exchange and the DAX after 2003. The panel data set investigated contains the network of executives and members of supervisory boards for the years 2001, 2003 and 2005.

Company Data
The dependent variable is the average executive remuneration - subsequently the acronym AER is used - of each DAX company in each year. AER of each company is the sum of total remuneration pay divided by the number of executive members of each company. The data source exploited is published by the German shareholder association[2].

Table 4.1 shows a continuous increase in AER. Mean and median as well as maximum and minimum rise by several hundred thousand euros whereas the standard deviation is nearly constant. Across the observation period the AER rises around 50% from 1.2 Mio. euros to 1.8 Mio. euros. Infineon and Commerzbank show the highest AER growth in the data set. In 2001, executives of Infineon had the lowest AER and quadrupled their remuneration pay whereas executives of Commerzbank also increased their remuneration level significantly within five years.

[1]Table A1 in the Appendix of this chapter contains the abbreviations of company names being used throughout the chapter.

[2]The official German name is 'Deutscher Schutzverband für Wertpapierbesitz e.V. (DSW)'.

Table 4.2: Number of Persons in the Management and Supervisory Board

Year	Persons	in Management Board	in Supervisory Board
2001	683	228	595
2003	712	219	641
2005	655	202	586

Data source: Annual reports of DAX-companies.

The German Corporate Governance Code[3] and the German shareholder association recommend performance-oriented remuneration systems. The goal of such a flexible remuneration system is the avoidance of rising AER when company profits or share prices are constant or even decline. Therefore, several profit variables such as earnings before interests and taxation (EBIT), earnings before taxes (EBT), annual surplus as well as the change in market capitalization are taken into account. The EBT variable exhibits the highest significance and robust results such that statistical figures center upon it. Table 4.1 shows that the AER as well as the EBT rise continuously. From 2001 to 2005 all descriptive statistical measures of EBT rise. A positive influence of company profits on the AER is expectable due to variable remuneration packages (cf. Winter 2002).

Finally, this subsection concludes by discussing the effect of a former CEO becoming chief of the supervisory board (CSB) in the same company. Höpner (2002) argues that this special replacement process comes along with higher executive earnings for large German companies. The binary variable CSBeCEO indicates companies where such a replacement process occurs and is introduced to test this hypothesis.

Network Analysis of DAX Supervisory Boards

The descriptive analysis is continued by describing the network of supervisory board links. A link is defined as a directed link if an executive of company A is a member of the supervisory board of company B. Accordingly, non-directed links can be defined if a non-executive of a DAX company is a member of two different DAX-supervisory boards (cf. Beyer and Höpner 2004). Our estimation results suggest that undirected links are not causal for the level of executive remuneration. Table 4.2 shows the number of persons being on the management board and supervisory board of all DAX companies.

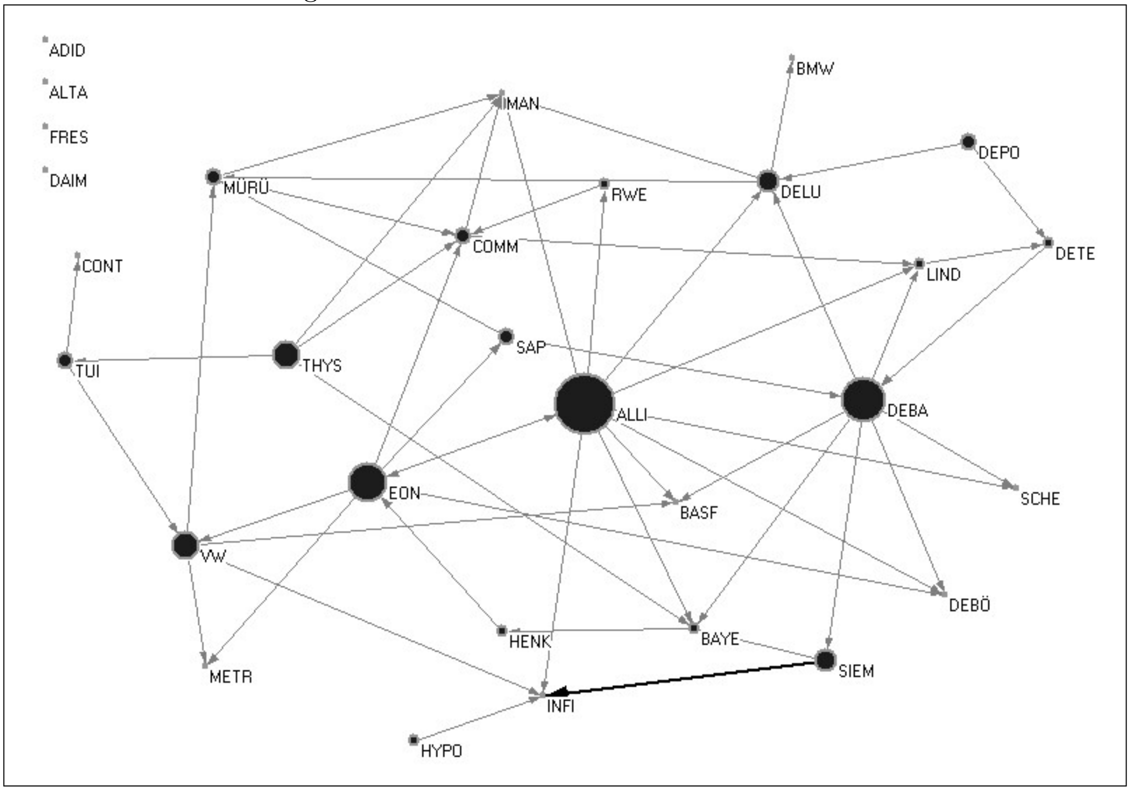
For each company two directed variables can be distinguished. The variable OutDegree counts the number of arcs emanating from a vertex and are directed towards a different company. Accordingly, the variable InDegree counts the number of arcs being directed towards the

[3] The official German name is “Deutscher Corporate Governance Kodex”.

considered vertex but emanates from different companies. In particular, financial companies have a large number of managers being supervisors in other companies. Höpner (2002) reports a strong influence of banks on industrial companies and interprets his finding as a weak monitoring via outsiders whereas insiders are active monitors.[4]

The InDegree and OutDegree variables are highly correlated with the indegree closeness-centrality and outdegree closeness-centrality. This fact rests on the small size of the network and the high network density of around 0.07.[5] Indegree and outdegree variables are only used as regressors in the panel analysis below because they are easier to interpret than the centrality measures.

Figure 4.1: Network of DAX Executives 2005



Own Source: Short forms of company names are explained in Table 4.7 in the Appendix. The network figure is drawn with Ucinet and Netdraw (cf. Borgatti et al. 2002).

[4]Cf. Höpner (2004) reports moderate monitoring levels of outsiders and a strong monitoring of insiders.

[5]The correlation coefficient is 0.8482 and 0.8383. The OutDegree Closeness-Centrality of person i is defined as $C_i = \frac{g-1}{\sum_{j=1}^{g} d(i,j)}$ where g is the number of actors in the network $d(i,j)$ is the number of links on the shortest path between company i and company j (cf. Wasserman and Faust 1994).

Table 4.3: Outdegree and Indegree in 2001 and 2005

Outdegree				Indegree			
Company	2001	2005	Company	Company	2001	2005	Company
ALLI	12	10	ALLI	MURE	8	5	INFI
DEBA	10	7	DEBA	INFI	6	5	MAN
SIEM	8	6	EON	MAN	5	4	COMM
HYPO	6	4	THYS	VW	4	4	BAYE
EON	4	4	VW	COMM	4	3	DELU
BASF	4	3	SIEM	DEBÖ	4	3	MURE
THYS	3	3	DELU	SIEM	3	3	LIND
DAIM	3	2	SAP	EON	3	3	BASF
VW	3	2	MURE	LIND	3	3	DEBÖ
RWE	2	2	COMM	ALLI	2	2	DEBA

Own Source: Short forms of company names are explained in Table 4.7 in the Appendix. Outdegree is the number of links emanating from a company. Indegree is the number of links being directed towards a company.

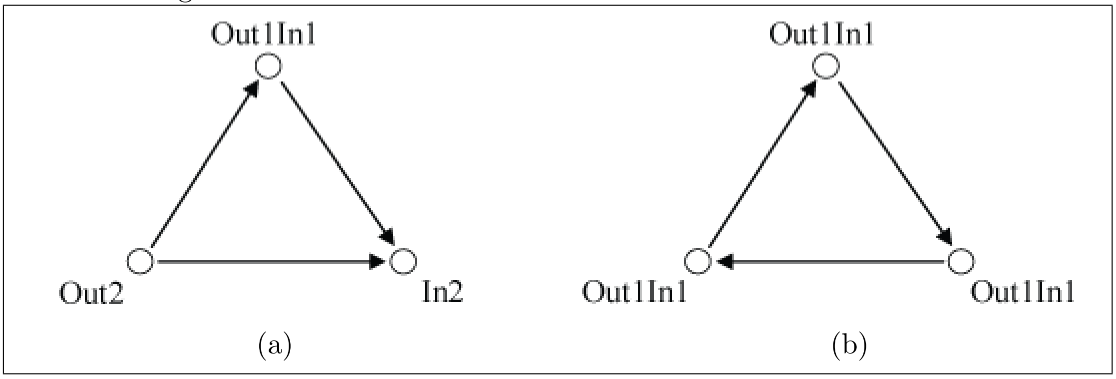
Figure 4.1 shows the directed network of interlocking DAX-directors. Network measures such as line width increase with the number of directed links between two companies and the size of the vertices depends on the number of outdegrees and indegrees. In 2005 adidas (ADID), Altana (ALTA), Daimler (DAIM) and Fresenius (FRES) were not interwoven with other DAX companies and are separated vertices in the network shown above.

Companies having a high closeness-centrality are often seen as powerful entities (cf. Windolf and Nollert 2001 and others). In this analysis, the centrality statistic and degree measure are quite similar such that companies having a high number of outdegrees could be interpreted as powerful. Accordingly, a company is influential if many executives are supervisors of other companies and have the possibility to exercise control. In contrast, companies having a high number of indegrees have many DAX-executives on that supervisory boards and might be tightly monitored. The top ten companies with the most outdegrees and indegrees are listed in Table 4.3. To emphasize the changes within the network, data from 2001 and 2005 is compared.

§100(2) No.3 AktG[6] prohibits reciprocal network links of executives and supervisory board members. However, transitive and cyclic network structures are feasible. They might be substitutes for reciprocal links and could impact on executive remuneration. If cyclic network structures exist as shown in 4.2b and supervisory board members might increase executive pay in

[6] AktG is the abbreviation of 'Aktiengesetz' - Germany's Companies Act.

Figure 4.2: Network Triads - Transitive and Circular Structures



Own Source: Three positions can be distinguished in transitive triads. Position 'Out2' has two outdegrees. Position 'Out1In1' has one outdegree and one indegree. Position 'In2' has two indegrees. In a circular triad each vertex has one outdegree and one indegree.

one company then the optionee might pass the favour on to a second executive and, eventually, the second executive would pass the favour on to the initiator such that all executives benefit from each other and increase their AER.

Also, transitive triplets as shown in Figure 4.2a might lead to rising executive remuneration. If AER rises in a company holding position 'Out2' then, subsequently executives of this company might favour higher executive pay in company 'In2' and 'Out1In1' and also 'Out1In1', then may agree to increase AER in company 'In2', too.

Table 4.4 shows how often companies take one of the three positions within the transitive triplets in 2001. The table points out that in particular financial companies such as HypoVereinsbank, Allianz and Deutsche Bank are often involved in transitive structures.

Table 4.4: Transitive Structures in 2001

Company	Out2	Company	Out1In1	Company	In2
HYPO	8	ALLI	4	MURE	9
ALLI	5	DEBA	1	MAN	6
DEBA	5	DELU	1	INFI	3
SIEM	3	ADID	0	LIND	2
DAIM	1	ALTA	0	ALLI	1
EON	1	BASF	0	BMW	1
ADID	0	BAYE	0	DEBÖ	1
ALTA	0	BMW	0	DELU	1
BASF	0	COMM	0	EON	1
BAYE	0	CONT	0	SIEM	1

Own Source: Short forms of companies are explained in Table 4.7 in the Appendix. The three positions 'Out2', 'Out1In1' and 'In2' within the transitive structures are shown in Figure 4.2.

4.4 Results

To investigate the factors impacting on executive remuneration, the dependent variable is regressed on company and network variables discussed before. The available data allows the application of panel methods. Accordingly, the regressions performed control for time constant unobserved heterogeneity which might include variables such as corporate culture or organisational structures. These unobserved variables may be highly correlated with observed factors such that fixed effects estimators are applied to avoid inconsistent estimators. Equation 4.1 describes the applied regression which contains company-specific variables and time effects

$$AER_{it} - \overline{AER}_i = \alpha + (C_{it} - \overline{C}_i)\beta + (N_{it} - \overline{N}_i)\gamma + (YD_t - \overline{YD})\delta + \varepsilon_{it} - \overline{\varepsilon}_i \qquad (4.1)$$

where AER_{it} is the average executive remuneration, α the constant, C_{it} a vector containing company variables and N_{it} a vector of network variables of company i at point in time t and YD_t is an indicator variable for year t. The bars indicate averages such that $\overline{AER}_i = \frac{1}{3}\sum_{t=01}^{05} AER_{it}$ and all other means are defined accordingly. The within estimator eliminates constant unobserved factors already mentioned. Hence, the influence of network variables on executive remuneration is separated from these variables such that the data generating process might be revealed.

Table 4.5 shows heteroscedasticity-robust estimation results. The intercept measures AER being unrelated to company profits and network variables. The coefficient of the intercept variable is rather robust and amounts to approximately 1.1 Mio. euros. The year variables YD03 and YD05 measure the corresponding mean across DAX-companies in 2003 and 2005. Accordingly, the average executive pay being independent of company profits and network effects of all DAX-executives rises by 0.3 Mio. euros and 0.5 Mio. euros in 2003 and 2005, relative to 2001.

Also, the coefficient of EBT is positive in accordance with our expectations. Ceteris paribus, executive remuneration increases by 80.000 euros if company profits rise by 1 billion euros. In contrast, the frequently debated variable CSBeCEO exhibits neither a significant nor a positive coefficient. Therefore, these results do not corroborate the hypothesis that companies where the former CEO is the current chief of the supervisory board suffer from a loss of control.

In specification (3) to (6), the influence of several network variables on executive pay is tested. In specification (3), the variables OutDegree and InDegree, i.e. the number of outdegrees and the number of indegrees of DAX companies are added as regressors. Even if a 10% significance level is applied the variables are insignificant. The non-significance may be driven by the small size of sample. The signs of both variables accord with findings in the literature. The results may represent important factors influencing executive remuneration. In particular, the variable OutDegree has a p-value of 13% and, therefore, is almost significant to the 10%-level. Accordingly, the following interpretation may be appropriate. If an executive of company A is also a member of the supervisory board of company B then the executive remuneration in company A rises. In the opposite case, the AER in company A is lower if the number of executives of other DAX companies rises in the supervisory board.

Specification (4) measures the effect of the difference between the variables OutDegree and InDegree. The new variable DifDegree is significant to the 10% significance level and the coefficient amounts to 0.049. This implies that if the difference between the number of executives being sent to and the number of executives being hired from other DAX-companies is one then AER increases by 49.000 euro. Correspondingly, the effect on AER multiples if the difference between the OutDegree and InDegree variable is larger than one.

The panel regression identifies significant variables such as DifDegree but the causality driving the effects is not immediately revealed. The remuneration of an executive is not affected if a position at a supervisory board of another company is accepted. The transitive and cyclic

Table 4.5: Results of Fixed Effects Estimation

Dependent variable: Average executive remuneration (AER) in Mio. euro

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Constant	1.098	1.110	1.028	1.094	1.090	1.028
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
YD03	0.302	0.311	0.300	0.301	0.293	0.343
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.000)
YD05	0.476	0.489	0.477	0.468	0.478	0.532
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EBT	0.076	0.077	0.082	0.081	0.075	0.077
	(0.099)	(0.099)	(0.078)	(0.070)	(0.113)	(0.074)
CSBeCEO		-0.056				
		(0.603)				
OutDegree			0.061			
			(0.130)			
InDegree			-0.031			
			(0.487)			
DifDegree				**0.049**		
				(0.057)		
Cycle					0.089	
					(0.326)	
TransOut2						**0.085**
						(0.014)
TransOut1In1						0.054
						(0.526)
TransIn2						-0.010
						(0.653)
#Obs	90	90	90	90	90	90
R^2(overall)	0.282	0.294	0.394	0.400	0.283	0.357
R^2(within)	0.491	0.493	0.520	0.518	0.497	0.543
R^2(betw)	0.326	0.353	0.360	0.381	0.323	0.345

Legend: p-values in parentheses. Variables significant at the 10%-level are in bold letters. YD0x=indicator variable being one for 200x, EBT=Earnings Before Taxation, CSBeCEO is an indicator variable being one if the former CEO is the current chief of the supervisory board (CSB) of the same company, OutDegree=number of executives of a considered company being a member of the supervisory board in another company, InDegree=number of members at the supervisory board of the considered company being executives at other DAX companies. DifDegree=OutDegree-InDegree, TransOut2=counts the number of transitive triplets of a DAX company in Position Out2. TransOut1Ini and TransIn2 are defined accordingly. #Obs=number of observations, R^2=explained variance relative to total variance.

network triads can shed some light on to the data generation process as discussed in the precedent chapter. The effect of these structures are investigated in specification (5) and (6). The variable Cycle counts the number of circular network triplets of each company (cf. Figure 4.2b). Due to specification (5) the number of cycles increases the AER, however, the coefficient of this variable is insignificant. Moreover, only a small number of circular network triplets are observed in the data set.

Specification (6) tests the influence of transitive network triads. The number of different network positions of each company within transitive triplets is counted by the variables TransOut2, TransOut1In1 and TransIn2. The variable TransOut2 implies that two executives[7] of that company are sent to two other companies within a triplet (cf. Figure 2a). The coefficient of this variable is highly significant. Due to our results such a network position seems fairly attractive. An additional transitive structure in the board network increases AER of the emanating company by 85.000 euro. The increased power of executives rises the remuneration significantly in comparison with companies exhibiting similarly observed as well as unobserved characteristics.

The descriptive data analysis in Chapter 4.3 reveals the numerous network links of financial companies. Therefore, the significant network variables of specification (4) and (6) are separated into variables of financial and non-financial companies. This procedure allows to check whether documented results are only spurious correlations due to the presence of financial companies. Banks and insurers often pay high executive remuneration and - without any causality - may also have a high number of seats on supervisory boards to push their business. Specifications (7) and (8) in Table 4.6 show the results of the fixed-effects estimation with the new variables where financial companies are separated from non-financial companies. The suffixes "Fin" and "Non" are used to distinguish both groups.

In accordance with specification (8), AER of financial companies increases by 114.000 euro, if a company holds position TransOut2 in a transitive triplet. However, also the AER of non-financial companies is affected by network variables. AER of non-financial companies rises by 66.000 euro if DifDegreeNon is one. This results suggest that the findings documented in Table 4.5 are not spurious since even the executive remuneration of non-financial companies is related to network effects.

[7] Alternatively, the same executive can be sent to two different companies.

Table 4.6: Financial vs. Non-Financial Companies

Dependent variable: AER in Mio. euros

Variable	(7)	(8)
Constant	1.047	1.041
	(0.000)	(0.000)
YD03	0.362	0.352
	(0.000)	(0.000)
YD05	0.516	0.517
	(0.000)	(0.000)
EBT	0.090	0.086
	(0.043)	(0.045)
DifDegreeFin	-0.028	
	(0.532)	
DifDegreeNon	**0.076**	**0.066**
	(0.057)	(0.059)
TransOut2Fin	**0.131**	**0.114**
	(0.000)	(0.000)
TransOut2Non	-0.056	
	(0.586)	
#Obs	90	90
R^2(overall)	0.400	0.412
R^2(within)	0.578	0.578
R^2(betw)	0.351	0.364

Legend: p-values in parentheses. Variables significant at the 10%-level are in bold letters. AER abbreviates 'average executive remuneration'. All variables are defined according to Table 4.5 whereas the suffix 'Fin' denotes financial companies and the suffix 'Non' denotes non-financial companies.

4.5 Conclusion

The analysis performed shows that with respect to average executive remuneration the executive network of DAX companies cannot be seen as a means of transferring control to executive boards and supervisory boards. Especially, there is evidence that companies with lower average executive remuneration have more executives of other DAX companies on their supervisory board. In contrast, not the controlled company but the controlling unit increases average executive remuneration. Executive remuneration rises significantly if an executive is also a supervisory board member on other DAX boards. A reasonable explanation might be that executives in a controlling position are well connected. Accordingly, they have excellent chances at the executive job market and may be able to realise higher earnings in salary negotiations. Alternative explanations could be a higher prestige as well as outstanding capabilities justifying high remuneration packages.

The results document that executives have high incentives to take on additional jobs at supervisory boards in different companies. Company profits higher than 1 billion euro increase - almost independently of the chosen specification - average executive remuneration by the same amount as an additional outdegree relationship or an additional transitive structure in the board network. In the light of this result, it is a debatable point whether incentives structures of executives are well specified. Put another way, the question arises whether executives are not sorely tempted to maximize their own remuneration whereas interests of stakeholders and shareholders are neglected. Network studies investigating the impact of supervisory board networks on firm perfomance often find that more connected executives run less profitable firms. The finding corroborates the business hypothesis stating that strongly connected directors are not able to successfully run their own company as well as to efficiently monitor other companies. The confirmation of this business hypothesis is documented for Dutch companies (cf. Non and Franses 2007), for large French companies (cf. Kramarz and Thesmar 2006), for German DAX companies (cf. Miczaika and Witt 2004, Prinz 2006) and for U.S. companies (cf. Core et al. 1999, Fich and Shivdasani 2006).

In Germany, the public as well as the academic discussion on reforming current law regarding the remuneration of executives could be refined in two key points. First, companies where a former CEO becomes chief of the supervisory board have no larger average executive remuneration than other companies. Accordingly, the interdiction of this process may be pointless. Second, the maximal number of supervisory boardseats of each executive should be restricted. As shown, strong financial incentives exist to take many positions on supervisory boards whereas neither an advantage for the sending nor for the receiving company may arise.

4.6 Appendix

Table 4.7: Full Company Names and their Abbreviations

Number	Name	Short Form
1	adidas AG	ADID
2	Allianz AG	ALLI
3	Altana AG	ALTA
4	BASF AG	BASF
5	Bayer AG	BAYE
6	BMW AG	BMW
7	Commerzbank AG	COMM
8	Continental AG	CONT
9	DaimerChrysler AG	DAIM
10	Deutsche Bank AG	DEBA
11	Deutsche Börse AG	DEBÖ
12	Deutsche Lufthansa AG	DELU
13	Deutsche Post AG	DEPO
14	Deutsche Telekom AG	DTAG
15	E.ON AG	EON
16	Fresenius Medical Care AG & Co KGaA	FRES
17	Henkel KGaA	HENK
18	HypoVereinsbank	HYPO
19	Infineon Technologies AG	INFI
20	Linde AG	LIND
21	MAN AG	MAN
22	METRO AG	METR
23	M¨unhener R¨uck AG	MÜRÜ
24	RWE AG	RWE
25	SAP AG	SAP
26	Schering AG	SCHE
27	Siemens AG	SIEM
28	ThyssenKrupp AG	THYS
29	TUI AG	TUI
30	Volkswagen AG	VW

Own Source.

Chapter 5

The Coauthor Network of the Deterrence Puzzle

Main Author: Jochen Möbert
Coauthor: Thomas Rupp

5.1 Introduction

One of the most intriguing questions in criminology and the economics of crime is under which circumstances deterrence variables are a practical instrument of policy to reduce criminal activities. Becker's application of the "expected utility theory" to the crime market takes into account measures such as the severity of punishment or a higher probability of being arrested (cf. Becker 1968). There are numerous empirical studies investigating the impact of these variables on delinquency. It is widely known that results vary with respect to economic and statistical significance. Such inconclusive results have existed for decades with the consequence that this controversial research problem could be called 'deterrence puzzle'.

The goal of this contribution is not to offer an innovative solution to this puzzle. Instead, the coauthor network of most researchers who contributed to this line of research is depicted and described. The network under study consists of vertices representing the authors and edges between these vertices representing research articles written by several authors (cf. Network Figure 1 to 7). Subsequently, we investigate the impact of author characteristics on sign and significance of deterrence variables. Therefore, the data set exploited and evaluation methods applied on it open up new vistas for the understanding of the criminological research market. This interdisciplinary market might also shed some light on incentives and behaviour of researchers in other academic fields.

The main contribution of this article is the measurement and evaluation of non-content related variables on research outcomes. A comparison of author-specific effects, market-specific effects as well as network effects is performed. The author-specific analysis measures the impact of previous studies on subsequent findings of researchers as well as the relationship between certain deterrence variables of each author. Market-specific inspections reveal how strongly authors' results are influenced by peer groups and network-specific variables contain information on whether research results are affected by the coauthor network of researchers. This work is also unique with respect to its historical dimension. The coauthor network encompasses researchers from more than three decades. To the best of our knowledge and that of Goyal, van der Leij, Moraga-González's (2006),[1] this coauthor analysis investigates the longest time span.

The large amount of data necessary to carry out the analysis is a spin-off from the research project "Metaanalysis of Empirical Studies on Deterrence"[2] , which surveyed relevant empirical contributions to the deterrence research. The project goal is to assess the actual and current situation of deterrence research. In a first step, scientific data base, such as ISI, Ingenta, Econlit, SSRN, RePEc among others, were examined in detail for contributions to the deterrence research. Other meta analyses and bibliographies of studies included in the data base were also used as source of references. Research articles tackling issues such as Index I and II[3] crimes have been selected from several thousand articles. The project team also selected articles which investigate tax evasion, environmental crimes, and violating requirements related to the deterrence research. The top five journals among the many in which articles were found were Criminology, Journal of Law and Economics, Law and Society Review, Applied Economics, and Accident Analysis and Prevention.[4] Finally, 491 studies, their results, methods and other variables are evaluated.

[1]Goyal et al. (2006) say that their study is the one which takes into account the longest period of time.

[2]This project is funded by the German Research Foundation (Deutsche Forschungsgemeinschaft - DFG).

[3]In the US often two crime indices are distinguished. The index I contains murder, assault, larceny, sexual offences, among others. The list of index II crimes often contains less grave offences such as narcotics, vandalism, fraud, among others.

[4]The publications contained in the meta data base are also taken from many other journals, e.g. Journal of Criminal Justice, Journal of Criminal Law and Criminology, American Economic Review, American Sociological Review, Journal of Research in Crime and Delinquency, Social Forces, Social Science Quarterly, Journal of Legal Studies, American Journal of Economics and Sociology, Review of Economics and Statistics, Social Problems, Economic Inquiry, Journal of Quantitative Criminology, Journal of Studies on Alcohol, Southern Economic Journal, International Review of Law and Economics, Journal of Public Economics, Crime and Delinquency, Journal of Behavioral Economics, and Journal of Political Economy, among others.

First analyses of this research project are documented in Dölling et al. (2006, 2007) and Rupp (2006).

Before the data is investigated, relevant contributions to the coauthor network literature are reviewed in Chapter 5.2. In Chapter 5.3 hypotheses investigated are introduced. In Chapter 5.4 the coauthor network is described and evaluated. The relationship between deterrence variables is analysed in Chapter 5.5 and Chapter 5.6 concludes.

5.2 Literature on Coauthor Networks

Scientometric work attracts a great deal of attention. For instance, articles on journal rankings or institutional rankings are among the most downloaded research articles (cf. Kalaitzidakis et al. 1999, 2003, Neary et al. 2003, Süssmuth et al. 2006, among others). In recent years, due to the increasing data availability research on coauthor networks seems to arouse similar interest. Such contributions on coauthor networks and, occasionally, other scientometric studies are reviewed here.

At the beginning of this century, several researchers started the investigation of coauthor networks. Newman (2001a, 2001b, 2001c, 2004) used network methods to compare the coauthor network of different disciplines such as physics, biology, computer science, and mathematics.[5] In all networks similar structures were found with respect to the power-law form of articles per author - also called Lotka's Law[6], authors per collaborators, the existence of the giant component, the small-world property, and others. But the networks differ with respect to certain other measures. For example, the average distance in a coauthor network of high-energy physicists is 4.0 while the same figure is 9.7 for computer scientists. This finding is probably caused by the high number of authors per article in high-energy physics – some papers are written by several hundred coauthors (cf. Newman 2001b) – which shrinks network distances.[7]

This observation poses the question what can we learn from the comparison of collaboration networks of different disciplines. Of course, the existence of some general characteristics found in many networks is interesting but this descriptive research ignores incentives and behaviour. Hence, it seems difficult that general advice can be given as a result of this line of research.

[5] In Newman (2001a, 2001b, 2001c) the same data set is used to compare the collaboration network of physicists, biologists, and computer scientists. In Newman (2004) coauthor networks in physics, biology, and mathematics are investigated.

[6] See Lotka (1926). For a recent historical update of this finding read Bremholm (2004).

[7] Cronin (2001) termed this phenomenon often found in high energy physics as 'hyper-authorship'.

The high-energy physicists face a totally different working environment than other scientists. An explanation for the findings is provided by Laband and Tollison (2000). They compared the formal and informal relationship among biologists and economists and showed that research articles in biology are written by more coauthors than articles by economists'. Biologists often name each member of a research team. Economists have, in turn, a larger number of informal intellectual collaboration than biologists. Hence, the research done by Newman and other physicists might only be the first step towards a more *social* network analysis where customs and goals of researcher are taken into account.

A network study similar to Newman's work was performed by Barabási et al. (2001). This research group take up a dynamic view which is often missed in the theoretical as well as empirical social network literature. They investigate how the coauthor networks of mathematicians and neuro-scientists developed through an eight year span. The main innovation of these authors is the development of a descriptive theory explaining the data. Moreover, they use parameters calculated from their data sets to perform a Monte-Carlo simulation. The simulation model replicates functional forms of many network characteristics. However, some observed values seem contradictory to the simulation results. For instance, the diameter is decreasing over time although the theoretical models imply an increasing diameter. The authors convincingly explained this artefact by the lack of a complete data set. In reality the development of the coauthor network among mathematicians and neuro-scientists started before the eight year time span investigated. The simulations performed confirm that the missing links among researchers before the first observation period may be causal for the discrepancy of observed and simulated data. Fortunately, we can hope that our work is unaffected by this problem since our data base is almost complete.

Coauthor data can also be analysed as a bipartite network where the set of authors and articles are two partitions and links are only formed between them. In bipartite networks the number of links to a paper represents the number of coauthors and number of links to an author count the number of articles written by each author. Börner et al. (2004) develop a model replicating the dynamic evolvement of network statistics which are found in a 20-year data set of PNAS.[8] PNAS contains approximately 45,120 articles and 105,915 working papers. The authors are particular interested in citation distributions and find that power laws are violated at the upper end of the distribution due to aging effects. Therefore the success-breeds-success effect,[9] which is often causal for the existence of power laws, shrinks since older articles are cited less, even if they are fairly important. New research generations probably take insights developed by antecedent scholars for granted and therefore stop citing them.

[8]PNAS is the abbreviation for 'Proceedings of the National Academy of Science of the United States of America'.

[9]This effect is also called Matthew effect or rich-get-richer effect.

Börner et al. (2004) focus on the development of citations and ignore the interaction of authors. Therefore, many network characteristics are not simulated. An improvement of this situation is performed by Goldstein, Morris, and Yen (2005), who investigate a sample containing 900 articles and 1354 authors taken from the Science Citation Index. They reproduce some scientometric variables by a theoretical model explaining the behavior of research groups instead of single authors. They argue that the success-breeds-success process is observable within each research group and also across research groups. The structure described and the functions used are able to mimic certain network characteristics such as the distribution of Lotka's Law and the clustering coefficient.

Some characteristics of the coauthor networks described so far are also found in economics data bases. Goyal et al. (2006) wrote the most influential economic research article on coauthor networks and showed that the coauthor network of economists has been developed from many small components in the 1970s to a small-world network. The existence of a small world is caused by interconnected stars who have short geodesic distances to each other and many coauthors who just have links to them. A very central feature of such interconnected star networks, which are illustrated by local networks of well-known researchers such as Dixit, Tirole and others, is the high importance of a few links relative to the set of all links of an author. The different importance of links was also observed in coauthor networks of physicists. Newman (2001b) together with Strogatz coined the term "funneling" which captures the observation that all geodesic paths from one author to all others in a network component typically go through a very small number of coauthors of each researcher. Intuitively, it seems reasonable that interconnected stars and the funneling property are mutually dependent.[10] The observations described suggest that deleting an interconnected star-author affects the complete network architecture. The giant component could shrink, the number of components could increase and the average distance might be significantly higher.[11] Goyal et al. (2006) explain the presence of interconnected stars using a theoretical model assuming productivity differences of researchers and increasing marginal costs to form links with respect to the number of coauthors. These considerations are confirmed in the sequel paper by Fafchamps, van der Leij, and Goyal (2006). Economists who exhibit differences with respect to the number and the quality of published articles are more likely to collaborate. They also find evidence for the existence of an acquaintance network encompassing the coauthor network of economists which is important for the formation of new collaboration links.

Digression: An interdisciplinary View on Coauthor Networks

Some stylized facts also imply that the whole global research industry is a small world, just

[10] A counter example for a no-funneling network is a regular one where the significance of each link is equally important and no author is central.

[11] This might explain the differences in average distance in different disciplines which are reported by Newman (2001b) and are mentioned above.

as each individual research discipline is. This statement is underpinned by the analysis of the collaboration network by Paul Erdös (1913-1996). He is one of the most important mathematicians and published more scientific articles than most researchers before him and it has been proved that he had more different coauthors than anyone else. As a matter of fact, Erdös had 509 coauthors during his life time. Goffman (1969) asked, "And what is your Erdös number?", thereby, stimulating further research on Erdös and his network. The Erdös number measures the geodesic distance between Erdös and any other direct or indirect coauthor. The Erdös number is one for researchers who were coauthors of Erdös, two for researchers who were coauthors of coauthors of Erdös whereas no direct link exists, and so on.[12]

A graph-theoretic analysis of the Erdös collaboration network was done by Batagelj and Mrvar (2000). The data base of the American Mathematical Society (MathSciNet)[13] is the basis for a more in-depth investigation. It contains mathematicians as well as researchers from many math-related disciplines and reveals that about 268K of approximately 401K researchers in the data base have a finite Erdös number. The distribution of the finite Erdös numbers is shown in Figure 5.1.[14] It shows that the majority of researchers are connected to Erdös via three to six lines in the global coauthor network. Moreover, many Nobel prize winners have low Erdös numbers. There are 50 physicists, 15 economists, 14 chemists, and also 5 physicians who won the Nobel prize and have finite Erdös numbers.[15] The mean average Erdös number for Nobel-prize winning physicists, economists, and chemists is between four and five while Nobel-prize winning physicians have a geodesic distance about seven. Hence, Erdös numbers of Nobel-prize winners are similar to Erdös numbers of the whole math community.[16] It is reasonable to assume that Nobel-prize winners are well connected within their own discipline, such that the Erdös number of many non-mathematicians is finite and small. These findings suggest that at least the math-related global research world is tightly interconnected.[17]

[12] If there is neither a direct nor an indirect link then the Erdös number is set to infinite.

[13] http://www.ams.org/msnmain/cgd/index.html

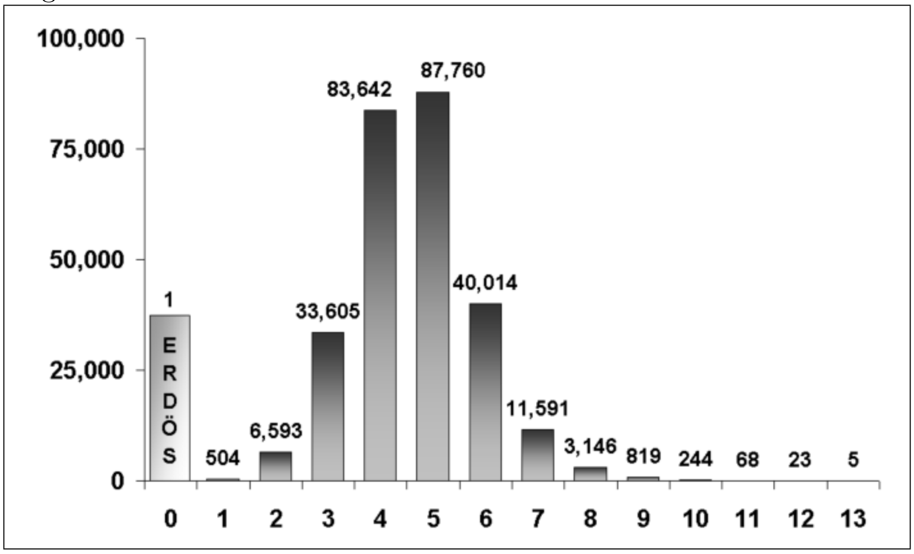
[14] Data source: http://www.oakland.edu/enp/trivia.html

[15] Downloaded on 10 March 2006

[16] Also, we have finite Erdös numbers: Rupp (7) and Moebert (7). The shortest path is Erdös-Moon-Sobel-Arrow-Nerlove-König-Entorf-Moebert+Rupp. Marc Nerlove (4) a coauthor of nobel-prize winner Kenneth J. Arrow contributed Montmarquette, Nerlove, Forest (1985) to the deterrence literature. In the Network Figures Nerlove has No. 473. Horst Entorf (6), a former doctoral student of Heinz König, our supervisor has No. 394.

[17] The data is gathered by the "Erdös Number Project" at the University of Oakland - see http://www.oakland.edu/enp/

Figure 5.1: The Distribution of Erdös Finite Numbers in MathSciNet



Own Source: The abscissa evaluates the Erdös number, i.e. the distance of the shortest path between Erdös and a researcher is shown. The ordinate counts the number of researchers. Notice, not all 509 directly linked coauthors are contained in the MathSciNet data base.

5.3 Hypotheses

Glaeser (2006) discusses incentives of researchers and biases in research findings resulting out of them. He challenges the naive assumption that economists are impartial analysts and argues "But while economists assiduously apply incentive theory to the outside world, we use research methods that rely on the assumption that social scientists are saintly automatons." Dismissing the assumption of objective researchers introduces discretionary power which might be misused by researchers and could lead to 'initiative biases'.

There is only a small number of theoretical work tackling the incentives of econometricians. However, empirical evidence corroborating the existence of those biases is not available. The deterrence research as well as the unique data set constructed might be well-suited to test whether these biases exist. The deterrence puzzle is unsolved for decades and still today a full understanding of contradictory research results is out of reach. Hence, the discretionary power of researchers delving into the deterrence matter might be large such that the potential for 'initiative biases' could be high.

To derive testable hypotheses it is assumed that researchers are objective observers striving for discovering true casual relationships. Therefore, the main hypothesis is: "Research findings are independent of any other influences." This independence assumption is operationalized in different ways. The structure of the available data set allows to test the presence of three different types of hypotheses being denoted author-specific, market-specific as well as network-specific type.

First, the author-specific type is discussed. Researchers might have incentives to confirm the results of their previous findings. Successful research careers often depend on the construction of reputation. Hence, trying to publish papers with contradictory results might be counterproductive with respect to the promotion of career opportunities of researchers. Second, researchers might also be inclined to favor findings being in accord with the prevailing opinion among leading researchers. Otherwise, the probability to publish in peer-reviewed journals might be reduced due to referees which emphasize adverse arguments and prefer contributions confirming their own findings. Third, researchers might be influenced by their research network they are embedded in. Especially, co-authors may influence each other. However, also indirectly connected researchers might impact on research results of authors such that also network-specific effects might bias research output.

Due to this deliberations the arguments are operationalized via the following five hypotheses. Author-specific hypotheses assume that research results regarding different crime categories are independent of each other (Hypothesis 1). Moreover, it is assumed that the research results in earlier studies are not related to the same variables in later studies (Hypothesis 2). Market-specific effects are tested via the following hypothesis. Research results are independent of results of other researchers in the same point of time. This statement is tested for all deterrence researchers as well as for specific disciplines (Hypothesis 3). Finally, the network approach enables us to test that authors are not influenced by their network they are embedded in. Neither research results of authors being part of the same network component (Hypothesis 4) nor research results of indirectly connected researchers are related to the findings of the author (Hypothesis 5). All hypotheses are summarized before the inductive analysis in Table 5.5.

5.4 Descriptive Analysis of the Meta Data Base

Our database contains 623 authors and 491 research articles.[18] All articles surveyed are empirical studies and their results and characteristics are used to construct author-specific variables.

5.4.1 Network Characteristics

The Coauthor Network, its Components, and Important Coauthors
To capture the dynamics of the coauthor network we calculated descriptive network statistics shown in Table 5.1 for 1976, 1986, 1996, and 2006. The data is accumulated such that younger networks contain older ones. All four networks are depicted in Network Figure 1 to 4. The 2006-network contains all authors who contributed to the deterrence issue. It consists of 623 vertices, where each vertex represents an author and between these vertices 664 undirected non-multiple research links are formed.[19] Each link represents either a loop if a researcher has written a single-authored article or an edge if two researchers are coauthors.[20] A link between two vertices is established if at least two coauthors wrote at least one single research article.[21] In the 2006-network the number of all single-authored articles (loops) amounted to 145. Therefore, in recent decades a stronger tendency towards coauthored work is observable. The share of single-authored paper to all links declined from 0.464 in the period until 1976 to 0.174 in 2006.[22] Due to the accumulation of networks this indicates that single-authored contributions have been unlikely in the last few years. Hollis (2001) shows that the increased tendency towards collaboration among economists might be favourable with respect to the length and the quality

[18] Meanwhile, the meta data base of the project "Metaanalysis of Empirical Studies on Deterrence" (the German title is "Metaanalyse empirischer Abschreckungsstudien - ein quantitativer methodenkritischer Vergleich kriminologischer und ökonomischer Untersuchungen zur negativen Generalprävention") increased to exactly 700 studies. In the majority of cases we collected data from English written research articles since English search words have been used. However, the author set includes researchers from many different countries.

[19] Yoshikane et al. (2006), in a study on computer scientists, built a "directed graph where links are oriented from coauthors to the first author of each article." However, due to the alphabetical order in economic journals the identification of the first author and second author cannot be distinguished.

[20] Of course, many researchers have written more than one article with the same coauthors. The multiple-link 2006-network consists of 195 loops and 641 edges. However, the analysis of the multiple network is not continued here.

[21] Note that the number of links increase exponentially to the number of authors involved in writing an article. For instance, four authors writing a joint research paper produce six edges and if eight researchers collaborate 28 edges are formed.

[22] A similar decline is reported for many other disciplines (cf. Clarke 1964, Heffner 1981, Glänzel and Schubert 2004, among others). Beaver and Rosen (1978) developed a theory of scientific collaboration and used it for a long-term historical analysis of research success of large European nations. They conclude that French researchers where much more productive than English or German ones due to their collaboration networks, while English and German scientists preferred stand-alone research.

Table 5.1: Descriptive Network Statistics

	1976	1986	1996	2006
Vertices	68	205	392	623
Links	56	206	405	664
Edges	30	136	305	519
Loops	26	70	100	145
#A Giant Component	4	7	16	16
Density 10^{-2}	3.16	1.46	0.86	0.57
Components	42	108	182	275
#5-Components	0	8	13	19
#9-Components	0	0	3	7
#13-Components	0	0	1	2

Note: Measures are based on non-multiple network formation. 'Loops' count the number of single-authored papers and 'Edges' the number of links formed through coauthored research. '#A Giant Component' counts the number of authors who are in the largest network component. 'Density' measures the number of available edges relative to all possible edges. 'Components' count the number of disconnected network components and '#x-Component' counts the number of disconnected components which contain at least x researchers.

of research articles, whereas it lowers the number of articles by each researcher if each article is weighted with the number of authors. Sutter and Kocher (2004) confirm Hollis' (2001) results with respect to the quality of articles.

The number of authors and links grew steadily through the decades. Yet, the network density decreases because the number of possible links grows even faster. Due to the low network density, several network components exist and it seems reasonable to call it "a collection of islands" (cf. Goyal et al. 2006 who coined this term). Hence, the deterrence network might have similar characteristics than the global 1970-coauthor network of economists.[23]

Table 5.2 shows the most central players measured by the degree of each vertex[24] for each of the four sub-networks. The degree has increased among the top twenty authors from decade to decade. Unsurprisingly, well-known researchers such as *Ehrlich*, *Witte*, *Saltzman*, and others are among the most central players. For instance, there are eight articles by *Ehrlich* in our data base and six of them are single-authored research articles.[25] This shows that he prefers stand-alone research and, consequently, is only losely connected to others. The other extreme

[23] A collection of islands was also observed by Gossart and Özman (2007), who study the coauthor network of Turkish social scientists and arts scholars.

[24] The degree of a vertex is defined by the number edges emanating from it.

[25] In Table 5.2 only seven are mentioned in the 1996-network. Of course, Ehrlich and Zhiqiang (1999) was written beyond 1996. In the 2006-network he is no longer among top central researchers.

is observable in the 2006-network. *Mann*, *Vingilis*, *Smart*, *Stoduto*, *Beirness*, *Lamble*, and *Adlaf* are among the top twenty central authors in Table 5.2. These researchers have a large degree due to multi-authored work where eight researchers (cf. also Network Figure 7) have contributed to Mann et al. (2003). This reveals a shortcoming of the Network Figures because it is impossible to distinguish whether a link is the result of research done by two or more than two researchers. However, in the descriptive analysis the term 'main authors' is defined to avoid multi-counting.

Instead of focussing on the top authors, the full distribution of the 2006-nework is shown in Figure 5.2(a). Most researchers have only a small number of coauthors, whereas very few of those reported in Table 5.2 have a large number. In Subfigure (b) only 'main authors' are defined as the one or two researchers of each article who bore the burden of work. The definition of this term is only important for multi-authored articles where more than two researchers are involved.[26] Obviously, the distribution in Subfigure (b) is less volatile and the highest number of main coauthors is much smaller than the number of all coauthors in Subfigure (a). For the interpretation of these figures it is important to note that axes are in logarithmic scale such that the nearly straight lines indicate a power law distribution. These heavy-tail distributions are recurrently observed in the network science.[27]

Another interesting feature of a network study is the investigation of network components instead of the whole market or the individual author-specific characteristics. Components are chosen which contain well-known researchers and are also interesting from a topological point of view. For example, *Levitt's* component is very centralized, the *Mann*-component has a high cluster coefficient, and the *Bailey*-component is the largest network component and consists of many directly and indirectly connected coauthors. All three networks are depicted in Network Figure 5 to 7.

Levitt has written twelve articles tackling the deterrence issue. Seven articles are single-authored, four articles are written by him and a further researcher, and, of course, three collaborators wrote *Katz*, *Levitt*, *Shustorovich* (2003). Given our data set, all coauthors of *Levitt*, except *Lochner*, who also wrote three single-authored articles, have not contributed to the literature without *Levitt* himself. Hence, the link between *Katz* and *Shustorovich* is the only existing direct link between his coauthors. Due to this structure, we can conclude that Levitt is the (center of a) star of his network component.

The sociologist *Bailey* has written four coauthored and seven single-authored articles. In his component - which is the largest component in each decade (cf. Table 5.1) - he has written

[26] For a detailed definition of the term 'main authors' see the discussion below.
[27] Cf. Barabasi and Albert (1999), among many others.

more articles than any other researcher. Hence, he has a centrality similar to *Levitt* in Network Figure 5. However, in the *Bailey*-component there are other researchers such as *Burkett*, *Gray*, and *Ward*, who also extensively contributed to the deterrence literature. *Bailey* and the other sociologists mentioned are cut-vertices such that the removal of one of them would split the *Bailey*-component into two separated components. Therefore, these researchers take up central positions. Another difference between *Levitt's* and *Bailey's* network is the publication period. All articles by *Levitt* were published in the last decade. However, the last research contributions of authors contained in the *Bailey*-component were produced by *Jensen* and *Metsger* (1994) and *Bailey* (1998). Therefore, both network components mainly describe different periods. This observation is also underpinned by the fact that *Levitt* was two years old when the first paper of the *Bailey*-component was published by *Gray* and *Martin* (1969).

The last component explored is that of the sociologist *Mann*. It is special because most contributions are written by several researchers (as mentioned up to eight authors are involved). *Mann* was involved in the production of all articles in his component. However, he might be not as central as *Levitt* or *Bailey* because such multi-authored articles may express the high degree of communication among researchers. Hence, other important researchers in this component are *Vingilis* who coauthored four articles and *Smart* who contributed to three articles. The high interconnectedness in the *Mann*-component is also underpinned by its high cluster coefficient of 0.8.

A reason for the different network components of *Levitt* and *Bailey* on the one hand and *Mann* on the other might be differences in productivity differences (cf. Goyal et al. 2006). The observed star formations could be caused by high productivity differences between the central and the peripheral co-workers. Probably, the difference between *Mann* and his collaborators is less distinct than productivity differences in *Levitt's* component. Another possible explanation is the existence of different research customs as shown by Laband and Tollison (2000). Possibly, different customs of disciplines contributing to the deterrence research also exist.

5.4.2 Meta Analysis on Empirical Deterrence Studies

Before the data set is described, some data problems and their solutions are addressed. Most non-network variables in our data base capture features of the studies investigated. These variables describe the deterrence variables such as probability of detection and severity of punishment, whether the data of each study is obtained through experiments, the number of pages, and many others. Since our goal is to investigate the findings and the behaviour of researchers as well as the interdependencies among researchers, we have to condense the variable-related information to author-related variables.[28] As shown in Network Figure 7 some research articles are written by several coauthors. Hence, switching from the variable-level to the author-level can lead to spurious statistical results. If each author is weighted equally, then all variables are allocated to each author and the findings of coauthored or multi-authored articles therefore lead to double or multi-counting.

To avoid multi-counting we define 'main authors'. In many disciplines such as sociology, the authors who are mentioned first have contributed a larger part than the subsequently named coauthors. Accordingly, we define the first two authors of each article as the 'main authors' and set their weight to one. If more than two coauthors wrote an article the later mentioned coauthors were allocated zero weights. In economic journals researchers are mostly mentioned in alphabetical order[29] such that the main authors are not identified by this definition.[30] However and fortunately, most economic articles are written by one or two researchers and, therefore, the procedure seems reasonable.[31]

Another important aspect in managing our data set is the time dimension. The inclusion of the publication year in the data base opens up additional estimation strategies. In the inductive part in Chapter 5.5, we will test how the results of previous studies impact upon the findings in later studies of each author. Similarly, we can estimate how the findings of an author in a given year are influenced by his reference group. To tackle these issues, the time dimension is exploited. However, to keep the amount of data tractable and to increase the number of non-missing observations, the data is summarized to twelve 'observation periods' which are named 1973, 1976, 1979,..., 2000, 2003, and 2006. The observation 1973 summarizes all studies which are written in 1973 or before and all other observation periods summarize the current and two precedent years, e.g. the observation 2000 includes for each author all studies published in 1998, 1999, and 2000.[32]

[28] Notice variable-related, study-related, and author-related variables are distinguished.

[29] That alphabetical ordering influences academic success is shown by Einav and Yariv (2006). Laband and Tollison (2006) find that alphabetised coauthorship is cited more often than non-alphabetised.

[30] We have chosen not to allocate each study variable to the first-mentioned author only. If an economic article has two authors, it is not easily possible to identify the more important one in the data base. Moreover, the double-counting of variables seems not overly important and might produce only minor statistical imperfections.

[31] Newman (2001a,b,c) reports the same problem in his studies. Moreover, he mentioned that authors were not always identifiable because some authors had the same names (homonym) and in different articles of the same authors different initials were used (journal rules). The homonym problem decreases the number of authors, whereas the journal-rule problem increases it. Due to both problems, the analysed network may differ from the original coauthor network. In our data set both problems are solved. Moreover, the data preparation techniques used to perform a network analysis automatically involves double-checking of the data and is helpful in improving the quality of data sets.

[32] In the rest of this article we use the term 'observation period' to refer to these timeframes.

Deterrence Variables

Existence of the Deterrence Puzzle
Before the data is described, the existence of the deterrence puzzle is documented. Table 5.3 shows the findings of all studies in our sample which try to explain the deterrence puzzle. The variable-related estimates of the standard deterrence measures 'probability of detection' and 'severity of punishment' (subsequently, called probability-measures and severity-measure) is available for three categories of crime '(Violent) Crimes against the person', 'Crime against property' (subsequently, called violence-category and property-category), and a third category called 'others' which contains anything that cannot be allocated to one of the categories mentioned. Offences such as murder, rape, and assault belongs to the violence category, robbery[33], burglary, and larceny belong to the property-category, and driving under the influence, ecological crimes, and tax fraud, for example, are classed as 'other Crimes'. Table 5.3 shows that for each of the two deterrence variables and each of the three categories five possible values ranging from 'Becker's theory is (1) wholly applicable, (2) partly applicable, (3) neutral, (4) more inapplicable, to (5) wholly inapplicable' are defined. The interdisciplinary researchers of this meta analysis selected several criteria such that the status of each article was classifiable in the data base (for details cf. Rupp 2008).

Table 5.3 documents how often the rational choice theory is confirmed and rejected. For each of the six variables #Obs indicates how often the corresponding variables have been tested in the sample. Obviously, the probability-variable was tested more often than the severity-variable and the probability-variable confirms the implications of the expected utility theory more often than the severity-variable. However, the deterrence puzzle is present for each of the six variables.

The existence of the puzzle is also corroborated by considering the time dimension. For this purpose, the following steps were conducted. First, and based on the information in Table 5.3, a study-related variable was computed by averaging all six[34] variable-related information of each study. Second, all studies by each author within a given year are averaged. Third, findings are summed up across all authors for each year. In Subfigure 5.3(a) the historical development of this variable is shown and the number of confirmations and refutals of Becker's theory is indicated.

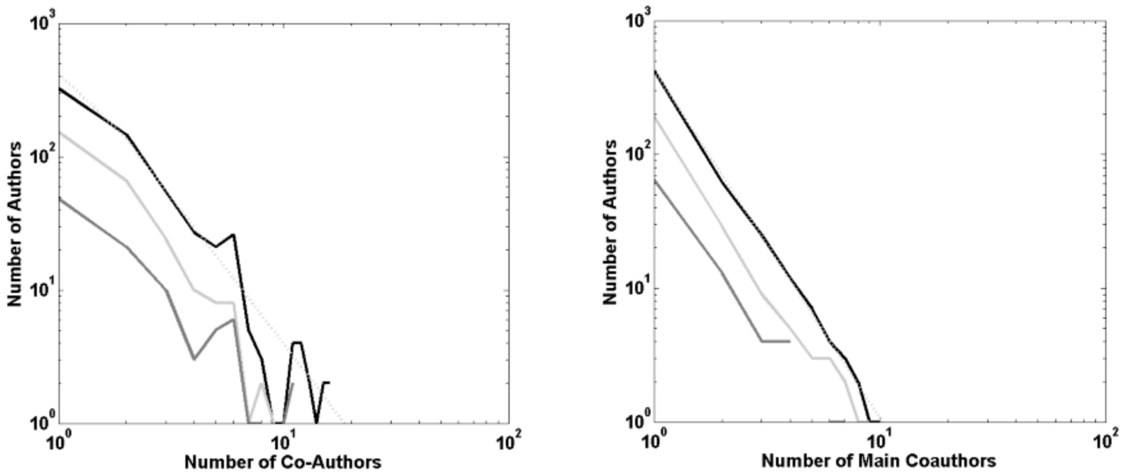
Economists' interest in the empirical assessment of deterrence was mainly laid down by Ehrlich's (1973) work. Before his seminal contribution only a few articles were published

[33]Sometimes robbery also belongs to the property-category.
[34]Two rational choice variables, the probability of detection and severity of punishment, are available for three crime categories.

Table 5.2: Top20 Researchers with respect to Degree(Loops) after 4 Decades (upper half)
Figure 5.2: Number of Authors vs. Number of Coauthors (lower half)

1976		1986		1996		2006	
Bailey Wil	4(0)	Chiricos The	16(0)	Patern. Ray	18(1)	*Mann Rob*	22(0)
Ehrlich Isa	3(3)	Waldo Gor	16(0)	Chiricos The	16(0)	Vingilis Eve	20(0)
Gray Lou	3(0)	Patern. Ray	13(0)	Waldo Gor	16(0)	Patern. Ray	18(1)
Ross Lau	3(1)	*Saltzman Lin*	12(0)	*Saltzman Lin*	12(0)	Chiricos The	16(0)
Campbell Don	3(1)	*Gray Lou*	9(0)	Grasmick Har	11(0)	Waldo Gor	16(0)
Glass Gen	3(1)	*Bailey Wil*	8(5)	*Gray Lou*	10(0)	Benson Bru	15(0)
Tittle Cha	3(2)	Hakim Sim	7(1)	*Bailey Wil*	10(6)	Rasmussen Dav	15(0)
Martin Dav	3(0)	*Ehrlich Isa*	6(6)	Hakim Sim	9(1)	Smart Reg	14(0)
Logan Cha	2(2)	Erickson May	6(0)	Ross Lau	8(2)	Hakim Sim	13(1)
Chiricos The	2(0)	Gibbs Jac	6(0)	Cloninger Dal	8(6)	*Levitt Ste*	13(7)
Waldo Gor	2(0)	Stafford Mar	6(0)	Alm Jam	8(0)	*Saltzman Lin*	12(0)
Teevan Jam	2(2)	Menke Ben	6(0)	*Ehrlich Isa*	7(6)	Stoduto Gin	12(0)
Swimmer Eug	2(2)	*Ward Dav*	6(0)	*Ward Dav*	7(0)	Beirness Dou	12(0)
Antunes Geo	2(0)	Votey Har	5(3)	Kaulitzki Rei	7(0)	Lamble Rob	12(0)
Hunt A.	2(0)	Jensen Gar	5(1)	Schumann Kar	7(0)	Grasmick Har	11(0)
Greenwood Mic	2(0)	Grasmick Har	5(0)	Stafford Mar	6(0)	*Bailey Wil*	11(7)
Wadycki Wal	2(0)	Kirchner Rob	5(0)	Menke Ben	6(0)	Sloan Fra	11(0)
Chambers Lar	2(0)	Schnelle Joh	5(0)	*Witte Ann*	6(1)	Adlaf Edw	11(0)
Roberts Rob	2(0)	Domash Mic	5(0)	*Mann Rob*	6(0)	*Gray Lou*	10(0)
Voelker Cam	2(0)	Larson Lyn	5(0)	Bursik Rob	6(0)	Cloninger Dal	9(6)

Own Source: The degree-centrality counts the number of loops and edges of each researcher in Network Figure 1 to 4. Loops are single-authored articles. 'Paternoster' is abbreviated to save space. In the case of 'Hunt A.', only the first letter of the first name is available. Italic written researchers are mentioned in the text.



(a) All Edges of the 2006-Network

(b) Main Edges of the 2006-Network

Sociologists — Economists — All — Simulation

Own Source: Log-Log-Specification. The dashed line shows a power law function $f(x) = x^{-\gamma}$. In Subfigure (a) $\gamma = 2.2$ whereas in Subfigure (b) the exponent is $\gamma = 2.6$.

Table 5.3: Two Deterrence Variables vs. Three Crime Categories

			V A R I A B L E		
	Confirmation of deterrence hypothesis	**in %**	Probability of being arrested *DETp*	Severity of Punishment *DETs*	Sum of #Obs
	(Violent) Crimes	(1)	**26.7**	**20.7**	128
C	against the	(2)	**24.8**	**22.8**	126
	Person	(3)	**18.2**	**24.9**	108
A	*DET_V*	(4)	**18.5**	**20.2**	100
		(5)	**11.8**	**11.4**	61
T	#Obs		330	193	523
	Crimes against	(1)	**35.5**	**16.9**	166
E	the Property	(2)	**26.1**	**17.5**	131
	DET_P	(3)	**10.3**	**23.0**	81
G		(4)	**18.4**	**29.5**	124
		(5)	**9.7**	**13.1**	61
O	#Obs		380	183	563
	Other Crimes	(1)	**18.8**	**7.6**	79
R		(2)	**31.8**	**32.3**	185
		(3)	**16.6**	**20.5**	106
Y		(4)	**21.3**	**22.1**	125
		(5)	**11.5**	**17.5**	82
	#Obs		314	263	577
	Sum of #Obs		1024	639	1663

Note: The scale means 'Becker's theory is (1) wholly applicable, (2) partly applicable, (3) neutral, (4) more inapplicable, (5) wholly inapplicable'. The researchers of the meta analysis selected several criteria such that the status of each article was assignable in the data base. #Obs indicates the number of estimated values of all evaluated studies of each author in our sample. Sum of #Obs adds up the number of observations across variables, categories, or both. Overall our results are based on an upper limit of 1663 estimates. Variable names DET_V, DET_P, DETp, and DETs are used on in the analysis later.

(cf. Figure 5.3b).[35] Subsequently, the number of involved researchers mostly increased in time, but was interfered by some erratic short-term fluctuations. In the recent past, at the turn of the millennium a high number of authors who wrote research articles is observed. In 2004 and 2005 – in the last observation period – a reduced number of estimates is included. This is a statistical artefact owing to the fact that the choice of sources and articles took place at the project outset in 2004. Accordingly, the data base might be incomplete in the last years. Regarding the existence of the deterrence puzzle, there is no year or time span in which the theory is clearly confirmed or rejected. Therefore, we can argue that the deterrence puzzle is continuously observable across the whole sample.

16 Deterrence Variables
Table 5.3 is the basis for the derivation of several deterrence variables which are used to test the hypotheses constructed in Chapter 5.3. An important variable is DET_mean indicating the findings of each author with respect to Becker's theory. First, to calculate this variable, the variable-related information was averaged to study-related variable. Second, the study-related variable of an author is summarized for each observation period and then averaged to an author-related variable. The computation of DET_1own is similar. Instead of all articles, only the first observation period in our sample of each author is considered to calculate the average of all study-related variables.

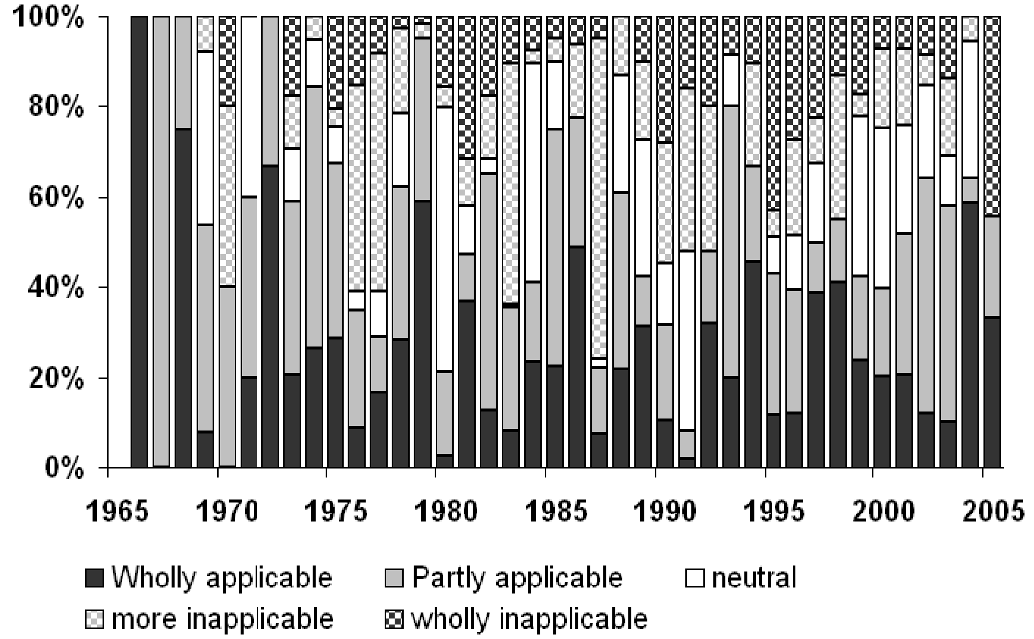
The categorical variables DET_V and DET_P as well as deterrence variables DETs, and DETp were calculated in the same way. Except in the first step, the probability and severity variable of the violence-category were taken into account for the calculation of DET_V whereas the probability and severity variable of the property-category were used for DET_P. These variables allow us to test Hypothesis 1. The confirmation or refutal of Becker's theory with respect to one variable is not related to the other variable.

DETp and DETs are the averages of the probability and severity variables across all three crime categories. These variables are used to calculate the variables DETp_t1, DETp_t2, DETs_t1, and DETs_t2, where t1 and t2 abbreviate different observations periods. DETp_t1 and DETs_t1 were specified as the arithmetical mean of all but the last observation period for each author and DETp_t2 and DETs_t2 is the value of the last available observation period of each author. These variables allow us to test Hypotheses 2 that deterrence variables in previously performed studies are not related to deterrence variables in articles published later.

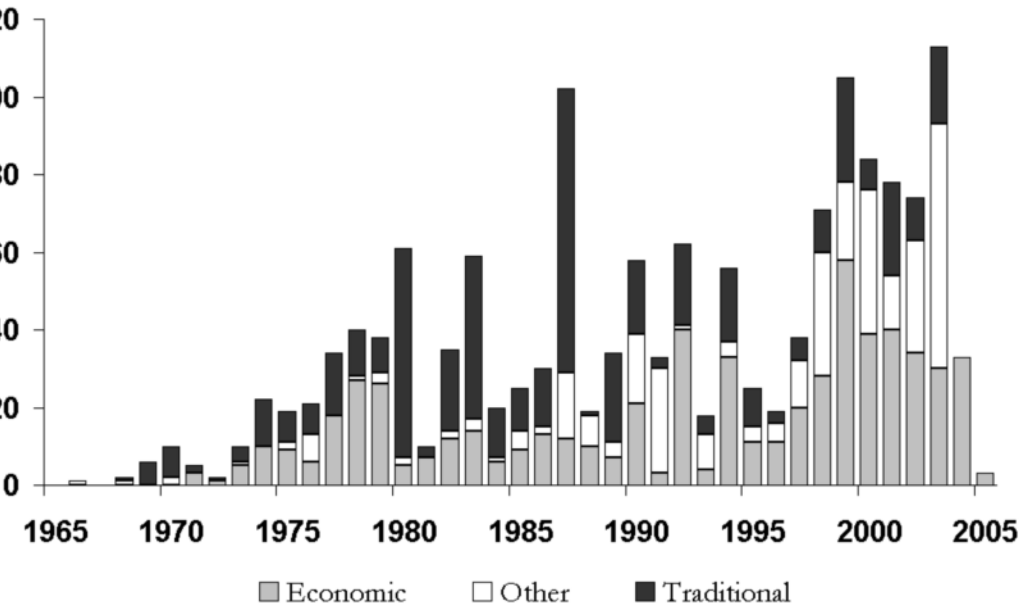
DET_mean is also used to compute scientific market variables. For each author the variable DET_mean_t is specified where study-related findings are not averaged across all studies but only across studies within the same observation period. Subsequently, the market variable DET_m1p_{ti} of author i is the average of all DET_mean_{tj} values of all other authors $j \neq i$ of the same discipline author i belongs to and finally, for each author the average across all observation periods t is taken to get DET_m1p_i. DET_m1p is used to test its influence on DET_mean. Researchers who

[35]The oldest study in our sample, written by Karl F. Schuessler (1952), is not shown in Figure 5.3.

Figure 5.3: Chronological Analysis of Variables



(a) Refusal and Confirmation of Becker's Theory



(b) Tested Theories – Traditional vs. Economic Approach

Own Source: Chronological Analysis of Deterrence Variables and tested Theories. Abscissas show the year and the ordinates the fraction of articles refuting or confirming the deterrence hypothesis (Figure a) or the absolute number of articles testing a specific theory (Figure b) within each year. The oldest study in our sample written by Karl F. Schuessler (1952) is not shown in Figure 5.3.

want to discover the structure of societies we are living in should be interested in the quality of an article but not its results. Hence, this variable tests Hypothesis 3 whether individual results of researchers are independent of its peer group.

DET_m1p of an economist (sociologist) is the average of all other economist's (sociologist's) DET_mean variable in the same observation period. The DET_m1p variable contains all disciplines. To distinguish certain disciplines DET_m1p*eco* contains only economists and DET_m1p*scl* contains only sociologists, criminologists, and law researcher. In addition, the variable DET_m3p was also specified, which takes into account three instead of one observation period for the construction of DET_mean$_t$. However, the distributions of DET_m3p and DET_m1p are very similar and both variables are nearly perfectly correlated such that the evaluation of DET_m3p is not continued.

The Pearson correlation between DET_m1p and DET_mean is 0.27. This is a rather small correlation coefficient. However, as shown in the Appendix, if all observations are independent of each other, the correlation coefficient between both variables is minus one and not zero. This is also intuitively reasonable. If the observation x'_i is large, then $\bar{x}'_i$ defined as $\frac{N\bar{x}-x_i}{N-1}$ is small relative to a situation where x''_i is small, since then $\bar{x}''_i$ increases because the small x''_i is not included whereas the large x'_i is included. Hence, the value of 0.27 indicates a rather positive relationship.

Finally, deterrence variables are specified which are based on the network component an author is part. DET_iclu5$_i$ and DET_iclu9$_i$ of author i is the average of all DET_mean$_j$ values of all authors $j \neq i$ which are part of the same component in the 2006-network. To reduce the risk of spurious results[36] only components with at least five (nine) researchers for DET_iclu5 (DET_iclu9) are taken into account. Additionally, the variable DET_cludi2 is specified which is an average across all DET_mean$_t$ values in the same component. However, for each observation period T only those DET_mean$_t$ values of closely connected but not directly connected researchers and of observation periods $t \leq$ T are considered. This variable enables us to test whether DET_meant$_t$ of closely connected but not directly connected researchers impact on DET_1own which is DET_mean$_t$ of the first observation period in which a researcher has published an article contained in the meta data base. Both types of variables are specified to test Hypothesis 4 and 5 whether authors are influenced by direct coauthors as well as indirectly connected researchers.

Figure 5.4 shows box plots of all 16 deterrence variables. In all four subfigures, medians lie between (2) partly applicable and (3) neutral. For the author-specific variables shown in Subfigure (a) and (b), the boxes covering both medial quartiles mostly range from (2) to (4) more inapplicable. For the market and network variables in Subfigure (c) and (d), the medial quartiles are much smaller and are more in accordance with Becker's theory. In Subfigure (a) and (b), the upper and lower adjacent values are the maximal and minimal values or lie close to

[36]See the discussion above.

them. Unsurprisingly, in (c) and (d) upper and lower adjacent values are smaller since for the averages of market variables some network variables are calculated across a subset of researchers.

The 16 deterrence variables show well-known criminological research results. In Subfigure (a), the median and the box of the property-category DET_P exhibit smaller values than the violence-category DET_V. Similarly, and as expected, the distribution of DET_m1p*eco* is more in favour of Becker's theory than the distribution of DET_m1p*scl*.

Moderator Variables

Almost any variable introduced in this subchapter is variable-related or study-related information pieces in the data base. The information is summarized to author-related variables. Many control variables are indicator variables. In some cases the reference category can be directly taken out of context and is, therefore, omitted.

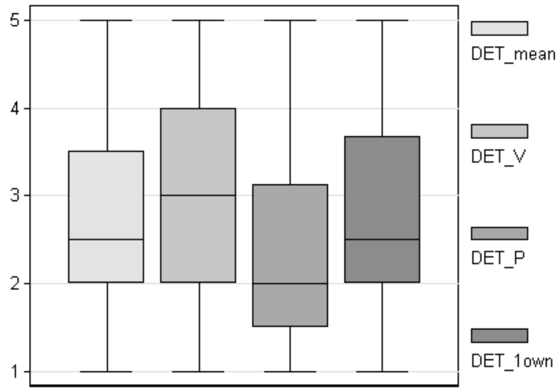
Vertex Variables
Most control variables in the meta data base describe the studies representing the links in the network. However, two vertex variables containing characteristics of the authors themselves are available. Each author is characterized by a country-variable, i.e. the country where the place of work is located and each researcher also belongs to a scientific discipline. Most research articles in our data base are written by economists (41.3%), the shares of the other researchers are sociologists (17.0%), criminologists (8.6%), psychologists (5.7%), and law researcher (2.5%). Researchers who are statisticians, work in the field of public administration or work in other public institutions fall into the category 'others' (19.4%).[37] From the point of view of an economist, it is difficult to distinguish sociologists from criminologists and law researchers for which reason the indicator variable DET_scl is one for researcher who belongs to one of these disciplines and zero otherwise. This simplifies the comparison with DET_eco and DET_psy, the indicator variables for economists and psychologists, respectively.

The other vertex variable is the country of the institution in which a researcher is working. U.S. research institutions dominate the deterrence market. In the 2006-network 69.1% of all researcher are located in the U.S. Other important countries where researchers work on deterrent effects are Canada 11.3%, UK 4.1%, Germany 2.9%, Israel 1.9%, Australia 1.4%, Brasil 1.1%, Netherlands 1.1%, Irland 0.9%, Norway 0.8%, Switzerland 0.8%, Finland 0.6%, and South Korea 0.5%.[38] The indicator variables COU_can, COU_uk, and COU_usa are specified to capture the influence of the country a researcher is located.

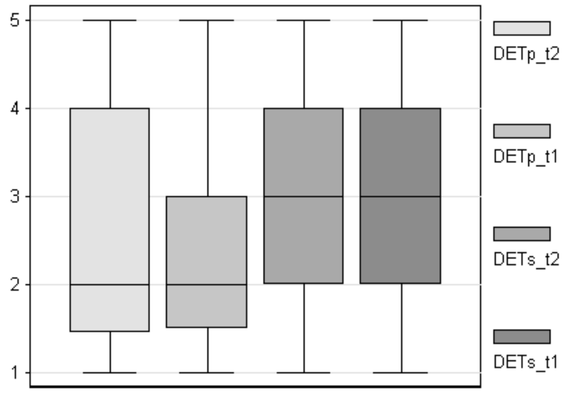
[37]The missing observations (5.5%) complete the data.

[38]Other countries below the 0.5% threshold are Argentina, Chile, France, Singapore, Turkey, Sweden, Italy, Spain, Congo, Japan, New Zealand, Russia and Taiwan.

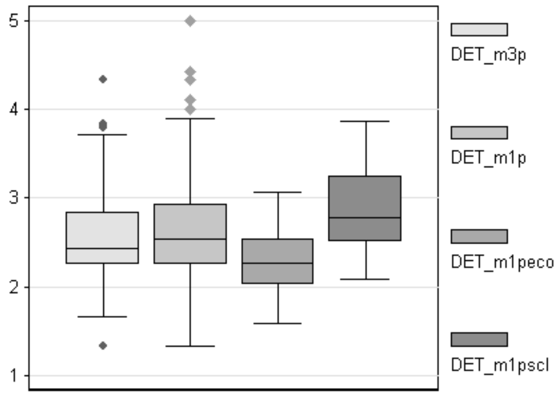
Figure 5.4: Confirmation of Author, Market, and Network Deterrence Variables



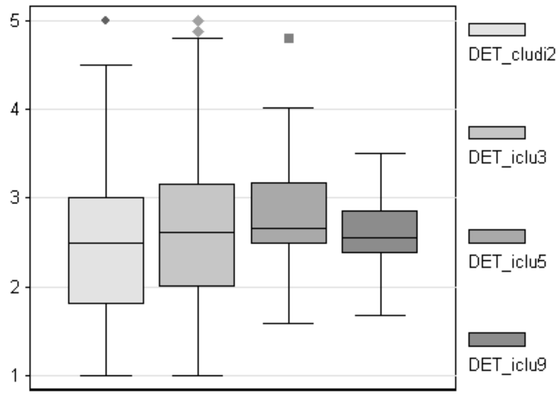
(a) Author Variables (Overall, Categories, 1st)



(b) Author Variables (Time Dimension)



(c) Market Variables



(d) Network Variables

The scales on the ordinates mean 'Becker's theory is (1) wholly applicable, (2) partly applicable, (3) neutral, (4) more inapplicable, (5) wholly inapplicable.'

Variable	Brief Description (Details are explained in the text)
DET_mean	Information on two deterrence variables across three crime categories of all articles.
DET_1own	DET_mean of the first observation period of each author.
DET_C	Information of the categories '(violent) crime against the persons' if $C = V$ and of 'crime against the property' if $C = P$.
DETv_t1	Information of the probability ($v = p$) or severity ($v = s$) variable where DETv is averaged across all except the last observation period of each researcher.
DETv_t2	DETv of the last observation period of a researcher.
DET_mτp	Information of the market (discipline) a researcher is part of without her own work. τ accounts for the number of observation periods which are taken into account for the calculation, $\tau = 1, 3$.
DET_m1pd	Market variable which considers only research field d. The research field is the economic one if $d = eco$ and the field of sociologist, criminologists, and law researcher if $d = scl$.
DET_iclu$n$	Average of DET_mean of all authors belonging to the same component containing at least n authors without the considered researcher herself.
DET_cludi2	Average of DET_mean of indirectly connected authors, i.e. a network distance of at least 2.

Definition of Boxplots: The line inside the box is the median. The box covers the area from the 25th to 75th percentile, i.e. the medial quartiles. The horizontal lines above and below the box are the upper and lower adjacent values. Let A be the value of the 25th and B the value of the 75th percentile. Then the upper adjacent value is $\arg\min[B + 1.5(B - A), Maximum]$ and the lower adjacent value is $\arg\max[A - 1.5(B - A), Minimum]$. Observations outside the upper and lower adjacent values can be interpreted as outliers.

The number of international and interdisciplinary research links is small. The mode of multinational links was ten and was formed between researchers located in Israel and the U.S. Only two international cooperations took place between two non-English speaking institutions - an Israel-Netherland link and a Germany-Switzerland link.[39] Similarly, only 18 interdisciplinary research articles are contained in our data base where nearly half of the interdisciplinary articles were written by criminologists and sociologists.

Link Variables

The low degree of interdisciplinarity especially between economists and non-economists is a result of the different ways of thinking both groups evince. These different line of thoughts also result in different theoretical assumptions. In general, two kinds of crime theories are distinguishable, the traditional theory and the economic theory. The starting point for an empirical verification of the economic theory is Ehrlich (1973), who wrote, "The basic thesis underlying our theory of participation in illegitimate activities is that offenders, as a group, respond to incentives in much the same way that those who engage in strictly legitimate activities do as a group."

Before this incentive-driven economic theory was tested, the traditional approach of criminologists was and still is that deviant behavior is to be explained by deviant characteristics of criminals. Several different theories such as social disorganisation theory, inequality theory, routine activities theory, differential association theory, social control theory, self-control theory, strain theory, and others can be subsumed under the traditional approach.[40] These sub-theories of the traditional approach are distinguishable by different causes such as disrupted social environments, the intensity of attachment to peer groups or families, the frustration felt when someone is falling short of expectations, etc. These potential reasons might be the basis for the development of characteristics being associated with personality disorders and, finally, personality disorders can cause delinquent behavior. The indicator variables THEO_trad and THEO_eco are constructed to measure their impact on the deterrence variables and Figure 5.3 shows how often each theory was tested within the last decades.

Different research approaches were applied to solve the deterrence puzzle. Three different indicator variables are distinguished to measure the influence of the applied approach on findings. ST_crim is one for longitudinal, cross-section, and panel criminological studies. ST_surv is one for longitudinal as well as cross-sectional surveys. ST_exp is one for field and laboratory experiments. The vast majority of authors, 58.2%, invariably performed criminological studies. These are often based on public data, such that the data preparation process is less expensive than the collection of a unique data set. 24% of all authors invariably performed surveys and 9.5% experiments. Many authors - in particular those who were very active in the deterrence research - applied several different methods.

[39] Similar international collaboration links are also reported in Glänzel (2001), who investigated research fields such as Clinical Medicine, Biomedical Research, Biology, Chemistry, Physics, Mathematics, Engineering and Earth and Space Sciences.

[40] See Entorf and Spengler (2002) or Pratt (2001) for a detailed overview.

Another important piece of information is the quality of the surveyed articles. The variable QLTY is specified to control for their impact on the deterrence variables. The variable is specified such that high quality articles have lower values. QLTY measures several factors which indicate the quality of an article. Table 5.4 elucidates each of the eight factors of the index. The absolute weight of each component is shown in the last column and ranges from 0 to 6. Component 4 and 7 distinguish two quality levels. If requirements of significance tests are only partly fulfilled the quality index increases by one point and if no requirements are fulfilled it increases by two points. For example, the index rises when an author applied non-robust standard errors although heteroscedasticity is apparent. Likewise, the quality index rises if an article is published in a collected volume and rises by two points if it is published in neither a journal nor a collected volume.

Factor 8 reports whether the author mentioned econometric or data problems and whether additional problems are found during the meta project. The following check list was used. First, the adequacy of the chosen statistical method was scrutinised. Second, endogeneity problems such as simultaneity, measurement bias, or omitted variable bias were checked. Third, the severity or probability variable and appropriate control variables are considered. Fourth, did study-specific problems arise, e.g in the data assessment process? In the worst case where "econometric/data problems are not mentioned by the author and major additional problems are found" then factor 8 raises the quality index by six points. All points are weighted by 19 - the worst value of the quality index - such that the values of QLTY lie in the unit interval.

Lastly, four miscellaneous control variables are introduced which are not related to any other variable group. The content-related variable MISC_dp indicates whether a study tackles the death penalty issue. This variable is included to control for different results regarding the death penalty and their deterrence effects. Many well-known deterrence researcher such as *Bailey*, *Ehrlich*, *Levitt*, and *Shepherd* contribute to this branch of the deterrence literature.

The indicator variable MISC_pro is specified to test whether prominent authors agree upon a specific topic. An author is called prominent if she has strongly contributed to the literature (cf. Rupp 2008). These researchers are *Bailey, Benson, Bursik, Chiricos, Cloninger, Ehrlich, Entorf, Erickson, Gibbs, Grasmick, Hakim, Levitt, Marvell, Nagin, Paternoster, Piquero, Pogarsky, Rasmussen, Tittle, Virén, Waldo,* and *Witte.*

The indicator variable MISC_jour measures the effect of journals on the deterrence variables. The reference category contains working and conference articles as well as books and edited volumes. Around 85% of all contributions in the data base are published in journals.

Finally, two indicator variables show different sizes of the study population. MISC_sml is one for all studies with a small sample size equal to or below 500 observations and MISC_lrg is an indicator variable which is one for studies which include more than 500 observations. The reference category includes the missing observations.

Table 5.4: Factors and their Weights of the Quality Variable QLTY

Factor	Variable	Nominator
1	#pages<10	2
2	No representative sample	1
3	No error checking	2
4	Requirements of significance tests	
	∘ only partly fulfilled	1
	∘ not fulfilled	2
5	No goodness-of-fit measures	2
6	No control variables	2
7	Type of publication (no journal article)	
	∘ collected edition	1
	∘ other	2
8	Econometric/Data Problems are mentioned by the author	
	∘ and no additional problems found	0
	∘ and minor additional problems found	1
	∘ and major additional problems found	3
	Econometric/Data Problems are **not** mentioned by the author	
	∘ and no additional problems found	2
	∘ and minor additional problems found	4
	∘ and major additional problems found	6
Worst Quality Index (=Denominator of each factor)		19

Own Source: The weight of each factor is calculated as nominator/denominator. # abbreviates 'number of'.

5.5 Inductive Analysis

The hypotheses stated above in Subchapter 5.3 are summarized in Table 5.5 and are tested in this chapter. The following steps were performed to select appropriate control variables. First, the appropriate control variables were chosen by two stepwise OLS regressions. An automatic variable selection process is chosen to ensure objectivity. One stepwise regression starts with the empty model and performs a forward-stepwise variable selection followed by backward elimination, whereas the other regression starts with the complete model and performs a backward-stepwise variable elimination followed by forward selection. For each stepwise regression the chosen Wald tests were applied where a 10%-significance level for forward and backward selection and elimination was chosen. Second, a variable was chosen as a control variable in the final specification if it fulfilled three conditions. (a) it was significant in both stepwise regressions, (b) the maximum of each correlation value with all other variables was smaller than one half, and (c) in the case of an indicator variable at least 3% of all authors have to be indexed. If condition (b) or (c) was unfulfilled in the appropriate subsample, then step one was repeated by excluding the appropriate variables. Third, the hypotheses were tested and results are shown in Table 5.6, 5.7 and 5.8. Fourth, variables which became insignificant were dropped in the final regression when the deterrence variable is included.

The regression results in Table 5.6 show that all author-specific hypotheses can be rejected. An increase in DET_P of one point comes along with a significant increase of around 0.5 of DET_V. Similarly, an increase of one point in previous studies results in an increase of around 0.2 for the probability variable and around 0.4 for the severity variable in the last observation period of each author. For the severity-variable a high significance level is found, whereas the probability variable is only nearly significant at the 10% value. These results imply a strong relationship between the findings of each author. Hence, if a deterrence effect is measured with respect to one deterrence variable it is very likely that similar deterrence effects are found with respect to other deterrence variables.

Hypotheses 3 of the complete deterrence research market can be rejected as shown in Table 5.7. Similarly, the market variables significantly impact on the findings of economists and on sociologists, criminologists, and law researchers as shown in specification (M2) and (M3). For all three specifications in Table 5.7 the coefficient of the market variables DET_m1p is around 0.5. Accordingly, if the value of the peer group rises by one point, the results of each author increases in average by 0.5 points.

In the network analysis shown in Table 5.8 the results are mixed. Specification (N1) implies that a higher value of DET_iclu5 is accompanied by a higher DET_mean value of each author. However, if the number of components is decreased by increasing the limit from at least five researchers to nine then the variable DET_iclu9 is insignificant. This result may indicate that the network effects are not very strong. Possibly, the positive coefficient in specification (N1)

Table 5.5: Author-Specific, Market-Specific, and Network-Specific Hypotheses

No.	Null Hypotheses	Regressand	Regressor	Type
1	Authors confirming Becker's theory with respect to DET_V do not confirm the theory with respect to DET_P values.	DET_V	DET_P	A
2	Each author's results regarding the probability ($v = p$) or severity ($v = s$) variable from earlier studies have no explanatory power for later studies.	DETv_t2	DETv_t1	A
3	Each author's results are independent of the findings of other authors working in the same research field d where d is total, eco or scl.	DET_mean	DET_m1pd	M
4	Each author's results are independent of the network component containing at least n authors of whom she belongs to.	DET_mean	DET_iclu$n$	N
5	The results of the 1st paper of each author are not influenced by indirectly connected authors.	DET_1own	DET_cludi2	N

Variable	Brief Description (Details are explained in the text)
DET_mean	Information on two deterrence variables across three crime categories of all articles.
DET_1own	DET_mean of the first observation period of each author.
DET_C	Information of the categories '(violent) crime against the persons' if $C = V$ and of 'crime against the property' if $C = P$.
DETv_t1	Information of the probability ($v = p$) or severity ($v = s$) variable where DETv is averaged across all except the last observation period of each researcher.
DETv_t2	DETv of the last observation period of a researcher.
DET_mτp	Information of the market (discipline) a researcher is part of without her own work. τ accounts for the number of observation periods which are taken into account for the calculation, $\tau = 1, 3$.
DET_m1pd	Market variable which considers only research field d. The research field is the economic one if $d = eco$ and the field of sociologist, criminologists, and law researcher if $d = scl$.
DET_iclu$n$	Average of DET_mean of all authors belonging to the same component containing at least n authors without the considered researcher herself.
DET_cludi2	Average of DET_mean of indirectly connected authors, i.e. a network distance of at least 2.

Own Source. Three types of hypotheses are distinguished, A, M, and N are author-specific, market-specific, and network-specific hypotheses. Each null hypothesis is specified such that the alternative hypothesis is in line with our expectations.

is a spurious result. In small samples the double-counting of coauthored articles might lead to significant results since the same information is regressed on itself. Specification (N3) sheds more light on the network effects. The results of the first observation period of the meta data base summarized in DET_1own are regressed on DET_cludi2. This regressor is the mean of all indirectly connected authors who have contributed to the deterrence literature beforehand. DET_cludi2 excludes all possible double-counting processes since the variables of all direct authors are not considered. As shown in specification (N3), a highly significant relation is found.

Given these findings, one may conclude that authors are driven by three non-content-related forces. First, each author might have incentives to report consistent results, as indicated by the author-specific specifications in Table 5.6. A major goal of a researcher is the establishment of a reputation. If results of each researcher steadily change, this goal may prove elusive. Second, because each author is eager to publish in peer-reviewed journals, it seems fairly difficult to publish an article if it is at odds with the findings of peers. Hence, the significant findings in the market specifications are not surprising.

Third, network effects might be present, i.e. researchers might be affected by their coauthors and members of research groups which are often met at workshops or conferences. It seems reasonable to assume that the positive relationship of indirectly connected authors is greatly influenced by central authors. For instance, *Levitt* has no indirect link to any author in his component, such that he is automatically excluded in specification (N3), whereas all his coauthors are included. If each author tends to produce similar results, then authors sharing the same coauthor might also be influenced by each other. This interpretation is also in accordance with author-specific results where authors tend to confirm previous results, as shown in Table 5.6.

As a matter of course, the question is whether the OLS coefficients and their standard errors are reliable and multivariate relations measure causal effects? Endogeneity problems may flaw our results. It might be the case that research ideas are proposed to the community via research articles or at conferences. Several researcher might possibly seize these ideas and get similar results since they have performed similar analyses. A simultaneity issue might be especially important in the market specifications and network specifications (N1) and (N2). However, a solution for the potentially existing simultaneity problem is out of reach. Appropriate instruments should measure the behaviour and incentives of researchers and not only their findings, methods and other content-related variables.

Another endogeneity problem likely to be present in our regressions is the omitted variable problem. The political attitude of researchers, for instance, might impact on results. The choice of major at university may be a proxy for the political attitude since it seems reasonable to assume that more liberal thinking students choose economics whereas sociology students are more left-wing oriented. Accordingly, DISC_eco has a correlation of -0.55 with DET_m1p. However, DISC_eco is very likely to be correlated with the error term since DET_m1p contains

Table 5.6: Author-specific Analysis: Crime Categories, Probability and Severity Variable

Specification	(V)		(P)		(S)
Regressand	DET_V		DETp_t2		DETs_t2
constant	0.526**	constant	1.194**	constant	3.536**
	(0.005)		(0.000)		(0.000)
DET_P	0.499**	DETp_t1	0.188	DETs_t1	0.384**
	(0.000)		(0.109)		(0.009)
COU_can	1.084**	COU_usa	0.537+	COU_uk	-1.696*
	(0.004)		(0.070)		(0.000)
COU_uk	0.709+	THEO_trad	1.434**	DISC_eco	-1.003**
	(0.051)		(0.000)		(0.009)
DISC_scl	0.381**			QLTY	-5.539**
	(0.014)				(0.000)
MISC_lrg	0.275*			ST_exp	1.164*
	(0.033)				(0.017)
ST_crim	0.686**				
	(0.000)				
THEO_trad	0.522**				
	(0.003)				
R^2	0.420		0.256		0.476
#Obs	231		86		53
#Var	6		2		7
% Var	100%		100%		57%

Variable	Brief Description (Details are explained above)
DET_C	Information of the categories '(violent) crime against the persons' if $C = V$ and of 'crime against the property' if $C = P$.
DETv_t1	Information of the probability ($v = p$) or severity ($v = s$) variable where DETv is averaged across all except the last observation period of each researcher.
DETv_t2	DETv of the last observation period of a researcher.
COU_l	Country a researcher is located where l=CAN, UK, USA indicates Canada, United Kingdom and the United States.
DISC_d	Disciplines investigated where d=*eco* abbreviates economics, d=*psy* abbreviates psychology and d=*scl* indicates the disciplines sociology, criminology and law researcher.
MISC_lrg	Studies with more than 500 observations.
ST_t	Type of study where t=crim indicates longitudinal, cross-section and panel criminological studies and t=exp indicates experimental studies.
THEO_trad	Studies testing traditional theory.
QLTY	Indicates the quality of a study due to the quality index shown in Table 5.4.

Own Source: p-values in parentheses. 1%, 5%, 10% significance levels are labelled by **, *, +. #Obs abbreviates the number of observations. #Var indicates the number of control variables which are present in at least one of both stepwise regressions. %Var indicates the number of control variables used in the final regression relative to #Var.

Table 5.7: Research Market Analysis

Specification	(M1)		(M2)		(M3)
Regressand	DET_mean		DET_mean		DET_mean
constant	1.561**	constant	1.057	constant	1.791**
	(0.000)		(0.128)		(0.002)
DET_m1p	0.427**	DET_m1p*eco*	0.574^{+}	DET_m1p*scl*	0.522**
	(0.000)		(0.057)		(0.003)
DISC_eco	-0.221^{+}	MISC_pro	-0.555*	MISC_dp	0.790**
	(0.052)		(0.030)		(0.006)
DISC_psy	0.621*			MISC_jour	-0.577*
	(0.018)				(0.032)
MISC_dp	0.412*				
	(0.042)				
R^2	0.095		0.019		0.129
#Obs	558		268		159
#Var	3$^{\diamond}$		1		6
% Var	100%		100%		33.3%

Variable	Brief Description (Details are explained above)
DET_mean	Information on two deterrence variables across three crime categories of all articles.
DET_m1p	Information of the market (discipline) a researcher is part of without her own work where researchers are compared within an observation period.
DET_m1p*d*	Market variable which considers only research field *d*. The research field is the economic one if $d = eco$ and the field of sociologist, criminologists, and law researcher if $d = scl$.
DISC_*d*	Disciplines investigated where *d*=*eco* abbreviates economics, *d*=*psy* abbreviates psychology and *d*=*scl* indicates the disciplines sociology, criminology and law researcher.
MISC_dp	Studies tackling the death penalty issue.
MISC_pro	Indicates prominent authors.
MISC_jour	Indicates studies being published in refereed journals.

Own Source: p-values in parentheses. 1%, 5%, 10% significance levels are labelled by **, *, $^{+}$. #Obs abbreviates the number of observations. #Var indicates the number of control variables which are present in at least one of both stepwise regressions. %Var indicates the number of control variables used in the final regression relative to #Var.

$^{\diamond}$Notice, a fourth variable MISC_pro was significant after the stepwise regressions, although it turned insignificant when we include DET_m1p.

Table 5.8: Network Analysis

Specification	(N1)		(N2)		(N3)
Regressand	DET_mean		DET_mean		DET_1own
constant	2.413**	constant	3.555**	constant	3.785**
	(0.000)		(0.000)		(0.000)
DET_iclu5	0.514**	DET_iclu9	-0.029	DET_cludi2	0.345**
	(0.000)		(0.902)		(0.002)
MISC_jour	-0.808*	COU_uk	-0.484*	COU_uk	-1.119*
	(0.013)		(0.023)		(0.019)
MISC_lrg	-0.587*	ST_exp	-1.482**	MISC_jour	-0.859**
	(0.039)		(0.000)		(0.006)
MISC_sml	-0.451$^+$	ST_surv	-0.899**	MISC_lrg	-1.410**
	(0.073)		(0.000)		(0.000)
		THEO_eco	-1.469**	MISC_sml	-0.748**
			(0.000)		(0.005)
				QLTY	-1.986**
					(0.002)
R^2	0.183		0.476		0.249
#Obs	150		79		115
#Var	4		6		5‡
% Var	100%		66.7%		100%

Variable	Brief Description (Details are explained above)
DET_mean	Information on two deterrence variables across three crime categories of all articles.
DET_1own	DET_mean of the first observation period of each author.
DET_iclu$n$	Average of DET_mean of all authors belonging to the same component containing at least n authors without the considered researcher herself.
DET_cludi2	Average of DET_mean of indirectly connected authors, i.e. a network distance of at least 2.
MISC_jour	Indicates studies being published in refereed journals.
MISC_s	Studies with s=lrg (sml) equal or more (less) than 500 observations.
COU_uk	Indicates researcher being located in United Kingdom.
ST_t	Type of study where t=exp indicates experimental studies and t=surv indicates surveys.
THEO_eco	Studies testing economic theory.
QLTY	Indicates the quality of a study due to the quality index shown in Table 5.4.

Own Source: p-values in parentheses. 1%, 5%, 10% significance levels are labelled by **, *, $^+$. #Obs abbreviates the number of observations. #Var indicates the number of control variables which are present in at least one of both stepwise regressions. %Var indicates the number of control variables used in the final regression relative to #Var.

‡Notice, the variable COU_can was also significant after the stepwise regressions. It turned insignificant when we include DET_cludi2.

individual outcome variables DET_mean. Therefore, the chosen approach again makes it very difficult to find appropriate instruments.

5.6 Conclusion

This study descriptively evaluates the coauthor network among economists and other researchers who work on deterrence effects. The descriptive network analysis is one basis to shed some light on the interdependencies of research outcomes. The analysis implies that the findings of researchers are positively related to findings in their previous work, to the findings of researchers who work on similar research questions, and to the coauthor network in which a researcher is embedded. The results presented might be flawed by endogeneity problems which, due to the absence of appropriate instruments, are not solvable. If the results at least to some degree represent causal relationships then this work challenges the value of deterrence research and the following questions arise. First, has the research article of an established researcher anything new to offer or do established researchers support each other and abuse their market power in research environments involving a referee-system?[41] Second, have researchers incentives to discover the structure of societies in which we live? or do they promote their own carrier goals, forcing the researcher to accept certain truths shared by the majority of researchers in the same discipline because the publication probability in the referee-system is otherwise strongly reduced? Third and finally, what is the optimal structure of a coauthor network? Research networks are important for exchanging information which might increase the productivity of researchers. However, research networks may also reduce the social welfare. If researchers react on each other such that each research output is not a genuine source of information but rather the result of misguided research incentives.

From a structural perspective, this article shows that the complete current deterrence network is a 'collection of islands'. Accordingly, not only network components of different disciplines tackling the deterrence issue exist but many different components within each discipline are also found. Such a collection of islands was also observed by Goyal et al. (2006) for the coauthor network of economists in the 1970's. Given the observation that today's network of economists is a small world and contemporaneously the productivity of researchers has increased, the question arises whether the deterrence puzzle might be solvable if the deterrence network also turns into a small world. Goyal et al. (2006) explain the existence of a small world network by the presence of inter-connected highly productive star-authors. Possibly, the most important deterrence researchers from within as well as across disciplines should work together to solve it.

[41] Some evidence for the abuse of market power was recently found by Combes, Linnemer, Visser (2006), who showed that applicants for vacant professorships in France have a higher acceptance rate if jury members are acquainted with the candidates.

5.7 Appendix

Proposition 5.7.1 (Correlation of Market and Author Variables) *Let* $x_i \in_R \{x_1, \ldots, x_N\}$ *be random and independent drawings from the set of all available observations. Furthermore, let* $\overline{x}_i := (N-1)^{-1} \sum_{j \neq i} x_j$ *be the average of all observations without the ith element and* $Var(x_i) = \sigma^2 \; \forall i$*. It follows*[42] *that* $Corr(x_i, \overline{x}_i) = -1$*.*

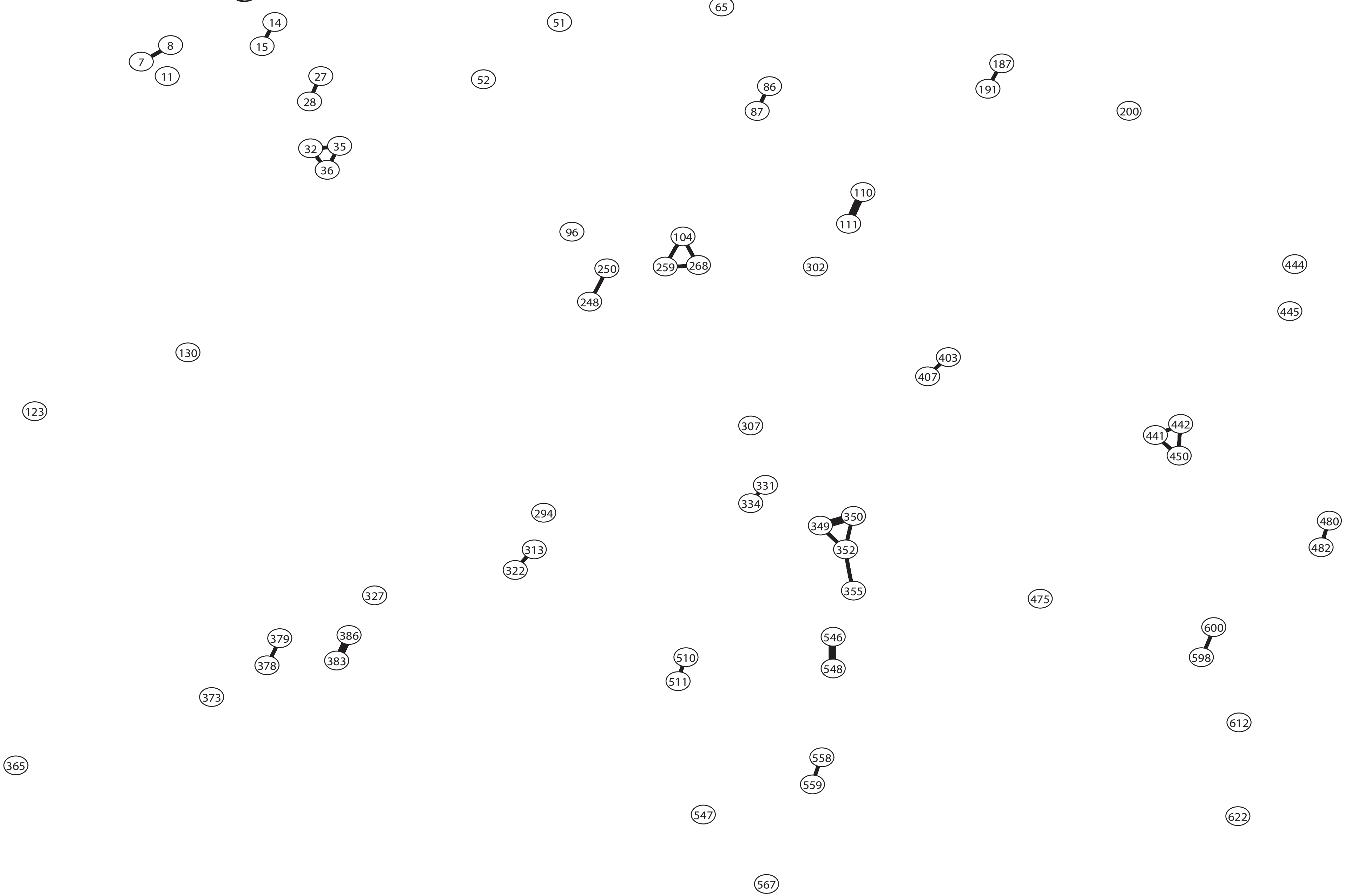
Proof It is important to remember that randomness is introduced by the drawings - the set of observations $\{x_1, \ldots, x_N\}$ is given. Therefore, $\overline{x}$ is an unknown but deterministic value which has zero variance.

$$
\begin{aligned}
\mathrm{Corr}(x_i, \overline{x}_i) &= \frac{\mathrm{Cov}(x_i, \overline{x}_i)}{\sqrt{\mathrm{Var}(x_i)}\sqrt{\mathrm{Var}(\overline{x}_i)}} = \frac{\mathrm{Cov}(x_i, \frac{N\overline{x}-x_i}{N-1})}{\sigma\sqrt{\mathrm{Var}(\frac{N\overline{x}-x_i}{N-1})}} \\
&= \frac{\frac{1}{N-1}\mathrm{Cov}(x_i, -x_i)}{\sigma\sqrt{\frac{1}{(N-1)^2}\mathrm{Var}(-x_i)}} = \frac{-\frac{\sigma^2}{N-1}}{\sigma\frac{\sigma}{N-1}} \\
&= -1
\end{aligned}
$$

□

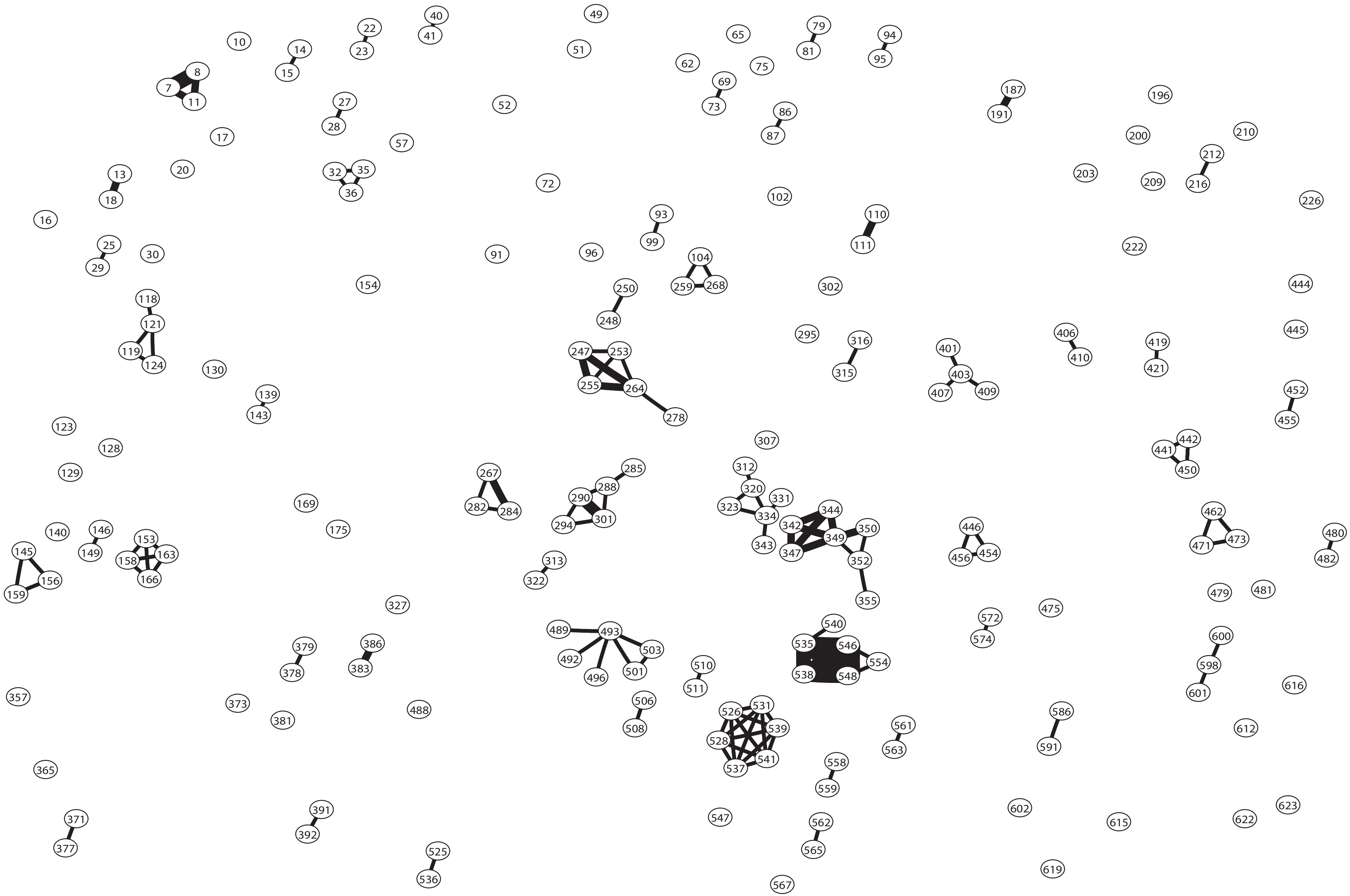
[42] Although x_i and $\overline{x}_i$ are based on disjoint sets, they are not independent.

Network Figure 1: 1976



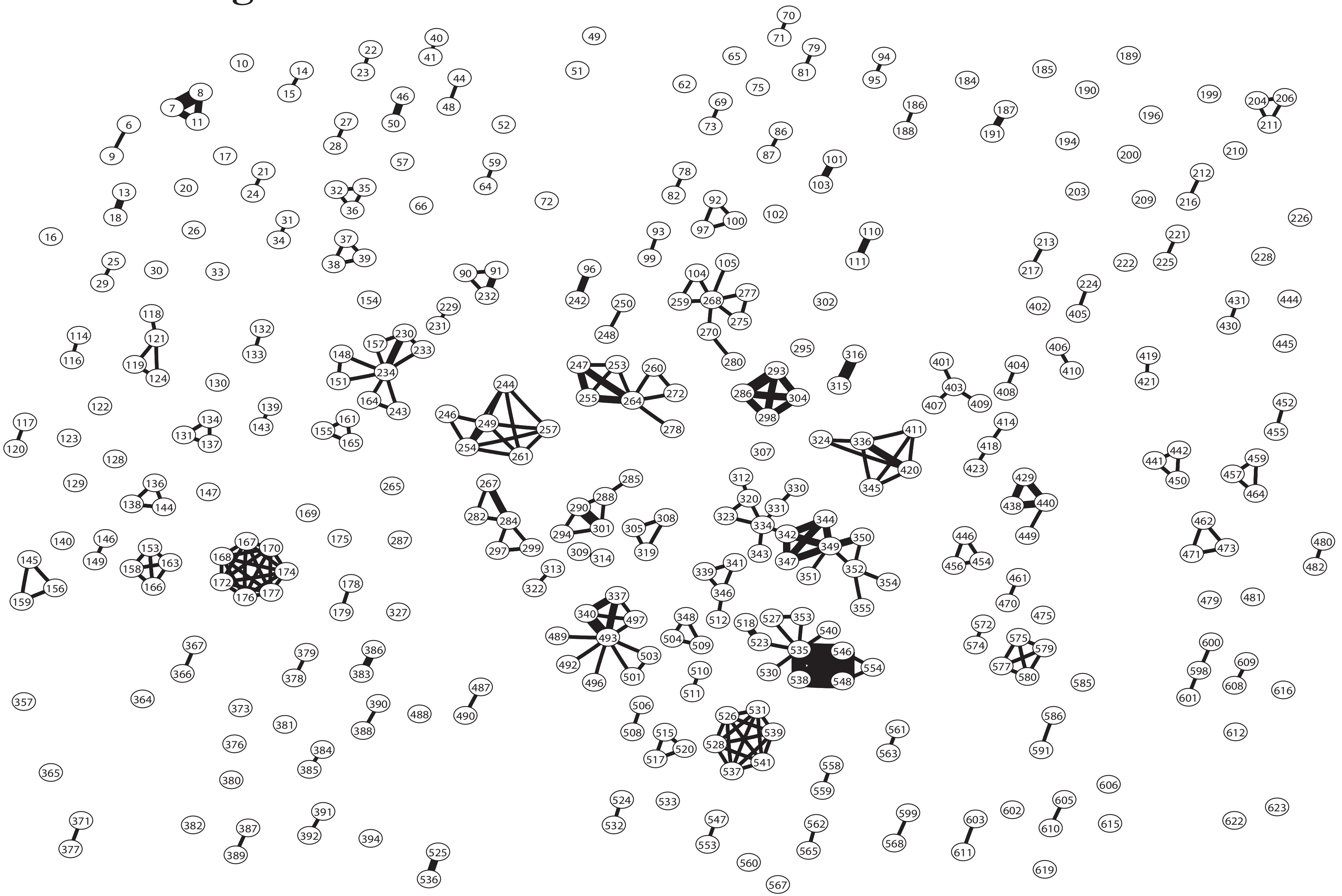
Hint: Thickness of edges increase with number of papers. Loops, i.e. single-authored papers, are deleted.

Network Figure 2: 1986



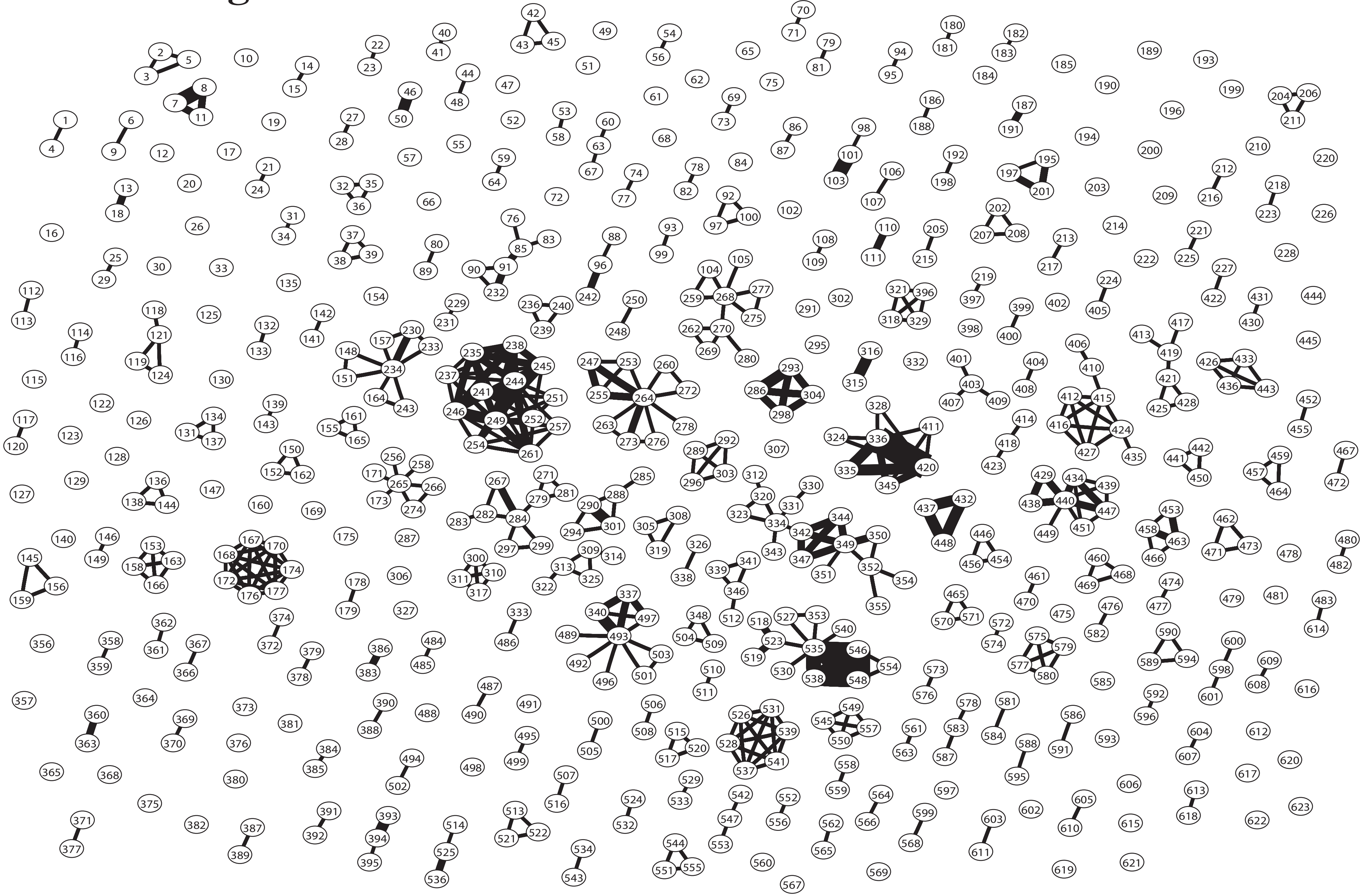
Hint: Thickness of edges increase with number of papers. Loops, i.e. single-authored papers, are deleted.

Network Figure 3: 1996



Hint: Thickness of edges increase with number of papers. Loops, i.e. single-authored papers, are deleted.

Network Figure 4: 2006



Hint: Thickness of edges increase with number of papers. Loops, i.e. single-authored papers, are deleted.

Alphabetical Order of Authors

573 List Joh
542 Liu Zhi
437 Loayza Nor
171 Lochner Lan
288 Loftin Col
294 Logan Cha
419 Lott Joh
355 Lott Rut
90 Lovitch Nor
369 Ludwig Jen
225 Lundman Ric
407 Lundstedt S.
317 Lydon Rea
125 Macdonald Joh
63 Machin Ste
3 Madigan Dav
391 Magaddino Jos
568 Magat Wes
515 Maghsoodloo Sae
603 Maguin Eug
121 Maital Shl
18 Mak Jam
326 Maki Den
249 Mann Rob
88 Marchesini Rob
514 Marelich Wil
292 Marquart Jam
485 Marselli Ric
350 Martin Dav
101 Marvell Tho
287 Masih Rum
335 Mast Bre

381 Mathur Vij
58 Maultby Cam
338 Mauser Gar
616 Mc Farland Sam
82 McAleer Mic
277 Mccleary Ric
148 Mcclelland Gar
503 McCollom Car
143 Mccormick Rob
193 McCrary Jus
285 Mcdowall Dav
182 McGeorge Jil
457 Mcgraw Kat
230 McKee Mic
526 McNees Pat
510 McPheters Lee
392 Medoff Mar
404 Meera Aha
67 Meghir Cos
410 Mehay Ste
320 Meier Rob
192 Meloni Osv
347 Menke Ben
135 Merrifield Jef
190 Merriman Dav
330 Metsger Lin
475 Michaels Ric
423 Mikesell Joh
348 Milder Tru
446 Milton Edw
146 Minor Wil
206 Mirand Amy

351 Miranne Alf
61 Miron Jef
178 Mixon Dar
179 Mixon Fra
85 Mocan H.
462 Montmarquette Cla
103 Moody Car
15 Morris Dou
582 Mui H.w
217 Mullahy Joh
243 Murray Mat
421 Mustard Dav
75 Myers Jr. Sam
523 Nagin Dan
362 Nelson Mic
473 Nerlove Mar
575 Neuman Car
116 Neustrom Mic
39 Neville Dor
569 Nilsson Ann
33 Niskanen Wil
114 Norton Wil
205 Nott Dav
28 O'donoghue M.
166 Okano Fra
41 Orsagh Tho
479 Otterbein Kei
247 Ovadia Ari
415 Pacula Ros
566 Papps Ker
592 Park Cha
48 Park Joo

581 Parker Jef
591 Parker Rob
55 Parsley J.
452 Passell Pet
385 Pate Ant
535 Paternoster Ray
218 Payne Bri
456 Peek Cha
222 Pestello Fra
504 Petee Tho
354 Peterson Rut
54 Pfeiffer Man
203 Phillips Dav
600 Phillips Lla
557 Piehl Ann
583 Piquero Ale
418 Pirog-Good Mau
477 Plassmann Flo
519 Pogarsky Gre
130 Pogue Tho
17 Pontell Hen
173 Porter Jac
486 Posadas Jos
302 Press S.
458 Pudney Ste
463 Pyle Dav
580 Rabow Jer
2 Raftery Adr
498 Ralston Roy
565 Rankin Jos
112 Raphael Ste
336 Rasmussen Dav

76 Rees Dan
438 Reilly Bri
590 Reinfurt Don
276 Rengert Geo
214 Resignato And
329 Retting Ric
508 Rich Mic
89 Richardson Lil
521 Ritsema Chr
35 Roberts Rob
34 Rogers Pat
268 Ross Lau
322 Rowe Ala
197 Rubin Pau
26 Ruhm Chr
107 Rustichini Ald
124 Rutenberg Ary
181 Sacerdote Bru
346 Saffer Hen
253 Sagi Eli
378 Salem Ric
538 Saltzman Lin
145 Samuelson Sve
466 Saruc Tol
429 Schenzler Chr
267 Schmidt Pet
539 Schnelle Joh
31 Schoenig Ste
464 Scholz Joh
607 Schram Art
567 Schuessler Kar
151 Schulze Wil

Numerical Order of Authors

1 Kennedy Les
2 Raftery Adr
3 Madigan Dav
4 Baron Ste
5 Hoeting Jen
6 Thistle Pau
7 Erickson May
8 Gibbs Jac
9 Cover Jam
10 Stack Ste
11 Jensen Gar
12 Fischer Jus
13 Fuji Edw
14 Tweeten Lut
15 Morris Dou
16 Zedlewski Edw
17 Pontell Hen
18 Mak Jam
19 Allen W.
20 Zimring Fra
21 Clark Dav
22 Spruill Nan
23 Silverman Les
24 Cosgrove Jam
25 Gove Wal
26 Ruhm Chr
27 Bacon Pet
28 O'donoghue M.
29 Geerken Mic

31 Schoenig Ste
32 Voelker Cam
33 Niskanen Wil
34 Rogers Pat
35 Roberts Rob
36 Chambers Lar
37 Graham Joh
38 Evans Wil
39 Neville Dor
40 Black The
41 Orsagh Tho
42 Toomey Tra
43 Grosvenor Dav
44 Legge Jer
45 Wagenaar Ale
46 Virén Mat
47 Tao Hun
48 Park Joo
49 Watson Roy
50 Koskela Erk
51 Heisler Ger
52 Chapman Jef
53 Bodman Phi
54 Pfeiffer Man
55 Parsley J.
56 Gelau Chr
57 Layton All
58 Maultby Cam
59 Chressanthis Geo

61 Miron Jef
62 Dölling Die
63 Machin Ste
64 Grimes Pau
65 Silberman Mat
66 Smith Kev
67 Meghir Cos
68 Andrienko Yur
69 Hollinger Ric
70 Cappel Cha
71 Sykes Gre
72 Leamer Edw
73 Clark Joh
74 Dipasquale Den
75 Myers Jr. Sam
76 Rees Dan
77 Glaeser Edw
78 Veall Mic
79 Hexter J.
80 Houston Dav
81 Sesnowitz Mic
82 McAleer Mic
83 Gittings Kaj
84 Zhang Jun
85 Mocan H.
86 Horai Joa
87 Tedeschi Jam
88 Marchesini Rob
89 Richardson Lil

91 Corman Hop
92 Hagan Joh
93 Epple Den
94 Stahura Joh
95 Huff Ron
96 Cloninger Dal
97 Keane Car
98 Kaminski Rob
99 Visscher Mic
100 Gillis A.r
101 Marvell Tho
102 Chilton Rol
103 Moody Car
104 Campbell Don
105 Klette Han
106 Gneezy Uri
107 Rustichini Ald
108 Heckelman Jac
109 Yates And
110 Greenwood Mic
111 Wadycki Wal
112 Raphael Ste
113 Winter-Ebmer Rud
114 Norton Wil
115 Goodman Dou
116 Neustrom Mic
117 Heikkila Eri
118 Benjamini Yae
119 Friedland Neh

121 Maital Shl
122 Grogger Jef
123 Yunker Jam
124 Rutenberg Ary
125 Macdonald Joh
126 Leung Amb
127 Becsi Zso
128 Fox Jam
129 Klemke Llo
130 Pogue Tho
131 Bunn Dou
132 von Hofer Han
133 Tham Hen
134 Gropper Dan
135 Merrifield Jef
136 Caudill Bar
137 Caudill Ste
138 Ungerleider Ste
139 Tollison Rob
140 Fabrikant Ric
141 Wheeler Tim
142 Gawande Kis
143 Mccormick Rob
144 Kantor Gle
145 Samuelson Sve
146 Minor Wil
147 Wilkinson Jam
148 Mcclelland Gar
149 Harry Jos

30 Houston Joh
151 Schulze Wil
152 Truong You
153 Tanaka Ran
154 Storey D.
155 Weigel Rus
156 Isachsen Arn
157 Jackson Bet
158 Ghali Moh
159 Strom Ste
160 Curti Hen
161 Elffers Hen
162 Wong Win
163 Estores Emo
164 Bahl Roy
165 Hessing Dic
166 Okano Fra
167 Hill Wil
168 Contronea Ros
169 Williams Iii Fra
170 Franco Mar
171 Lochner Lan
172 Kalfus Gra
173 Porter Jac
174 Balser Dav
175 Alcorn Dav
176 Ferrari Jos
177 Arean Pat
178 Mixon Dar
179 Mixon Fra
180 Bal-ilan Avn
181 Sacerdote Bru
182 McGeorge Jil

60 Hansen Kir
183 Aitken C.
184 Thurman Qui
185 Cameron Sam
186 Cornwell Chr
187 Clark C.
188 Trumbull Wil
189 Erard Bri
190 Merriman Dav
191 Avio Ken
192 Meloni Osv
193 McCrary Jus
194 Cohen Mar
195 Shepherd Joa
196 Victor Mic
197 Rubin Pau
198 Cerro Ana
199 Cheatwood Der
200 Buikhuisen W.
201 Dezhbakhsh Has
202 Sullivan Kar
203 Phillips Dav
204 Wieczorek Wil
205 Nott Dav
206 Mirand Amy
207 Deffenti Cas
208 Kaene Bet
209 Gabor Tho
210 Albrecht Han
211 Callahan Chr
212 Jonah Bri
213 Sindelar Jod
214 Resignato And

90 Lovitch Nor
215 Green Pet
216 Wilson R.
217 Mullahy Joh
218 Payne Bri
219 Scribner Ric
220 Vinod H.
221 Demers Dav
222 Pestello Fra
223 Gainey Ran
224 Fell Jam
225 Lundman Ric
226 Withers Gle
227 Grau Mon
228 Karstedt-Henke Sus
229 Iwase Nob
230 McKee Mic
231 Deshapriya E.
232 Joyce The
233 Beck Wil
234 Alm Jam
235 Beirness Dou
236 Fortin Ber
237 Asbridge Mar
238 Lamble Rob
239 Lacroix Guy
240 Villeval Mar
241 Sykora K.
242 Brumm Har
243 Murray Mat
244 Vingilis Eve
245 Stoduto Gin
246 Smart Reg

120 Craig Ste
247 Ovadia Ari
248 Cushing Rob
249 Mann Rob
250 Bean Fra
251 Lei H.
252 Blefgen H N
253 Sagi Eli
254 Anglin Lis
255 Weinblatt Jim
256 Ayres Ian
257 Gavin Dou
258 Kessler Dan
259 Glass Gen
260 Friedman Jos
261 Adlaf Edw
262 Tippetts A.
263 Fishman Gid
264 Hakim Sim
265 Levitt Ste
266 Katz Law
267 Schmidt Pet
268 Ross Lau
269 Lange Jam
270 Voas Rob
271 Clarke Ala
272 Spiegel Uri
273 Shachmurove Yoc
274 Shustorovich Ell
275 Lafree Gar
276 Rengert Geo
277 Mccleary Ric
278 Gross Mei

150 Liang Fam
279 Witt Rob
280 Hause Jan
281 Fielding Nig
282 Sickles Rob
283 Williams Jen
284 Witte Ann
285 Mcdowall Dav
286 Schumann Kar
287 Masih Rum
288 Loftin Col
289 Brewer Vic
290 Kessler Ron
291 Kelly Mor
292 Marquart Jam
293 Kaulitzki Rei
294 Logan Cha
295 Willis K.
296 Sorensen Jon
297 Griesinger Har
298 Berlitz Cla
299 Tauchen Hel
300 Denny Kev
301 Greenberg Dav
302 Press S.
303 Wrinkle Rob
304 Guth Han
305 Aasness Jor
306 Ihlanfeldt Kei
307 Teevan Jam
308 Eide Erl
309 Gertz Mar
310 Harmon Col

311 Walker Ian
312 Johnson Wel
313 Tittle Cha
314 Gould Ler
315 Decker Sco
316 Kohfeld Car
317 Lydon Rea
318 Williams All
319 Skjerpen Ter
320 Meier Rob
321 Feldman Amy
322 Rowe Ala
323 Hickmann Car
324 Sollars Dav
325 Bratton Jas
326 Maki Den
327 Erickson Pat
328 Leburn Ian
329 Retting Ric
330 Metsger Lin
331 Jensen Eri
332 Foglia Wan
333 Balbo Mar
334 Burkett Ste
335 Mast Bre
336 Rasmussen Dav
337 Chamlin Mit
338 Mauser Gar
339 Cahloupka Fra
340 Bursik Rob
341 Grossmann Mic
342 Ward Dav
470 Talley Way

343 Carrithers Wil
344 Stafford Mar
345 Kim Ilj
346 Saffer Hen
347 Menke Ben
348 Milder Tru
349 Gray Lou
350 Martin Dav
351 Miranne Alf
352 Bailey Wil
353 Bachmann Ron
354 Peterson Rut
355 Lott Rut
356 Soares R.
357 Layson Ste
358 Stolzenberg Lis
359 D'alessio Ste
360 Funk Pat
361 Goel Raj
362 Nelson Mic
363 Kugler Pet
364 Andreoni Jam
365 Zador Pau
366 Triest Rob
367 Sheffrin Ste
368 Thomson Ern
369 Ludwig Jen
370 Cook Phi
371 Holtmann A.
372 Uysal Muz
373 Wellford Cha
374 Sirakaya Erc
502 Arvanites Tho

375 Zimmerman Pau
376 Hsing By
377 Yap L.
378 Salem Ric
379 Bowers Wil
380 Allen Ral
381 Mathur Vij
382 Williams Kir
383 Antunes Geo
384 Hamilton Edw
385 Pate Ant
386 Hunt A.
387 Godfrey Chr
388 Bold Fre
389 Ensor Tim
390 Hull Bro
391 Magaddino Jos
392 Medoff Mar
393 Spengler Han
394 Entorf Hor
395 Winker Pet
396 Farmer Cha
397 Cohen Deb
398 Diez-Ticio Amo
399 Frey Bru
400 Feld Lar
401 Hero Rod
402 Burnell Jam
403 Spicer Mic
404 Meera Aha
405 Johnson Del
406 Furlong Wil
534 Kelling Geo

407 Lundstedt S.
408 Jayakumar Mal
409 Thomas Eve
410 Mehay Ste
411 Zuehlke Tho
412 Zarkin Gar
413 Bronars Ste
414 Good Dav
415 Pacula Ros
416 Bray Jer
417 Whitley Joh
418 Pirog-Good Mau
419 Lott Joh
420 Benson Bru
421 Mustard Dav
422 Groves The
423 Mikesell Joh
424 Farrelly Mat
425 Gould Eri
426 Thébaud Oli
427 Wendling Bre
428 Weinberg Bru
429 Schenzler Chr
430 Liska All
431 Yu Jia
432 Fajnzylber Pab
433 Hatcher Aar
434 Stout Emi
435 Desimone Jef
436 Jaffry Sha
437 Loayza Nor
438 Reilly Bri
566 Papps Ker

439 Davies Hes
440 Sloan Fra
441 Chaiken Jan
442 Lawless Mic
443 Bennett Eli
444 Swimmer Eug
445 Jones Ter
446 Milton Edw
447 Liang Lan
448 Lederman Dan
449 Githens Pen
450 Stevenson Kei
451 Whetten-Goldstein Kat
452 Passell Pet
453 Deadman Der
454 Chalfant H.
455 Taylor Joh
456 Peek Cha
457 Mcgraw Kat
458 Pudney Ste
459 Steenbergen Mar
460 Doyle Joa
461 Anderson Eri
462 Montmarquette Cla
463 Pyle Dav
464 Scholz Joh
465 Steel Mar
466 Saruc Tol
467 Sloan Joh
468 Ahmed Ehs
469 Horn Rob
598 Votey Har

471 Forest Pau
472 Kovandzic Tom
473 Nerlove Mar
474 Tideman Nic
475 Michaels Ric
476 Ali M.M
477 Plassmann Flo
478 Sigman Hil
479 Otterbein Kei
480 Danziger She
481 Bishop Don
482 Wheeler Dav
483 Fehr Ern
484 Vannini Mar
485 Marselli Ric
486 Posadas Jos
487 Anderson Eli
488 Cohen Lar
489 Appleton Lyn
490 Diaz Joa
491 Borack Jul
492 Scott Wil
493 Grasmick Har
494 Defina Rob
495 Carmichael Fio
496 Bryjak Geo
497 Cochran Joh
498 Ralston Roy
499 Ward Rob
500 Willington Man

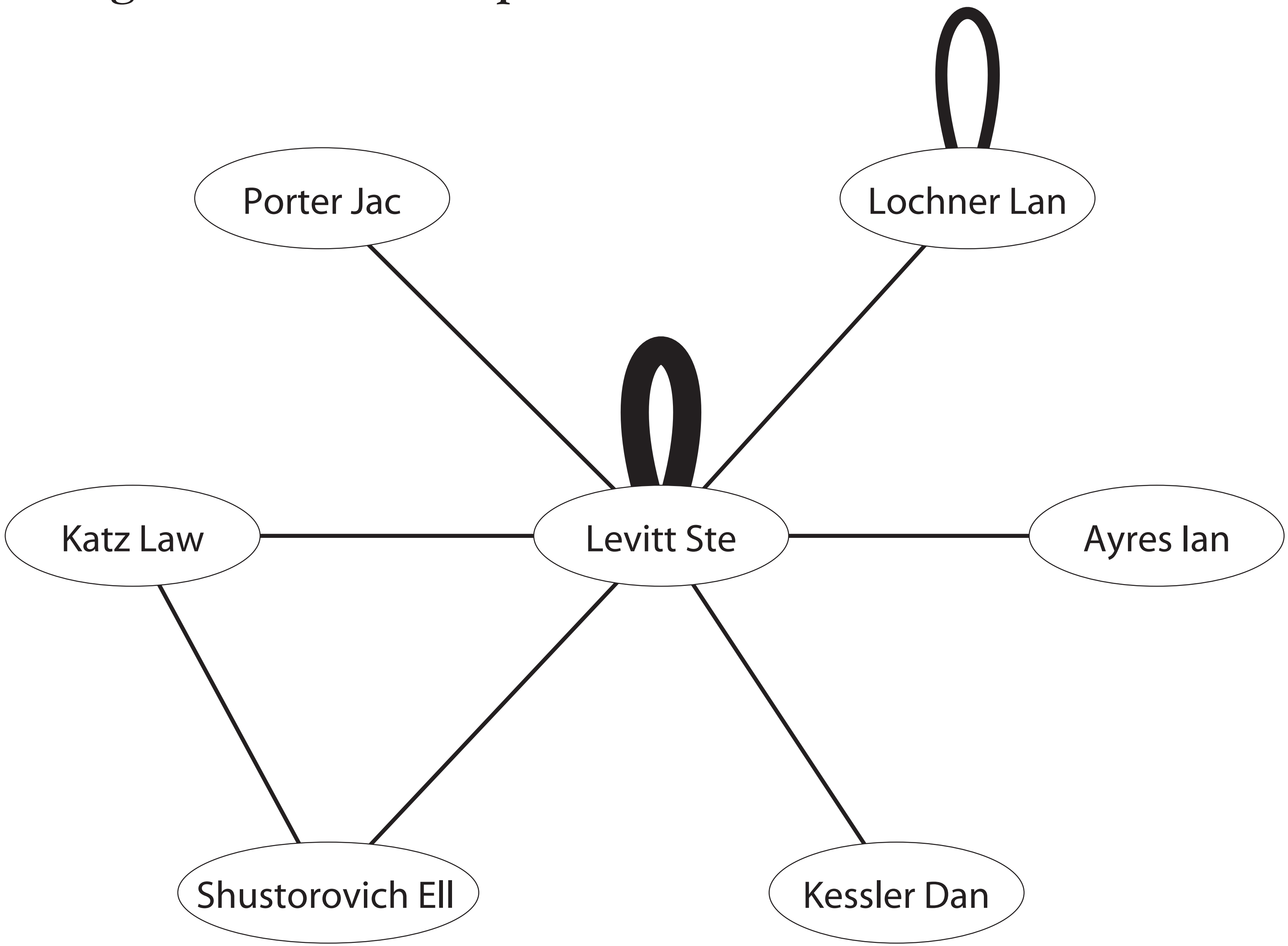
503 McCollom Car
504 Petee Tho
505 Chambouleyron And
506 Jacob Her
507 Giacopassi Dav
508 Rich Mic
509 Welch Mic
510 McPheters Lee
511 Stronge Wil
512 Chaloupka Fra
513 Ferrier Gar
514 Marelich Wil
515 Maghsoodloo Sae
516 Forde Dav
517 Greathouse Per
518 Klepper Ste
519 Pogarsky Gre
520 Brown Dav
521 Ritsema Chr
522 Thomas Deb
523 Nagin Dan
524 Jarrell Ste
525 Berger Dal
526 McNees Pat
527 Ward Sal
528 Carr Ada
529 Koch Ste
530 Smith Dou
531 Domash Mic
532 Howsen Roy

535 Paternoster Ray
536 Snortum Joh
537 Kirchner Rob
538 Saltzman Lin
539 Schnelle Joh
540 Iovanni Lee
541 Larson Lyn
542 Liu Zhi
543 Sousa Jr. Wil
544 Koopman Sie
545 Waring Eli
546 Chiricos The
547 Ehrlich Isa
548 Waldo Gor
549 Kennedy Dav
550 Braga Ant
551 Sridharan San
552 Damphousse Kel
553 Brower Geo
554 Anderson Lin
555 Vujic Sun
556 Kaplan How
557 Piehl Ann
558 Carr-Hill R.
559 Stern N.
560 Wong Yue
561 Hoenack Ste
562 Wells L.
563 Weiler Wil
564 Winkelmann Rai

567 Schuessler Kar
568 Magat Wes
569 Nilsson Ann
570 Ley Edu
571 Fernández Car
572 Bailey Ken
573 List Joh
574 Sheley Jos
575 Neuman Car
576 Cherry Tod
577 Watts Ron
578 Brezina Tim
579 Hernandez Ant
580 Rabow Jer
581 Parker Jef
582 Mui H.w
583 Piquero Ale
584 Atkins Ray
585 Stevans Lon
586 Smith M.
587 Taxman Fay
588 Anderson Lis
589 Foss Rob
590 Reinfurt Don
591 Parker Rob
592 Park Cha
593 Buonanno Pao
594 Stewart J.
595 Stafford Sar
596 Hyun Jin

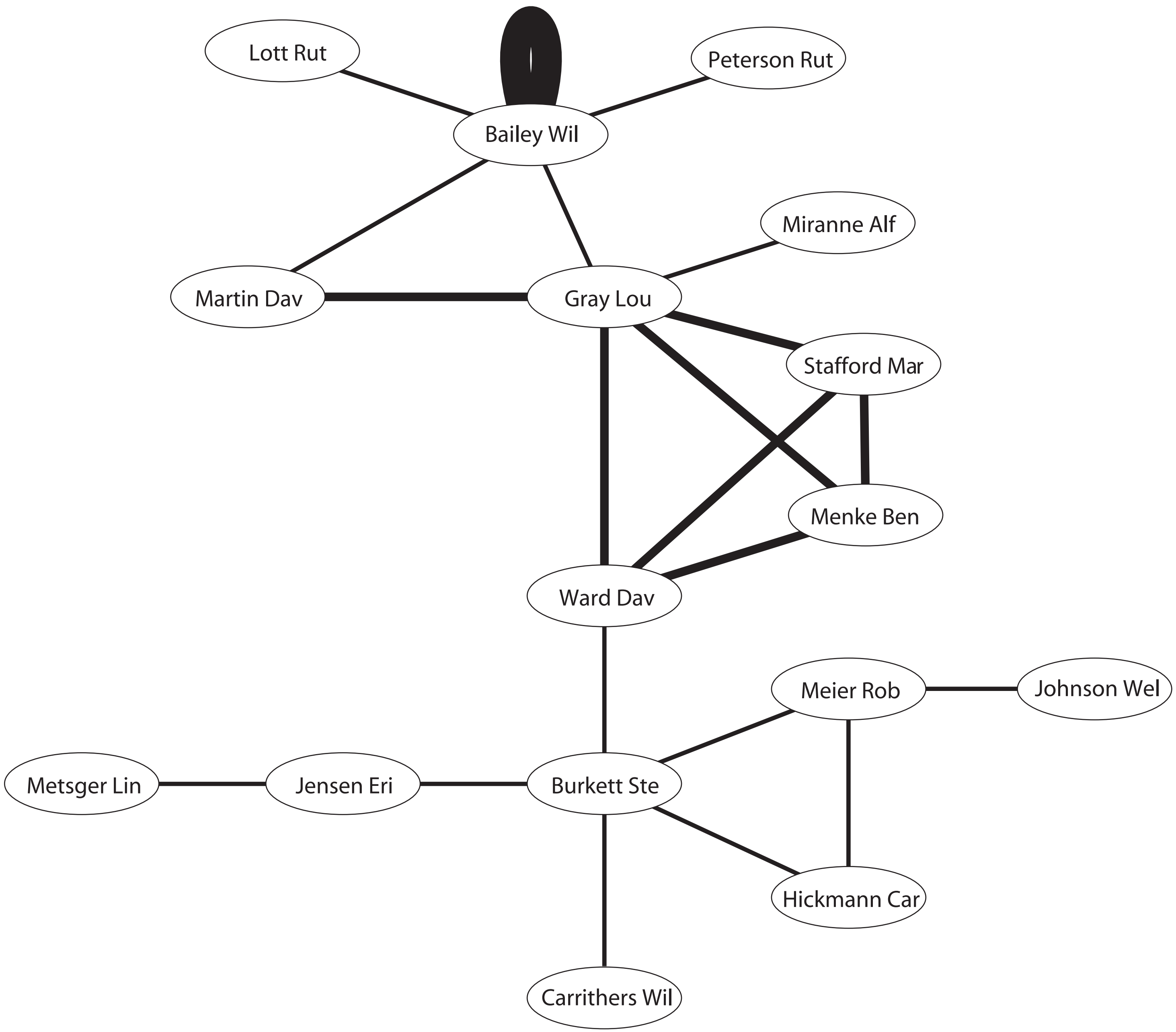
599 Viscusi W.
600 Phillips Lla
601 Shapiro Per
602 Wolpin Ken
603 Maguin Eug
604 Gërxhani Kla
605 Thompson Lyk
606 Green Don
607 Schram Art
608 Toni Mak
609 Braithwaite Joh
610 Soper Jos
611 Shore Els
612 Clarke Ron
613 Crew R.e
614 Gächter Sim
615 Thaler Ric
616 Mc Farland Sam
617 Spencer De
618 Weber J.m
619 Killias Mar
620 Gius Mar
621 Earnhart Die
622 Forst Bri
623 Vandaele Wal

Network Figure 5: Levitt-Component



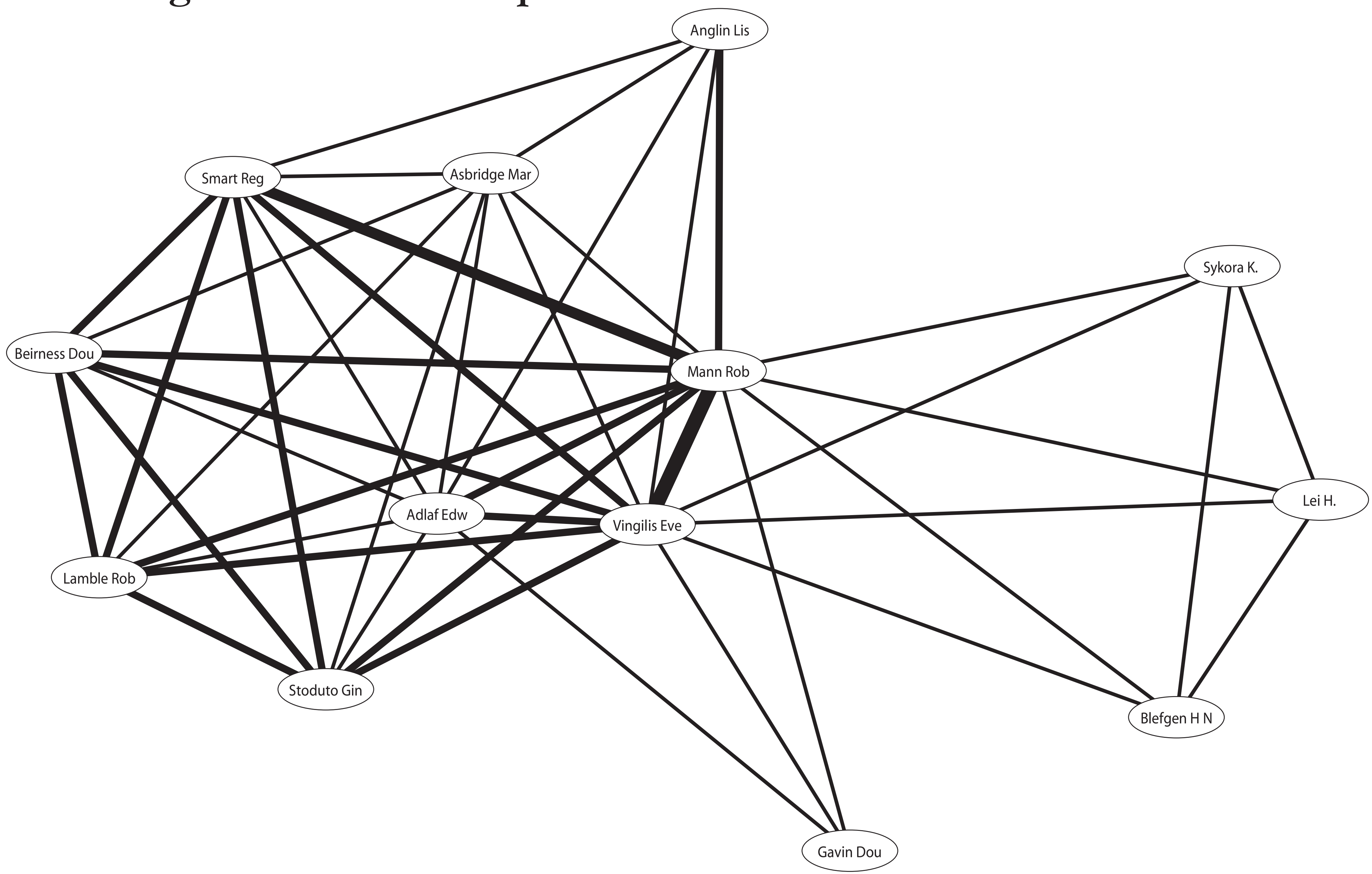
Hint: Thickness of edges increases with number of papers.

Network Figure 6: Bailey-Component



Hint: Thickness of edges increases with number of papers.

Network Figure 7: Mann-Component



Hint: Thickness of edges increases with number of papers.

Chapter 6

Supplement

6.1 Glossary

This is a non-mathematical glossary of basic network notions. The list is sorted from simple to more complex notions.

(1)	VERTEX, pl. Vertices	Nodes in networks often represent players, companies, authors or other economic units.
(2)	LINK	A line in a network which directly (without involving other vertices) connects two vertices and typically indicates a relationship between them. Each link is either an arc, an edge or a loop.
(3)	MULTIPLE LINK	If more than one direct link between two vertices exist than a multiple link is formed. For instance, a multiple-link in a coauthor network indicates that two researchers collaborated several times.

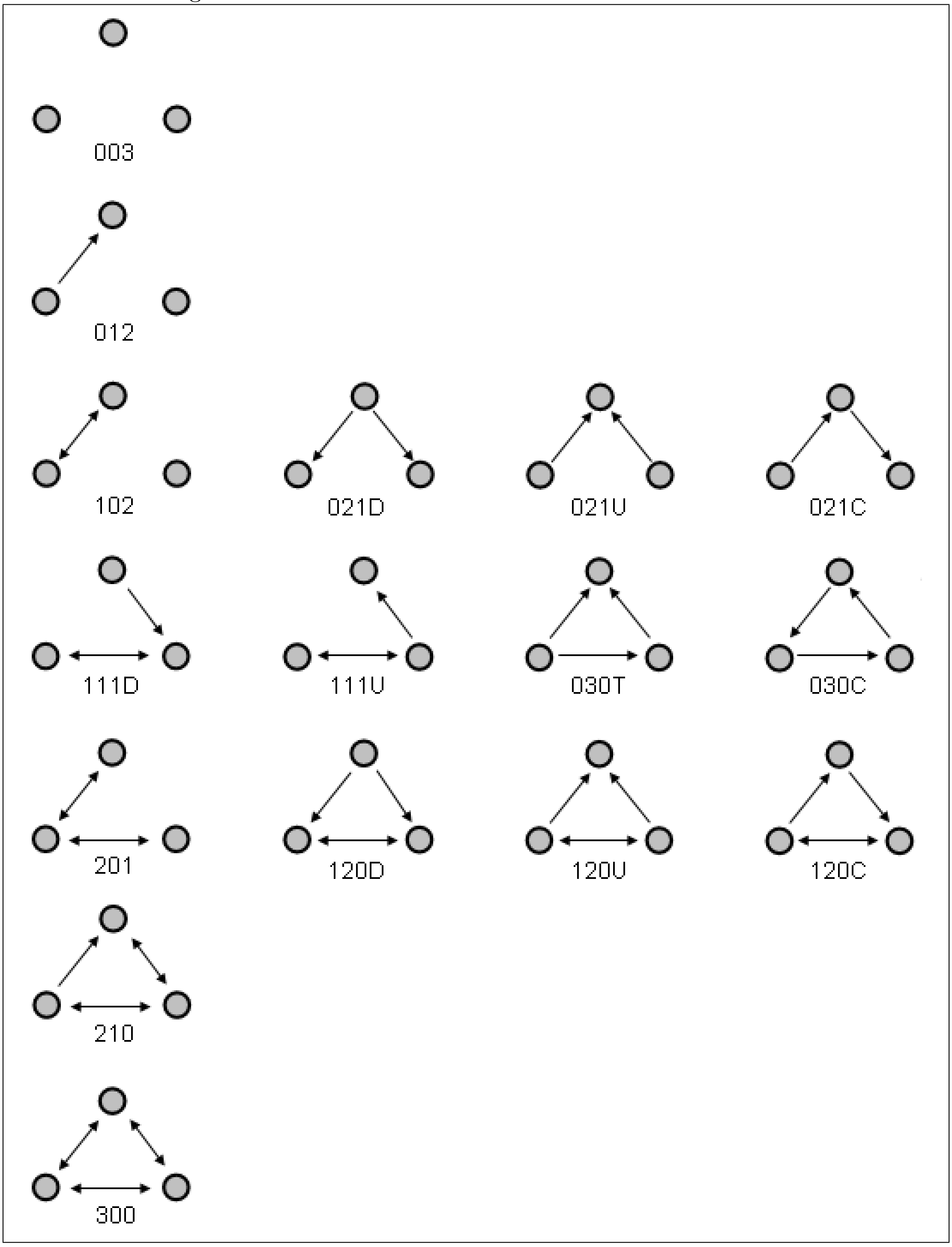
(4)	ARC	An arc is a directed link. In Chapter 3, an arc from vertex A to vertex B indicates that company A is owned by company B.
(5)	EDGE	An edge is a non-directed link. Coauthor relationship can be represented by edges since if author A has worked with B then B has also worked with A.
(6)	LOOP	A loop is a link which starts and ends at the same vertex.
(7)	NETWORK	A network consists of vertices being connected by links.
(8)	BIPARTITE NETWORK	A bipartite network consists of two partitions where links are only formed between partitions but not within each partition. For instance, research articles and researchers are two partitions where links between a researcher and an article indicate that the researcher is an author of the article.
(9)	COMPONENT	Each network can be partitioned in components where each vertex within a component is directly or indirectly connected to each other vertex within the same component whereas no direct nor indirect connection exists between vertices of different components.
(10)	GIANT COMPONENT	The giant component contains a large number of vertices of a network.
(11)	PATH	A path consists of vertices and links such that vertices are adjacent and links are incident to each other and each vertex and link occurs only once.
(12)	GEODESIC	The geodesic is the shortest path between two vertices.
(13)	DISTANCE	The distance of two vertices within a network is defined as the number of links on the geodesic.
(14)	SMALL-WORLD	Milgram (1967) discovers that most humans on earth are only separated by a few links within their acquaintance network. Accordingly, this network characteristic is called the small-world property.
(15)	DEGREE	The degree of a vertex is the number of links emanating from it (also called Degree-Centrality).
(16)	INDEGREE	The indegree of a vertex is the number of incoming arcs of the vertex.

(17)	Outdegree	The outdegree of a vertex is the number of arcs emanating from the vertex.
(18)	Closeness-Centrality	"The closeness centrality of a vertex is the number of all other vertices divided by the sum of all distances between the vertex and all others" (cf. de Nooy et al. 2005).
(19)	Empty Network	An empty network only consists of non-connected vertices, i.e. no links exist at all.
(20)	Star	A star network consists of a centre vertex being connected to each other vertex whereas each other vertex is only directly connected to the centre.
(21)	Regular Network	In a regular network each vertex has the same number of links. For example, the empty network and the complete network are regular.
(22)	Complete Network	In a complete network each vertex is directly connected to each other vertex.
(23)	Network Density	The number of existing links in a network relative to the number of all possible links in the same network.
(24)	Cluster Coefficient	The number of existing links in a subset of vertices relative to the number of all possible links in that subset.
(25)	Dyad	A pair of vertices in a network with or without links.
(26)	Mutual Dyad	A pair of vertices with two arcs or an edge.
(27)	Asymmetric Dyad	A pair of vertices with one arc.
(28)	Null Dyad	A pair of vertices with no links.
(29)	Triad	Three vertices in a network with or without links. A triad consists of three dyads where each dyad is either a mutual, asymmetric, or null dyad.
(30)	MAN classification scheme	16 possible existing triads where only the structural information is important and not the position of single vertices. Confer Figure 6.1.

6.2 MAN Classification Scheme

The MAN classification scheme is a mean to describe a network in brief. In a network with N vertices $\binom{N}{3}$ triads exist. MAN abbreviates **m**utual, **a**symmetric and **n**ull and denotes different links present or absent in dyads. Figure 6.1 shows all different triads which could exist in a network. The MAN classification scheme simply counts the number of triads among the $\binom{N}{3}$ existing triads. Table 6.1 shows corresponding probabilities for each triad if links are randomly formed.

Figure 6.1: All Triads in the MAN-Classification Scheme



Source: "The triad isomorphism classes (with standard MAN labeling)", Wasserman and Faust (1994), p. 566. The first three number counts the number of mutual dyads M, asymmetric dyads A, and null dyads N. The letter behind the number distinguishes otherwise identical triad formations from each other: D=Down, U=Up, C=Cycle, and T=Transitive.

Table 6.1: Probabilities in a Random Network

Conditional Probabilities for each triad type			
$P(003\|0L) = 1$			
$P(012\|1L) = 1$			
$P(102\|2L) = 0.2$	$P(021D\|2L) = 0.2$	$P(021U\|2L) = 0.2$	$P(021C\|2L) = 0.4$
$P(111D\|3L) = 0.3$	$P(111U\|3L) = 0.3$	$P(030T\|3L) = 0.3$	$P(030C\|3L) = 0.1$
$P(201\|4L) = 0.2$	$P(120D\|4L) = 0.2$	$P(120U\|4L) = 0.2$	$P(120C\|4L) = 0.4$
$P(210\|5L) = 1$			
$P(300\|6L) = 1$			
Probabilities that a certain number of links is formed in a triad.			
$P(0L) = \binom{6}{0} p^0 (1-p)^6$			
$P(1L) = \binom{6}{1} p^1 (1-p)^5$			
$P(2L) = \binom{6}{2} p^2 (1-p)^4$			
$P(3L) = \binom{6}{3} p^3 (1-p)^3$			
$P(4L) = \binom{6}{4} p^4 (1-p)^2$			
$P(5L) = \binom{6}{5} p^5 (1-p)^1$			
$P(6L) = \binom{6}{6} p^6 (1-p)^0$			

Own Source: A random network is defined as a network where each link has the same formation probability p. In our case $p = \frac{Existing\ Links}{Maximal\ Number\ of\ Links} = \frac{3711}{2784\ 2783} = 0.00047897$. Therefore, the expected number of triads which include many arcs in Table 3.3, for instance number of 300-triad, 210-triads, etc., is close to zero. 0L=zero links are formed, 1L=one link is formed,...,6L=six links are formed. It holds that $P(2L) = P(102) + P(021D) + P(021U) + P(021C)$ and similar for $P(3L)$ and $P(4L)$.

References

Agarwal, R. and J. A. Elston (2001). Bank-Firm Relationships, Financing, and Firm Performance in Germany. Economic Letters 72:225-232.

Albach, H. and H.-P. Kless (1982). Personelle Verflechtungen bei deutschen Industrieaktiengesellschaften. Zeitschrift f¨ur Betriebswirtschaft 52:959-977.

Allen, J. W. and G. M. Phillips (2000). Corporate Equity Ownership, Strategic Alliances, and Product Market Relationships. Journal of Finance 55:2791-2815.

Angilella, S., S. Greco, F. Lamantia and B. Matarazzo (2004). Assessing non-additive utility for multicriteria decsision aid. European Journal of Operational Research 158:734-744.

Atanasov, V. (2005). How much value can blockholders tunnel? Evidence from the Bulgarian mass privatization auctions. Journal of Financial Economics 76:191-234.

Attig, N., K. Fischer and Y. Gadhoum (2003). On the Determinants of Pyramidal Ownership: Evidence on Dilution of Minority Interests. Working Paper.

Bala, V. and S. Goyal (2000). A Noncooperative Model of Network Formation. Econometrica 68(5):1181-1229.

Bailey, W. C. (1998). Deterrence, Brutalization, and the Death Penalty - Another Examination of Oklahomas Return to Capital Punishment. Criminology 36(4):711-733.

Ballester, C., A. Calvó-Armengol and Y. Zenou (2006). Who's Who in Networks. Wanted: The Keyplayer. Econometrica 74(5):1403-1417.

Barabási, A.-L., and R. Albert (1999). Emergence of Scaling in Random Networks. Science 286:509-512.

Barabási, A.L., H. Jeong, Z. Néda, E. Ravasz, A. Schubert, and T. Vicsek (2001). Evolution of the social network of scientific collaborations, arXiv:cond-mat/0104162v1, 10 Apr 2001, last version, March 10, 2006.

Batagelj, V. and Andrej Mrvar (2000). Some analyses of Erdös collaboration graph. Social Networks 22:173-186.

Beauchamp, M. A. 1965). An improved index of centrality. Behavioral Science 10:161-163.

Beaver, deB D. and R. Rosen (1978). Studies in scientific collaboration Part I. The professional origins of scientific co-authorship. Scientometrics 1(1):65-84.

Bebchuk, L. A., R. Kraakman and G. Triantis (2000). Stock Pyramids, Cross-Ownership and Dual Class Equity: The Mechanisms and Agency Costs of Separating Control From Cash-Flow Rights, in R. Morck, ed.: Concentrated Corporate Ownership (University of Chicago Press, Chicago, IL).

Becht, M. and E. Böhmer (2003). Voting control in German corporations. International Review of Law and Economics 23:1-29.

Becht, M. and Böhmer, E. (2001). Ownership and voting power in Germany. In F. Barca and M. Becht (eds.), The control of corporate Europe. Oxford: Oxford University Press, 128-153.

Becht, M. and A. Röell (1999). Blockholdings in Europe: An international comparison. European Economic Review 43:1049-1056.

Becht, M. and E. Böhmer (1997). The transparency of ownership and control in Germany, in European Corporate Governance Network. The separation of ownership and control: A survey of 7 European countries. Preliminary report to the European Commission (Vol. 3). Brussels: European Corporate Governance Network (http://www.ecgn.org/ecgn/euprelimreport.htm).

Becker, G. S. (1968). Crime and Punishment: An Economic Approach. Journal of Political Economy 76(2):169-217.

Bentham, J. (1789). An introduction to the principles of morals and legislation. London, Payne. Republished in Oxford: Clarendron Press, 1907.

Berle, A. and G. Means (1932). The Modern Corporation and Private Property, New York, Macmillan.

Bertrand, M., P. Mehta and S. Mullainathan (2002). Ferreting out Tunneling: An Application to Indian Business Groups. Quarterly Journal of Economics 117:121-148.

Beyer, J. and M. Höpner (2004). Alle Macht den Aktionären? Unternehmenskontrolle in Deutschland, Max-Planck-Institut f¨ur Gesellschaftsfrschung, Deutschland.

Börner, K., J.T. Maru, R.L. Goldstone (2004). The simultaneous evolution of author and paper networks. pnas 101(1):5266-5273.

Bonacich, P. (1987). Power and Centrality: A Family of Measures. American Journal of Sociology 92:1170-1182.

Borgatti, S.P., M.G. Everett, and L.C. Freeman (2002). Ucinet for Windows: Software for Social Network Analysis. Harvard: Analytic Technologies.

Borgatti, S.P. (2003). The Key Player Problem, in Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers. Ed. by R. Breiger, K. Carley, and P. Pattison. Washington, DC.

Bremholm, T.L. (2004). Author Productivity and Citation Frequency in the Proceedings of the Oklahoma Academy of Science, 1921-2000. Proceedings of the Oklahoma Academy of Science 84:53-66.

Burkart, M., F. Panunzi and A. Shleifer (2003). Family Firms. Journal of Finance 58:2167-2201.

Calvó-Armengol, A. (2004). Job contact networks. Journal of Economic Theory 115:191-206.

Carayol, N., P. Roux and M. Yildizoglu (2005). Efficiency of network structures: The needle in the haystack. Cahiers du GRES, (2005-06).

Chapelle, A. and A. Szafarz (2005). Controlling firms through the majority voting rule. Physica A 355:509-529.

Claessens, S., S. Djankov and L. Lang (2000). The Separation of Ownership and Control in East Asian Corporations. Journal of Financial Economics 52:81-112.

Clarke, B.L. (1964). Multiple Authorship Trends in Scientific Papers. Science 143:822-24.

Combes, P.-P., L. Linnemer, M. Visser (2006). Publish or Peer-rich? The Role of Skills and Networks in Hiring Economics Professors. Working Paper, Insitut National de la Recherche Agronomique.

Core, J., R. Holthausen and D. Larcker (1999). Corporate governance, chief executive officer compensation, and firm performance. Journal of Financial Economics 51:371-406.

Cronin, B. (2001). Hyperauthorship: a postmodern perversion or evidence of a structural shift in scholarly communication practices? Journal of the American Society for Information Science and Technology 52:558-569.

de Nooy, W., A. Mrvar and V. Batagelj (2005). Exploratory Social Network Analysis with Pajek. Cambridge University Press.

Del Guercio, D. and J. Hawkins (1999). The motivation and impact of pension fund activism. Journal of Financial Economics 52:293-340.

Dittmann, I., E. Maug and C. Schneider (2005). Bankers and the Performance of German Firms. Working Paper, University of Mannheim.

Dölling, D., D. Hermann, A. Häring, T. Rupp and A. Woll (2007). Zur generalpräventiven Abschreckungswirkung des Strafrechts - Befunde einer Metaanalyse, erscheint in Helmut Kury (Hrsg.): Soziale Probleme, Sonderausgabe: Härtere Strafen - weniger Kriminalität? Zur Verschärfung der Sanktionseinstellungen.

Dölling, D., H. Entorf, D. Hermann, T. Rupp and A. Woll (2006). Metaanalyse empirischer Abschreckungsstudien Untersuchungsansatz und erste empirische Befunde. Darmstadt Discussion Paper in Economics Nr. 170, Darmstadt.

Edwards, J. S. S. and A. J. Weichenrieder (2004). Ownership Concentration and Share Valuation. German Economic Review 5:143.

Ehrlich, I. (1973). Participation in Illegitimate Activities: A Theoretical and Empirical Investigation. Journal of Political Economy 81:521-565.

Ehrlich, I. and L. Zhiqiang (1999). Sensitivity Analyses of the Deterrence Hypothesis: Let's Keep the Econ in Econometrics. Journal of Law and Economics 42(1):455-487.

Einav, L. and L. Yariv (2006). What's in a Surname? The Effects of Surname Initials on Academic Success. Journal of Economic Perspectives 20(1):175-188.

Entorf, H. and H. Spengler (2002). Crime in Europe. Springer-Verlag Berlin Heidelberg New York.

Faccio, M. and L.H.P. Lang (2002). The ultimate ownership of Western European corporations. Journal of Financial Economics 65:365-395.

Fafchamps, M. M. J. van der Leij and S. Goyal (2006). Scientific Networks and Co-authorship. Discussion Paper Series, University of Oxford.

Fee, C. E., C. J. Hadlock and T. Shawn (2006). Corporate Equity Ownership and the Governance of Product Market Relationships. Journal of Finance 61(3):1217-1251.

Fich, E. and L. White (2003). CEO compensation and turnover: The effects of mutually interlocked boards. Wake Forest Law Review 38(3):935-959.

Fich, E. and A. Shivdasani (2006). Are Busy Boards Effective Monitors? Journal of Finance LXI(2):689-724.

Fohlin, C. (2005). The History of Corporate Ownership and Control in Germany. In R. K. Morck, ed.: A History of Corporate Governance Around the World: Family Business Groups to Professional Managers (University of Chicago Press, Chicago, IL).

Franks, J. R. and C. Mayer (2001). Ownership and Control of German Corporations. Review of Financial Studies 14:943-977.

Franks, J. R., C. Mayer and H. F. Wagner (2005). The Origins of the German Corporation - Finance, Ownership and Control. ECGI - Finance Working Paper No. 110/2005.

Freeman, L.C. (1979). Centrality in affiliation networks. Social Networks 19:157-191.

German Corporate Governance Codex (2006). Deutscher Corporate Governance Kodex, $http : //www.corporate - governance - code.de$, last visit on 07 May 2007.

German Shareholder Association (2003). Table in the appendix of "DSW-Studie zur Vorstandsverg¨utung: Pressekonferenz der DSW am 15. Dezember 2003 in Berlin" (Deutsche Schutzvereinigung für Wertpapierbesitz), $http : //www.dsw - info.de/uploads/media/Tabelle1.pdf$, last visit on 23 January 2007.

German Shareholder Association (2005). Table in the appendix of "DSW-Studie zur Vorstandsverg¨utung: Pressekonferenz der DSW am 20. September 2005 in Frankfurt" (Deutsche Schutzvereinigung für Wertpapierbesitz), $http : //www.dsw - info.de/uploads/media/Tabelle_0 1.pdf$, last visit on 23 January 2007.

German Shareholder Association (2006). Table in the appendix of "DSW-Studie zur Vorstandsverg¨utung: Pressekonferenz am 16. Oktober 2006 in Frankfurt" (Deutsche Schutzvereinigung f¨ur Wertpapierbesitz), $http : //www.dsw - info.de/uploads/media/Tabelle_D SW - Pressekonferenz.pdf$, last visit on 23 January 2007.

Gill, P.S. and T.B. Swartz (2004). Bayesian analysis of directed graphs with applications to social networks. Applied Statistics 53:249-260.

Glänzel, W. (2001). National characteristics in international scientific co-authorship relations. Scientometrics 51(1):69-115.

Glänzel, W. and A. Schubert (2004). Analyzing Scientific Networks through Co-authorship. In H.F. Moed et al. (eds.), Handbook of Quantitative Science and Technology Research 257-276.

Glaeser, E.L. (2006). Researcher Incentives and Empirical Methods, Harvard Institute of Economic Research. Discussion Paper Number 2122, October 2006.

Goergen, M., M.C. Manjon Antolin and L. Renneboog (2004). Recent Developments in German Corporate Governance. ECGI, Finance Working Paper No. 41.

Godsil, C. and G. Royle (2001). Algebraic Graph Theory. Graduate Texts in Mathematics (Springer Verlag).

Goffman, C. (1969). And what is your Erdös number? American Mathematical Monthly 76:791.

Goldstein, M. L., S.A. Morris and G.G. Yen (2005). Group-based Yule model for bipartite author-paper networks. Physical Review E 71:026108-1 – 026108-6.

Gorton, G. and F.A. Schmid (2000). Universal banking and the performance of German firms. Journal of Financial Economics 58:29-80.

Gossart, C. and M. Özman (2007). Fostering national research networks: The case of Turkish coauthorship patterns in the social sciences. Working paper.

Goyal, S., M. van der Leij and J.L. Moraga-González (2006). Economics: an emerging small world? Journal of Political Economy 114(2):403-432.

Gray, L. N. and D. J. Martin (1969). Punishment and Deterrence - Another Analysis of Gibbs Data. Social Science Quarterly 49:389-395.

Guedj, I. and A. Barnea (2007). CEO Compensation and Director Networks. EFA 2007 Ljubljana Meetings Paper.

Hallock, K. F. (1997). Reciprocally Interlocking Boards of Directors and Executive Compensation. Journal of Financial and Quantitative Analysis 32(3):331-344.

Hanany, E. (2001). The Ordinal Nash Social Welfare Function. CMS-EMS, Northwestern University, hananye@northwestern.edu.

Heinze, T. (2004). Dynamics in the German System of Corporate Governance? Empirical Findings regarding Interlocking Directorates. Economy & Society 33:218-238

Holland, P. W. and S. Leinhardt (1970). A method for detecting structure sociometric data. American Journal of Sociology 76:492-513.

Hollis, A. (2001). Co-authorship and the output of academic economists. Labour Economics 8:503-530.

Höpner, M. (2002). Wer beherrscht die Unternehmen? Shareholder Value, Managerherrschaft und Mitbestimmung in Deutschland. Dissertation Fern-Universität Hagen.

Höpner, M. and L. Krempel (2004). The Politics of the German Company Network. Competition and Change 8:339-356.

Jackson, M. O. and A. Wolinsky (1996). A Strategic Model of Social and Economic Networks. Journal of Economic Theory 71:44-74.

Jensen, E. L. and L. K. Metsger (1994). A Test of the Deterrent Effect of Legislative Waiver on Violent Juvenile Crime. Crime and Delinquency 40(1):96-104.

Johnson, S., R. La Porta, F. Lopez-de-Silanes and A. Shleifer (2000). Tunneling. American Economic Review 90:22-27.

Kalaitzidakis, P., T. P. Mamuneas, and T. Stengos (1999). European economics: An analysis based on publications in the core journals. European Economic Review 43:1150-1168.

Kalaitzidakis, P., T. P. Mamuneas, and T. Stengos (2003). Rankings of academic journals and institutions in economics. Journal of the European Economic Association 1:1346-1366.

Kammerath, J. (1999). Methodische und empirische Grundlagen der quantitativen Erfassung kontrollierender Verbindungen deutscher Unternehmen mit ihren direkten und indirekten Eignern. Report commissioned by the Ifo-Institute, Munich.

Kaneko, M. and K. Nakamura (1979). The Nash Social Welfare Function. Econometrica 47:423-435.

Kaserer, C. and N. Wagner (2004). Executive Pay, Free Float, and Firm Performance: Evidence from Germany. Working Paper, Technische Universität München.

Katz, L., S. D. Levitt, and E. Shustorovich (2003). Prison Conditions, Capital Punishment and Deterrence. American Law and Economic Review 5(2):318-343.

Kengelbach, J. and A. Roos (2006). Entflechtung der Deutschland AG. The Boston Consulting Group GmbH, Sonderdruck aus M&A Review, Heft 1/2006:12-21.

Kogut, B. and G. Walker (2001). The Small World of Germany and the Durability of National Networks. American Sociological Review 66:317-335.

Köke, F. J. (1999). New evidence on ownership structures in Germany. ZEW Working Paper No. 99-60, Mannheim.

Koschützki, D K., A. Lehmann, L. Peeters, S. Richter, D. Tenfelde-Podehl and O. Zlotowski (2005). Centrality Indices. In Ulrik Brandes and Thomas Erlebach ed.: Network Analysis, Lecture Notes in Computer Science (Springer Verlag).

Kramarz, F. and D. Thesmar (2006). Social Networks in the Boardroom. CEPR Discussion Papers 5496.

Kruse, T. A. (2005). Ownership, Control and Shareholder Value in Italy: Olivetti's Hostile Takeover of Telecom Italia. Finance Working Paper 83, University of Arkansas.

La Porta, R., F. Lopes-de-Silanes, A. Shleifer and R. W. Vishny (1998). Law and finance. Journal of Political Economy 106:1113-1155.

La Porta, R., F. Lopes-de-Silanes and A. Shleifer (1999). Corporate Ownership Around the World. Journal of Finance 54:471-517.

La Porta, R., F. Lopes-de-Silanes, A. Shleifer and R. W. Vishny (2002). Investor Protection and Corporate Valuation. Journal of Finance 57:1147-1170.

Laband, D. N. and R. D. Tollison (2000). Intellectual Collaboration. Journal of Political Economy 108(3):632-662.

Laband, D. N. and R. D. Tollison (2006). Alphabetized Coauthorship. Applied Economics 38:1649-1653.

Larcker, D., S. Richardson, A. Seary, and I. Tuna (2005). Director Networks, Executive Compensation, and Organizational Performance, Working Paper, Stanford // Wharton.

Leech, Dennis (2002). An Empirical Comparison of the Performance of Classical Power Indices. In: Political Studies 50:1-22.

Lemmon, M. L. and K. V. Lins (2003). Ownership Structure, Corporate Governance, and Firm Value: Evidence from East Asian Financial Crisis. Journal of Finance 58:1145-1168.

Lincoln, J. R., M. Gerlach and C. Ahmadjian (1996). Keiretsu networks and corporate performance in Japan. American Sociological Review 61:67-88.

Lincoln, J. R. and M. Gerlach (2004). Japan's Network Economy: Structure, Persistence, and Change (Cambridge University Press).

Lotka, A. J. (1926). The frequency distribution of scientific productivity. Journal of Wash Acad Sci 16:317-323.

Mann, R. E., R. G. Smart, G. Stoduto, E. Adlaf, E. R. Vingilis, D. Beirness, R. Lamble, M. Asbridge (2003). The Effects of Drinking-Driving Laws: a Test of the Differential Deterrence Hypothesis. Addiction 98(11):1531-1536.

MathSciNet. Mathematical Reviews on the Web. http://www.ams.org/mathscinet, American Mathematical Society.

Maury, B. (2005). Family ownership and firm performance: Empirical evidence from Western European corporations. Journal of Corporate Finance 12:321-341.

Meoli, M., S. Paleari and G. Urga (2006). When controlling shareholders "live like kings". The case of Telecom Italia. Working Paper.

Miczaika, J and P. Witt (2004). Personelle Verflechtungen, Vorstandsvergütung und Aktionärsrendite. V. Symposium zur Ökonomischen Analyse der Unternehmung, Vallendar.

Milgram, S. (1967). Small-World Problem. Psychology Today 1(1):61-67.

Mitzenmacher, M. (2003). A Brief History of Generative Models for Power Law and Lognormal Distributions. Internet Mathematics 1(2):226-251.

Miyajima, H. and F. Kuroki (2005). The Unwinding of Cross-Shareholding in Japan: Causes, Effects, and Implications. RIETI Discussion Paper Series 05-E-006.

Montmarquette, C., M. Nerlove and P. Forest (1985). Deterrence and Delinquency - An Analysis of Individual Data. Journal of Quantitative Criminology 1(1):37-58.

Moreno, J. L. (1934). Who Shall Survive? Foundations of Sociometry, Group Psychotherapy and Sociodrama. Nervous and Mental Disease Publishing Company, Washington, DC.

Nash, J. F. (1950). Two-Person Cooperative Games. Econometrica 21(1):128-140.

Neary, J.P., J. A. Mirrlees, and J. Tirole (2003). Evaluating Economics Research in Europe: An Introduction. Journal of the European Economic Association 1(6):1239-1249.

Newman, M. E. J. (2001a). Scientific collaboration networks. I. Network construction and fundamental results. Physical Review E 64:016131.

Newman, M. E. J. (2001b). Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality. Physical Review E 64:016132.

Newman, M. E. J. (2001c). The structure of scientific collaboration networks. Proceedings of the National Academy of Sciences 98:404-409.

Newman, M. E. J. (2004). Coauthorship networks and patterns of scientific collaboration. Proceedings of the National Academy of Sciences 101:5200-5205.

Non, M. C. and P.H. Franses (2007). Interlocking Boards and Firm Performance: Evidence from a New Panel Database. Tinbergen Institute Discussion Papers 07-034/2, Tinbergen Institute.

Nowak, E., O. Ehrhardt and F. M. Weber (2006). 'Running in the Family': The Evolution of Ownership, Control, and Performance in German Family-Owned Firms, 1903-2003. Swiss Finance Institute Research Paper No. 06-13.

Pappi, F. U., P. Kappelhoff and C. Melbeck (1987). Die Struktur der Unternehmensverflechtungen in der Bundesrepublik. Eine Blockmodellanalyse der Personal- und Kapitalverflechtungen zwischen den größten Unternehmen. Kölner Zeitschrift für Soziologie und Sozialpsychologie 39:693-717.

Pratt, T. C. (2001). Assessing the relative Effects of Macro-Level Predictors of Crime: A Meta-Analysis. Dissertation, mimeo.

Prigge, S. (2007). The Performance of Measures of Shareholder Influence. University of Hamburg, mimeo.

Prinz, E. (2006). Director Networks in Germany and their Impact on Financial Performance. Université de Bourgogne - LEG/Fargo Working Paper 1061001, LEG/Fargo (Research center in Finance, organizational ARchitecture and GOvernance).

Rawls, J. (1971). A Theory of Justice. Harvard University Press, Boston.

Rupp, T. (2006). Meta Analysis of Empirical Deterrence Studies: an explorative contest. Darmstadt Discussion Paper in Economics Nr. 174, Darmstadt.

Rupp, T. (2008). Meta Analysis of Crime and Deterrence - A Comprehensive Review of the Literature. Dissertation, Darmstadt University of Technology (forthcoming).

Sabidussi, G. (1966). The centrality index of a graph. Psychometrika 31:581-603.

Schmid, F. A. (1997). Vorstandsbezüge, Aufsichtsratsvergütung und Aktionärsstruktur. Zeitschrift für Betriebswirtschaft 67:67-83.

Schuessler, K. F. (1952). The Deterrent Influence of the Death Penalty. Annals of the American Academy of Political and Social Science 284:54-62.

Sen, A. (1979). Utilitarianism and Welfarism. The Journal of Philosophy 76(9):463-489.

Sen, A. (1999). The Possibility of Social Choice. American Economic Review, 89(3):349-378.

Shleifer, A. and R. Vishny (1997). A survey of corporate governance. Journal of Finance 52:737-784.

Slesnick, D. T. (1998). Empirical Approaches to the Measurement of Welfare. Journal of Economic Literature XXXVI:2108-2165.

Süssmuth, B., M. Steininger and S. Ghio (2006). Towards a European economics of economics: Montoring a decade of top research and providing some explanations. Scientometrics 66(3):579-612.

Sutter, M. and M. Kocher (2004). Patterns of co-authorship among economics departments in the USA. Applied Economics 36:327-333.

Terberger, E. (2003). The German financial system: great institutional change and little effect? Journal of Theoretical and Institutional Economics 159:707-716.

Watts, D. and S. Strogatz (1998). Collective Dynamics of 'Small World' Dynamics. Nature 393:440-442.

Villalonga, B. and R. Amit (2006). How do family ownership, control and management affect firm value? Journal of Financial Economics 80:385-417.

Wasserman, S. and K. Faust (1994). Social Network Analysis: Methods and Applications (Cambridge University Press).

Windolf, P. and J. Beyer (1995). Kooperativer Kapitalismus. Unternehmensverflechtungen im internationalen Vergleich. Kölner Zeitschrift für Soziologie und Sozialpsychologie 17(1):1-36.

Windolf, P. and J. Beyer (1996). Cooperative Capitalism. British Journal of Sociology 47:205-231.

Windolf, P. and M. Nollert (2001). Institutionen, Interessen, Netzwerke: Unternehmensverflechtung im internationalen Vergleich. Politische Vierteljahresschrift 42:51-78.

Windolf, P. (2002). Corporate Networks in Europe and the United States (Oxford University Press).

Windolf, P. (2005). The Emergence of Corporate Networks in Germany and the United States 1896-1938. Working Paper.

Winter, S. (2002). Management- und Aufsichtsratsvergütung unter besonderer Ber¨ucksichtigung von Stock Options - Lösung eines Problems oder zu lösendes Problem? In: Hommelhoff, Peter, Hopt, Klaus J., von Werder, Axel (Hrsg.): Handbuch Corporate Governance. Otto Schmidt und Schäffer-Poeschel, Köln, Stuttgart.

Yafeh, Y. and O. Yosha (2003). Large Shareholders and Banks: Who Monitors and How? Economic Journal 113:128-146.

Yoshikane, F., T. Nozawa and K. Tsuji (2006). Comparative analysis of co-authorship networks considering author's roles in collaboration: Differences between the theoretical and application areas. Scientometrics 68(3):643-655.

Erklärung

Gemäß §9 der Allgemeinen Bestimmung der Promotionsordnung der Technischen Universität Darmstadt vom 12. Januar 1990 (Abl. 1990, S. 658) in der Fassung der VI. Änderung vom 15. Februar 2006 versichere ich hiermit, die vorliegende Dissertation ohne unzulässige fremde Hilfe und nur mit den ausdrücklich genannten Quellen und Hilfsmitteln selbständig verfasst zu haben.

Darmstadt, 17. April 2008 Jochen Möbert

Lebenslauf

Jochen Möbert studierte an der Universität Mannheim Volkswirtschaftslehre und promovierte in Barcelona, Mannheim und Darmstadt. In seiner Dissertation beschäftigte er sich mit sozialen Netzwerken als auch Unternehmensnetzwerken.