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ABSTRACT

We analyze the dynamics of the Japanese board network from 2004 until 2013. We find that the network exhibits some clustering with visible firm conglomerates. Ties between firms are rather persistent, despite noticeable churning among directors. Ownership relations explain only a small fraction of board links. Besides densely connected conglomerates, some tendency of within-sector linkages and linkages to financial institutions can be confirmed. We further investigate the increase in the number of outside directors and find that sectoral differences as well as shareholder characteristics explain to large extend the variation in board composition. The connectivity of firms in the ownership and board network is sometimes related to firm profitability. Firms that are linked to peers with above average profitability are likely also more profitable than firms in other ownership relationships.

Keywords: corporate board interlock, corporate governance, board composition

JEL classification: L14, M12, G32

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1. Introduction

We study the dynamics and the determinants of the corporate board interlocks of roughly 4,000 Japanese firm from 2004 until 2013. These interlocks emerge when directors serve on the board of more than one company. Board interlocks have been investigated in the literature for several reasons. First of all studies have analyzed to which extend shared directors exist as a natural consequence of ownership and control. More importantly however shared directors and other interorganizational networks have been analyzed as influencing factor for firm profitability, strategy, managerial practice and corporate governance (see, e.g., Hermalin and Weisbach, 2003; Provan et al., 2007; Mizruchi, 1996; Gulati and Gargiulo, 1999).

Corporate interlocks are also an interesting phenomenon for social networks science, since the networks of directors with multiple mandates are (partly by construction) very dense and show high degrees of clustering, even though the average connectivity is very low (Conyon and Muldoon, 2006; Davis et al., 2003; Battiston and Catanzaro, 2004). This raises the question how the structure of this network might influence decision making and the formation interest groups (Borgatti, 2006; Haunschild and Beckmann, 1998; Kramarz and Thesmar, 1992). It also leads to the discussion that is concerned with the dynamics of this network.

Less research has focused on the dynamics of corporate interlocks, but it seems clear that some amplification mechanisms are in place that foster multiple mandates at highly capitalized firms and that imply replacement of very central directors with alike peers when mangers retire or leave the company (Milaković et al., 2010; Bellenzier and Grassi, 2014; Mariolis and Jones, 1982).

The dynamics of corporate interlocks have also been analyzed with respect to changes in the relationship of public and private companies, and the changes in funding policies and capital market requirements. The privatization of former public companies and the emphasis of shareholder value principles are forces that tendencially lead to the desolution of dense clusters of board interlocks (Heemskerk, 2007). Current research has however shown that rather a quantitative but not a qualitative decrease of board interlock can be observed (Kogut and Walker, 2001; Raddant et al., 2017)

Network ties and board interlock have also been analyzed for Japan. Some studies have focused on ties in the automotive industry (Asanuma, 1985), other studies include (Schaede, 1995; Lincoln and Gerlach, 2004; Nakano and

Nguyen, 2012; Lincoln et al., 1992). A topic that is specific the Japanese economy are the fading effects of the so-called *keiretsu* (Lincoln and Shimotani, 2001). This term describes six historic conglomerates of cooperations that have dominated the Japanese economic landscape after the second World War. Studies found that today only very few traces of their former structure can be found even though the names of the original concerns persist. Kanamitsu (2013) finds that the relationship between having long-serving CEOs and high firm centrality is fading, which could hint at a restructuring of the Japanese board network towards more business sector oriented board relationships.

A different facette of this debate is the composition of the board. There is no consensus in general about the question if the appointment of outside directors is of any benefit to ensure good governance and accurate reporting (see the survey by Petra, 2005). Neverthless we observe an increasing number of outside board members in Japan. Traditionally outside directors in Japan often come from banks, related corporations or are retired government officials. There is however no evidence that this leads to significant differences in company success (Miwa and Ramseyer, 2005). There is however evidence that foreign ownership has an effect on firm valuation (Mian and Nagata, 2015), which leaves the question if the growing number of outside directors can be connected to such influences.

In our study we focus on the dynamics of the Japanese corporate board network together with the most important ownership relationships. We find that the board network exhibits some clustering, which however is probably not a keiretsu remainder. Ties between companies are very persistent and we show that this is likely an effect of selective executive replacement. There is some increase in the number of outside directors, even though these are more likely to be replaced than regular board members. More detailed analysis reveals that outside board members are mainly hired at firms with high foreign share ownership and especially in the IT sector. In our analysis of firm profitability we find that ties between firms that perform above average can be beneficial. These ties can be part of both, the ownership or the board network.

In the following we will first review the data set and the methods that we have applied to it in order to discuss the resulting networks. After this we will present the dynamics of these networks on an aggregate level. In the next section we will then analyze where the persistence of ties in the company network stems from. After this we will discuss board composition and the role of outside directors. Finally we will analyze dependencies between firm network effects and profitability.

2. Materials and Methods

2.1. Company data and network generation

The Japanese system of corporate boards used to be a very special one at least until the 1990s. Boards used to be large, with little intend to care about international governance standards or even shareholder value. Really important decisions were taken within smaller groups of senior board members anyhow. The crisis of the 1990s lead to some change and influences from the US system. Following Sony, boards mostly shrank to a size of about 10 "corporate executive officers" plus 2 to 3 externals, including the auditor. An alternatively is the "company with committees" system. In this system additional to a board of directors three committees would handle audit, nomination and remuneration duties (Buchanan and Deakin, 2009). Hence, in our analysis we look in the very large majority at cases where the board of directors consists of 6 to 15 corporate executive officers, one auditor and possibly 1 or 2 outside board members. Only few mainly very large cooperations report up to 35 total board members.

For our analysis we collected the data on all publicly listed Japanese firms which were reporting to the Tokio Stock Exchange (TOPIX). This means that our sample includes all the roughly 1,700 firms of the so-called first section and also roughly the same amount of smaller firms. For our analysis we combine the data on the composition of company boards available from Toyo Keizai, with financial data obtained from Thompson Reuters Datastream. In particular we use the information on market value, income, total assets, the business sector and share holder composition.

The information on the composition of the board is updated annually in the middle of the year. Besides the names of the board members we obtain information on the age, gender and role of the director. The naming and numerical identifiers of board members are unanimous within each year, but not necessarily throughout the years. Hence we have developed an algorithm to trace the destinies of board members over time based on parts of their names, date of birth and affiliations.[1] The financial data of the firms is matched using the same yearly frequency.

[1] We have confirmed the validity of this algorithm by manual checks. The only known

The basics of the treatment of the board members data is simple. For each year we observe a set of directors and a set of firms. Board members serve on the boards of one or more firms. This creates relationships (incidences) between the set of board members and the set of firms, and resemble a bipartite graph. Incidences can be described by positive entries in a matrix I, where the dimensions of I are given by the number of firms and the number of board members within a year. Hence, if a manager i works for firm j the element I_{ij} is 1, and 0 otherwise.

From the incidence matrix I we can obtain two different un-directed networks by projection.

$A_D = II'$ creates an adjacency matrix for the network of board members, where positive entries resemble cases where board members know each other from serving on at least one firms' board together. In the following we will however focus on a different interpretation of the data, namely a network of firms.

By multiplying $I'I = A_B$ we obtain an adjacency matrix that describes the network of the firms based on board interlocks. A_B is a square matrix with as many rows and columns as we have firms in our sample. A positive entry A_{ij} describes a connection between the firms i and j that is given by at least one shared board members. In the following we will refer to this network as the board network.

2.2. Basic descriptive statistics over time

The networks that we look at naturally show some churning over time, caused by entry and exit of firms as well as retirement and replacement of board members. Nevertheless the basic statistics provided in table 1 show that the number of firms varies steadily between 3,532 and 3,943 (distinct: 4,505). In the same time the average number of board members is slightly declining from almost 12 in 2004 to 11.1 in 2013. The number of board members we observe per year lies around 40,000 (distinct: 95,192).

The middle part of table 1 shows some statistics for the board network. The mean degree and the very low density reveal that in fact most firms do not share any board member. Hence, for many investigations of this network

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limitation of this method is that we may loose traces of board members who exit the data set and re-appear at a later year at a different company. We are however confident that this problem applies only to a very limited number of board members who did not play a decisive role in the board member network anyhow.

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
counts	no. firms	3767	3849	3943	3887	3767	3672	3595	3543	3532	3545
	no. b. members	42175	42635	43121	41998	39907	38759	37731	36884	36452	36697
	no. mandates	45119	45760	46257	44991	42693	41461	40318	39458	39103	39503
	avg. board	11.98	11.89	11.73	11.57	11.33	11.29	11.22	11.14	11.07	11.14
	avg. mandates	1.070	1.073	1.073	1.071	1.070	1.070	1.069	1.070	1.073	1.076
	max mandates	11	9	8	8	8	8	7	7	7	7
board network	edges	3996	4281	4208	3932	3629	3491	3344	3310	3416	3646
	density	0.00014	0.00015	0.00014	0.00013	0.00013	0.00013	0.00013	0.00013	0.00014	0.00016
	mean degree	2.12	2.22	2.13	2.02	1.93	1.90	1.86	1.87	1.93	2.06
giant comp.	companies g.c.	1408	1571	1547	1495	1387	1383	1373	1380	1490	1625
	edges g.c.	3149	3538	3426	3132	2815	2728	2645	2648	2847	3132
	density g.c.	0.00080	0.00072	0.00072	0.00070	0.00073	0.00071	0.00070	0.00070	0.00064	0.00059
	mean degree g.c.	4.473	4.504	4.429	4.190	4.059	3.945	3.853	3.838	3.821	3.855
	clustering	0.1441	0.1416	0.1304	0.1184	0.1130	0.1082	0.1037	0.0985	0.1000	0.1023
	avg. clust. loc.	0.3192	0.3334	0.3241	0.3264	0.3032	0.2840	0.2806	0.2690	0.2628	0.2698
	max degree	23	26	28	25	26	29	27	30	31	23

Table 1: Network statistics

The table shows annual statistics for the board members (top part) , the board networks created by board members (middle part), and the giant component of the board network (bottom part). The networks become slightly less dense and less clustered over time. The number of companies and executives is slightly decreasing in the years after the financial crisis.

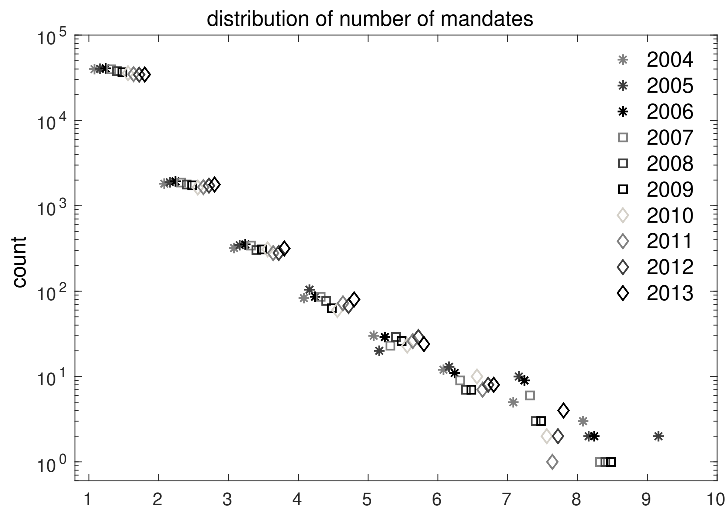

Figure 1: Mandates statistics.
We print the number of mandates with an offset and use a log-scale for the count. The tail of the distribution shows similarity to a power-law. The highest numbers of mandates are only observed until 2009.

it makes sense to focus on those firms which form the giant connected component of the board network. The statistics of this part of the board network are given in the bottom part of the table. This network is still a sparse one but shows features of a social network, for example some clustering.

All of these figures show a slight dip that falls in the period of 2006 – 2008. In this period we observe of drop of the (global) clustering coefficient, the number of firms, and the connectivity. The degree distribution of the board network roughly follows a power-law. The low range of degrees however prevent a sensible estimation, for details see figure A.7 in the appendix.

The disparity between the average number of mandates and its maximum rectify a short look at the distribution of the number of mandates. Figure 1 shows that this distribution is also heavy-tailed. While around 40,000 directors have around 1 mandate each year, only around 200 have 3 mandates, and only a handful of directors find themselves with 8 or more.

2.3. Visualization and clustering

A good starting point for the analysis of networks is to look at a visualization and to check for structures that indicate pronounced deviations from

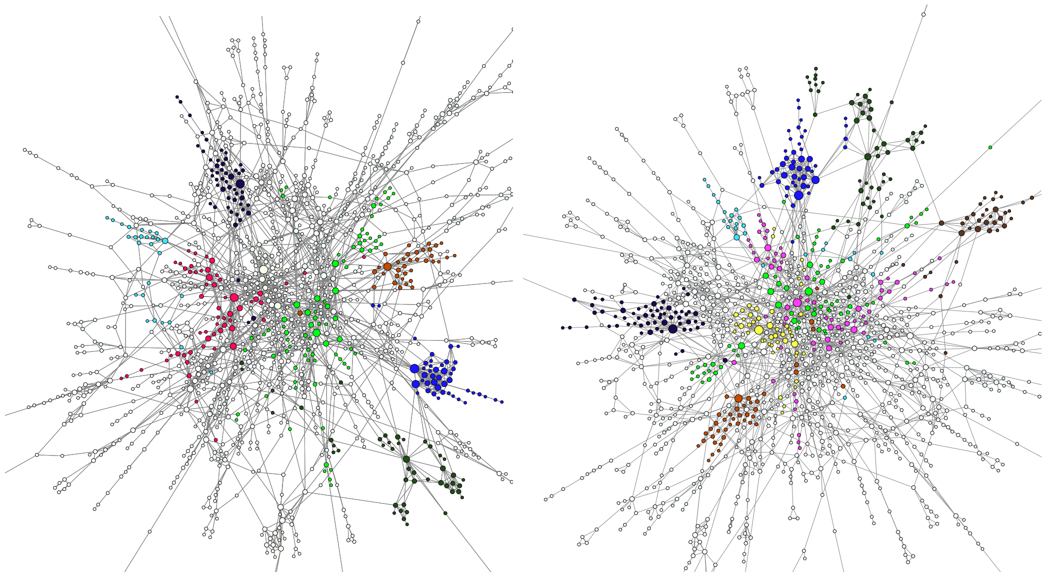

Figure 2: Board networks

Vizualisation of the giant components of the board network in 2004 (left) and 2013 (right). The node size is proportional to the firm's degree. Colors represent communities. The visualization was performed in Gephi with the Force Atlas algorithm (see Jacomy et al., 2014).

random connectivity. We have already verified that the degree distribution of the board network is close to a power-law, and in fact the visualizations in figure 2 look like rather typical scale-free graphs. The center is rather densely connected, including some hubs, the periphery thins out and shows the typical hair-like ends composed of degree two nodes.

The network visualizations shows some grouping, which however is not too pronounced. The details for a visualization therefore admittedly depend on the choice and parameterization of the algorithm that is used. The same holds for the identification of communities. We used the "fast unfolding" algorithm (Blondel et al., 2008) to search for communities in the networks and have color-coded the nodes based on the results. The left panel shows the giant component of the board network in 2003, the right panel shows 2013. The visual impression confirms our statistics, the network in the right panel is a bit less dense, the left panel shows slightly more clustering. We will only discuss the largest and most significant communities here and we have also omitted findings where communities are based on trivial 'holding

& subsidiary' structures. All such firms appear as plain white nodes.

In general the board networks have very few closed communities, even in the periphery we do have firms that provide shortcuts between groups. For example, for 2004 we can find three rather obvious communities outside the center of the network. To the top left of the center we find one group which is arranged around the company Toyota (dark purple). On the right side of the network we find a group (in blue) around Aeon. In the center of the network we find companies arranged around Fuji Kyuko (red), Hitachi (brown), and Mitsubishi (green).

Until 2013 the clusters in the middle of the network become even more overlapping. In the right panel we still see groups around Toyota, Aeon and Hitachi a bit away from the center of the network. In the center we see (slightly changed) intertwined areas around Fuji Kyuko (pink), Tokyu (yellow) and Mitsubishi (green). In the periphery some weaker structures exist around Softbank and SBI (beige), Rakuten (dark green), and Pioneer and Seiko Epson (brown). For more details see also figure A.9 in the appendix.

2.4. Ownership network

Links in the board network are to some extend of course the result of business activity between firms. In the most basic sense these can be relationships between producers and suppliers. For a study of such networks we refer the reader to the study by Krichene et al. (2018). For our purposes the analysis of this level of connectivity would however delve too deeply into a different direction. However, business relationships that are more elaborate often result in some kind of shareholding or even cross-shareholding relationship. Hence, to control for influences on the board network that stems from ownership relations we have obtained data that reports the five largest shareholders (and their exact shareholding) for all of the firms in our sample. This might at first seem a little restrictive, yet in practice significant influence onto a company is unlikely to be performed by more than five owners. Also, since this data is reported from the point of the owned company this still results in a rather complete picture of the ownership network.

In the following we will refer to the firm networks based ownership simply as the ownership networks. The ownership networks differs from the board networks by the fact that they are directed networks. The densities are however comparable, the ownership network in 2004 contains roughly 2574 links and we see a steady increase until 2013 when the network has 3695 links.

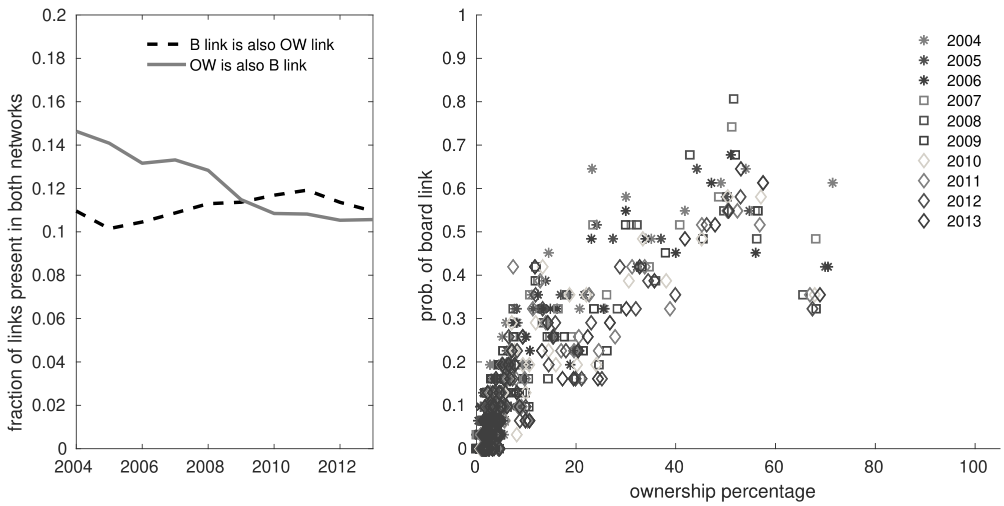

Figure 3: Ownership statistics

The left panel shows the fraction of board links for which the respective link is also present in the ownership network, vice versa. The right panel shows the relationship between the percentage of ownership of two firms and the conditional probability of having a link in the board network. The calculation is based on subsamples of 30 firms with similar ownership.

The ownership network is very stable, about 90 percent of the links survive from each one year to the next. However, the overlap between links in the firm network and the ownership network is with about 10 percent relatively small, as is shown in the left panel of figure 3.

One can condition this relationship on the level of shareholding. For this reason we have binned pairs of firms with similar ownership percentage ($N = 30$) and have calculated how many of those are also linked in the board network. Results are shown in the right panel of figure 3. We can observe that the probability of having a board link increases with ownership and passes the unconditional probability one we reach about 10 percent ownership. Interestingly at the high end when ownership reaches 50 percent this relationship slows down and might even slightly drop. It is possible that since this represents a majority ownership, there is less demand for control by shared board members.

A particular difference between the ownership and the board network is that a handful of life insurers and securities companies appear as very connected hubs in this network. Their shareholdership in a firm is normally small but their activity is very spread out. In fact much of their holdings are likely to be on behalf of their clients. Apart from this obvious observation, communities in a classical sense do not exist, and if they do they overlap. Not surprisingly large companies like Toyota, Mitsubishi, Fujitsu, Honda, Mitsui and Nippon Steel can be classified as smaller hubs. A visualization of the ownership network in 2013 can be found in figure B.10 in the appendix.

3. Dynamics of the board network

In the last sections we have checked for the existence of communities in the networks. Even though these are not very pronounced we have observed that certain groups in the board network that existed in 2004 still exist in a very similar form in 2013. This raises questions about the persistence of the board network and the mechanisms that make it persistent.

We start by looking at two very basic properties of firms, namely their size and centrality.

First we calculate the persistence of firm's market values over time. The top part of table A.10 (in the appendix) shows that the firm's market values are in fact highly correlated over time, which means that the overall economic importance of firms changes only gradually.

We can further check if this translates to a similar behavior in firms' board network centrality. We have thus calculated the eigenvector centrality of all firms that stay part of the giant component in all years and calculate the rank cross-correlations of the eigenvector centrality. The results show that there is also persistence in this figures, although much less than for the market values. Persistence mostly fades after two years, however the variation is high. Larger changes in the centrality seem to have happened in 2009 and 2012-13. The complete results are shown in the bottom part of table A.10.

The reasons for this persistence in firm centrality can be the strategic maintenance of ties in the board network, which we will analyze later, but of course some of it also stems from firm characteristics. One would for example expect that larger firms have larger boards and are also generally better networked. In fact we find that the rank-correlation between the eigencentrality and the market value is significantly positive around 0.35.

	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$	$t+9$
2004	0.9750	0.9517	0.9180	0.8792	0.8482	0.8219	0.8004	0.7847	0.7730
2005	0.9771	0.9423	0.9000	0.8683	0.8410	0.8194	0.8030	0.7906	
2006	0.9650	0.9226	0.8907	0.8620	0.8385	0.8212	0.8088		
2007	0.9563	0.9233	0.8943	0.8691	0.8508	0.8377			
2008	0.9660	0.9360	0.9092	0.8898	0.8760				
2009	0.9692	0.9417	0.9218	0.9067					
2010	0.9716	0.9513	0.9355						
2011	0.9791	0.9630							
2012	0.9839								

Table 2: Firm survival

The table shows the probability of survival for the firms from one to every other year, based on the existence of the company identifier in TOPIX.

Before we can investigate the determinants for the maintenance of ties in the board network we have to look at the general survival rates of firms and board members. For this reason we have counted how many of the firms that are present in a given year are also present in any year in the future. The identity in this case is determined by the existence of the TOPIX numerical code of the firms and results are shown in table 2. We observe that the unconditional survival probability of the firms in our data set is very stable and lies around 96%. Slightly lower values are only observed around 2007, which is in line with weak GDP growth around that time.

The same exercise can be done with the board members. The survival rates for the them are also rather stable and vary around 83 %. Slightly lower figures are observed around 2007–08 and slightly higher values are observed towards the end of the sample period (see table 3).

4. Determinants of board member survival

Since we have seen that some board members have multiple mandates it is useful to investigate how the survival figures change when we condition the survival on the number of mandates that a board member has. These conditional survival probabilities are shown in figure 4. The probability for board members with one mandate (p_1) differs only insignificantly of that from the entire population (83%). The likelihood to survive increases to around 93% with another mandate, further additional mandates only lead to marginal improvements. So even if directors with multiple mandates are of

	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$	$t+9$
2004	0.8438	0.6855	0.5588	0.4508	0.3840	0.3175	0.2659	0.2263	0.1989
2005	0.8209	0.6685	0.5402	0.4542	0.3774	0.3155	0.2697	0.2345	
2006	0.8230	0.6665	0.5615	0.4601	0.3854	0.3282	0.2858		
2007	0.8161	0.6862	0.5665	0.4669	0.3976	0.3448			
2008	0.8462	0.6987	0.5779	0.4866	0.4230				
2009	0.8325	0.6886	0.5807	0.4997					
2010	0.8361	0.7065	0.6109						
2011	0.8532	0.7395							
2012	0.8714								

Table 3: Board member survival

The table shows the survival probability of board members from one year to every other year based on the information in the Toyo Keizai database and our identification method described in setion 2.1.

course more likely to survive one can easily verify that the losses of mandates are not independent.

We can verify this by calculating the probability that a board member with two mandates looses both of them $(1 - p_2)$, under the assumption of independence, from the probability of losing one mandate $(1-p_1) = 1-0.83 = 0.17$. Then $1 - p_2 = (1 - p_1)^2 = 0.0289$, which would predict a survival probability of close to 97% for managers with 2 mandates.

Based on these results about board member survival we can have a more detailed look at determinants of their destinies. Since the large number of board members prohibited us from collecting detailed information on each of their career paths we have to confine ourselves to some of their basic characteristics together with details on the firms for which they work.

For this reason some details of the Japanese board system demand our attention. While the boards in the US and most of the European countries are often split into executives and supervisors or internal and external members, the Japanese system knows only one board. This board mainly consists of executives which are joined by few external directors and the auditor. Sometimes former executives remain part of the board up to a very high age. In such cases they are often still listed as an executive even when their role is more of a supervisory and sometimes even honorary nature.

Given this framework we can check if the role of a board member has an influence on his survival probability. We can further check if gender or

	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
MF R^2	0.0071	0.0180	0.0068	0.0101	0.0108	0.0156	0.0148	0.0162	0.0183
LR	257.7	722.0	274.7	405.0	368.9	546.3	497.5	498.9	510.9
N	42175	42635	43121	41998	39907	38759	37731	36884	36452
survivors	35589	34998	35488	34276	33769	32266	31548	31469	31764
const	1.9569	1.8349	1.5866	1.3504	1.8192	1.9528	2.1018	2.2074	2.4642
	(32.26)	(28.86)	(26.46)	(26.92)	(32.37)	(34.70)	(37.29)	(37.20)	(36.29)
mand_{t-1}	0.5069	0.6577	0.5495	0.6095	0.5903	0.6800	0.6704	0.7582	0.7959
	(10.51)	(14.02)	(12.18)	(12.82)	(11.46)	(13.20)	(12.74)	(12.79)	(12.20)
age	0.0003	-0.0348	0.0005	0.0002	-0.0185	-0.0293	-0.0286	-0.0258	-0.0286
	(1.82)	(-21.03)	(4.32)	(1.83)	(-10.49)	(-16.66)	(-15.85)	(-13.49)	(-13.98)
female	0.3158	-0.0314	-0.0888	0.0260	0.1092	0.4961	0.2913	0.4529	0.6935
	(2.13)	(-0.25)	(-0.80)	(0.22)	(0.80)	(3.31)	(2.10)	(3.03)	(4.08)
log MV	-0.0228	-0.0018	0.0077	0.0251	0.0063	-0.0064	-0.0201	-0.0189	-0.0287
	(-3.87)	(-0.30)	(1.35)	(5.24)	(1.16)	(-1.16)	(-3.64)	(-3.27)	(-4.35)
outs. board	-0.4197	-0.5002	-0.4112	-0.5475	-0.4586	-0.3224	-0.2243	-0.4197	-0.2781
	(-6.64)	(-8.72)	(-7.31)	(-10.36)	(-7.96)	(-5.56)	(-3.84)	(-7.43)	(-4.64)
outs. audit	0.2885	0.0668	-0.0555	0.2167	0.2633	0.0360	0.0209	0.2054	0.2771
	(7.28)	(1.92)	(-1.66)	(6.19)	(6.73)	(0.99)	(0.56)	(5.03)	(6.27)

Table 4: Determinants of board member survival

The table shows the results of a logit regression. t-values are shown in parentheses. Although survival is to a large part random, we find significant influence for holders of multiple mandates (mand), outside board members and outside auditors. The age, gender and the market value of the company (log MV) are of changing importance.

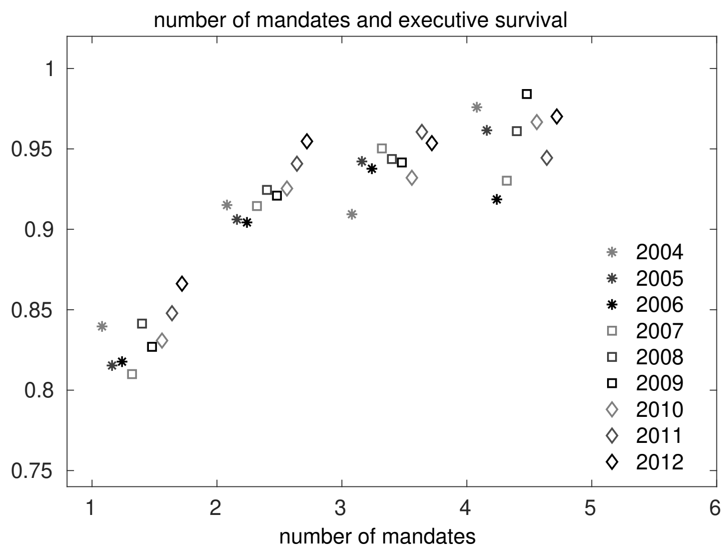

Figure 4: Influence of number of mandates on survival
The figure shows the survival of board members with 1,2,3 and 4 mandates. The results are printed with an offset for the years 2004–2012.

the size of the company are important aspects of director survival, while we control for the number of mandates and age. Since survival is a binary variable this demands for a logistic regression where the observed survival or death (in the sense of leaving the data set) depends on the number of mandates, age, gender, log market value of the largest firm a director serves, whether he is an outside board member and whether he is the auditor.

The results in table 4 confirm our previous calculations but they also show that the survival of directors is mostly a matter of luck and individual decisions that we cannot decipher. The number of previously held mandates is of course important but the overall exploratory power is limited still. The impact of age is mostly negative or insignificant, as expected, with exception of the years 2006/07. Only very few women are serving as directors, less than 2%, and only at the end of our sample period we see a slight tendency of higher survival. It does not matter too much if directors work at firms with high or low market values, if at all there seems to be a tendency to replace directors more often at large (highly capitalized) firms.

Rather clear are the effects for directors who are not executives. Outside board members are being dropped with a higher likelihood throughout the

year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
MF R^2	0.0545	0.0464	0.0458	0.0489	0.0540	0.0500	0.0464	0.0471	0.0432	0.0442
LR	1,970.2	1,920.9	1,815.4	1,820.8	1,809.5	1,646.5	1,509.0	1,529.2	1,5232.7	1,767.7
N	990,528	1,233,235	1,195,831	1,116,765	961,191	955,653	941,878	951,510	1,109,305	1,319,500
links	2,598	2,931	2,800	2,633	2,387	2,343	2,309	2,303	2,490	2,779
const	-6.2261	-6.3117	-6.3142	-6.3036	-6.2623	-6.2609	-6.2413	-6.2548	-6.3099	-6.3793
	(0.0236)	(0.0221)	(0.0225)	(0.0230)	(0.0243)	(0.0244)	(0.0244)	(0.0244)	(0.0232)	(0.0220)
b size	0.3133	0.3952	0.3871	0.3912	0.4007	0.4110	0.4305	0.4545	0.4355	0.4752
	(0.0123)	(0.0132)	(0.0128)	(0.0134)	(0.0139)	(0.0151)	(0.0159)	(0.0166)	(0.0155)	(0.0149)
same sec	1.4880	1.3643	1.2509	1.2144	1.2554	1.1836	1.0939	1.1339	1.0601	1.0363
	(0.0502)	(0.0481)	(0.0505)	(0.0533)	(0.0558)	(0.0575)	(0.0594)	(0.0587)	(0.0582)	(0.0553)
fin link	0.5870	0.5492	0.5772	0.6259	0.6398	0.6907	0.5555	0.4503	0.4794	0.5014
	(0.0850)	(0.0841)	(0.0826)	(0.0848)	(0.0904)	(0.0891)	(0.0950)	(0.0980)	(0.0964)	(0.0939)
ownersh.	0.2347	0.1945	0.1706	0.1762	0.1826	0.1681	0.1557	0.1594	0.1486	0.1406
	(0.0137)	(0.0113)	(0.0093)	(0.0092)	(0.0098)	(0.0091)	(0.0078)	(0.0085)	(0.0071)	(0.0058)

Table 5: Links by function

Results of the logistic regression. Standard errors in parentheses. All variables are highly significant ($p < 10^{-9}$). Controlling for company board size (b size) we find that corporate boards have a tendency to form links to boards of other companies from the same sector (same sec) but also show a certain preference for links to financial corporations (financial link).

sample period. This intuitively make sense since they are a more dispensable part of the board. On the other hand it is common practice to stick to an auditing company once relations are established and thus outside auditors stay on the board longer than executives. The outlier in 2006/07 for the survival of auditors is at first sight puzzling, but is in fact easily explained by the ChuoAoyama PricewaterhouseCoopers accounting scandal (Skinner and Srinivasam, 2012) that lead to a temporary increase in auditor replacement.[2] In addition to the results presented in the table we have checked if the existence of ownership ties increases the probability of executive survival. We could not find proof of such a relationship.

5. The persistence of ties in the board network

When one speaks about board network ties ties one has to first raise the question whether there are preferences with respect to the type of firm to link to. We have seen before that large firms, which also have large boards, tend to be central in the network and are thus more connected. Apart from

[2] See also: The Economists, May 11th 2006, Auditors in Japan.

size one can ask if firms from certain sectors are more connected than others. For this reason a closer look at the 33 TOPIX industry classifications is useful. Since a link always matches two firms this leads to 540 combinations of sectors for two firms, which are far too much to evaluate based on only 3,000 links that we observe per year. We can however test two important hypotheses: The first one is to evaluate if firms tend to have more links to firms from the same sector. This would speak in favor of hiring outside directors that might bring some special expertise. The second hypotheses is that ties to the financial industry are reflected in additional ties. This would for example speak in favor or relationships of firms to a main bank who sends a director to monitor bank's exposure.

The analysis is done in form of a logistic regression where we encode all the possible and realized links between firms as zeros and ones and then regress on two dummy variables. These dummies carry ones for links within the same sector and for links to the financial industry. We control for the ability of boards to generate ties to one another. We assume that this ability is proportional to the product of the numbers of board members of the two firms. We also check for the influence of ownership relations.[3] In other words, our regression tests the assumption that links within the same sector and to the financial sector are over-represented against the hypotheses that links are randomly distributed between firms and that their likelihood just depends on the number of directors on the respective boards.

We note that in this case links are actually rather rare events, only about 0.2 percent of potential links exist. To prevent biases in our estimation results we therefore use a penalized ML estimation, see also Firth (1993) and King and Zeng (2002).

The results are shown in table 5 and basically confirm both our hypotheses. There is a slight but constant tendency of links to the financial industry and a more obvious tendency for links to firms with the same TOPIX industry code. The latter is gradually declining. Hence, these two motives influence the structure of ties in the board network, but the results also show that the majority of links do not depend on them (and also not on board or firm size). We further confirm that there is a slight overlap between the ownership and the board network. However, this effect is small and roughly

[3] The board size variable is measured as the deviation from its mean divided by 100. Ownership is a percentage value.

similar to that of within-sector ties. A gradual increase of the ownership effect is observed over time. This stems partly from the increase of ties in the ownership network. One can interpret this as a signal of a slight shift from informal firm ties in the board network towards more formal ties that incorporate also significant shareholding.

This leads to the question where the persistence of the network structure in the board network comes from. If it were just a matter of board members with multiple mandates at highly capitalized firms then we should have seen higher survival rates of executives at this companies. We have however seen that this is not the case. This implies that there must be mechanism of upkeep of board network ties that goes beyond the existence of central directors.

For this reason we use the same method as in Raddant et al. (2017) and compute how many links between companies are being kept from one year to the next and look into how this link is kept. The findings are summarized in table 5. We observe that only very few links are being lost because firms disappear. About 76% of the links survive from one year to the next and about 73% do so because at least one of the board members who was bridging the two boards is still there. Another 3% of links however is being kept because a new board member is replacing the function, in more than half of the cases he was already member of one of the boards. In any case he was already a central player in the board network, with typically 2-3 mandates in the year before.

6. The role of outside board members and multiple mandates

Finally we can have a look at changes in the general composition of corporate boards. This will include a closer look on the role of outside directors.

First, it is worth stressing again the still very low share of women in Japanese corporations. Table 7 shows that their number has grown significantly, though only on a very low level. Even in 2013 less then 2% of board members are women.

The average age of board members is increasing slightly from 57.2 years in 2004 to almost 59 years in 2013. Female board members are on average younger, but the gap is slowly closing.

We also see a clear trend towards having outside directors in the boardroom. The share of directors who are labeled as outside directors (at least in one board) has almost doubled of to 8.25% until 2013. It is worth noting

	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
links_{t-1}	3221	3498	3415	3266	3045	2956	2883	2869	2984
firms alive_t	3207	3491	3405	3260	3035	2949	2879	2867	2978
links alive_t	2499	2569	2530	2519	2373	2272	2281	2343	2487
in %	77.58	73.44	74.08	77.13	77.93	76.86	79.12	81.67	83.34
same b. member	2376	2423	2398	2401	2259	2176	2184	2250	2399
in %	73.77	69.27	70.22	73.52	74.19	73.61	75.75	78.42	80.40
new b. member	123	146	132	118	114	96	97	93	88
in %	3.82	4.17	3.87	3.61	3.74	3.25	3.36	3.24	2.95
mand_{t-1}	2.9350	2.9110	2.5833	2.7034	3	2.6875	2.6495	2.6989	2.7159
former b. member	68	79	83	67	58	63	49	63	54
in %	55.28	54.11	62.88	56.78	50.88	65.63	50.52	67.74	61.36

Table 6: Persistence of board network links over time

The top part of the table summarizes how many of the links between two firms survive from one year to the next. Next we summarize how many of these links are preserved by the same board members vs. new board members. In the bottom of the table we report how many mandates those new board members held in the last year and how many of them have been part of at least one of the two companies' boards.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
b. members	42175	42635	43121	41998	39907	38759	37731	36884	36452	36697
female	439	506	533	515	493	514	536	571	623	713
% female	1.04	1.19	1.24	1.23	1.24	1.33	1.42	1.55	1.71	1.94
age	57.2	57.3	57.2	57.4	57.7	58.1	58.3	58.4	58.7	58.9
age f.	51.3	50.9	51.6	52.0	52.3	52.8	52.9	53.3	53.8	54.1
outside dir	1823	2044	2194	2276	2214	2277	2355	2474	2603	3028
mult dir	2268	2383	2423	2338	2194	2141	2039	2040	2108	2206
both	527	554	593	591	571	569	545	564	596	678
% outside	4.32	4.79	5.09	5.42	5.55	5.87	6.24	6.71	7.14	8.25
% mult	5.38	5.59	5.62	5.57	5.50	5.52	5.40	5.53	5.78	6.01

Table 7: Board composition and characteristics

The first 5 rows give information about the number of female board members and the average age of board members. The next three rows give the total numbers of directors who are labeled as an outside director, have multiple mandates according to our data set, or where both applies. Rows 9 and 10 state the percentage of outside directors and directors with multiple mandates among all directors.

that this trend has only slightly increased the percentage of directors who are part of more than one board (multiple mandates), as their percentage only rose from 5.38% to 6.01%.

The increase in the number of outside directors demands a closer look. Our data set allows us to look more closely into which board rooms these additional outside directors go. Therefore we perform a Poisson regression in which our dependent variable is the number of outside board members in a firm. The number of outside directors should depend in the size of the board, which is also a proxy for the size of the firm (which we therefore cannot account for in isolation). Further we test the influence of the composition of a firm's shareholders. The data allows to differentiate between the percentage of shares held by financial institutions, by security companies, by other corporations and held by foreign corporations (the remainder is held by individual investors).

The results are summarized in table 8. We show the results separately for each year, always with and without sector dummy variables. We calculate a pseudo R^2 value by calculating the ratio of correct predictions of the number of outside directors using the predictions rounded to integer values.

As expected, the number of outside directors varies with board size. More interestingly, the share holder characteristics are highly significant. A high fraction of foreign share holders increases the likelihood of having outside directors. The influence of shares held by other corporations is also high, though slightly weaker.

These results hold when we include dummy variables for the most populated sectors according to the TOPIX classification. These variables add slightly to the explanatory power since in some sectors outside directors are still not that common. This includes firms from the sectors construction, glass, machinery, transportation equipment and (for most of the time) banks. On the other side of the spectrum we find the IT industry, which for the entire sample period employs significantly more outside directors than the average.

7. Networks and firm profitability

The structure of the top layer management of a corporation and how it is connected with the management of other corporations has implications for the long run success of a company. Executives or board members who can bring in experience from outside the company can be very valuable to navigate economic downturns or restructuring processes. On the other and,

	2004		2005		2006		2007		2008		2009		2010		2011		2012		2013	
N	2628	2628	2662	2662	2702	2702	2706	2706	2640	2640	2565	2565	2502	2502	2459	2459	2432	2432	2433	2433
ps. R^2	0.4365	0.4787	0.4065	0.4542	0.4049	0.4352	0.3703	0.4180	0.3765	0.4083	0.3372	0.3836	0.3269	0.3857	0.3241	0.3790	0.3244	0.3631	0.3859	0.3979
disp.	1.2323	1.2124	1.2461	1.2160	1.2248	1.2099	1.2057	1.1942	1.1699	1.1595	1.1596	1.1402	1.1552	1.1372	1.1352	1.1166	1.0809	1.0569	0.9617	0.9371
const	-2.0030	-1.9970	-1.9214	-1.8519	-1.9096	-1.8297	-1.7852	-1.6948	-1.7801	-1.7362	-1.5973	-1.5135	-1.5914	-1.4955	-1.5236	-1.4311	-1.3716	-1.2547	-1.1754	-1.0722
	(-21.70)	(-16.45)	(-21.90)	(-16.40)	(-22.12)	(-16.45)	(-20.80)	(-15.35)	(-20.87)	(-15.64)	(-19.38)	(-14.09)	(-19.64)	(-14.17)	(-19.15)	(-13.82)	(-17.98)	(-12.56)	(-16.29)	(-11.29)
board	0.0656	0.0678	0.0780	0.0790	0.0784	0.0787	0.0730	0.0746	0.0735	0.0748	0.0662	0.0668	0.0706	0.0699	0.0742	0.0731	0.0660	0.0631	0.0621	0.0588
size	(14.80)	(15.01)	(16.97)	(17.03)	(18.33)	(18.33)	(17.28)	(17.44)	(16.66)	(16.67)	(14.01)	(13.90)	(14.46)	(14.18)	(15.70)	(15.30)	(15.20)	(14.34)	(14.67)	(13.75)
share	1.8339	1.8132	1.5450	1.5205	1.4457	1.4656	1.3345	1.3996	1.3729	1.4751	1.2319	1.3331	1.1078	1.1764	1.0825	1.1297	0.9947	1.0364	0.8984	0.9476
corp.	(13.23)	(13.19)	(11.91)	(11.83)	(11.19)	(11.31)	(10.23)	(10.69)	(10.30)	(11.00)	(9.36)	(10.08)	(8.56)	(9.07)	(8.56)	(8.88)	(8.01)	(8.30)	(7.64)	(7.95)
share	-0.3633	-0.1468	-0.9289	-0.5668	-0.9005	-0.5773	-0.8994	-0.4984	-0.9984	-0.5635	-0.8295	-0.3674	-0.3810	0.0513	-0.6596	-0.2059	-0.2706	0.1894	0.0739	0.3897
fin.	(-1.88)	(-0.73)	(-4.77)	(-2.77)	(-4.66)	(-2.85)	(-4.61)	(-2.42)	(-4.89)	(-2.60)	(-4.11)	(-1.72)	(-2.04)	(0.26)	(-3.46)	(-1.01)	(-1.48)	(0.97)	(0.43)	(2.10)
share	3.3419	3.3039	3.1159	2.9022	2.9972	2.9271	2.8790	2.8523	2.7847	2.8249	2.7126	2.7438	2.7101	2.7285	2.7229	2.7085	2.6313	2.6000	2.2745	2.2638
foreign	(19.13)	(17.58)	(17.31)	(15.53)	(18.17)	(16.93)	(17.43)	(16.86)	(16.33)	(16.02)	(15.44)	(15.17)	(14.91)	(14.42)	(15.22)	(14.79)	(15.74)	(15.07)	(14.19)	(13.70)
share	3.2552	3.1806	2.9309	2.8000	4.3778	4.2378	4.4931	3.7897	6.0401	5.3443	5.5209	4.4666	5.8376	4.4168	5.7727	4.8675	3.7179	3.1053	3.8730	3.6440
sec.	(6.40)	(6.05)	(5.74)	(5.27)	(5.50)	(5.25)	(5.05)	(4.12)	(7.02)	(5.93)	(5.73)	(4.41)	(5.65)	(4.00)	(5.60)	(4.53)	(4.39)	(3.41)	(5.17)	(4.70)
Constr		-0.3475		-0.4484		-0.3807		-0.4300		-0.4864		-0.6742		-0.6849		-0.7673		-0.6805		-0.5302
		(-2.84)		(-3.73)		(-3.25)		(-3.76)		(-4.05)		(-5.26)		(-5.21)		(-5.84)		(-5.55)		(-4.89)
Food		-0.1323		-0.2291		-0.0925		-0.1560		-0.1656		-0.1461		-0.2159		-0.1065		-0.1647		-0.1080
		(-0.93)		(-1.66)		(-0.73)		(-1.21)		(-1.24)		(-1.12)		(-1.61)		(-0.85)		(-1.32)		(-0.95)
Text.		-0.0846		-0.1523		-0.3897		-0.4480		-0.2973		-0.1711		-0.2439		-0.1262		-0.1288		-0.2499
		(-0.48)		(-0.85)		(-2.02)		(-2.29)		(-1.54)		(-0.94)		(-1.27)		(-0.69)		(-0.75)		(-1.48)
Chem		-0.1866		-0.3046		-0.3379		-0.3909		-0.3673		-0.4052		-0.3944		-0.3689		-0.3622		-0.2313
		(-1.53)		(-2.60)		(-2.99)		(-3.53)		(-3.27)		(-3.67)		(-3.62)		(-3.49)		(-3.60)		(-2.53)
Pharm		0.1362		0.1523		0.2066		-0.1358		-0.0052		0.1030		0.1088		0.0897		0.2155		0.2417
		(0.82)		(0.92)		(1.34)		(-0.79)		(-0.03)		(0.68)		(0.73)		(0.61)		(1.64)		(2.01)
Glass		-0.6486		-0.6376		-0.5023		-0.4423		-0.3730		-0.4549		-0.3887		-0.4084		-0.3970		-0.3064
		(-2.69)		(-2.85)		(-2.39)		(-2.22)		(-1.93)		(-2.32)		(-2.04)		(-2.15)		(-2.19)		(-1.91)
IronS		-0.1808		-0.3710		-0.2794		-0.4186		-0.4541		-0.4739		-0.4716		-0.5690		-0.5287		-0.4725
		(-0.98)		(-2.00)		(-1.68)		(-2.48)		(-2.63)		(-2.76)		(-2.79)		(-3.12)		(-2.91)		(-2.79)
MetalP		-0.3943		-0.4230		-0.3475		-0.4955		-0.4117		-0.4965		-0.4270		-0.4424		-0.5553		-0.4696
		(-2.08)		(-2.31)		(-1.98)		(-2.73)		(-2.27)		(-2.75)		(-2.48)		(-2.57)		(-3.17)		(-2.97)
Mach		-0.3121		-0.4820		-0.5866		-0.5521		-0.4893		-0.4891		-0.3767		-0.3935		-0.3301		-0.3230
		(-2.49)		(-3.91)		(-4.79)		(-4.83)		(-4.34)		(-4.45)		(-3.53)		(-3.72)		(-3.32)		(-3.47)
ElAppl		0.1089		0.0440		0.0135		-0.0822		-0.1141		-0.1554		-0.1584		-0.1600		-0.1514		-0.0753
		(1.08)		(0.47)		(0.15)		(-0.91)		(-1.23)		(-1.70)		(-1.71)		(-1.79)		(-1.76)		(-0.94)
TransE		-0.9209		-1.0968		-1.1406		-1.2784		-1.2238		-1.1965		-1.0749		-0.9154		-0.8376		-0.6338
		(-5.39)		(-6.26)		(-6.45)		(-7.15)		(-6.92)		(-7.02)		(-6.57)		(-6.03)		(-5.87)		(-5.05)
OtherP		-0.2901		-0.4637		-0.3847		-0.4441		-0.3884		-0.4093		-0.3895		-0.3816		-0.3546		-0.2091
		(-1.68)		(-2.70)		(-2.38)		(-2.83)		(-2.50)		(-2.60)		(-2.45)		(-2.45)		(-2.39)		(-1.59)
LTrans		0.3364		0.2389		0.1876		0.1395		0.1050		0.0635		-0.0043		0.0298		-0.0297		0.0264
		(2.41)		(1.74)		(1.36)		(1.04)		(0.76)		(0.47)		(-0.03)		(0.22)		(-0.23)		(0.22)
WHT		-0.0738		-0.0112		-0.0730		-0.2156		-0.1604		-0.2620		-0.2531		-0.1622		-0.2210		-0.2481
		(-0.35)		(-0.06)		(-0.38)		(-1.13)		(-0.85)		(-1.37)		(-1.35)		(-0.90)		(-1.25)		(-1.46)
IT		0.4020		0.3953		0.2163		0.2244		0.2599		0.2779		0.3634		0.3435		0.3386		0.2675
		(4.03)		(4.35)		(2.37)		(2.53)		(2.90)		(3.16)		(4.16)		(3.98)		(4.03)		(3.31)
WTrade		-0.0898		-0.1941		-0.2055		-0.2429		-0.2195		-0.3371		-0.3817		-0.2997		-0.3310		-0.2602
		(-0.83)		(-1.88)		(-2.04)		(-2.46)		(-2.20)		(-3.36)		(-3.76)		(-3.08)		(-3.51)		(-3.00)
RTrade		-0.2243		-0.1832		-0.1353		-0.2379		-0.1236		-0.1934		-0.1878		-0.1140		-0.2564		-0.1849
		(-1.54)		(-1.39)		(-1.08)		(-1.91)		(-1.04)		(-1.57)		(-1.56)		(-1.00)		(-2.18)		(-1.74)
Banks		-0.4943		-0.4512		-0.3829		-0.3546		-0.2992		-0.3233		-0.3371		-0.2366		-0.2374		-0.1218
		(-3.12)		(-2.93)		(-2.72)		(-2.69)		(-2.25)		(-2.40)		(-2.58)		(-1.92)		(-2.05)		(-1.18)
RealE		0.2593		0.0012		0.0030		-0.2810		-0.2653		-0.2113		-0.0956		-0.0600		-0.0348		-0.0526
		(1.65)		(0.01)		(0.02)		(-1.86)		(-1.72)		(-1.46)		(-0.67)		(-0.41)		(-0.25)		(-0.39)
Services		0.1287		0.1087		0.0967		0.0598		0.1404		0.1114		0.1359		0.0884		0.0868		0.0693
		(1.10)		(1.00)		(0.92)		(0.60)		(1.39)		(1.12)		(1.36)		(0.89)		(0.91)		(0.76)

Table 8: Poisson regression results for the number of outside directors of a firm

The Poisson regression explains the number of outside directors of a firm by the ratio of shares held by other corporations, shares held by financial institutions, shares held by foreign investors and shares held by security houses. We control for the firms's board size. For each year we estimate this model and with and without additional controls for the (most populated) sectors based on the TOPIX classification in the odd and even columns. t-values are shown in parenthesis.

executives and board members who serve as a mere transmission channel for the needs of affiliated companies can slow down the effective management of a company. Similar effects occur in the case of ownership or equity ties between corporations. Connected firms can profit from these connections if it supports a chain of value generating activities that would be hard to achieve otherwise. When ties exist for the mere sake of diversification of business activities the effects are often ambiguous. In the case of Japan corporate ties however have a special history. Firm conglomerates often refereed to as *keiretsu* used to have a huge influence on the economic system until the middle of the 20th century. Traces of it are still visible today, even if many argue that the economic downturn of the 1990s dissolved most of them.

Studies on the long-run success of these conglomerates find that these structures go at hand with within-group interventions and risk sharing. A process that in total has been found to significantly lower the return on assets of conglomerate members.

We will follow up on this issue and analyze if there are effects from firm connectedness on profitability by using variables from the board and ownership network together with some control variables. Similar to the work by Lincoln and Gerlach (2004) we measure profitability by the return on assets (ROA) and we use the total assets and the ratio of loans to total assets as controls.[4] Data on this key financials are not consistently available for all the firms in our sample. This limits the subsample for this part of the analysis to around 2,000 in each year. This are however still more firms than what are present in the giant component of the board network.[5]

Since the number of variables describing network relations, centralities, or local connectivity and clustering is almost endless, we choose to break this analysis into two steps. First we employ a simple machine learning algorithm that we feed with many different variables that might affect ROA. From this process we learn which variables seem to have impact on the ROA. This approach also allows us to employ variables which are only defined for some of the firms, like the ROA of a connected firm. It also helps to identify variables that might interact. In both these cases, the results from the ML

[4]We found that the ROA is the variable that works best for a large sample comprised of firms from different sectors, including variables like sales into our model would necessitate either a much more complex model or a drastically reduced sample size.

[5]We omit firms from the analysis which report a ROA that is outside the range $-20\% < ROA < 25\%$ since such results are typically not the result of continuing business activity.

algorithm can then be used to construct dummy variables which significance can later be analyzed within a regression analysis.

The result of a regression tree is a hierarchical structure where at each branch the dataset is split into two parts depending on the value or state of the most important variable. An example of such a tree is shown in figure C.11 in the appendix. We have run the tree model separately for all the ten years of our dataset and we have evaluated which variables, thresholds of variables, and combinations of variables repeatedly appear in the regression trees for all the ten years. We have supported this by calculating the importance scores for all the variables for all ten years. These results are shown in figure 5.

We have employed the following variables: log total assets, loans to total assets, number of outside directors, log eigencentrality in board network, sector dummies, log eigencentrality in ownership network, log eigencentrality in undirected ownership network, total ownership of other companies, fraction of company owner by other companies, average ROA of company linked to in board network, ROA of largest owner (min 3.8% ownership), average ROA of companies owned (min 2% ownership), degree in board network, in- and out-degree in ownership network, local clustering in board and ownership network, and foreign share ownership.

From this analysis we can learn that the ROA of owned firms as well as the ROA of the main owner have most influence on the ROA of a firm. The regression trees show us in fact even more, namely that these two variable often appear as two successive branches in the tree with predicted ROAs significantly different from the mean when both, the ROA of the owner as well as the average ROA of owned firms are greater or smaller than 3.5 percent. Also other variables from the ownership network have some importance, namely the in- and out-degree as well as total ownership and total share owned by other firms (which are of course related). What is further interesting is that also the ROA of a firm which is linked by a shared board member is playing a role.

As a result we can now test the significance of the influence of links in the ownership and board network by estimating the determinants of ROA. Since only some of the firms have a connection in the board and ownership network we cannot use the ROA of connected firms as a variable directly. Also, in the case of the ownership network, both directions of ownership seem to be important. Hence we set up two dummy variables. The board link dummy is 1 if the mean of the ROA of connected firm is larger than the mean of all

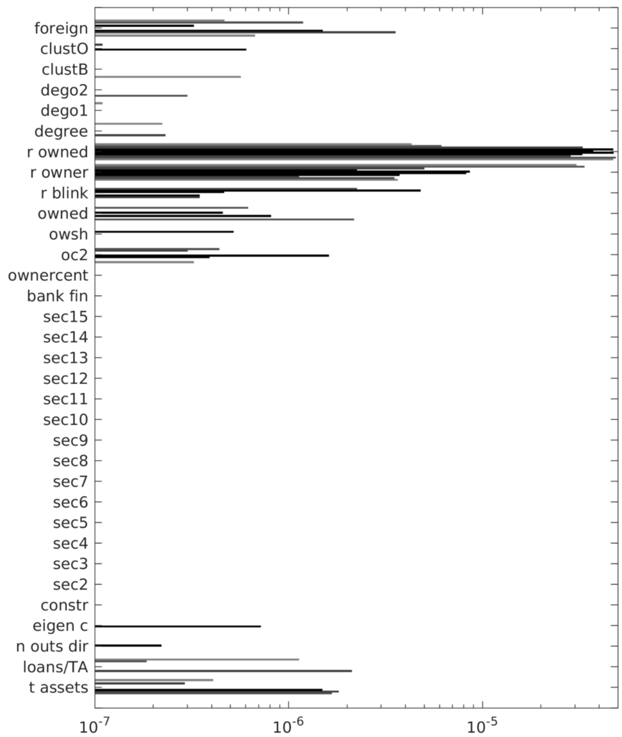

Figure 5: Importance of variables in regression tree

The figure shows the importance scores of all our variables for all 10 years in a combined bar plot and on a log scale. Variables that are not used at any node in the regression tree will have a score of zero, while the score of other variables depends on the relative improvement to describe the data when the variable is used as eiter a primary or surrogate splitter.

firms plus 0.2 times the standard deviation. The dummy for the ownership network is 1 if both, the average ROA of owners and of owned firms is larger than the mean ROA minus 0.3 times the standard deviation (resulting in a still slightly positive ROA). Hence, it signals that a firm is not sandwiched in between badly performing owner and similarly bad performing partly owned firms. We further test for the influence of the position of a firm in the ownership network by adding the variable *total ownership* which describes the cumulative percentage shares held by other companies in the ownership network, and *degree/total assets* the number of companies of which a firms holds shares of divided by total assets. These specifications are chosen to make sure that these two variables do not correlate with *total assets* but give a measures of ownership relative to the size of a firm.

We now estimate three versions of this model. The first version one uses only the just mentioned variables without any further differentiation for sectors or years. Since the threshold for our ownership and board link ROA variables depend on the yearly averages of the ROA a pooling for all 10 years should in principal be possible. The results for this model are shown in the left column of table 9. Since the financial crisis of 2008 has probably let to more than just minor fluctuations it makes of course sense to employ individual constants for each year. As we can see, this does not change the estimation results much, yet it improves the explained variance quite a bit. Finally we can add variables to classify the most populated Topix sectors. This should help to explain differences in ROA which are caused by differences in the asset base that are due to industry specific needs. We use 12 dummy variables for the sectors, yet in the table we only show the most important ones. We should note that the financial sector is a merged category that contains banks, insurances, and firms offering other financial services.

Interestingly our analysis shows that ownership relations tend to lead to lower ROAs. There are however one exceptions from this, positive effects can be found when both the owner and the (partly) owned firms are profitable (signaled by the variable ROA owner). Positive effects can also be found from links in the board network (ROA boardl), if connected firms have above average profitability.[6]

[6] As a robustness check we have performed the same regression on a yearly basis and found similar results, although the *ROA* variables were not significant in all years. We

model	simple pooled		year dummy		year and sector	
R^2	0.0464		0.0794		0.1107	
σ^2	0.0030		0.0029		0.0028	
N	20942		20942		20942	
$vars$	7		15		32	
const	0.05467	(10.56)				
const 1–10			•		•	
Tot assets	0.00077	(1.58)	0.00058	(1.22)	0.00150	(2.97)
loans/TA	-0.08289	(-10.89)	-0.07927	(-10.58)	-0.08662	(-11.04)
tot owned	-0.00166	(-7.41)	-0.00168	(-7.63)	-0.00132	(-5.92)
deg/TA	-0.05415	(-2.00)	-0.04806	(-1.8)	-0.06166	(-2.31)
ROA owner	0.01647	(4.32)	0.01696	(4.52)	0.01502	(4.06)
ROA boardl	0.00820	(4.14)	0.00816	(4.19)	0.00695	(3.61)
sec constr					-0.01773	(-4.93)
sec chem					-0.00047	(-0.88)
sec machinery					0.00317	(0.34)
sec elec appl					-0.00674	(-2.20)
sec finance					-0.02019	(-3.23)
sec IT comm					0.01848	(5.49)
sec pharma					0.02718	(4.55)
sec 7–16					•	

Table 9: Determinants of ROA

The table shows the estimation results for three different models of influences on the return on assets. The simplest model in the left column only considers the main variables. The model in the middle column considers a dummy variable for each year. The model in the right columns considers a year dummy and 16 dummies for sectors, of which the results for the seven most important ones are given. t-statistics based on t-distributed errors are given in parenthesis.

At last, the results on the effects of ownership deserve a closer look. We want to investigate if instead of referencing to connected firms ROA structural features could be responsible for our results.

First one could argue that in some cases we might see effects from minority shareholder relationships. Some authors claim that minority shareholders can be disadvantaged against controlling shareholder that enjoys private access that is denied to smaller shareholders which impact valuation and profitability (see, e.g. Guedes and Loureiro, 2006; Claessens et al., 2002).

Second, our general result on negative effects from ownership relations is in fact in line with many studies on diversification. Although diversification as an instrument of risk management is often successful, many studies show that corporations which invest into companies that operate outside of their own area of expertise are likely to negatively influence their own profitability(see, e.g. Berger and Ofek, 1995; Schommer et al., 2019; Kawakami, 2017).

In order to judge if any of these effects are related to our findings we will look at subsamples of companies from the five most populated sectors, namely construction, chemicals, machinery, electrical appliances and IT and communications. We will compare the ROAs which we normalize by the yearly group averages.

The results are presented in figure 6. We show box plots for three different comparisons for firms from five different sectors. The top panel shows the differences in the normalized ROA for our good ownership dummy variable as defined in our regression analysis and serves as a reference point. The averages of the bar plots labeled as 'no' and 'yes' almost always significantly different, thus confirming that the results of our regression analysis can in principal be confirmed without further control variables.

We can now look at differences in between the same firms that might be caused by minority shareholdership. The middle panel show a comparison where the firms are now grouped by the criterion whether they have an owner that controls at least 20 percent of the company. The results for

have also left out the control variables total assets and loans/TA, this changes the results for the sector dummies but leaves other results qualitatively unchanged. Including further network measures does not improve the model and leads to problems since these variables tend to be related to the existing measures of degree. We note that foreign share ownership is highly correlated with total assets and also partly explained by the sector dummies and can thus not be included into this estimation.

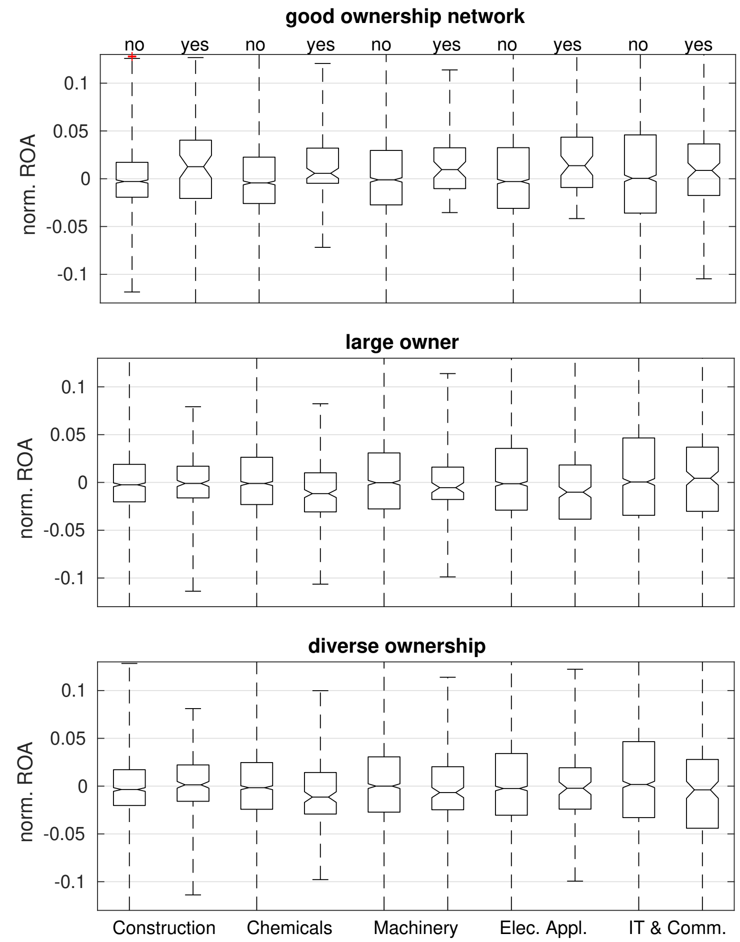

Figure 6: Influences of ownership structures

The figure shows the differences in normalized ROA for firms from five large sectors and for three comparisons. The top panel compares firms with a 'bad' versus a 'good' ownership network. The middle panel compares firms with and without a large owner with at least 20 percent shareholdership. The bottom panel compares firms that have diversified through ownership of a company in another sector versus firms which do not diversity.

this comparison are ambiguous. Firms from the sectors chemicals and electrical appliances do in fact have a significantly lower normalized ROA when they have a large owner, for firms from other sectors this effect cannot be confirmed.

Finally we group the firms by asking whether they own at least one percent of some other firm that is active in a sector different from their own. This aims at check at effects from diversification. At a first glance the results, presented on the bottom panel, appear unsystematic. For some sectors the difference is positive, for others negative. However, a pattern shows once we go back to the sector-based dummy variables from our regression analysis in table 9. In those sectors where the average ROA is above or similar to the economy average (chemicals, machinery, IT) the average normalized ROA is lower for coorporations which diversify to other sectors. For the two sectors where the average ROA is below economy average (construction, electrical appliances) diversifying into other sectors yields a slightly higher normalized ROA. These results are admittedly not in all cases significant, yet they show an interesting tendency. The benefits of diversification might depend on what the heritage of a corporation is and whether they can in the long run divert funding into activities in more lucrative fields.

8. Conclusions

In this study we have shown that the Japanese board network is still revealing traces of conglomerates of companies. It would not be adequate to compare these structures to the *keiretsu* structures of the past, but these clusters are more pronounced compared to studies of the respective US, German or Italian networks.

The board-to-board linkages show a high level of persistence. When board members leave boards that they have connected they are very often replaced with other executives of high connectivity. This explains most of the persistence of the firm network structure and firm centrality, even though we observe that the year-to-year firm survival rate is much higher than the survival rate of individual directors.

Throughout the sample period we observe an increase in the number of outside directors. While the maximum number of mandates of a board member decreases, this development goes at hand with a slight increase in the average number of mandates (and the share of board members with multiple mandates). The trend towards outside directors is more pronounced for companies with a high ration of foreign share ownership. This might speak in favor of a mild influence of governance practices from overseas. The sector-based differences also point into the direction that traditional and more locally operating industries fall behind this trend, while the more open IT industry is at the forefront of this development.

For the economic effect of interorganizational networks we find mixed results. Firms that are organized in conglomerate-like structures tendencially have lower ROAs. This effect can be reversed if ties to above average profitable firms exist in either the board or ownership network.

Further research is needed on these effects of ownership ties. This however necessitates more fine-grain information on financial ties, including information on the main bank and borrowing relationships.

Acknowledgments

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Appendix A. Statistics of the board network

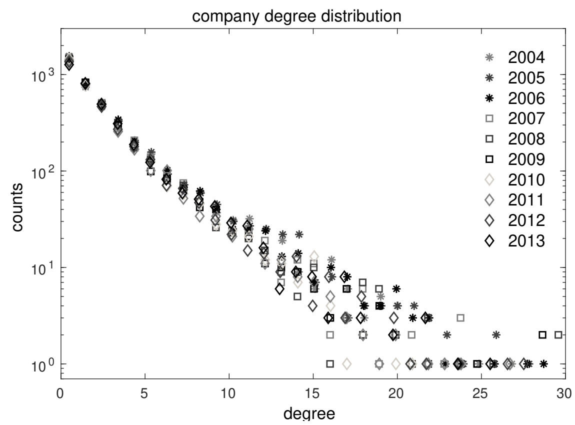

Figure A.7: Company network degree distributions
The figure shows that the degree distributions (plotted on semi-log scale) show similarity to a power-law.

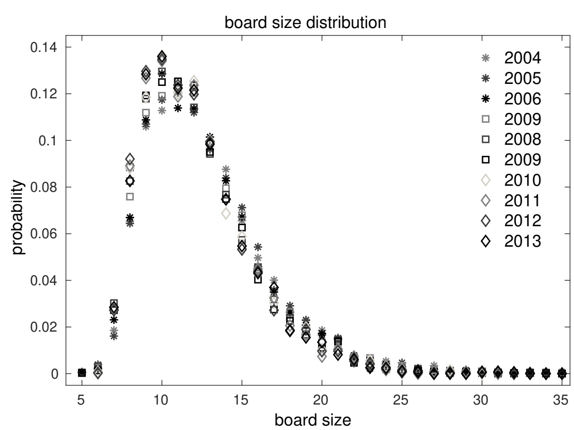

Figure A.8: Distributions of board size
The distribution of the board size shows only little variation over time. Since the board size is mostly determined by company size it shows a tail which for $x > 15$ *shows similarity to a power-law.*

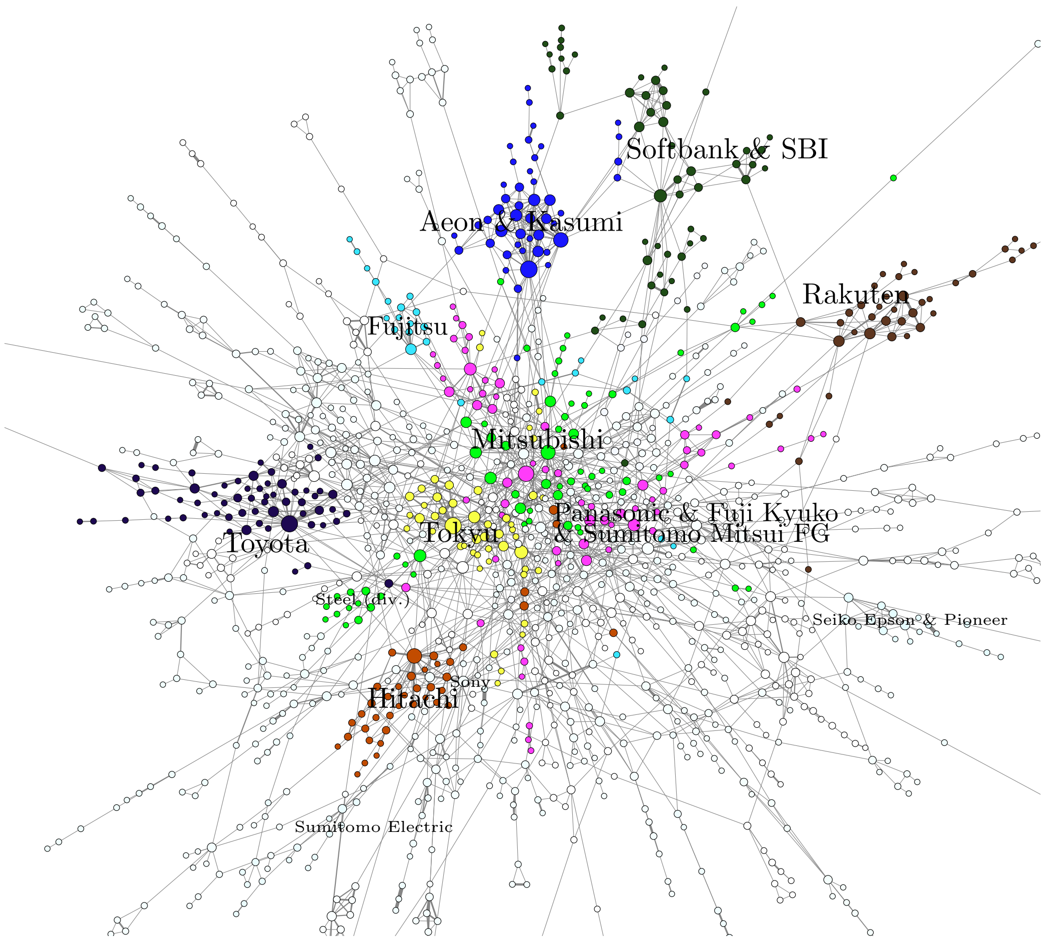

Figure A.9: Detailed board network in 2013

The largest communities are color coded and labeled according to the most connected companies. In general the firm network has very few closed communities, even in the periphery we do have firms that provide shortcuts between them.

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
corr. market value	2004	1.0000	0.9780	0.9543	0.9356	0.9249	0.9226	0.9191	0.9082	0.9031	0.9053
	2005	0.9780	1.0000	0.9776	0.9598	0.9457	0.9395	0.9344	0.9257	0.9204	0.9209
	2006	0.9543	0.9776	1.0000	0.9825	0.9641	0.9534	0.9497	0.9416	0.9330	0.9330
	2007	0.9356	0.9598	0.9825	1.0000	0.9832	0.9694	0.9641	0.9560	0.9448	0.9425
	2008	0.9249	0.9457	0.9641	0.9832	1.0000	0.9847	0.9781	0.9698	0.9585	0.9514
	2009	0.9226	0.9395	0.9534	0.9694	0.9847	1.0000	0.9871	0.9757	0.9674	0.9578
	2010	0.9191	0.9344	0.9497	0.9641	0.9781	0.9871	1.0000	0.9882	0.9784	0.9669
	2011	0.9082	0.9257	0.9416	0.9560	0.9698	0.9757	0.9882	1.0000	0.9874	0.9737
	2012	0.9031	0.9204	0.9330	0.9448	0.9585	0.9674	0.9784	0.9874	1.0000	0.9841
	2013	0.9053	0.9209	0.9330	0.9425	0.9514	0.9578	0.9669	0.9737	0.9841	1.0000
corr. eigencentrality	2004	1.0000	0.8721	0.5857	0.4403	0.4765	0.3823	0.5311	0.3671	0.3566	0.4801
	2005	0.8721	1.0000	0.6864	0.4955	0.5252	0.4511	0.5732	0.4486	0.3948	0.5223
	2006	0.5857	0.6864	1.0000	0.6408	0.5813	0.5708	0.5118	0.4845	0.3832	0.5264
	2007	0.4403	0.4955	0.6408	1.0000	0.7597	0.6577	0.4433	0.4359	0.4421	0.4100
	2008	0.4765	0.5252	0.5813	0.7597	1.0000	0.5915	0.4154	0.4428	0.4785	0.3768
	2009	0.3823	0.4511	0.5708	0.6577	0.5915	1.0000	0.5971	0.6248	0.4751	0.5474
	2010	0.5311	0.5732	0.5118	0.4433	0.4154	0.5971	1.0000	0.6067	0.4520	0.7441
	2011	0.3671	0.4486	0.4845	0.4359	0.4428	0.6248	0.6067	1.0000	0.4620	0.5323
	2012	0.3566	0.3948	0.3832	0.4421	0.4785	0.4751	0.4520	0.4620	1.0000	0.4361
	2013	0.4801	0.5223	0.5264	0.4100	0.3768	0.5474	0.7441	0.5323	0.4361	1.0000

Table A.10: Rank cross-correlations of firm's market value and eigenvector centrality

The upper half of the table shows the rank cross-correlation of all the 2081 firms for which data on the market value is available. The buttom part shows the rank cross-correlation of the eigenvector centrality for the 482 firms which have a positive centrality from 2004–2013.

Appendix B. Ownership network

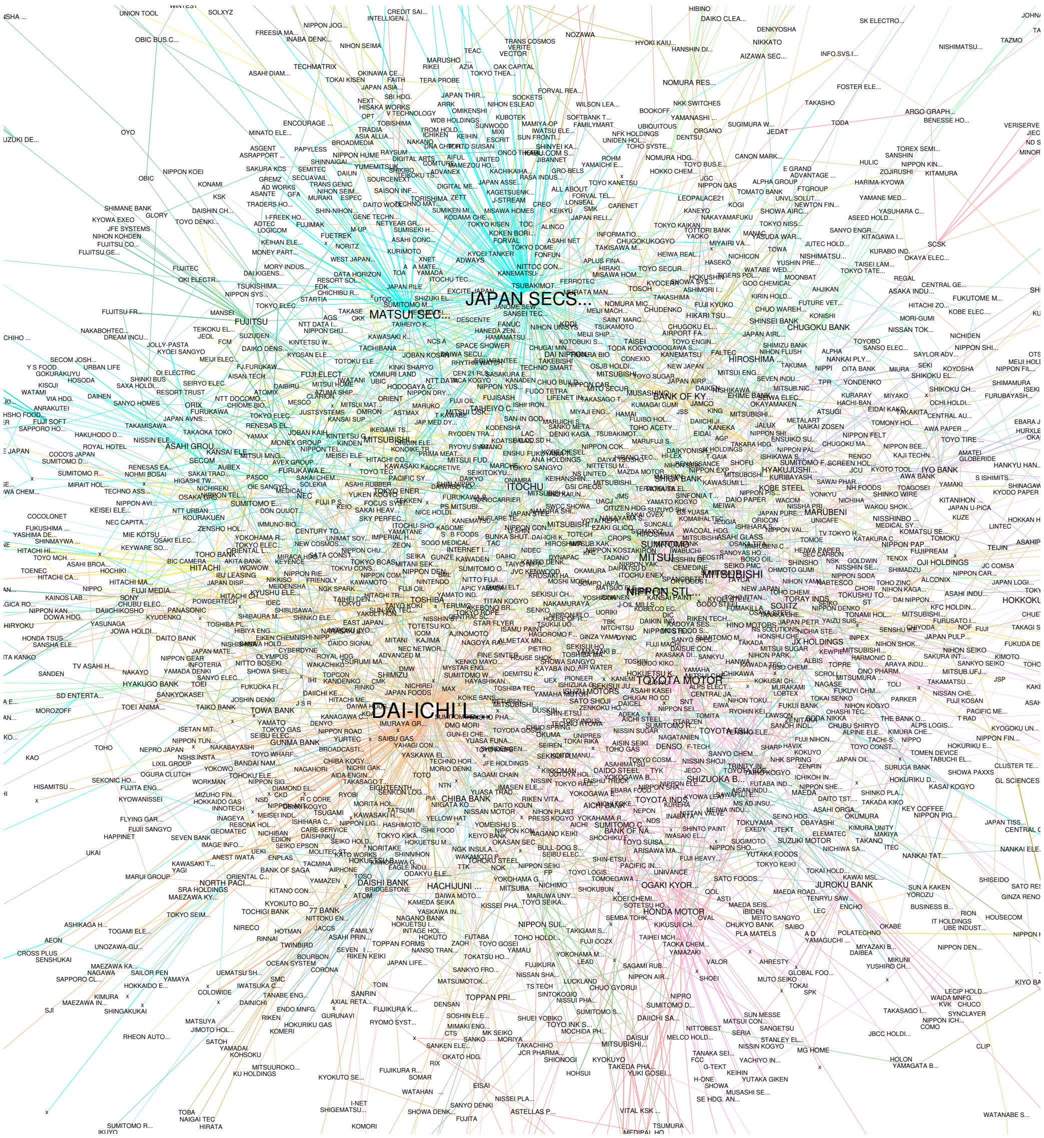

Figure B.10: Ownership network in 2013

This visualization shows the ownership network. The label size is proportional to the number of links. Color coding has been used to highlight the (overlapping and weak) communitiy structures.

Appendix C. Firm profitability analysis

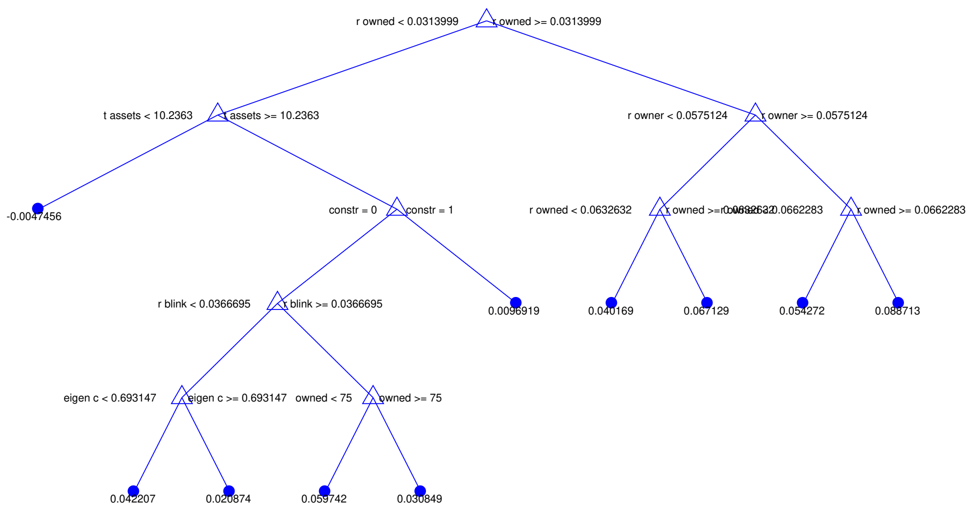

Figure C.11: Regression tree for 2010

This example shows prototypically the results of the regression tree analysis. Branches are labeled with the split variable and the split point value. End leaves show the expected resulting ROA for firms that fall into the category that is defined by the splits in the tree strucure.