Board Interlock and Shareholder Networks in Japanese Companies

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Abstract

This study examines the effects of position in the board interlock and shareholder networks on their profits in Japanese listed companies. The positions in the networks are measured via centrality notions: the degree centrality, the betweenness centrality, and the Katz-Bonacich centralities, which express direct, intermediate, and synergy effects, respectively. Although previous studies have focused on the characteristics of board members – such as the ratio of independent directors or female directors – our study adds the positions in the networks to the features of board members. We also examine the structural changes in the Japanese economy by ranking centralities. We find that the shareholder network is relatively stable, but that there is discontinuity between 2013 and 2018 in the board interlock networks. There are positive intermediate effects and negative direct effects in the board interlock and shareholder networks. Synergy effects are observed only in the board interlock networks.

1 Introduction

Social network analyses have revealed that an agent's performance depends on their characteristics and position within the network. When we focus on companies, we have the following question: How does a company's place in the company network affect corporate profits?

Kikuchi (2006) classifies interlocking boards in Japanese companies – such as interlocking relationships of shareholders by a financial company or non-financial company groups, or connections with professionals (lawyers, accountants, or professors), etc. Kikuchi (2006) has identified the changes to Japanese interlocking networks from 1969 to 1999 and noted that the influence of the traditional Japanese company groups (the "big-six" horizontal groups: Mitsubishi, Sumitomo, Mitsui, Dai-Ichi Kangyo, Fuyo, and Sanwa) has weakened. Beyond this classification, Kanamitsu (2007) derives some network statistics (clustering coefficients, average path length, and redundancy) characterizing the Japanese interlocking network and examines the underlying mechanisms. Using the same data as Kikuchi (2006), Kanamitsu and Inaba (2013) examine the relationship between the Japanese interlock network and good corporate governance and show that, in 2000, the eigenvector centrality of the interlock network has a positive correlation with the good governance, and that the degree centrality and the clustering coefficient have, in turn, a negative correlation with the good governance.

The relationship between board interlocks and corporate performance is discussed broadly but the stylized facts cannot be derived (Kikuchi, 2006; Mizruchi, 1996; Peng et al., 2015; Zona et al., 2018). The purpose of this study is to examine the relationship between a position in a cooperation network and corporate performance using Japanese board interlock and shareholder data.

Our study differs from previous studies in the following ways: First, in Kanamitsu and Inaba (2013), shareholder relationships are introduced by incorporating three classes of directors: dispatched directors (*haken yakuin*), loaned directors (*syukkou yakuin*), and interlocking director (*kennin yakuin*). Our study, on the other hand, measures shareholder relationships by deriving shareholder networks among companies via the use of shareholding ratios. Recently, the capital relationship – that is, the Keiretsu or Group Companies – has weakened among Japanese companies. In addition, the presence of independent directors has strengthened. Therefore, we consider board interlock networks and shareholder networks both independently and simultaneously. Second, previous Japanese studies focus on the internal quality of the board and do not focus on the characteristics of the network (Irie & Noma, 2008; Miwa, 2010; Morikawa, 2019; Sako & Kubo, 2019; Tanaka, 2019). Finally, we use various measurements for corporate performance (operational profit, ordinal profit, net profit, return on asset (ROA), return on equity (ROE), and average employee income).

Our main results are as follows. There are several correlations between some centralities and ordinary and net profits. For both the board interlock networks and the shareholder networks, direct relations have a negative correlation, and mediational relations positively correlate with profits. The higher-order (or synergy) network effects only have a positive correlation with the board interlock network. However, operational profit, ROA, ROE, and average employee income do not correlate with any centrality notions.

The remainder of this study is organized as follows: in Section 2, we present the data and network concepts for examination. Section 3 presents the empirical results, including network centrality rankings by companies and the estimated results. Finally, we conclude the study in section 4.

2 Data and Methods

We employ data for listed companies in Japan from the Directors Data (*Yakuin Shikiho*), Major Shareholder data (*Oo-Kabunushi* Data), and Company Overview data (*Kaisya Gaiyo* Data) by Toyo Keizai. A link through a board interlock was created by the Directors Data. When one person is a director of two companies, we consider these two companies as being connected. In this case, an undirected link is created between the two companies. Major shareholders affect company management. In this sense, there is a directed link between shareholders and the company. Thus, we treated this connection as follows: if Company A owns at least 10% of the stock of Company B, then there is a directed link from Company A to Company B.

Both the board interlock networks and shareholder networks are measured using data obtained in 2008, 2013, and 2018. Corporate performance is measured using data collected in 2009, 2014, and 2019. Using these datasets, the networks are predetermined against the corporate performance. The one-year lag between the network and corporate profit data excludes reverse causality from profit to network.

The descriptive statistics for each network are presented in Table 1. Company networks through the board interlocks became denser from 2008 to 2018 as all average degrees, the total number of edges, and the largest component size increased. These facts indicate that interlocking through a director is common among various companies. Company networks through shareholders became sparser from 2008 to 2018 because all average degrees, the total number of edges, and the largest component size decreased. By comparing the board interlock and the shareholder networks, the index of transitivity differs significantly. Transitivity is defined by the ratio of triangles and connected triples in the graph (for a directed graph, the direction of the edges is ignored). For the board interlock networks, we offer the following interpretation: suppose that both a connection between Companies A and B and a connection between Companies B and C exist. There is then a connection between Companies A and C with a probability of 30%. For shareholder networks, the probability

was less than 1%. In this sense, the shareholder-company network has a less-circulated relationship than the board interlock network. Figures 1 and 2 show graphs of all six networks.

We use the following three major centralities: 1) The degree centrality indicates the number of direct links of a company, and this index measures the immediate effects of other companies. 2) The betweenness centrality is defined as follows: consider the shortest path between Company X and Company Z. If the path includes Company A, then Company A's betweenness centrality increases by 1. We can then calculate the betweenness centrality of Company A when we consider all pairs of two companies in the network. This index measures the intermediate role of a company in a network. 3) The Katz-Bonacich centrality measures the sum of higher-order effects (Bonacich, 1987; Katz, 1953). The first-order effect is to obtain information from a directly connected company. This is then equal to the degree centrality. The second-order effect obtains information via the path with the second distance, and the information of the two companies along the path is combined. If broader contents are included and complement each other, the combined information becomes more valuable for the management, which means that the second-order effect is more valuable than the first one. If the distance of the path is extended, some noise of information is also included, and the value decreases. The decay parameter expresses this decrease. The Katz-Bonacich centrality captures the above synergetic benefits.

Table 2 shows descriptive statistics for the company's attributes and centralities. We take a logarithm of both the number of employees and total assets. However, we cannot take a logarithm of shareholders' equity given that it can take on negative values. ROE is calculated directly by dividing the net income by shareholders' equity. Similarly, ROA is calculated directly by dividing the net income by the total assets. The size of the board, the ratio of outside directors on the board,[1] the ratio of female directors on the board, and the ratio of professionals (professors, lawyers [*bengoshi*], and certified public accountants [*konin kaikeishi*]) on the board are directly calculated from the Directors Data.

The correlation matrix for the variables used for our estimation is shown in Table 3. We confirm that many centralities positively correlate to some extent with both ordinary profit and net profit. On the other hand, none of the centralities correlated with either ROE or ROA – given that the values are less than 0.1. Among the centralities in the board interlock networks, there were relatively high correlations. On the other hand, among the centralities of shareholder networks, there are relatively low correlations. These may originate from the density (or sparseness) of the networks.

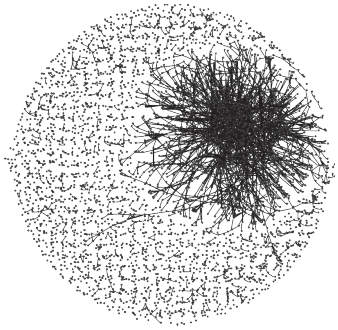
For estimation purposes, we made use of fixed-effects models to utilize the advantages of panel data. By the Hausman test, random-effects models were rejected.[2]

Table 1 : Descriptive Statistics for Networks

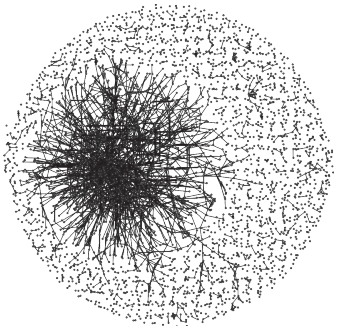
	Board-Interlock Network 2008	Board-Interlock Network 2013	Board-Interlock Network 2018	Shareholder Network 2008	Shareholder Network 2013	Shareholder Network 2018
The total number of nodes	3887	3532	3708	3804	3499	3741
Average degree	1.66	1.68	2.26	0.61	0.55	0.47
Reciprocity	1	1	1	0.0052	0.0073	0.0057
Transitivity	0.3	0.27	0.24	0.0084	0.0095	0.006
The total number of edges	3234	2960	4193	1162	970	876
Max degree	25	22	17	35	31	26
Min degree	0	0	0	0	0	0
Largest component size	1473	1489	2286	506	399	227

1 The "outside" director here follows the definition in the Directors Data (*Yakuin Shikiho*), which includes directors from banks and affiliated companies.

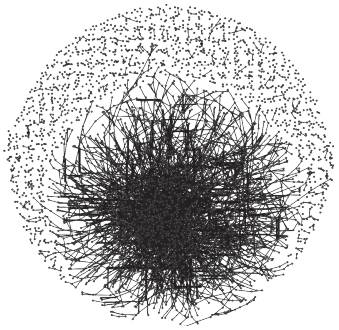
2 The exception is Model 5 in Table 6. A random-effects model for Model 5 is, thus, not rejected. However, there is no qualitative difference between the fixed- and random-effects models. In addition, the comparison is relatively easy for the same model. For these reasons, we use the fixed-effects model for Model 5.



(a) Board Interlock Network 2008

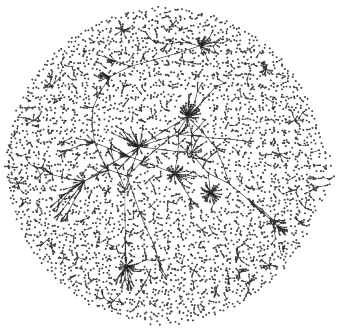


(b) Board Interlock Network 2013

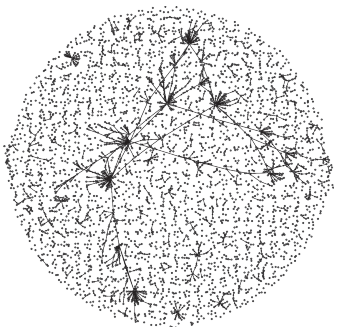


(c) Board Interlock Network 2018

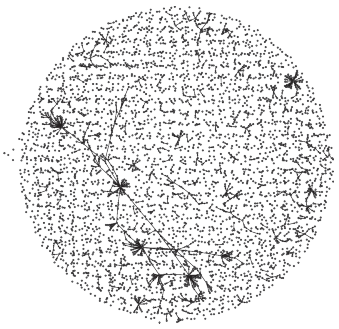
Figure 1 : Graphs for the board interlock networks.



(a) Shareholder Network 2008



(b) Shareholder Network 2013



(c) Shareholder Network 2018

Figure 2 : Graphs for the shareholder networks.

Table 2 : Descriptive statistics for dependent and independent variables.

	N	Mean	St. Dev.	Min	Max
Operational profit (1 billion yen)	9,267	18.3	143	-461	5,344
Ordinal profit (1 billion yen)	9,406	13.5	77.5	-779	2,441
Net profit (1 billion yen)	9,406	7.38	55.4	-787	1,883
ROE (%)	9,382	-3.13	121	-5,850	1,841
ROA (%)	9,382	1.03	13.5	-476	54.8
Average income of employees (10 thousand yen)	10,792	592.3	152.9	220	2,478
Total number of employees (raw value)	9,321	4,869	17,945	3	376,445
Log(total number of employees)	9,321	6.95	1.62	1.10	12.8
Asset (10 billion yen)	9,412	71.8	770	0.01	31,114
Log(asset)	9,412	1.57	1.92	-4.87	10.3
Equity (10 billion yen)	9,412	12.1	57.4	-6.01	1,935
Board size (number of members)	11,127	11.1	3.45	4	37
Ratio of outside directors (%)	11,127	0.34	0.13	0	0.9
Ratio of female directors (%)	11,127	0.03	0.05	0	0.7
Ratio of professional directors (%)	11,127	0.12	0.11	0	0.8
Degree c. in board interlock net.	11,127	1.87	2.44	0	25
Betweenness c. in board interlock net.	11,127	2.81	8.52	0	119
Katz-Bonacich c. in board interlock net.	11,127	0.18	0.98	0	19.9
Degree c. in shareholder net.	11,044	0.55	1.48	0	35
Betweenness c. in shareholder net.	11,044	0.04	0.37	0	14
Katz-Bonacich c. in shareholder net.	11,044	0.05	1	0	35.2

Table 3：Correlation matrix.

	Ope. profit	Ord. profit	Net profit	ROE	ROA	Ave. income	Emloyees
Operational profit							
Ordinal profit	0.591						
Net profit	0.526	0.934					
ROE	0.015	0.029	0.040				
ROA	0.027	0.056	0.074	0.329			
Ave. income of employees	0.192	0.262	0.230	0.030	0.091		
Total number of emloyees	0.361	0.551	0.451	0.013	0.024	0.251	
Log(employees)	0.248	0.330	0.265	0.066	0.168	0.376	0.531
Asset	0.404	0.478	0.369	0.005	0.000	0.116	0.294
Log(asset)	0.315	0.364	0.294	0.059	0.155	0.528	0.449
Equity	0.567	0.835	0.748	0.016	0.027	0.278	0.669
Board size	0.150	0.189	0.142	0.034	0.075	0.329	0.273
Ratio of outside directors	0.027	0.035	0.043	-0.031	-0.065	0.057	0.016
Ratio of female directors	0.093	0.092	0.093	0.005	0.013	-0.008	0.080
Ratio of professional directors	0.040	0.041	0.046	0.007	0.021	0.051	0.020
Degree c. (board)	0.237	0.263	0.213	0.021	0.051	0.356	0.376
Betweenness c. (board)	0.278	0.290	0.252	0.019	0.043	0.313	0.372
Katz-Bonacich c. (board)	0.136	0.162	0.120	0.005	0.009	0.160	0.256
Degree c. (share.)	0.190	0.366	0.314	0.009	0.011	0.264	0.511
Betweenness c. (share.)	0.058	0.113	0.084	0.000	0.007	0.087	0.062
Katz-Bonacich c. (share.)	-0.003	-0.003	-0.004	0.003	0.002	0.045	0.000

	Log(employees)	Asset	Log(asset)	Equity	Board size	Outside officer	Female officcer
Log(employees)							
Asset	0.179						
Log(asset)	0.814	0.284					
Equity	0.386	0.713	0.449				
Board size	0.557	0.106	0.588	0.243			
Ratio of outside directors	-0.168	0.038	-0.142	0.033	-0.369		
Ratio of female directors	0.002	0.073	0.003	0.099	-0.072	0.200	
Ratio of professional directors	-0.059	0.021	-0.056	0.027	-0.215	0.321	0.224
Degree c. (board)	0.418	0.185	0.433	0.336	0.351	0.181	0.107
Betweenness c. (board)	0.350	0.220	0.379	0.360	0.272	0.156	0.127
Katz-Bonacich c. (board)	0.218	0.127	0.235	0.232	0.229	-0.003	-0.006
Degree c. (share.)	0.337	0.155	0.325	0.428	0.256	0.003	0.007
Betweenness c. (share.)	0.114	0.006	0.108	0.073	0.087	-0.011	0.001
Katz-Bonacich c. (share.)	0.018	-0.003	0.029	0.002	0.059	-0.019	-0.012

	Special. off.	Degree (board)	Btw. (board)	Bona. (board)	Degree (share.)	Btw. (share.)	Bona. (share.)
Ratio of professional directors							
Degree c. (board)	0.119						
Betweenness c. (board)	0.080	0.769					
Katz-Bonacich c. (board)	-0.013	0.505	0.366				
Degree c. (share.)	-0.051	0.382	0.333	0.263			
Betweenness c. (share.)	-0.030	0.106	0.058	0.036	0.225		
Katz-Bonacich c. (share.)	-0.025	0.022	0.014	0.007	0.077	0.081	

Notes: The order of variable names corresponds to those in Table 2.

3 Results

3.1 Centrality ranking

The rankings of the network centralities for the board interlock and shareholder networks are listed in Tables 4 and 5.[3]

First, we compare the rankings of different centralities within either the board interlock network or shareholder network. From the descriptive statistics are given in Table 1, the board interlock networks are relatively denser, and the ranking of the degree of centrality is similar to that of other centralities (the betweenness centrality or the Katz-Bonacich centrality). This is because, in a denser network, direct links tend to have an intermediate role and obtain higher-order effects. The exception is the ranking of the Katz-Bonacich centrality in 2018. In this case, several GMO companies form a group and obtain a higher-order effects within the loops via the group.

Shareholder networks are sparse, but the maximum degrees are larger than those in board interlock networks. Major makers and trading companies (*Syosha*) execute their influence through shareholding. On the other hand, the betweenness centrality is small compared to that of the board interlock networks because the shareholder networks are relatively sparse and directed networks, and the number of paths reduces more in the directed networks than in the undirected networks. The company rankings in terms of the betweenness and Katz-Bonacich centralities are different from those in the degree centrality. Again the sparseness of the network is one reason for this difference – especially for the Katz-Bonacich centrality, whereby some locally-grouped companies are distinguished in the sparse network and increase the ranking of the Katz-Bonacich centrality through the loop within the company group. In the rankings outside of the top 10, which is not listed in Table 5, the Katz-Bonacich centrality in terms of the shareholder networks decreases drastically from 8 or 10 to less than 0.01. After this drastic decrease, the ranked company in terms of the degree centrality appears on the list. This indicates that the number of links alone is not sufficient for increasing the Katz-Bonacich centrality; some loops in certain paths within the network are needed.

Second, we focus on the time-series changes in the rankings. For degree centrality, the shareholding network is more stable in the long run than that of the board interlock network. In the shareholder network, the same eight companies are in the top 10 for three consecutive periods. However, only one company is in the top 10 for three consecutive periods in the board interlock network. We can confirm the volatility apparent in the board interlock networks: for the degree centrality, the same seven companies appear in 2008 and 2013, but only two companies appear in both 2013 and 2018, indicating a discontinuity after 2013. Moreover, this is clearer for the Katz-Bonacich centrality, with companies relating to GMO dominating the rankings in 2018.

As for the ranking of the Katz-Bonacich centrality of the shareholder networks, there is similar stability with the same six companies present in all three periods. The weak stability is found in the betweenness centrality with the same three companies. On the other hand, there is no such stability in the board interlock networks judging by companies present in all three periods.

Finally, we focus on the companies. Many traditional Japanese representative companies are listed in the ranking of degree centrality in shareholder networks (Table 5). But the other rankings, including the board interlock networks, show this trend diminishing – especially in the betweenness centrality of the shareholder networks, including more diverse companies.

3 See also Fujiyama and Hirai (2021) for a detailed analysis of the ranking of board interlock networks.

Table 4：Centrality rankings in the board interlock networks.

	Degree Centrality in Board Interlock Net. 2008		Degree Centrality in Board Interlock Net. 2013		Degree Centrality in Board Interlock Net. 2018	
1	Toyota Mortor Corporation	25	Mitsubishi Corporation	22	Panasonic Corporation	17
2	Fuji Kyuko Co., Ltd.	23	Toyota Mortor Corporation	20	Mitsubishi Corporation	17
3	Sony Corporation	22	Tokyu Railways Co., Ltd.	19	Imperial Hotel, Ltd.	17
4	Furukawa Electric Co., Ltd.	18	Fuji Kyuko Co., Ltd.	18	Kintetsu Group Holdings Co.,Ltd.	16
5	Hitachi, Ltd.	18	JX Holdings, Inc.	17	Kansai Electric Power Co., Inc.	16
6	Tokyu Railways Co., Ltd.	18	Sony Corporation	17	IHI Corporation	15
7	Hankyu Hanshin Holdings, Inc.	18	Hankyu Hanshin Holdings, Inc.	17	ASICS Corporation	15
8	Fuji Television Network	16	Asahi Broadcasting Corporation	17	AEON Co., Ltd.	15
9	Mitsui & Co., Ltd.	16	Mitsubishi Research Institute, Inc.	16	Komatsu Ltd.	14
10	Sumitomo Mitsui Financial Group, Inc.	16	Mitsui & Co., Ltd.	16	Mitsui & Co., Ltd.	14
11	Tokio Marine Holdings, Inc.	16			Japan Exchange Group, Inc.	14
12	Kansai Electric Power Co., Inc.	16			Transcosmos inc.	14

	Betweenness Centrality in Board Interlock Net. 2008		Betweenness Centrality in Board Interlock Net. 2013		Betweenness Centrality in Board Interlock Net. 2018	
1	Sony Corporation	111985	Fuji Kyuko Co., Ltd.	100502	Komatsu Ltd.	118922
2	Toyota Mortor Corporation	103261	Mitsubishi Corporation	90806	AEON Co., Ltd.	116974
3	Fuji Kyuko Co., Ltd.	96418	Toyota Mortor Corporation	87220	ANA Holdings Inc.	116303
4	Tokio Marine Holdings, Inc.	67256	Imperial Hotel, Ltd.	82596	Kansai Electric Power Co., Inc.	115548
5	Kansai Electric Power Co., Inc.	65008	JX Holdings, Inc.	79341	Panasonic Corporation	107135
6	Sumitomo Mitsui Financial Group, Inc.	62086	Yokogawa Electric Corporation	70333	IHI Corporation	106908
7	Mitsui & Co., Ltd.	61307	Tokyo Electric Power Company,Inc.	67605	Fast Retailing Co., Ltd.	101239
8	Kadokawa Group Holdings, Inc.	56497	AEON Co., Ltd.	63395	Imperial Hotel, Ltd.	98186
9	Kasumi Co., Ltd.	56238	FIDEA Holdings Co. Ltd.	59137	Japan Post Bank Co., Ltd.	92033
10	Imperial Hotel, Ltd.	50583	Sumitomo Mitsui Financial Group, Inc.	59005	Tokyo Broadcasting System Holdings, Inc.	86884

	Katz-Bonacich Centrality in Board Interlock Net. 2008		Katz-Bonacich Centrality in Board Interlock Net. 2013		Katz-Bonacich Centrality in Board Interlock Net. 2018	
1	Fuji Kyuko Co., Ltd.	17.06	Toyota Mortor Corporation	19.4	GMO CLOUD K.K.	19.93
2	Toyota Mortor Corporation	14.29	Fuji Kyuko Co., Ltd.	13.18	GMO Payment Gateway, Inc.	19.86
3	Sony Corporation	13.4	Mitsui & Co., Ltd.	12.47	GMO Media,Inc.	19.31
4	Furukawa Electric Co., Ltd.	11.25	Sumitomo Mitsui Financial Group, Inc.	11.77	GMO Research,Inc.	19.26
5	Fuji Electric Holdings Co., Ltd.	10.7	Japan Exchange Group, Inc.	11.47	GMO Pepabo,Inc.	19.03
6	Sumitomo Mitsui Financial Group, Inc.	9.89	Panasonic Corporation	10.74	GMO AD Partners Inc.	19.03
7	Zeon Corpration	9.31	Komatsu Ltd.	10.5	GMO TECH, Inc.	19.03
8	ADEKA Corporation	9.15	Brother Industries, Ltd.	10.5	GMO internet, Inc.	19.03
9	The Yokohama Rubber Co., Ltd.	9.03	Seven Bank,Ltd.	9.88	Nexyz.Group Corporation	18.01
10	NIPPON EXPRESS Co.,Ltd.	8.63	Odakyu Electric Railway Co.,Ltd.	9.83	GMO Financial Holdings, Inc.	17.42

Table 5 : Centrality rankings in the shareholder networks.

	Degree Centrality in Shareholder Net. 2008		Degree Centrality in Shareholder Net. 2013		Degree Centrality in Shareholder Net. 2018	
1	Mitsubishi Corporation	35	Mitsubishi Corporation	31	Mitsubishi Corporation	26
2	Mitsui & Co., Ltd.	32	AEON Co., Ltd.	29	AEON Co., Ltd.	26
3	AEON Co., Ltd.	29	Nippon Steel & Sumitomo Metal Corporation	28	Toyota Mortor Corporation	23
4	Toyota Mortor Corporation	28	ITOCHU Corporation	27	ITOCHU Corporation	23
5	ITOCHU Corporation	28	Toyota Mortor Corporation	25	Nippon Steel & Sumitomo Metal Corporation	21
6	Hitachi, Ltd.	21	Mitsui & Co., Ltd.	22	Mitsui & Co., Ltd.	14
7	Nippon Steel Corporation	19	Honda Motor Co., Ltd.	15	Honda Motor Co., Ltd.	13
8	NEC Corporation	17	Hitachi, Ltd.	12	Mitsubishi Electric Corporation	11
9	Honda Motor Co., Ltd.	14	Mitsubishi Electric Corporation	12	HIKARI TSUSHIN, Inc.	11
10	TAIHEIYO CEMENT Corporation	12	Kobe Steel, Ltd.	11	JXTG Holdings, Inc.	10
11	Mitsubishi Electric Corporation	12	NEC Corporation	11	Kobe Steel, Ltd.	10
12	Marubeni Corporation	12	HIKARI TSUSHIN, Inc.	11		

	Betweenness Centrality in Shareholder Net. 2008		Betweenness Centrality in Shareholder Net. 2013		Betweenness Centrality in Shareholder Net. 2018	
1	Toyota Tsusyo Corporation	10	Toyota Tsusyo Corporation	14	KDDI Corporation	10
2	Yahoo Japan Corporation	8	The Nisshin OilliO Group, Ltd.	8	Toyota Tsusyo Corporation	8
3	The Nisshin OilliO Group, Ltd.	7	Yahoo Japan Corporation	8	NCXX Group Inc.	4
4	DAIDO STEEL Co., Ltd.	7	KDDI Corporation	8	The Nisshin OilliO Group, Ltd.	3
5	Osaka Securities Financing Co., Ltd.	6	DAIDO STEEL Co., Ltd.	5	S Foods Inc.	2
6	SFCG Co., Ltd.	6	SCSK Corporation	4	CAICA Inc.	2
7	Nissho Electronics Corporation	6	NTT DOCOMO, Inc.	3.5	M3, Inc.	2
8	Matsushita Electric Works	5	NTT DATA Corporation	3.5	CHIMNEY Co., Ltd.	2
9	Misawa Homes Co., Ltd.	4	WonderCorporation	3	CRE, Inc.	2
10	NHK SPRING Co., Ltd.	4	Renesas Electronics Corporation	3	Sekisui Jushi Corporation	2
11	MAG NET Holdings, Inc.	4			SOLXYZ Co., Ltd.	2
12	Toho Real Estate Co., Ltd.	4			SAKATA INX Corporation	2
13	KDDI Corporation	4			TOYO INK SC HOLDINGS Co., Ltd.	2
14	TOHO Co.,Ltd.	4			Hitachi Construction Machinery Co.,Ltd.	2
15	Hitachi Software Engineering Co.,Ltd.	4			ARGO GRAPHICS Inc.	2
16					FORVAL Corporation	2
17					Tokyo Century Corporation	2
18					TOHO Co.,Ltd.	2
19					SCSK Corporation	2
20					YAMAYA Corporation	2

	Katz-Bonacich Centrality in Shareholder Net. 2008		Katz-Bonacich Centrality in Shareholder Net. 2013		Katz-Bonacich Centrality in Shareholder Net. 2018	
1	Osaka Securities Financing Co., Ltd.	35.24	NIPRO Corporation	20.91	NIPRO Corporation	23.69
2	Daiko Clearing Services Corporation	35.24	Takashimaya Co., Ltd.	20.91	TOEI Co., Ltd.	23.69
3	TV Asahi Corporation	17.62	H2O Retailing Corporation	20.91	Nippon Electric Glass Co., Ltd.	23.69
4	TOEI Co., Ltd.	17.62	TV Asahi Corporation	20.91	TV Asahi Holdings Corporation	23.69
5	IHI Corporation	8.81	TOEI Co., Ltd.	20.91	SHOWA PAXXS Corporation	15.79
6	SHOWA PAXXS Corporation	8.81	Nippon Electric Glass Co.,Ltd.	20.91	Sun A. Kaken Co., Ltd.	15.79
7	Sun A. Kaken Co., Ltd.	8.81	SHOWA PAXXS Corporation	10.46	S.Science Co., Ltd.	15.79
8	OKABE Co., Ltd.	8.81	Sun A. Kaken Co., Ltd.	10.46	Tori Holdings Co., Ltd.	15.79
9	New Tachikawa Aircraft Co., Ltd.	8.81	S.Science Co., Ltd.	10.46	Nippi, Inc.	15.79
10	Nippi, Inc.	8.81	Tori Holdings Co., Ltd.	10.46	Regal Corporation	15.79
11	Regal Corporation	8.81	OKABE Co., Ltd.	10.46		
12	Kobayashi Metals Ltd.	8.81	Nippi, Inc.	10.46		
13	Tachihi Enterprise Co., Ltd.	8.81	Regal Corporation	10.46		
14			Kobayashi Metals Ltd.	10.46		

3.2 Centrality and corporate profits

The estimation results are listed in Table 6. Models 1 to 6 have different dependent variables – that is, operating profit, ordinary profit, net profit, ROA, ROE, and employees' average income. Because Models 1, 4, 5, and 6 have lower R-squared values, we focused on Models 2 and 3.

Degree centralities of both the board interlock and the shareholder networks have negative and significant coefficients at 5% level (hereafter, we use 5% as a significance level); direct effects from other companies worsen profits. One possibility is to increase communication or coordination costs among them. For example, when some advice from others is conflicting, they must find a ground for compromise.

The betweenness centralities of the board interlock networks and the shareholder networks have positive and significant coefficients, except for the net profit case (at a 10% significance level). Betweenness centrality measures intermediate roles in company networks. The following interpretations can be made: First, the company can control the flow of information through the shortest path to improve the situation. This centrality corresponds to bridging social capital. Another interpretation relates to collecting information; the more centered companies obtain much more information through the shortest paths and improve their profits. Our results support the positive effects of betweenness centrality.

The Katz-Bonacich centrality of the board interlock network has positive and significant coefficients when the dependent variable is ordinary profit. The net profit is positive and significant at the 10% level. Since this centrality expresses the synergy effects, our result is consistent with a situation in which directors who interlock two companies provide new and external information that enhances profits. In this sense, board interlock networks are suitable for achieving synergy effects. On the other hand, in the shareholder network, we cannot find synergistic effects. One interpretation is that, because links in the shareholder network mean the measures for supervising or ordering other companies management, there is little room for feedback or synergy effects.

The magnitude of these effects was also substantial. The impact on ordinary profit is as follows: an increase of one standard error in the betweenness centrality of the board interlock networks will increase by 1.76 billion yen. Similarly, the Katz-Bonacich centrality of the board interlock networks is 1.52 billion yen, and the betweenness centrality of the shareholder networks is 2.46 billion yen. On the other hand, degree centrality has adverse effects. An increase of one standard error in the degree centrality of the board interlock networks will bring a decrease of 5.20 billion yen. Similarly, the degree centrality of shareholder networks is a decrease of 4.47 billion yen. The magnitudes of net profit are similar.[4] As the magnitude of the degree centrality is larger than that of the other centralities, efficient link creation is required so that the positive effects exceed the negative effects.

4 Only the effect of the degree centrality of the shareholder network has a relatively large change from 4.47 billion yen to 12.09 billion yen.

Table 6：The effects of centralities on cooperation performance.

	Dependent variable:					
	Operational profit	Ordinal profit	Net profit	ROA	ROE	Average income of employees
	(1)	(2)	(3)	(4)	(5)	(6)
Log(total number of employees)	-2.934	-1.939	-2.772	0.969*	-6.248	-14.662**
	(2.559)	(2.333)	(2.084)	(0.418)	(4.061)	(3.363)
Log(asset)	6.943**	1.833	0.953		4.610	46.620**
	(2.592)	(2.361)	(2.109)		(4.097)	(3.406)
Equity	1.370**	1.841**	1.543**	-0.007		0.199**
	(0.030)	(0.025)	(0.023)	(0.006)		(0.041)
Board size	-1.028**	-1.023**	-0.855**	-0.196**	-0.837	0.766+
	(0.335)	(0.302)	(0.270)	(0.073)	(0.526)	(0.430)
Ratio of outside directors	-0.855	-8.818	2.814	-7.626**	-32.149*	7.001
	(8.349)	(7.576)	(6.767)	(1.826)	(13.185)	(10.852)
Ratio of female directors	-0.414	10.489	17.549	0.336	1.888	-35.967+
	(16.723)	(15.114)	(13.501)	(3.649)	(26.215)	(21.800)
Ratio of professional directors	-10.334	3.927	-0.203	5.473*	4.210	40.364**
	(10.100)	(9.178)	(8.198)	(2.216)	(15.967)	(13.247)
Dummy year 2014	0.786	3.931**	4.183**	3.995**	12.980**	-10.783**
	(1.232)	(1.117)	(0.998)	(0.265)	(1.943)	(1.592)
Dummy year 2019	1.164	1.834	2.340+	4.320**	15.049**	15.906**
	(1.729)	(1.570)	(1.403)	(0.355)	(2.732)	(2.246)
Degree c. in board interlock net.	-2.285**	-2.133**	-2.027**	-0.085	0.409	0.563
	(0.541)	(0.490)	(0.438)	(0.118)	(0.853)	(0.705)
Betweenness c. in board interlock net.	0.048	0.206*	0.162+	0.003	-0.050	0.118
	(0.110)	(0.099)	(0.089)	(0.024)	(0.173)	(0.144)
Katz-Bonacich c. in board interlock net.	-2.606**	1.556*	1.110+	0.003	-0.084	-0.280
	(0.726)	(0.653)	(0.583)	(0.158)	(1.116)	(0.906)
Degree c. in shareholder net.	1.176	-3.018**	-8.167**	-0.383	-1.470	-0.112
	(1.206)	(1.098)	(0.981)	(0.265)	(1.864)	(1.565)
Betweenness c. in shareholder net.	4.304	6.636**	7.140**	-0.154	-1.157	-2.906
	(2.645)	(2.406)	(2.149)	(0.581)	(4.172)	(3.419)
Katz-Bonacich c. in shareholder net.	-0.571	-0.323	0.121	-0.027	-0.071	-0.364
	(0.827)	(0.755)	(0.674)	(0.182)	(1.314)	(1.126)
R2	0.344	0.551	0.535	0.068	0.014	0.176
Adjusted R2	-0.141	0.219	0.192	-0.619	-0.711	-0.441
F Statistics	180.553**	428.407**	402.333**	27.286**	5.511**	72.482**
	(df=15; 5168)	(df=15; 5246)	(df=15; 5246)	(df = 14; 5247)	(df = 14; 5247)	(df = 15; 5100)

+p<0.1; *p<0.05; **p<0.01

As for the characteristics of boards, only size has a significant and negative coefficient. One interpretation is that a larger board of directors brings higher coordination costs which, in turn, negatively affect profits. Other independent variables related to the board of directors were not statistically significant. The ratio of professionals (professors, lawyers, and certified public accountants) on the board represents outside and specialized directors. This independent variable is statistically insignificant, in contrast to the previous findings with positive and significant effects (Irie & Noma, 2008; Miyajima & Nitta, 2006; Sako & Kubo, 2019). The ratio of female directors on the board has an insignificant coefficient, which differs from the results presented by Tanaka (2019). However, our results are consistent with those of Miwa (2010) and Morikawa (2019), who do not find outside directors' clear and positive effects.

4 Concluding Remarks

With the increasing focus on inter-company networks, there is a need to further investigate the relationship between companies' positions and profits. From the rankings of network centralities, we find discontinuous changes in board interlock networks. We also present empirical evidence that network centralities have a significant impact on corporate profits. For both the board interlock and the shareholder networks, degree

centrality negatively correlates with profits, and the betweenness centrality – which corresponds to aspects of controlling and collecting information – positively correlates with profits. For only the board interlock network, the Katz-Bonacich centrality – which corresponds to the synergy effects – positively correlates with profits. Our results support positive aspects. In contrast to the apparent effects of network centralities, the effects of characteristics on the board of directors are unclear — only the size of the board negatively affects profits; independent outside directors and female directors have no significant effects. One of our contributions is that the network position through the board is more significant than the characteristics of the board.

Our study is a preliminary report and is limited to showing a list of empirical results. A more detailed examination of the underlying mechanisms is required in the future. There are the following other issues to be addressed.

First, an extended period of time (in years) is needed for our panel data. More data will allow us to examine the robustness of our results and may improve the low R-squared measures found in models 1, 4, and 5 (in particular). The financial crisis in 2008 could also have affected our results, even though we considered dummy variables for the year. Greater extended data mitigate shocks from the financial crisis on our results.

We also need to examine the type of desirable dependent variables. In other studies, ROA and Tobin's Q are often used, but our study obtains significant results concerning ordinary profit and net profit. On the other hand, when ROA is used as the dependent variable in our study, the ratio of professional directors has a significant and positive effect. There could be a different mechanism behind different profit notions.

As for the independent variables, we must consider dispatched directors. Traditionally, dispatched directors have played a significant role in controlling companies. Furthermore, this allows us to define the independence of outside directors more precisely. In terms of minor points, it has also been interesting to examine the robustness of the highly professional directors' positive and significant effect on the average salary in Model 5.

The estimation method also needs to be improved. In this study, panel data analysis is used to reduce the effects of unobservable variables. A lag of one year is placed between the network dataset and corporate profit dataset to exclude reverse causality. However, instrumental variable (IV) estimation is required in the future. Furthermore, a more rigorous consideration of causal inferences is required.

Despite these limitations and future tasks, our study shows the importance of the multiplex network (the board interlock and the shareholder networks) analysis on corporate profit beyond the characteristics of the board of directors.

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