Bank-Insurer-Firm tripartite interconnectedness of credit risk exposures in a cross-shareholding network

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Abstract

This study assesses the interconnectedness of credit risk exposures in a tripartite network of cross-shareholdings among banks, insurers, and firms in Japan's stock market during the fiscal years 2008–2015. We use consistent measures: credit risk exposure by PD (probability of default)/LGD (loss given default) approach in Basel III and RORA (return on risk-weighted assets). We conduct a credit risk analysis of the risk exposures in the cross-shareholdings. The result shows that by following the PD/LGD approach, the credit risk weights become approximately 1.5 to 5 times as large as by the transitional risk weight method. The mean exposure-weighted risk for the firm's shareholdings is 1.67 times as large as the bank's and the insurer's. We analyze the network structure of the cross-shareholdings using network centrality measures. Our analysis can provide each entity with important implications on credit risk management in their cross-shareholdings.

Keywords: credit risk; cross-shareholding; interconnectedness; return on risk-weighted assets (RORA); centrality measure;
JEL classification: G32; G10; D85; L14

1. Introduction

In past decades, banks, insurers, and firms in Japan have traditionally adopted a cross-shareholding corporate governance structure. In terms of business relations between banks and firms, shareholdings enable banks and firms to maintain good relationships with counterparties. By contrast, from the perspective of insurers, especially life insurers that are mostly mutual

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insurance firms, their shareholdings are in portfolio investments rather than cross-shareholdings. However, as insurers hold large number of shares as policy owners, they virtually conduct both cross-holdings and portfolio investment. Hence, cross-shareholdings in this study include not only mutual shareholdings but also unilateral ones.

Currently, banks are regulated based on the Basel III framework (BCBS, 2005). The "transitional measure" of equity exposures of banks adopting an internal ratings-based approach (i.e., IRB approach) ended in June 2014. This triggered a large increase of risk weights in the assets of Japanese banks. Hence, the dissolution of shareholding stocks by major banks adopting the IRB approach is of concern. As alternatives for measuring risk weights on equities under Basel III, banks receive the "Market-based approach" and "PD/LGD approach"[1]. Both approaches largely increase the risk weights approximately 1.5 to 4 times (i.e., 150–400%) compared to 100% in the transitional measure.

By contrast, insurance regulation in Japan depends on the Japan local supervisory framework based on the "solvency margin ratio." This framework is simple and a so-called first-generation solvency regulation,[2], which is similar to the Basel I in international banking regulations. "Solvency margin standard" was introduced for both life and general insurance firms in fiscal year[3] 1996. The solvency margin is calculated as the ratio of solvency margin divided by the half of risk amount. In terms of equity exposure, the risk amount is calculated on the risk of occurrence of loss caused by excessive changes in market value in market risk management.

Triggered by the bankruptcy of Lehman Brothers, many banks, insurers, and firms with cross-holding stocks suffered significant capital losses, with some booking impairment losses. In addition, in response to recent requests of investors for highly transparent management, in June 2015, Japanese firms adopted "Japan's Corporate Governance Code (JCGC)" (Council of Experts Concerning the Corporate Governance Code, 2015), which requires that management explain the purposes and reasons for holding shares of listed stocks.

[1]This approach calculates risk-weighted lending assets using the probability of default (PD) and loss given default (LGD).

[2]An example of second-generation solvency regulation, the Swiss Solvency Test is a risk based capital standard for insurance firms in Switzerland, in use since 2006. In addition, the EU's Solvency II regulation came into force on January 1, 2016.

[3]Japan's fiscal year runs from April 1 to March 31.

Principle 1.4 of the JCGC mentions cross-shareholdings as follows: when firms hold shares of other listed firms as cross-shareholdings, they should disclose their policy with respect to their holdings. In addition, the board should examine the mid- to long-term economic rationale and outlook of major cross-shareholdings annually, considering both associated risks and returns. The board should present detailed explanations of the objective and rationale behind cross-shareholdings after this annual examination.

Inspired by the JCGC, three mega-bank groups (i.e., Mitsubishi UFJ Financial Group, Sumitomo Mitsui Financial Group, and Mizuho Financial Group) adopted return on risk-weighted assets (RORA). Firms generally adopt return on assets (ROA) as a profitable financial ratio. However, the denominator of the ROA, the total asset amount, is less sensitive to risk. The RORA is a risk-adjusted profit indicator, and hence, much more preferable than the ROA or the return on equity capital (ROE).

We contribute to the literature by providing quantitative insight into cross-shareholdings considering credit risk management. Japan's stock market is a good example of cross-shareholding practices in the world.

Our study assesses the interconnectedness in the tripartite network of banks, insurers, and firms by using consistent measures common to all three entities: credit risk exposure (i.e., credit risk-weighted asset) measured by the PD/LGD approach and RORA during the period (FY 2008–2015) from the global financial crisis to the aftermath of JCGC implementation.

First, we conduct a credit risk analysis using the PD/LGD approach in Basel III. We consider an equity exposure same as a lending exposure. In addition, by adopting the RORA, banks, insurers, and firms can assess their exposures using one consistent risk-sensitive measure.

Second, we analyze interconnectedness in the cross-shareholding network using various network centrality measures (Jackson, 2010; Kanno, 2015; Kanno, 2016). We base the network analysis on data of bilateral shares of all listed Japanese entities in the Nikkei NEEDS Financial QUEST database. Hence, our datasets cover almost all bilateral shareholding contracts among banks, insurers, and listed firms with at least one contract with a bank and/or an insurer.

Section 2 reviews prior literature on cross-shareholding and interconnectedness in various financial networks. Section 3 contains the credit risk analysis using some measures. Section 4 presents the network structure analysis of cross-shareholding and Section 5 concludes the study.

2. Literature review

The finance literature on cross-shareholding contains studies over the past few decades from several countries, including Yonezawa and Miyake (1998) (Japan), Suetorsak (2007) (Japan), Almeida et al. (2011) (Korea), Choi et al. (2014) (Japan), and Kanno (2016). However, none of these studies except Kanno (2016) examines cross-shareholding from the network perspective.

By contrast, most network analyses of cross-shareholding are from the perspective of econophysics. Ma et al. (2011) analyze the relationships among domestic mutual investments in China based on the cross-shareholding networks of listed firms. Li et al. (2014) analyze the topological properties and the evolution of cross-shareholding networks of listed firms in China.

Our study contributes to cross-shareholding literature by analyzing the network structure of cross-shareholding by combining credit risk analysis with network analysis. Network analysis is a highly effective approach in examining the interconnectedness of firm relationships in stock markets, which represent complex contract networks using sets of "nodes" connected by "edges." In a cross-shareholding stock network, a node represents a shareholder or an issuer and an edge represents the cross-shareholding relationship between two entities.

De Masi and Gallegati (2012) and Lux (2014) are extant studies on bank-firm bipartite credit networks. Lux (2014) studies a stochastic model of network for credit linkages between banks and non-financial firms based on well-known and plausible stylized facts confirmed by recent studies using comprehensive data sets for several industrial countries.

An analytically tractable example of financial networks is the interbank network characterized by bilateral exposure in the interbank market. Prior studies of financial networks adopt two approaches. The first approach assesses the strength of the contagion channels and network resilience by observing the responses of the financial network structures to shocks. Introducing a shock assumes a specific transmission mechanism, such as defaults by counterparties. Alves et al. (2013) refer to this approach as "dynamic network analysis." Elsinger et al. (2006), Cocco et al. (2009), and Haldane and May (2011) analyze contagion effects in their network analyses.

The second approach describes network structures using topological indicators, often relating these indicators to model graphs based on network theory. This approach does not assume a mechanism by which shocks propagate within the network; therefore, it is referred to as "static network analysis" (Alves et al., 2013). Eisenberg and Noe (2001), Boss et al. (2004), and Kanno (2015, 2016) are examples of studies based on this approach. Our study adopts the static network analysis.

3. Credit risk analysis

We analyze the credit risk based on the RORA by calculating risk-weighted assets based on the Basel III – PD/LGD approach, using a large-scale database.

3.1. Methodology

3.1.1. Risk-weighted assets for equity exposures

First, we calculate risk-weighted assets for equity exposures. In Basel III, the methodology and minimum requirements for the PD/LGD approach for equity exposures are the same for the IRB foundation approach for corporate exposures, subject to the following specifications. The bank's estimate of the PD of a firm that holds an equity position must satisfy the same requirements as the bank's estimate of the PD for its lending exposures. There is no IRB advanced approach for equity exposures, given the 90% LGD assumption.

LGD would be assumed as 90% in deriving the risk weight for equity exposures. Minimum risk weights are set under the PD/LGD approach. When the sum of UL and EL associated with the equity exposure results in less capital than would be required from applying one of the minimum risk weights, the minimum risk weights must be used. The minimum risk weight of 100% applies to policy ownership securities.

For all other equity positions, including net short positions, capital charges calculated under the PD/LGD approach may be no less than the capital charges calculated under a simple risk weight method using a 200% risk weight for publicly traded equity holdings and a 300% risk weight for all other equity holdings. The maximum risk weight of the PD/LGD approach for equity exposures is 1250%.[4]

For equity exposures not in default, the formula for calculating risk-weighted assets (RWA) is as follows:

$$RWA = K \times 12.5 \times EAD, \tag{1}$$

[4]In practice, if there is both equity and IRB credit exposure to the same counterparty, a default on the credit exposure would trigger a simultaneous default, for regulatory purposes, on the equity exposure.

where EAD is the exposure at default and capital requirement (K) is as

$$K = LGD\left[\Phi\left(\sqrt{\frac{1}{1-R}}G(PD) + \sqrt{\frac{R}{1-R}}G(0.999)\right) - PD\right] \times f(M, PD),$$

where G is the inverse of standard normal cumulative distribution, M is the effective maturity, and LGD is 90%. The adjustment term (f), maturity adjustment (b), and correlation (R) are as follows:

$$\begin{aligned} f(M, PD) &= \frac{1 + (M - 2.5)b(PD)}{1 - 1.5b(PD)} \\ b(PD) &= (0.11852 - 0.05478 \times \ln(PD))^2 \\ R(PD) &= 0.12 \cdot \frac{1 - e^{-50PD}}{1 - e^{-50}} + 0.24 \cdot \left(1 - \frac{1 - e^{-50PD}}{1 - e^{-50}}\right), \end{aligned}$$

where, for exposures to small- and medium-sized entities (SME) borrowers, defined as firm exposures in which the reported sales of the consolidated group is less than 500 million yen, a firm-size adjustment (i.e., $0.04 \times (1 - (S - 5)/45)$) is made to the corporate risk weight formula for exposures to SME borrowers. S is expressed as total annual sales in billions of yen with values of S falling in the range of equal to or less than 500 million yen, or greater than or equal to 500 million yen. Reported sales of less than 500 million yen will be treated as equivalent to 500 million yen for the firm-size adjustment of SME borrowers. Thus, the correlation for exposures to SME borrowers is as follows:

$$R(PD) = 0.12 \cdot \frac{1 - e^{-50PD}}{1 - e^{-50}} + 0.24 \cdot \left(1 - \frac{1 - e^{-50PD}}{1 - e^{-50}}\right) - 0.04 \cdot \left(1 - \frac{S - 5}{45}\right).$$

3.1.2. RORA

Next, we calculate the RORA for the period FY 2008–2015. Essentially, the numerator return should include capital gain (loss) and income gain (loss). However, because we cannot obtain information of the trade dates of each firm and the outstanding at the dates for capital gain (loss), we utilize only the dividend data for income gain (loss).

3.2. Data for credit risk analysis

We use firm-level financial data and probability of default (PD) data for FY 2008–2015 for credit risk analysis.

The analysis requires bilateral outstanding data for equity risk exposures, which we obtain from the Nikkei NEEDS Financial QUEST database provided by Nikkei Inc., a Japanese newspaper firm. Hence, we calculate the market value (i.e., EAD in equation (1)) of a holding stock, multiplying the share by the market price at each evaluation time point. The Nikkei NEEDS Financial QUEST database comprises of some sub-databases. Two sub-databases are firms' shareholding database and the blockholding database. The former does not include shareholding data of banks and insurers; however, the latter includes the shareholdings of banks and insurers as blockholders. Hence, we extract two datasets from these sub-databases for our study. As shown in Figure 1, one dataset is the firms' shareholding dataset ("FH") and the other is the blockholding dataset ("BH").

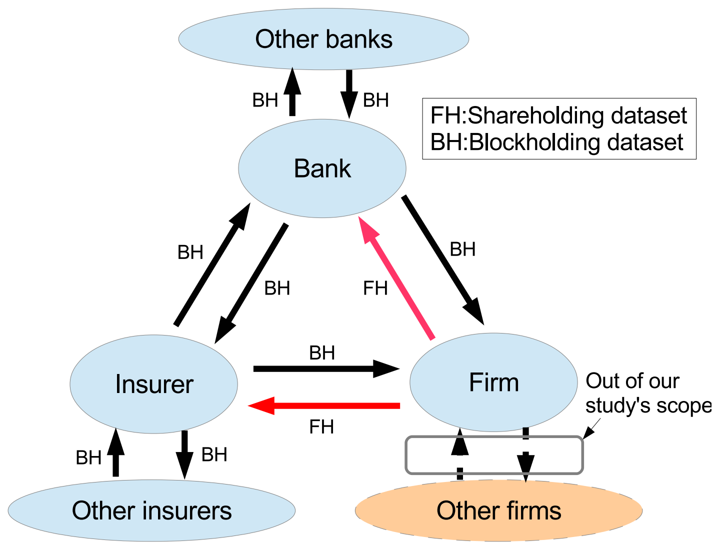

Figure 1: Two shareholdings in the dataset

The firms' shareholding dataset contains information on listed firms that own shares of listed entities such as banks and insurers. However, as shareholdings between firms are outside the scope of our study, we exclude them from the dataset. The dataset contains the shares of 2,936 Japanese listed firms, as of June 2016, covering fiscal years (FY) 2008–2015 (i.e., from the start of April 2008 to the end of March 2016). The dataset contains information on stock investments, the stocks of affiliates, and cross-holding stocks as a sub-database, and firms' shareholding database. The label "policy ownership securities" in this sub-database identifies the cross-holding stocks held by a firm.

By contrast, the blockholding dataset contains information on banks and insurers as blockholders ranked in the top thirty by entity. The banks include city banks, regional banks, second-tier regional banks, and shinkin banks.[5] The insurers include both life insurers and non-life insurers. However, because shareholdings between firms are beyond the scope of our study, we exclude firm blockholders from the dataset.

We also obtain dividend data from the Nikkei NEEDS Financial QUEST database. In addition, we obtain data by entity for the probability of default (PD) from the Credit Research Initiative (CRI) database published free of charge by the National University of Singapore (NUS)[6].

3.3. Analysis results

We present estimation results of risk weight, risk-weighted assets for equity exposures, and RORA.

3.3.1. Risk weight

Figure 2 and Table 1 denote the scatter plot for risk weight and mean for exposure-weighted risk weight by fiscal year for the period FY 2008–2015. The "PD/LGD approach" largely increases the risk weights approximately 1.5 to 5 times (i.e., 150–500%) as large as (i.e., 100%) in the transitional risk weight method, which utilizes the standardized approach of credit risk. Especially, the maximum risk-weight reached over 500% for the result in FY 2008 corresponding to the global financial crisis. As Basel II applied the

[5] As trust funds of foreign banks do not have any identification codes in the database, we exclude them from the dataset.

[6] The initiative is a non-profit undertaking by the Risk Management Institute at NUS, and seeks to promote research and development in the field of credit risk. The CRI promotes the PD model (NUS, 2013) as its foundation, which was developed using a database of over 60,000 listed firms in Asia Pacific, North America, Europe, Latin America, the Middle East, and Africa.

transitional risk weight method during this time, equity exposures did not substantially affect Japanese banks.

In addition, the mean exposure-weighted risk weight for the firm's shareholdings is 1.67 times as large as that of the blockholdings. For cross-shareholdings, it is evident that firms hold stocks with larger risk weights than banks and insurers. Therefore, banks and insurers use cross-shareholdings for credit risk management, whereas firms have strong ties with their corporate group or keiretsu and use cross-holdings as anti-takeover measures.

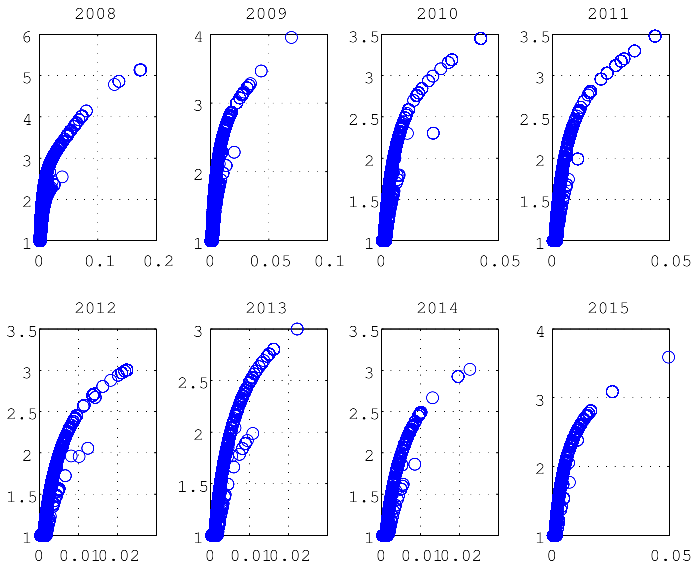

Figure 2: Risk weight scatter plot by fiscal year

Note: Risk weight is calculated based on the risk weight function in the IRB approach to capital requirements for credit risk in Basel III for FY 2008–2015.

3.3.2. Risk-weighted assets for equity exposures

Table 2 reports the quartiles and mean & standard deviation in the upper tier and the sums of original exposures by shareholding purposes in the lower tier, related to credit risk-weighted assets (i.e., credit risk exposures) at the end of fiscal years 2008–2015. Blockholdings correspond to shareholdings designated "BH" in Figure 1. By contrast, temporary investments, policy

Table 1: Mean exposure-weighted risk weight expressed as percentage by fiscal year

	2008	2009	2010	2011	2012	2013	2014	2015	Mean
FH	300	252	225	232	170	210	137	195	215
BH	240	116	106	108	105	137	107	113	129

Note: Abbreviations: FH: firm's shareholding dataset; BH: blockholding dataset. "Mean" indicates the overall mean for the period FY 2008–2015.

ownership securities, portfolio investments, and deemed securities correspond to shareholdings designated "FH" in Figure 1. In addition, the upper tier of Figure 3 illustrates the percentile distribution of bilateral credit risk-weighted assets by year.

From the upper tier of Table 2 and Figure 1, all of the exposure sizes are near zero at the 75th percentile; however, the sizes increase sharply from the 99.5th percentile to the maximum, and range from 509 billion in FY2009 to a maximum of 53,225 billion Japanese yen (JPY) in FY2008. This means that, for the purpose of reducing credit risk exposures, blockholdings decreased sharply just after the Lehman Brothers bankruptcy. By contrast, since FY2010, the first motivation of shareholdings by firms has been policy ownership.

Furthermore, from the lower tier of Table 2, the credit risk exposure size in the entire network decreased sharply to about one-tenth from FY2008 to FY2009 owing to the global financial crisis, and remains unchanged. After FY2012, it decreased slightly because the outstanding investment funds decreased (Flow of Funds Accounts Statistics issued by the Bank of Japan) and Japan's Corporate Governance Code went into effect (Council of Experts Concerning the Corporate Governance Code, 2015).

3.3.3. RORA

The upper tier of Table 3 reports the descriptive statistics of the RORA. In addition, Figure 4 shows the RORA histogram by fiscal year. The RORA almost remains in the 0–5% range; nevertheless, the mean gradually increases for the period FY2008–2015. This means growth in credit risk-adjusted return for shareholdings as a whole, among banks, insurers, and firms.

Table 2: Descriptive statistics of bilateral credit risk-weighted assets (in billions of JPY)

	2008	2009	2010	2011	2012	2013	2014	2015
25%-tile	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Median	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.2
75%-tile	1.3	1.1	0.7	0.7	0.8	1.0	1.0	1.0
Maximum	53,224.9	508.8	7,702.3	2,486.3	18,759.0	12,682.4	3,352.8	1,474.8
Mean	27.3	2.1	2.2	2.0	4.1	3.8	3.0	2.5
S.D.	755.0	9.6	62.3	31.8	159.6	114.1	37.5	18.9
Blockholdings (BH)	417,452.1	28,012.6	33,160.8	28,151.1	80,262.3	60,172.9	42,906.7	29,685.9
Temporary Investments (FH)	0.4	0.3	0.3	1.2	1.0	0.0	0.0	0.0
Policy ownership securities (FH)	—	5,623.2	5,337.6	5,513.8	5,519.3	7,007.6	5,648.1	5,592.1
Portfolio investments (FH)	7,841.5	6,738.8	4,946.6	5,502.0	5,394.6	2,126.3	1,134.1	1,102.6
Deemed securities (FH)	0.0	0.0	810.3	1,153.0	1,150.8	1,497.5	1,109.5	1,169.1
Total amount	425,294.0	40,374.9	44,255.6	40,321.2	92,327.9	70,804.3	50,798.4	37,549.7

Note: Abbreviations: S.D.: standard deviation; FH: firm's shareholding dataset; BH: blockholding dataset. Blockholdings by foreign investment funds are excluded. There is no classification of "policy ownership securities" in FY2008 on the database.

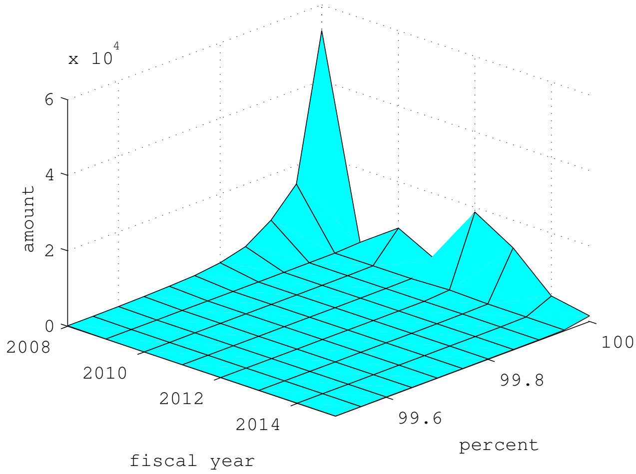

Figure 3: Bilateral credit risk-weighted assets distribution

Note: Exposure amounts are expressed in billions of JPY. The distribution shows the range from the 99.5th percentile to the 100th percentile.

In addition, we carefully examine features of the RORA in the lower tier of Table 3. The "BH" part in the lower tier of Table 3 denotes the RORA of the credit risk exposure of a firm by a mega bank group/major life insurer in each upper row and the credit risk-weighted asset amount in billions of yen of the bank/insurer in each lower row. The "PI" part in the lower tier of Table 3 denotes the RORA of the credit risk exposure of investment securities of a mega bank group/major life insurer by a firm in each upper row and the credit risk-weighted asset amount in billions of yen of the bank/insurer in each lower row. The "CH" part in the lower tier of Table 3 denotes the RORA relating to policy ownership securities of a mega bank group/major life insurer by a firm in each upper row and the credit risk-weighted asset amount in billions of yen of the bank/insurer in each lower row.

Consequently, the average RORA for blockholdings (BH) of the mega bank groups (MUFJ FG, SMFG, and Mizuho FG) is 0.93 to 1.45 times as high as the average RORA for cross-shareholdings (CH) of bank or insurer stocks by firms. This means that cross-shareholdings are against firms' interests in terms of a risk-adjusted return. By contrast, the RORA of blockholdings by firms is higher than the RORA of portfolio investment and cross-shareholding of bank or insurer stocks by firms for FY2008–2013. Hence, firms obtain high profits if they hold shares as blockholders. However, they suffer from the low profits from cross-shareholdings.

Furthermore, the outstanding credit risk-weighted asset amounts for megabank groups and major insurers substantially reduce to less than one-tenth just after the global financial crisis and slightly decrease after the implementation of JCGC. By contrast, the outstanding cross-holdings of banks' and insurers' stocks by firms were almost unchanged. Considering their business relations with banks or insurers, firms cannot easily reduce outstanding cross-holdings, even after JCGC.

In addition, the figure in each upper row in the rightmost column denotes the correlation between the $RORA(t-1)$ and the $ARRA(t)$ at $t =$ the end of March 2010 to March 2016. The figure in each lower row in the rightmost column denotes the correlation between the $RORA(t-1)$ and the $ARRA(t)$ at $t =$ the end of March 2016. We define the correlation as follows:

$$Corr. = correlation(RORA(t-1), ARRA(t)), \tag{2}$$

where $ARRA(t)$ denotes the annualized return of risk-weighted assets calculated in equation (1) at each end time t for the period FY2010–2015. As banks or insurers validate the investment performance of their equity portfolios in the previous year and decide its holding policy the following year, we can reasonably assume that $ARRA$ lags one year behind $RORA$.

All values in the Corr. part of Table 3 indicate positive correlations except of the cross-shareholding and the portfolio investment relating to Dai-ichi Life. The result demonstrates that both insurers and banks initiate risk-sensitive cross-shareholdings. Especially, they dissolve cross-shareholdings after JCGC implementation in June 2015, as Corr. at $t =$ the end of FY2016 are 100% across all banks and insurers except of the cross-shareholding and the portfolio investment relating to Dai-ichi Life.

4. Network analysis

This section describes the analysis of the cross-shareholding structures (including unilateral shareholdings) of the bank-insurer-firm tripartite network in Japan's stock market. This analysis is based on credit risk exposures (i.e., credit risk-weighted assets), different from nominal exposures examined in most extant literature on credit risk management.

Table 3: Descriptive statistics of RORA, credit risk-weighted asset amounts (RWA), and correlation between RORA and annual return of RWA

		2008	2009	2010	2011	2012	2013	2014	2015	Corr.
25%-tile		0.58%	0.73%	1.00%	1.04%	1.00%	1.06%	1.02%	1.14%	
Median		1.06%	1.08%	1.39%	1.40%	1.53%	1.23%	1.59%	1.65%	
75%-tile		1.90%	1.70%	1.74%	1.89%	1.85%	1.74%	1.93%	2.15%	
Maximum		11.33%	9.82%	7.80%	14.63%	10.37%	6.50%	8.58%	9.94%	
Mean		1.36%	1.31%	1.46%	1.52%	1.48%	1.39%	1.54%	1.68%	
S.D.		1.18%	1.03%	0.97%	1.01%	0.92%	0.84%	0.85%	0.94%	
MUFJ	BH	1.83%	1.68%	1.89%	1.99%	1.88%	1.81%	1.63%	1.84%	57.2%
FG		95,609	3,907	4,670	3,705	10,390	11,741	4,751	3,714	100.0%
	PI	0.81%	0.87%	1.39%	1.04%	1.58%	1.06%	1.87%	1.46%	57.9%
		2,256	2,152	1,233	1,723	1,190	646	230	284	100.0%
	CH	0.81%	0.87%	1.39%	1.04%	1.58%	1.06%	1.87%	1.46%	57.9%
		2,256	2,152	1,233	1,723	1,190	646	230	284	100.0%
SMFG	BH	1.74%	1.68%	1.92%	1.99%	1.88%	1.82%	1.64%	1.79%	39.4%
		30,854	1,964	1,226	4,211	2,656	5,885	2,899	2,596	100.0%
	PI	0.58%	1.08%	1.39%	1.18%	1.07%	1.30%	2.83%	2.46%	43.5%
		1,112	850	619	747	1,017	205	83	101	100.0%
	CH	0.58%	1.08%	1.39%	1.18%	1.07%	1.30%	2.83%	2.46%	43.5%
		1,112	850	619	747	1,017	205	83	101	100.0%
Mizuho	BH	1.57%	1.54%	1.83%	1.94%	1.76%	1.69%	1.55%	1.67%	68.4%
FG		523	343	308	299	19,192	1,024	2,461	2,373	100.0%
	PI	1.76%	1.28%	1.27%	1.44%	1.03%	1.14%	1.70%	2.15%	52.1%
		1,136	1,061	705	811	1,104	339	204	162	100.0%
	CH	1.76%	1.86%	2.16%	2.29%	1.58%	1.14%	1.70%	2.15%	79.0%
		1,136	1,061	705	811	1,104	339	204	162	100.0%
Nippon	BH	1.76%	1.67%	1.88%	2.00%	1.87%	1.78%	1.60%	1.69%	72.9%
Life		116,418	6,674	4,526	5,233	10,955	6,920	7,485	5,574	100.0%
Dai-ichi	BH	1.74%	1.65%	1.87%	2.00%	1.88%	1.81%	1.63%	1.77%	22.2%
Life		28,203	2,675	1,574	3,790	2,484	2,121	2,378	1,937	100.0%
	PI	-	-	0.01%	0.01%	0.01%	0.77%	0.76%	1.07%	-32.6%
		-	-	102	99	99	77	64	57	-100.0%
	CH	-	-	0.01%	0.01%	0.01%	0.77%	0.76%	1.07%	-21.6%
		-	-	102	213	106	77	64	57	-100.0%
Sumitomo	BH	1.58%	1.53%	1.73%	1.81%	1.65%	1.62%	1.39%	1.50%	47.8%
Life		20,585	808	548	506	621	738	1,062	929	100.0%
All firms	BH	1.67%	1.63%	1.83%	1.93%	1.79%	1.73%	1.57%	1.70%	76.5%
		417,452	28,013	33,161	28,151	80,262	60,173	42,907	29,686	100.0%
	PI	0.84%	0.93%	1.16%	1.22%	1.22%	1.11%	1.50%	1.65%	28.6%
		7,841	6,739	4,947	5,502	5,395	2,126	1,134	1,103	100.0%
	CH	0.84%	1.06%	1.37%	1.42%	1.38%	1.14%	1.52%	1.65%	44.1%
		7,841	6,739	4,947	5,502	5,395	2,126	1,134	1,103	100.0%

Note 1: Abbreviations: S.D.: standard deviation; Corr.: correlation. BH means the shareholdings by blockholders, such as mega-bank groups or major life insurers. PI denotes the shareholdings of investment securities issued by three mega-bank groups or Dai-ichi Life. CH means the cross-holdings of policy ownership securities issued by three mega-bank groups or Dai-ichi Life. Because Nippon Life and Sumitomo Life are not joint-stock companies but mutual insurance firms, they issue no policy ownership security.

Note 2: The figure in each upper row of the lower tier of this table denotes the RORA of a bank/insurer, whereas the figure in each lower row denotes the credit risk-weighted asset amount of the bank/insurer in billions of yen. The figure in each upper row in the rightmost column denotes the correlation between the $RORA(t-1)$ and the $ARRA(t)$ at $t =$ the end of March 2010 to March 2016. The figure in each lower row in the rightmost column denotes the correlation between the $RORA(t-1)$ and the $ARRA(t)$ at $t =$ the end of March 2016.

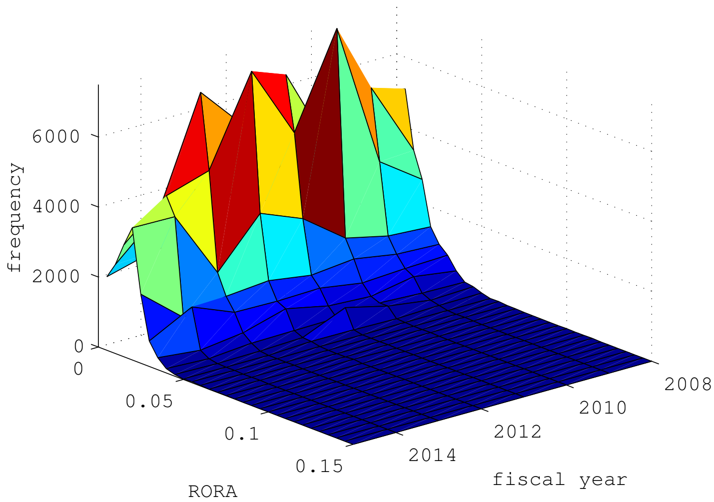

Figure 4: RORA histogram by fiscal year

4.1. Data for network analysis

The following $(N \times N)$ matrix X represents the cross-shareholding relationships in Japan's stock market:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{iN} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & x_{NN} \end{bmatrix}, \tag{3}$$

where x_{ij} denotes the outstanding shares of firm i in the shareholding of firm j. Summation across row i gives firm i's total outstanding shares of its counterparties, and summing down column j gives firm j's total outstanding shares held by counterparties. Hence, matrix X is asymmetric.

As the analysis requires bilateral outstanding data for the credit risk exposure matrix X, we utilize the details of outstanding data by shareholding purposes shown in Table 2.

Relation between keiretsu and data. Japan has various types of firm groups. A keiretsu is a group of firms with interlocking business relationships and shareholdings. The keiretsu dominated the Japanese economy in the second half of the 20th century.

Two types of keiretsu, horizontal and vertical, can be further categorized into Kigyo shudan ("horizontally diversified business groups"), Seisan keiretsu ("vertical manufacturing networks"), and Ryutsu keiretsu ("vertical distribution networks"). As our study focuses on the bank-insurer-listed firm tripartite network as shown in Figure 1, we do not treat vertical networks. The primary characteristic of a horizontal keiretsu, also known as a financial keiretsu, is to maintain business relationships with a bank by cross-shareholdings with other firms.

The Japanese recession in the 1990s had a profound effect on the financial keiretsu. Many of the largest banks were hard-hit by non-performing loans and forced to merge or go out of business. This blurred the lines between the individual keiretsu: three mega-bank groups (i.e., Mitsubishi UFJ Financial Group, Sumitomo Mitsui Financial Group, and Mizuho Financial Group) descended from the big six keiretsu: Mitsui, Mitsubishi, Sumitomo, Fuyo, Sanwa, and Dai-Ichi Kangyo banks.

4.2. Methodology and analysis results

We calculate the network statistics and centrality measures for FY2008–2015 (Table 4). Network size indicates the total number of links in the cross-shareholding network. Table 4 indicates that after FY2008, the network size remained unchanged as a whole. In addition, we calculate five centrality measures: degree centrality, eccentricity, closeness centrality, betweenness centrality, and eigenvector centrality. Table 4 reports the averages for each type of centrality.

"Direct" centrality measures capture the level of interconnectedness in a local region based on adjacent connections, and are proxies for cross-shareholding influence. These measures are degree and eigenvector centrality. By contrast, "indirect" centrality measures enable the analysis of a counterparty's exposure in the entire network by its distance to all other firms. We use these measures to evaluate information value-oriented networks. Eccentricity, closeness, and betweenness are examples of indirect centrality measures, and show how close a firm node is to other nodes in the entire network to reflect the importance of one firm in the network (Renneboog and Zhao, 2014).

It is important to understand that managerial influence and information, such as firm importance, are two aspects of the same network. The two measures are not exclusive; the direct measures that express a firm's managerial influence on its counterparties also have the ability to capture information, which could benefit the firm. Nonetheless, the correlation between direct and indirect centrality measures is generally low (Kanno, 2016b), suggesting that direct and indirect measures indeed capture different properties of the network.

In terms of degree centrality, the "degree" of a firm is the number of shareholding links connected to the firm. The "out-degree" is a firm's total number of shareholdings and the "in-degree" is a firm's total number of shareholdings held by other firms. In a directed graph, which depicts a set of firms in which all shareholdings are directed from one firm to another, each firm has a maximum of two degrees for each shareholding. The total degree of a firm is the sum of its in- and out-degrees. The degree of a firm is a proxy variable for its interconnectedness in the network.

By contrast, eccentricity and closeness centrality represent a firm's closeness, whereas betweenness centrality measures a firm's substitutability and indicates the firm's central role in the network. Eigenvector centrality captures the magnitude of the network relationships.

The following subsections use the definitions for each type of centrality to analyze interconnectedness, focusing on eccentricity, closeness centrality, betweenness centrality, and eigenvector centrality in more detail.

4.2.1. Eccentricity

Eccentricity is a measure of the maximum distance between a single firm and any other firm in the network. The distance $E(b_i, b_j)$ between firms b_i and b_j is the sum of the edge weights expressed in the shareholding exposures on the shortest path from b_i to b_j in network G. Thus, the eccentricity of a firm b_i is

$$E(b_i) = \arg \max_{b_j \in G} d(b_i, b_j), \tag{4}$$

where $E(b_i) \geq 1$. Table 4 shows that the average of this measure is approximately 3.3, with no large structural change in the network, regardless of 3.8 in FY2014.

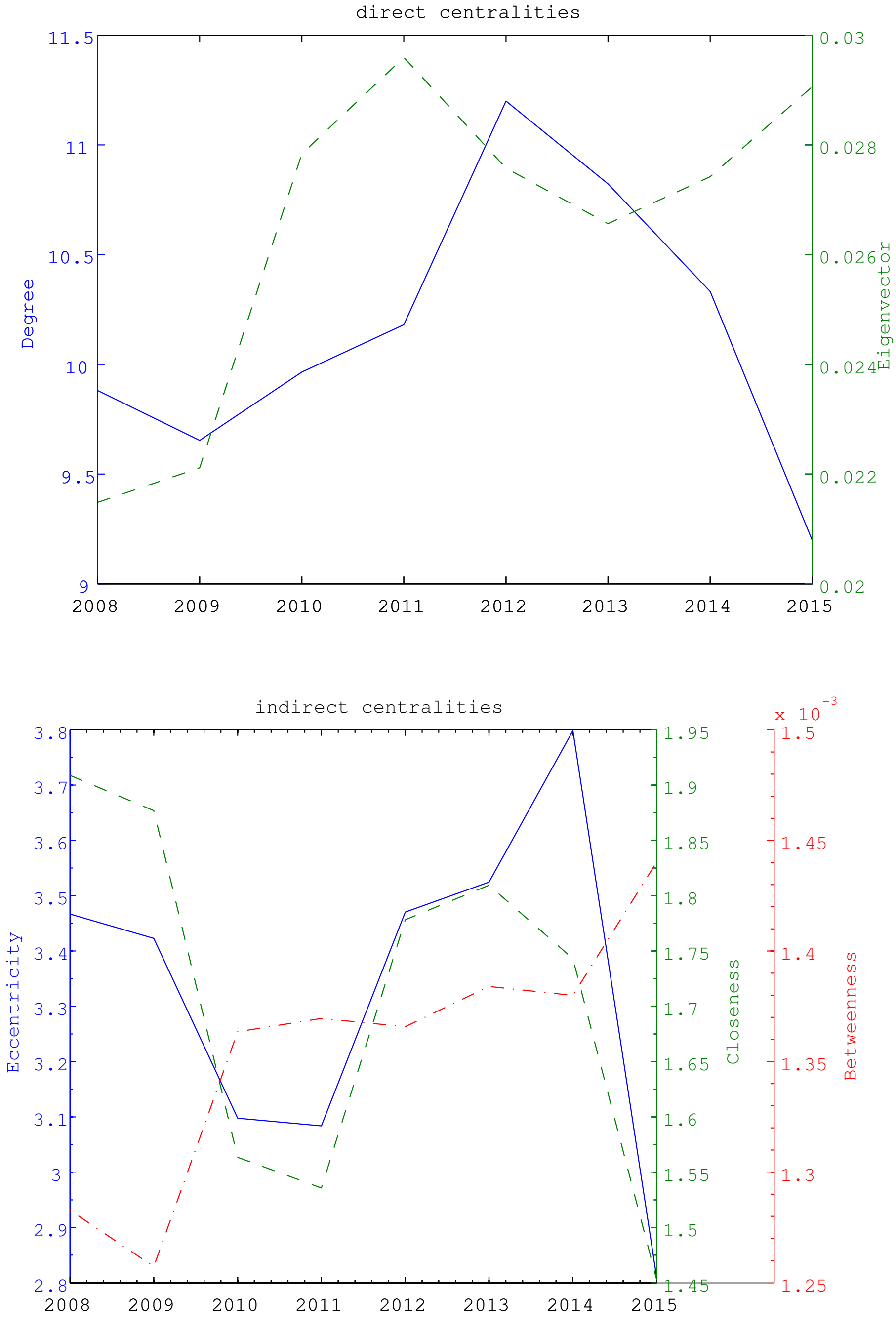

Figure 5: direct and indirect centralities

Table 4: Cross-shareholding network structure based on credit risk exposures among Japanese banks-insurers-listed firms.

FY	Network size	Degree	Ecc.	Clo.	Betw.	Eigenv.
2008	14,925	9.88	3.467	1.909	0.00128	0.0215
2009	14,581	9.65	3.423	1.877	0.00126	0.0221
2010	15,052	9.96	3.098	1.563	0.00136	0.0278
2011	15,378	10.18	3.084	1.536	0.00137	0.0296
2012	16,917	11.20	3.470	1.778	0.00137	0.0276
2013	16,347	10.82	3.525	1.809	0.00138	0.0266
2014	15,606	10.33	3.798	1.743	0.00138	0.0274
2015	13,892	9.20	2.808	1.452	0.00144	0.0291

Note: Abbreviations: Ecc.: Eccentricity; Clo.: Closeness; Betw.: Betweenness; Eigenv.: Eigenvector. Network size is the total number of shareholding relationships in the network.

4.2.2. Closeness centrality

Closeness centrality is the function of farness, which represents the sum of distances to all other firms. The centrality for firm i is

$$C(b_i) = \sum_{j=1}^{n} d(b_i, b_j)/(n-1), \tag{5}$$

where $d(b_i, b_j)$ is the number of shareholdings in the shortest path between firms i and j, and hence, $d \geq 1$.

Closeness centrality tracks the proximity of one firm to another. However, this measure does not apply to networks with disconnected components because the firms in this case have infinite distance between them. A potential alternative allows researchers to apply the measure to disconnected component networks, and simultaneously, maintain the original theory behind the measure. Table 4 shows farness gradually decreasing from 1.91 to 1.45 for the period. This means that firms are more closely interconnected over time.

4.2.3. Betweenness centrality

Betweenness centrality (Krause and Giansante, 2012; Kanno, 2015) represents the number of times a firm acts as a bridge along the shortest path between two other firms. A firm with high betweenness centrality can potentially influence the spread of information through the network. If the normalized betweenness centrality, defined as $(bc - \min(bc))/(\max(bc) - \min(bc))$ (bc: the betweenness centrality of a firm), is close to one, a node (i.e., firm A) acts as a bridge along most of the shortest paths connecting two other firms (i.e., firms B and C). If it is close to zero, firm A is less important to firms B and C) (Kanno, 2015).

The betweenness centrality of firm i in a network is

$$B(b_i) = \sum_{j<k; i \notin \{k,j\}} \frac{g_{j,k}(b_i)}{g_{j,k}}, \tag{6}$$

where $g_{j,k}$ is the number of shortest paths between firms j and k, and $g_{j,k}(b_i)$ is the number of shortest paths between firms j and k, with firm i acting as a bridge.

Table 4 shows that after FY2009, normalized centrality increases slowly for the period. In addition, the correlations between this centrality and two other indirect centralities (eccentricity and closeness) are both negative for the period (lower panel of Figure 5).

4.2.4. Eigenvector centrality

Eigenvector centrality is a natural extension of the simple degree centrality. Degree centrality awards one centrality point for every network neighbor of a firm. However, not all neighbors are equivalent. In many cases, a firm's importance in a network increases owing to its connections to other important firms. This defines the concept of eigenvector centrality (Newman, 2010). The advantage of eigenvector centrality over other centrality measures is that it not only captures the number of firms linked to the target firm (degree centrality), but also the centrality of those adjacent firms. Hence, a firm has a higher eigenvector centrality score if it is connected to more firms with higher centrality scores.

Let $C^e(g)$ denote the eigenvector centrality associated with network g. A firm's centrality is proportional to the sum of the centrality of its neighboring firms, $\lambda C^e_i(g) = \sum_j g_{ij} C^e_j(g)$, for firm i. Using matrix notation,

$$\lambda C^e(g) = g C^e(g), \tag{7}$$

where λ is a proportionality factor. Thus, from Equation (7), $C^e(g)$ is an eigenvector of g and λ is its corresponding eigenvalue. As its centrality is a measure with nonnegative values, we use the eigenvector associated with the largest eigenvalue (Jackson, 2010).

Table 4 shows that the average eigenvector centrality for the period gradually increases with the network size. In addition, the upper panel of Figure 5 denotes the average increasing trend with time of lapse, which is quite different from the degree centrality. In many cases, it is appropriate for firms with high in-degrees to have centrality even if they are not in a strongly connected component or its out-component (Newman, 2010). In response, we examine the sums of in-degree and out-degree of the top thirty entities. Consequently, the eigenvector centrality increases when the in-degree is higher than the out-degree in the following fiscal year. This tendency is in accordance with the upper panel of Figure 5.

4.2.5. Tripartite network by blockholdings

As shown in Figure 1, we analyze the tripartite network related to blockholdings. Banks or insurers hold almost no insurer stocks. Hence, we focus on bank stocks held by insurers or banks.

Table 5 shows in-degrees expressed in numbers of bank stocks held by major blockholders. Major blockholders include eight life insurers, eight non-life insurers including three mega-non-life insurers (Tokio Marine, Sompo Japan Nippon Koa, and MS&AD Insurance), and seven major banks including three mega-bank groups (Mitsubishi UFJ Financial Group, Mizuho Financial Group (including Mizuho Trust), Sumitomo Mitsui Financial Group). Mitsui Sumitomo Insurance Group Holdings, Aioi Insurance, and Nissay Dowa General Insurance merged into MS&AD Insurance Group Holdings in April 2010.

There is a “double-gearing problem” in shareholdings of bank stocks by life insurers. This denotes the act or practice of two or more firms pooling their risk by placing capital in each other. In one of the most common examples of double gearing, a life insurer buys shares in a bank, and in exchange, the bank extends credit to the insurer.

As shown in Table 5, major life insurers hold more bank shares than non-life insurers and banks in terms of the number of listed banks, which is 94 (April 2008 to September 2014) to 93 (October 2014 to March 2016). These numbers indicate that life insurers hold large numbers of bank stocks compared to that of banks and non-life insurers. However, the number is gradually decreasing due to the sell-off of stock cross-holdings. If life insurers use a risk-adjusted performance measure such as RORA, as shown in Table 3, a more effective market discipline will work on the bank shares held by life insurers.

4.2.6. Firm ranking by degree

Table 6 shows the ranking of the top twenty entities according to interconnectedness, measured by the degree of their nodes. They include 11–13 banks and 7–9 insurers. No firm ranks in the top twenty, although we exclude relations between firms from our dataset.

This table includes major banks such as Mitsubishi UFJ Financial Group, Mizuho Financial Group (including Mizuho Trust), Sumitomo Mitsui Financial Group, Resona Holdings, Sumitomo Mitsui Trust Holdings (Sumitomo Trust prior to the merger), major regional banks such as Yokohama bank, Hokuhoku FG, and Fukuoka FG; three mega non-life insurance groups such as Tokio Marine Holdings, MS&AD Insurance Group Holdings, Sompo Japan Nipponkoa Holdings; and major life insurers such as Nippon Life, Dai-Ichi Life Insurance, Sumitomo Life, T&D Holdings.

Because these insurers conduct portfolio investments, their degrees equal to in-degrees. By contrast, because banks traditionally conduct cross-holdings to maintain business relationships, their degrees comprise both in-degrees and out-degrees. Especially, the degree centralities for the three mega-bank groups are all over one thousand. This explains that listed firms conduct cross-shareholdings with three mega-banks.

However, the degree centralities for the three mega-bank groups at the end of March 2016 decreased sharply from the levels at the end of March 2015 (MUFJ FG: −21.5%, Mizuho FG: −16.7%, and SMFG: −13.9%). In a June 20, 2016 Nikkei newspaper article, these institutions declared that they do not hold cross-holding stocks for the purpose of policy.

Figures 6 & 7 depict directed graphs based on degrees over 70 at the end of March 2009 and the end of March 2016, respectively, for a visual analysis. The direction of the arrow is from issuer to shareholder. For example, Nippon Life, a major institutional investor in Japan, has 955 in-degrees and 0 out-degrees in FY2009. As the edge is weighted by exposure, some thick ingoing edges flow into banks and life insurers. These graphs do not show firms.

In addition, the Mitsubishi UFJ Financial Group and Sumitomo Mitsui Financial Group repurchased shares in FY2015. They bought back issued shares at 100 billion yen and around 200 million yen, respectively, for premium redemption to shareholders. As its background, MUFJ FG issued

Table 5: In-degrees expressed in the number of bank stocks held by major blockholders

FY	2008	2009	2010	2011	2012	2013	2014	2015
Nippon Life	49	49	39	38	47	46	43	40
Sumitomo Life	35	32	22	16	14	14	14	11
Dai-ichi Life	39	40	30	31	40	39	40	35
Asahi Life	9	9	2	2	7	5	6	5
Mitsui Life	5	4	2	2	3	4	5	3
Fukoku Life	5	5	2	2	4	3	3	3
T&D HD	7	7	6	6	5	5	6	4
Meiji Yasuda Life	0	0	0	0	0	0	0	0
Total	149	146	103	97	120	116	117	101
Tokio Marine HD	0	0	0	0	0	0	0	0
Sompo HD	30	32	22	21	26	25	38	33
Nippon Koa	19	19	17	16	18	19	-	-
MS&AD Insurance Group HD	-	-	-	-	19	18	18	14
Mitsui Sumitomo Insurance	20	21	15	14	-	-	-	-
Aioi Insurance	9	9	-	-	-	-	-	-
Nissay Dowa Insurance	7	9	-	-	-	-	-	-
Nisshin Fire	4	4	2	2	4	4	3	4
Kyoei Fire	3	3	1	1	3	3	3	2
Daido Fire	2	2	2	2	2	2	2	2
Fuji Fire	2	2	0	0	1	1	1	1
Asahi Fire	1	1	1	1	1	0	0	0
Total	97	102	60	57	74	72	65	56
MUFJ FG	49	43	28	28	34	34	34	28
Mizuho FG	59	51	24	22	36	32	33	31
SMFG	8	10	6	6	10	9	9	9
Resona HD	5	4	2	1	2	2	2	2
Sumitomo Mitsui Trust Bank	4	4	1	1	6	6	7	6
Chuo Mitsui Trust Bank	2	2	1	1	-	-	-	-
Shinsei Bank	2	1	2	2	2	2	2	1
Aozora Bank	1	1	1	1	1	1	1	1
Total	130	116	65	62	91	86	88	78

Note: A hyphen denotes that the firm is not an extinct firm in the fiscal year. As the life insurer is a mutual insurance firm, no bank or insurer holds life insurer stocks.

senior bonds worth USD 5 billion in March 2016 and USD 2 billion in April 2016 to meet the total loss absorbency capacity (TLAC)[7] requirements for the G-SIBs in Basel III (BCBS, 2016). SMFG also issued senior bonds worth EUR 1.5 billion in June 2016 and USD 4.5 billion in July 2016.

Figure 8 shows the six transition panels of a directed graph based on degrees over 70 for FY2009–2014. The graphs do not show any firms, although the dataset has the largest number of firms in the tripartite network.

4.2.7. Firm ranking by betweenness centralities

Table 7 lists the top twenty entities according to interconnectedness, measured in terms of the betweenness centrality of their nodes. Compared to Table 6, the number of insurers is 2–3. Instead, the number of major regional banks increased to 11–13. By contrast, few or no firms are shown in this table. For example, Nippon Life, which has high degrees, does not rank even in the top fifty. Issuers with shares held by many entities tend to have higher betweenness centrality, whereas life insurers conduct portfolio investments as unilateral shareholdings, not cross-holdings. As mega-bank groups have a strong presence in maintaining business relationships through cross-shareholdings, they play an important role in Japan's stock market.

[7] In November 2015, the Financial Stability Board issued the final TLAC standard for G-SIBs. The TLAC standard defines a minimum requirement for the instruments and liabilities that should be readily available to absorb losses in resolution. Under the standard, each G-SIB is required to hold TLAC debt in an amount not less than 16% of its risk-weighted assets and 6% of the applicable Basel III leverage ratio denominator by January 1, 2019, and not less than 18% of its risk-weighted assets and 6.75% of the applicable Basel III leverage ratio denominator by January 1, 2022.

Table 6: Top 20 companies ranked by interconnectedness: degree centrality

Ranking	2008	2009	2010	2011	2012	2013	2014	2015
1	MITSUBISHI UFJ FG (2075)	MITSUBISHI UFJ FG (2075)	MITSUBISHI UFJ FG (1994)	MITSUBISHI UFJ FG (2052)	MITSUBISHI UFJ FG (2191)	MITSUBISHI UFJ FG (2138)	MITSUBISHI UFJ FG (2056)	MITSUBISHI UFJ FG (1828)
2	MIZUHO FG (1595)	MIZUHO FG (1591)	MIZUHO FG (1535)	MIZUHO FG (1655)	MIZUHO FG (1795)	MIZUHO FG (1717)	MIZUHO FG (1639)	MIZUHO FG (1491)
3	SMFG (1135)	SMFG (1139)	SMFG (1212)	SMFG (1289)	SMFG (1400)	SMFG (1365)	SMFG (1316)	SMFG (1182)
4	NIPPON LIFE (955)	NIPPON LIFE (952)	DAI-ICHI LIFE (784)	SUMITOMO MITSUI TRUST (830)	SUMITOMO MITSUI TRUST (969)	SUMITOMO MITSUI TRUST (936)	SUMITOMO MITSUI TRUST (901)	SUMITOMO MITSUI TRUST (806)
5	SUMITOMO MITSUI TRUST (636)	SUMITOMO MITSUI TRUST (654)	NIPPON LIFE (770)	DAI-ICHI LIFE (775)	NIPPON LIFE (883)	NIPPON LIFE (826)	DAI-ICHI LIFE (753)	DAI-ICHI LIFE (685)
6	DAI-ICHI LIFE (612)	DAI-ICHI LIFE (593)	SUMITOMO MITSUI TRUST (725)	NIPPON LIFE (753)	DAI-ICHI LIFE (839)	DAI-ICHI LIFE (813)	NIPPON LIFE (730)	NIPPON LIFE (622)
7	RESONA HOLDINGS (577)	RESONA HOLDINGS (573)	RESONA HOLDINGS (587)	RESONA HOLDINGS (600)	RESONA HOLDINGS (643)	RESONA HOLDINGS (624)	RESONA HOLDINGS (605)	RESONA HOLDINGS (529)
8	MS&AD INSURANCE (417)	MS&AD INSURANCE (411)	MS&AD INSURANCE (444)	MS&AD INSURANCE (453)	MS&AD INSURANCE (505)	MS&AD INSURANCE (493)	MS&AD INSURANCE (476)	MS&AD INSURANCE (413)
9	SOMPO JAPAN (376)	SUMITOMO LIFE (377)	MIZUHO TRUST (378)	SUMITOMO LIFE (288)	SUMITOMO LIFE (332)	SUMITOMO LIFE (311)	SOMPO JAPAN (329)	SOMPO JAPAN (258)
10	SUMITOMO LIFE (374)	MIZUHO TRUST (315)	SUMITOMO LIFE (290)	SOMPO JAPAN (231)	SOMPO JAPAN (262)	SOMPO JAPAN (234)	SUMITOMO LIFE (282)	SUMITOMO LIFE (249)
11	MIZUHO TRUST (320)	SOMPO JAPAN (304)	SOMPO JAPAN (244)	YOKOHAMA BANK (220)	YOKOHAMA BANK (243)	YOKOHAMA BANK (228)	YOKOHAMA BANK (208)	HOKUHOKU FG (191)
12	YOKOHAMA BANK (236)	YOKOHAMA BANK (243)	YOKOHAMA BANK (221)	HOKUHOKU FG (187)	HOKUHOKU FG (212)	HOKUHOKU FG (211)	HOKUHOKU FG (199)	TOKIO MARINE HOLDINGS (175)
13	NIPPONKOA INSURANCE (196)	HOKUHOKU FG (192)	HOKUHOKU FG (188)	MIZUHO TRUST (177)	MIZUHO TRUST (211)	MIZUHO TRUST (208)	MIZUHO TRUST (199)	MIZUHO TRUST (161)
14	HOKUHOKU FG (184)	NIPPONKOA INSURANCE (165)	AIOI NISSAY DOWA INS (171)	TOKIO MARINE HOLDINGS (177)	AIOI NISSAY DOWA INS (194)	AIOI NISSAY DOWA INS (181)	TOKIO MARINE HOLDINGS (180)	SOMPO JAPAN NIPPONKOA (151)
15	AIOI NISSAY DOWA INS (164)	YAMAGUCHI FG (144)	TOKIO MARINE HOLDINGS (170)	AIOI NISSAY DOWA INS (167)	TOKIO MARINE HOLDINGS (178)	TOKIO MARINE HOLDINGS (176)	AIOI NISSAY DOWA INS (170)	T&D HOLDINGS (143)
16	YAMAGUCHI FG (142)	AIOI NISSAY DOWA INS (142)	JOYO BANK (150)	T&D HOLDINGS (159)	T&D HOLDINGS (173)	T&D HOLDINGS (167)	T&D HOLDINGS (158)	YAMAGUCHI FG (138)
17	FUKUOKA FG (129)	FUKUOKA FG (128)	SOMPO JAPAN NIPPONKOA (149)	SOMPO JAPAN NIPPONKOA (157)	NOMURA HOLDINGS (160)	SOMPO JAPAN NIPPONKOA (155)	SOMPO JAPAN NIPPONKOA (155)	AIOI NISSAY DOWA INS (136)
18	JOYO BANK (129)	JOYO BANK (128)	NOMURA HOLDINGS (147)	NOMURA HOLDINGS (155)	SOMPO JAPAN NIPPONKOA (157)	JOYO BANK (149)	YAMAGUCHI FG (147)	FUKUOKA FG (130)
19	T&D HOLDINGS (124)	HIROSHIMA BANK (127)	SENSHU IKEDA HOLDINGS (146)	SENSHU IKEDA HOLDINGS (154)	JOYO BANK (155)	FUKUOKA FG (148)	JOYO BANK (144)	HIROSHIMA BANK (122)
20	NISHI-NIPPON CITY BANK (122)	T&D HOLDINGS (127)	T&D HOLDINGS (146)	JOYO BANK (147)	YAMAGUCHI FG (154)	YAMAGUCHI FG (143)	FUKUOKA FG (142)	CHIBA BANK (122)

Note: Figures in parentheses indicate degree centrality in the thousands.

Table 7: Top 20 companies according to interconnectedness: betweenness centrality

Ranking	2008	2009	2010	2011	2012	2013	2014	2015
1	MITSUBISHI UFJ FG (1)	MITSUBISHI UFJ FG (1)	MITSUBISHI UFJ FG (1)	MITSUBISHI UFJ FG (1)	MITSUBISHI UFJ FG (1)	MITSUBISHI UFJ FG (1)	MITSUBISHI UFJ FG (1)	MITSUBISHI UFJ FG (1)
2	MIZUHO FG (0.649)	MIZUHO FG (0.657)	MIZUHO FG (0.609)	MIZUHO FG (0.662)	MIZUHO FG (0.689)	MIZUHO FG (0.662)	MIZUHO FG (0.647)	MIZUHO FG (0.687)
3	SMFG (0.333)	SMFG (0.343)	SMFG (0.366)	SMFG (0.394)	SMFG (0.403)	SMFG (0.403)	SMFG (0.386)	SMFG (0.424)
4	SUMITOMO MITSUI TRUST (0.129)	SUMITOMO MITSUI TRUST (0.133)	DAI-ICHI LIFE (0.248)	DAI-ICHI LIFE (0.235)	DAI-ICHI LIFE (0.29)	DAI-ICHI LIFE (0.279)	DAI-ICHI LIFE (0.255)	DAI-ICHI LIFE (0.225)
5	RESONA HOLDINGS (0.126)	RESONA HOLDINGS (0.128)	RESONA HOLDINGS (0.14)	SUMITOMO MITSUI TRUST (0.156)	SUMITOMO MITSUI TRUST (0.174)	SUMITOMO MITSUI TRUST (0.174)	SUMITOMO MITSUI TRUST (0.177)	SUMITOMO MITSUI TRUST (0.187)
6	MS&AD INSURANCE (0.056)	MS&AD INSURANCE (0.059)	SUMITOMO MITSUI TRUST (0.129)	RESONA HOLDINGS (0.142)	RESONA HOLDINGS (0.135)	RESONA HOLDINGS (0.136)	RESONA HOLDINGS (0.14)	RESONA HOLDINGS (0.135)
7	HOKUHOKU FG (0.055)	HOKUHOKU FG (0.057)	MS&AD INSURANCE (0.081)	MS&AD INSURANCE (0.088)	MS&AD INSURANCE (0.083)	MS&AD INSURANCE (0.083)	MS&AD INSURANCE (0.089)	MS&AD INSURANCE (0.084)
8	MIZUHO TRUST (0.045)	MIZUHO TRUST (0.044)	MIZUHO TRUST (0.06)	HOKUHOKU FG (0.045)	HOKUHOKU FG (0.049)	HOKUHOKU FG (0.05)	HOKUHOKU FG (0.054)	HOKUHOKU FG (0.065)
9	SOMPO JAPAN (0.041)	YOKOHAMA BANK (0.036)	HOKUHOKU FG (0.048)	NISHI-NIPPON CITY BANK (0.032)	YOKOHAMA BANK (0.031)	SHIZUOKA BANK (0.031)	SHIZUOKA BANK (0.032)	NISHI-NIPPON CITY BANK (0.036)
10	YOKOHAMA BANK (0.035)	NISHI-NIPPON CITY BANK (0.031)	NISHI-NIPPON CITY BANK (0.03)	SHIZUOKA BANK (0.029)	NISHI-NIPPON CITY BANK (0.027)	NISHI-NIPPON CITY BANK (0.029)	NISHI-NIPPON CITY BANK (0.03)	SHIZUOKA BANK (0.03)
11	NISHI-NIPPON CITY BANK (0.031)	YAMAGUCHI FG (0.025)	YOKOHAMA BANK (0.029)	YOKOHAMA BANK (0.028)	SHIZUOKA BANK (0.027)	YOKOHAMA BANK (0.026)	FUKUOKA FG (0.025)	FUKUOKA FG (0.029)
12	YAMAGUCHI FG (0.024)	HIROSHIMA BANK (0.024)	HACHIJUNI BANK (0.027)	HACHIJUNI BANK (0.025)	HACHIJUNI BANK (0.023)	FUKUOKA FG (0.026)	YOKOHAMA BANK (0.024)	HIROSHIMA BANK (0.027)
13	HIROSHIMA BANK (0.023)	SHIZUOKA BANK (0.023)	FUKUOKA FG (0.026)	FUKUOKA FG (0.023)	FUKUOKA FG (0.023)	HACHIJUNI BANK (0.023)	HIROSHIMA BANK (0.024)	HACHIJUNI BANK (0.026)
14	SHIZUOKA BANK (0.021)	HACHIJUNI BANK (0.021)	SHIZUOKA BANK (0.026)	HIROSHIMA BANK (0.023)	HIROSHIMA BANK (0.021)	HIROSHIMA BANK (0.023)	HACHIJUNI BANK (0.023)	CHUGOKU BANK (0.019)
15	T&D HOLDINGS (0.021)	FUKUOKA FG (0.018)	HIROSHIMA BANK (0.023)	CHIBA BANK (0.018)	T&D HOLDINGS (0.019)	CHIBA BANK (0.019)	CHIBA BANK (0.019)	IYO BANK (0.019)
16	HACHIJUNI BANK (0.02)	BANK OF KYOTO (0.018)	HOKKOKU BANK (0.017)	HOKKOKU BANK (0.017)	DAISHI BANK (0.018)	T&D HOLDINGS (0.019)	CHUGOKU BANK (0.019)	YAMAGUCHI FG (0.018)
17	MINAMI-NIPPON BANK (0.019)	CHUGOKU BANK (0.016)	BANK OF KYOTO (0.017)	IYO BANK (0.016)	CHIBA BANK (0.018)	DAISHI BANK (0.017)	BANK OF NAGOYA (0.017)	T&D HOLDINGS (0.016)
18	CHUGOKU BANK (0.017)	T&D HOLDINGS (0.016)	IYO BANK (0.017)	BANK OF KYOTO (0.016)	CHUGOKU BANK (0.017)	IYO BANK (0.017)	IYO BANK (0.017)	CHIBA BANK (0.016)
19	IYO BANK (0.016)	BANK OF NAGOYA (0.015)	CHUGOKU BANK (0.016)	CHUGOKU BANK (0.015)	SENSHU IKEDA HOLDINGS (0.016)	HOKKOKU BANK (0.017)	DAISHI BANK (0.016)	HOKKOKU BANK (0.015)
20	FUKUOKA FG (0.016)	DAISHI BANK (0.015)	JOYO BANK (0.016)	DAISHI BANK (0.015)	YAMAGUCHI FG (0.015)	CHUGOKU BANK (0.017)	T&D HOLDINGS (0.016)	BANK OF NAGOYA (0.015)

Note: Figures in parentheses indicate betweenness centrality in the thousands.

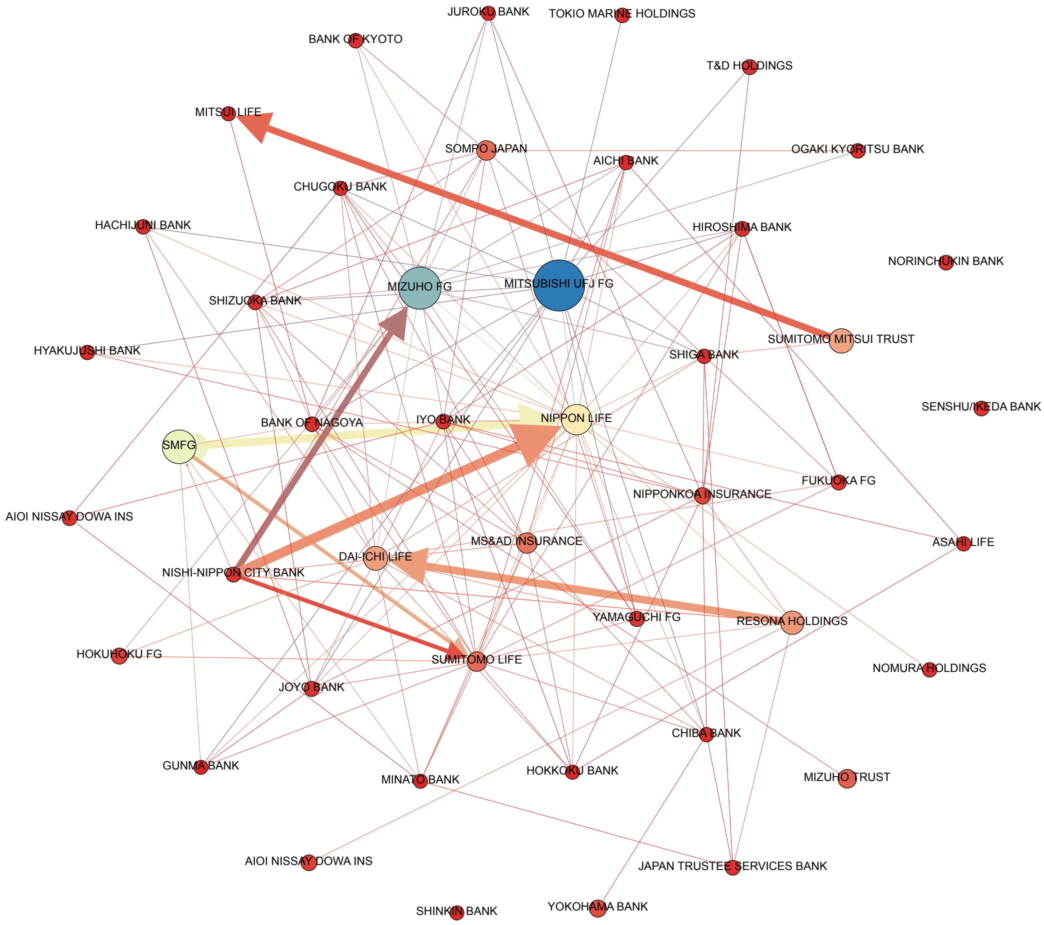

Figure 6: Directed graph of degrees over 70, end of March 2009 (just after the bankruptcy of Lehman Brothers)

Note: These graphs are drawn in the Fruchterman-Reingold layout.

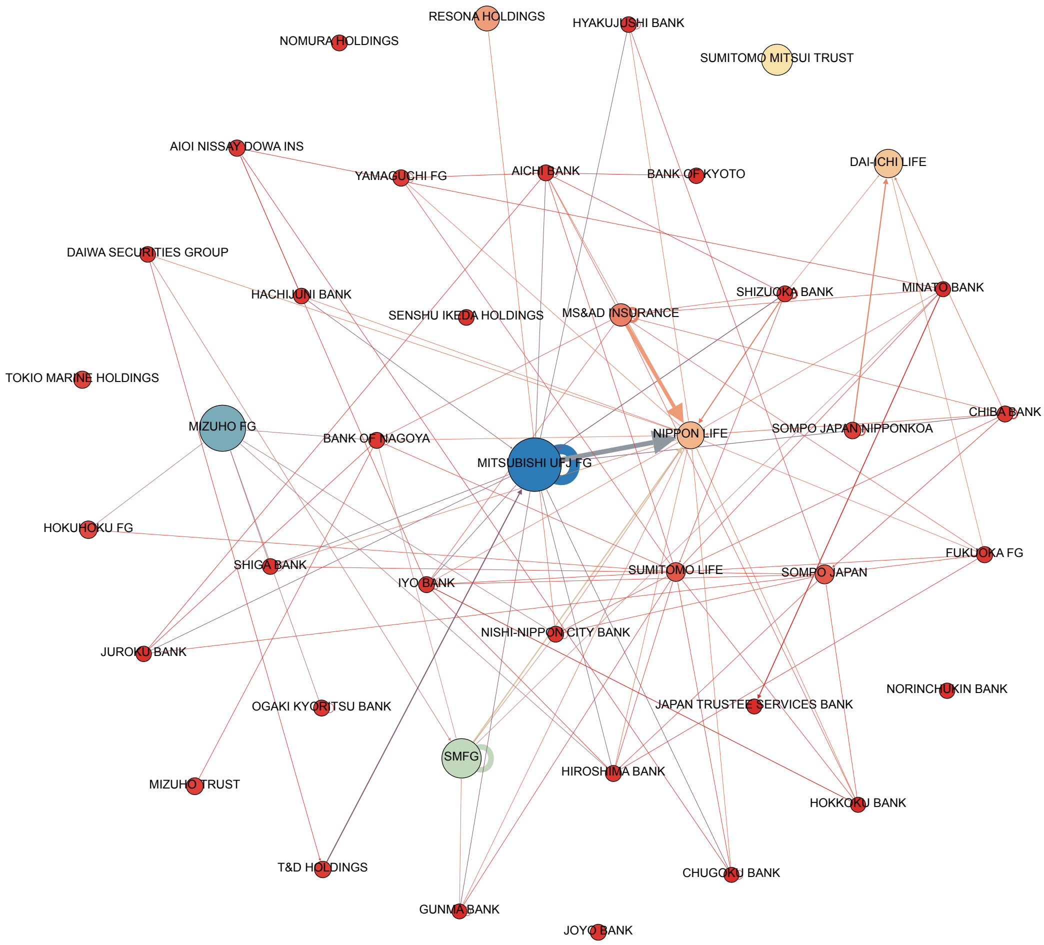

Figure 7: Directed graph of degrees over 70, end of March 2016 (after the implementation of Japan's Corporate Governance Code)

Note: These graphs are drawn in the Fruchterman-Reingold layout. A ring on the margin of a circle denotes self-repurchase.

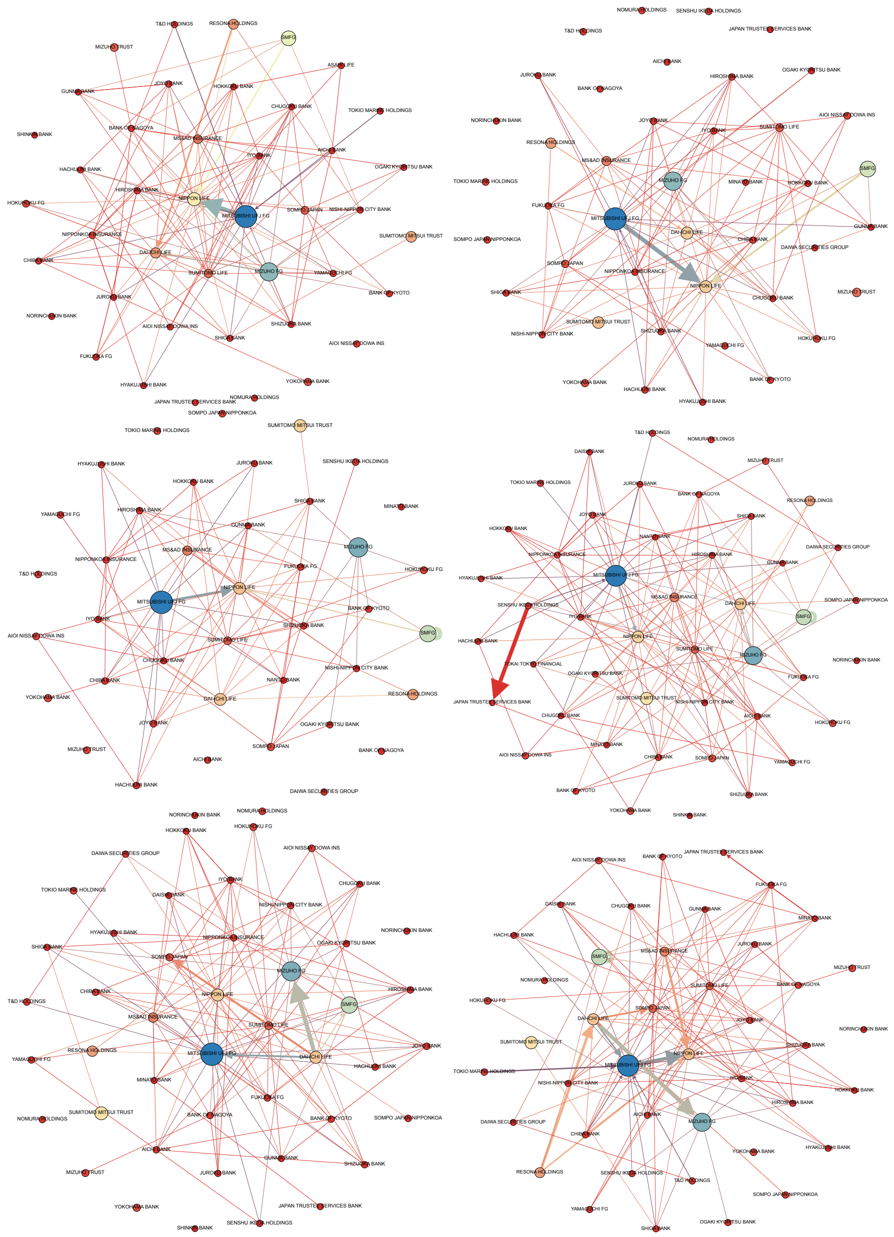

Figure 8: Directed graphs of degrees over 70

Note: The six panels show directed graphs of firm nodes over 70 degrees at the end of March 2010 and March 2011 from the upper-left panel to the upper-right panel; at the end of March 2012 and March 2013 from the middle-left panel to the middle-right panel; and at the end of March 2014 and March 2015 from the lower-left panel to the lower-right panel.

5. Conclusions

This study contributes to the literature by analyzing credit risk exposures in Japan's stock market.

First, in corporate credit risk management, we measured credit risk exposures in cross-shareholdings. Following the PD/LGD approach, credit risk exposures become much larger than by the transitional risk weight method. In addition, the outstanding credit risk exposures for mega-bank groups and major insurers substantially reduce just after the global financial crisis and slightly decrease after the implementation of JCGC. By contrast, the outstanding cross-holdings of stocks of banks and insurers by firms were almost unchanged. The analysis results show that firms take higher risks and obtain lower returns than banks and insurers in exchange for a good business relationship with banks.

Second, we calculated the RORA. In response to regulatory requirements, major Japanese banks recently adopted a performance measure based on the RORA. Compared to the Basel III, the solvency margin standard is not restrictive. Nevertheless, insurers have an incentive to adopt performance measures such as the RORA in future.

Third, we analyzed the tripartite network structure of cross-shareholdings among banks, insurers, and firms in Japan's stock market using major centrality measures. Banks and insurers are central to the network in degree centrality. By contrast, banks play a central role in betweenness centrality. In addition, the implementation of JCGC had only a limited effect in reducing shares held via policy ownership.

Fourth, in terms of holdings of bank stocks by life insurers, we analyzed a double-gearing problem. Major life insurers hold more bank shares than non-life insurers and banks in terms of the number of listed banks. In-degrees relating to bank stocks held by life insurers are large compared to that of banks and non-life insurers. However, the in-degrees are gradually decreasing owing to the sell-off of stock cross-holdings. If life insurers use a risk-adjusted performance measure such as RORA, a more effective market discipline will work on their bank shareholdings.

Finally, our credit risk analysis and network analysis can warn entities about credit risk management in their cross-shareholdings.

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