Credit rating migration risk and interconnectedness in a corporate lending network

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Background of our research (1/2)

- Currently, internationally active banks in Japan are regulated based on Basel III. Most major banks adopt an IRB approach. This approach calculates risk-weighted assets in terms of firms' lending assets in accordance with the firms own obligor credit risks.
- By contrast, insurance regulation in Japan depends on the Japanese local supervisory framework, which is based on the "solvency margin ratio." This framework is a first-generation solvency regulation, which is similar to Basel I.
- Triggered by the bankruptcy of Lehman Brothers (LB), many Western banks and insurers suffered significant capital losses, with some also recording impairment losses. By contrast, Japanese banks were hardly affected owing to their experience of non-performing loan disposal in the country's bubble economy.

Background of our research (2/2)

- However, a network analysis of contractual relationships in the corporate lending network has yet to be conducted, even though large firms ordinarily have accounts with 10 or so banks.
- Further, the bankruptcy, or credit rating downgrade, of a firm causes an increase in credit risk; thus, it is important to analyze the credit rating migration risk in the lending network.

Methodology for credit risk exposure analysis (1/2)

- Credit rating migration (i.e., CRM) is an essential component in credit portfolio valuation. Outlines a framework for gauging the effects of CRM on portfolio risk measurements.
- The approach is based on discounted cash flow valuation, whereby a lending asset is valued by discounting the expected cash flow at a discount rate adjusted for credit risk.
- Filtered probability space, $(\Omega, \mathcal{F}, \mathcal{F}_t, Q)$. Thereby supporting the CRM process in terms of discrete time, $t = 0, 1, \ldots, T$, where Q is a physical probability measure and the horizon, T, is assumed to be a positive integer indicating the maturity. The filtration, $\mathcal{F}_t$, models the flow of all the observations available to lenders. Formally, given an initial rating, C_0, of a borrower, future changes in the rating are described by a stochastic migration process, C.

Methodology for credit risk exposure analysis (2/2)

- The set of rating classes is $\{1, \ldots, K\}$, where K corresponds to the default event. The order of the states is fixed so that the state, $j = 1$, represents the highest ranking, whereas the state, $j = K - 1$, represents the lowest non-default ranking.
- Theoretical price of a lending asset at time t:

$$P = E^Q \left[\sum_{t=1}^{T} \frac{CF_t}{(1 + r(C_t^i))^t} \middle| \mathcal{F}_t \right], \quad (1)$$

where the lending type corresponds to a term loan of equal monthly payments with interest. Maturity T corresponds to 3 years in the case of city banks and trust banks and 5 years in other cases. CF_t is cash flow scheduled at time t. $r(C_t^i)$ is a discount rate adjusted for credit risk w.r.t. the rating C_t^i at time t provided by a rating agency i.

Data summary

Item	Description	Sources
Lendings outstanding	Data on bilateral lending relations, such as bank-to-listed firm and insurer-to-listed firm	Nikkei NEEDS FQ
Lending interest rates	Average interest rates for lendings outstanding by bank type	Bank of Japan
Credit ratings	Credit rating history data including both 'date of the change' and 'old and new credit ratings' by entity	Nikkei Astra Manager
Yield curves by credit rating	Yield curves added credit risk premium by rating assigned by four credit rating agencies: R&I, JCR, Moody's, and S&P	JSDA

Lending interest rates data

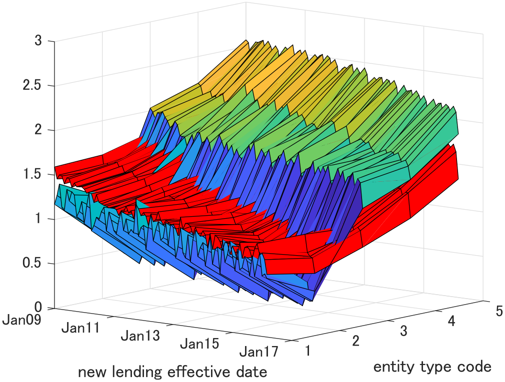
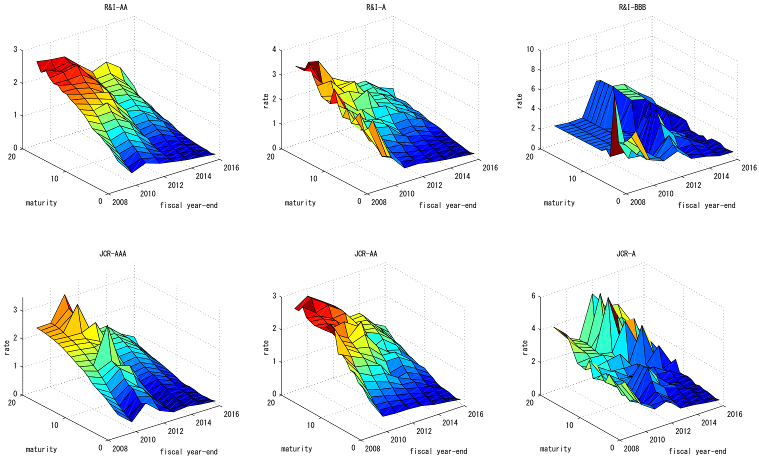


Figure: Average lending interest rate curves: Long-term lending (mixed color) and short-term lending (red) for the end of March 2009 to March 2017

Yield curves by credit rating: R&I and JCR



Descriptive stats: Outstanding bilateral credit risk exposure by institution (in JPY billion)

	2008	2009	2010	2011	2012	2013	2014	2015
25%	261	254	233	210	232	205	207	203
Median	852	804	766	724	811	787	772	748
75%	2,855	2,677	2,543	2,446	3,002	3,016	2,922	2,954
Maximum ($\times 10^3$)	2,130	2,149	3,890	3,856	3,537	3,395	3,132	3,113
Mean	6,929	6,819	7,126	7,251	8,447	10,355	10,545	10,570
S.D.	45,793	47,901	56,770	59,471	65,772	85,854	83,514	78,388
City banks	22,155	19,770	19,302	19,784	20,858	15,293	16,649	18,877
Trust banks	6,713	6,340	6,201	5,771	7,235	5,929	5,851	6,309
Shinsei & Aozora bank	968	791	596	560	880	726	831	856
Norinchukin bank	2,204	2,193	2,008	2,093	2,072	1,345	1,353	1,535
Reg. banks (I & II)	6,312	5,800	5,462	5,462	5,108	4,002	4,861	4,828
Shinkin & Credit unions	365	432	382	329	429	294	305	295
Other private FIs	4,311	4,044	3,984	4,343	4,995	3,660	3,624	3,793
Government FIs	5,090	5,842	7,455	6,086	6,268	5,238	4,812	4,395
Other foreign banks	138	113	92	66	35	28	34	35
Life insurers	7,912	6,656	7,051	7,006	6,588	4,195	3,340	3,319
Non-life insurers	82	83	90	66	85	72	80	98
Unknowns	37,752	39,841	41,810	46,306	43,019	65,172	93,804	92,994
Total	94,001	91,905	94,433	97,874	97,572	105,952	135,544	137,334

Methodology for portfolio credit risk analysis (1/4)

- Considers a lending portfolio with a set of firms as counterparties.
- Conducts a copula-based, multifactor simulation of CRMs.
- Counterparty CRMs and subsequent changes in portfolio values are calculated for each simulation scenario.
- To incorporate r.v. by counterparty (i.e., CP), uses a multifactor model, associating each CP's asset return with a latent r.v..
- Thresholds between credit ratings at the horizon are calculated directly from a rating transition matrix.
- Model's factors can depend on industry sectors and any other credit risk driver. Each CP is assigned weights that determine its sensitivity to each factor driving the underlying credit risk.

Methodology for portfolio credit risk analysis (2/4)

- Defines M as the number of borrowers in a portfolio and K as the number of systematic risk factors. A multifactor model is then as

$$A_i = \sum_{k=1}^{K} w_{i,k} Z_k + \sqrt{1 - \sum_{k=1}^{K} w_{i,k}^2} \epsilon_i, \quad (2)$$

  where A_i $(i = 1, \dots, M)$ is an asset return as a latent variable; Z_k $(k = 1, \dots, K)$ is a systematic risk factor for a specific industry or a domestic geographical region; and ϵ_i is firm i's idiosyncratic risk factor, which represents the firm-specific credit risk.

- A correlation coefficient, $\rho_{i,j}$, between A_i and A_j:

$$\rho_{i,j} = corr(A_i, A_j) = \sum_{k=1}^{K} \sum_{k'=1}^{K} w_{i,k} w_{j,k'} \tilde{\rho}_{k,k'}, \quad (3)$$

Methodology for portfolio credit risk analysis (3/4)

- W.r.t each simulation scenario, A_i has a credit rating on the value distribution at the horizon.
- In turn, by the credit rating curve, calculates the discounted value at the horizon of future cash flow at a later date than the horizon.
- When A_i are normally distributed, there is a Gaussian copula. An alternative is a t copula.
- The d.f. for a t copula controls the degree of tail dependence. The t copulas result in heavier tails than Gaussian copulas. Implied credit correlations are also larger with t copulas.
- Switching between these two copula approaches can provide important information on model risk.

Methodology for portfolio credit risk analysis (4/4)

- **VaR**: Given some confidence level (CL) $\alpha \in (0, 1)$, the VaR of a portfolio at the CL α is given by the smallest number x such that the prob. that the loss X exceeds x is no larger than $(1 - \alpha)$ as follows:

$$VaR_\alpha = \inf\{x \in \mathbb{R} | P(X > x) \leq 1 - \alpha\}.$$

- **ES**: For an integrable loss X and any $\alpha \in (0, 1)$, ES is the expected loss, given that the loss X is already beyond the pre-specified worst case level VaR_α as follows:

$$ES_\alpha = E(X | X \geq VaR_\alpha).$$

Inputs to portfolio credit risk model

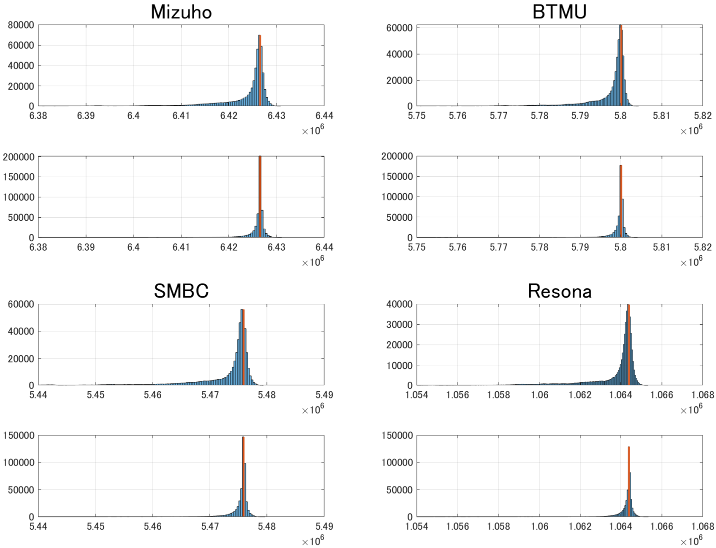
Item	Description	Sources
Portfolio values	Discounted PVs for future CFs of lending contracts calculated using eq (1), if there is no data for credit rating, lendings outstanding	JSDA
Ratings	CRM by firm: published by four credit rating agencies	Nikkei Astra Manager
Transition matrix	Matrix of credit rating transition probabilities with ratings as: AAA, AA, A, BBB, BB, B, CCC–C, and Default	R&I
LGD	Loss given default for corporate lending exposures: set to 45% evenly across all firms.	F-IRBA in Basel III
Weights	Factor and idiosyncratic weights for model	
C.I.	Target for VaR and ES: set to 99.9%	Own calc
Factor corr. matrix	33×33 correlations among returns of TOPIX Sector Indices	Nikkei Astra Manager and own calc
No. of scenarios	Set to 500,000	—

Credit risk amounts at the end of March 2016 (in JPY million, %)

Institution name	IB/DB	GC-VaR	GC-ES	t_5-C-VaR	t_5-C-ES	SME le & H-l-r	L-firm le-r	Cov1	Cov2	CT1
Mizuho Bank	IB	223,169	335,775	534,140	828,288	59.49	40.51	12.50	30.86	11.20
BTMU	IB	159,295	263,986	422,863	662,339	55.17	44.83	9.35	20.85	12.04
SMBC	IB	182,301	266,236	438,885	657,177	67.90	32.10	10.88	33.90	13.15
Resona Bank	DB	32,088	48,418	86,631	124,705	82.32	17.68	5.72	32.36	10.58
Saitama Resona Bank	DB	6,083	9,441	9,663	13,322	87.83	12.17	0.87	7.17	11.58
Subtotal: City banks						63.57	36.43	9.94	27.29	–
MUTB	IB	67,084	88,784	161,365	247,364	51.27	48.73	22.45	46.08	15.87
SMTB	IB	98,154	145,625	250,653	374,527	57.68	42.32	13.48	31.86	10.76
Mizuho TB	IB	96,717	143,002	224,847	346,465	50.00	50.00	13.77	27.54	18.73
Subtotal: Trust banks						55.82	44.18	16.08	36.39	–
Norinchukin Bank	IB	41,131	55,364	107,991	164,692	–	–	10.72	–	18.44
Yokohama Bank	IB	22,617	28,912	42,698	61,472	80.61	19.39	3.76	19.39	11.63
Shizuoka Bank	IB	8,321	11,403	13,890	20,178	77.68	22.32	1.45	6.49	16.35
Chiba Bank	IB	8,289	9,680	13,120	18,226	81.70	18.30	1.38	7.55	12.09
Subtotal: Regional banks I (64banks)						70.25	29.75	1.59	5.35	–
Nippon Life	–	90,844	104,516	118,329	183,935	–	–	17.71	–	–
Meiji Yasuda Life	–	58,065	100,986	76,366	138,383	–	–	18.07	–	–
Dai-ichi Life	–	16,052	23,952	25,065	38,077	–	–	10.36	–	–
Sumitomo Life	–	16,719	20,252	23,131	33,718	–	–	11.38	–	–
Subtotal: Major life insurers						–	–	17.84	–	–

Notes: Cov1 is the ratio of outstanding lending in the database to one for each institution's financial statement; Cov2 is the ratio of outstanding lending in the database to one for each institution's outstanding lending to large firms.

Distribution of portfolio values for selected institutions (in JPY million)



Lending outstanding matrix

X represents Japanese corporate lending relationships:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{iN} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & x_{NN} \end{bmatrix}, \tag{4}$$

where x_{ij} denotes the outstanding exposure pertaining to firm i in terms of the lending of institution j. The summation across row i provides firm i's total outstanding exposure of its borrowing liabilities. The summation of column j provides the total outstanding exposure of firm j's lending assets.

Methodology

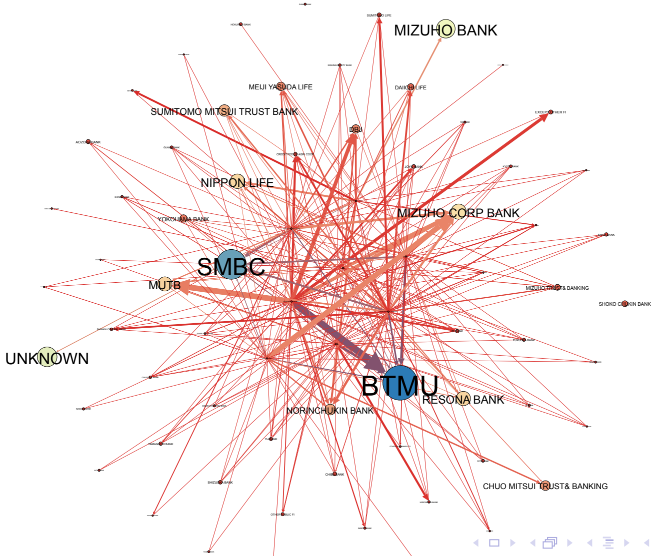
- Calculates the network stats and centrality measures for FY2008–2015.
- **Network size** indicates the total no. of links in the lending network.
- Calculates 4 centrality measures: degree centrality, eccentricity, HITS hub centrality, and eigenvector centrality.
- **Degree and eigenvector**: "**Direct**" centrality measures capture the level of interconnectedness in a local region, based on adjacent connections, and are proxies for lending influence.
- **Eccentricity, closeness, and betweenness**: "**Indirect**" centrality measures enable the analysis of a CP's exposure in the entire network in accordance with its distance to all other entities.
- The correlation between direct and indirect centrality measures is generally low (Kanno, 2016b), suggesting that such measures indeed capture different properties of the network.

Results: Lending network structure based on credit risk exposure with bank–firm and insurer–firm relationships.

FY	Network size	Degree	Eccentricity	Hub	Eigenvector
2008	13,567	8.39	0.577	0.000309	0.00339
2009	13,461	8.32	0.583	0.000309	0.00339
2010	13,254	8.22	0.591	0.000310	0.00340
2011	13,475	8.38	0.602	0.000311	0.00345
2012	11,414	7.11	0.503	0.000311	0.00360
2013	9,755	6.08	0.524	0.000312	0.00381
2014	10,466	6.53	0.666	0.000312	0.00278
2015	10,475	6.53	0.681	0.000312	0.00270

Note: Network size is the total number of lending relationships in the network.

Results: Directed graph of degrees over 40, end of March 2009 (just after the bankruptcy of LB)



Stress test: Transition matrix with averaged R&I's annual rating migration rates for FY2008–09

	AAA	AA	A	BBB	BB	B	CCC-C	Default
AAA	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
AA	0.00	79.50	18.35	1.10	0.70	0.35	0.00	0.00
A	0.00	3.90	88.00	7.60	0.00	0.00	0.00	0.50
BBB	0.00	0.00	14.85	78.10	4.30	0.00	0.00	2.75
BB	0.00	0.00	20.00	13.35	23.35	0.00	0.00	43.30
B	0.00	0.00	0.00	0.00	50.00	0.00	0.00	50.00
CCC-C	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
Default	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Notes: Stressed is loaded to the CRM matrix for one year from a future time point to a risk horizon. The matrix is provided as a one-year average for the 2008 and 2009 cohorts provided by R&I.

Results calculated using transition matrix for FY2008–09 (in JPY billion)

	Def. firms		Def. contr.		VaR		ES	
	No.	%	No.	%	Amt	%	Amt	%
GC	38	1.7	201	1.5	17,181	530	20,748	547
t_5-C	48	2.2	374	2.9	31,254	579	37,650	501

Notes: Each percentage in the columns for "Defaulted firms" and "Defaulted contracts" denotes a multiple of each total number. Each percentage in the columns for "VaR" and "ES" denotes a multiple of the risk amounts in normal times.

Contributions (1/2)

- First, in corporate credit risk management, evaluated credit risk exposure for all Japanese listed firms. Lending outstanding values for mega banks also substantially reduced just after the LB bankruptcy. By contrast, the outstanding values for life insurers increased after FY2009. The analytical results show that banks are affected by the capital requirement of Basel II and III, whereas life insurers aimed to improve their investment performance during the studied period.
- Second, measured the portfolio credit risk of corporate lending exposure for major banks and other large banks, and major life insurers. In particular, ES captures tail risk and has actually been introduced in insurer solvency regulation such as SST. In addition, the choice of copula is critical for correctly measuring the dependence between systematic risk factors.

Contributions (2/2)

- Third, analyzed the network structure of corporate lending among bank-to-listed firms and insurer-to-listed firms in Japan's lending market using major centrality measures. Banks and insurers play a central role in terms of degree centrality. However, degree centrality decreased gradually after the GFS.
- Fourth, this study conducted a stress test in terms of network structure. Because 1.7% of all Japanese listed firms defaulted in terms of Gaussian copula dependence and 2.2% in terms of t_5 copula dependence, the network structure became much sparser.
- Finally, this study's analyses on CRM risk and interconnectedness in a lending network can serve as warnings to related entities such as supervisory authorities and institutions about risk perception.

Contact information

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