Analysis of Corporate Transaction Network

(Summary)

This paper presents the FSA's recent initiatives to visualize the network structure among financial institutions and enterprises. Focusing on the corporate transaction network, this paper also considers indicators that can be used to identify significant enterprises that may spread or accumulate the impact of the default of an enterprise on the network. The computed indicators suggest that some enterprises are more important than others. The FSA will continue its research on network analysis methods to deepen its understanding of the financial system and the real economy and enhance its monitoring capabilities.

I. Introduction

From the macroprudential perspective, this paper emphasizes the interconnectedness (network structure) between economic agents and how it may affect the financial system, focusing on, for example, how financial institutions conduct transactions with one another and how they are interconnected with financial markets and the real economy. In the case of bank lending, it is necessary to assess risks not only on a borrower firm basis but also in light of the network structure to which the borrower firm belongs, such as supply chains.

It is important for the FSA to understand the network structure surrounding the Japanese financial system and its characteristics to ensure macroprudence. Network analysis techniques, which express networks as nodes (points) and links (lines) and then quantify and examine the characteristics, are applied in various fields, including communications and transportation, human friendships, and relationships between words in sentences. Economic activities, such as business-to-business transactions, are no exception, and a variety of previous studies are available, covering various industries and regions in scope. Research on analytical methods for efficiently handling complex networks using large-scale data is also developing.[1]

[1] For more information, see HAYASHI Yuki: "Python and Complex Network Analysis" (Kindai Kagaku Sha, Impress Group Publication

This paper presents the following two initiatives conducted by the FSA in relation to network structure: (1) visualizing the network structure between financial institutions and enterprises using bank loan-by-loan level data (Section II); and (2) identifying significant enterprises within the corporate transaction network that may spread or accumulate the impact of a corporate default in the network (Section III).

II. Visualization of the network structure between financial institutions and enterprises

The FSA has developed an internal tool to visualize a network comprised of corporate transactions, equity investment, and bank lending. The tool is based on bank loan data collected by the Common Data Platform,[2] a novel framework for data collection and management that has been launched in phases jointly with the Bank of Japan, and domestic business-to-business transaction data provided by a third-party vendor.[3] (Figure 1)

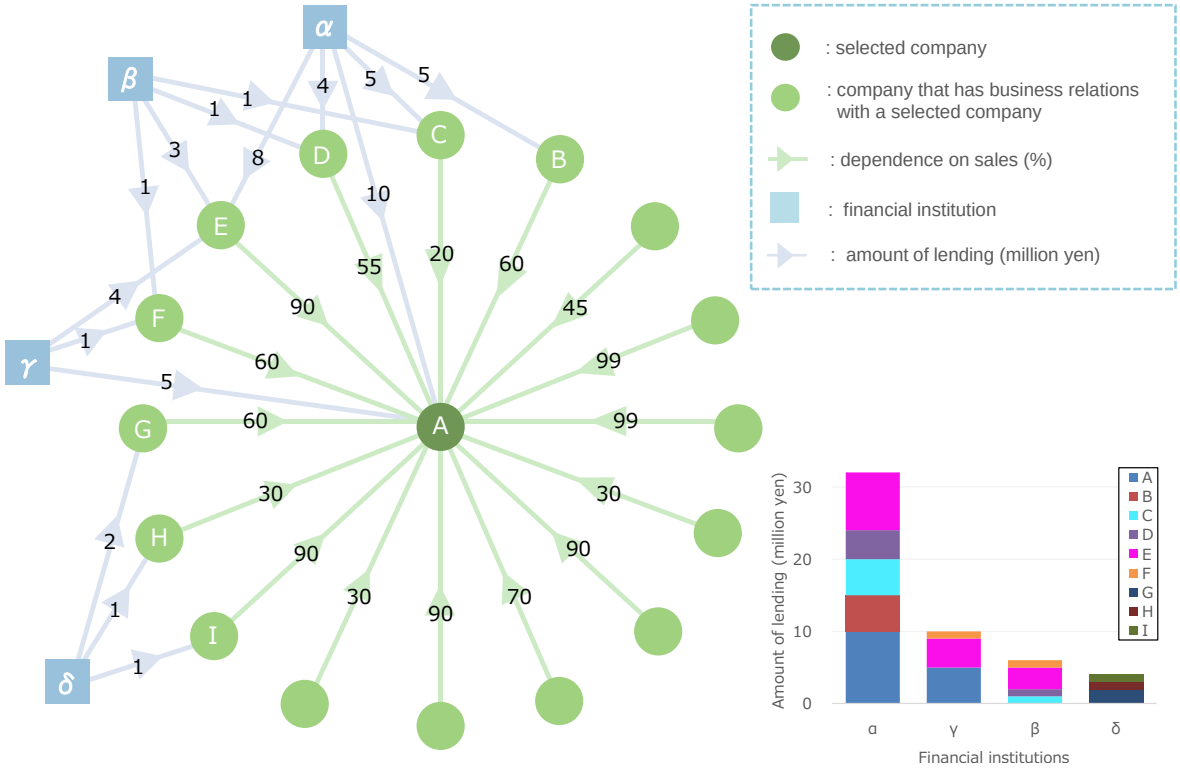
The tool renders a network that shows business relationships, such as lending and investment, as directional links with companies and financial institutions as nodes, and display relevant information, such as transaction amounts, all at once. Such visualization makes it possible to grasp the impact of a credit event, such as corporate bankruptcy, to a certain extent by explicitly showing the companies trading densely with the bankrupted firm and financial institutions with large amounts of loans to the firm within the scope of the data held.

Information, 2019) and SUZUKI Tsutomu: "Network Analysis" (Kyoritsu Shuppan, 2017). Hayashi's research includes an analysis of trade networks that takes into account the industrial diversity of countries, as well as research on methods for extracting "communities" in networks in which nodes are more closely connected.

[2] FSA, “Progress in Common Data Platform and Next Steps” <https://www.fsa.go.jp/en/news/2024/20240701/20240701.html>

[3] Information obtained from Teikoku Databank, Ltd.

Figure 1: Visualization of a network structure between financial institutions and enterprises



A network shown in Figure 1 only illustrates the network centered on Company A to ensure visibility. However, the actual transactions of the illustrated companies could be more complex given that Company B and others usually have business partners other than Company A. It is not easy to visualize the network including these secondary and tertiary customers in a form that can be understood intuitively. Therefore, in order to accurately understand the impact of the whole network on the financial system, it would be effective to introduce some indicators that cover the network features not shown in the visualization.

Other initiatives within the FSA to visualize the network structure are undertaken in the field of the derivatives market using transaction data on over-the-counter derivatives[4] and securities companies' funding network using data on repo markets[5]. In order to further promote such analyses using granular transaction data, it is necessary to continue efforts to ensure the quality of the collected data.[6]

[4] KAWAI Daisuke, HASEGAWA Masaki, and YAGI Risa, “An analysis of the transaction network in the Japanese OTC derivatives markets,” 2021, FSA Staff Reports and Columns < https://www.fsa.go.jp/frtc/english/seika/srhonbun/20210707_SR_Derivative_ArticleEN.pdf>
[5] See p56 in column of "The JFSA Strategic Priorities July 2023-June 2024."
[6] For example, the data collected under the over-the-counter derivatives reporting system has a problem of duplicate reporting as both parties are required to report under the original system. The system is being improved.

III. Network analysis of corporate transactions

Various indicators have been proposed for measuring important nodes in network analysis. Typical indicators include degree centrality, which uses the number of links to other nodes, and closeness centrality, which focuses on the shortest distance to other nodes. Such indicators are useful in that they enable quantitative comparisons among nodes and network structures, even if these structures are complex. On the other hand, in order to utilize the indicators for systemic risk analysis, it is desirable for indicators to reflect the characteristics of nodes, such as the financial condition of companies.

Since the financial crisis in 2008, the assessment of interconnectedness has become an important part of global systemic analysis. In the Financial Sector Assessment Program (FSAP)[7] for Japan conducted by the International Monetary Fund (IMF) from 2023 to 2024, interconnectedness was reviewed as a part of the systemic risk assessment for the Japanese financial system. In the FSAP, mutual exposure data, including deposits, securities holdings of Japanese banks, insurance companies, and securities companies, is used to understand the network structure of the Japanese financial system. In addition, the following two assessments were conducted, taking into account not only the network structure but also the characteristics of nodes, such as the soundness of each financial institution: (i) the degree of impact of the failure of a certain financial institution on other financial institutions, and (ii) the degree of impact of the failure of other financial institutions on a certain financial institution.

In this paper, with reference to the above FSAP point of view, two indicators that measure the importance of networks are developed for the domestic corporate transaction network, i.e., (i) the impact of a failure of a certain firm on other firms (Contagion index) and (ii) the impact of a failure of other firms on a certain firm (Vulnerability index).

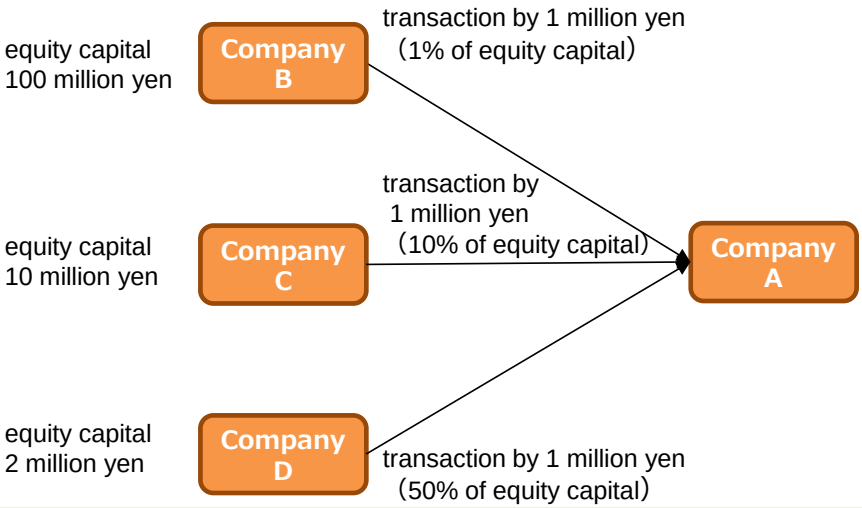
[7] The FSAP is a program by which the IMF assesses the stability of member countries' financial sectors. Major countries, including Japan, undergo a review every five years. For the results of the 2023 FSAP, see below.<https://www.fsa.go.jp/inter/etc/20240514/20240514.html>

1. Impact of failure of a certain firm on other firms (Contagion index)

As a simplified example, assume that Company A has purchased (accounts payable) 100 million yen from Companies B, C and D, respectively (Figure 2). If Company A enters bankruptcy, making it impossible for Companies B, C and D to collect their accounts receivable from Company A, Companies B, C and D will book credit losses for that amount. The impact of the loss will vary depending on the business strength of each company. To capture the impact of loss to all suppliers (in this case, Companies B, C and D) due to the counterparty failure (in this case, Company A), taking into account the business strength of the suppliers, the "cumulative capital loss ratio"[8] is calculated as follows: compute the ratio of loss to each supplier relative to equity capital when the counterparty fails, and aggregate these ratios. The indicator enables a consideration of the impact in accordance with the amount of equity capital of the company that suffers losses, in addition to the transaction amount.

In the following sections, the above "cumulative capital loss ratio" is defined as a "Contagion index" that measures the impact of one firm's failure on other firms in the network.[9]

Figure 2: Example calculation of the “cumulative capital loss ratio”



“Cumulative capital loss ratio” (by failure of Company A) equals 61%.
(1% + 10% + 50% = 61%)

[8] Instead of equity capital, the ratio to total assets or sales can also be used.
[9] It should be noted that the "Contagion index" focuses on the financial impact of the failure of a firm receiving goods or services on the firm providing those goods or services, but not vice versa.

2. Impact of failure of other firms on a certain firm (Vulnerability index)

If the impact of the failure of a certain firm in the network is likely to lead to other firms' failure, there is a concern that the impact may propagate through the network in secondary and tertiary ways, thereby increasing systemic risk. Hereinafter, whether or not a firm is susceptible to the impact of other firms is calculated by referring to the method of Freeman et al.[10]

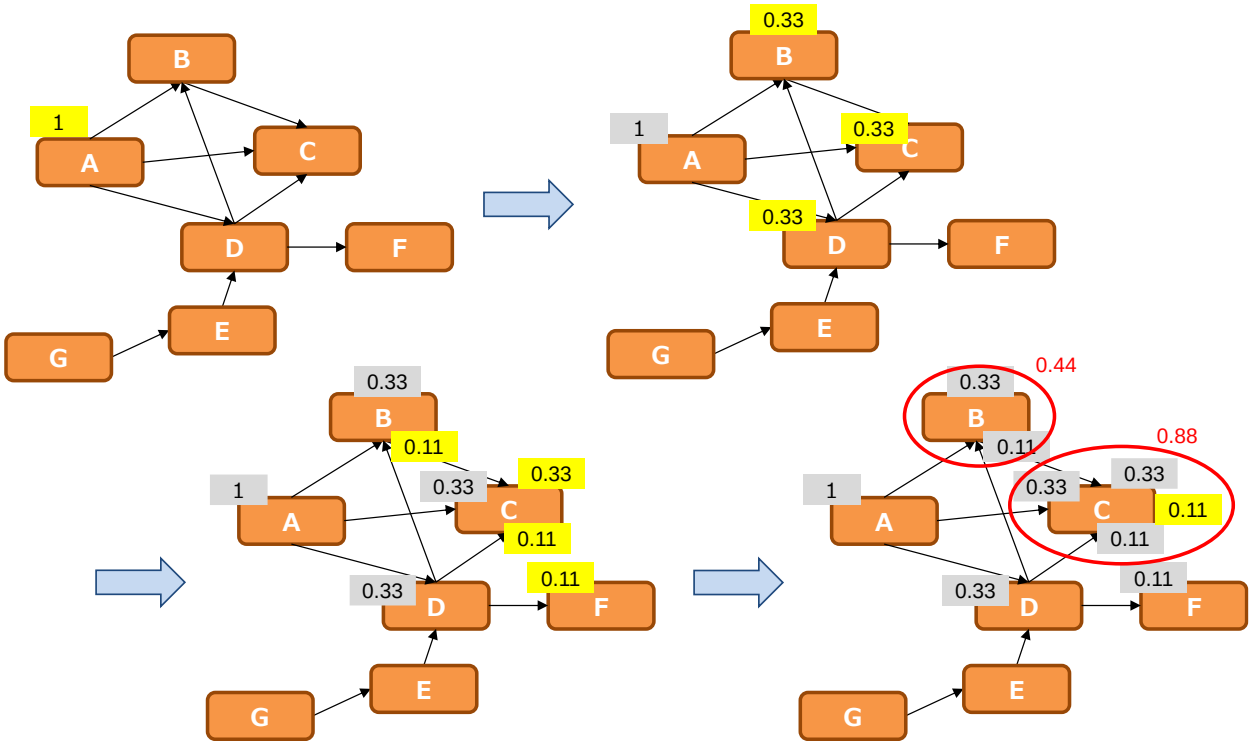
Freeman et al. assumed that certain company A in the network has a resource of 1 and distributes the resource equally among companies that have business relations with the company. A company that receives the resource also distributes the resource to each company that has business relations in the same manner, and the operation is repeated until reaching a steady state. The total of the resources that have passed through each node is defined as a "dependence index." Taking Figure. 3 as an example, it is possible to make a quantitative comparison, such as "the impact of the failure of Company A is larger for Company C than for Company B on the network."

Figure 3 shows the "dependence index" only for Company A, but the same calculation can be done for all companies on the network. Freeman et al. defined "importance index" as a value obtained by adding up, at each node, the "dependence index" for each company calculated in this way. This makes it possible to identify nodes through which resources uniformly distributed on the network frequently pass. In other words, a company with a higher "importance index" is more likely to be affected by other companies on the network.

In this paper, the "importance index" in Freeman et al. mentioned above is defined as "Vulnerability index."

[10] Freeman, Linton C., Stephen P. Borgatti, and Douglas R. White. "Centrality in valued graphs: A measure of betweenness based on network flow." Social networks 13.2, 1991, P.141-154.

Figure 3:[11] Example of the calculation of "Dependence index" (The case of Company A)



[11] The arrows in the figure represent the directions in which the services are provided. Specifically, it is assumed that Company A sells some sort of products to Companies B, C and D.

3. Results and discussion

Figures 4 and 5 show the distribution of the Vulnerability index and Contagion index calculated for a domestic corporate transaction network constructed from seclected samples[12] of business-to-business transaction data, with the maximum value of each index set at 100 for normalization.

Figure 4: Distributions of Vulnerability index and Contagion Index

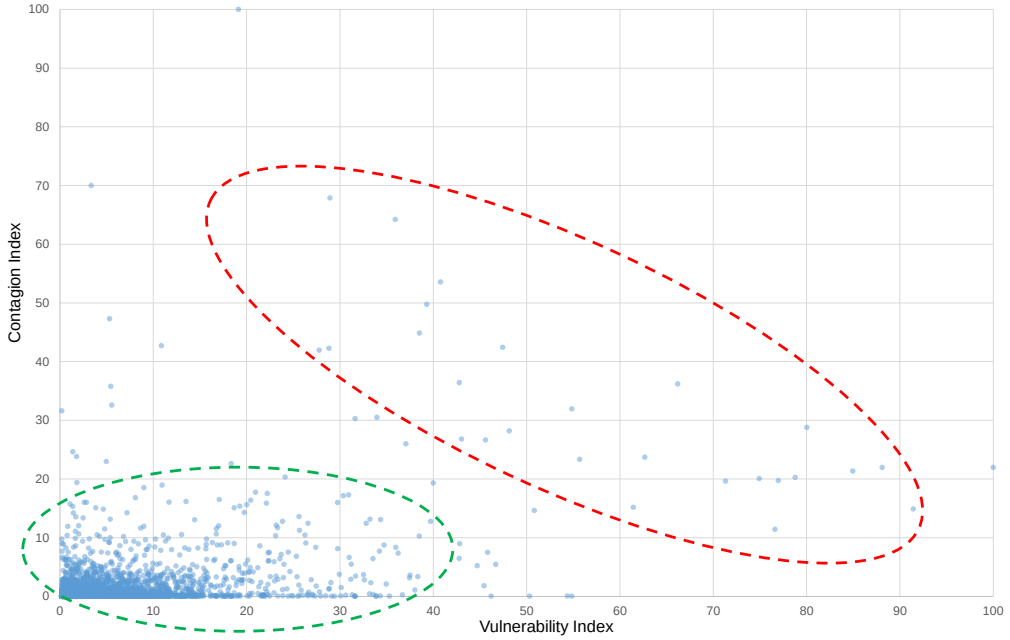
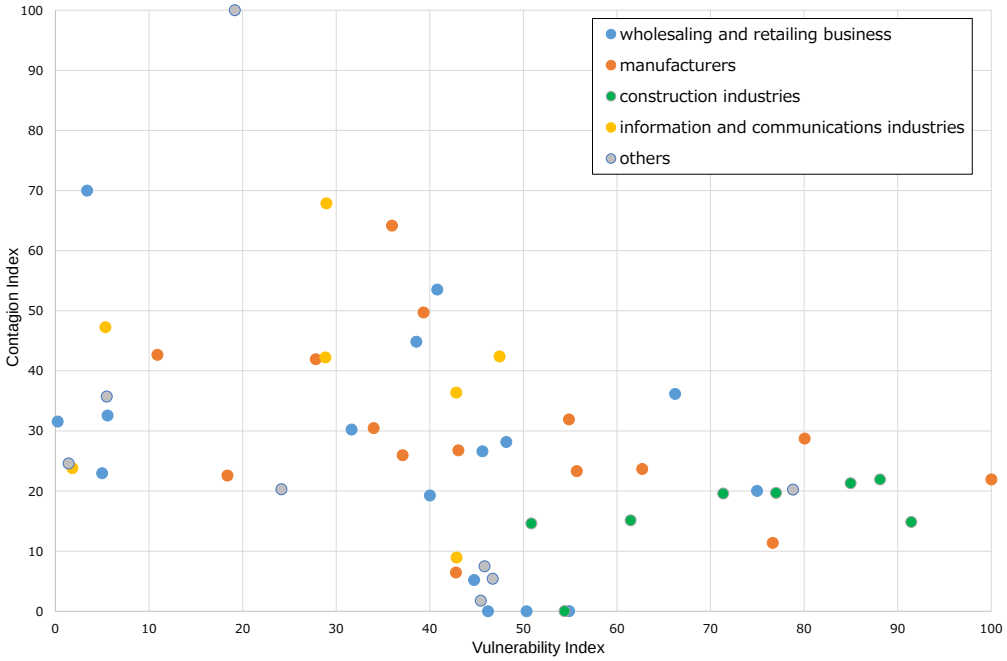


Figure 5: Distributions of Vulnerability index and Contagion Index (broken down by industry, only Vulnerability index > 40 and Contagion index > 20 are shown to ensure visibility)



[12] Firms with a transaction amount of 100 million yen or more are included in the scope. The number of samples is around 22,000.

Two trends can be observed from Figure 4. First, for both indices, companies tend to be concentrated where the index is small (circled in green), indicating that only a small number of companies have a relatively large network influence or are likely to be significantly affected.

Second, for firms where one or both indicators are above a certain level (circled in red), there is a tendency for a trade-off to occur in which a large one of the indicators leads to another indicator being small. As shown in Figure 5, looking at the industries of firms where both indicators are above a certain level, it is observed that manufacturers (automobile manufacturers) and information and communications industries have relatively high contagion indices, while manufacturers (heavy industries) and construction industries have relatively high vulnerability indices.

This trend is likely due to differences in the natures of firms that have an influence on other firms and firms that are affected by other firms. Both indicators, by definition, have a common feature in that they increase as the number of firms (suppliers) that have sales to the firm increases. While the Contagion index increases as the number of suppliers that have sales to the firm increases relative to their own capital, the Vulnerability index tends to increase as nodes on a network become densely populated, such as where the firm and its suppliers use up many resources. In a nutshell, differences in the number and nature of suppliers among firms or industries may be a factor in such distribution.

Among the samples used in this analysis, no firms had extremely high values for both the Contagion index and the Vulnerability index. However, if the same calculation is performed for a network limited to a specific region or industry, a different result may be obtained. In addition, as stated in the footnote, since the scope of the analysis is limited to firms with a transaction amount of 100 million yen or more, transactions related to SMEs and retail consumers are considered to be excluded in many cases. If the index is constructed without setting a threshold for the transaction amount, the result of industries that conduct small-scale transactions with many counterparties or industries that conduct transactions with retail consumers may change.

IV. Conclusion

In this paper, the FSA's initiatives to visualize the network structure among financial institutions and enterprises are presented, and indicators to identify enterprises that are important in the network are calculated, taking into account the characteristics of enterprises, such as their size, using the corporate transaction data obtained from a third-party vendor. The results suggest that these indicators could be utilized to grasp and identify not only the network structure but also the significant nodes in the network. However, the indicators developed in this paper form just one example. There is room for further improvement, for example, incorporating the evaluation of enterprises that are difficult to substitute in the supply chain (such as those possessing monopolistic technology).

The results of this analysis, when used in conjunction with banks' loan data, are expected to contribute to the assessment of banks' credit risk and contagion simulation in light of the network structure to which borrowers belong. Furthermore, the addition of foreign firms to the network could lead to the development of a country risk simulation. In addition, while this analysis focused on micro-level data, such as business-to-business transaction data, more macro-level data (e.g., input-output table) could also be used to deepen the analysis. The FSA will continue to advance research on network analysis methods with the aim of enhancing monitoring while deepening our understanding of the financial system and the real economy.