Systemic Risk in a Japanese Financial Network*

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Abstract

We study Japanese bank-firm bipartite network, whose links are bank’s lending to each firm. By assigning ‘distress variable’ to each agent in this work and studying spread of distress from a bank to the whole network, we evaluate the bank’s importance with respect to the systemic risk of this financial network.

1 Introduction

Systemic risk is of topmost importance in any analysis of the economy, as is evident from recent Lehman crisis and other crises that were repeated over and over and affected huge number of people worldwide.

Economy as a whole is made of vast number of economic agents who interact in a (large) number of ways. As ways they choose partners with whom they interact are affected by a large number of factors, including each agent’s individual situations, even outside the economy, the network is far from regular. Thus numerical analysis is relevant for evaluation of systemic risk.

There are basically two ways to approach this problem:

- Realistic, but complex approach: One may set up some numbers of equations for dynamic interactions between agents, whose variables are entries in financial statements, like saving, borrowings, sales, profit and what not.

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Abstract, but simple approach: One may define some abstract quantities that reflects the most important characterization of each agent and define interactions among them.

Both approaches have advantages and short comings: The former may be close to the reality and one can may look into various aspects of the system, like the tax system, on how they affect the system and what not, while as one tries to construct more realistic models the numbers of the variables and the numbers of the equations increase. The parameters in the equations may rise accordingly and one may have hard time in determining their values and identifying which parameter values are significant cause of any particular economic phenomena. On the other hand, in the latter approach, the simple fact that it is abstract may raise discussion on how it can be important and what is really analyzed in comparison with reality. The merit of the this approach, however, is that its structure can be made quite simple, being tailored to the particular phenomena (the type of the systemic risk in that particular economic network).

In this paper, we take the latter approach, in particular, DebtRank approach, which was originally proposed in Battiston et al. (2012) in the banking system in U.S.. We first extend this approach, using the framework we proposed in Fujiwara et al. (2009). We then carry out the calculation of the DebtRank of the Japanese banks from 1980 to 2010.

2 Network Characteristics

The data we use is provided by Nikkei Inc. and contains amount of the long-term and short-term yearly lending by banks to the firms from 1980 to 2011. The banks and firms are identified by respective Nikkei codes and the names. All the yearly BS, PL and CS of both banks and firms are given. The number of firms and banks are plotted in Fig.1 and Fig.2.

Some network properties, including Minimum Spanning Tree (MST) of the banks, were studied in De Masi et al. (2009), whose main conclusion was that there are two kinds of major branches, 1) branch made of city (mega) banks, and 2 branches that are made of banks in the same region, i.e., a branch made of banks in Kansai region, a branch for banks in Tohoku region, etc. This would have indication as to the spread of distress in this bi-partite network.
Figure 1: Number of firms.

Figure 2: Number of Banks
3 Propagation of the distress

The purpose of our analysis is, as stated before, to evaluate the importance of the agents in this economic network with respect to systemic risk. In order to achieve this goal, we first assign a maximum distress to the agent and study the spread of the distress to the whole network. The degree of distress is quantified (in an abstract manner) as variables $h_\beta$ assigned to the bank $\beta$ and $h_f$ assigned to the bank $f$, each ranging from 0 to 1, 1 being the maximum distress (bankruptcy) and 0 corresponding to a ‘healthy’ state. Thus, in order to study the importance of a bank $\beta_0$, we initially assign $h_{\beta_0} = 1$ and all the rest of $h_\beta$ and $h_f$ to zero. We then let propagate $h$ from the banks ($\beta$) to the firm $f$ as,

$$h_f \rightarrow h_f + \sum_\beta w_{f\beta} h_\beta,$$

(1)

and from the firms $f$ to the bank $\beta$ as,

$$h_\beta \rightarrow h_\beta + \sum_f w_{\beta f} h_f$$

(2)

at each time step. The the propagation matrix elements $w$ are defined by the following,

$$w_{f\beta} := \frac{C_{\beta f}}{\sum_{\beta'} C_{\beta' f}}$$

(3)

$$w_{\beta f} := \frac{C_{\beta f}}{\sum_f C_{\beta' f}}$$

(4)

where we denote the lending from the bank $\beta$ to the firm $f$ by $C_{\beta f}$, as in Fig.3. We also note that we do not allow multiple visit around loops: once distress propagates from the bank $\beta$ to the firm $f$ and then back to the bank $\beta$, it no longer travels back the firm $f$, and similarly from the firm to the bank and back to the firm.
Figure 3: Distress propagation from the bank $\beta$ to the firm $f$.

4 DebtRank

After all the propagation is over (typically after 4 steps), we evaluate the weighted average of the distress on the banks and on the firms separately:

$$d_b = \frac{\sum_{\beta} A_\beta h_\beta}{\sum_{\beta} A_\beta},$$  \hspace{1cm} (5)  

$$d_f = \frac{\sum_{f} A_f h_f}{\sum_{f} A_f},$$  \hspace{1cm} (6)

where $A_\beta$ and $A_f$ are total assets of the bank $\beta$ and the firm $f$, respectively. We call these quantities the DebtRanks of the initial bank $\beta_0$.

Fig.4 gives the scatter plot of the bank’s asset $A_\beta$ and the total DebtRank $d_b + d_f$. The mega banks, such as Mitsubishi, have large assets and as a result of the weighted average (5) they achieve high total DebtRank, which is natural in the sense that they play major role in Japanese economy. On the other hand, it is surprising that below the three mega banks, Mitsubishi, Mizuho and Mizuho Corporate banks, the scatter plot flattens, with small regional banks such as Shizuoka achieving high DebtRank. This demonstrates clearly their importance in the local economy, if not all the domestic economy.

Fig.4 contains the plot of the DebtRank on the bank layer and on the firm layer separately. This further shows that local banks located in the top left area is of vital importance in the local economy.
5 Summary

In this talk we have presented new extension of the DebtRank concept to the bipartite network made of banks and firms. As a result, we have DebtRanks on the two layers of the network separately. From this we clearly see that mega-banks, having wide influence over all the Japanese economy, has large influence on the banks through lending to a large number of firms, while regional banks have large influence on the firms, who deal with the said bank almost exclusively. This conclusion implies the need for appropriate governmental support on not only the mega banks, but also influential regional banks who are identified by the high DebtRank on the firm layer.
Figure 5: The DebtRank on the bank layer and the one on the firm layer.
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References

