Estimation of sales decrease caused by disaster: Hokkaido blackout after earthquake in 2018

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Abstract. We simulate the inter-firm trading network which consists of approximately one million nodes, and we estimate the firm sales in Japan. We apply the gravity interaction model to the real Japanese inter-firm trading network in order to calculate the money transport between firms. Sales of each firm is evaluated through the scaling relation between the money flow and the sales, and then the total sales is calculated as an economic indicator. This calculation method is applicable to other situations. As an example, we present an estimation of sales decrease caused by the blackout due to the Hokkaido earthquake in September 6, 2018. The total sales is calculated in both cases: before and just after the earthquake. The total loss of sales is estimated as 35 billion yen per day for direct decrease in the firm sales in Hokkaido, while as 90 billion yen per day for indirect decrease in the other areas. The indirect sales decrease is about 2.6 times as well as the direct sales decrease.

Keywords: Inter-firm trading network, sales estimation

1 Introduction

The inter-firm trading network, or business transaction network, has been one of the key concepts for the understanding of the firm activities. In the context of the complex network systems, the networking between firms in respect to transactions has associated with various properties such as the preferential attachment [1], the exponential growth of the firms [2], the scaling relation between degree and sales [3], and the transport phenomena including network topology [4,5].

As the theoretical development of the inter-firm trading network, it becomes more and more important practically to forecast the firm activities in the whole country. The direct estimation of the economic indicators needs not only the network structure but also the empirical relations between the structure and the sales. For example, the degree distribution is not the economic indicators itself. The scaling relation helps to calculate the sales distributions, but there is no reason why the scaling relation is still valid in the specific situations or crisis. In other words, we have to remove possibilities of overfitting to the ordinary conditions.

In this study, we present an application of a simulator of the Japanese inter-firm trading network. The simulator calculates the sales of each firms using the network structure and several parameters, based on the gravity interaction model in the inter-firm trading [4,5]. The physical meanings of parameters are clear in this model. Therefore, we can suppose that some of the parameters are conserved and still valid in other situations.

We compute the sales decrease caused by the blackout in Hokkaido after the earthquake on Sep. 6, 2018 through the gravity interaction model. The sales decrease is categorized into two parts: the direct effect coming from the sales decrease of the firms in Hokkaido area, and the indirect effect coming from those in the other areas. The indirect decrease is about 2.6 times as much as the direct decrease, which implies that the network effect is more important.

2 Method

We model the Japanese inter-firm trading network as a directed graph, in which the nodes represents the firms and the links represents the transactions. The link directions are set as the same as the money flow: the buyers to the suppliers. The inter-firm transaction data is provided by TDB (Teikoku Databank, Ltd.).

We adopt the gravity interaction model proposed by Tamura, et al. [4,5] for the calculation of money transport property. The money flow f_{ik} from the firm *i* to the firm *k* is approximated by

$$f_{ik} = \frac{A_{ik}S_k^{\beta}}{\sum_j A_{ij}S_j^{\beta}} DS_i^{\alpha}, \tag{1}$$

where we denote the sale of the node i by S_i, the adjacency matrix by A_{ij}, the constant of proportionality D, and parameters which determines the partitions of flow by α and β. We presume the additional two assumptions concerning the interactions between the network and the environment as follows. The inflow from the environment to the firms are uniformly set to F, and the outflow from the firms to the environment is $\tilde{v}S_i^{\alpha}$. The balance equation is

$$\sum_i \frac{A_{ik}S_k^{\beta}}{\sum_j A_{ij}S_j^{\beta}} DS_i^{\alpha} + F = DS_k^{\alpha} + \tilde{v}S_i^{\alpha}. \tag{2}$$

Now we set the rescaled sales $x_k = DS_k^{\alpha}/F$, the dissipation parameter $v = \tilde{v}/D$, and the nonlinear parameter $\gamma = \beta/\alpha$. After this substitution, we obtain the simplified equations for the money transport of the inter-firm trading network:

$$\sum_i \frac{A_{ik}x_k^{\gamma}}{\sum_j A_{ij}x_j^{\gamma}} x_i + 1 - (1+v)x_k = 0. \tag{3}$$

We assume that the effect of the blackout is introduced as the following: the firms under the blackout are not involved in the economy. During the blackout, the firms in Hokkaido are removed from the network and have no sales. We presume that the parameters of the equations is not changed before and just after the earthquake, except for the node number and the adjacency matrix.

3 Results

The sales distribution is calculated before and just after the earthquake in Hokkaido on Sep.6, 2018. Here we use parameters for the gravity interaction model: $\alpha = 0.87, \gamma = 0.35, \nu = 0.09, D = 1.25, F = 38$. The unit of the sales S_i is a million yen. We plot the sales before earthquake versus the sales during the blackout for each firm in Fig. 1. The sales tend to decrease as a whole, some firms increases their sales. The figure 2 also confirms this bias. This behavior is explained by the down of the competitors; the gravity interaction model shows that the decrease of the flow partition may cause the increase of the flow partition of other firms.

We estimated the decrease in the total sales

$$\sum_k S_k = \sum_k (F x_k / D)^{1/\alpha}. \tag{4}$$

as in Table. 1. The effect of the blackout is attributed to the stop of all firm activities in Hokkaido. Then the total loss of sales is 35 billion yen per day in Hokkaido area, and 125 billion yen per day in the whole Japan. The indirect loss of sales, which is defined by the sales decrease in the areas other than Hokkaido, 90 billion yen per day is 2.6 times as much as the direct loss, sales decrease purely in Hokkaido. This implies that including the network structure is indispensable for the estimation of the loss caused by such disasters.

Table 1. The regional sales decrease caused by the blackout in Hokkaido.

Area	Decrease in sales (billion yen) per day
Hokkaido	35
Other than Hokkaido	90
Total	125

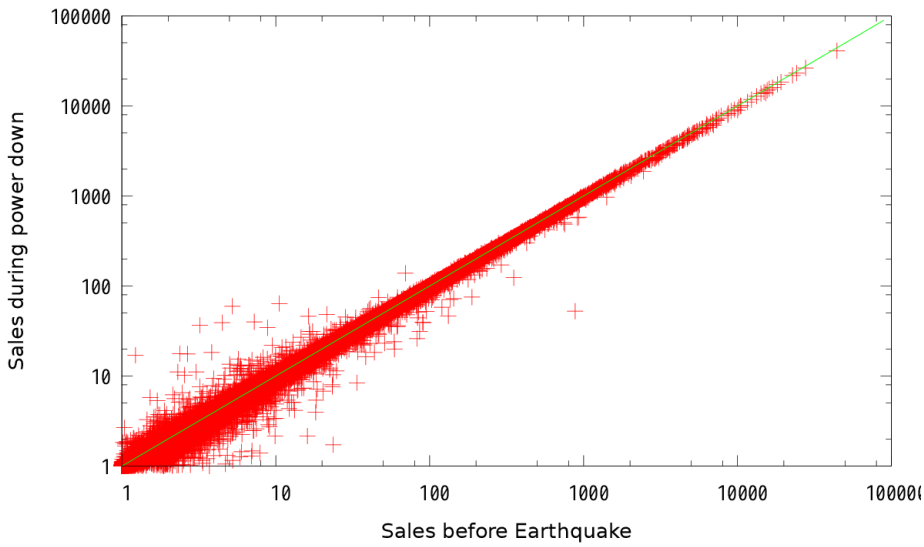

Fig. 1. The comparing of the sales before the earthquake to that during the blackout in Hokkaido on Sep. 6, 2018. The sales during the blackout is comparably small, although some firms have the benefits of the down of the competitors.

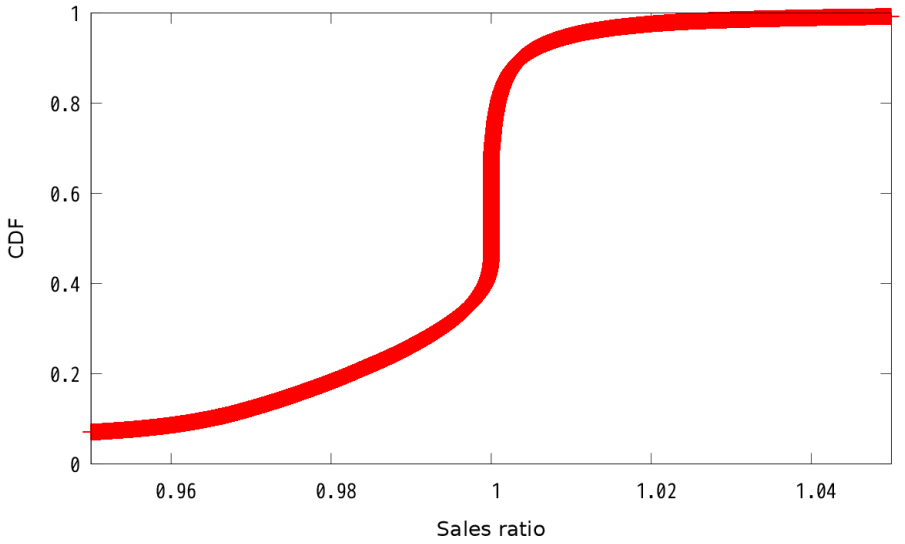

Fig. 2. The cumulative distribution function of the ratio of the sales during the blackout to the sales before the earthquake in the whole Japan. The CDF starts finite value even at zero sales because the sales of the firms in Hokkaido is counted as zero.

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References

1. Albert-László Barabási and Réka Albert: Science 286, 509-512 (1999).
2. W. Miura, H. Takayasu and M. Takayasu: Phys. Rev. Lett. 108, 168701 (2012).
3. H. Watanabe, H. Takayasu and M. Takayasu: Physica A 392, 4 ,741-756 (2013).
4. K. Tamura, W. Miura, and et al., Int. J. Mod. Phys. Conf. Ser. 16 93-104 (2012).
5. K. Tamura, H. Takayasu and M. Takayasu: Scientific Reports 8, 5517 (2018).