研究ノート

The Resilience of Food Supply Chains and Regional Economies

Kiyotaka ISHIKAWA

Ⅰ. Introduction

Amid the COVID-19 outbreak in Japan, the supply chain destined to food service industries was in disruption due to the government's self-quarantine request. The upstream such as wholesale, food processing and raw material industries dealing food and beverage products have been subject to unprecedented fall in commercial demand. Japan's food supply chain is characterized by its high rate of intermediate input locally produced within the regional industrial clusters; thus, it is potentially vulnerable to the industry-wide shocks in the downstream (Ishikawa (2023)).

This study focuses on the supplier-customer linkage that affects the performance of upstream players in the food supply chain in the post-pandemic period. It is important to figure out on what conditions the corporate or industrial performance is robust and more over easy to recover in terms of regional economy's resilience. The study relies on a proprietary data set provided by the private credit reporting agency Tokyo Shoko Research: it consists of credit information of each firm and supplier-customer linkage between firms. From this data, extracted the firms that in direct or indirect relation with a company of which main business is restaurant or bar in fiscal year 2020-2022. With this sumple, this study empirically examines how much the sales of those firms is affected by the distance of linkage in production network destined to those end users. This study also aims to compare the effect between two groups on location basis.

The outline of this research note is organized as follows. Section II discusses the contributions of the related literature on the network linkage model. Then, Section III reviews the framework to study the whole input-output linkage referring to statistical analysis of network data. Section IV explains data employed for this research and shows descriptive statistics about firms in the food supply chain. Finally, Section V presents the remaining tasks for further study and prospect for empirical analysis.

Ⅱ. Related Literatures

Before the pandemic, the food service industries hed been the engine that drives demand for food and beverage products (Akune (2009)), but the COVID-19 outbreak is changing the structure of value chain destined to them under business restraint or shortened business hours. According to the theory by Long & Plosser (1983), an asymmetric industrial structure may trigger a widespread impact if any industries under idiosyncratic risk are subject to wide network with numerous peripherals in input-output relation, which is known as macroeconomic tail-risk. This theory explains what becomes of supply chain disruption of the food service industries by the pandemic: following poor sales, employment reduction, reorganization of supply chain among suppliers.

Once a similar downturn took place after the Great East Japan Earthquake in 2011, some empirical studies regard the input-output relation in manufacturing industries as network and hence apply the methodologies developed in the context of network science into the quantitative analysis of relation between economic structure and resilience. As a matter of fact, the economic impact by earthquake is amplified countrywide through the supply chain of manufacturing industries. The casualties and material damages were concentrated in four prefectures: Aomori, Iwate, Miyagi and Fukushima, which covers 4. 7% of GDP, and the GRP among these four dropped by 3. 1 points after the quake. Without any indirect impacts out of the disaster area, the impact on GDP shall be no less than minus 0. 15 points; however, the GDP dropped by 0. 6 points. The difference shows that there are indirect impacts that overwhelm the primary impacts in the disaster area.

Carvalho et al. (2021) empirically identify the mechanism behind the amplified impacts. The supply chain disruption results in parts shortage, order loss and shipment delay etc. among firms out of the disaster area but with supplier-customer relations to damaged firms. Carvalho et al. (2021) regress linkage distance (e.g., take first degree if direct customer, second if customer's customer and so on) to firm's performance and find these ripple effects are significant no more than third degree relations to damaged firms but attenuate over distance. The effect is robust at least in terms of common trend over region and industry and non-network-origin factors such as brownout or power saving after the quake, which are all controlled.

Similar studies such as Barrot & Sauvagnat (2016), that focus on the input-output linkage of US firms who struck by hurricanes, provide some evidence that the subject damaged by natural disasters causes a chain reaction to its related suppliers or customers.

Regarding the resilience of business structure, Stella (2015) and Di Giovanni et al. (2015) show that economies with a higher weight on specific intermediate goods or services or hardly substitutable products tend to exhibit a higher volatility in GDPs. On the mechanism behind macroeconomic volatility, Hang et al. (2020) provide a framework to show the macroeconomic cost of resource misallocation. When there are firm-specific intermediate input distortions, the TFP estimated from value-added production is biased in the presence of input-output linkage across sectors. Baqaee (2018) claims that imperfect competition across firms generate an excess volatility in GDP once there is a shock in labor productivity. If any firms that put a markup on its products exit the oligopolistic market, there is a decrease in productivity across upstream and downstream sectors since they have a limited access to alternative customers or suppliers, and hence the sector-specific shock is amplified with negative spillover.

Ⅲ．Framework to Study Network

When we use the term ‘network,’ it refers to a collection of elements and their inter-relations (Kolaczyk & Csárdi (2014)). Since they are far more informative, it is difficult to understand its characteristics by ordinary graphs to visualize univariate or relations of multivariate; instead, we use network graphs as merely a collection of vertices and edges.

As individual social networks are visualized with persons (i.e., vertices) and relationships between them (i.e., edges), economic networks are formed by economic agents and business relationships between them. Specifically in this research, let us focus on input-output linkage in the food supply chains, so the subject of network is business enterprise that produce intermediate goods and services destined to food service industries, connected to each other with supplier-customer relationships (i.e., the direction of transaction is identified; thus edges are directed).

Nevertheless, as a representation of complex system, a graph alone shall be insufficient to describe the structure of inter-relations. Regarding some aspect of the structure of corresponding network graph, certain notions of the ‘importance’ of individual system elements may be captured by measures of how central they are as the corresponding vertex in the network. For example, if there are small groups of restaurant franchise that are dominant in the market and are major customers to supplier firms, they are central and thus important player in the input-output linkage of food supply chains. Consequently, fall of demand among these groups are highly likely to affect the performance of peripheral players and then the whole economy through every channel of network.

In a microeconomic perspective, not only industrial associations but also firm level connections matter in the analysis of ripple effects; in this sense, the search for specific fraction of ‘communities’ within a system or optimization in graph partitioning is another important question. In the case above, if these important groups of firms fail to recover after demand shock, they could turn into a bottleneck of the entire economy. Also, depending on the market structure, too much dependence on these firms (i.e., extremely asymmetric network structure) may spoil the resilience of supply chain.

In the following sections, let us process the dataset that incorporates Japan's food supply chains based on these frameworks, although many of concepts and ideas introduced in the previous context are yet to come in this research note.

Ⅳ. Analysis of Food Supply Chains

1. Data

The empirical analysis relies on identifying firm-level food supply chains throughout Japan and the subset of firms that were directly exposed to the food service industries such as restaurants, bars and cafes that had been subject to business restraint or shortened business hours requested by the government under the state of emergency declared intermittently between April 2020 and March 2022. Besides, consumer's hesitation to in-person contact in food services or social gatherings was one of the major reasons for unprecedented fall in commercial demand of these industries.

This study relies on a proprietary data set provided by the private credit reporting agency Tokyo Shoko Research (henceforth, TSR): it consists of credit information of each firm and supplier-customer linkage between firms. From this data, I extract the firms that in direct or indirect relation with a company of which main business is restaurant or bar in fiscal year 2020–2022 and that has been in operation more than a year before the outbreak of COVID-19. The information of each firm covers headquarter location, type of industry, nature of main business, date of establishment, number of employees, sales and revenue. The resulting database contains roughly twenty thousand firms across 47 prefectures including the related sectors destined to food service industry.

Since the fiscal year end varies over firms; usually it closes at the end of March or December, the observations of sales and revenue are in a span of several months. In order to correct the information in the recovery period after the first outbreak, I extract the latest data of which fiscal year end is no earlier than January 2022 and sales are observed more than twice after the first wave of epidemic. Therefore, the sample is restricted to the subset of firms for which I can construct annual sales growth rate in the post-COVID-19 fiscal year, defined as the fiscal year that contains January 2020 (that is, the beginning of the first outbreak) and observe the firm-level covariates. This procedure leaves with a baseline sample of 19, 325 firms.

２. Descriptive Statistics

In this post-COVID-19 period, in which the firms in the food supply chains survived through the sudden fall of demand and begin to adapt themselves to the ‘new normal’ with the periodic waves, sales and revenue are in the trend to recover.

To analyze the pace of recovery, I compare annual nominal sales growth rate in the post-COVID-19 period across five major categories of industrial sectors in the food supply chain in Figure 1 and 2. Since there is no access to information on firm-specific prices, I leave the sales value nominal yet it could be deflated by the regional price indices for the respective industries and prefectures, as Carvalho et al. (2021) suggest.

As the figures illustrates, the mean nominal sales growth of firms in the period is positive: 5. 97% for entire food industries, 0. 87% for agriculture, 2. 52% for food processing, 6. 73% for beverage and tobacco, 8. 94% for food wholesale and 3. 78% for food service, respectively. It is interesting that the intermediate industries such as food wholesale outperforms the others in sales growth rate. On the other hand, agriculture and food processing in the upstream experience fewer growth and presumably minimal damage amid COVID-19 outbreak. For further analysis, I will complement this analysis by further comparison to the pre-outbreak period as common trend.

As an alternative index for performance, I compare annual nominal revenue growth rate in the post-COVID-19 period across five major categories of

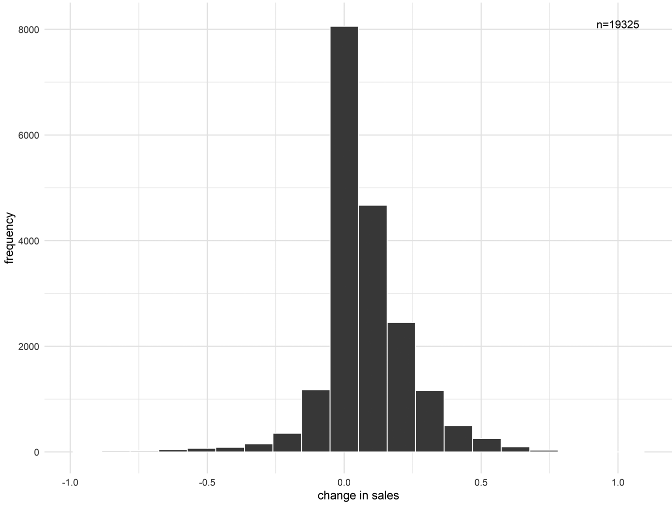

Figure 1　Sales Growth Rate Distribution

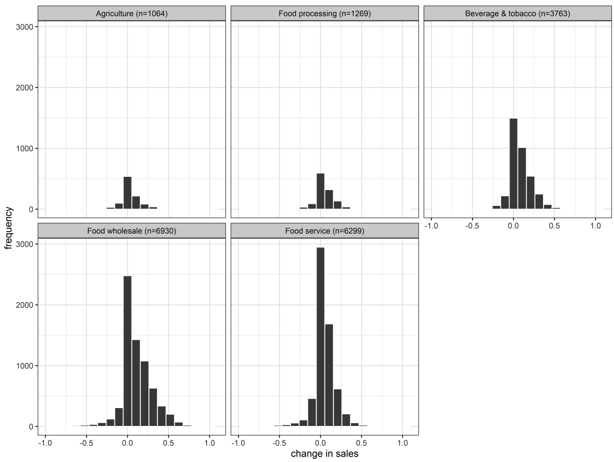

Figure 2　Industrial Composition of Sales Growth Rate

Note: Distribution of nominal sales growth rate for all and respective industrial sectors. Outlier samples that show more than 100% or less than -100% growth are excluded.

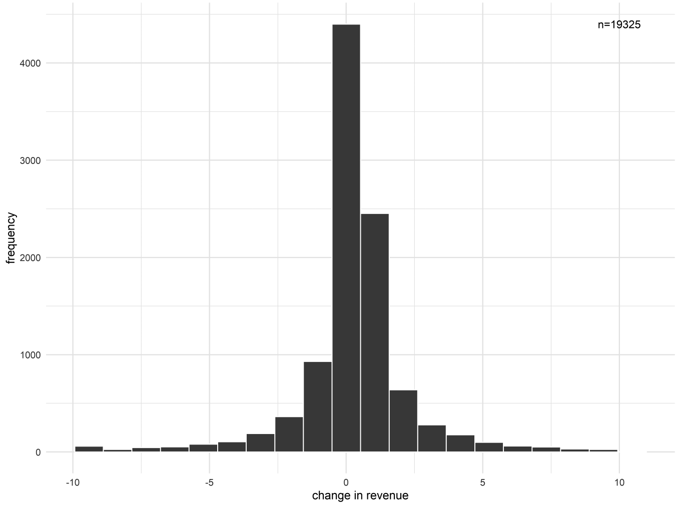

Figure 3　Revenue Growth Rate Distribution

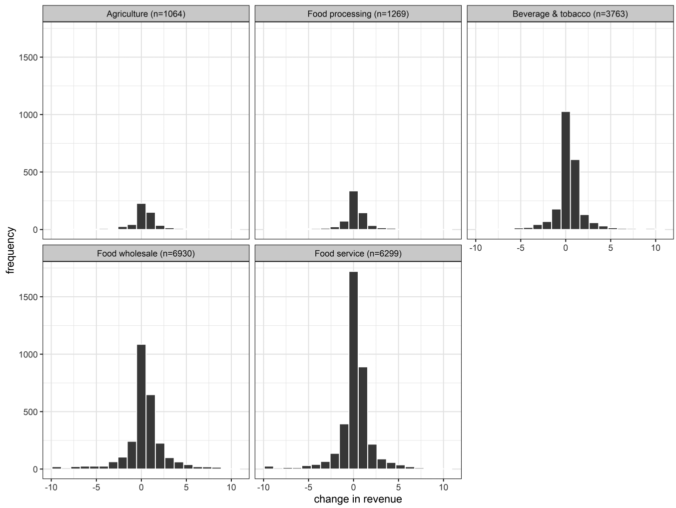

Figure 4　Industrial Decomposition of Revenue Growth Rate

Note: distribution of nominal revenue growth rate for all and respective industrial sectors. Outlier samples that show more than 1000 % or less than -1000% growth are excluded.

industrial sectors in Figure 3 and 4. The recovery trend is similar to that of sales; however, they distribute in a wider range since different cost structure by nature of business across firms generates a larger deviation in revenue. Hence in the following empirical analysis, firm's performance shall be represented by sales growth.

Yet, there are some notable features illustrated in the figures. Compared to the sales growth, the median is distributed around zero line, which indicates that the pace of recovery in revenue is not as resilient as those in sales. This fact suggests that most firms might have compromise in relation to suppliers or customer in terms of price or that they are still restructuring the business in search for more profitable and less volatile alternatives.

Table 1 shows descriptive statistics by comparing other post-pandemic characteristics of firms in the food supply chains. Beside sales scale, the typical firm characteristics such as age (measured by years of operation) and size (measured by the number of employees) are comparable between food service and the rest of related sectors. Table 2, on the other hand, shows the distribution of firm size for each industrial sectors. The industrial structures of agriculture and food wholesale are relatively small firms oriented with no more than 10 employees, yet there is no remarkable difference across sectors. For further analysis, Table 1 shall be disaggregated based on their post-

Table 1　Post-COVID-19 Characteristics of Firms

		By industrial sector				
	All firms	Agriculture	Food processing	Beverage & tobacco	Food wholesale	Food service
Log sales	12.72	12.43	12.87	13.71	11.72	13.25
	(1.99)	(1.68)	(2.02)	(1.86)	(1.80)	(1.80)
Log size	2.61	2.18	2.80	2.76	2.20	3.00
	(1.41)	(1.25)	(1.37)	(1.28)	(1.41)	(1.37)
Age	39.74	27.75	55.07	46.07	29.74	45.24
	(21.34)	(16.59)	(24.70)	(19.71)	(18.22)	(19.82)

Notes: Summary statistics of post-COVID-19 characteristics of firms. Values are averages across firms in each industrial sector with standard deviations in parentheses.

Table 2　Firm Size Distribution

	Number of employees										
	0–4	5–9	10–19	20–29	30–49	50–99	100–299	300–999	1000–1999	2000–	total
All firms	4, 398	3, 775	3, 719	2, 014	2, 032	1, 719	1, 178	397	61	32	19, 325
	(0. 228)	(0. 195)	(0. 192)	(0. 104)	(0. 105)	(0. 089)	(0. 061)	(0. 021)	(0. 003)	(0. 002)	
Agriculture	320	280	196	93	76	53	36	8	2	0	1, 064
	(0. 301)	(0. 263)	(0. 184)	(0. 087)	(0. 071)	(0. 050)	(0. 034)	(0. 008)	(0. 002)	(0. 000)	
Food	179	293	298	139	128	106	76	39	4	7	1, 269
processing	(0. 141)	(0. 231)	(0. 235)	(0. 110)	(0. 101)	(0. 084)	(0. 060)	(0. 031)	(0. 003)	(0. 006)	
Beverage	601	744	843	467	445	354	233	67	6	3	3, 763
& tobacco	(0. 160)	(0. 198)	(0. 224)	(0. 124)	(0. 118)	(0. 094)	(0. 062)	(0. 018)	(0. 002)	(0. 001)	
Food	2, 484	1, 403	1, 080	525	536	471	305	104	14	8	6, 930
wholesale	(0. 358)	(0. 202)	(0. 156)	(0. 076)	(0. 077)	(0. 068)	(0. 044)	(0. 015)	(0. 002)	(0. 001)	
Food	814	1, 055	1, 302	790	847	735	528	179	35	14	6, 299
service	(0. 129)	(0. 167)	(0. 207)	(0. 125)	(0. 134)	(0. 117)	(0. 084)	(0. 028)	(0. 006)	(0. 002)	

Notes: distribution of the number of employees with fractions to the total number in parentheses in each of the respective bins.

COVID-19 performance to examine whether the recovery pace is specific to each industry regardless of covariates of each firm. In addition, Table 2 should be compared to the results from an exhaustive survey such as census data to check the biasedness of samples in TSR dataset. According to the survey policy of TSR, the survey targets are selected so that the firm size distribution matches that of the population. However, in this dataset, those firms in relation to food service industries are selected; therefore, it needs to check whether it underestimates or overestimates the fraction of each firm size.

3. Preparation for Visualization

The dataset includes supply chain information though it is not summarized on this research paper yet, as mentioned in the end of Section III. The information about supplier-customer linkage is described in directed lateral relations between pairs of firms. One of the challenges is too large sample size to visualize the entire network (19,325 firms and 46,324 linkages). Obviously, it is necessary to restructure it into more readable and informative form; for example, by aggregating related companies or group companies or dividing into prefectures.

V. Remaining Tasks

Concluding this note, let us summarize the remaining tasks to complete the descriptive analysis of TSR dataset. First, the sales values should be deflated by the regional price indices for the respective industries and prefectures to represent real values. Second, distribution of firm size should be compared to the results from an exhaustive survey such as census data to confirm the biasedness of samples in TSR dataset. Third, the covariates including network features should be disaggregated into the fractions based on performance to examine whether the recovery pace is specific to each industry regardless of covariates of each firm.

Finally, as a reminder, the study's goal is to compare the effect between two groups on location basis: one that provides exclusively local customers and the other that reaches consuming regions in metropolitan area. This is followed by the hypothesis that the network structure is asymmetric between different destinations of food and beverage products.

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