# Analysis of the Economic Impacts of a Natural Disaster Using Interregional Input-Output Tables for the Affected Region: A Case Study of the Tokai Flood of 2000 in Japan

**Yoshifumi Ishikawa [1], Nanan University**
**Toshitaka Katada [2], Gunma University**

## 1. Introduction

The impacts of natural disasters such as earthquakes and floods extend to other regions through interregional trade, and they economically impact not only the affected region but also other regions. Furthermore, the economic impacts of unscheduled events stem not only from damages and losses but also from recovery and reconstruction activities.

In Japan, the Tokai flood disaster struck Nagoya City and its surrounding municipalities in 2000. The disaster brought the factories in the directly damaged region to a standstill and had serious economic impacts. For instance, the closure of mills in the directly damaged region affected factories in other regions because the supply of essential parts was discontinued.

The impacts of the damage spread over time and economically affected the directly damaged and other regions in the short and long run. In other words, the impacts of disasters include not only the negative effects of damages and losses but also the positive economic effects due to recovery and reconstruction.

Many studies have conducted Regional Input-Output analysis to measure the economic impacts of disasters. Various studies assessing the direct and indirect damages inflicted by an event were conducted by using a previously prepared input-output table. However, due to the time lag, the analysis using these tables does not precisely evaluate the economic impacts. Therefore, it is necessary to investigate the dynamic process of the paths of the impacts and the recovery process following a disaster.

In this study, using an interregional input-output table for the directly affected region and the other regions, we propose a framework for estimating the economic impacts of actual natural disasters post-occurrence. Further, this study presents an ex-post analysis of the economic impacts of the Tokai flood that occurred in Japan in 2000. For this purpose, we constructed interregional input-output tables for both the affected region and the other regions.

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[1] Faculty of Policy Studies, Nanzan University, E-mail: yishi@ps.nanzan-u.ac.jp

[2] Development of Civil Engineering, Gunma University, E-mail: t-katada@ce.gunma-u.ac.jp

## 2. Method of Impact Analysis of Natural Disasters Using Interregional Input-output tables

In this study, we focus on the ex-post analysis after the event has occurred. Therefore, in order to assess the regional economic impacts due to unexpected events we need to gain an understanding of input-output structure for both before and after the occurrence of a natural disaster.

In Japan, we can use many regional input-output tables. The simplest method to measure the economic impacts of a natural disaster is probably the input-output modeling using these previously prepared regional input-output tables. However, the regional divisions in the prepared table do not correspond to the directly damaged regions. Further, most regional input-output tables are not interregional but intraregional. Therefore, an analysis performed using these tables would not take into consideration the impacts on the other regions. Moreover, we are unable to obtain a regional input-output table that is indicative of the economic situation during the stagnant period soon after the occurrence of the event. Factories would have switched vendors from those in the affected region to those in other regions. We attempted to gain an understanding of interregional input-output structure for before and after the occurrence of the event for the affected and other regions.

It is generally recognized that there are three approaches to constructing interregional tables: survey, non-survey, and hybrid. In order to accurately estimate economic impacts, the survey approach of constructing regional input-output tables was adopted in this study. The interregional trade patterns of an economy change before and after disaster. Since we aim to gauge the economic effects of a natural disaster after its occurrence, a detailed survey and considerable efforts are needed to gauge the interregional flow in terms of goods.

We consider three periods—the ordinary activity period, stagnant period after an event, and recovery period. Figure 1 shows the image of the time series variation in the economic activity of the affected region and the other regions.

In the wake of a natural disaster, many establishments switch business connections to other regions because of the stagnant activity of factories and severed lifelines in the affected regions. Bi-region interregional input-output tables for the ordinary activity period and the stagnant period after the occurrence of the event make it possible to analyze economic effects on each region.

Therefore, first, we capture the bi-region interregional input-output structure during the ordinary activity period by constructing an input-output table. Second, we calculate the interregional input coefficients for the ordinary activity, stagnant, and recovery periods. The comparison of these three interregional input coefficients indicates the change in business relationships.

The changes in the following three types of final demands due to natural disasters have economic impacts. Therefore, we need to estimate the economic impacts of these three types of final demand changes:

① Impacts of ordinary final demands of each regional economy during the stagnant period after the occurrence of an event. This impact is associated with a change in the interregional trade pattern

② Impacts of private sector demand for factory equipment and domestic articles in the affected region at the recovery stage

③ Impacts due to reconstruction demand in the affected region

Among these, the impacts of ordinary final demand are assessed based on the difference in production that is estimated using individual interregional input-output models for the ordinary activity and stagnant periods.

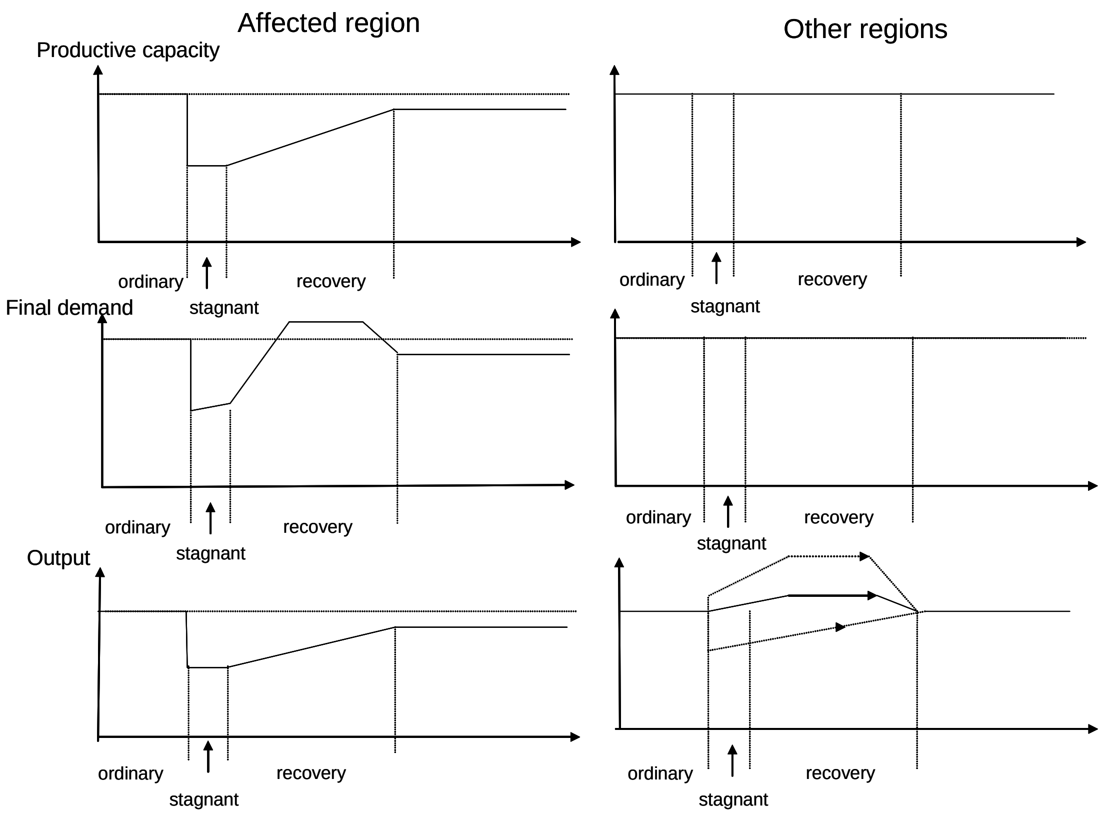



Figure.1 Image of Changes in Productive Capacity, Final Demand and Output over Time

In this study, we compiled Chenery-Moses type bi-region interregional input-output tables. Therefore, the analysis of economic impacts of the three types of final demand changes is assessed using the following formula:

$$X^h = \left[ I - \left( A^{gh} - \overline{M}^h A^* \right) \right]^{-1} \left[ F^{gh}{}_D - \overline{M}^h F_D^* + E^h \right]$$

$$M^h = \overline{M}^h \left( A^* X^h + F_D^* \right) \qquad (1)$$

$$A^* = \begin{pmatrix} A^{11} & & & & 0 \\ & \ddots & & & \\ & & A^{gh} & & \\ & & & \ddots & \\ 0 & & & & A^{nn} \end{pmatrix} \quad F^* = \begin{bmatrix} F_D^{11} \\ \vdots \\ F_D^{gh} \\ \vdots \\ F_D^{nn} \end{bmatrix}$$

$A^{gh}$ : matrix of input coefficient from region g to h

$X^h$ : total output vector of the region h

$F^{gh}{}_D$ : final demand vector of region g to h

$E^h$ : export vector for the region h

$M^h$ : import vector for the region h

$g,h$ : region g and region h

## 3. Ex-post Analysis of the Regional Economic Impacts of the 2000 Tokai Flood Disaster in Japan

(1) Outline of the Tokai flood disaster of 2000 in Japan

Aichi prefecture received record heavy rainfall from September 11 to 12, 2000. The autumn rain front, which had stagnated near Honshu, increased its force as a result of the influence of typhoon No.14, causing heavy rainfall from the Tokai region through to the Shikoku region. The Nagoya Meteorological Observatory recorded a total precipitation of 567 mm and a maximum hourly precipitation of 93 mm. At many of the monitored points in the two rivers, the water level exceeded the expected level and signs of the possible collapse of banks were observed in many places.

Eventually, the Shinkawa riverbank collapsed, and together with inundations that were already widespread within the sheltered areas, caused extended and deep inundations over approximately 6,000 houses. Many of these houses suffered over floor flooding, which caused high amounts of property loss.

It was reported that due to the damage caused by the Tokai heavy rain, the death toll was 10, recommendations were made for providing refuge facilities for about 580,000 people, the number of damaged houses in which the flooding reached above the floor level was 23,896, and the number of damaged houses in which the flooding remained below the floor level was 39,544.

The studied areas are the Shonai and Shin river basins, located approximately in the center of Japan, including the Nagoya city area—5th largest city in Japan with a population of about 2.5 million. These, two rivers that flow through densely populated areas and into the Pacific Ocean are typical city-type rivers in Japan.

The Tokai flood disaster is an example of typical urban flood hazards that have recently been increasing in Japan. This increase is due to the development of flood planes, dense land use, less water penetration due to the construction of pavements, and low capability of keeping water upstream in the mountains.

(2) The disaster affected region and sector classification

The region directly hit by the Tokai flood is shown in figure 2—the upper Shinkawa river basin and the northern part of Nagoya city and Kasugai city. The sector number of the input-output tables compiled in this study is 21.

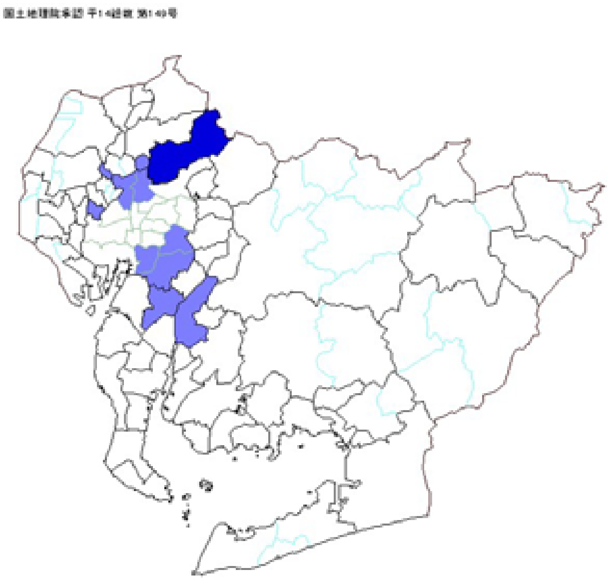


Figure.2　Affected Region

(The upper Shinkawa river basin, the southern part of Nagoya city　and Kasugai city)

(3) Industrial structure of the affected region

Production in the affected region —based on the interregional input-output table in the ordinal period— amounts to approximately 10 trillion 788 billion yen. Of this amount, the affected region accounts for approximately 15% of Aichi prefecture. Public administration and service and transport equipment have a high rate of production. Furthermore, textiles, machinery, pulp, paper, wooden products, and electronics account for a high share in Aichi prefecture.

Table 1. Outputs by Sector in the Affected Region

million yen

| | Affected Region | Affected Region／Aichi |
|---|---|---|
| Agriculture, forestry and fishery | 26,462 | 5% |
| Foods | 322,065 | 14% |
| Textile products | 380,333 | 39% |
| Pulp, paper and wooden products | 340,496 | 27% |
| Chemical products | 123,340 | 12% |
| Plastic products | 232,402 | 17% |
| Ceramic, stone and clay products | 73,416 | 8% |
| Iron and steel | 305,435 | 10% |
| Metal products | 228,318 | 18% |
| General machinery | 862,737 | 28% |
| Electrical machinery | 701,548 | 27% |
| Transportation equipment | 1,228,340 | 9% |
| Precision instruments | 14,599 | 7% |
| Miscellaneous manufacturing products | 304,139 | 16% |
| Construction | 909,988 | 20% |
| Electricity, gas and heat supply | 285,635 | 15% |
| Commerce | 725,229 | 10% |
| Financial and insuranceReal estate | 760,530 | 15% |
| TransportCommunication and broadcasting | 877,756 | 18% |
| Public administration and servies | 2,009,831 | 17% |
| Others | 75,366 | 15% |
| Total | 10,787,966 | 15% |

(4) Construction of input-output tables for the affected region and the other region

First, in order to construct input-output tables for the affected region, we carried out a questionnaire survey and acquired data on the regional export direction for the ordinary, stagnant, and post-recovery periods. Second, we prepared intraregional input-output tables for the affected region using certain regional economic statistics and the results of the questionnaire survey. Also, in order to compile intraregional input-output tables for the rest of Japan that was not affected, we used the input-output tables that were constructed as intraregional input-output tables and other input-output tables for the entire country. Further, bi-region interregional input-output tables were compiled using interregional trade coefficients that were estimated using intraregional input-output tables and the results of the questionnaire survey.

(5) Outline of the questionnaire survey

In order to analyze the characteristic features of damage to establishment, we performed a sample survey of selected establishments. This survey was designed to maximize the response rate to the 5000 mailed questionnaires. A total of 743 usable questionnaires were returned, indicating an overall response rate of approximately 15%. For each establishment surveyed, the respondents were essentially requested to estimate three aspects: (1) the value of total output; (2) the proportion of each sale and purchase made within and outside the affected region both before and after the disaster; (3) the damage caused to the establishment; and (4) the factors that affected the activity of the establishment.

(6) The characteristic features of the damage to establishments

1)The duration of stagnant and recovery periods

First, we investigated the duration of stagnant and recovery periods after the event. In the case of the upper Shinkawa river basin, which experienced significant damage, the duration of stagnant and recovery periods was 19 and 37 days, respectively. For the southern part of Nagoya, which had a short recovery period, the number of days until recovery was about 20.

The reason for the long delay until recovery commenced was that the establishments could not use inundated factory equipments, and thus spent a considerable amount of time in cleaning the equipment for use.

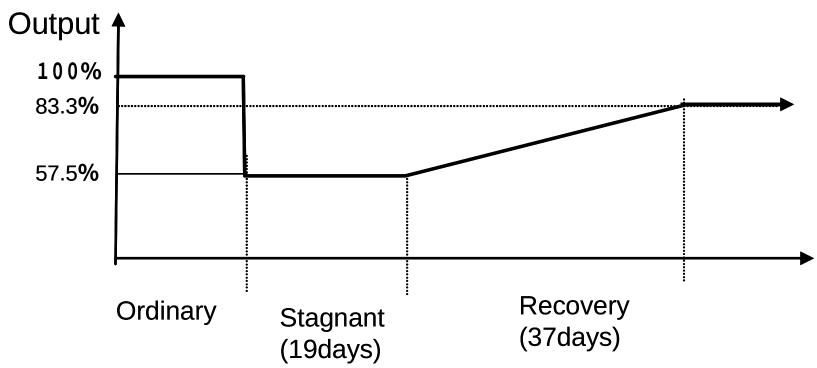
2)The difference in output before and after the event

Next, we observed the difference in output before and after the event. In the upper Shinkawa river basin, there was also a decline in the sales of many establishments. Further, the output during the stagnant period is approximately 58% of that during the ordinary period; the output after the recovery period is approximately 83% of that during the ordinary period.

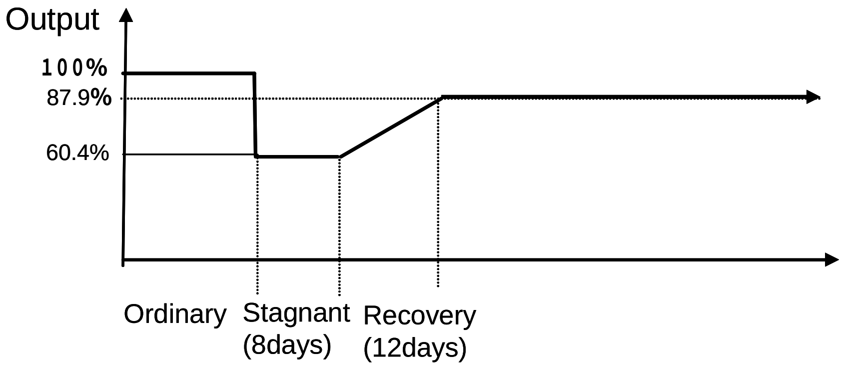
3)Changes in sales in the upper Shinkawa river basin, the southern part of Nagoya, and Kasugai city after the flood

Figure 3 shows the changes in the sales of the upper Shinkawa river basin, the southern part of Nagoya, and Kasugai city. As is evident from this figure, in the upper Sinkawa river basin, the disaster caused the most significant decrease in sales after the event because the region had experienced significant damage. In the southern part of Nagoya, the ratio of the affected establishments to the total number of establishments and the ratio of the affected houses to the total number of houses was the highest, after the upper Shinkawa river basin. The slump in the sales in this region is approximately the same as that in the upper Sinkawa river basin but the durations of the stagnant and recovery periods are shorter than those in the upper Shinkawa river basin.

(The Upper Shinkawa River Basin)




(The Southern Part of Nagoya City)



(Kasugai City)

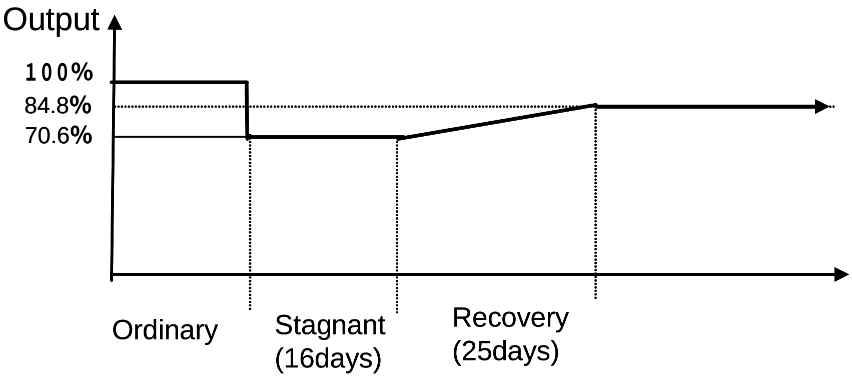



Figure.3 The Changes in Output in the Upper Shinkawa River Basin, the Southern Part of Nagoya City and Kasugai City

(7) Analysis of changes of interregional trade pattern

The ratio of regional imports of products and services from other regions for most sectors during the stagnant period is higher than that during the ordinary activity period. This indicates that several establishments in the affected region were unable to acquire materials and other products.Subsequently, the ratio of the input of materials and other products from other regions increased, thus decreasing the self sufficiency ratio in the affected region lowering the output from the affected region during the stagnant period. Table 2 lists the ratios of intermediate input of the affected region to that of other regions.

Table 2. The Changes of Self Sufficiency Ratio in the Affected Region

| | Ordinary | Stagnant | Recovery |
|---|---|---|---|
| Agriculture, forestry and fishery | - | -2.0% | 0.0% |
| Foods | - | -2.1% | -0.1% |
| Textile products | - | -2.2% | -1.2% |
| Pulp, paper and wooden products | - | 6.0% | 1.1% |
| Chemical products | - | -1.1% | 0.2% |
| Plastic products | - | -4.0% | 2.3% |
| Ceramic, stone and clay products | - | -1.5% | 0.2% |
| Iron and steel | - | -3.0% | -0.9% |
| Metal products | - | -3.4% | 0.7% |
| General machinery | - | -3.3% | -1.0% |
| Electrical machinery | - | -8.8% | -1.3% |
| Transportation equipment | - | -9.0% | 0.3% |
| Precision instruments | - | -3.8% | 0.0% |
| Miscellaneous manufacturing products | - | -0.6% | 0.7% |
| Construction | - | -2.5% | 2.0% |
| Electricity, gas and heat supply | - | -2.4% | -0.7% |
| Commerce | - | -3.0% | 0.5% |
| Financial and insuranceReal estate | - | -0.9% | 0.3% |
| TransportCommunication and broadcasting | - | -3.3% | 0.1% |
| Public administration and servies | - | -2.7% | -0.4% |
| Others | - | 1.2% | 0.6% |
| Average | - | -2.5% | 0.2% |

(8) Economic impacts of the 2000 Tokai flood disaster

1)Economic impacts of private consumption during the stagnant period

Private consumption during the stagnant period amounts to 224 billion yen for the affected region and 22 trillion yen for the rest of Japan. The final demand arises not only in the stagnant period but also after the event. The changes in interregional trade patterns differ in production in each region. In the affected region, the decrease in production amounts to approximately 7.4 billion yen.

Table 3. Economic Impacts of the 2000 Tokai Flood Disaster

million yen

| | Ordinary | Stagnant | Difference |
|---|---|---|---|
| Agriculture, forestry and fishery | 1,842 | 1,819 | -22 |
| Foods | 19,195 | 18,574 | -621 |
| Textile products | 19,837 | 19,308 | -529 |
| Pulp, paper and wooden products | 10,084 | 10,157 | 72 |
| Chemical products | 4,506 | 4,495 | -12 |
| Plastic products | 7,601 | 7,499 | -102 |
| Ceramic, stone and clay products | 889 | 867 | -22 |
| Iron and steel | 4,417 | 4,354 | -63 |
| Metal products | 3,663 | 3,625 | -39 |
| General machinery | 3,562 | 3,545 | -17 |
| Electrical machinery | 14,082 | 10,728 | -3,354 |
| Transportation equipment | 37,964 | 36,549 | -1,415 |
| Precision instruments | 164 | 164 | 0 |
| Miscellaneous manufacturing products | 12,903 | 12,651 | -252 |
| Construction | 2,582 | 2,562 | -20 |
| Electricity, gas and heat supply | 13,416 | 13,384 | -32 |
| Commerce | 37,412 | 37,272 | -141 |
| Financial and insuranceReal estate | 51,841 | 51,768 | -73 |
| TransportCommunication and broadcastin | 42,674 | 42,305 | -369 |
| Public administration and servies | 71,659 | 71,276 | -384 |
| Others | 2,856 | 2,814 | -42 |
| Total | 363,150 | 355,715 | -7,435 |

2) Economic impacts of emergency operation and equipment recovery on establishments

The cost of emergency operations is 35 billion yen, and the cost of equipment repair and replacement amounts to 413 billion yen. A major portion of the emergency operation cost is the cost for cleaning, etc. The final demand for emergency operation brings about the production inducement effect, which is valued at approximately 98 billion yen for Japan as a whole, inclusive of the affected region, and approximately 76 billion yen for the affected region only. The final demand for equipment repair and replacement brings about the production inducement effect, which is valued at approximately 882 billion yen for Japan as a whole, inclusive of the affected region, and approximately 565 billion yen for the affected region only.

3) Natural disaster relief expenditure

Natural disaster relief expenditure amounts to 8.4 billion yen, and the demand increase in the affected region results in the production inducement effect, which is valued at approximately 11 billion yen for the affected region and 15 billion yen for the entire country.

## 4. Conclusions

The results of this study are as follows:

1)We presented a framework for the analysis of economic impacts of the flood disaster. Our method can assess the economic impacts on the affected region and the rest of the country.

2) We assessed the economic impacts of the 2000 Tokai flood disaster using the method that is presented in this study. First, the industrial structure in the affected region and the changes in the interregional trade pattern are analyzed using bi-region interregional input-output tables. There are some industries that exhibit a decrease in the self-sufficiency ratio. Further, the three types of final demands bring about the production inducement effect in the affected region, which is 2–3% of the outputs of the entire country.

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