The Analytical Survey and Empirical Study of Economic Impact of the Natural Disasters: Input-Output framework

野　崎　道　哉※

要旨：

本論文の目的は予期せざる自然災害の経済的インパクトに関する分析的アプローチをサーベイし、中部圏地域間産業連関表を用いたケーススタディにより、東日本大震災における東北地域の経済被害が他地域に与えるインパクトを評価することである。

キーワード：自然災害、地域間産業連関表、経済被害

The Analytical Survey and Empirical Study of Economic Impact of the Natural Disasters: Input-Output framework

Michiya NOZAKI※

Abstract:

The aim of this paper is to survey the analytical approaches about the economic impacts on unscheduled natural disasters, and then to estimate the economic damages of the Great East Japan Earthquake on March 11, 2011 by means of Interregional Input-Output table for Chubu region and the Rest of Japan, as an example, the economic damage repercussion to other regions, especially for Chubu Region.

Key Words: Natural disasters, Interregional Input-Output table, Economic damages.

I. Introduction

The damages and losses from unscheduled events, such as earthquakes, flood, and other major natural disasters, have significant and intense impacts on a region's economy. The demand for the estimation of the economic impacts of recovery and reconstruction as well as of damages *per se* may become immediate after such events. Most analytical models of urban and regional economies, however, cannot confront these unscheduled and significant changes, since, at best, they assume incremental changes in system over time. The consequences associated with the event, moreover, will have many aspects including damages on demand and supply sides, for example, since the event may affect a wide range of regional activities in different ways. The difficulties with impact analysis of unscheduled events are, therefore, 1) disentangling the consequences stemming directly and indirectly from the event; 2) deriving possibly different assessments at each spatial level, and 3) evaluating the reaction of households which are poorly

※ Researcher, Chubu Region Institute for Social and Economic Research, Nittochi Nagoya BLD. 15F, 1-1 Sakae 2, Naka-ku, Nagoya, Aichi, Japan, 460-0008. E-mail: nozaki@criser.jp

understood (Okuyama, Sonis, and Hewings,1999, p.113).

In the standard Input-Output analysis given by Leontief, consumption demand is treated as an exogenous variable for household sectors as it is transferred to the processing sectors, and being regarded as an industry whose output is labor and whose input is consumption goods. This analysis considers various economic sectors as a series of inputs of raw materials in the form of services and outputs of semi-finished and finished goods that are also in the form of services. In other words, the output of one industry is the input of another.

Immediately following the tragic earthquake and tsunami on March 11 in the Tohoku region, we are still in the middle of this large effort to support the Japanese people through its government and the Japanese Joint Task Force, but some of us participating in the relief operations are already accumulating lessons learned and thinking about the future.

This catastrophe, which involved a magnitude-9.0 earthquake (and thousands of aftershocks), a massive tsunami, and problems with nuclear reactors, has shown more than ever that devastation knows no administrative borders. Hundreds of communities in almost ten prefectures have been affected. Many different layers of the bureaucracy--at the local, prefectural, and national level--are involved, and because of the time necessary to navigate and coordinate the various jurisdictions, quick responses are often not possible (The Daily Yomiuri, April 20, 2011).

In this present study, the impacts from this event have spilled over from the damaged region to other regions, and the impacts have influenced the national economy as a whole. Okuyama, Sonis and Hewings (1999) analyzed the Great Hanshin Earthquake by utilizing the interregional input-output table provided by Ministry of International Trade and Industry of Japan (1990). Miyazawa (1976) formulated a matrix multiplier that combines Leontief's propagation process with the Keynesian propagation process in the form of the Leontief inverse multiplied by the subjoined inverse matrix.

Moreover, Miyazawa's internal and external multipliers derived to analyze interregional linkages.

Okuyama, Sonis and Hewings (1999) presented their analytical methodology employing the Miyazawa's framework and some extensions.

The aim of this paper is to survey the analytical approaches about the economic impacts on unscheduled natural disasters, and then to estimate the economic damages of the Great East Japan Earthquake on March 11, 2011 by means of Interregional Input-Output table for Chubu region and the Rest of Japan, as an example, the economic damage repercussion to other regions, especially for Chubu Region.[1.]

II. Miyazawa's Analytical Framework: Internal and External Multipliers

According to the Miyazawa's analysis (1976), in the usual input-output analysis, the $n \times n$ inverse matrix shows the ultimate total effects of inter-industrial propagation, but it cannot show us any information on the disjointed effects. Separating the effects involves formulating partitioned matrix multipliers, thus showing the relationship among two or three regions that might be structurally different.

Miyazawa's study is an attempt to clarify the following two problems: the existence of an interdependent model of the goods-producing and service sectors, and an interregional repercussion model of the Japanese economy.

Let us follow the original derivations of Miyazawa's analytical tools theoretically. We divide n industries in the usual input-output table into two subgroups: designated P sector, which consists of l industries, and S sector, which consists of m industries.

$$\boldsymbol{A} = \begin{array}{c} \\ \\ \end{array}\begin{matrix} \boldsymbol{l} & \boldsymbol{m} & \\ \left(\begin{matrix} \boldsymbol{A_p} & \boldsymbol{A_{PI}} \\ \boldsymbol{A_{SI}} & \boldsymbol{A_S} \end{matrix}\right) & & \begin{matrix} \boldsymbol{l} \\ \boldsymbol{m} \end{matrix} \end{matrix} \qquad \boldsymbol{l} + \boldsymbol{m} = \boldsymbol{n} \qquad (1)$$

where $\boldsymbol{A_p}$ and $\boldsymbol{A_{PI}}$ are submatrices of coefficients showing the input of P sector's products in the P and S sectors, respectively, and $\boldsymbol{A_{SI}}$ and $\boldsymbol{A_S}$ are submatrices of coefficients showing the input of S sector's products in P and S sectors, respectively. $\boldsymbol{A_p}$ and $\boldsymbol{A_S}$ are squares submatrices having the order $l \times l$ and $m \times m$ respectively, and $\boldsymbol{A_{PI}}$ and $\boldsymbol{A_{SI}}$ are rectangular submatrices having the order $l \times m$ and $m \times l$ respectively.

Since the $n \times n$ Leontief inverse matrix

$$\boldsymbol{B}^* = (\boldsymbol{I} - \boldsymbol{A})^{-1} \qquad (2)$$

shows us only the total ultimate effects but not the disjointed interdependence of the above two activities, we must introduce some device consisting of partitioned matrix multiplier. To solve this problem, Miyazawa decomposed the elements of the Leontief inverse into three sides of the propagation aspects:

(a) internal propagation activities inside P sector's industries,

(b) internal propagation activities inside S sector's industries,

(c) intersectoral propagation activities between P and S sectors' industries.

For aspects (a) and (b), we will show the internal matrix multiplier of the P sector that has order ($l \times l$)

$$\boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{A_p})^{-1} \qquad (3)$$

and the internal matrix multiplier of the S sector that has order ($m \times m$):

$$\boldsymbol{T} = (\boldsymbol{I} - \boldsymbol{A_s})^{-1} \qquad (4)$$

Of course, each internal matrix multiplier does not operate interdependently under its own power, but is able to operate with the other sector's industrial activity.

The intersectoral propagation activities between the P and S sectors' industries can be written as the form of four rectangular *sub-matrix-multipliers*, which express aspect (c), that is,

$B_1 = A_{SI}B$: S-goods input in P sector induced by internal propagation in P sector's industries ($m \times l$).

$B_2 = BA_{PI}$: internal propagation in P sector's industries induced by P-goods input in S sector ($l \times m$).

$T_1 = A_{PI}T$: P-goods-input in S sector's induced by internal propagation in S sector's industries ($l \times m$).

$T_2 = TA_{S1}$: internal propagation in S sector's industries induced by S-goods input in P sector（$m \times l$）.

Such a repercussion process due to these induced effects naturally leads to the intersectoral multiplier between the P and S sectors. If we selected the coefficients of the induced effect on production（i.e., B_2 and T_2）as the base of this intersectoral multiplier, then it will take the form

$$\boldsymbol{K} = (\boldsymbol{I} - \boldsymbol{T_2 B_2})^{-1} \quad (5)$$

$$\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{B_2 T_2})^{-1} \quad (6)$$

We could define the matrix K as *the external matrix multiplier of the S sector*（$m \times m$）, and the matrix L as *the external matrix multiplier of the P sector*（$l \times l$）.

Thus, we have arrived at the fact that the total of the propagation effects in P and S sectors' industries are expected to take the values LB and KT, respectively, that is, ***"the internal matrix multiplier"*** pre-multiplied by ***"the external matrix multiplier."***

$$\boldsymbol{KT} = \boldsymbol{M}$$

$$\boldsymbol{LB} = \boldsymbol{N}$$

$$\boldsymbol{B}^* = (\boldsymbol{I} - \boldsymbol{A})^{-1} = \begin{bmatrix} \mathbf{B + B_2 M B_1} & \mathbf{B_2 M} \\ \mathbf{MB_1} & \mathbf{M} \end{bmatrix}$$

$$= \begin{bmatrix} \mathbf{N} & \mathbf{NT_1} \\ \mathbf{T_2 N} & \mathbf{T + T_2 N T_1} \end{bmatrix} \quad (7)$$

Finally, if X_p denotes the output vector of P sector's industries, X_s denotes the output vector of S sector's industries, and F_p and F_s denote the final demand vectors of P and S sectors, respectively, then the following equations is as follows:

$$\left\{ \begin{aligned} \boldsymbol{X_p} &= \boldsymbol{A_p X_p} + \boldsymbol{A_{p1} X_s} + \boldsymbol{F_p} \\ \boldsymbol{X_s} &= \boldsymbol{A_{s1} X_p} + \boldsymbol{A_s X_s} + \boldsymbol{Fs} \end{aligned} \right\} \quad (8)$$

Thus, the solution of this system is as follows:

$$\begin{bmatrix} \boldsymbol{X_p} \\ \boldsymbol{X_s} \end{bmatrix} = \begin{bmatrix} \mathbf{B + B_2 M B_1} & \mathbf{B_2 M} \\ \mathbf{MB_1} & \mathbf{M} \end{bmatrix} \begin{bmatrix} \boldsymbol{F_p} \\ \boldsymbol{F_s} \end{bmatrix}$$

$$= \begin{bmatrix} \mathbf{N} & \mathbf{NT_1} \\ \mathbf{T_2 N} & \mathbf{T + T_2 N T_1} \end{bmatrix} \begin{bmatrix} \boldsymbol{F_p} \\ \boldsymbol{F_s} \end{bmatrix} \quad (9)$$

Another alternative expression of the Leontief inverse by the partitioned matrix multipliers is as follows:

$$\boldsymbol{B}^* = (\boldsymbol{I} - \boldsymbol{A})^{-1} = \begin{bmatrix} \mathbf{LB} & \mathbf{LB_2 T} \\ \mathbf{KT_2 B} & \mathbf{KT} \end{bmatrix} = \begin{bmatrix} \mathbf{LB} & \mathbf{LBT_1} \\ \mathbf{KTB_1} & \mathbf{KT} \end{bmatrix} \quad (10)$$

The identity between this expression and equation（8）can be readily proved.[2.]

III. The Analytical Method of the Economic Impacts on Natural Disasters

Okuyama, Sonis, and Hewings (1999) stated that Miyazawa's concept of the interrelational income multiplier was designed to analyze the structure of income distribution by endogenizing consumption demands in the standard Leontief model and included that the income formation process has clear advantages for linking production with consumption processes (Okuyama, Sonis, and Hewings, 1999, p.115).

Miyazawa considered the following system:

$$\left(\frac{\boldsymbol{X}}{\boldsymbol{Y}}\right) = \left(\frac{\boldsymbol{A} \quad | \quad \boldsymbol{C}}{\boldsymbol{V} \quad | \quad \boldsymbol{O}}\right)\left(\frac{\boldsymbol{X}}{\boldsymbol{Y}}\right) + \left(\frac{\boldsymbol{f}}{\boldsymbol{g}}\right) \tag{11}$$

where X is a vector coefficient output, Y is a vector of total income for some r-fold division of income groups, A is a block matrix of direct input coefficients, V is a matrix of value-added ratios, f is a vector of final demands except household consumption, and g is a vector of exogenous income for r-fold income groups. Solving this system yields

$$\left(\frac{\boldsymbol{X}}{\boldsymbol{Y}}\right) = \left(\frac{\boldsymbol{B}(\boldsymbol{I} + \boldsymbol{CKVB}) \quad |\boldsymbol{BCK}}{\boldsymbol{KVB} \quad\quad | \quad \boldsymbol{K}}\right)\left(\frac{\boldsymbol{f}}{\boldsymbol{g}}\right) \tag{12}$$

where

$\boldsymbol{B} = (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix,

$\boldsymbol{BC}$ is a matrix of production induced by endogenous consumption,

$\boldsymbol{VB}$ is a matrix of endogenous income earned from production,

$\boldsymbol{L} = \boldsymbol{VBC}$ is a matrix of expenditures from endogenous income, and

$\mathbf{K} = (\mathbf{I} - \mathbf{L})^{-1}$ is a matrix of the Miyazawa interrelational income multipliers.

Sonis and Hewings (1993) extended this framework using the following perspective:

$$\left(\frac{\boldsymbol{B}(\boldsymbol{I} + \boldsymbol{CKVB}) \quad |\boldsymbol{BCK}}{\boldsymbol{KVB} \quad\quad | \quad \boldsymbol{K}}\right)\left(\frac{\boldsymbol{I} \ |\boldsymbol{O}}{\boldsymbol{V} \ |\boldsymbol{I}}\right)\left(\frac{\Delta \ |\boldsymbol{O}}{\boldsymbol{O} \ |\boldsymbol{I}}\right)\left(\frac{\boldsymbol{I} \ |\boldsymbol{C}}{\boldsymbol{O} \ |\boldsymbol{I}}\right) = \left(\frac{\Delta \quad |\Delta\boldsymbol{C}}{\boldsymbol{V}\Delta \quad |\boldsymbol{I} + \boldsymbol{V}\Delta\boldsymbol{C}}\right) \tag{13}$$

where

$$\Delta = (\mathbf{I} - \mathbf{A} - \mathbf{CV})^{-1} = \mathbf{B}(\mathbf{I} + \mathbf{CKVB})$$

is an enlarged Leontief inverse. From (12) and (13), we get the following Miyazawa interrelational multiplier matrix:

$$\mathbf{K} = \mathbf{I} + \mathbf{V}\Delta\mathbf{C} \tag{14}$$

The changes in direct input , consumption , and value added , of the system are presented by the following matrix:

$$\boldsymbol{E} = \left(\frac{\mathbf{E_A} \ |\mathbf{E_C}}{\mathbf{E_V} \ | \ \boldsymbol{O}}\right) \tag{15}$$

Then, after the calamity, equation (13) will become

$$\left(\frac{\boldsymbol{I} \quad | \ \boldsymbol{O}}{\mathbf{V}+\mathbf{E_V} \ | \quad \boldsymbol{I}}\right)\left(\frac{\Delta(\mathbf{E}) \quad | \ \mathbf{O}}{\boldsymbol{O} \quad | \ \boldsymbol{I}}\right)\left(\frac{\boldsymbol{I} \quad | \ \boldsymbol{C}+\mathbf{E_C}}{\boldsymbol{O} \ | \quad \boldsymbol{I}}\right)=$$

$$=\left(\frac{\Delta(\mathbf{E}) \quad | \ \Delta(\mathbf{E})[\boldsymbol{C}+\mathbf{E_C}]}{[\mathbf{V}+\mathbf{E_V}]\,\Delta(\mathbf{E}) \quad | \ \boldsymbol{I}+[\mathbf{V}+\mathbf{E_V}]\Delta(\mathbf{E})[\boldsymbol{C}+\mathbf{E_C}]}\right) \qquad (16)$$

where

$$\mathbf{B(E)} = (\mathbf{I}-\mathbf{A}-\mathbf{E_A})^{-1}$$
$$\mathbf{K(E)} = (\mathbf{I}-[\mathbf{V}+\mathbf{E_V}]\mathbf{B(E)}[\boldsymbol{C}+\mathbf{E_C}])^{-1}$$
$$\widetilde{\boldsymbol{E}} = \mathbf{E_A}+\mathbf{CE_V}+\mathbf{E_C E_V}$$

$$\begin{aligned}\Delta(\mathbf{E}) &= (\mathbf{I}-[\mathbf{A}+\mathbf{E_A}]-[\boldsymbol{C}+\mathbf{E_C}][\mathbf{V}+\mathbf{E_V}])^{-1}\\ &= (\mathbf{I}-\mathbf{A}-\mathbf{CV}-\widetilde{\boldsymbol{E}})^{-1}\\ &= ([\mathbf{I}-\mathbf{A}-\mathbf{CV}][\mathbf{I}-\Delta\widetilde{\boldsymbol{E}}])^{-1}\\ &= (\mathbf{I}-\Delta\widetilde{\boldsymbol{E}})^{-1}\Delta \end{aligned} \qquad (17)$$

Consider the changes in the final demand resulting from the event df of the gross output dX and of the total income dY. If g, the exogenous income in (12), can be ignored, and by applying (16), the change in gross output is

$$\begin{aligned}\boldsymbol{dX} &= \Delta(\boldsymbol{E})[\boldsymbol{f}+\boldsymbol{df}]-\Delta\boldsymbol{f} =\\ &= [\Delta(\boldsymbol{E})-\Delta]\boldsymbol{f}+\Delta(\boldsymbol{E})\boldsymbol{df}\end{aligned} \qquad (18)$$

$$\begin{aligned}\boldsymbol{dY} &= [\mathbf{V}+\mathbf{E_V}]\Delta(\boldsymbol{E})[\boldsymbol{f}+\boldsymbol{df}]-\mathbf{V}\Delta\boldsymbol{f} =\\ &= \boldsymbol{V}[\Delta(\boldsymbol{E})-\Delta]\boldsymbol{f}+\mathbf{E_V}\Delta(\boldsymbol{E})\boldsymbol{f}+\boldsymbol{V}\Delta(\boldsymbol{E})\boldsymbol{df}+\mathbf{E_V}\Delta(\boldsymbol{E})\boldsymbol{df}\end{aligned} \qquad (19)$$

where $\boldsymbol{V}[\Delta(\boldsymbol{E})-\Delta]$ is the effect from the changes in the enlarged Leontief inverse, $\mathbf{E_V}\Delta(\boldsymbol{E})\boldsymbol{f}$ is the effect from the changes in value added, $\boldsymbol{V}\Delta(\boldsymbol{E})\boldsymbol{df}$ is the mixed effect from the value added and final demand changes.

Miyazawa's internal and external multipliers were derived to partition the standard Leontief inverse into the internal propagation activities and external propagation activities, respectively, for some strategic industries or regions.

Consider a two-region system represented by the following block structure:

$$\boldsymbol{A}=\left(\frac{\mathbf{A_{11}} \ |\boldsymbol{A_{12}}}{\boldsymbol{A_{21}} \ |\, \boldsymbol{A_{22}}}\right) \qquad (20)$$

where A_{11} and A_{22} are intraregional matrices of direct inputs within the first and second region, and A_{12} and A_{21} are the interregional matrices representing direct input connections between regions 1 and 2. The standard Leontief inverse will have the following form:

$$\boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{A})^{-1} = \begin{pmatrix} \boldsymbol{B_{11}} & | \boldsymbol{B_{12}} \\ \hline \boldsymbol{B_{21}} & | \boldsymbol{B_{22}} \end{pmatrix} \tag{21}$$

Miyazawa claimed that this standard Leontief inverse displays only the total ultimate effects of the economy, and introduced the decomposed elements of the Leontief inverse in order to separate the components of the two regions as follows:

$$\boldsymbol{B_1} = (\boldsymbol{I} - \boldsymbol{A_{11}})^{-1}; \boldsymbol{B_2} = (\boldsymbol{I} - \boldsymbol{A_{22}})^{-1} \tag{22}$$

where B_1 and B_2 are the Miyazawa internal matrix multiplier for regions 1 and 2, respectively. With these internal matrix multipliers, interregional propagation activities will be shown as four rectangular sub-matrix multipliers as follows:

$$\boldsymbol{P_1} = \boldsymbol{A_{21}B_1}; \boldsymbol{P_2} = \boldsymbol{B_1A_{12}} \tag{23}$$

$$\boldsymbol{S_1} = \boldsymbol{A_{21}B_2}; \boldsymbol{S_2} = \boldsymbol{A_{12}B_2} \tag{24}$$

where P_1 is the matrix multiplier indicating input from region 1 to region 2 induced by internal propagation in region 1; P_2 is the matrix multiplier for internal propagation in region 1 to region 2 induced by internal propagation in region 2; S_1 is the matrix multiplier of input from region 1 to region 2 induced by internal propagation in region 2; and S_2 is the matrix multiplier for internal propagation in region 2 induced by transactions moving from region 2 to region 1.

From these sub-matrix multipliers, the external matrix multipliers for the regions can be derived as follows[3]:

$$\begin{aligned} \Delta_{11} &= (\boldsymbol{I} - \boldsymbol{P_2S_2})^{-1} = (\boldsymbol{I} - \boldsymbol{B_1A_{12}} \quad \boldsymbol{B_2A_{21}} \quad)^{-1} \\ \Delta_{22} &= (\boldsymbol{I} - \boldsymbol{S_2P_2})^{-1} = (\boldsymbol{I} - \boldsymbol{B_2A_{21}} \quad \boldsymbol{B_1A_{12}} \quad)^{-1} \end{aligned} \tag{25}$$

$$(\boldsymbol{I} - \boldsymbol{A})^{-1} = \begin{pmatrix} \Delta_{11} & | \boldsymbol{O} \\ \hline \boldsymbol{O} & | \Delta_{22} \end{pmatrix} \begin{pmatrix} \boldsymbol{I} & | \boldsymbol{B_1A_{12}} \\ \hline \boldsymbol{B_2A_{21}} & | \boldsymbol{I} \end{pmatrix} \begin{pmatrix} \boldsymbol{B_1} & | \boldsymbol{O} \\ \hline \boldsymbol{O} & | \boldsymbol{B_2} \end{pmatrix} \tag{26}$$

IV. Modeling the Regional Economic Loss of Natural Disasters

The ability to measure vulnerability represents a key step towards effective risk reduction and the promotion of a culture of disaster resilience. Coping capacity represents a combination of all strengths and resources available that can reduce the level of risk, or the effects of a disaster.

In a chaotic situation, following the outbreak of a calamity, the economic behavioral changes require a special treatment. Following this, the theoretical aspects of natural hazards needs to be reviewed and analyzed. The value of information is evaluated thereafter. Finally, the conclusions, including future research directions in the field of economics of natural hazards, are arrived at (Boscoianu, 2008, pp.174–179).

According to the article of Okuyama, Sonis, and Hewings (1999), input-output analysis has been employed in many studies to evaluate the economic impacts of unexpected events. Although it provides useful information in terms of consequences in some specific aspects, that is, effects from the decreased final demand by damages, and/or from the increase of reconstruction demand, many of these studies have failed to take account of the interregional effects and the relationship between output production and income formation process in their analyses.[4.]

Yamano, Kajitani, and Shumuta (2004) examine the economic impacts of natural disasters by integrating district-level economic data and Japanese interregional input-output model. Their model deals with the direct and indirect output losses due to disruptions of electricity, damages of transport network, and decrease in economic demand. They compiled the 500 m district-level output and employment data to analyze the precise output losses. Numerical example of Hyogo prefecture shows that the indirect economic loss is much larger than the direct output loss in most districts. The damages on material manufacturers and business centers induce a greater economic loss to the suburban areas.

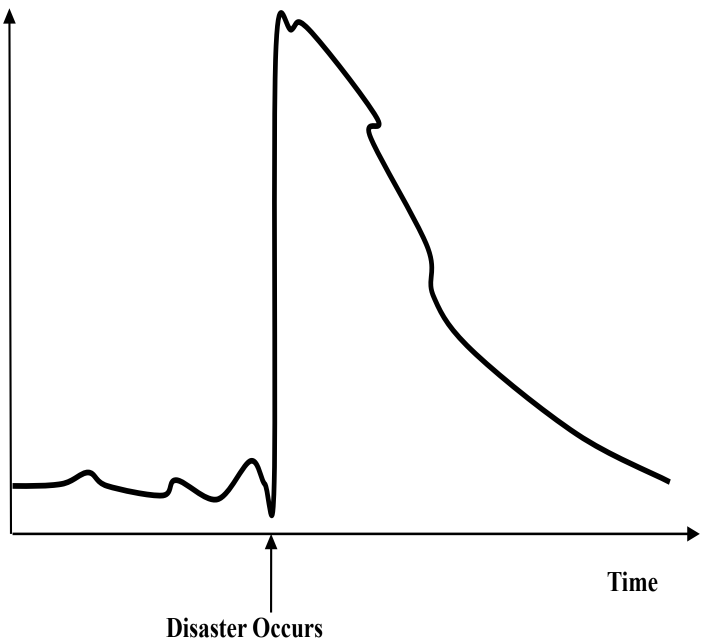
Okuyama (2003) observes that the concepts of risk and uncertainty have been used in disaster related literature, but they are used in an ambiguous concept. Knight (1921) had made the distinction between risk and uncertainty, while von Neumann and Morgenstern (1944) had advocated one of the ‘risk’ schools (Okuyama, 2003: 10). Savage (1954) had advocated expected utility function with subjective probabilities theory.

Davidson (1991) reconsidered the Knightian uncertainty as the only relevant form of randomness in economics. From this Post Keynesian perspectives, decision makers either avoid choosing between “real” alternatives because they haven’t got a clue about the future, or follow their “animal spirits” for positive investment action in a “ damn the torpedoes, full speed ahead” approach (Davidson, 1991, p.130).

However, the Knightian risk is only possible in very controlled scenarios with very clear alternatives (Boscoianu, 2008, p.176).

A major problem with the Knightian definition of “uncertainty” is that the degree and extent of “uncertainty” after a disaster are not fixed—as emergency response and recovery starts (Okuyama, 2003, p.11; Okuyama and Chang, 2004).

Figure 1: Degree of uncertainty in and after the disaster Uncertainty



Source: Figure 1, cited in Okuyama, 2003, p.12

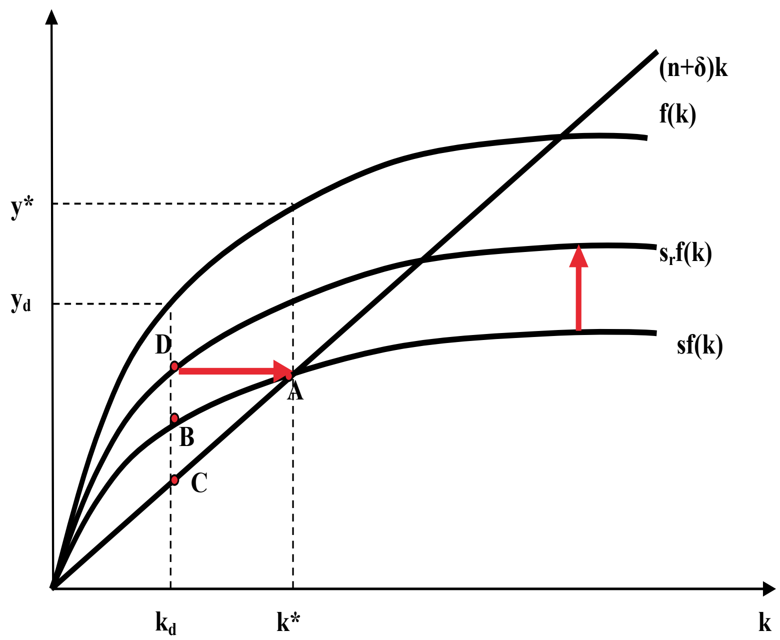
To simplify, let us consider the basic neo-classical model of the Solow-Swan (1956) type. We can denote the production function without technological progress, in intensive form

$y = f(k)$. Let us denote saving rate s, capital depreciation δ , and population growth rate n as constant variables. The change in per capita capital stock over time is as follows:

$$k = dk/dt = s - f(k) - (n + \delta)k \quad (28)$$

Let us consider a steady state economy and a catastrophic shock without casualties in labor population. The per capita capital level decreases from the steady state level y^* to the damaged level y_d. The economy goes out of its steady state and yields a space (**B** − **C**) for the recovery. Because of the extra output allocated towards the reconstruction of damaged capital stocks, the recovery saving rate s_r, may accelerate the speed of recovery (**D** − **C** > **B** − **C**). As the economy recovers, the recovery saving rate returns to the normal rate *S* (**D** goes to **A**).

Figure 2: Solow-Swan-type model and the dynamics of recovery after the disaster



Source: Figure 2, Okuyama 2003: p.15

The dynamics of recovery from a disaster can be expressed by introducing the growth rate k (**B** − **C**), which becomes zero due to the intersection to two lines,

$$sf(k)/k = (n + \delta) \quad (29)$$

V. Input-Output Analysis of the Great Earthquake[5]

Then we have to limit the analysis of decreasing production.

Let us denote the direct damage ratio d $(1 > d > 0)$. Now, let us denote the remaining production ratio λ, $\lambda = 1 - d$.

The definition of "forward linkage effect" is the industrial activities can affect the production of industrial goods which have been used as an intermediate product of that industry. The definition of, and on other hand, The definition of "backward linkage effect" is to affect the production activities of another industry which product demand variation of some of the industry is supplying intermediate goods to the industry.

In this paper, we will analyze these two effects by two different models.

About the Forward Linkage effect, we will analyze using the Ghosh inverse matrix inter-regional spread of the process-based value-added amount of damage[6]). When we analyze the economic damage of the Great East Japan Earthquake, we are to be exogenous the damage of the production of the Tohoku region, we analyze the forward linkage effects to other regions in Japan.

$\boldsymbol{X}_1$ is a column vector of the output of the Tohoku region, $\boldsymbol{X}_2$ is a column vector of the production out of the Tohoku region. $\boldsymbol{G}'_{ij}$ is the transposed matrix of output coefficients of intermediate goods that are sold from region i to region j ', $\boldsymbol{V}_1$ is a column vector of the gross value added of the Tohoku region, $\boldsymbol{V}_2$ is a column vector of the gross value added other than the Tohoku region.

$$\begin{bmatrix} \boldsymbol{X}_1 \\ \boldsymbol{X}_2 \end{bmatrix} = \begin{bmatrix} \boldsymbol{G}'_{11} & \boldsymbol{G}'_{21} \\ \boldsymbol{G}'_{12} & \boldsymbol{G}'_{22} \end{bmatrix} \begin{bmatrix} \boldsymbol{X}_1 \\ \boldsymbol{X}_2 \end{bmatrix} + \begin{bmatrix} \boldsymbol{V}_1 \\ \boldsymbol{V}_2 \end{bmatrix} \tag{30}$$

$$\boldsymbol{X}_1 = \boldsymbol{G}'_{11}\boldsymbol{X}_1 + \boldsymbol{G}'_{21}\boldsymbol{X}_2 + \boldsymbol{V}_1$$

$$\boldsymbol{X}_2 = \boldsymbol{G}'_{12}\boldsymbol{X}_1 + \boldsymbol{G}'_{22}\boldsymbol{X}_2 + \boldsymbol{V}_2$$

$$\boldsymbol{X}_2 = \left(\boldsymbol{I} - \boldsymbol{G}'_{22}\right)^{-1}\left(\boldsymbol{G}'_{12}\boldsymbol{X}_1 + \boldsymbol{V}_2\right) \tag{31}$$

$$\Delta\boldsymbol{X}_1 \rightarrow \Delta\boldsymbol{X}_2$$

$$\Delta\boldsymbol{X}_2 = \left(\boldsymbol{I} - \boldsymbol{G}'_{22}\right)^{-1}\boldsymbol{G}'_{12}\Delta\boldsymbol{X}_1 \tag{32}$$

Where $\mathbf{G}_{ij} = \widehat{\mathbf{x}_{ij}}^{-1}\boldsymbol{X}_{ij} = \widehat{\mathbf{x}_{ij}}^{-1}\mathbf{A}_{ij}\widehat{\mathbf{x}_{ij}}.$

We will analyze the backward linkage as how it will propagate the damaged production loss between nationwide using Leontief inverse. When we analyze the economic damage of the Great East Japan Earthquake, we are to be exogenous the damage of the production of the Tohoku region, we analyze the backward linkage effects to other regions in Japan.

$\boldsymbol{X}_1$ is a column vector of the output of the Tohoku region, $\boldsymbol{X}_2$ is a column vector of the production out of the Tohoku region. $\boldsymbol{A}_{ij}$ is the input coefficients of intermediate goods that are sold from region i to region j, $\boldsymbol{F}_1$ is a column vector of the final demand of the Tohoku region, and $\boldsymbol{F}_2$ is a column vector of the final demand other than the Tohoku region.

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} F_1 \\ F_2 \end{bmatrix} \qquad (33)$$

$$X_1 = A_{11}X_1 + A_{12}X_2 + F_1$$
$$X_2 = A_{21}X_1 + A_{22}X_2 + F_2$$

$$X_2 = (I - A_{22})^{-1}(A_{21}X_1 + F_2) \qquad (34)$$
$$\Delta X_1 \rightarrow \Delta X_2$$

$$\Delta X_2 = (I - A_{22})^{-1} A_{21} \Delta X_1 \qquad (35)$$

Where $\mathbf{A}_{ij} = \widehat{\mathbf{x}_{ij}} \mathbf{G}_{ij} \widehat{\mathbf{x}_{ij}}^{-1}$.

Ⅵ. Empirical Studies on the economic impact of the Great East Japan Earthquake

Calculating the share of the total number of employees in the stricken area counties, which output value of each industry in each prefecture (GRP in fiscal year 2008) calculated, it was estimated as the scale of damage.

Cabinet Office Government of Japan (2011) estimates the damaged stock of the Great east Japan Earthquake as table 1.

Table 1. The damaged stock of the Great east Japan Earthquake

Contents	Damaged Stock (Unit: trillion yen)
Construction (Houses, residential lands, Offices, Machines)	10.4
Lifelines (Water, Gas, Electricity, Communications and Broadcasting facilities)	1.3
Infrastructure (Rivers, Roads, Ports, Sewers, Airports, etc.)	2.2
Agriculture and Fishery Industrial Facilities	1.9
Other Facilities	1.1
Total	16.9

Source: Cabinet Office Government of Japan, (2011)

The direct damaged stock is 16.9 trillion yen, which contends with constructions, lifelines, and infrastructure2).

And we have also estimates of the direct economic damage of capital stock of the Great east Japan Earthquake by estimating of Dr. Masakatsu Suzuki , a researcher of CRISER, as Table 2.

Table 2. The damaged stock of the Great east Japan Earthquake（CRISER）

Unit: million yen, %

	Housing Stock	Private Capital Stock	Social Capital Stock	Total	Direct Economic Damage of Capital Stock	Direct Damage Rate of Capital Stock
Iwate	696,380	9,063,333	10,742,624	20,502,337	3,690,421	18.0%
Miyagi	2,074,190	17,590,221	13,480,209	33,144,620	6,628,924	20.0%
Fukushima	1,140,970	20,758,217	13,673,343	35,572,530	3,912,978	11.0%
Ibaraki	385,750	29,060,461	13,868,985	43,315,196	2,165,760	5.0%
Total	3,600,910	76,472,233	51,765,161	132,534,684	16,398,083	12.4%

Source: original capital stock data compiled by Dr. Suzuki.

An Interregional Input-Output Table is composed of Toyama Prefecture, Ishikawa Prefecture, Fukui Prefecture, Nagano Prefecture, Gifu Prefecture, Shizuoka Prefecture, Aichi Prefecture, Mie Prefecture, Shiga Prefecture and the Rest of Japan. Other , by using Interregional Input-Output Table in Japan（nine regions with National wide）. An extended Interregional Input-Output Table be decomposed into eight regions Hokkaido, Tohoku, Kanto, Kinki, China, Shikoku, Kyushu and Okinawa, the central 17 inter-industry relations table between regions （the "inter-regional extension table"）to reconfigure as other prefecture.

Please see Figure 3. This is the table of an extended Interregional I-O Table for explanation.

Figure 3. An extended Interregional I-O Table for 17 regions

Souces of Interregional trade coefficients	Appling to trade coefficients	
Interregional Input-Output Table for Chubu Region	C	use directly
Interregional Input-Output Table（9 blocks in Japan）	J	use directly
	Kan	on behalf of average value of Kanto region
	Chu	on behalf of average value of Chubu region
	Kin	on behalf of average value of Kinki region

	北海道	東北	関東	富山	石川	福井	長野	岐阜	静岡	愛知	三重	滋賀	近畿	中国	四国	九州	沖縄
北海道	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J
東北	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J
関東	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J
富山	chu	chu	chu	C	C	C	C	C	C	C	C	C	chu	chu	chu	chu	chu
石川	chu	chu	chu	C	C	C	C	C	C	C	C	C	chu	chu	chu	chu	chu
福井	kin	kin	kin	C	C	C	C	C	C	C	C	C	kin	kin	kin	kin	kin
長野	kan	kan	kan	C	C	C	C	C	C	C	C	C	kan	kan	kan	kan	kan
岐阜	chu	chu	chu	C	C	C	C	C	C	C	C	C	chu	chu	chu	chu	chu
静岡	kan	kan	kan	C	C	C	C	C	C	C	C	C	kan	kan	kan	kan	kan
愛知	chu	chu	chu	C	C	C	C	C	C	C	C	C	chu	chu	chu	chu	chu
三重	chu	chu	chu	C	C	C	C	C	C	C	C	C	chu	chu	chu	chu	chu
滋賀	kin	kin	kin	C	C	C	C	C	C	C	C	C	kin	kin	kin	kin	kin
近畿	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J
中国	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J
四国	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J
九州	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J
沖縄	J	J	J	chu	chu	kin	kan	chu	kan	chu	chu	kin	J	J	J	J	J

Source: Nozaki, Ihara and Thitipongtrakul（2011）, p. 30, Figure 1.

On the four prefectures of Iwate Prefecture Miyagi, Fukushima, Ibaraki were greater scale of damage caused by earthquake and tsunami, to estimate the income loss affected areas of the municipality affected by the following method. Upon estimation, for the sake of simplicity, let us assume that damage of the earthquake that occurred in all the Tohoku region to do the calculations money transferred to the amount of damage in Ibaraki Prefecture.

① We estimate the number of employees by industry, municipal disaster, the ratio of employees in the economic census (small classification by prefecture). For selection of the municipality affected, out of the "specific local governments affected", was selected as reference information published municipal newspaper, suffered earthquake damage, the tsunami.

② The total production by citizens and industry by prefecture of economic calculation by multiplying the rate of employees and the rate of directly damage ratio stock on each prefecture to calculate the loss of income by industry.

Using the extended "Interregional Input-Output table", a direct impact on economic losses in the Tohoku make an estimate of indirect damage. Here, the affected municipalities have been assumed to identify the municipalities that are specified in the affected areas, production activities in the region has been stopped for one year.

The total loss of income of the damaged regions is about 1.097 trillion yen.

Table 4. The Loss of Income of the damaged regions

unit: million yen

	Iwate	Miyagi	Fukushima	Ibaraki	Total
Agriculture, Forestry, and Fisheries	1,810	10,003	5,207	645	17,666
mining	341	121	151	90	703
Coal mining, crude petroleum and natural gas	0	2	0	0	2
Food and Beverage	11,011	31,323	7,372	2,149	51,900
Textile products	1	10	7	1	19
Wearing apparel and other textile products	41	102	33	10	187
Timber and wooden products,Furniture and fixtures	1,924	3,923	1,877	291	8,014
Pulp, paper, paperboard, building paper	214	9,459	1,455	401	11,529
Printing, plate making and book binding	315	6,977	752	270	8,314
Chemical fertilizer	163	518	6,215	1,395	8,291
Synthetic resins	99	143	132	257	631
Final chemical products, n.e.c.	13	1,004	2,390	118	3,524
Petroleum refinery products and Coal products	28	5,773	13	19	5,834
Plastic products	851	3,407	1,147	577	5,982
ceramic, stone and clay products	590	1,827	1,960	669	5,045
iron or steel products	899	2,391	797	7,276	11,363
Non-ferrous metal products	0	1,387	1,213	6,002	8,603
Metal products	772	4,857	3,221	1,264	10,115
general machines	2,769	4,187	3,960	12,143	23,058
Machinery for office and service industry	0	244	492	374	1,110
electronic components	422	1,398	429	3,725	5,974
Other electronic components	0	966	103	130	1,200
Household electronics equipment	0	99	179	2,948	3,226
Communication machinery and devices	208	1,517	7,844	1,874	11,442
Semiconductor devices and Integrated circuits	0	1,789	550	3,745	6,084
Motor vehicle	13	847	3,370	798	5,028
Other transportation equipment and repair of transportation equipment	4,406	3	342	72	4,823
Precision instruments	37	937	918	620	2,512
Miscellaneous manufacturing products	402	1,872	967	217	3,458
construction	10,281	35,844	12,001	4,567	62,694
Electricity	2,075	6,840	33,497	3,682	46,094
Gas and heat supply	372	3,922	1,523	279	6,096
Water supply and Waste management service	1,861	12,964	7,069	1,114	23,008
Commerce	13,076	101,127	15,664	6,644	136,511
Finance and insurance	4,906	17,504	7,000	2,550	31,961
Real estate agencies and rental services	17,535	93,083	18,121	9,741	138,480
Transport	5,734	67,691	8,581	5,118	87,124
Information services	107	4,700	809	3,536	9,153
Other Information services	993	10,890	1,147	574	13,604
Public administration	13,280	47,437	17,249	4,769	82,735
Education and Research	174	3,354	859	2,536	6,924
Other Public Services	5,035	55,763	14,821	5,659	81,278
Goods rental and leasing services	733	4,473	778	208	6,192
Other business services	2,715	11,268	5,865	2,295	22,143
Personal services	20,515	66m883	17,047	9,733	114,177
Activities not elsewhere classified	705	1,427	395	194	2,721
Total	127,445	643,146	215,647	111,344	1,097,581

Forward linkage occurs when the products of one industry is used as the raw material of another industry. It can involve an industry in primary production linking with an industry in secondary production. Forward linkage is when one industry is producing the raw material for another industry.

In Table 5, Damaged output by the Great East Japan Earthquake of the forward linkage is about 1.497 trillion yen.

Table 5 Damaged Output by the Great East Japan Earthquake（Forward Linkage）

unit: million yen

Damaged Output (Forward Linkage)	Hokkaido	Tohoku	Kanto	Toyama	Ishikawa	Fukui	Nagano	Gifu	Shizuoka	Aichi	Mie	Shiga	Chubu Region	Kinki	Chugoku	Shikoku	Kyushu	Okinawa	Total
Agriculture, Forestry, and Fisheries	1,361	17,666	1,922	32	38	20	271	45	290	207	84	39	1,027	245	217	276	740	36	23,488
mining	31	703	92	5	3	1	26	3	12	7	6	2	65	17	13	10	24	3	955
Coal mining, crude petroleum and natural gas	12	2	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
Food and Beverage	3,097	51,900	13,114	109	128	76	790	289	2,682	1,611	409	223	6,317	4,427	907	644	1,891	256	82,554
Textile products	2	19	181	9	40	51	5	32	55	124	13	41	371	143	48	19	22	0	806
Wearing apparel and other textile products	12	187	253	7	7	19	14	18	22	49	10	10	156	146	103	43	56	1	956
Timber and wooden products,Furniture and fixtures	285	8,014	1,378	72	51	29	117	108	441	249	66	52	1,184	450	198	116	173	2	11,800
Pulp, paper, paperboard, building paper	527	11,529	1,969	91	19	72	100	116	1,679	370	50	164	2,662	1,127	243	390	178	2	18,627
Printing, plate making and book binding	155	8,314	2,858	11	48	17	72	22	146	263	22	43	642	783	135	46	146	6	13,086
Chemical fertilizer	132	8,291	4,114	23	7	16	13	8	126	120	344	9	665	415	705	192	223	1	14,739
Synthetic resins	2	631	1,199	11	16	12	0	7	89	59	106	20	320	86	153	54	46	0	2,491
Final chemical products, n.e.c.	80	3,524	4,484	122	40	60	88	91	849	377	173	185	1,986	1,334	261	139	231	1	12,041
Petroleum refinery products and Coal products	323	5,834	2,839	26	1	1	7	2	11	28	389	2	467	75	88	35	77	4	9,741
Plastic products	88	5,982	3,164	70	27	52	153	176	559	822	179	222	2,261	673	332	138	219	2	12,858
ceramic, stone and clay products	207	5,045	1,404	24	20	16	75	89	134	289	128	76	853	242	136	53	187	9	8,135
iron or steel products	308	11,363	6,603	76	21	4	40	74	190	1,540	68	38	2,052	2,503	4,225	81	632	7	27,774
Non-ferrous metal products	22	8,603	4,018	331	24	78	254	47	1,262	413	290	152	2,850	526	230	102	133	1	16,486
Metal products	179	10,115	3,086	128	50	35	212	141	410	576	134	177	1,862	985	294	91	297	9	16,918
general machines	87	23,058	8,769	178	386	44	1,122	281	1,541	1,733	384	727	6,396	2,533	1,080	276	875	0	43,075
Machinery for office and service industry	2	1,110	2,010	5	8	7	140	37	132	461	250	35	1,073	211	32	1	47	5	4,489
electronic components	38	5,974	1,704	13	33	27	219	60	874	639	373	57	2,293	542	268	39	202	1	11,061
Other electronic components	14	1,200	2,240	4	11	39	409	26	621	91	46	47	1,294	691	61	184	129	0	5,814
Household electronics equipment	2	3,226	445	1	1	1	82	43	494	112	4	269	1,008	353	43	4	21	0	5,101
Communication machinery and devices	90	11,442	2,922	3	95	8	1,463	149	834	650	155	85	3,441	736	388	63	289	0	19,372
Semiconductor devices and Integrated circuits	124	6,084	4,056	119	140	138	1,368	136	257	580	700	183	3,621	1,000	659	225	1,009	0	16,778
Motor vehicle	134	5,028	16,018	67	67	50	577	446	6,591	10,507	1,389	409	20,102	1,060	2,913	10	2,659	0	47,924
Other transportation equipment and repair of transportation equipment	42	4,823	1,460	3	44	1	43	75	301	808	92	44	1,409	543	358	224	279	8	9,146
Precision instruments	6	2,512	1,279	2	5	21	297	10	236	97	3	34	706	205	54	12	83	0	4,857
Miscellaneous manufacturing products	86	3,458	2,595	52	30	10	98	53	681	520	163	123	1,730	633	247	49	272	4	9,074
construction	2,158	62,694	18,332	203	257	185	985	277	2,141	1,619	500	341	6,508	3,392	1,185	639	1,672	152	96,731
Electricity	242	46,094	2,329	32	51	60	227	18	232	164	194	2	980	205	160	55	164	13	50,241
Gas and heat supply	34	6,096	874	5	2	1	18	3	34	51	29	2	145	111	14	2	27	1	7,304
Water supply and Waste management service	113	23,008	1,814	13	30	7	74	14	94	93	23	16	365	210	74	27	105	9	25,725
Commerce	843	136,511	11,648	76	113	47	345	89	518	1,012	103	67	2,369	1,816	501	234	694	40	154,657
Finance and insurance	316	31,961	3,505	39	45	26	98	50	236	254	53	44	845	666	209	118	276	18	37,914
Real estate agencies and rental services	171	138,480	2,586	18	15	9	127	18	160	197	27	35	606	428	99	47	158	14	142,589
Transport	589	87,124	5,597	46	58	45	252	99	840	825	129	76	2,371	870	367	147	501	86	97,651
Information services	58	9,153	3,707	8	13	4	38	6	35	133	3	4	244	226	40	14	49	4	13,496
Other Information services	304	13,604	7,632	31	98	23	119	35	190	372	70	25	963	1,032	177	107	301	23	24,142
Public administration	805	82,735	3,113	25	124	18	145	57	233	140	76	47	864	458	309	136	711	85	89,216
Education and Research	190	6,924	4,472	35	30	19	237	46	384	397	37	76	1,262	602	233	95	260	13	14,052
Other Public Services	1,374	81,278	6,884	118	162	97	454	166	678	861	213	180	2,927	2,896	1,074	766	2,042	176	99,416
Advertising services	57	1,052	2,601	5	8	3	26	5	57	126	4	1	236	321	41	13	72	4	4,398
Goods rental and leasing services	51	6,192	1,127	7	11	3	29	8	40	66	6	4	174	176	38	16	62	4	7,839
Other business services	581	22,143	8,121	77	98	43	348	95	433	865	119	61	2,139	1,494	486	213	797	51	36,025
Personal services	1,478	114,177	14,114	107	159	82	910	183	1,175	1,160	200	151	4,127	2,650	621	401	1,239	153	138,961
Activities not elsewhere classified	228	2,721	1,791	27	27	17	97	34	226	220	63	37	747	543	177	80	244	17	6,548
Total	17,039	1,097,581	196,460	2,463	2,663	1,595	12,583	3,785	29,226	31,857	7,879	4,633	96,685	40,780	20,196	6,626	20,513	1,221	1,497,101

And Backward Linkage is the relationship between a firm or industry and the suppliers of its inputs, or raw materials. An increase in the output of the firm or industry is transmitted backward, yielding an increase in the demand for inputs. Development planners usually prefer to target industries with significant backward linkages, so that investments have additional multiplier effects in generating benefits for other sectors and in helping to further growth in input industries.

In Table 6, Damaged output by the Great East Japan Earthquake is about 4.952 trillion yen.

Table 6 Damaged Output by the Great East Japan Earthquake（Backward Linkage）

unit: million yen

Damaged Output （Forward Linkage)	Hokkaido	Tohoku	Kanto	Toyama	Ishikawa	Fukui	Nagano	Gifu	Shizuoka	Aichi	Mie	Shiga	Chubu Region	Kinki	Chugoku	Shikoku	Kyushu	Okinawa	Total
Agriculture, Forestry, and Fisheries	17,632	17,666	13,555	325	122	79	3,531	289	5,393	1,476	480	268	11,962	2,258	2,970	5,023	8,943	186	80,195
mining	1,012	703	7,551	375	13	157	439	375	275	1,350	199	59	3,242	1,647	3,938	4,146	4,400	59	26,698
Coal mining, crude petroleum and natural gas	18,156	2	78,211	466	45	45	1,445	33	182	5,678	0	34	7,928	7,163	12,206	3,665	3,050	758	131,140
Food and Beverage	10,735	51,900	28,065	127	65	26	2,418	443	12,577	3,820	515	785	20,775	6,814	2,258	1,652	5,210	126	127,536
Textile products	48	19	3,268	320	949	1,811	73	1,212	1,028	3,630	209	1,048	10,280	2,580	1,313	501	213	5	18,228
Wearing apparel and other textile products	387	187	4,167	69	29	174	91	272	152	1,031	67	63	1,946	1,569	1,695	279	558	2	10,789
Timber and wooden products,Furniture and fixtures	2,722	8,014	10,199	696	149	314	677	1,499	4,034	3,456	613	419	11,858	3,938	2,866	2,086	1,657	3	43,343
Pulp, paper, paperboard, building paper	7,990	11,529	16,943	1,721	59	711	403	2,135	17,248	3,459	442	1,429	27,606	9,369	4,031	6,869	2,267	6	86,610
Printing, plate making and book binding	785	8,314	29,059	162	326	122	1,157	240	2,374	2,947	204	409	7,940	4,545	1,102	399	1,284	13	53,441
Chemical fertilizer	2,771	8,291	71,336	1,380	145	582	242	395	3,024	3,597	12,086	592	22,043	13,013	25,445	5,232	6,692	18	154,842
Synthetic resins	74	631	18,978	281	103	301	26	218	1,678	991	3,503	374	7,475	2,839	4,223	1,283	1,287	0	36,789
Final chemical products, n.e.c.	1,099	3,524	47,820	3,614	369	907	639	1,496	10,981	5,378	2,862	2,808	29,055	15,409	4,679	2,514	4,803	2	108,906
Petroleum refinery products and Coal products	30,869	5,834	125,088	1,320	32	75	235	35	489	5,470	11,468	56	19,179	8,994	16,660	5,246	3,564	1,057	216,492
Plastic products	1,169	5,982	44,526	1,639	290	1,227	1,943	3,636	10,238	14,142	2,792	5,559	41,467	10,029	4,444	2,099	2,793	5	112,514
ceramic, stone and clay products	2,625	5,045	13,636	451	157	311	655	1,631	1,107	4,126	1,918	1,669	12,025	3,435	2,546	1,039	3,389	6	43,747
iron or steel products	10,569	11,363	117,962	1,838	194	58	412	807	1,905	32,350	527	556	38,649	45,650	49,693	1,566	31,203	3	306,658
Non-ferrous metal products	488	8,603	34,522	8,373	394	1,565	1,107	1,111	12,803	10,001	7,087	1,641	44,082	5,672	7,617	6,422	3,052	1	110,459
Metal products	3,521	10,115	40,538	3,611	451	641	3,422	3,920	6,740	9,978	2,728	3,267	34,758	16,230	4,262	1,846	3,264	9	114,542
general machines	1,095	23,058	29,618	1,562	1,815	144	4,893	2,500	7,047	9,519	2,017	5,005	34,502	17,372	6,525	2,136	3,583	1	117,890
Machinery for office and service industry	5	1,110	4,117	11	12	10	244	258	220	3,405	168	102	4,429	814	81	2	70	8	10,636
electronic components	258	5,974	6,048	121	178	131	1,377	770	6,106	4,533	3,480	339	17,037	2,521	553	115	849	0	33,354
Other electronic components	94	1,200	3,959	23	28	266	1,064	145	2,520	328	182	379	4,936	2,778	402	487	630	0	14,486
Household electronics equipment	38	3,226	850	3	0	1	151	203	1,009	253	7	961	2,588	1,291	78	12	34	0	8,118
Communication machinery and devices	55	11,442	2,258	3	394	828	67	779	798	129	166	2,812	882	314	42	147	0	17,952	
Semiconductor devices and Integrated circuits	740	6,084	29,309	1,965	805	1,927	10,058	347	3,371	4,877	7,049	3,675	34,074	10,613	4,867	2,655	3,605	0	91,947
Motor vehicle	499	5,028	23,620	159	47	24	1,197	2,226	14,211	39,449	3,828	1,135	62,275	2,217	8,934	38	2,204	0	104,815
Other transportation equipment and repair of transportation equipment	720	4,823	10,554	12	311	2	348	736	2,473	5,551	118	160	9,710	3,941	1,363	2,420	817	43	34,391
Precision instruments	52	2,512	2,351	4	7	49	696	19	1,031	274	17	96	2,192	772	328	105	482	0	8,794
Miscellaneous manufacturing products	1,141	3,458	28,216	1,001	265	69	489	862	5,358	7,717	2,167	2,021	19,950	7,133	4,797	702	4,304	22	69,723
construction	1,114	62,694	17,244	289	94	175	876	199	2,066	1,565	586	243	6,093	3,831	1,083	388	1,028	18	93,494
Electricity	3,873	46,094	22,045	1,055	640	2,981	8,939	808	13,433	3,822	1,605	36	33,318	4,743	4,929	1,731	3,022	50	119,805
Gas and heat supply	100	6,096	5,516	21	11	7	38	25	218	3,540	187	20	4,067	2,328	194	48	118	1	18,469
Water supply and Waste management service	634	23,008	7,461	155	69	72	718	462	1,236	1,123	345	264	4,443	2,091	871	288	607	15	39,419
Commerce	17,996	136,511	281,436	1,365	1,169	554	3,029	1,276	10,805	25,526	2,325	986	47,035	60,608	13,659	7,232	17,007	439	581,923
Finance and insurance	6,467	31,961	82,525	947	390	406	1,755	1,402	7,227	5,628	1,680	897	20,333	13,787	4,716	3,360	4,858	194	168,201
Real estate agencies and rental services	6,230	138,480	28,051	148	70	42	299	116	938	1,282	317	116	3,329	4,294	921	432	1,352	75	183,164
Transport	17,208	87,124	95,331	1,249	450	592	3,395	1,525	17,179	14,323	3,192	1,360	43,266	19,738	12,922	5,608	13,752	1,663	296,613
Information services	341	9,153	109,501	111	130	43	893	63	1,280	1,260	84	33	3,898	2,360	402	132	425	26	126,237
Other Information services	5,131	13,604	118,790	372	432	100	1,140	525	2,727	2,560	1,142	294	9,294	9,195	2,134	1,199	2,504	171	162,023
Public administration	296	82,735	2,686	57	17	16	110	84	373	210	146	41	1,053	517	201	107	256	7	87,858
Education and Research	2,080	6,924	66,768	678	72	171	2,134	737	4,881	5,335	439	1,443	15,890	11,849	3,803	1,436	2,421	12	111,183
Other Public Services	671	81,278	2,010	65	21	17	104	88	247	231	92	76	941	356	397	221	459	35	86,367
Advertising services	3,682	1,052	86,817	119	56	41	458	78	1,373	1,501	82	23	3,731	4,909	786	285	1,027	48	102,336
Goods rental and leasing services	1,999	6,192	76,983	239	272	85	918	282	1,645	2,452	257	99	6,247	5,023	1,088	453	1,909	148	100,041
Other business services	9,264	22,143	144,142	841	354	419	3,539	873	6,932	8,883	1,359	629	23,831	18,781	4,782	1,817	4,805	125	229,690
Personal services	225	114,177	5,988	16	6	5	85	25	195	173	33	78	616	325	109	32	193	8	121,673
Activities not elsewhere classified	1,415	2,721	13,328	285	66	85	544	424	2,587	1,412	593	217	6,213	2,598	1,050	550	1,116	34	29,024
Total	196,074	1,097,581	2,012,949	39,645	11,721	17,544	69,232	36,869	211,694	270,409	81,328	41,932	780,374	378,821	234,237	85,902	161,213	5,404	4,952,555

Ⅶ. Concluding Remarks

We surveyed the analytical approaches about the economic impacts on unscheduled natural disasters, and estimated the indirect economic damages of the Great East Japan Earthquake on March 11, 2011 by means of Interregional Input-Output table in Japan.

According to the article of Okuyama, Sonis and Hewings (1999), input-output analysis has been employed in many studies to evaluate economic impacts of unscheduled events. Although it provides useful information in terms of consequences in some specific aspects, i.e., effects from the decreased final demand by damages, and/or from the increase of reconstruction demand, many of these studies have failed to take account the interregional effects of impacts and the relationship between output production and income formation process in their analysis.

Yamano, Kajitani, and Shumuta (2004) examine the economic impacts of natural disasters by integrating district level economic data and Japanese interregional input-output model. Their model deals with the direct and indirect output losses due to the disruptions of electricity, damages of transport network, and the decrease in economic demand. They compiled the 500m district level output and employment data to analyze the precise output losses. Numerical example of Hyogo prefecture shows that the indirect economic loss is much larger than the direct output losses in most districts. The damages on material manufacturers and business center will induce a great economic loss compared to suburban area.

As Okuyama (2003) states, the concepts of risk and uncertainty have been used in the disaster related literature, but they are used to be in an ambiguous concept.

Calculating the share of the total number of employees in the stricken area counties, which output value of each industry in each prefecture (GRP in fiscal year 2008) calculated, it was estimated as the scale of damage.

References

Tsunenori Ashiya and Toshiki Jinushi (1999) "Estimating an Input-Output table for the economic impact study of the Great Hanshin Awaji Earthquake," *Business Journal of PAPAIOS*, 8(4): 6–14.

Tsunenori Ashiya and Toshiki Jinushi (2001) "The Great Earthquake and Structural change of Industrial Classification", *The Kokumin Keizaigaku Zasshi*, 183(1): 79–97.

Mircea Boscoianu (2008), "Emerging Research Directions for Modeling the Impact, Short Time Recuperation and Long Term Recovery in the Case of Natural Hazards," *Environmental Problems and Development*, 2008, pp.174–179.

Cabinet Office Government of Japan, (2011), "On the estimates of the damaged stock of the Great east Japan Earthquake," Cabinet Office Government of Japan (Disaster prevention), June 24, 2011.

Cochrane, Halord C., (2004) "Indirect Losses from Natural Disasters: Measurement and Myth," in chapter 3 of Yasuhide Okuyama and Stephanie E. Chang (edited), *Modeling the Spatial and Economic Effencts of Disasters*, New York, Springer.

Davidson, Paul, (1991) "Is Probability Theory Relevant for Uncertainty?: A Post Keynesian perspective", *Journal of Economic Perspectives*, (1): pp.129–43.

Toshitaka Katada, Yoshifumi Ishikawa, Shunji Kimura and Takashi Satou (2004), "A Study on the structure of damage to establishments by the heavy rainfall disaster in Tokai region", *Doboku Keikakugaku Kenkyu Ronbunshu*, 29.

Nobuhiro Hosoe, (2011), "An Input-Output Analysis of Impact of Voluntary Self-restraint on the Recreation Industries," *GRIPS Discussion Paper* 11–04.

Yoshihisa Inada, Hiroaki Irie, Akihiro Shima and Takumi Toizumi, (2011), "Macroeconomic Impact of the damage by the Great east Japan earthquake: the complex damage of earthquake, Tsunami, and nuclear power generation", (in Japanese), *KISER REPORT*.

Yoshifumi Ishikawa (2005) "Analysis of the Spatial Impacts of the Niigata Chuetsu Earthquake," *Doboku Keikakugaku Kenkyu Ronbunshu*, 31.

Ministry of Economy, Trade and Industry (2005), *An Inter-regional Input-Output Table in Japan.*

Knight, Frank H., (1921) *Risk, Uncertainty and Profit*, 1964 reprint, New York, NY; August Kelley.

Michiya Nozaki, Takeo Ihara and Nontachai Thitipongtrakul (2011), "How to Grasp the Economic Impact of the Great East Japan Earthquake: An Influence for Chubu Region" (in Japanese), *Business Journal of PAPAIOS Input-Output Analysis – Innovation & I-O Technique–*, Vol.19, No.3.

Miyazawa, K., (1976), *Input-Output Analysis and the Structure of Income Distribution*, Springer-Verlag.

Yasuhide Okuyama, Michal Sonis and Geoffrey Hewings (1999), "Economic Impacts of an Unscheduled, Disruptive Event: A Miyazawa Multiplier Analysis", in *Understanding and Interpreting Economic Structure*, G.J.D. Hewings, M.Sonis, M.Madden and Y.Kimura (edited), Springer–Verlag.

Yasuhide Okuyama (2003) "Economics of natural Disasters: A Critical Review", *Research Paper 2003–12, paper presented at the 50th North American Meeting*, Regional Science Association International, November 20–22, 2003, Philadelphia, PA.

Yasuhide Okuyama, Michal Sonis and Geoffrey Hewings, (2004) "Measuring Economic Impacts of Disasters: Interregional Input-Output Analysis Using Sequential Interindustry Model", in chapter 5 of Yasuhide Okuyama and Stephanie E. Chang (edited), *Modeling the Spatial and Economic Effencts of Disasters*, New York, Springer.

Savage, L.J., (1954) The Foundations of Statistics, New York, NY; Dover.

Shuntaro Shishido (supervised), PAPAIOS (edited), (2010), *Handbook of Input-Output Analysis*, Toyo keizai shinpousha.

Solow, Robert M., (1956) "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70 (1): 65–94.

Swan, Trevor W., (1956) "Economic Growth and Capital Accumulation," *Economic Record*, 32(November): 334–361.

von Neumann and O. Morgenstern (1944) *The Theory of Games and Economic Behavior*, Princeton, NJ; Princeton University Press.

Norihiko Yamano, Yoshio Kajitani, and Yoshiharu Shumuta (2004), "Modeling the Regional Economic Loss of Natural Disasters: Indirect Loss Diffusion due to the Electricity Disruptions and Interindustry Economic Activities," *Regional Economic Applications Laboratory Discussion Paper*, 2004, University of Illinois.

Endnote

1) Nozaki, Ihara and Thitipongtrakul (2011).

2) Cabinet Office Government of Japan, (2011). And about the private and social capital stock from 1974-2008, thanks for Dr. Suzuki, a researcher of Chubu Industrial and Regional Advancement Center.