Globalization and Localization of Disaster Impacts: An Empirical Examination

Yasuhide Okuyama*

Introduction

The damages and losses brought by disasters, such as earthquakes, floods, hurricanes, cyclones and so on, can potentially have significant and intense impacts on a nation's economy. However, despite the importance of assessing the economic impacts of damages and losses in the aftermath of such events, estimating the impacts is rather challenging. The consequences associated with the event will have many other aspects including damages on demand and supply sides, for example, since the event may affect a wide range of economic activities in many different ways. The difficulties with impact analysis of disasters are, therefore, (1) disentangling the consequences stemming directly and indirectly from the event, (2) deriving possibly different assessments at each spatial level – cities, region, or nation – (Hewings and Mahidhara 1996), and (3) evaluating the reaction of households which are poorly understood (West and Lenze 1994). Data availability for the impact assessment is another important issue. West and Lenze (1994) claim that sophisticated economic impact models requiring precise numerical input have to be reconciled with imperfect measurements of the damages. They proposed a systematic way to estimate the impacts from the available data; however, "impact assessment of unscheduled events is an inexact science" (Hewings and Mahidhara 1996, 216).

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Albala-Bertrand (2007) claimed that economic impact of a disaster, which causes localized damages and losses on capital and activities, may not affect negatively the macro-economy in both short and longer term. This appears to contradict with some empirical observations, such as the 1999 Chi-Chi earthquake in Taiwan which caused a hike in price of computer memory chips in the United States and other countries, and the 2005 hurricane Katrina which led to the increase in oil price domestically and internationally. These observations indicate that while the degree of damages and losses is much severer in the areas hit by such a natural hazard, the impacts of the event appear to spread over many other areas and nations. In this regard, the propagation process of disaster impact in a global sense is examined in this paper using the empirical case of the 2004 Indian Ocean earthquake and tsunami.

In the following section, Albala-Bertrand's 'Globalization and Localization: An Economic Approach (2007)' is reviewed and analyzed. The third section defines and describes terminology associated with economic impact assessment of natural disaster. Analysis of empirical case study based on the 2004 Indian Ocean earthquake and tsunami is carried out and discussed. The final section concludes the paper with some remarks on future directions for this line of research.

Review of globalization and localization

Albala-Bertrand has been actively studying about the economic consequences of natural disasters, especially in the developing country's context. In his studies, he often claims that economic impacts of natural disasters are rather minor in a macroeconomic sense, even with a catastrophic one. For example, he claimed that the indirect effects of disaster are "more a possibility than a reality" (Albala-Bertrand 1993, 104). He also argued that in a long run the negative impacts from damages made by a disaster and the positive impacts from recovery and reconstruction may potentially cancel out and then the estimation of the total impacts often ends up deriving insignificant values (Albala-Bertrand 1993). While his arguments were based on some empirical evidence of the past disasters (in 1960s and 1970s for his 1993 publication), with the recent progress on globalization and increased interdependency between economies, economic impact of disasters should be examined with the augmented complexity of recent economy.

In his recent publication (Albala-Bertrand 2007), Albala-Bertrand analyzed the effect of globalization on disaster impacts from an economic perspective. His main conclusions are:

1. Disaster impacts, such as casualties and economic losses, will be economically localized and thus are unlikely to influence negatively the national economy, even in a long run.
2. Positive features of globalization, like access to larger markets and suppliers, etc., may lead to even more localization of disaster impacts, while negative features of globalization, which are fast efficiency and productivity improvements through privatization and deregulations and lead to thinner and weaker social fabric against emergency situations, make localized disaster impact much more condensed into the local community than before.
3. The synchronization of business cycle caused by globalization, especially with the US economy, may regulate the financial capability for disaster response of the world, especially when the leading economies are under recession.

These conclusions reflect his above arguments on disaster impact, while he acknowledges the uncertainty of disaster consequences, shown in 2 and 3, may increase due to globalization.

In a macroeconomic or an aggregated sense, his arguments appear plausible for not such significant total impacts. However, the economic structure can affect the extent and significance of disaster impacts in different parts of an economy, geographically and/or socially, and the distribution and volume of negative and positive impacts may differ over space and for different sectors. In this line, Albala-Bertrand's claim, which urges for future studies to start classifying disaster impacts over localities, is imperative. This may contradict his claim of negligible total impact of disasters in an aggregate sense, but the disaggregation of disaster impacts, showing disequilibrium between negative and positive impacts in various economic spaces and agents, is necessary and essential on the way to display the macroeconomic impacts.

Economic impacts of disasters: concept and definition

In order to discuss the economic impacts of disasters, we need to clarify the terminology first, since the use of similar words has created some confusion in many disaster literatures. According to Okuyama and Chang (2004, 2), "*hazard* is the occurrence of the physical event *per se,* and *disaster* is its consequence". In this context, while the occurrence of hazards cannot be prevented, the extent and intensity of a disaster can be managed. Hence, the measuring the extent and intensity of economic consequences (disaster) caused by a hazard is necessary to evaluate and determine the countermeasures against hazards and is central to understand how the consequences of a hazard become a disaster.

In terms of 'disaster' economic impacts, many comparable terms, such as damages and losses which are further differentiated between direct and indirect losses, have been employed interchangeably without making any distinction or definition of them, and have led to further perplexity. Oftentimes, the direct loss refers to the damages on stock like buildings, roads, houses, etc., while the indirect loss implies the loss of flow due to business disruptions caused by stock damages. And then, the total loss is often calculated by adding these direct and indirect losses. However, in economics term, stock and flow are two different things and summing these up leads to potential double counting (Rose 2004). Also, in the above way, the distinction between flow losses caused directly by the stock loss and flow losses caused via inter-industry linkage (often referred as 'ripple' effect) cannot be made, and this distinction is vital to illustrate the extent of disaster impact.

Consequently, the clear definition of disaster impact should be made. Okuyama and Sahin (2009) proposed the following terminology for disaster economic impacts: *damages* are by economics definition the damages on stocks, which include physical and human capitals; *losses* are business interruptions, such as production and/or consumption, caused by damages and can be considered as *first-order losses; higher-order effects,* which take into account the system-wide impact based on first-order losses through inter-industry relationships; and *total impacts* are the total of flow impacts, adding losses (first-order losses) and higher-order effects. Rose (2004) further suggested that listing both damages and losses, but not adding them together, is appropriate for showing the different aspects of economic impact. In the following sections, these terms are used for the analysis.

What we are going to estimate in this paper is the economic intensity of a natural hazard on flow, while a comprehensive assessment of a natural disaster requires to include both negative impact of a natural hazard and positive effects of recovery and reconstruction activities. More concretely, the results shown in the following section are only the negative impact of a natural hazard over a year, without any restoration, recovery, or reconstruction. This appears to be a very unlikely scenario, but this serves as the worst-case scenario (do-nothing-scenario)[1] and also provides the extent to which recovery and reconstruction need to be done. In addition, those restoration, recovery and reconstruction strategies will be decided based on the total impacts of a disaster and the distribution of them; thus, the estimation of negative impact only becomes a basis of decision making and is well worth doing.

Empirical examination: 2004 Indian Ocean earthquake and tsunami

This section examines how economic impacts of a local disaster can (or cannot) spread over internationally, employing the 2004 Indian Ocean earthquake and tsunami as the case study. While this event was a multi-country incident, involving at least five countries (India, Indonesia, Maldives, Sri Lanka and Thailand), the damaged areas in each country were relatively limited geographically. Thus, using Albala-Bertrand's term, this was a localized event for each country. The economic impacts of this event are evaluated using the 2000 Asian International Input-Output Table for analyzing whether or not any sizable economic impacts were propagated over other countries, i.e. globally.

[1] There would potentially be some worse scenarios than this, if the recovery and reconstruction activities were misguided to create further negative influence.

The 2004 Indian Ocean disaster

The December 2004 Indian Ocean disaster was caused by an earthquake, and the earthquake generated a tsunami, carrying many million tons of water in a series of very large waves that traversed the Indian Ocean in a matter of hours. These waves hit beaches, flooding low-lying lands coastal areas. The destruction was widespread: the most seriously affected areas were Banda Aceh, Indonesia, as well as in tourism resorts in Thailand, Sri Lanka, and the Maldives. Many small and medium sized rural villages located along the beachside in the five countries were also wiped out (ADPC 2005).

According to the preliminary assessment of damages and losses, total of 281,900 persons died as a result of the earthquake and tsunami; 189,500 persons were injured, physically and psychologically, and required immediate or medium-term treatment; and, 1.2 million persons became homeless and even a year after the tsunami many were still housed in temporary camps, a sizable fraction of which still requires shelter, food and health services. The total economic effects of this event were estimated as USD 5.6 billion of damages and 4.3 billion of losses over five countries – Indonesia, India, Sri Lanka, Maldives, and Thailand (ADPC 2005). In this paper, the total impacts of this event are estimated and analyzed for Indonesia and Thailand using the 2000 Asian International IO Table, since other three countries (India, Maldives and Sri Lanka) was not included in the IO Table.

Here are some nation-specific information on the damage and loss for Indonesia and Thailand. The total damage and loss in Indonesia were estimated as 2,664 and 1,136 million US dollars, respectively (ADPC 2005). The housing sector had the largest damage with 1,398 million US dollars (52 percent of total damage). The transport sector had the second largest damage, 409 million US dollars. The productive sector, especially agriculture and industry (manufacturing), also had some sizable damages. On the other hand, the losses were concentrated on these productive sectors, 550 million US dollars for agriculture and 280 million US dollars for industry, and together, they had about 73 percent of total loss.

The total damages and losses in Thailand were estimated to reach 509 and 1,690 million US dollars, respectively. The damages were concentrated on tourism with 376 million US dollars (74 percent of the total damage), resulted from the washed out resorts and hotels on the beaches. Other noticeable damages were on agriculture. The losses were also mostly on tourism with 1,470 million US dollars (87 percent of the total loss), and agriculture and industry had some losses around 100 million US dollars each.

Methodology

There is a wide range of methodologies adopted to estimate the higher-order effects, and thus the total impacts of disasters (further detailed discussion of methodologies for impact estimation can be found at Rose (2004), Okuyama (2007) and Greenberg *et al.* (2007)). Input-Output (IO) model has been the most widely used methodology for disaster impact estimate for the recent decades (for example, Cochrane 1997; Gordon and Richardson 1996; Rose *et al.* 1997; Okuyama *et al.* 1999; Hallegatte 2008). The popularity of IO models for disaster related research is based mainly on the ability to reflect the economic interdependencies within an economy in detail for deriving higher-order effects, and partly on its simplicity. On the other hand, this simplicity of the IO model creates a set of weaknesses, including its linearity, and rigid structure with respect to input and import substitutions as well as a lack of explicit resource constraints, and responses to price changes (Rose 2004).

Input-output (IO) framework was developed by Wassily Leontief in the late 1920s and early 1930s. The structure of IO mimics the double-entry style of bookkeeping scheme. For the production side, the output is determined as the sum of intermediate demand and final demand as follows:

$$x_i = \sum_j x_{ij} + f_i \qquad (1)$$

where x_i is the output of sector i, x_{ij} is intermediate demand from sectors j to i, and f_i is the final demand for sector i. Direct input coefficient, a_{ij}, is calculated by $a_{ij} = x_{ij}/x_j$, and equation (1) can be transformed as follows:

$$x_i = \sum_j a_{ij} x_j + f_i \qquad (2)$$

In the matrix notation, (2) becomes:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} \qquad (3)$$

Solving this relationship for **x** yields:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \qquad (4)$$

(I-A)$^{-1}$ is the Leontief inverse matrix. For the impact analysis, the impact of changes in final demand can produce the changes in output in the following manner:

$$\Delta\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\Delta\mathbf{f} \qquad (5)$$

Miyazawa's (1976) extended input-output analysis intends to analyze the structure of income distribution by endogenizing consumption demands in the standard Leontief model. In some sense, Miyazawa's system is considered the most parsimonious in terms of the way it extends the familiar input-output formulation. Miyazawa considered the following system:

$$\begin{bmatrix} \mathbf{x} \\ \hline \mathbf{y} \end{bmatrix} = \begin{bmatrix} \mathbf{A} & \mathbf{C} \\ \hline \mathbf{V} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ \hline \mathbf{y} \end{bmatrix} + \begin{bmatrix} \mathbf{f} \\ \hline \mathbf{g} \end{bmatrix} \qquad (6)$$

where **x** is a vector of 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 for r-fold income groups, **C** is a corresponding matrix of consumption coefficients, f is a vector of final demands except households consumption, and **g** is a vector of exogenous income for r-fold income groups. Solving this system yields:

$$\begin{bmatrix} \mathbf{x} \\ \hline \mathbf{y} \end{bmatrix} = \begin{bmatrix} \mathbf{B}(\mathbf{I} + \mathbf{CKVB}) & \mathbf{BCK} \\ \hline \mathbf{KVB} & \mathbf{K} \end{bmatrix} \begin{bmatrix} \mathbf{f} \\ \hline \mathbf{g} \end{bmatrix} \qquad (7)$$

where:

B=**(I-A)**$^{-1}$ is the Leontief inverse matrix;
BC is a matrix of production induced by endogenous consumption;
VB is a matrix of endogenous income earned from production;
L=VBC is a matrix of expenditures from endogenous income; and
K=**(I-L)**$^{-1}$ is a matrix of the Miyazawa interrelational income multipliers.
In this paper, the IO model used is transformed to the Miyazawa's extended IO framework for the analysis of impact on income generation.

In order to analyze the interregional (or international) spillovers of a particular impact, the method of multiplier decomposition[2] is employed. Suppose we have a two-region (or two-nation) system, consisting of regions r and s. The above equation (6) can be rewritten as follows:[3]

$$\begin{bmatrix} \mathbf{x}^r \\ \mathbf{x}^s \\ \hline \mathbf{y}^r \\ \mathbf{y}^s \end{bmatrix} = \left[\begin{array}{cc|cc} \mathbf{A}^{rr} & \mathbf{A}^{rs} & \mathbf{C}^{rr} & \mathbf{C}^{rs} \\ \mathbf{A}^{sr} & \mathbf{A}^{ss} & \mathbf{C}^{sr} & \mathbf{C}^{ss} \\ \hline \mathbf{V}^{rr} & \mathbf{V}^{rs} & \mathbf{0} & \mathbf{0} \\ \mathbf{V}^{sr} & \mathbf{V}^{ss} & \mathbf{0} & \mathbf{0} \end{array}\right] \begin{bmatrix} \mathbf{x}^r \\ \mathbf{x}^s \\ \hline \mathbf{y}^r \\ \mathbf{y}^s \end{bmatrix} + \begin{bmatrix} \mathbf{f}^r \\ \mathbf{f}^s \\ \hline \mathbf{g}^r \\ \mathbf{g}^s \end{bmatrix} \qquad (8)$$

We can isolate the intraregional and interregional elements of the coefficient matrix in the following manner:

$$\left[\begin{array}{cc|cc} \mathbf{A}^{rr} & \mathbf{A}^{rs} & \mathbf{C}^{rr} & \mathbf{C}^{rs} \\ \mathbf{A}^{sr} & \mathbf{A}^{ss} & \mathbf{C}^{sr} & \mathbf{C}^{ss} \\ \hline \mathbf{V}^{rr} & \mathbf{V}^{rs} & \mathbf{0} & \mathbf{0} \\ \mathbf{V}^{sr} & \mathbf{V}^{ss} & \mathbf{0} & \mathbf{0} \end{array}\right] = \qquad (9)$$

$$\left[\begin{array}{cc|cc} \mathbf{A}^{rr} & \mathbf{0} & \mathbf{C}^{rr} & \mathbf{0} \\ \mathbf{0} & \mathbf{A}^{ss} & \mathbf{0} & \mathbf{C}^{ss} \\ \hline \mathbf{V}^{rr} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{V}^{ss} & \mathbf{0} & \mathbf{0} \end{array}\right] + \left[\begin{array}{cc|cc} \mathbf{0} & \mathbf{A}^{rs} & \mathbf{0} & \mathbf{C}^{rs} \\ \mathbf{A}^{sr} & \mathbf{0} & \mathbf{C}^{sr} & \mathbf{0} \\ \hline \mathbf{0} & \mathbf{V}^{rs} & \mathbf{0} & \mathbf{0} \\ \mathbf{V}^{sr} & \mathbf{0} & \mathbf{0} & \mathbf{0} \end{array}\right]$$

Then, the multiplier matrix in equation (7) can be decomposed in the following multiplicative form:

$$\left[\begin{array}{c|c} \mathbf{B}(\mathbf{I}+\mathbf{CKVB}) & \mathbf{BCK} \\ \hline \mathbf{KVB} & \mathbf{K} \end{array}\right] = \mathbf{M}_3\mathbf{M}_2\mathbf{M}_1 \qquad (10)$$

where:

$\mathbf{M}_1 = \left(\mathbf{I}-\tilde{\bar{\mathbf{A}}}\right)^{-1}$; $\mathbf{M}_2 = \mathbf{I}+\bar{\mathbf{A}}^*$; and $\mathbf{M}_3 = \left[\mathbf{I}-\left(\bar{\mathbf{A}}^*\right)^2\right]^{-1}$;

while

$$\tilde{\bar{\mathbf{A}}} = \left[\begin{array}{cc|cc} \mathbf{A}^{rr} & \mathbf{0} & \mathbf{C}^{rr} & \mathbf{0} \\ \mathbf{0} & \mathbf{A}^{ss} & \mathbf{0} & \mathbf{C}^{ss} \\ \hline \mathbf{V}^{rr} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{V}^{ss} & \mathbf{0} & \mathbf{0} \end{array}\right] \text{ and } \bar{\mathbf{A}}^* = \left(\mathbf{I}-\tilde{\bar{\mathbf{A}}}\right)^{-1}\left(\bar{\mathbf{A}}-\tilde{\bar{\mathbf{A}}}\right).$$

[2] The detailed illustration of multiplier decomposition is articulated in Millar and Blair (2009).
[3] For more precise formulation based on the Isard's fully specified interregional model, the final demand vector in this formula should have the interregional components and thus should become a matrix. Because the damages brought by a hazard will not have interregional damages, this formulation, a multiregional model, is sufficient in this setting. After all, damages caused by a hazard are indeed very much localized.

In this decomposition, M1 captures intraregional (or domestic) effects, M2 contains interregional (or international) spillover (a.k.a. *open-loop*) effects, and M3 records interregional (or international) feedback (a.k.a. *closed-loop*) effects. This multiplicative decomposition can be transformed into an additive decomposition (Stone 1985), through isolating the *net* effects as follows:

$$\mathbf{M}_3\mathbf{M}_2\mathbf{M}_1 = \mathbf{I}+(\mathbf{M}_1-\mathbf{I})+(\mathbf{M}_2-\mathbf{I})\mathbf{M}_1 + (\mathbf{M}_3-\mathbf{I})\mathbf{M}_2\mathbf{M}_1 \qquad (11)$$

In the above additive form, $(\mathbf{M}_1-\mathbf{I})$ indicates the *net* intraregional effects, $(\mathbf{M}_2-\mathbf{I})\mathbf{M}_1$ shows the *net* interregional spillover effects, and $(\mathbf{M}_3-\mathbf{I})\mathbf{M}_2\mathbf{M}_1$ captures the *net* interregional feedback effects. Analyzing these decomposed multiplier may reveal to what extent the higher-order effects can propagate intraregionally and interregionally.

The empirical model used in this paper is the 2000 Asian International Input-Output Table published by the Institute of Developing Economies (IDE), the Japan External Trade Organization (JETRO). This table includes nine countries and one region (Indonesia, Malaysia, Philippines, Singapore, Thailand, China, Taiwan, Korea, Japan, and the United States) with seven industrial sectors (agriculture, mining, manufacturing, utility, construction, trade and transport and services). This is the only officially available data source for this type of international input-output table, while the data year 2000, is a bit earlier than the year when the event occurred (the end of 2004), implying that some of the international trade relationships as well as the domestic economic structures may have changed between these years, especially with China. In addition, since the original international input-output table is a multiregional table, in which the international final demand transactions and wage transactions are not separated from the domestic final demand and wage values, when transformed to the Miyazawa structure, the consumption coefficient matrix **C** and the value added coefficient matrix ***V*** are converted to block-diagonal matrices, having zeros in interregional blocks.

The sectors in the original model are aggregated as much as possible to fit with the data of damages and losses in order to maintain the detail and reliability of the input data. The IO model is a demand driven model so that the input to model should be the form of changes in final demand, and then changes in output will be derived. Therefore, losses (decreased output level) are converted to final demand change in each sector, using Miller and Blair's (2009) method – dividing the changes in output (output loss) by the diagonal term of the Leontief inverse matrix for IO model. Then, the derived changes in final demand model are multiplied with Leontief inverse matrix to calculate impact by sector. Because of extension to the Miyazawa framework, the model can yield both the output impact (higher-order effects) and the impact on income generation (income impact) as the results.

Analysis

The economic impacts of the 2004 Indian Ocean earthquake and tsunami for Indonesia and Thailand, and other Asian countries are calculated and evaluated in this subsection. Table 1 shows the input data, damages and losses, and the results, output impact and income impact in Indonesia. The derived total impacts amount to 2,386 million US dollars (0.93 percent of 2004 GDP) for output and 1,219 million for income. The most significant output impact falls on manufacturing with 814 million US dollars (with 280 million of output decrease as loss), followed by agriculture with 672 million. The sectors with large impact tend to be accompanied with large losses, while the other sectors with small or no losses, such as mining, utilities, and construction, have limited higher-order effects. This may lead to the relatively small impact multiplier of 2.10.

The derived impact for Thailand on output and income are 3,205 million US dollars (1.99 percent of 2004 GDP) and 1,240 million, respectively, as seen in Table 2. The total impacts fall mostly on services (including tourism industry) with 1,535 million (48 percent of the total output impact). Meanwhile, manufacturing has a sizable impact of 872 million US dollars (27 percent of the total output impact), indicating that Thailand's domestic industries are highly interwoven and interdependent so that the total impacts spread across the sectors. However, the calculated impact multiplier is 1.90 – a relatively low value. This implies that while the tourism industry is one of the major industries in

Table 1

Economic impacts of 2004 Indian Ocean earthquake and tsunami – Indonesia (in 2007 million US dollars)

Sector		Data			Converted		Calculated	
		Damages	Losses	Sectors in model	Output decrease	Demand decrease	Output impact	Income impact
Infrastructure	Housing	1,389	39	Agriculture	550	410	672	
	Transport	409	148	Mining	0	0	69	
	Electricity	68	0	Manufacturing	280	158	814	
	Water & sanitation	27	3	Utilities	3	3	30	
	Urban & municipal	132	89	Construction	0	0	20	
Social	Water resources			Trade & transport	148	113	370	
	Health & nutrition	111	9	Services	116	80	412	1,219
	Education	166	18	HH income decrease	39			
Production	Agriculture	186	550					
	Industry	167	280					
	Service							
	Tourism							
Total		2,664	1,136		1,136		2,386	1,219

Source: Author's calculation.

Thailand, the losses are concentrated on one industry (tourism) and thus the total impacts are somehow limited and not widely spread to the entire economy.

As seen above, the impacts of the event appear not so large within the two countries (0.93 percent of GDP in Indonesia and 1.99 percent of GDP in Thailand). With increased economic interdependency between countries through international trades, this simultaneous damages and losses in multiple neighboring countries may bring the higher-order effects to other surrounding countries or even globally. As described in the previous subsection, the model used for this particular case (2000 Asian International IO Table) includes the above two countries, seven other Asian countries, and the United States so that the impacts to those countries can be estimated.

Table 3 indicates the impacts for these countries. Except those directly affected countries Indonesia and Thailand, Japan receives the largest total impacts (thus the largest higher-order effects, since there are no first-order losses in Japan) in this system, with 428 million US dollars. The United States has the second largest total impacts of 306 million. China follows these two countries and has USD 156 million of the total impacts. Among the sectors, manufacturing has the most significant impact in total (2,307 million US dollars) and for each country in this system. This also is an evidence of increasing interdependence among manufacturing firms through international trades *a la* vertical specialization. Compared to the total impacts in Indonesia and Thailand and to their own GDPs, these impacts in the other countries can be considered as negligible. At the same time, for the system as a whole, the aggregated total impacts reach 6,761 million US dollars with the impact multiplier of 2.39, and these numbers are noticeably larger than the above two countries'. For the multi-country disaster case such as this Indian Ocean earthquake and tsunami, this type of international analysis is useful to capture the comprehensive picture of the impacts.

So, does this mean that this type of localized but multi-country disaster can have any global economic impact? At this stage of the analysis the answer would be probably 'No', since the high-

Table 2

Economic impacts of 2004 Indian Ocean earthquake and tsunami – Thailand (in 2007 million US dollars)

Sector		Data		Converted			Calculated	
		Damages	Losses	Sectors in model	Output decrease	Demand decrease	Output impact	Income impact
Infrastructure	Housing	22	0	Agriculture	102	89	228	
	Transport	7	9	Mining	0	0	33	
	Electricity	4	10	Manufacturing	93	58	872	
	Water & sanitation	1	3	Utilities	13	10	132	
	Urban & municipal	15		Construction	0	0	3	
	Water resources			Trade & transport	9	7	401	
Social	Health & nutrition	9	3	Services	1,473	946	1,535	
	Education			HH income	0			1,240
Production	Agriculture	75	102	decrease				
	Industry		93					
	Service							
	Tourism	376	1,470					
Total		509	1,690		1,690		3,205	1,240

Source: Author's calculation.

er-order effects to other surrounding countries are very small in value. As described in the previous subsection, the derived economic impacts do not include the positive impacts from recovery and reconstruction activities in the respective countries. If included, the economic impacts to other surrounding countries may become much smaller than the values in Table 3. Thus, we need to further analyze the derived total impact in detail through the decomposition into domestic and non-domestic (international) effects.

Now, the decomposition of total impact to intraregional (domestic: Indonesia, and Thailand) effects, interregional (international) spillover effects and interregional (international) feedback effects, based on the multiplier decomposition technique described in the previous subsection, is summarized in Table 4. With the gross multipliers, the domestic effect in both Indonesia and Thailand becomes around 81 percent of the total impact, while international spillover effect and international feedback effect are estimated to be around 18 and 0.4 percent, respectively. When using the net multipliers, subtracting initial demand decrease, these figures change to 77, 23 and 0.5 percent, respectively. Since the initial demand decrease only falls on to the countries where the event occurred, the net percentages become larger than the gross numbers. In either way, the non-domestic effects, summing international spillover effect and international feedback effect, are quite significant, being the range around one fifth of the total impact. This is not a negligible share. Indeed, looking at the actual values, the sum of international spillover effect and international feedback effect and the initial demand decrease are nearly equal, 1.85 and 1.92 billion US dollars, respectively. This is a striking result indicating that the size of initial demand decrease, which is converted from the value of losses, is transmitted to and is replicated in the rest of system. At the same time, the distribution of non-domestic effects across sectors is quite different from the one for the initial demand decrease. While service sector in Thailand is the largest demand decrease, followed by agriculture sector and manufacturing sector in Indonesia, the manufacturing sector in the rest of the system is the largest for the non-domestic effects, and services sector and trade and transport sector are the second and third. This difference in the distribution may come from the two factors: the one is the distribution of losses which determines the origin of impact path and the path itself – forward and backward linkages of inter-

Table 3

Spatial distribution of total impacts of 2004 Indian Ocean earthquake and tsunami (in 2007 million US dollars)

	Sectors in model	Indonesia	Thailand	Malaysia	Philippines	Singapore	China	Taiwan	Korea	Japan	USA	Total
Output impact	Agriculture	672	228	2	1	0	19	2	3	8	13	948
	Mining	69	33	5	0	0	7	0	0	1	4	118
	Manufacturing	814	872	36	7	33	96	42	59	230	120	2,307
	Utilities	30	132	1	1	1	6	1	2	11	7	192
	Construction	20	3	0	0	0	1	1	0	4	2	30
	Trade & transport	370	401	5	2	7	14	9	7	64	47	926
	Services	412	1,535	9	2	9	14	15	19	110	114	2,239
	Total	2,388	3,205	58	14	50	156	69	90	428	306	6,761
Income impact		1,219	1,240	22	5	12	39	24	26	154	143	2,855

Source: Author's calculation.

Table 4

Decomposition of total impact to domestic and international effects (in 2007 million US dollars)

		Output decreases (loss)	Demand decrease	Total impact	Decomposition of total impact			Non-domestic effects		Non-domestic effect/Initial demand decrease (%)
					Domestic effect	International spillover effect	International feedback effect	Gross %	Net %	
Indonesia	Agriculture	550	410	671	667	4	0.65	0.63	1.62	0.84
	Mining	0	0	68	65	2	0.99	4.33	4.33	no initial loss
	Manufacturing	280	158	812	794	16	2.38	2.24	2.77	8.43
	Utilities	3	3	30	30	0	0.06	1.45	1.59	3.43
	Construction	0	0	20	19	0	0.04	1.20	1.20	no initial loss
	Trade & transport	148	113	370	364	5	0.76	1.53	2.20	4.71
	Services	116	80	411	407	4	0.69	1.07	1.33	0.43
	HH income	39	39	1,218	1,202	13	2.63	1.28	1.33	40.08
Thailand	Agriculture	102	89	228	227	1	0.26	0.58	0.94	0.26
	Mining	0	0	33	32	1	0.07	2.25	2.25	no initial loss
	Manufacturing	93	58	871	859	9	2.60	1.33	1.42	5.36
	Utilities	13	10	132	131	1	0.14	0.49	0.53	4.98
	Construction	0	0	3	3	0	0.00	0.34	0.34	no initial loss
	Trade & transport	9	7	401	397	3	0.65	0.83	0.84	2.78
	Services	1,473	946	1,535	1,532	2	0.48	0.15	0.40	0.23
	HH income	0	0	1,239	1,233	5	1.34	0.53	0.53	16.89
Rest of system	Agriculture	0	0	45	0	45	0.58	100	100	9.05
	Mining	0	0	21	0	21	0.30	100	100	no initial loss
	Manufacturing	0	0	610	0	602	7.59	100	100	282.96
	Utilities	0	0	33	0	32	0.41	100	100	253.78
	Construction	0	0	8	0	8	0.10	100	100	no initial loss
	Trade & transport	0	0	173	0	171	2.15	100	100	144.61
	Services	0	0	375	0	370	4.68	100	100	36.52
	HH income	0	0	508	0	501	6.35	100	100	1301.86
Total		2,826	1,912	9,813	7,963	1,814	36	18.85	23.42	
				Gross %	81.15	18.49	0.37			
				Net %	76.58	22.96	0.45			

Source: Author's calculation.

industry relationship; and the other is the international trade relationships which lead to the extent of international spillover effect and feedback effect. As globalization is reaching every corner of the world, these domestic and international inter-industry relationships have become so intertwined, and thus they demand a careful inspection.

The effects on household income deserve some discussion. The initial household income decrease amounts to just 39 million US dollars in Indonesia due to housing damages, whereas the total impact on household income is estimated as almost 3 billion US dollars, more than 75 times larger than the initial one. The total impact on household income includes wage decrease due to the decreased output, caused not only by the damages and through inter-industry production relationships but also by the consumption decrease due to such wage declines, leading to further ripple effect on the wage-consumption relationship. It is also remarkable that the interregional spillover effect on household income becomes around 500 million US dollars and this effect creates further repercussions in the rest of system, bringing further USD 6 million of household income decrease.

Summary and conclusions

In this paper, the total impacts of the 2004 Indian Ocean earthquake and tsunami were estimated using the 2000 Asian International Input-Output Table. The results show that the higher-order effects and total impacts of disasters are significant and complex domestically. The spread of higher-order effects to other surrounding countries do exist, while the value *per se* is relatively small compared to the localized higher-order effects and to their respective size of the economy. However, this does not mean that there is little global or international ripple effect of the disaster impact. Rather, with the multiplier decomposition technique, the non-domestic effect including international spillover effect and international feedback effect consists of around 20 percent of total impacts, in both gross and net analyses. The results also display that the distribution of higher-order effect across sectors is quite different from that of initial losses, especially for the non-domestic ones. This is caused by the increased complexity of domestic economic structure as well as of international trade. The effect of globalization, especially the first half of 2 and 3 in the Albala-Bertrand argument above, has made such complexity and interdependency of economic activities in the world. More thorough analysis using two (or more) different time points with the same disaster situation, which may reveal how the progress of globalization affects the propagation of disaster impact, is called for. If proper development and domestic policy and appropriate recovery and reconstruction strategies were not practiced, these higher-order effects would spread over globally.

At the same time, all of the derived results above include only negative impact of losses without having positive impact of recovery and reconstruction activities; thus, they are after all *potential* total impact. Perhaps, in the real event, the propagation of negative impact to other countries was very minimal, if at all, because the negative impact was cancelled out with (or the propagation was avoided by) the positive impact of recovery and reconstruction activities. However, this fact does not undermine the results in this paper, since without such recovery and reconstruction activities the results of this paper would have been unfolded and materialized. And, some parts of recovery and reconstruction activities were aided and financed by the international organizations and international community. This implies that if proper development and domestic policy to install countermeasures for such hazards and appropriate recovery and reconstruction strategies were not practiced, these higher-order effects would have spread over the world. In other words, the localized risk of natural hazard will be shared with, or extend to global community. This is the true issue of globalization and localization of hazard risk.

The data for damages and losses used as input for estimation in this paper are based mostly on the ECLAC methodology (UN ECLAC 2003). While the accuracy of these data is the key for the precision of the estimated results and in this regard the data collection methodology needs to be streamlined further (Greenberg *et al.* 2007), this ECLAC methodology can standardize the assessment of damages and losses of a disaster, and this standardization not only enables inter-disaster comparison but also encourages the discussion of mitigation, preparedness against disasters and vulnerability analysis of economies based on the common framework. An important next step would be to make the estimation methodology of higher-order effects a part of a standardized methodology – such as the ECLAC methodology – evaluating a more accurate measure of disaster impacts.

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