Long-run Effects of a Disaster:
Measuring the Economic Impacts of the Kobe Earthquake

Yasuhide Okuyama

University of Kitakyushu, and
Center for Urban Earthquake Engineering, Tokyo Institute of Technology, Japan

Abstract:

In 1995, the Great Hanshin-Awaji Earthquake, a.k.a. Kobe Earthquake, occurred in the second largest economic region of Japan, and its economic damages were accounted around 10 trillion yen (Okuyama et al., 1999). A catastrophic event in this magnitude would have surely created some long-run impacts on the regional economy as well as on the surrounding regions. In addition, the recovery and reconstruction activities would have affected the economic structure of the region and interdependencies between regions. While these long-run economic impacts are considered to be sizable, few studies have conducted to empirically measure or estimate such impacts, due to the significant noises in economic data disturbed by macroeconomic fluctuations and to the lack of detailed economic data on the damages and losses caused by the earthquake. At the same time, several cross-country and/or cross-hazard studies, for example Skidmore and Toya (2002) and Cuaresma et al. (2008), have been carried out to analyze whether or not long-run economic implications of disasters actually materialize, while their results are somewhat mixed. This paper presents an empirical investigation of long-run economic impacts of the Kobe earthquake, using econometric models.

1. Introduction

While significant progress has been made in recent years for the economic analysis of disasters, especially in the field of economic modeling for disaster impact (for example, Okuyama and Chang, 2004; and an excellent compilation of related papers by Kunreuther and Rose, 2004). Since the pioneering work by Dacy and Kunreuther (1969), a generalized framework for the economic analysis of natural disasters had been proposed (for example, Sorkin, 1982; and Albala-Bertrand, 1993). The recent advancements have been more toward empirical analysis and toward strategies for modeling extensions and modifications to fit them to disaster situations. This trend is due to improved data availability of disaster damages and losses and to increased multidisciplinary research activities about disasters, including sociology, economics, and psychology. At the same time, the uniqueness of each hazard and of its damages and impacts presents enormous challenges in economic modeling for disaster impact estimates; many issues remain unsolved to this date. In particular, while the domination of flow analysis models employed in the recent research indicates that the impacts of a catastrophic disaster spread over to other regions or nations through expanded trades between regions (Okuyama et al., 1999) and/or sometimes between nations (Okuyama, 2010), some other researchers claimed that the the impact estimation of even a large disaster ends up “insignificant total impacts.” (Albala-Bertrand, 1993)

These arguments should have entertained the measurement of empirically observed disaster impacts; however, few studies, if non-existent, have done such study. Most of those studies estimating the impacts of a particular disaster after its occurrence only assessed the impacts based on the available input data and some economic models, like input-output models and so on. It appears considerably entangled to literary measure disaster impacts based on empirically available macroeconomic data, partly because the disaster statistics are not standardized even among developed countries and are even “somewhat crude measures,” (Skidmore and Toya, 2002) and also because in usual macroeconomic indicators, such as gross domestic products or gross regional products, economic impacts of a particular disaster may be potentially hidden within macroeconomic fluctuations and may be more likely cancelled out between negative impacts from damages and positive impacts of recovery and reconstruction activities. At the same time, empirical measurement of disaster impacts is necessary and critical to improve the accuracy of and assure those impact estimates derived based on economic model, and to understand how a disaster affect economies in terms of readily available data and indices.

In this paper, the economic impacts of the Hanshin-Awaji Earthquake occurred in 1995 are measured empirically using the time-series data and econometric models. Next section briefly summarized the previous studies and findings related to economic impacts of natural disasters. Section 3 presents the econometric models for measurement and sets time frame for the case study. The results of model estimation and the discussions are presented in Section 4. Section 5 concludes this paper with the discussion of findings and some remarks.

2. Economic Impacts of Natural Disasters

Natural disasters can cause physical destructions to built-environment and networks, such as transportation and lifelines, and can also cause casualties and injuries to human lives. These damages are often called *damages*, and are by economics' definition the damages on stocks, which include physical and human capitals. Then, these damages lead to the interruptions of economic activities, such as production and/or consumption, and the losses from business interruptions are called the (*first-order*) *losses* of a disaster. At the same time, there is another term called *higher-order effects*, which take into account the system-wide impact of flow losses through interindustry relationships. (Rose, 2004). And, *total impacts* are the total of flow impacts, adding (first-order) losses and higher-order effects (Okuyama and Sahin, 2009). While some researchers critique that the higher-order effects of disaster are "more a possibility than a reality" (Albala-Bertrand, 1993, p. 104), the estimation of indirect effects has been attempted to "gauge individual and community vulnerability, evaluate the worthiness of mitigation, determine the appropriate level of disaster assistance, improve recovery decisions, and inform insurers of their potential liability" (Rose, 2004, p. 13).

The economic impacts of natural disasters have been studies in various contexts and with a range of time frames. Ex-ante analysis of a hypothetical and/or potential hazard occurrence is often done for the decision-making of preparedness and mitigation strategies; and ex-post analysis of actual hazards and disasters is usually carried out to investigate how the event affected the economy and to examine to what extent the relief efforts by various levels of public sector and by other institutions are needed. The impact studies of natural disasters can be also categorized between short-run impact analysis and long-run impact analysis. Short-run analysis of disaster impact studies intends to estimate the total (flow) impacts of a hazard, defined above, for the period of a few years, and usually employs input-output model, social accounting matrix, or computable general equilibrium model of a particular region, regions, or nation. By its nature, short-run analysis measures only flow changes and can distinguish between the negative impacts based on loss data and the positive impacts from recovery and reconstruction activities, which serve as intense demand injections to the region. Several shor-run analyses of disasters were compiled in Okuyama and Chang (2004) and the methodologies are summarized in Okuyama (2007). On the other hand, long-run analysis of disaster studies aims to measure the effects of damages on stock, which may affect the long-run growth path of the damaged region, resulted from the changes in physical and human capital accumulation level and technology replacement (Okuyama, 2003). The long-run analysis of disasters usually employs econometric models with time series data; and because of it, they cannot distinguish between negative and positive impacts of a disaster and can only derive net impacts. Notable studies in this line include Skidmore and Toya (2002), Rasmussen (2004), and Cuaresma et al. (2008). Comparing to short-run analysis, long-run analyses of natural disasters have been limited, due mainly to the significant noises in macroeconomic data and also to the difference in details and extent of damage data gathered over time.

3. Empirical Models for Statistical Tests and Measurement of the Impact of an Earthquake

We employ the Hanshin-Awaji Great Earthquake (hereafter Kobe Earthquake),which occurred in 1995 at Kobe, Japan, as the case study for empirically measuring the trends of the total impact over time. In doing so, we construct time-series models for City of Kobe and Hyogo Prefecture that includes Kobe.

3.1 Recap of Kobe Earthquake

On January 17, 1995, the worst disaster in the postwar Japan struck the second largest region of Japan—the Kinki region. The City of Kobe and surrounding municipalities experienced massive destruction of houses, buildings, roads, rails, and infrastructure. The magnitude of this event can be shown with the following facts: according to the Hyogo Prefecture Government (2010), the number of casualties was 6,434; the number of injuries was 43,792; the number of evacuees was 316,678 (at its peak); and the number of damaged houses was about 640,000. The direct damages from this Kobe Earthquake were estimated at about 10 trillion yen (US$ 100 billion, as $1=100 yen), equivalent to about 2.1% of Japan's GDP and 11% of Kinki's GRP (Gross Regional Product) at that time. These direct damages were concentrated in the destruction of buildings (including houses and production facilities), transportation facilities, and utilities. Although the damaged area was geographically only 4% of Kinki, it included 15% of the Kinki's population. The damages to capital stocks were estimated about 0.8% of Japan's total (Okuyama et al., 1999).

3.2 Time-Series Models

In order to statistically analyze the total impact of the Kobe Earthquake using the empirical time-series data, a series of time-series models is constructed. The functional form of these models employs an autoregressive-distributed lag model (Hendry, 1995). This is because we are interested in the total impact of an exogenous shock (earthquake) on gross regional product (GRP), a flow measure of the economy, and also because we measure the total impact as departures from the long-run growth path of an economy. The general form of the linear autoregressive-distributed lag model can be written as follows:

$$y_t = \beta_1 z_t + \beta_2 y_{t-1} + \beta_3 z_{t-1} + \varepsilon_t$$

where y_t is the dependent variable, z_t is the independent variable. In this formulation, z_t can be used to control exogenous factors influencing the growth path of y_t. Any miscellaneous influences to y_t will be captured by ε_t, residuals.

Base on this formulation, three models are constructed to statistically measure and test the total impact of the Kobe Earthquake. The first model is for the City of Kobe where the earthquake struck and damaged most severely:

$$KOBE_t = \beta_0 + \beta_1 JPN_t + \beta_2 JPN_{t-1} + \beta_3 KOBE_{t-1} + \varepsilon_t \quad (1)$$

where $KOBE_t$ is the logarithm of GRP per capita for the City of Kobe at t, JPN_t is the logarithm of GDP for Japan at t. JPN_t and its lagged variable intend to control the macroeconomic trends, such as changes in inflation, interest rate, currency exchange rate, economic booms (bubble economy of mid and late 80's) and slumps (after early 90's), etc., of Japan. The second model is for the Hyogo Prefecture, which includes the City of Kobe and other cities and municipalities hit by the earthquake:

$$HYOGO_t = \beta_0 + \beta_1 JPN_t + \beta_2 JPN_{t-1} + \beta_3 HYOGO_{t-1} + \varepsilon_t \quad (2)$$

where $HYOGO_t$ is the logarithm of GRP per capita for the Hyogo Prefecture at t. As seen above, the basic structure of equation (2) is exactly the same as the one of equation (1). One of the assumptions here to use JPN_t and its lagged variable in the right hand side of equations (1) and (2) is that the earthquake did not impact on the Japan's GDP per capita. If it did, the inclusion of JPN_t in the right hand side may lead to the violation of residual distribution assumptions, and the models require some countermeasures, like instrumental variable or others, for estimation. In order for testing whether or not the earthquake impacted on Japan's GDP, the third model is constructed:

$$JPN_t = \beta_0 + \beta_1 JPN_{t-1} + \varepsilon_t \tag{3}$$

This form constitutes a univariate time-series model, a variant of the above linear auto-regressive lag model.

In order to test the hypothesis that the earthquake has some impact on the respective long-run growth path, dummy variables for the year when the earthquake occurred and subsequent years are added to each model.

3.3 Data and Period

The time series data used for the analysis was extracted from the Cabinet Office of Japan's web site[1]. The data are "National Accounts" for GDP, and "Prefectural Accounts" for GRPs. Since the Japanese government started collecting and releasing these statistics using the Systems of National Accounts (SNA) from 1975, the consistent time series data are also from 1975. Thus, the period of analysis for this study becomes during 1975 and 2006, which is the latest data point. Note that all the data that the Japanese government publishes are fiscal year base, and the Japanese fiscal year starts from April and ends at March of the next year. This implies that while the Kobe earthquake occurred in January, 1995, it is within the fiscal year 1994.

All the data are converted to the 2000 constant price. An overview of the trends of three variables, *JPN*, *HYOGO*, and *KOBE* are shown in Figure 1. The Japan's GDP per capita had steadily increased throughout the period, while the rate of growth had slowed down a bit after 1990, when the bubble economy bursted, and has regained some speed after 2002. Hyogo's GRP per capita is mostly lower than Japan's, and the rate of growth appears to parallel to the Japan's till 1993. The fiscal year 1994, when the Kobe earthquake occurred, shows a small dent, whereas 1995 and 1996 show sharp increases. At the same time, after 1997, the Hyogo's trend looks downward, until it turned to upward after 2004. The Kobe's growth path mirrors the Hyogo's, but the values are generally larger than not only Hyogo's but also Japan's. The dent of 1994 for Kobe is much larger than the Hyogo's, and the increase in 1995 is also higher. Unlike Hyogo's, however, Kobe seems

---

[1] http://www.esri.cao.go.jp/jp/sna/toukei.html#kenmin (in Japanese)

not to turn the trend upward until 2006. This may be resulted partly from population changes in the City of Kobe after the earthquake. As displayed in Figure 2, after the sharp decline of its population in 1994, Kobe had struggled to regain its population to the pre-earthquake level until 2002, and the population increase has continued afterwards. On the other hand, the Hyogo Prefecture, including the City of Kobe, also lost their population in 1994, but it was not as sever as Kobe did in terms of the rate of change. Hyogo returned to its previous population level in 1998, and after 2003 their population trends appear flat. With these casual observations, the effects of the Kobe Earthquake are apparent: a sharp negative impact in 1994, positive ones in the following few years, and some slumps afterwards until picking up the paces in the mid 2000s. We estimate these trends statistically in the following section to see whether or not this observation is supported statistically.

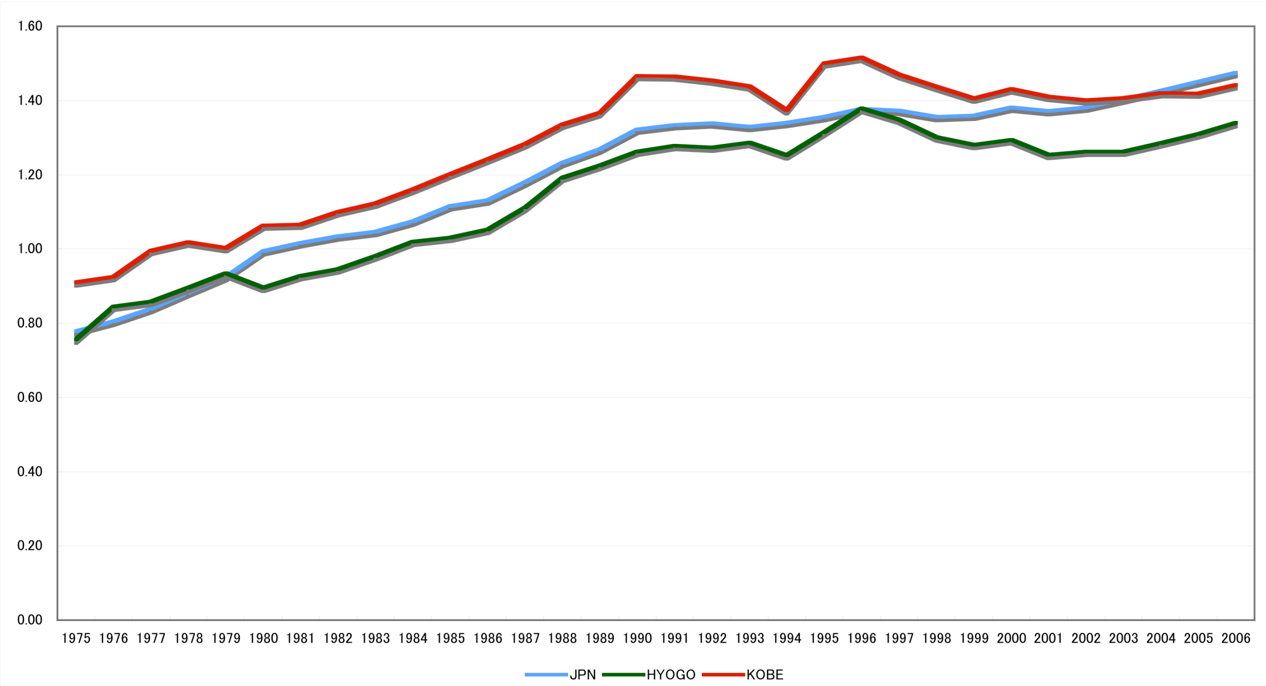

Figure 1. Trends of per capita GDP and GRPs (logarithm)

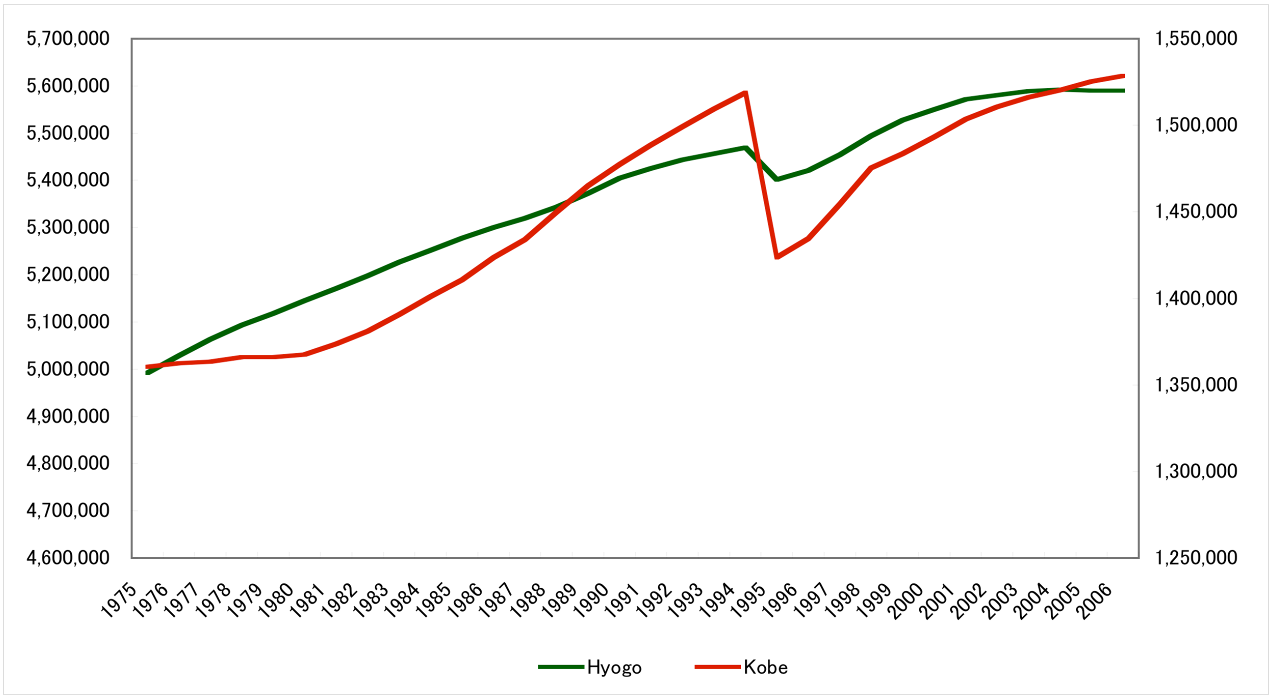

Figure 2. Trends of Population for Hyogo Prefecture and City of Kobe
(right vertical axis for Kobe and left vertical axis for Hyogo)

4. Hypothesis Tests and Analysis

In this section, a series of hypothesis tests are carried out to investigate whether or not the Kobe earthquake's total impact made statistically significant influence on the respective economy's long-run growth path. In addition, with the estimated long-run growth model, the earthquake's total impacts are measured for the period after the occurrence.

4-1. Hypothesis Tests

First, we test the hypothesis whether or not the earthquake had any statistical impact on the long-run growth path of Japanese's economy. Equation (3) above was estimated using the Japan's GDP data during 1976 and 2006[2]. Dummy variables for each year after fiscal year 1994 are included to see their statistical significance. The estimation results are shown in Table 1 below.

---

[2] 1975 data was lost due to the lag structure of the model. Thus, the number of sample for this and subsequent models becomes 31.

Table 1
Significance of the earthquake on GDP (JPN as dependent variable)

Variables Dependent variable	Model 3-1 JPN	Model 3-2 JPN	Model 3-3 JPN	Model 3-4 JPN	Model 3-5 JPN
Constant	1.073*		1.165*	1.194*	1.307**
	(0.566)		(0.582)	(0.585)	(0.602)
JPN (t-1)	0.897***	1.002***	0.888***	0.885***	0.873***
	(0.056)	(0.002)	(0.057)	(0.058)	(0.059)
D94			0.095		0.105
			(0.120)		(0.121)
D95				0.106	0.116
				(0.121)	(0.122)
Number of observations	31	31	31	31	31
R-squared	0.90	0.90	0.90	0.90	0.90
BIC	-20.70	-20.61	-19.32	-19.40	-18.11

Standard error in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant ar the 1% level.

Models 3-1 and 3-2 do not include any time dummy variables. Model 3-1 includes the constant term, β_0 in the above equation (3), and it is barely significant at 10% revel. While R-squared for both models are about the same, the value of BIC for Model 3-1 is slightly better than 3-2's, the models with time dummy variables include the constant, indicating a moving average process. Models 3-3, 3-4, and 3-5 include time dummy variables in different ways[3]. As seen above, however, these time dummy variables for the fiscal years 1994, when the earthquake occurred, and 1995, when the reconstruction activities were at their full swing, are not statistically significant in any of three models. Also, the inclusion of these dummy variables either does not improve the values of R-squared and of BIC. This is an indication that the Kobe earthquake did not influence and did not have any impacts on the long-run growth path of Japan. This also implies that the use of Japan's GDP as an independent variable to control macroeconomic influences in equations (1) and (2) can be rationalized, and does not cause the endogeneity problem.

Secondly, we estimate equation (2) to test the statistical significance of the earthquake impact on the Hyogo's economy. The results are shown in Table 2.

[3] Time dummy variables after the fiscal year 1996 were also implemented and estimated, but they appeared not statistically significant at all, either included separately or all together. Thus, the results for these cases are not included in this table. This tendency also found in the following HYOGO and KOBE cases; therefore, the tables below do not include those results, either.

Table 2
Significance of the earthquake on GRP (HYOGO as dependent variable)

Variables Dependent variable	Model 2-1 HYOGO	Model 2-2 HYOGO	Model 2-3 HYOGO	Model 2-4 HYOGO	Model 2-5 HYOGO
Constant	0.065				
	(0.044)				
JPN	0.602*	0.894***	0.856***	0.911***	0.907***
	(0.316)	(0.250)	(0.250)	(0.244)	(0.239)
JPN (t-1)	-0.354	-0.668**	-0.651**	-0.698**	-0.650**
	(0.335)	(0.263)	(0.261)	(0.256)	(0.251)
HYOGO (t-1)	0.686***	0.760***	0.783***	0.772***	0.725***
	(0.140)	(0.133)	(0.133)	(0.130)	(0.128)
D94			-0.037		
			(0.031)		
D95				0.048	
				(0.030)	
D96					0.057*
					(0.030)
Number of observations	31	31	31	31	31
R-squared	0.97	0.97	0.97	0.98	0.98
BIC	-60.59	-61.13	-60.21	-60.80	-61.40

Standard error in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant ar the 1% level.

The results of Models 2-1 and 2-2 illustrate no statistical significance of constant term; thus the following estimations with time variables do not include the constant term in their models. The estimation with time dummy variables displays the mixed results. The dummy variables for the fiscal year 1994 when the earthquake occurred and the following fiscal year, 1995, are not statistically significant with large margins, while the dummy variable for the fiscal year, almost two years after the earthquake is statistically significant at 10% level with a small and positive coefficient value. The value of BIC with the 1996 dummy variable is marginally better than the model without time dummy variables. The interpretation of these results requires some caution. This anomaly of the fiscal year 1996 may or may not be caused by the earthquake, since we cannot distinguish between the impact from the earthquake and related activities, such as recovery and reconstruction activities, and the other influence specific to the Hyogo Prefecture in the current model structure. The coefficient for the 1996 dummy variable is positive and relatively small. This means the slight increase in the Hyogo's GRP, departing from the long-run growth path. If it were resulted from the earthquake related activities, however, this result implicates that the influence from such activities would have required some time, in this case around two years, to materialize in a larger region, the Hyogo Prefecture. Or, maybe, the total impact from the earthquake would have absorbed in a larger economy, canceling out between the negative impact from destructions and damages and the positive impact of demand injections through recovery and reconstruction activities for the fiscal years 1994 and 1995. Again, it is difficult to conclude how this positive departure in the fiscal year 1996 emerged.

Finally, the results of Kobe's model (1) are summarized in Table 3. Based on the Models 1-1 and 1-2, the constant term is not included in the following analysis, since the constant term in Model 1-1 is not significant and the model without constant term, Model 1-2, has the better BIC. Models 1-3 and 1-4 reveal that the fiscal years 1994 and 1995 are statistically different from the long-run growth model[4]. The coefficients are negative for 1994, when the earthquake occurred, and positive for 1995. These signs are consistent with the trend observation above and with disaster theory that the destructions by earthquake lead to the negative impacts on the economy, while the demand injection of recovery and reconstruction activities can create some positive impacts later on.

Table 3
Significance of the earthquake on GRP (KOBE as dependent variable)

Variables Dependent variable	Model 1-1 KOBE	Model 1-2 KOBE	Model 1-3 KOBE	Model 1-4 KOBE	Model 1-5 KOBE
Constant	0.030				
	(0.056)				
JPN	1.175***	1.291***	1.221***	1.298***	1.231***
	(0.352)	(0.272)	(0.258)	(0.203)	(0.181)
JPN (t-1)	-1.002**	-1.143***	-1.096***	-1.225***	-1.179***
	(0.379)	(0.268)	(0.254)	(0.201)	(0.179)
KOBE (t-1)	0.808***	0.852***	0.877***	0.919***	0.942***
	(0.138)	(0.110)	(0.104)	(0.083)	(0.074)
D94			-0.066**		-0.062***
			(0.031)		(0.022)
D95				0.119***	0.117***
				(0.025)	(0.022)
Number of observations	31	31	31	31	31
R-squared	0.97	0.97	0.98	0.98	0.99
BIC	-57.76	-59.32	-60.00	-67.27	-69.83

Standard error in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant ar the 1% level.

We also tested the Model 1-5, which includes both the dummy variables of 1994 and 1995. The result indicates a better BIC value and the largest R-squared among the models we estimated. All the coefficients become statistically significant at 1% level, and the sign and size of them are consistent with the previous models. Unlike the Hyogo's case, it is less ambiguous that why 1994 and 1995 are dissociated with the Kobe's long-run growth path; these negative and positive departures are considered as the result from the occurrence of the Kobe Earthquake. However, if this is the case, we may encounter two potential problems: 1) the size of negative impact in 1994 is

[4] Dummy variables for all other years after 1996 are not statistically significant.

about a half of the 1995's positive impact, implying that the earthquake created net positive impact, i.e. net gain, in Kobe; and 2) the impacts of the earthquake and of the recovery and reconstruction activities appear lasted only two years. These problems are investigated in the following sub-section by measuring the total impacts of the earthquake using the time-series model.

4-2. Measuring the Effects of the Kobe Earthquake

The total impact of the Kobe Earthquake is measured based on the model estimated above. Usually, the impact of a shock can be derived as the difference between the observed values after the shock and the projected values based on the prior trend to the shock. In order to do so, the prior trend before the Kobe earthquake was estimated, using only the data during 1976 and 1993. The estimation results are summarized in Table 4. Since the constant term in Model 1-6 is not statistically significant, the pr-earthquake trend was projected to the later year with Model 1-7 without constant term. The sign of three coefficients in Model 1-7 are the same as ones in 1-5, while the size of them is smaller in Model 1-7 than the ones in 1-5, indicating a relatively smooth trend. In fact, as seen in Figure 1, the trends of the Kobe's GRP per capita during 1975 and 1993 seem to have narrower fluctuations except the ones after 1990, when the bubble economy was collapsed.

Table 4
Comparison of KOBE Models for Different Periods

Variables Dependent variable Estimation Period	Model 1-5 KOBE 1976-2006	Model 1-6 KOBE 1976-1993	Model 1-7 KOBE 1976-1993
Constant		0.005	
		(0.044)	
JPN	1.231***	1.091***	1.110***
	(0.181)	(0.298)	(0.248)
JPN (t-1)	-1.179***	-0.741**	-0.765**
	(0.179)	(0.343)	(0.267)
KOBE (t-1)	0.942***	0.672***	0.682***
	(0.074)	(0.184)	(0.160)
D94	-0.062***		
	(0.022)		
D95	0.117***		
	(0.022)		
Number of observations	31	18	18
R-squared	0.99	0.99	0.99
BIC	-69.83	-39.05	-40.48

Standard error in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant ar the 1% level.

Based on the above Model 1-7. the projection of Kobe's per capita GRP after 1994 was performed as follows:

$$\left.\begin{array}{ll}\widehat{KOBE}_t^{pre} = \hat{\beta}_1^{pre} JPN_t + \hat{\beta}_2^{pre} JPN_{t-1} + \hat{\beta}_3^{pre} KOBE_{t-1} & \textit{until } 1994 \\ \widehat{KOBE}_t^{pre} = \hat{\beta}_1^{pre} JPN_t + \hat{\beta}_2^{pre} JPN_{t-1} + \hat{\beta}_3^{pre} \widehat{KOBE}_{t-1}^{pre} & \textit{after } 1995\end{array}\right\} \quad (4)$$

A trend line in green on Figure 3 indicates the projection. The differences between the projected trend in green and the observed one (in blue) after 1994 illustrate quite large and increasing gaps. The initial impact (difference) is a negative one in 1994, and followed by positive ones for a few years after 1995, while these positive impacts are short-lived and the gap becomes negative and larger after 1998. The projected trend line based on the pre-earthquake trend becomes upward after 2002, reflecting the uprising trend of Japan's GDP per capita, as shown in Figure 1. This implies that the long-run effect of the Kobe earthquake appears long-lasting with increasingly negative in value.

In order to further investigate the long-run effect, we calculated another projected trend after 1994, based on Model 1-5 derived in the previous section. The structure of Model 1-5 is as follows:

$$\widehat{KOBE}_t = \hat{\beta}_1 JPN_t + \hat{\beta}_2 JPN_{t-1} + \hat{\beta}_3 KOBE_{t-1} + \hat{\beta}_4 D_{94} + \hat{\beta}_5 D_{95} \quad (5)$$

This model is estimated using the data during 1976 and 2006, including the Kobe earthquake and the structural change occurred specific to Kobe after 1994. Two dummy variables in the right hand side of equation (5) can capture the short-run (yearly) impact of the event for 1994 and 1995, but not long-run effect underlying after 1994. In other words, the short-run impact of the event can be separated out by omitting the dummy variables from (5), and the differences between what left and the observed values become the long-run effect of the event. The trend of Model 1-5 without having two dummy variables can be derived as follows:

$$\widehat{KOBE}_t = \hat{\beta}_1 JPN_t + \hat{\beta}_2 JPN_{t-1} + \hat{\beta}_3 KOBE_{t-1} \quad (6)$$

However, the equation (6) includes a lagged variable, $KOBE_{t-1}$, which represents the observed Kobe's GRP values containing the earthquake's influences after its occurrence. This may create a causality problem--for example, the projected 95 value is derived based on equation (6) using the actual 1994 GRP value, $KOBE_{94}$, including the earthquake's influence. Therefore, the projected

1995 value without earthquake influences should not adopt the observed 1994 value; rather, it should employ the estimated 1994 value, $\widehat{KOBE}_{94}$, in equation (6). This modifies the equation (6) as follows after 1995:

$$\left.\begin{array}{ll} \widehat{KOBE}_t = \hat{\beta}_1 JPN_t + \hat{\beta}_2 JPN_{t-1} + \hat{\beta}_3 KOBE_{t-1} & \textit{until } 1994 \\ \widehat{KOBE}_t = \hat{\beta}_1 JPN_t + \hat{\beta}_2 JPN_{t-1} + \hat{\beta}_3 \widehat{KOBE}_{t-1} & \textit{after } 1995 \end{array}\right\} \quad (7)$$

In this way, the short-run impacts of earthquake are excluded in the projected values after 1994. The projected 'no-earthquake' values based on equation (7) are compared with the 'fitted' values derived using equation (5). This is because the residuals of Model 1-5, difference between actual and fitted values, include some other unknown disturbances specific to Kobe than macroeconomic influences controlled by the Japan's GDP trend and the impacts of the earthquake controlled by dummy variables. Hence, the comparison between the 'fitted' values and the projected 'no earthquake' values counts out those unknown disturbances. The trends of observed (labeled as 'actual' and in blue), 'fitted' (in red), projected 'no-earthquake' (in yellow), and 'pre-event' projection (in green) are shown together in Figure 3.

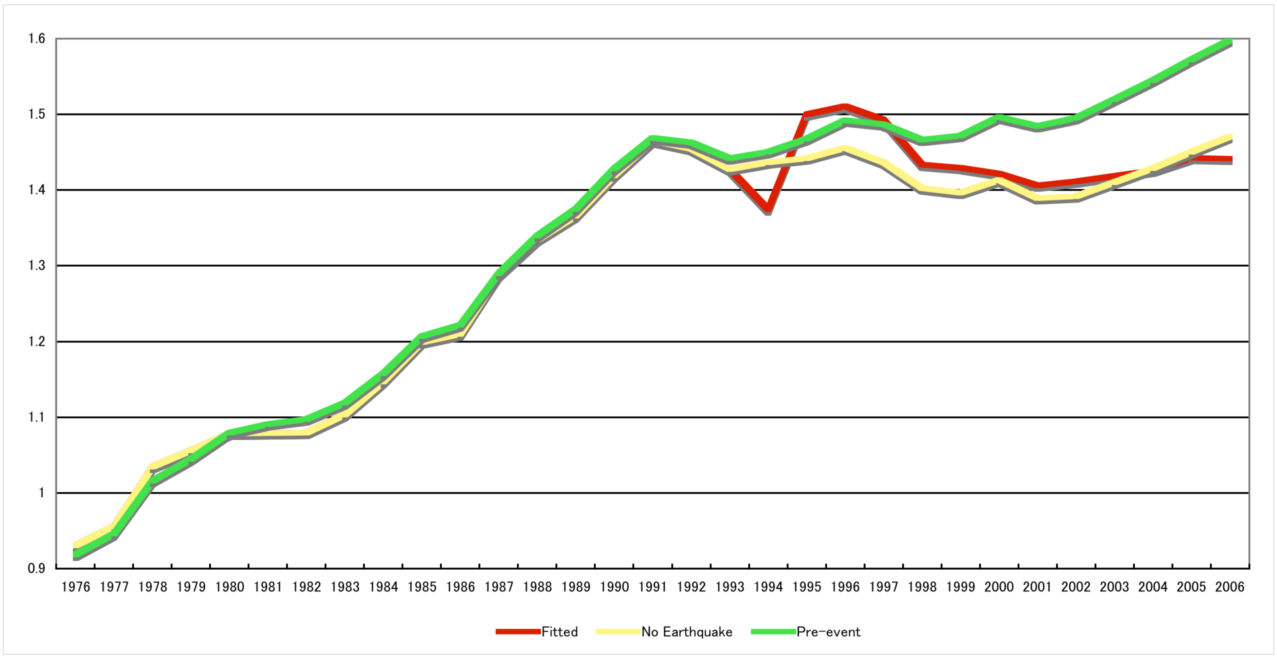

Figure 3. Comparison of Trends with and without the Kobe Earthquake
(logarithm of per capita GRP; in 2000 constant price)

The differences between green trend of 'pre-event' projection and yellow trend of 'no-earthquake' values are evident: while the green trend looks mostly upward progression, the yellow trend is mostly flat with small ups and downs until 2002 and then become an upward direction afterwards. And the trends of these differences are increasing over time, implying the growing tendency of long-run effect. Figure 4 shows the trends of the short-run impact (fitted minus 'no-earthquake values), the long-run effect ('no-earthquake' minus 'pre event' projections), and the total impacts (sum of short-run and long-run effects, equal to the difference between fitted and 'pre event' values). The trend of short-run impact agrees with the results of impact analysis, indicating the initial negative shock followed by positive impact from demand injections for a few years, and gradually returning to the original trend with mostly small difference from the fitted values. However, the trend of long-run effect has quite a distinctive appearance from the short-run's, showing a steady downward departure from the short-run trend, while the trend looks a bit flatter after 2000.

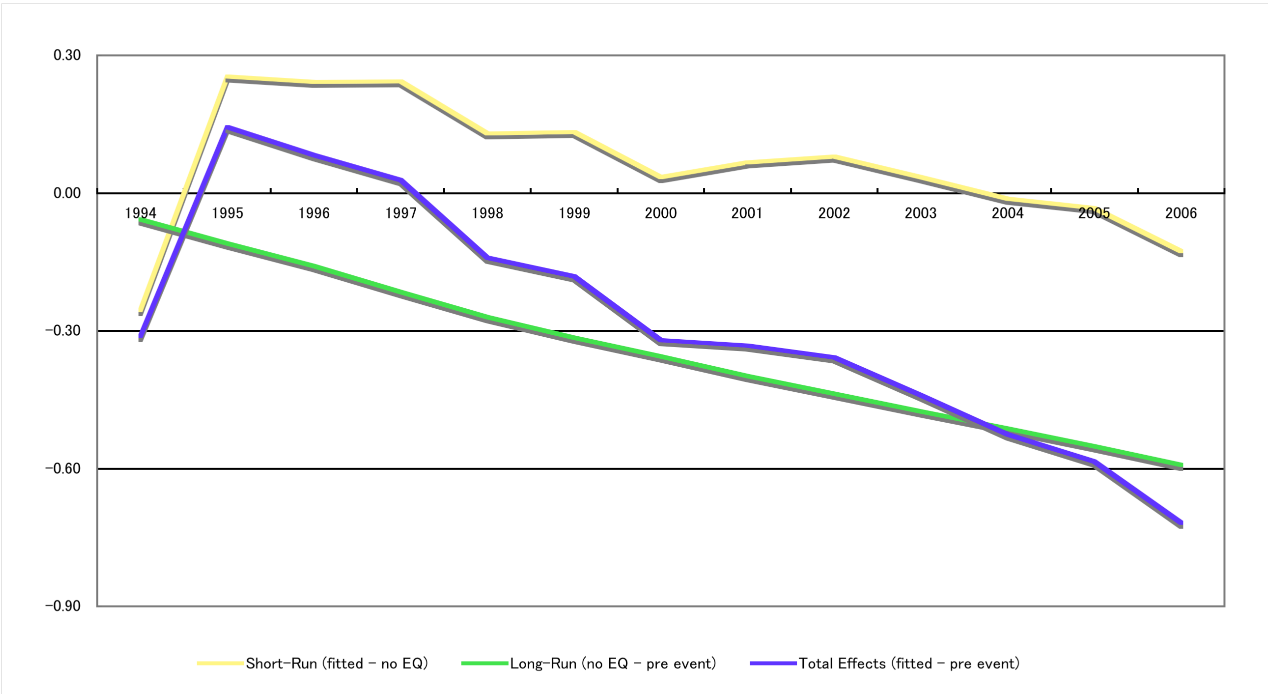

Figure 4. Comparison of Calculated Effects
(values are per capita GRP; million yen in 2000 constant price)

How is the distinction between short-run and long-run effects derived? One explanation is that the 'no-earthquake' model (equation (7)), specifically the coefficients, is estimated using the data including the post-earthquake data of Kobe (1994-2006), while the 'pre event' model does not, employing only the 1976-1993 data. This implies if any structural change specific to the Kobe economy arose after the earthquake, the 'pre event' model cannot take into account--producing only projections based on the past trend, whereas the 'no-earthquake' model did implicitly include such changes. It has been reported that the earthquake's catastrophic destructions resulted some companies' bankrupt, some other companies' moving away from the Kobe area, or some new companies' replacing the old and damaged ones, etc. These alterations in the Kobe economy have surely caused changes in the economic structure and interindustry relationships. In addition, when companies restore their old and damaged equipments and facilities, they might have replaced the damaged ones with newer and more sophisticated ones, causing technology update (Okuyama, 2003). While the the trend of short-run impact looks more plausible and appears consistent with the empirical observations and other studies (for example, Okuyama et al., 1999), the long-run effects, emanating from the resulted structural changes, needs to be taken into account for capturing the full range of the effects. If the trend of total effects in Figure 4 is the case, the effects of the Kobe earthquake should become much larger and severer than what we derived previously with short-run models.

In order to measure the effects of the Kobe earthquake on production in the Kobe economy, the above trends are converted to monetary values of gross regional products. In doing so, the population trend of the 'pre event' case needs to be estimated. Since Kobe experienced a rather rapid population growth during 1981 and 1994 (until just before the event), the projection based on the past trend (from 1976 to 1993), similar to the projection of 'pre event' GRPs, would derive a steadily increasing population (increase of 140 thousand during 1994 and 2006), resulting a considerable growth of GRP. In the mean time, the population trend of national average (Japanese population) was growing around 0.2% annually. Because of these, we consider the projected population based on the past trend is the upper bound, while the estimated population trend using the national growth rate for each year is the lower bound for the 'pre event' case. The calculated trends of GRP and of the event's effect are shown in Figure 5.

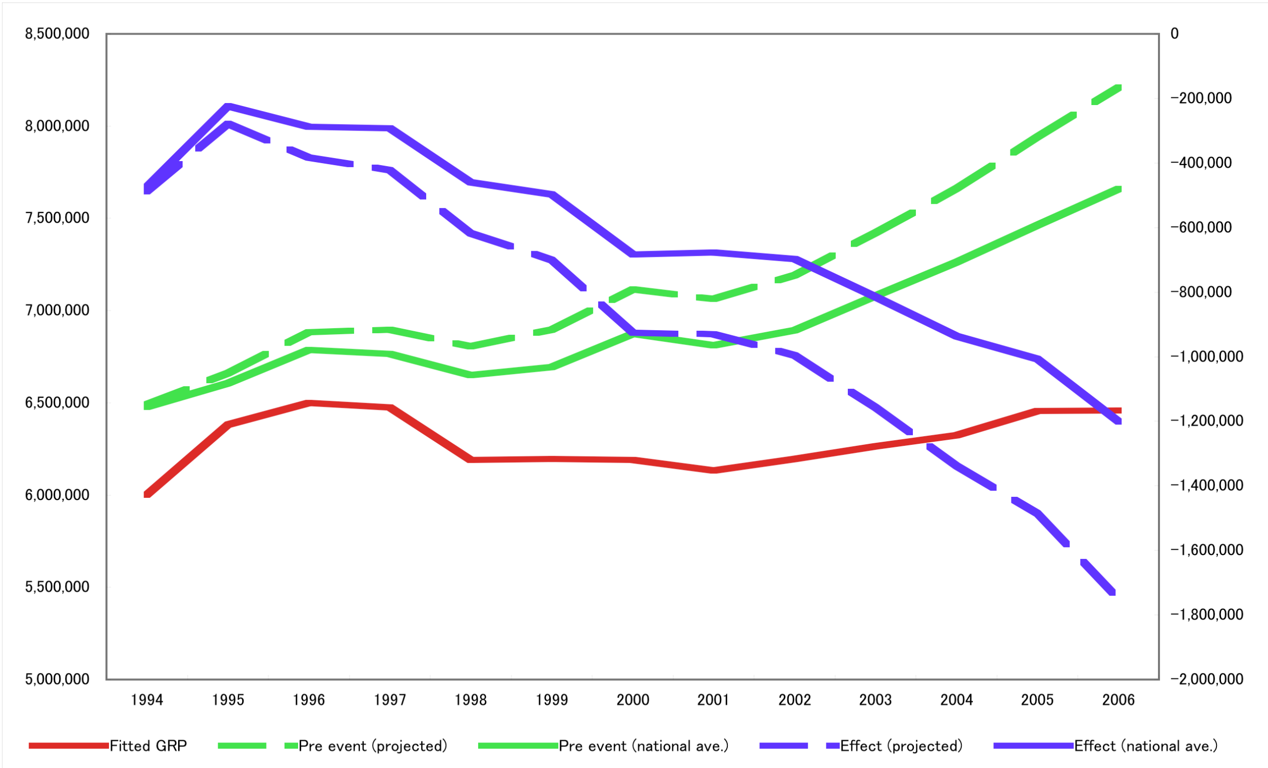

Figure 5. Trend Comparison of GRP and Effects
(right vertical axis for GRP trends and left vertical axis for effect's trends;
million yen in 2000 constant price)

One of the striking results in Figure 5 is that all the effects of the event are negative values, contrary to the many previous studies and to the results in Figure 4 for per capita values, while the shapes of effect's trend for Figures 4 and 5 are quite similar. This may be caused by the changes in population right after the event: since the Kobe's population declined significantly in 1995 and was gradually increasing afterwards, per capita GRP indicating productivity of the region was notably increased due both to the increased production by the demand injections and to the declined population, resulted the positive effects during 1995 and 1997 in Figure 4. These demand injections for recovery and reconstruction narrowed the gap between the actual (fitted) and pre-event forecast for GRP during 1995 and 1997, but the negative effects continued and became increasing larger. The effect ended up about 1.2 to 1.8 trillion yen in 2006. These are 19 to 28% of the pre-event GRP level. Kobe may have been reconstructed, but the regional production level has never been close to the pre-event trends and the effects of the event have been increasing.

5. Analysis of Structural Change in Kobe Economy

To be added later...

6. Conclusions

This study aimed to measure the total impacts of the Kobe Earthquake using the empirical time series data. Based on the econometric analyses, the estimated impacts have the negative initial impact in the year the earthquake occurred, followed by the positive gains resulted from the demand injections for recovery and reconstruction activities, and leading to the negative long-run effects due to the changes in economic structure of Kobe. In addition, the results appear consistent with the conventional disaster theory and other studies. Particularly, the estimation results in Tables 1, 2, and 3 may have proved the Albala-Bertrand's (2007) claim that the economic impact of a disaster may not affect negatively the macro-economy in both short-term and long-term, and rather may concentrate on the local economy. Our results clearly show that earthquake's impacts on the long-run growth path are statistically significant only for Kobe, and not significant with Hyogo or Japan, larger economies.

These results are contradictory to the findings in other studies that analyze interregional impacts of disasters (for example, Okuyama et al., 1999 and Okuyama, 2010), suggesting that sizable impacts spill over to other regions through interregional and interindustry relationships. It turns out that this is exactly the evidence that the measurement of impacts using macroeconomic indicator, i.e. GDP or GRP, can derive only the net impacts, the sum of negative and positive impacts. The larger the economy becomes, the more these negative and positive impacts may offset each other and may become insignificant. For the further and more detailed analysis of the aftermath and how a disaster affects economy, net impact needs to be disaggregated to negative and positive impacts separately. This is because negative impact and positive gain affect the economy in many different ways, and because the extent of their effects may differ by its significance and over space. Careful examinations of these disaggregated impacts will provide important and useful information for decision making on preparedness and mitigation strategies for the future catastrophes and on recovery and reconstruction strategies of the next calamity.

This disaggregation of total impacts to negative and positive ones requires also to consolidate this line of empirical study for the bench mark with other economic evaluation models, such as input-output (I-O) model and computable general equilibrium (CGE) model and the standardized database of damages and losses caused by an earthquake and recovery and reconstruction activities. These evaluation models can estimate negative and positive impacts separately (or all together), and can disaggregate the impacts also over space and/or by income group, for example. At the same time, the accuracy of estimation by these evaluation models depends essentially on the accuracy of the input data--data of damages, losses,and recovery and reconstruction activities. As discussed above, in disaster research community, even the definition of damages and losses are vague. We need a standardized definition and framework to collect the damage and loss data consistently, so that comparative study of disaster impact can be carried out and the historical data can be accumulated. In addition, as Greenberg et al. (2007) suggested, the standardization of evaluation models is also an urgent task. Of course, empirical measurement of economic impacts like this study should be also carried out for major disasters to investigate the long-run effects, which may be quite different from the short-run impact estimation.

References

Albala-Bertrand, J.-M. (2007) "Globalization and Localization: An Economic Approach", in H. Rodriguez, E.-L. Quarantelli, and R.-R. Dynes, eds., *Handbook of Disaster Research*. Springer, New York, 147-67.

Albala-Bertrand, J.M. (1993) *The Political Economy of Large Natural Disasters: With Special Reference to Developing Countries*. Oxford, UK: Clarendon Press.

Cuaresma, J.C., Hlouskova, J., and Obersteiner, M. (2008) "Natural Disasters as Creative Destruction?: Evidence from Developing Countries", *Economic Inquiry*, 46 (2), pp. 214-226.

Dacy , D.C. and H. Kunreuther. (1969) *The Economics of Natural Disasters*. New York: The Free Press.

Greenberg, M.-R., M. Lahr, and N. Mantell, (2007) "Understanding the Economic Costs and Benefits of Catastrophes and Their Aftermath: A Review and Suggestions for the U.S. Federal Government", *Risk Analysis* 27 (1), 83-96.

Hendry, D.F. (1995) *Dynamic Econometrics*. New York, NY: Oxford University Press.

Hyogo Prefecture Government. (2010) S*tatus of Recovery and Reconstruction after the Hanshin-Awaji Great Earthquake*. (in Japanese)

Kunreuther, H. and A. Rose. eds. (2004) *The Economics of Natural Hazards, Volume I & II*. Northampton, MA: Edward Elgar.

Okuyama, Y. (2003) Economics of Natural Disasters: a Critical Review, Research Paper 2003-12, Regional Research Institute, West Virginia University.

Okuyama, Y. (2007) "Economic Modeling for Disaster Impact Analysis: Past, Present, and Future", *Economic Systems Research*, 19 (2), pp. 115-124.

Okuyama, Y. (2010) "Globalization and Localization of Disaster Impacts: An Empirical Examination," *CEFifo Forum*, 11 (2): 56-66.

Okuyama, Y. and Chang, S.E. eds. (2004) *Modeling Spatial and Economic Impacts of Disasters*. New York: Springer.

Okuyama, Y. and S. Sahin (2009) “Impact Estimation of Disasters: A Global Aggregate for 1960 to 2007,” Policy Research Working Paper 4963, the World Bank.

Okuyama, Y., G.J.D. Hewings, and M. Sonis, (1999) "Economic Impacts of an Unscheduled, Disruptive Event: A Miyazawa Multiplier Analysis," in G.J.D. Hewings, M. Sonis, M. Madden, and Y. Kimura (eds.) *Understanding and Interpreting Economic Structure*, Springer-Verlag: 113-144.

Rasmussen, T.N. (2004) Macroeconomic implications of natural disasters in the Caribbean, IMF Working Paper WP/04/224, International Monetary Fund.

Rose, A. (2004) “Economic Principles, Issues, and Research Priorities in Hazard Loss Estimation”, in: Y. Okuyama and S.E. Chang eds. *Modeling Spatial and Economic Impacts of Disasters*, New York: Springer; 13-36.

Skidmore, M. and Toya, H. (2002) “Do Natural Disasters Promote Long-run Growth?” *Economic Inquiry*, 40 (4), pp. 664-687.

Sorkin, A.L. (1982) *Economic Aspects of Natural Hazards*. Lexington, MA: Lexington Books.

United Nations. (2008) *World Economic and Social Survey 2008: Overcoming Economic Insecurit*y. New York, NY: UN.