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The macroeconomic impacts of natural disasters: A case study of Japan

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自然災害の日本経済への影響－1970～98年のパネルデータから

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Abstract

On March 11, 2011, the Great East Japan Earthquake, the fourth largest in recorded history, caused a major tsunami, the size of which strikes only once every few hundred years, claiming around 20,000 lives. After the earthquake, there was debate over the long-term economic impact of natural disasters. For instance, Sawada et al. (2011) argued that disasters cause positive economic growth through the "Schumpeterian" creative destruction process However, even 17 years after the Great Hanshin Earthquake (or Kobe earthquake) in 1995, it is still difficult to say that the economy of the region has fully recovered. Do disasters really have a long-term positive impact on economic growth?

Economic analysis on natural disasters has only just started. Only a small number of papers have done empirical analysis in the past, but the number has been growing over the last few years. There is no consensus as to whether natural disasters have a positive or negative impact. There is a strong need for more empirical studies.

The past literature fails to capture the heterogeneous nature of natural disasters. Most studies use the number of disasters occurring in a country as an explanatory variable. Considering the nature of most disasters, their direct impact is local rather than national. Then, for empirical study, it seems to be more appropriate to use disaggregate data to capture the heterogeneous nature. For example, in the case of Japan, prefectural data on disasters is available. Utilizing these data, we would be able to capture a better picture of the macroeconomic impact.

Further, most studies analyze the relationship between the number of natural disasters and economic growth. Since natural disasters have different effects depending on many various conditions, rather than the number of disasters, it seems more appropriate to use data, such as the total amount of damage and number of victims, to capture the real impact.

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To tackle the above issues, this paper investigates the impact of natural disasters on the growth rate of gross prefectural domestic product, utilizing the 47 prefectural government's unbalanced panel data of Japan for 20 years from 1975 to 1995. The initial empirical study between "average annual growth rate per capita over the 1970-98 period" and "natural log of the number of victims" shows a negative and statistically significant relationship.

Then, in the following detailed study, since the economic model includes a lag variable, to tackle endogeneity issue, this paper employs Blundell-Bond GMM (General Method of Moments) and OLS (Ordinary Least Square) as the estimators. Unlike several past studies indicating a positive long-term effect, this paper found mixed results. In the initial period (0-4 years), the disasters have negative impacts, but then, in the middle term (5-9 years), they have positive impacts, again followed by negative impacts in the long term (10-14 years), but in the very long run (15-20 years), no statistically significant impacts are observed.

This study indicates that recovery and reconstruction policy need to have a long-term view to prevent the positive impacts of the first 5-9 years from becoming negative in the middle term.

Keywords : Growth, Macroeconomic impact, Natural disasters, Panel data analysis, Japan

1. Introduction

On March 11, 2011, the Great East Japan Earthquake, the fourth largest in recorded history, caused a major tsunami, the size of which only once every few hundred years, claiming around 20,000 lives. After the earthquake, there was debate over the long-term economic impact of natural disasters. For instance, Sawada et al. (2011) argued that disasters cause positive economic growth through the "Schumpeterian" creative destruction process. However, even 17 years after the Great Hanshin Earthquake (or Kobe earthquake) in 1995, it is still difficult to say that the economy of the region has fully recovered. Do disasters really have a long-term positive impact on economic growth?

Economic analysis on natural disasters has only just started. Only a small number of papers have done empirical analysis in the past, but the number has been growing over the last few years. There is no consensus as to whether natural disasters have a positive or negative impact. There is a strong need for more empirical studies.

As we will see in detail in the next section, it seems the past literature fails to capture the heterogeneous nature of natural disasters. Most studies use the number of disasters occurring in a country as an explanatory variable. Considering the nature of most disasters, their direct impact is local rather than national. Then, for empirical study, it seems to be more appropriate to use disaggregate data to capture the heterogeneous nature. For example, in the case of Japan, prefectural data on disasters is available. Utilizing these data, we would be able to capture a better picture of the macroeconomic impact.

Further, most studies analyze the relationship between the number of natural disasters and economic growth. Since natural disasters have different effects depending on many various conditions (e.g. the impacts of earthquake are different depend on magnitude), it seems more appropriate to use data, such as the total amount of damage and number of victims rather than the number of disasters, to capture the real impact.

To tackle the above two issues, this paper investigates the impact of natural disasters on the growth rate of gross prefectural domestic product, utilizing the 47 prefectural government's unbalanced panel data of Japan for 20 years from 1975 to 1995.

2. The macro-economic impact of natural disasters in previous research

There are three types of research. The first type of research investigates the macro-economic impact of natural disasters (e.g. Albala-Bertrand 1993a and 1993b, Skidmore and Toya 2002, Kahn 2004, Noy 2009, Noy and Vu 2010, Sawada et al. 2011). Second is micro-economic research, especially disaster impacts on household consumption and the role of insurance in supporting household recovery (Barro 2009, Sawada and Shimizutani 2008). The third type examines specific disaster events, such as the Kobe earthquake or hurricane Mitch in Honduras, focusing on various issues such as the role of social capital (e.g. Horwich 2000, Benson and Clay 2004, Aldrich 2010).

This paper focuses on the first category. There is an ongoing debate, as we will review next, on whether disasters have positive or negative macroeconomic impacts. Some analysis have found that natural disasters are detrimental to economic growth, but others have found them to be a form of "Schumpeterian creative destruction." There is need for more empirical study, and this paper aims to contribute to this debate.

Disasters can be classified into three categories according to the Center for Research on Epidemiology of Disasters: natural disasters, technological disasters (e.g. industrial accidents), and man-made disasters (e.g. war, financial crisis) (CRED 2010). Depending on the study, the definition of disaster is different. This paper focuses only on natural disasters. Macro-economic impacts can be different depending on the time framework (short-term or long-term). This section reviews existing studies classifying these two frameworks. Many past studies use cross-country panel data, which is available from the EM-DAT data. There are very few papers that examine the impact in a specific country (e.g. Noy and Vu (2010) on Vietnam). This paper is one of them.

2.1 Short-term impact of disasters

Studing the economic impact of disasters started with the short-term effect on the economy. The growth model approach to natural disasters was first introduced by Dacy and Kunreuther (1969). They found that GDP tends to increase immediately after a natural disaster.

The analysis is supported by empirical studies by Albala-Bertrand (1993a, 1993b) and Tol and Leek (1999). The former developed an analytical model of disaster occurrence and reaction and collected data on a set of disaster events (28 disasters in 26 countries during 1969-79). Using before-after statistical analysis, he found the following variables increase, GDP, capital formation, twin deficits; and agricultural and construction output. He concludes that capital loss is unlikely to have a profound effect on growth and that a very moderate response expenditure may be sufficient to prevent the growth rate of output from falling[1].

Tol and Leek (1999) found a positive impact on GDP in the short-term following a natural disaster, explaining that the disaster destroys the capital stock and increases the flow of new production.

Chaveriat (2000) and Hochrainer (2009), however, found a mixed pictures. The Chaveriat found a pattern of GDP decreasing in the year of the disaster and then growing in the following two years due to high investment into fixed capital. The paper also argued that the short-term impacts depend on the loss-to-GDP-ratio and whether the disaster was local or country-wide.

Hochrainer studies the counterfactual versus the observed gross domestic product. He also assesses disaster impacts as a function of hazard, exposure of assets, and vulnerability. He found in the medium-term (up to five years) that natural disasters on average can lead to negative GDP growth.

As these empirical studies show, the views on the short and middle-term impacts vary.

2.2 Long-term economic growth

Natural disasters can have long-term effects through a number of channels. Those channels could include: destruction of schools to human capital stock; crowding out effect of reconstruction expenditure on private investment; worsening fiscal balance leading to inflation; environmental damage to agriculture, fishing, and forestry.

[1] He found no significant longer-term effects in developing countries, He concluded that in developing countries, aggregate effects fade away after two years. He, therefore, concluded that natural disaster effects are primarily a "problem of development," but essentially not a "problem for development."

(Rasmussen 2004).

When we discuss long-term economic growth, as Hallegatte and Przyluski (2010) pointed out, it is important to distinguish between direct and indirect losses. The former is damages immediately caused by the disaster, and the latter is damages "that are not caused by disaster itself, but by its consequences" such as reduction in economic output. They insisted that direct losses alone are is not a sufficient indicator of a disaster's seriousness and that it is crucial to include indirect losses. However, there are large uncertainties in estimating indirect disaster cost, and it is impossible to define "the cost" of a disaster as the relevant cost depends largely on the purpose of assessment.

Regarding the indirect cost of natural disasters, Skidmore and Toya (2002) extend the short-term analysis to long-term economic impact by examining the possible linkage among disasters, investment decisions, and total factor productivity. They also examine the long-term impact of natural disasters on growth, seeking whether natural disasters lead to higher rates of economic growth, by encouraging the adoption of new technologies and investment in human capital (endogenous growth framework). They count the frequency of natural disasters from 1960-1990 for each country and pursue an empirical investigation[2].

Their regression found the following: (1) natural disasters do not affect economic growth through physical capital accumulation; (2) the climatic disaster variables are significant and positively correlated with every measure of human capital accumulation. However, the effects of geologic disasters are negative but generally not statistically significant; and (3) climatic disaster variables are positive and statistically significant on the growth of total factor productivity, whereas the coefficients on the geologic disaster variables are negative but statistically insignificant[3].

The findings of Sawada et al. (2011) are in line with Skidmore and Toya (2002), that disasters have a positive effects on economic growth, especially climatic disasters.

They assessed and compared the impacts of various natural and man-made disasters quantitatively with 189 cross-country panel data within the range of 1968 and

2 They have three hypotheses. First, they state that disaster risks could have both positive and negative ambiguous impacts. They argued that the impact could be negative by lowering the expected return on physical capital, but could also lead to increased investment to meet the needs of disaster management. Second, regarding human capital, they follow the endogenous growth theory (Lucas (1988), Azariadis and Drazen (1990)). They argued that a lower expected return on physical capital could lead to increased human capital, then to a higher rate of economic growth. The last factor is the adoption of new technology. The coefficient A determines how much output can be produced with given capitals.

3 Regarding the empirical model, they adopt the Cobb-Douglas production function, then transform it into a growth equation. Y_t denotes total output per capita at time t, h_t is the level of per capita human capital. A is a coefficient that represents the level of technology, and k_t is the per capita capital stock.

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{A}_t}{A_t} + \alpha\left(\frac{\dot{K}_t}{K_t}\right) + (1-\alpha)\left(\frac{\dot{h}_t}{h_t}\right)$$

2001. The empirical findings are as follows. First, in the short-term all disasters had a negative impact on GDP per capita, in particular, climatological disasters, wars and banking crises. Second, in the long-term natural disasters have the largest positive impact on per capita GDP growth. Sawada et al. argued that this counterintuitive positive growth effect was from the "Schumpeterian" creative destruction process[4].

Regarding their findings on long-term impacts, it would be better to read the results carefully. Even if the total estimate of natural disaster impacts in the long-term are positive, different disasters have different impacts. While climatological disasters have a positive impact after 20 years, geophysical disasters have a negative impact in any time framework. This difference needs to be taken into consideration when making long-term recovery plans after a disaster such as the recent Great East Japan Earthquake.

Contrary to the findings of Skidmore and Toya and Sawada et al., the results of the research by Cuaresma et al. (2008) showed a different picture. They argued that the view expressed by Skidmore and Toya on "Schumpeterian" creative destruction is different from that of Schumpeter (1950). Schumpeter's view on creative destruction stressed competition dynamics as the engine behind technological progress, but Skidmore and Toya use the same term as more literal interpretation only on technological replacement after a disaster.

The paper tested the validity of the Schumpeterian view expressed by Skidmore and Toya by means of gravity equation to examine the relationship between technological transfer to and disaster in developing countries in the long run. They found disaster risk is negatively correlated to the extent of R&D content of imports, while only countries with higher level of development (higher level of per capita income) can benefit from technological transfer after a disaster.

Similary, Noy (2009) also found that: (1) the amount of property damage incurred during the disaster is a negative determinant of GDP growth and (2) there is no evidence of any correlation between the disaster population variables (number killed or affected) and GDP growth.

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4 Their economic model is:

$$\Delta \log c_{i,t} = a_o + a_1 \Delta \log y_{i,t} + a_i + a_t + u_{it},$$

where Δ is a first difference operate, c represents the welfare outcome qualified by per capita consumption, and i and t represent country and year. y is per capita GDP, a_i is the country fixed effect, a_t is the time effect, and u is the error term. In this equation, there is a concern about endogenous bias arising from correlation between unobserved consumption growth in the error term and the per capita GDP growth rate. To mitigate this bias, the following first stage regression is used.

$$\Delta \log y_{it} = N_{it}\beta_N + W_{it}\beta_W + E_{it}\beta_E + \gamma_i + \gamma_t + \varepsilon_{it},$$

where N, W, and E represent a set of variables related to natural disasters, wars and conflicts, and economic crises. γ_i and γ_t are country fixed effect and time effect. This equation aims to compare which disaster has the greatest impact on welfare.

He studied the determinants of macroeconomic output decline using a linear regression modeling approach and found that countries with (1) higher literacy rate, (2) better institutions, (3) higher per capita income, (4) higher degree of openness to trade, and (5) higher levels of government spending are better able to withstand the initial disaster shock and prevent further spillovers into the macro economy.

The other empirical study that concludes natural disasters have a negative impact on long-term economic growth is Benson and Clay (2003), while World Bank (2003) and Rasumussen (2004) found that natural disasters have no significant impact on growth.

Rasumussen (2004) studied several Caribbean Islands. He found that developing countries tend to be affected the most by natural disasters. Small island states have a high frequency of natural disasters. The paper identified a median reduction of the growth rate by 2.2 perventage points in the year of the event, but also found that the long term effect of natural disasters is inconclusive[5].

As we review the past literature, there is no consensus as to the macro economic impacts of disasters. There is a strong need to have more empirical studies on the consequences. Accumulating this knowledge will certainly contribute to policy planning for recovery after a disaster.

One of the common problems with the past literature is the treatment of data. Almost all of the past studies use the EM-DAT database collected by the Centre for Research on the Epidemiology of Disasters (CRED)[6]. The EM-DAT database has worldwide coverage, and contains data on the occurrence and effects of natural disasters from 1900 to the present. It seems, however, the past literature fails to capture the heterogeneous nature of natural disasters. Most studies use the number of disasters in a country as an explanatory variable. Considering the nature of a disaster, its direct impact is local rather than national. For example, Okinawa, is far to the south of the Japanese mainland and is prone to have more hurricane than Tokyo. Then, for empirical study, it seems to be more appropriate to use disaggregate data to capture the heterogeneous nature. For example, in the case of Japan, prefectural data on disaster is available. Utilizing these data, we would be able to capture a better picture of the impacts.

Further, most studies like Skidmore and Toya (2002) analyze the relationship between the number of natural disasters and economic growth. Again, natural disasters

5 Rasumussen (2004) provides a box reviewing studies on the macroeconomic implications of natural disasters such as (1) an immediate contraction in economic output, (2) a worsening of external balance, (3) a deterioration in fiscal balances, and (4) an increase in poverty.

6 The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutions and press agencies.

have different effects depending on many various conditions (e.g. an earthquake's magnitude). Therefore, rather than the number of disasters, it seems more appropriate to use data such as the total amount of damage and number of victims to capture the real impacts because the number of people affected indicates the direct impact of the disaster[7].

3. Initial evidence on disasters and economic growth

Before going into detail, this paper will present on initial analysis on the simple relationship between disasters and long-term economic growth for the 47 prefectures of Japan using the same analytical framework of Skidmore and Toya (2002). (Figure 1)

The vertical axis represents the average annual per capita growth rate over the 1970-98 period. The horizontal axis measures the likelihood of a natural disaster. Skidmore and Toya (2002) presented the relationship between the total number of disasters and per capita GDP growth. As discussed above, instead of the number of disasters, in this paper the natural log of the number of victims was used as a better

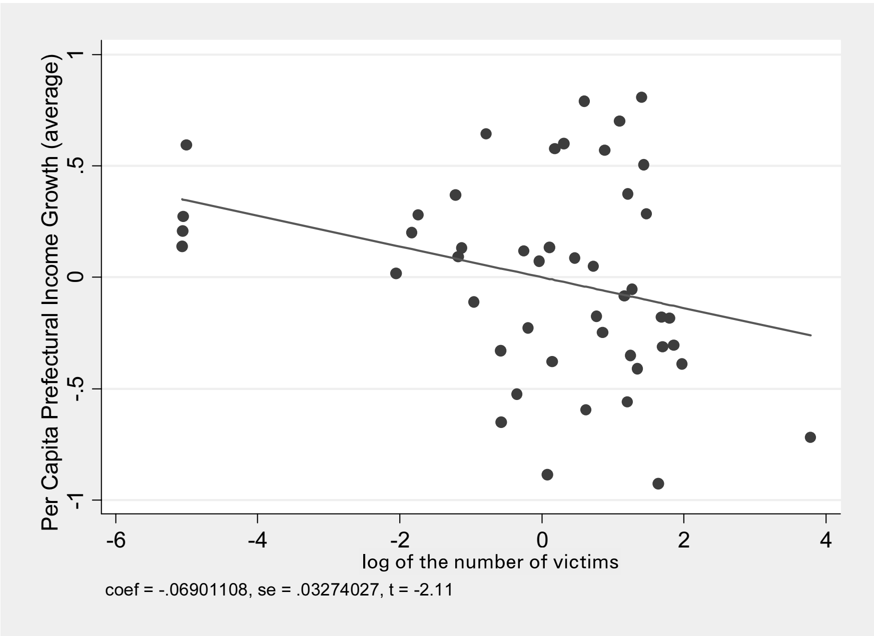

Figure 1. Per capita Prefectural Income Growth and Disaster
(Source: by this author)

7 Noy (2009) disaggregated the EM-DAT data by region. He found that island countries are on average twice as vulnerable to disasters as other countries.

indicator to grasp the impact of a natural disaster[8].

This regression line shows negative and statistically significant relationship between the number of victims and economic growth. The coefficient is -0.069. This seems to be very small, but the absolute value of the coefficient is still bigger than that of Skidmore and Toya (2002), which is 0.0033. With this number they argued that disasters have a positive impact. Naturally, the impact of a natural disaster on economic growth is small, but this estimate is statistically robust, and explains as much as 8.99% of the variation in the growth of per capita GDP.

Table 1 Per capita Prefectural Income Growth and Disasters

Dependent variable: Per Capita Prefectural Income Growth (average)

log victims	-0.069
	[-2.11]**
Constant	7.7936
	[22.49]***
N	47
R-squared	0.0899
Adj-R-squared	0.0696
* p<0.1, ** p<0.05, *** p<0.01	

(Source: by this author)

Table 2 Definitions and sources of variables

Variables	Description	Source
gdp_pc_ave	Per capita prefectural income growth	Cabinet Office, Government of Japan
log victims	Logarithm of the number of victims	Prefectural data on natural disasters, Statics Bureau, Ministry of Internal Affairs and Communications

(Source: by this author)

Table 3 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Gdp_pc_ave	47	7.075348	0.44705	6.148276	7.882759
victims	47	100442.8	211094.6	209.2	1448103

(Source: by this author)

8 This paper uses absolute figures rather than relative figures. The past literature uses both. This is because absolute figure sometimes better capture the real impact of a natural disaster. Furthermore, past studies, such as Skidmore and Toya (2002), examined the impact using both relative and absolute figures, and found the same results each time.

4. Data

For more detailed empirical analysis, this paper used the variables listed in Table 4. The definitions and data sources are also listed in Table 5. As discussed in the literature review section, this paper uses prefectural disaster data.

The database is unbalanced panel data, covering all 47 Japanese prefectures for 20 years from 1975-1995. The maximum number of total damage is huge because of the Great Hanshin earthquake in 1995.

On the other hand, there is no prefectural data available on the number of disasters to actually hit a prefecture classified into geophysical disasters, meteorological disasters, and hydrological disasters. Therefore, unlike other past studies, this paper will not compare the impacts of each class of disaster. Further, past studies differentiated between developed countries and developing countries, but in the case of Japan the gap among prefectures is small, and in many cases people easily move from one prefecture to another. Therefore, this paper will not classify prefectures into income groups.

Table 4 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
grdp_ave	235	7.69E+12	1.1E+13	8.29E+11	8.49E+13
tot_damage~e	235	4.27E+11	2E+12	569000000	2.75E+13
pgex_ave	234	7.15E+10	7.3E+10	2.03E+10	6.83E+11
privtcapst~e	234	1.19E+13	1.51E+13	1.14E+12	1.31E+14

(Source: by this author)

Table 5 Definitions and sources of variables

Variable	Discription	Source
GPDP	Gross prefectural domestic product (at current price)	Cabinet Office, Government of Japan
Tot_damage	Total amount of prefectural damage in Japanese Yen	White paper by the Fire Defense Agency (each year)
Pgex	Prefectural government expenditure	Ministry of Internal Affairs and Communication (Chihou Zaisei Nenpou)
Privtcapstx	Prefectural private capital stock	Takero Doi (2002)

(Source: by this author)

5. Methodology

In order to set the stage for the analysis, this section presents an analytical framework for empirical analysis, which modifies the model of Noy (2009) and Noy and Vu (2010).

$$Y_{i,t} = \alpha_i + \beta Y_{i,t-1} + \gamma Dis_{i,t-1} + \mu^1 X^1_{i,t,.} + \varepsilon_{i,t}$$

$Y_{i,t}$ is gross prefectural domestic product. i is a prefectural index to capture prefecture-specific effects, and t is the time index. $Dis_{i,t-1}$ is the measure for disaster magnitude, estimated by the amount of direct damage. Since disaster affects the following year, this is the disaster lag variable. $X^1_{i,.}$ is control lagged variables (such as *pgex* and *privtcapstx*). This model includes a GDI growth lag.

As Islam (1995) discussed, a time span of just one year (annual data) is too short because the short-term business cycle may influence the estimation results in such brief spans, so he proposed five-year time intervals. Thus, considering the period of 1970-1998, we have six data (time) points for each country: 1970, 1975, 1980, 1985, 1990 and 1995. When t=1975, for example, $t-1$ is 1970. Furthermore, to capture the long lasting effects on the prefectural output, this paper will employ average figures such as 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, and 1995-1998.

The lagged dependent variable might correlate with the error term. If this is the case, the OLS estimate is not consistent. Therefore, we employ two types of estimation method. One is the ordinary least squares (OLS) estimation. The OLS estimators are consistent only when all regressors are not correlated to the error term. In order to correct for the endogenity arising from the presence of a lagged dependent variable, this paper also employs the System General Method of Moments (GMM) estimator (Noy and Vu 2010, Roodman 2003).

Arellano and Bond (1991) developed the "difference-GMM" estimator for dynamic panels. Arellano and Bond estimation starts by transforming all regressors, by differencing, and uses the GMM. This paper employs both one-step estimation and two-step estimation. This paper implements the Hansen test for joint validity of the instruments, and also implement the AR test for autocorrelation.

6. Estimation results: the impacts on economic growth

The OLS and GMM results are presented in Tables 6 to 9. Each table shows the results from a different time lag of *tot_damage_ave*.

As table 6 shows, the F-test result (Prob>F=0.0000) indicates that the fixed effect model is more appropriate than the pooling regression model. Considering this, the Breusch and Pagan test and the Hausman test were implemented. The Breusch and Pagan test result (Prob > chibar2 =1.0000) indicates that the polling regression model is more appropriate than the random-effects model. Then, the Hausman test result (Prob>chi2 = 0.0000) means the fixed-effects model is better than the random-effects model. These three tests confirm that the fixed-effect model is the most suitable model for the OLS estimator. According to the fixed-effect model, the impact is positive after one term (5-9 years)[9]. The result, however, is not statistically significant for the rest of the lag terms.

Now, we need to consider the OLS results, taking GMM estimate results into consideration. The results of the Hansen test and the Arellano-Bond statistics implies the following. First, in most cases, the instruments are orthogonal to the error term and the error term is not auto-correlated in the difference GMM estimation. Second the p value of the Hansen test in Table 9 (lag of three terms) is 1.000. According to Roodman (2007), a high p value is obtained when there are too many instruments, and in that case the Hansen test is weak.

The difference GMM estimation results show a mixed picture of the impacts. In the initial term (0-4 years), the impact is negative. This is understandable intuitively. A natural disaster will certainly have a negative impact on the economy. On the other hand, in the middle-term (5-9 years), the results show positive impacts. There are maybe two possible reasons for this. First, because of the initial negative impacts, any economic recovery made the middle-term result positive. Second, aside from the first point, the recovery effort itself could contribute to this positive result. Further, in the long-term (10-14 years), the impacts again become negative. This negative turn is important Mitigating this negative impact is the key for a smooth sustainable economic recovery. The GMM estimator in the very long-run (15-19) did not have statistically significant results.

9 As I discussed, this paper employ fiver year time interval. Thus, considering the period of 1970-1998, we have five data (time) points for each country: 1970, 1975, 1980, 1985, 1990 and 1995. When t=1975, for example, t-1 is 1970. Furthermore, to capture the long lasting effects on the prefectural output, this paper will employ average figure such as 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, and 1995-1998.

Table 6 no lag on tot_damage_ave

Dependent Variable: grdp_ave

	OLS			Difference GMM	
	Pooled OLS	Random Effect	Fixed Effect	one step	two step
L.grdp_ave				0.7643	0.7702
				[37.02]***	[78.83]***
pgex_ave	-3.6349	-128.881	-3.6349	21.6989	21.4778
	[-0.39]	[-10.07]***	[-0.39]	[1.67]	[5.16]***
privtcapstx_ave	0.7101	1.1018	0.7101	0.0558	0.0572
	[15.97]***	[16.68]***	[15.97]***	[0.80]	[2.53]**
tot_damage_ave	-0.0504	0.3646	-0.0504	-0.0488	-0.0614
	[-0.40]	[3.55]***	[-0.40]	[-1.39]	[-4.57]***
cons	-4.73E+11	3.64E+12	-4.73E+11		
	[-1.43]	[8.66]***	[-1.43]		
N	234	234	234	140	140
R-squared	0.9009	0.9009	0.9386		
Adj-R-squared	0.8997		0.9357		
Sargan Test				Prob>chi2=0.000	Prob>chi2=0.103
Hansen test				Prob>chi2=0.054	Prob>chi2=0.027
AR (1)				0.183	0.000
AR (2)				0.029	0.054
F-test	Prob>F=0.0000		Prob>F=0.0000		
Breusch and Pagan Lagrangian multiplier test test Prob > chibar2 = 1.0000					
Hausman Test	Prob>chi2 = 0.0000				
* p<0.1, ** p<0.05, *** p<0.01					

Table 7 1 term lag

Dependent Variable: grdp_ave

	OLS			Difference GMM	
	Pooled OLS	Random Effect	Fixed Effect	one step	two step
L.grdp_ave				0.7601	0.7559
				[38.29]***	[78.96]***
pgex_ave	-10.2625	-114.4479	-10.2625	24.9171	20.5703
	[-1.06]	[-9.10]***	[-1.06]	[2.23]**	[6.63]***
privtcapstx_ave	0.7429	0.8771	0.7429	0.0404	0.0658
	[15.96]***	[12.54]***	[15.96]***	[0.65]	[3.91]***
L.tot_damage_ave	0.3608	-0.0189	0.3608	0.1163	0.1008
	[2.88]***	[-0.19]	[2.88]***	[2.65]**	[5.09]***
cons	-4.79E+11	6.04E+12	-4.79E+11		
	[-1.18]	[11.95]***	[-1.18]		
N	187	187	187	140	140
R-squared	0.9005	0.5716			
Adj-R-squared	0.8988	0.4184			
Sargan Test				Prob>chi2=0.128	Prob>chi2=0.000
Hansen test				Prob>chi2=0.034	Prob>chi2=0.035
AR (1)				0.000	0.128
AR (2)				0.035	0.034
* p<0.1, ** p<0.05, *** p<0.01					

Table 8　2 terms lag

Dependent Variable: grdp_ave

	OLS			Difference GMM	
	Pooled OLS	Random Effect	Fixed Effect	one step	two step
L.grdp_ave				0.7131	0.7399
				[15.68]***	[21.88]***
pgex_ave	-13.7397	-81.5227	-13.7397	13.0093	10.9553
	[-0.99]	[-8.80]***	[-0.99]	[2.31]**	[2.24]**
privtcapstx_ave	0.7523	0.4735	0.7523	0.0919	0.1037
	[11.30]***	[7.90]***	[11.30]***	[2.50]**	[3.77]***
L2.tot_damage_ave	-11.9183	26.9949	-11.9183	-4.834	-2.8044
	[-0.52]	[2.07]**	[-0.52]	[-2.24]**	[-1.47]
cons	2.54E+11	8.96E+12	2.54E+11		
	[0.37]	[18.53]***	[0.37]		
N	140	140	140	93	93
R-squared	0.887	0.4635			
Adj-R-squared	0.8845	0.1713			
Sargan Test				Prob>chi2=0.000	Prob>chi2=0.000
Hansen test				Prob>chi2=0.017	Prob>chi2=0.017
AR (1)				0.542	0.515
AR (2)				-	-
* p<0.1, ** p<0.05, *** p<0.01					

Table 9　3 terms lag

Dependent Variable: grdp_ave

	OLS			Difference GMM	
	Pooled OLS	Random Effect	Fixed Effect	one step	two step
L.grdp_ave				0.1797	0.136
				[2.81]***	[2.26]**
pgex_ave	-52.0277	-2.1754	-77.0332	1.0124	-6.8839
	[-2.82]***	[-0.67]	[-4.57]***	[0.18]	[-1.57]
privtcapstx_ave	0.9291	-0.0275	0.5827	0.0058	0.0108
	[11.02]***	[-1.33]	[5.83]***	[0.24]	[0.44]
L3.tot_damage_ave	36.4621	5.0357	-19.9716	5.1948	0.7161
	[1.38]	[1.55]	[-1.04]	[1.40]	[0.23]
cons	2.20E+11	1.09E+13	8.61E+12		
	[0.23]	[87.30]***	[6.12]***		
N	93	93	93	46	46
R-squared	0.8745	0.5551			
Adj-R-squared	0.8703	0.048			
Sargan Test				Prob>chi2=0.000	Prob>chi2=0.000
Hansen test				Prob>chi2=1.000	Prob>chi2=1.000
AR (1)				0.806	0.857
AR (2)				0.234	0.091
* p<0.1, ** p<0.05, *** p<0.01					

7. Conclusion

This paper analyses the economic impact of natural disasters by utilizing the 47 prefectural panel data of Japan for 20 years. What can we conclude from the empirical findings above?

The initial empirical study between “average annual per capita growth rate over the 1970-98 period” and “natural log of the number of victims” shows a negative and statistically significant relationship.

Then, in the following detailed study, since the economic model includes a lag variable, to tackle endogeneity issue, this paper employs Blundell-Bond GMM as well as OLS as the estimator. Unlike several past studies indicating a positive long-term effect, this paper found mixed results. In the initial period (0-4 years), the disasters have negative impacts, but then, in the middle-term (5-9 years), they have positive impacts, again followed by negative impacts in the long-term (10-14 years), but in the very long-term (15-20 years), no statistically significant impacts are observed.

This study indicates that recovery and reconstruction policy need to have a long-term view to prevent the positive impacts of the first 5-9 years from becoming negative in the middle-term.

The findings of this paper are specific to Japan. General conclusions can only be reliably derived from a meta-analysis relying on a larger number of similar empirical studies.

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