International Journal of Education, Business and Economics Research (IJEBER)

ISSN: 2583-3006

Vol. 3, Issue.6, Nov – Dec 2023, pp. 131-145

To cite this article: Tam Bang Vu (2023). Natural Disasters And Northeast-Asian Economies. International Journal of Education, Business and Economics Research (IJEBER) 3 (6): 131-145

# NATURAL DISASTERS AND NORTHEAST-ASIAN ECONOMIES

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https://doi.org/10.59822/IJEBER.2023.3611

## ABSTRACT

We examine the multi-façade impact of natural disasters in four Northeast-Asian countries—China, Mongolia, South Korea, and Japan—from 1995 to 2022 the article analyzes three main types of losses—the number of deaths (mortalities), the number of people affected (affected people), and the magnitudes of direct damages in US dollars (direct damages) — caused by technological disasters. The paper looks at three economic sectors— primary, secondary, and tertiary—in relation to disaster losses. The results show that mortalities have adverse effects on the primary and secondary sectors. The impacts on the tertiary sector are mostly not statistically significant. However, the effects of affected people and direct damages on the economy depend on economic sectors and nations in East Asia.

JEL classification: O40, Q54

**KEYWORDS**: Natural disasters, losses, hazards, sectors, Northeast Asia.



## 1. INTRODUCTION

Natural disasters have caused great suffering for people worldwide. In this paper, we investigate aggregated and disaggregated effects of natural disaster son the Northeast-Asian economies. We focus on four Northeast Asian countries: China, Japan, Mongolia, and South Korea, excluding Hong Kong, Macao, North Korea, and Taiwan. We think it is misleading to call Hong Kong and Macao “nations,” whereas data for North Korea and Taiwan are not comprehensive.

The losses caused by natural hazards comprise the number of deaths (mortalities), the number of people affected (affected people), and the magnitudes of direct damages in U.S. dollars (damages).
The paper examines three economic sectors—primary, secondary, and tertiary—and estimates the damage impacts on foregone production for each of the above sectors using a panel dataset from 2000 to 2022. Data on the economic variables are from the World Bank, the U.S. Department of Agriculture (USDA), and the International Monetary Fund (IMF) websites. We first analyze the

determinants of these costs for Northeast Asia as a group. We then compare the economic costs of disasters across nations.

Our paper aims to describe the short-run dynamics of the macro economy following disasters. The long-run analysis raises questions of endogeneity in disaster impacts that are, to no small extent, absent in the short-run. Using national data enables us to analyze the effects of disasters on Northeast Asia countries as a group. At the same time, it also allows us to compare across nations in the region to find their similarities and disparities based on their specific levels of development and openness. The involvement of all disasters helps us draw general conclusions in a realistic scenario, which otherwise might be absent in single-occurrent analyses.

Section 2 discusses the existing research and outlines our goals in this paper. Section 3 introduces the methodology and data. Section 4 analyzes the results. Finally, section 5 concludes the paper.

## 2. EXISTING RESEARCH

In the following section, we review the existing literature on cerning disaster impacts caused by natural hazards.

Northeast Asia has quite a high frequency of hurricanes, floods, and droughts. Although geophysical disasters such as earthquakes, volcanic eruptions, and tsunamis occur less frequently in this region, the magnitude can sometimes be extreme.

Albala-Bertrand (1993) employs a statistical model of disasters. Using a dataset on 28 natural disasters in 26 nations during the 1960-1979 periods, they investigate the macroeconomic effects of these events. Surprisingly, the findings show that there is a correlation between a disaster and an increase in real GDP per capita, capital formation, agricultural production, construction outputs, and foreign reserves. However, disasters cause trade deficits and fiscal deficits, with the trade deficit increasing more than the fiscal one. Also, the effects of natural disasters on inflation and exchange rates are not statistically significant.

Several scholars investigate economic losses due to a specific incident such as Hurricane Iniki, which hit the Hawaiian island of Kauai in September 1992, or Hurricane Mitch in Central America in late October 1998, or the Kobe Earthquake in Japan in January 1995. Vos et al. (1999), Horwich (2000), Narayan (2001), Selcuk and Yeldan (2001), Benson and Clay (2004), Halliday (2006), and Coffman and Noy (2009) belong to this category. They find that disasters have adverse effects on output growth. They then provide policy implications for these individual cases.

Tol and Leek (1999) review the literature from the 1960s to the 1990s and point out that the positive impact of natural disasters on real GDP and sectoral outputs is in line with a required increase in new capital to replace the capital stock destroyed by the disasters. They explain this tendency by showing the incentives for saving and investment to cope with the damage caused by disasters and so implying disaster mitigation and recovery efforts by the governments and private sectors. This additional capital, in turn, fosters output growth after a disaster. This additional capital, called "creative destruction in natural disasters" by Cuaresma et al. (2008), is also evident in various developing and developed countries worldwide.

Skidmore and Toya (2002), as well as Noy and Nualsri (2007), analyze the long-run impact of natural disasters on output growth. Skidmore and Toya (2002) use the occurrence of natural disasters in a cross-sectional dataset adjusted for the specific land size of each nation. Noy and Nualsri (2007) employ a panel dataset with 5-year observations often seen in the contemporary literature that followed Barro (1997). Both papers investigate the long-run trend of output growth defined as the across-nation average and find a positive correlation between disasters and long-run GDP growth.

Rasmussen (2004) examines the outputs of several nations using data for the Caribbean Islands and finds similar results with those of the above papers.

Noy and Vu (2010) conduct a study on the Vietnamese economy for the period 2002-2010. Using sub-regional disaster data from the EM-DAT website, they examine the macro-economic impacts of natural disasters. From their results, disasters that cause more deaths decrease output growth, but disasters that destroy more property and capital seem to increase output growth. They also find that disasters have a different macroeconomic impact in different regions. They believe that these differences might be due to each region's different abilities to generate assistance and utilize funds transferred from the central government.

Vu and Noy (2018) use data for 64 provinces and municipal cities in Vietnam from the Disaster Information Management System (Desinventar.net) to estimate the microeconomic effects on companies' investment and retail sales. The results show that natural disasters hurt retail sales, but disasters appear to increase companies' investment. The findings in Noy and Vu (2010) and Vu and Noy (2018) might be the evidence support the "additional capital" argument discussed earlier in Tol and Leek (1999).

Vu and Noy (2015) analyze the effects of natural disasters on income and investment in China. Using provincial data on sudden events such as hurricanes, floods, and earthquakes, and a three-stage least-squares estimation procedure, they find that the impact of disasters is negative on both per capita GDP and investment when the damage refers to the number of deaths. In contrast, the impact on investment or per capita income appears to be positive when the damage is the number of people affected or the total amount of losses in dollars. The Chinese government's aggressive investment in post-disaster reconstruction might be the answer for these positive results.

Vu et al. (2017) study the correlations among global warming, hurricanes, and sustainable tourism in Northeast Asia. The authors construct a dataset on the damaging impact of cyclones based on the Tropical Best Track Tables and the Annual Tropical Cyclone Reports provided by the United States National Climatic Data Center for 1995-2014. They point out evidence of a correlation between rising temperatures caused by tourist activities and the intensity of cyclones. They also find a two-way causality between hurricanes and sustainable tourism: hurricanes sharply reduce tourist-arrival growth rate, and sustainable tourism reduces the frequency and the magnitude of the hurricanes.

The authors then provide policy suggestions to reduce tourist activities that lead to environmental degradation and subsequently achieve sustainable tourism in the region.

Paxson (1992), Townsend (1994), and Udry (1994) analyze various approaches in which rural households worldwide cope with unexpected income losses due to numerous shocks such as disasters, financial crises, and drastic changes in trade policies. They point out that households differ on how to insure against losses based on their expected income and financial capabilities to buy specific insurance policies. Several authors share the same insurance subject but use a single disaster occurrent as a case study.

Borensztein et al. (2008) discuss the possible insurance needs for Belize government against losses caused by all hazards and accidents. They propose two measures: the first is to establish public precautionary saving programs, and the second is to issue catastrophic bonds. They consider the needs as another motivation to accurately estimate the fiscal costs to reduce the risk of damages caused by an emergency.

Raddatz (2007) analyzes the impact of external shocks on output dynamics using a panel dataset for developing countries. Employing a Vector Auto-Regression (VAR) procedure, a stochastic model capturing the linear interdependencies among multiple time series, the author looks for the effects of these shocks on GDP volatility. The results show that the shocks appear to cause severe GDP instabilities in the short run but do not affect output fluctuations in the long run.

Noy (2009) analyzes the short-run impact of various shocks using a cross-nation dataset. He finds a negative correlation between disaster damages and the economy. He discusses several structural and institutional details that exacerbate the adverse effect. The results show that nations with higher per capita income, higher literacy rates, better institutions, more open trade, higher levels of government spending, and more foreign exchange reserves are better prepared to face the initial disaster shock and mitigate economic after-shocks. He also finds that countries with a lower degree of capital account openness to the outside world but with higher domestic credit levels are more able to mitigate the harmful effects of the shocks.

Regarding governmental expenditures, Fengler et al. (2008) find that public reconstruction costs after a disaster are sometimes more than the original magnitude of capital destruction caused by the disaster. Concerning the governmental budget issue, the impact of a disaster on tax and other revenue sources has often been discussed only qualitatively. Noy and Nualsri (2008) provide a global examination of these effects and point out that the stimulus policies differ significantly among the governments. Most of the time, they depend on the country-specific macroeconomic dynamics after an external shock, the pre-existing conditions of revenue sources, and the government plans.

Anbarci et al. (2005), Kahn (2004), Raschky (2008), and Skidmore and Toya (2007) analyze the institutional and structural aspects of the disaster costs immediately following a disaster. The results show that factors affecting these aspects are quite different for different countries. Similarly, (Cavallo and Noy, 2009) investigate economic development after a disaster of numerous countries and find that the nations differ significantly, depending on the initial level of development and government policies.

Concerning the link between climate changes and the increasing intensity of natural hazards or the increasing damage, Michaels et al. (2006) discover a threshold of sea-surface temperature (SST) when a tropical storm transforms into a hurricane. Specifically, when the SST exceeds 28.25o C, the direct relationship between global warming and the increasing intensity of the hurricanes becomes evident. To verify this hypothesis, Knutson et al. (2007) perform a simulation of these two variables for the Pacific region. They show that the intensity of the Pacific hurricanes appears to increase due to rising temperatures. Bender et al. (2010) apply the above concept for the Atlantic region. They confirm the correlations between global warming and the intensity of the hurricanes.
Chang (2010) investigate disasters in the Northeast Asian region and shows some evidence of the link between high temperature and the rising frequency of the hurricanes (called cyclones in Northeast Asia). Michaels et al. (2006) provide 28.25o C as the threshold for the nexus for the correlation between the two variables. Thus, Chang's finding makes sense because Northeast Asia likely has SST exceeding this threshold. Chang (2010) also analyzes Hurricane Vamei as a case study. Vamei wreaked havoc on Malaysia in December 2006, bringing heavy rainfall. The author believes that this high rainfall results from rising temperatures and recommends several measures to cope with increasing damage caused by global warming.

Mendelsohn et al. (2012) examine the nexus between climate changes and disaster frequencies worldwide. They find that each region's climate pattern determines the increasing frequency of high-intensity hurricanes in selected ocean basins. Estrada et al. (2015) focus on the disaster damage in the North Atlantic basin. They find that levels of disaster damage increase with global warming. They analyze the damage caused by disasters in the United States (U.S.) as an example. Although the government and private sectors in the U.S. are often well prepared for coping with disaster losses, the economy still endures severe damage. The authors estimate that between billion and 14 billion in disaster losses are due to climate changes in 2005 alone.

Vu et al. (2017) study the correlations among global warming, hurricanes, and sustainable tourism in Northeast Asia. The authors construct a dataset on the damaging impact of cyclones based on the Tropical Best Track Tables and the Annual Tropical Cyclone Reports provided by the United States National Climatic Data Center for 1995-2014. They point out evidence of a correlation between rising temperatures caused by tourist activities and the intensity of cyclones. They also find a two-way causality between hurricanes and sustainable tourism: hurricanes sharply reduce tourist-arrival growth rate, and sustainable tourism reduces the frequency and the magnitude of the hurricanes. The authors then provide policy suggestions to reduce tourist activities that lead to environmental degradation and subsequently achieve sustainable tourism in the region.

Tashanova et al. (2020) point out that he COVID-19 Pandemic has been causing significant losses due to governments' decisions to shut down production plants and businesses. Aifuwa et al. (2020) perform a linear regression of a surveyed dataset from private enterprises in Nigeria through questionnaires administered online. The results show that COVID-19 hurts both the financial and non-financial performance of private enterprises in this country. The authors propose that the

Nigerian government include private firms in its stimulus packages to help private sectors run smooth operations once the economy reopens.

## 3. METHODOLOGY

This section presents the data and the model for estimations. We will investigate the aggregate effects of the four countries as a group first and then examine country effects by adding three dummy variables while using the last one as the base country.

### 3.1 The Data

Data on these three types of disaster are from the Centre for Research on the Epidemiology of Disasters (CRED), which provides the data on the Emergency Events Database (EM-DAT) and identifies these events as "disasters" because they are hazards that actually cause harm. We collect data on losses caused by technological disasters in China, Mongolia, South Korea, and Japan are from the EM-DAT website for 1995-2022.

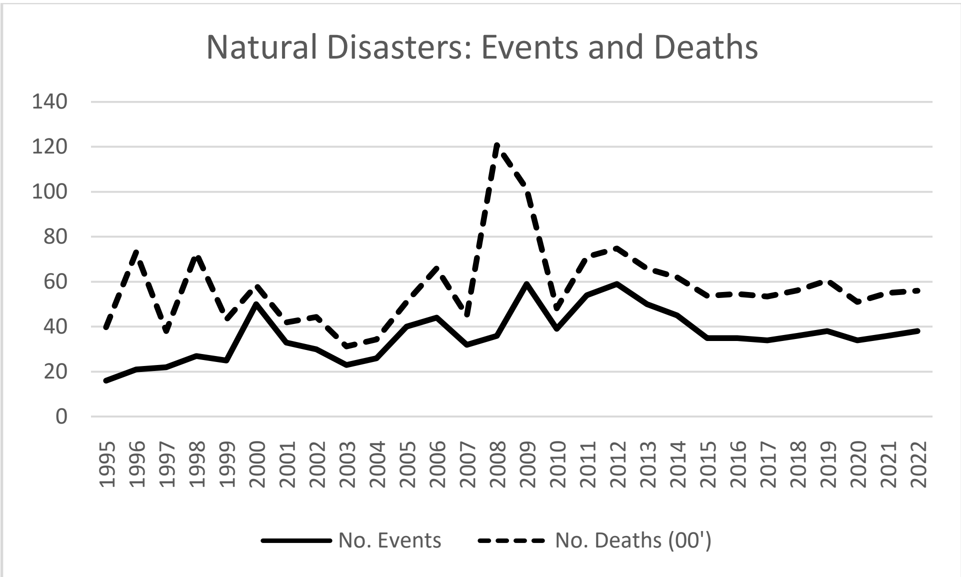


**Figure 2. Northeast-Asian Natural Disasters: Events and Deaths**
Source: Constructed by Tam Vu based on EM-DAT data

Figure 2 discloses that the number of events peaked in 2012, and the number of deaths peaked in 2008. The facts support the hypothesis that there is a direct relationship between global warming and the increasing frequency of natural disasters. They are also in line with *Michaels at al.* (2006) and Knutson *et al.* (2007), who stated that the intensity of natural disasters seems to increase due to rising temperatures.

Figure 3 charts the two series for the affected people and the total damage caused by technology disasters. The figure shows that these series are very volatile, peaking in 2002, and then declining slightly toward 2022.

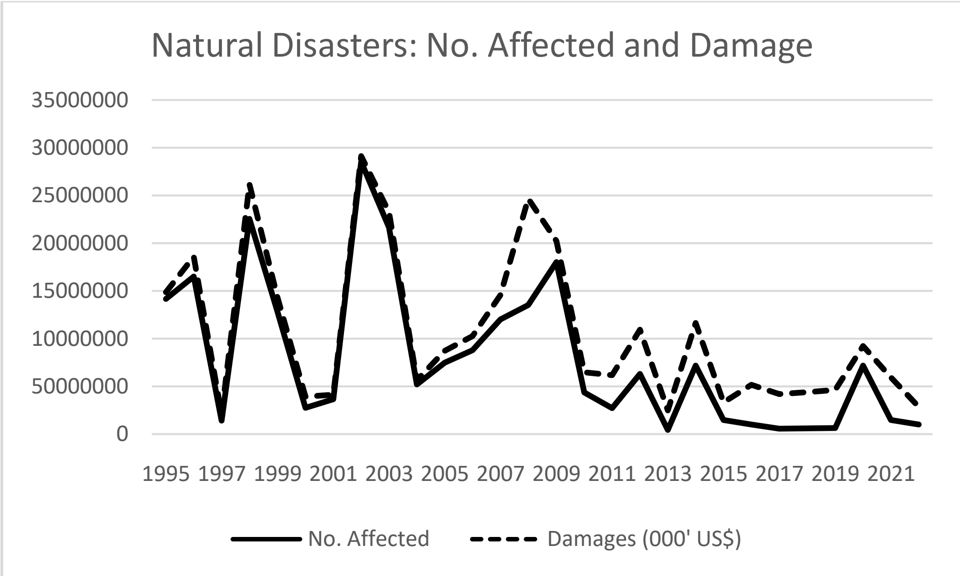


**Figure 4. Northeast-Asian Natural Disasters: Numbers Affected and Damage**
Source: Constructed by Tam Vu based on EM-DAT data

Observing the actual data, we see that the numbers of deaths and total damages were at their highest points due to the 2008 earthquake in Sichuan, China. In contrast, the total of people affected was at their maximum due to the 2002 flood incidents in Shaanxi and Hebei, China. These observations remind us to eliminate the maximum values in the subsequent regressions to avoid biases due to these outliers. With this intention in mind, we proceed to carry out the model-selection process for natural disasters.

Data on the output for three important sectors of the economy – primary, secondary, and tertiary – employment, trade, Foreign Direct Investment (FDI), infrastructure, human capital, and capital formation are from the World Development Indicators posted on the World Bank website. Data on interest rates, exchange rates, GDP deflators, and population are from the U.S. Department of Agriculture (USDA) Website and the International Monetary Fund (IMF) website. We calculate all school enrollments and divide by population to obtain a proxy for human capital in each country. To form a proxy for infrastructure, we calculate the sum of freights from rail lines, roads, and airlines, all in "million ton-km." The term "ton-km" is the total volume measured in metric tons times kilometers traveled. We then multiply all nominal values in U.S. dollars with the GDP deflators and divide by population to obtain real per-capita values.

Table 1 shows that the average GDP composition for the three important sectors in each country during 1995-1922 is quite different among the four countries.

**Table 1. GDP composition for Northeast Asia (%)**

| Country | Primary | Secondary | Tertiary |
|---|---|---|---|
| China | 14 | 40 | 46 |
| Japan | 4 | 26 | 70 |
| Mongolia | 32 | 37 | 31 |
| South Korea | 8 | 29 | 63 |

**Source:** Constructed by Tam Vu based on data from USDA

Since these four countries share similarities in cultural characteristics of Confucianism, high literacy rate, export growth policies, and increasing trade openness, their disparities in GDP composition make our study even more interesting.

### 3.2 The Model

Model (1) is a modified version of the production function in Barro R. (1997) and contains a system of equations to account for the possible feedback effects among the variables:

Model (1) is a general model containing a system of equations to account for the possible feedback effects among the variables:

$$PERCA_{i,t} = \alpha_1 DAM_{i,t} + \sum_{k=1}^{K} \alpha_k DAM_{i,t-k} + \beta X_{i,t} + q_i + s_t + \varepsilon_{i,t} \quad (1.1)$$
$$DAM_{i,t} = \varphi Z_{i,t} + \theta PERCA_{i,t} + \sum_{l=1}^{L} \gamma_l Z_{i,t-l} + v_i + w_t + \omega_{i,t} \quad (1.2)$$

Where *PERCA* is per capita output, which is the ratio of each sector's output to population, and *DAM* the ratio of damage caused by disasters to population. We will eliminate *Equation* (1.2) if our preliminary tests show the assumption of the weak exogeneity of the DAM measures used in Skidmore and Toya (2002) holds for a disaster type, implying there is no feedback effect. X and Z are two vectors of potential control variables that might affect the system's dependent variables. The subscript *i* is country index among EA countries, *t* is the time index measured in years, *k* and *l* are the numbers of lagged periods. The last three variables in each equation are country-specific effect, time-specific effect, and idiosyncratic disturbances.

Performing the Granger-causality test on the model for natural disasters, we find that the t-statistics for *PERCA* and the F-statistic for the joint significance of PERCA's current and lagged values indicate that PERCA does not Granger-cause DAM. To strengthen the Granger-causality test results, we carry out preliminary regressions of the system, including Equations (1.1) and 1.2) using the 3SLS technique. The results confirm the assumption of weak exogeneity for the natural-disaster damage used in Skidmore and Toya (2002). This assumption also appears in Raddatz (2007), Ramcharan (2007), and Noy (2009), who use natural-disaster measures as explanatory variables in different model specifications. Hence, the system-estimation model turns into a single-equation model for natural disasters:

$$PERCA_{i,t} = \alpha_1 DAM_{i,t} + \sum_{k=1}^{K} \alpha_k DAM_{i,t-k} + \beta X_{i,t} + q_i + s_t + \varepsilon_{i,t} \quad (2)$$

We then perform the Variance Inflation Factors (VIF) tests for Model (2). After eliminating variables with high correlations using the VIF test, we performed the RESET tests for omitted variables. The p-value for the model is greater than 0.342, implying that there is no critical omitted variable. The remaining control variables for Model (2) are INT, INF, CAP, EMP, and INI.

The modified Hausman test for endogeneity reveals that CAP is endogenous.
The Dickey-Fuller test shows that the series is stationary, and a Hausman test for model specification shows that a random effect is more appropriate than a fixed-effect model. Hence, the random effect two-stage least square estimation (RE2SLS) is employed instead of the panel VAR procedures. The Akaike Information Criteria procedure shows the model with one lagged value of DAM is the most appropriate. Hence, the empirical model for natural disasters is:

$$PERCA_{i,t} = \alpha_1 DAM_{i,t} + \alpha_2 DAM_{i,t-1} + \beta_1 INT_{i,t} + \beta_2 INF_{i,t} + \beta_3 CAP_{i,t} + \beta_4 EMP_{i,t} + \beta_5 INI_{i,t} q_i + s_t + \varepsilon_{i,t} \quad (3)$$

In cross-sectional regressions, finding an instrumental variable (IV) is exceedingly difficult because the IV must show a high association with the endogenous variable but no or, at the most, only a weak correlation with the error term. The Panel-Data technique can address this problem. In this chapter, we use lagged values of CAP as IVs, and the SGMM discussed above will control for any problem caused by the lagged dependent variables. System (4) presents the reduced forms: the predicted value from the regression of CAP on its own lagged values and all other exogenous variables would be a replacement of CAP in Model (3).

$$CAP_{i,t} = \pi_{11} CAP_{i,t} + \pi_{12} CAP_{i,t-2} + \pi_{13} INT_{i,t} + \pi_{14} INF_{i,t} + \pi_{15} EMP_{i,t} + +\pi_{16} INI_{i,t} + e_{1i,t} \quad (4.1)$$

$$PERCA_{i,t} = \pi_{21} DAM_{i,t} + \pi_{22} DAM_{i,t-1} + \pi_{23} INT_{i,t} + \pi_{24} INF_{i,t} + \pi_{25} CAPH_{i,t} + \pi_{26} EMP_{i,t} + \pi_{27} INI_{i,t} q_i + s_t + \varepsilon_{i,t} \quad (4.2)$$

Where CAPH in Equation 4.2) is the predicted value of CAP obtained by estimating Equation (4.1) using SGMM procedure.

## 4. RESULTS

### 4.1 The Aggregate Results for Northeast Asia as a Group

This section discusses the estimation results for Model (2) introduced in Section 3.
Table 2 reports the aggregate effects of natural disasters on three critical sectors.

We first investigate the aggregate effects of natural disasters on three essential sectors of the Northeast Asian economy as shown in Model (2). We investigate three measures of the disaster damage (DAM): the number of mortalities (MORT), the number of affected people (AFFT), and the magnitude of the total damage in US Dollars (DAMA), all in per capita ratios. The lagged values of MORT, AFFT, and DAMA are MORTL, AFFTL, and DAMAL. All original coefficient estimates have p-values for their t-tests in the respective parentheses. To see the combined effect (COM) of the two periods, we calculate the sum of the current and lagged values of MORT, AFFT, and

DAMA, with p-values for their F-tests of the joint significances also in the respective parentheses. Table 2 shows the results.

**Table 2. Aggregate effects of natural disasters**

Dependent variable: sectoral output per person

| Variable | Primary | Secondary | Tertiary |
|---|---|---|---|
| MORT | -2.45*** (.004) | -1.48** (.032) | -0.16** (.081) |
| MORTL | -0.22* (.067) | 0.03* (.074) | 0.02 (.155) |
| COM-MORT | -2.67** (.035) | -1.45** (.068) | -0.14 (.613) |
| AFFT | -1.69** (.026) | -1.24** (.035) | -0.32 (.219) |
| AFFTL | 0.13* (.054) | 0.12 (.165) | 0.11 (.165) |
| COM-AFFT | -1.56** (.045) | -1.12* (.059) | -0.21 (.172) |
| DAMA | -1.26** (.023) | -1.15* (0.62) | 0.06 (.278) |
| DAMAL | 0.02* (.056) | 0.03 (.313) | 0.13* (.091) |
| COM-DAMA | -1.24** (.035) | -1.12* (.071) | 0.19 (.165) |
| INT | -0.09** (.038) | -0.08** (.049) | -0.15** (.027) |
| INF | 0.14** (.047) | 0.12** (.036) | 0.12** (.025) |
| CAP | 0.31*** (0.009) | 0.34** (.043) | 0.33** (.041) |
| EMP | 0.56*** (.006) | 0.59** (.015) | 0.62** (.043) |
| INI | -0.04* (.062) | -0.08** (.036) | -0.05** (.045) |
| Observations | 116 | 116 | 116 |
| p-value for F-test | 0.007 | 0.004 | 0.000 |
| Average RMSE | 0.103 | 0.175 | 0.142 |
| p-value for AR (1) | 0.214 | 0.312 | 0.412 |
| p-value for AR (2) | 0.398 | 0.265 | 0.327 |
| $Chi^2$-Sargan | 0.327 | 0.296 | 0.256 |
| $Chi^{2-}$Hansen | 0.279 | 0.316 | 0.492 |

Notes: ***, **, * indicate the significant level at 1, 5, and 10 percent, respectively, with p-values in parentheses. The p-value for AR(1) and p-value for AR(2) are from Arellano-Bond test for AR(1) and AR(2) in first differences and second differences, respectively.

This table reveals that the current effect of natural disasters on the primary sector is negative and statistically significant at a one-percent level of significance. The lagged and combined effects are also harmful and statistically significant but at five-percent levels. Specifically, a one percent increase in the ratio of mortalities to population (MORT) in the current period decreases the primary output per person by 2.45 percent, holding other variables constant. The interpretation of AFFT or DAMA is in the same manner. The results for the control variables in the model are as expected.

The effects of natural disasters on the secondary sector are similar to those on the primary sector, except that some of the coefficient estimates are at lower significant levels.

As mentioned earlier, the effects on the tertiary sector are mostly insignificant with two exceptions:

1) The current effect of mortalities on the tertiary sector is negative and significant at a five percent level, emphasizing the importance of preserving human lives.
2) The total magnitude of the damage has a positive effect on the tertiary sector at a 10 percent level of significance, reflecting people's efforts to reinvest after each disaster event as discussed in Section 2. These results also imply that the Northeast Asian nations' shared characteristics—well-disciplined, excellent community spirit, and high literate level—might help them cope well with the disaster damage.

To see the impact of natural disasters on each of the four nations in the Northeast Asian economy, we use China as the base-group dummy and generate the interactions of three other country dummies with each of the damage measures. MORT's interactive variables are MOMORT, KOMORT, and JAMORT, for Mongolia, South Korea, and Japan, respectively. As such, the MORT's coefficient estimates represent the disaster effects for China, whereas the other countries' coefficient estimates reveal the comparative effects on other countries compared to China. The other interactive variables are generated in the same manner. The lagged effects are small and so excluded from our estimations to simplify the interpretations. Table 3 shows the results. Since the number of observations remains the same for all models, we omit this information in this and subsequent tables.

From this table, the orders of the natural disaster influences on the Northeast Asian economies, ranging from the least to the most, are South Korea, Japan, China and, then Mongolia. These results are easy to understand relating to the discussions in Sections 2 and 3. Although the Mongolian government and private sectors have made great efforts to cope with disasters' losses, the lack of resources due to its low GDP per capita hindered a satisfactory result. Japan's decades of stagnation also made its measures against disasters less effective than those of South Korea.

**Table 3. Country-specific effects of natural disasters**

Dependent variable: sectoral output per person

| Variable | Primary | Secondary | Tertiary |
|---|---|---|---|
| MORT (China) | -2.95** (.014) | -1.98** (.039) | -0.19* (.081) |
| MOMORT | -0.52** (.031) | -0.46** (.025) | -0.23 (.127) |
| KOMORT | 1.22*** (.009) | 1.21** (.044) | 1.12** (.034) |
| JAMORT | 0.97** (.027) | 0.83**(.031) | 0.89** (.044) |
| AFFT (China) | -2.39*** (.006) | -1.24** (.035) | -0.66* (.069) |
| MOAFT | -0.34** (.036) | -0.31** (.026) | -0.12* (.058) |
| KOAFFT | 1.06** (.041) | 1.13* (.057) | 0.92** (.034) |
| JAAFFT | 0.82** (.024) | 0.58** (.042) | 0.45** (.027) |
| DAMA (China) | -1.86** (.023) | -1.15* (0.62) | -0.06 (.278) |
| MODAMA | -0.47** (.036) | -0.42** (.034) | -0.07** (.046) |
| KODAMA | 0.78** (.049) | 0.72** (0.22) | 0.97** (.024) |
| JADAMA | 0.43** (.032) | 0.54** (.045) | 0.68** (.042) |
| INT | -0.08** (.032) | -0.09*** (.009) | -0.14** (.028) |

| | | | |
|---|---|---|---|
| INF | 0.15** (.041) | 0.13** (.031) | 0.14** (.045) |
| CAP | 0.30** (.029) | 0.35** (.044) | 0.34** (.048) |
| EMP | 0.59*** (.003) | 0.52** (.018) | 0.62** (.043) |
| INI | -0.03* (.069) | -0.06** (.037) | -0.04*** (.005) |
| p-value for F-test | 0.003 | 0.000 | 0.000 |
| Average RMSE | 0.124 | 0.163 | 0.172 |
| p-value for AR (1) | 0.256 | 0.303 | 0.282 |
| p-value for AR (2) | 0.323 | 0.287 | 0.343 |
| $Chi^2$-Sargan | 0.312 | 0.289 | 0.245 |
| $Chi^{2-}$Hansen | 0.282 | 0.331 | 0.402 |

Notes: ***, **, * indicate the significant level at 1, 5, and 10 percent, respectively, with p-values in parentheses. The p-value for AR(1) and p-value for AR(2) are from Arellano-Bond test for AR(1) and AR(2) in first differences and second differences, respectively.

The interpretation of any coefficient estimate for China is in the same manner as for those in table 2. The coefficient estimates for the interactive variables reported in Table 3 denote their comparative differences from those for China. For example, Mongolia's primary sector reveals that the coefficient estimate of MOMORT is 0.52 percent more negative (with its minus sign) than that for China. The p-value of 0.031 implies that it is at least statistically significant at five percent. The interpretation of the other coefficient estimate is in the same manner. The results for the control variables in the model are as expected.

To interpret the effects of natural disasters on any of the other three countries, we perform the following steps:

1) We calculate the absolute value by summing a coefficient estimate for China and the comparative coefficient estimate for that country reported in Table 3.
2) We then perform an F-test for the statistical significance of this sum.

For example, the absolute value of MOMORT in the primary sector will become – 3.47 (= –2.95 – 0.52). The result implies that a one percent increase in the ratio of the mortalities to population decreases the output per person in Mongolia's primary sector by 3.45 percent. The p-value for the F-test of this sum is 0.035 (not shown on the table but available upon request), indicating the absolute value is at least significant five percent. The interpretation of the other variables' coefficients is in the same manner and yields similar results for the F-tests of joint significances.

## 5. CONCLUSION

This paper analyzes the effects of natural disasters on three important sectors —primary, secondary, and tertiary—in four East Asian countries. We find that the impact of human losses is the most severe for all four countries. The effects of the number of people affected are the second. The adverse effects of the total damages in U.S. dollars are very mild and even favorable for some sectors in certain countries, depending on the level of development, government policies, and private sectoral efforts.

There are differences in losses among the three sectors, with the primary sector suffers the most and the tertiary the least. Since the composition of real GDP (shown in Section 3) are different among the four countries, we observe that Mongolia, the least developed nation with a high percentage of primary sector in its economy, is the most vulnerable to disaster losses. This observation might lead one to conclude that Japan should be the country that suffers the least from disaster losses. Our results reveal that this expectation does not hold. South Korea is a less developed country than Japan (with lower GDP per capita and a higher percentage of the primary sector). However, South Korea has been coping with disasters better than Japan has most of the time.

The less severe or favorable results from all disasters in South Korea compared with those in Japan might come from effective measures carried out by federal and local governments and the public seriousness in fighting against disasters in South Korea.

Additional research can focus on other efforts like public health programs, international assistance, and containment policies, government stimulus plans on various sectors of the economy during and after a disaster. Nations should strengthen coordination and assistance from foreign organizations and international multilateral institutions in planning to forecast the coming and magnitude of a natural disaster, and to prevent or mitigate disaster damages in the future.

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