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TECHNOLOGICAL DISASTERS AND EAST ASIAN ECONOMIES

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ABSTRACT

This paper investigates economic losses caused by technological disasters in four East Asian nations—China, Mongolia, South Korea, and Japan—from 1990 to 2019. 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. We examine three economic sectors—primary, secondary, and tertiary—fighting against these 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.

KEYWORDS: Technology, losses, hazards, sectors, East Asia.

JEL classification: O40, Q54

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1. INTRODUCTION

Technological disasters often take a back seat comparing to natural disasters in the existing literature on the East-Asian economies because the instant impacts are smaller. However, these impacts last much longer and so long-term effects are severe.

The existing literature on disasters also ignores sectoral analyses and skips comparative studies across the nations. The lack of comprehensive research on this topic inspires us to have aggregated and disaggregated looks for the East-Asian economy. We focus on four East 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.

Figure 1 shows a map of the four nations.



Figure 1. Map of East Asia

Source: <https://freeworldmaps.net/asia/eastasia/political.html>

The losses caused by technology hazards, henceforth called technology losses, 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 main sectors—primary, secondary, and tertiary—and estimates the damage impacts on foregone production for each of the above sectors using a panel dataset from 1990 to 2019 for these nations. 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 East Asia as a group. We then compare the economic costs of disasters across nations.

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 and provides the economic implications of the findings.

2. EXISTING RESEARCH

In the following section, we review the existing literature concerning disaster impacts caused by technology hazards.

Cohen (1995) discusses economic losses from coastal oil spills. The author uses a supply-demand general market model and data from various sources on harvest volumes, sale prices, and the Exxon

Valdez oil spill for all jurisdictions in South-central Alaska. The results show that the Exxon Valdez oil spill reduces the provisional harvest volumes significantly due to contamination. Fish prices are also falling due to decreasing buyers' confidence in fish quality. The magnitude of the reduction is different for specific types of fish and ranges from zero to 50 percent compared to the pre-spill forecasting.

Porto and Freista (1996) examine the increasing risk of chemical-industry accidents that affect thousands of people, causing health hazards and environmental damage. The authors review some of the worst chemical disasters in industrializing countries, relating them to data on the Bhopal disaster and Brazil's social and institutional characteristics. They argue that these countries' socio-political and economic structures make them vulnerable to accidents and cause severe impacts when disasters strike. The authors then suggest that only the transformation of local facilities and stronger technical cooperation between international organizations could mitigate these effects.

[Shaluf et al. \(2003\)](#) investigate the causes of technology hazards such as structural collapse, fires, and explosions in Malaysia. They point out the complication characteristics of the Major Hazard Installations (MHIs) system, which provide the regulated threshold of hazardous substances. As a result, the designers and operators of a plant might make errors in safety procedures due to the MHIs' hybridity. These errors are the leading causes of technological accidents, although MHIs' rules are sufficient to prevent disasters. The authors then review four investigation reports regarding major cases in Malaysia as examples.

Similarly, Aini and Ahmadun (2013) investigate technology accidents (called socio-technical disasters in their paper) in Malaysia. The authors analyze six public inquiry reports on technological disasters. They find that the leading causes of these accidents are either unsafe acts or unsafe conditions. They agree with Shaluf *et al.* (2003) that these underlying causes are the possible errors in the pre-disaster period, primarily the failures of organizational and regulatory factors. They encourage the local governments and private sectors to examine their system and pinpoint these possible errors. The related parties can then develop and implement necessary steps to adjust organizational structures, rules, and regulations to decrease future disasters' frequency and severity. Ibitayo *et al.* (2004) present a case study of an industrial explosion in Henderson, Nevada. The authors discuss three main issues:

- The technological disaster's ability to expose otherwise latent matters.
- The extent to which the technical hazard can trigger state significant policy development.
- The lack of coordination among policymakers in managing the accident.

The results show that the industrial explosion in Henderson reveals several public safety issues and motivates the public to pressure the government for significant policy development concerning production safety. Nevertheless, the heated public debates and the policymakers' superfluous activities do not appear effective in igniting acceptable policies. The authors then discuss the need for stronger cooperation between political makers, land-use planning officials, and technological disaster management.

Grimaldi *et al.* (2011) praise the improvements that a modified version of the Robust Satellite Technique (RST) has achieved in detecting and monitoring the recent maritime oil spills. The technique is exceptionally reliable and quite sensitive in detecting the presence of oil spills. The authors present two examples: the oil spill along the coasts of Kuwait and Saudi Arabia in January 1991 and the oil spill during the Lebanon War in July 2006. The authors call for the use of this technique elsewhere for detecting oil spills. They also suggest that the management might use any sensor aboard a geostationary satellite within the oil spill monitoring tools. Combining the two approaches will help integrate the products of optical resolution and high radar resolution systems.

Silei (2014) summarizes the history of management efforts on technological hazards worldwide. The author points out that there was a crucial change in attitude toward these disasters, although they have been in existence since ancient times. This change occurred during the industrializing phase of production when the management of new technologies and various accidental scenarios emerged. The authority started to develop policies to prevent and mitigate the impact of each accident. After World War I, numerous governments drafted specific steps to address technological disasters. By the time World War II ended, firms worldwide had carried out experimental implementations of their rules and regulations. The major accidents of the 1980s called for global cooperation to produce international standards.

[Yuan *et al.*](#) (2015) review more than 2000 dust explosions in the world during 1785-2012. They first analyze descriptive statistics of these events globally, including yearly averages, maximum, minimum, and distributions. They follow by examining the frequencies of accidents and find that nations with higher levels of development have lower numbers of incidents. Data analysis of dust explosions caused by combustible specks of dust in China and the United States serves as examples in their paper. They then classify levels of risks among existing firms based on factors that cause hazards. They conclude the paper by introducing various tools for identifying dust explosions and measures for safety improvement in private firms.

Babrauskas (2016) discusses the danger of using Ammonium Nitrate (AN), a detonable substance, for fertilizer purposes. The author points out that AN has caused uncontrolled fire incidents that have led to numerous accidents worldwide. He then recommends two actions to reduce the frequency of the disasters: developing alternative fertilizer formulations which decrease the probability of igniting an uncontrolled fire that causes detonation and implementing safety codes for production plants and storage facilities. He finally emphasizes the importance of close coordination between policymakers and private firms to address the issue.

The Emergency Care Research Institute (ECRI) Group (2017) provides the top-ten list of health technology hazards. The group points out that avoiding an event or reducing the potential damages depends on the careful management of technologies. This list focuses on the so-called generic hazards resulting from the risks inherent to the use of certain types or combinations of medical technologies. The article emphasizes that the safe use of health technology requires a good knowledge of possible sources of danger or difficulty with those technologies and steps to minimize the likelihood of adverse events.

Halkos and Zisiadou (2020) analyze the environmental damages caused by technological hazards using data from 1900 to 2016. They employ map visualization techniques and several graphical presentations to strengthen their statistical results. They find that the most developed countries have the highest property losses while the least developed countries have the most significant number of deaths. Both effects for the most developed countries and the least developed countries are statistically significant.

Based on the above literature review, a detailed analysis of technology hazards in East Asia is a compelling subject: its nations reveal differences in the levels of GDP per capita, infrastructure, and government involvement. On the other hand, they share similarities in cultural characteristics of Confucianism, high literacy rate, export growth policies, and increasing trade openness. Our paper aims to study the short-run impacts on the economic sectors. Using national data enables us to analyze the technology damages on the East Asian economy as a group. At the same time, it also allows us to compare across nations in the region to find the differences and similarities based on their national specific characteristics.

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 1992-2021.

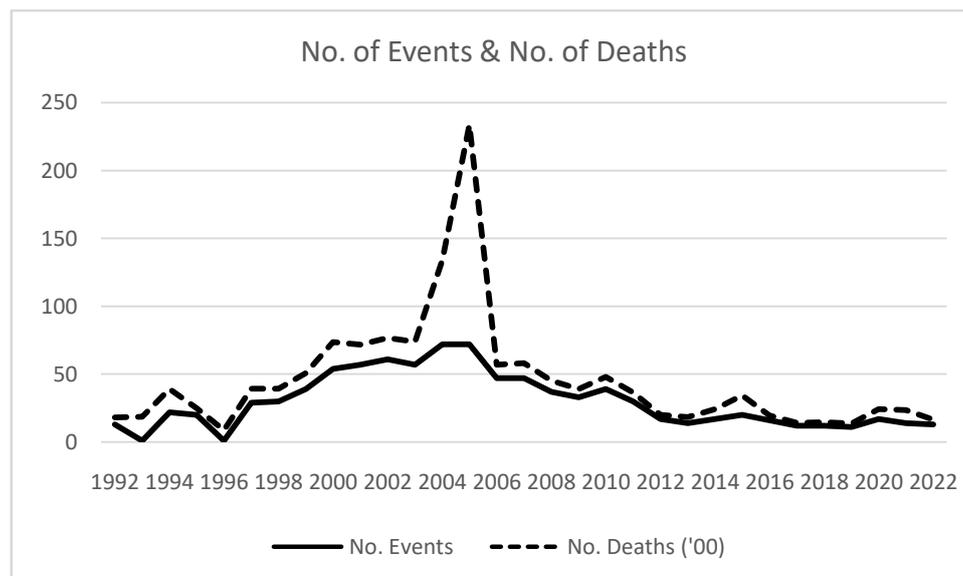


Figure 2. East Asian Technology Disasters: Frequency and Mortalities
Source: Constructed by Tam Vu based on EM-DAT data

Figure 2 discloses that both sets for the number of events and the number of deaths peaked in 2005. Observing the actual data, we see that neither peak is caused by a single significant incident. Instead, the maximum values come from two of the 2005 explosions at coal mines—one in Liaoning, one in Heilongjiang—in China.

Figure 3 charts the two series for the affected people and the total damages caused by technology disasters. The figure shows that these series are very volatile but decline slightly toward 2022.

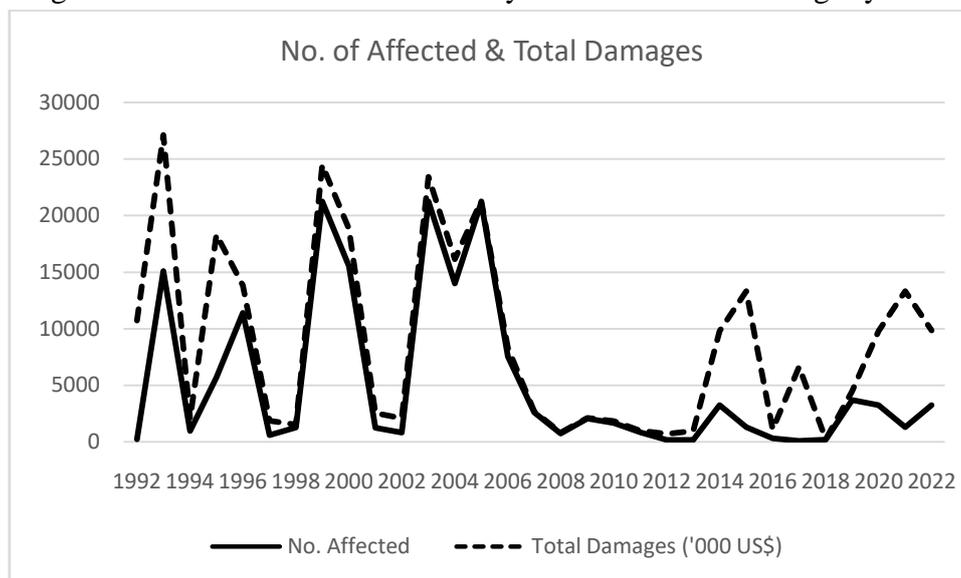


Figure 3. East Asian Technology Disasters: numbers affected and damages

Source: Constructed by Tam Vu based on EM-DAT data

Studying the dataset for the number of people affected, we see that each maximum point comes from a collection of many small values due to high frequency within a year instead of an outlier. There is also no clear peak in the dataset for the total damages. Thus, we keep the whole dataset for the subsequent regressions. For the mortality data in Figure 2, we remove the two outliers in 2005. Since there were 44 explosions in Liaoning Heilongjiang coal mines in 2005, removing these outliers will not affect the average estimate values.

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 1990-1919 is quite different among the four countries.

Table 1. GDP composition for East Asia (%)

Country	Primary	Secondary	Tertiary
China	15	41	44
Japan	5	27	68
Mongolia	34	36	30
South Korea	9	30	61

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:

$$PERCA_{i,t} = \alpha_1 LOSS + \sum_{k=1}^K \alpha_k LOSS + \beta X_{i,t} + q_i + s_t + \varepsilon_{i,t} \quad (1.1)$$

$$LOSS_{i,t} = \varphi Z_{i,t} + \theta PERCA_{i,t} + \sum_{l=1}^L \gamma_l Z_{i,t-l} + v_i + w_t + \omega_{i,t} \quad (1.2)$$

Where *PERCA* is per capita output, which is the ratio of each sector's production to population, and *LOSS* the percentage of a disaster-loss type to population, namely mortalities (MORT), affected people (AFFT), or total damage (DAMA). We will eliminate Equation (1.2) if our preliminary tests show the assumption of the weak exogeneity of the *LOSS* measures used in Skidmore and Toya (2002) holds for a specific type of disaster losses, implying there is no feedback effect. We can also extend the system to more than two equations if there is more than one feedback effect. *X* and *Z* are two vectors of potential control variables that might affect the system's dependent variables. The subscript *i* is the 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.

To investigate the possible feedback effects between *PERCA* and *LOSS*, we apply the Granger-causality test on Model (1) with each dataset. The *t*-statistics for *PERCA* and the *F*-statistic for the joint significance of the current and lagged values of *PERCA* indicate that *PERCA* does Granger-cause *LOSS* for all three types of *LOSS*. The preliminary 3SLS estimation confirms that the assumption of weak exogeneity for the technological-disaster damage used in Skidmore and Toya (2002) does not hold. In other words, there is a two-way causality between *PERCA* and *DAM* in the technological disaster model.

We then perform the Variance Inflation Factors (VIF) tests discussed by Kennedy (2008) for this model. After eliminating variables with high correlations using the VIF test, we perform the RAMSEY RESET tests for omitted variables. The *p*-value for the model is 0.512, implying that there is no critical omitted variable.

The Dickey-Fuller test reveals that the series is stationary, and a Hausman test shows that a random effect is more appropriate than a fixed-effect model. Hence, we employ the random effect three-stage least squares estimations (RE3SLS). The Akaike Information Criteria (1972) procedures also show the model with one lagged value is the most appropriate. Thus, Model (2) for technology disasters is:

$$PERCA_{i,t} = \alpha_1 LOSS_{i,t} + \alpha_2 LOSS_{i,t-1} + \beta_1 INT_{i,t} + \beta_2 CAP_{i,t} + \beta_3 INI_{i,t} + \beta_4 EXC_{i,t} q_i + s_t + \varepsilon_{i,t} \quad (2.1)$$

$$LOSS_{i,t} = \theta_1 PERCA_{i,t} + \lambda_1 HUM_{i,t} + \lambda_2 INF_{i,t} + \lambda_3 INI_{i,t} + r_i + u_t + e_{i,t} \quad (2.2)$$

We must see System (2) satisfy necessary (order) and sufficient (rank) conditions for a simultaneous estimation. At least one exogenous variable in Equation (2.1) is excluded from Equation (2.2) and vice versa, so the order condition holds. Preliminary estimations show that at least one exogenous variable in each equation excluded from the other equation has a nonzero coefficient estimate, so the rank condition holds. Lagged dependent variables again serve as IVs, and the SGMM procedure by Arellano-Bond (1991) helps us control for any problem caused by the lagged dependent variables. System (3) presents the reduced forms so that predicted values from the regression results of System (3) can serve as IVs for System (2):

$$LOSS_{i,t-p} = \pi_{11} LOSS_{i,t-2} + \pi_{12} INT_{i,t} + \pi_{13} HUM_{i,t} + \pi_{14} INF_{i,t} + e_{i,t} \quad \dots\dots (3.1)$$

$$PERCA_{i,t} = \pi_{21} PERCA_{i,t-1} + \pi_{22} EXC_{i,t} + \pi_{23} INI_{i,t} + \pi_{14} CAP_{i,t} + u_{i,t} \quad \dots\dots (3.2)$$

Having estimated System (3) using SGMM procedure to control for the presence of lagged dependent variables, we obtain predicted values of LOSS(LOSH) in Equation (3.1) and PERCA (PERH) in Equation (3.2) as the IVs for System (2). We then estimate System (2) simultaneously using the RE3SLS approach to avoid simultaneity bias.

4. RESULTS

4.1 The Aggregate Results for East Asia as a Group

This section discusses the estimation results for system (2) introduced in Section 3.

Table 2 reports the aggregate effects of technological disasters on three critical sectors. Since we employ 3SLS estimations, we report the results in two panels. Panel (2.1) shows the results for Equation (2.1) with per capita output as the dependent variable, and Panel (2.2) shows those for Equation (2.2) with damage measures as dependent variables. For Panel (2.2), the benchmark explanatory variables are primary production (PRIM), secondary production (SECND), and tertiary production (TERT); all three are in per capita terms.

We investigate three measures of LOSS: 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.

Panel (2.1) reveals that the current effect of technology disasters on the primary sector is negative and statistically significant. Specifically, a one percent increase in the ratio of mortalities to population (MORT) in the current period decreases the primary output per person by 2.21 percent, holding other variables constant. The lagged and combined effects are also harmful and statistically significant. The interpretation of AFFT or DAMA is in the same manner. For example, a one percent increase in the total damage causes a 1.12 percent decrease in primary output per person. The coefficient estimate is statistically significant at a one percent level.

The effects of MORT on the secondary sector are adverse and statistically significant at 5 percent. Those effects on the tertiary sector are also significant but only statistically significant at 10 percent. The results on MORT confirm the importance of preserving human lives.

The impacts of AFFT on the secondary sector are adverse and at least statistically significant at 10 percent. Most of those effects on the tertiary sector are statistically insignificant.

However, the effects of DAMA on the secondary and tertiary sectors are now positive and at least statistically significant at 10 percent. The results might imply that the preparedness against technology disasters in these sectors is more thorough than in the primary sector. They might also suggest that the efforts at reinvestments by private sectors after each disaster in these sectors are more substantial than those in the primary sector, even though the government recovery policies might be the same.

Table 2. Effects of Technology Disasters on East Asia as a Group

Panel (2.1) Dependent variable: Sectoral output per person			
Variable	Primary	Secondary	Tertiary
MORT	-2.21** (.025)	-1.48** (.032)	-0.16* (.079)
MORTL	-0.21** (.049)	-0.03** (.034)	0.02* (.065)
COM-MORT	-2.42** (.031)	-1.51** (.028)	-0.18* (.061)
AFFT	-1.54*** (.005)	-1.24* (.095)	-0.32 (.219)
AFFTL	0.13** (.034)	-0.12* (.065)	0.11 (.165)
COM-AFFT	-1.41** (.042)	-1.36* (.059)	-0.21 (.172)
DAMA	-1.12*** (.009)	0.16*** (0.008)	0.15 (.228)
DAMAL	0.04** (.046)	0.03** (.013)	0.09 (.131)
COM-DAMA	-1.08** (.031)	0.19** (.025)	0.24 (.315)
INT	-0.07** (.032)	-0.09** (.042)	-0.12** (.021)
CAP	0.34** (.022)	0.33*** (.008)	0.35** (.036)
EXC	-0.09** (.023)	-0.10** (.039)	-0.11*** (.007)
INI	-0.07** (.032)	-0.06*** (.001)	-0.05** (.024)
Panel (2.2) Dependent variable: Ratio of damage measure to population			
Variable	MORT	AFFT	DAMA
PRIM	-0.08** (.028)	-0.09** (0.45)	-0.12* (.069)
SECND	-0.13** (.034)	-0.17*** (.001)	-0.19** (.041)

TERT	-0.17*** (.007)	-0.21** (.033)	-0.23** (.022)
HUM	-0.08** (.031)	-0.07** (.018)	-0.09*** (.003)
INF	-0.14*** (.003)	-0.12*** (.005)	-0.13** (.034)
INT	0.07** (.049)	0.03* (.062)	0.09*** (.004)
p-value for F-test	0.002	0.000	0.006
Average RMSE	0.143	0.125	0.162
p-value for AR (1)	0.315	0.276	0.307
p-value for AR (2)	0.323	0.298	0.271
Chi ² -Sargan	0.289	0.235	0.562
Chi ² -Hansen	0.342	0.265	0.376

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.

From Panel (2.2), we see that an increase in per capita output helps reduce the adverse effects of disasters the most in the tertiary sector and the least in the primary sector.

The results for the control variables in the model are as expected.

4.2 Country-Specific Effects

To see the impact of technology disasters on each of the four nations in the East Asian economy, we use China as the base-group dummy and generate the interactions of three other country dummies with each of the loss measures. The interactive variable of Mongolia with MORT is MOMORT, South Korea KOMORT, and Japan JAMORT. The MORT's coefficient estimates represent the disaster effects for China, whereas the other countries' coefficient estimates reveal the comparative impacts on other countries compared to China. The other interactive variables are generated in the same manner. The lagged effects are minor and so excluded from our estimations to simplify the interpretations.

Table 3 reports the country-specific effects for benchmark variables. The control variables' results are quite like those in Table 2 and will be available upon request.

From Panel (3.1), we see that the order of technology-disaster influences on the countries' output per person from the least to the most is South Korea, Japan, China, and Mongolia. One exception is the effect of AFFT on Japan's tertiary sector, which is more favorable than that of South Korea. We also notice that the secondary sector's disaster effects are more severe than those in the primary sector.

Table 3. Country-specific effects of technology disasters

Panel (3.1) Dependent variable: Sectoral output per person			
Variable	Primary	Secondary	Tertiary
MORT (China)	-1.92** (.026)	-1.98** (.039)	0.19** (.021)
MOMORT	-0.41** (.036)	-0.46** (.025)	-0.23** (.027)
KOMORT	1.12*** (.009)	1.21** (.044)	0.42** (.031)
JAMORT	0.75** (.027)	0.83*** (.001)	0.38** (.041)
AFFT (China)	-1.12** (.046)	-1.24** (.035)	0.28** (.019)

MOAFT	-0.34** (.036)	-0.31** (.026)	-0.21** (.034)
KOAFFT	1.06** (.041)	1.13* (.057)	0.24** (.042)
JAAFFT	0.82*** (.004)	0.98** (.042)	0.35*** (.005)
DAMA (China)	-1.06** (.025)	-1.15* (.062)	0.06* (.078)
MODAMA	-0.42** (.027)	-0.42** (.034)	-0.12** (.037)
KODAMA	0.63*** (.041)	0.72*** (.002)	0.56** (.023)
JADAMA	0.46** (.028)	0.54** (.045)	0.43** (.028)
Panel (3.2) Dependent variable: Ratio of damage measure to population			
Variable	MORT	AFFT	DAMA
PRIM (China)	-0.05*** (.009)	-0.06** (.036)	-0.09** (.027)
Mongolia	0.01 (.103)	0.02 (.213)	0.02 (.272)
South Korea	-0.02** (.042)	-0.04** (.024)	-0.07*** (.006)
Japan	-0.01** (.024)	-0.03*** (.007)	-0.06** (.050)
SECND (China)	-0.10** (.034)	-0.14*** (.031)	-0.15** (.041)
Mongolia	0.01** (.035)	0.01** (.037)	0.02** (.039)
South Korea	-0.04*** (.003)	-0.05** (.047)	-0.08** (.024)
Japan	-0.03** (.042)	-0.04** (.046)	-0.08*** (.008)
TERT (China)	-0.12*** (.007)	-0.16** (.033)	-0.19** (.022)
Mongolia	0.03** (.035)	0.04** (.043)	0.05** (.018)
South Korea	-0.07** (.043)	-0.08** (.036)	-0.09** (.034)
Japan	-0.06*** (.004)	-0.07** (.050)	-0.08** (.046)
p-value for F-test	0.009	0.007	0.008
Average RMSE	0.116	0.163	0.243
p-value for AR (1)	0.341	0.243	0.217
p-value for AR (2)	0.198	0.312	0.254
Chi ² -Sargan	0.297	0.365	0.301
Chi ² -Hansen	0.265	0.302	0.294

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 effects on the tertiary sector are primarily positive and significantly so.

Panel (3.2) reveals that the impacts of changes in the output per person of Mongolia's primary sector are not statistically different from that of China since the p-values for MORT, AFFT, and DAMA are greater than 0.10. Note that the p-value of MORT in Mongolia's primary sector is almost significant at 10 percent.

In the secondary sector, an increase in Japan's output per person reduces the total damage by the same percentage as South Korea and even significantly at one percent compared to Korea's five percent significance.

The order reverses back to South Korea as the best country in coping with the disaster damage and Japan as the second-best in the tertiary sector. China once more ranked third and Mongolia the least capable nation in fighting disasters.

5. CONCLUSION

The above estimations yield the following implication. First, Human resource is the most critical factor of production, reflected through the most harmful effects of the disaster mortalities on all three important sectors of the economy.

Second, private companies should cooperate with the government in developing valuable and easy-to-follow rules and regulations to prevent technology accidents. After issuing a viable plan of action concerning safety codes, strict implementation, clear guidance to the managers, and monitoring the workers will reduce incidents and damages. Nations must bring forward any international coordination in reducing the number of accidents and the severity of each incident.

Third, government and private researchers must have better cost-benefit evaluations of preventive and mitigation programs followed by accurate estimates of a disaster's likely financial costs. Currently, policies are somewhat ad-hoc instead of based on the economic principle of maximizing public benefits or minimizing all costs.

Last, the availabilities of actual data are crucial in disaster prevention and mitigation. Governments and private institutions must improve their data collection and processing to fathom the disaster losses and develop appropriate measures to help a nation recover according to each disaster's impact on the economy.

In brief, this paper focuses on the effects of technology 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.

There are also new measures enhancing the active positions in fighting the disaster losses. 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 prevent a human-made or hybrid disaster, to forecast the coming and magnitude of a natural disaster, and to prevent or mitigate disaster losses in the future.

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