The seal of the University of Hawaii is a large, light green watermark in the background. It features a central torch with a flame, set against a circular background with a grid. The text "UNIVERSITY OF HAWAII" is at the top, "U A MAU KE EA O KA 'ĀINA I KA PONO" is at the bottom, and "MĀLAMALAMA" and "1907" are in the center.

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Natural Disasters and Economic Policy
for the Pacific Rim

by
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Abstract: We survey the history of natural disasters in the Pacific Rim, and the region's vulnerabilities. We also discuss the extent of our knowledge about the short- and long-term economic impacts of these disasters, and prevention, mitigation and post-disaster policies that may be implemented.

JEL Classification: O11, O40, Q54

Keywords: Natural disasters, Climate change, Growth, Economic impact, Pacific Rim

1. Disasters in the Pacific Rim

Many of the most destructive natural disasters of the past few decades occurred in Pacific Rim countries. During the past century for example, the most lethal earthquake (Tangshan, China, 1976), the most lethal tsunami (Aceh, Indonesia, 2004), and some of the most lethal storms and floods have all occurred in Asia bordering the Pacific.¹ Other catastrophic natural disasters, like the exceptionally strong earthquake in Chile in 1960 that generated a Pacific-wide tsunami, the most destructive natural disaster in modern history in terms of destroyed property (Tohoku, Japan, 2011), the Mexico City earthquake of 1985, the Managua earthquake of 1972 and the periodic hurricanes that dramatically impact Honduras and El Salvador, are all examples of how natural disasters play a significant part in the economies of almost all the Pacific Rim countries.

Even without these catastrophic infrequent events, some Pacific Rim countries are buffeted by repeated and very frequent natural disasters (e.g., the Philippines experiences, on average, 5.8 destructive tropical storms annually). The countries of the Pacific Rim, as well as the volcanic islands and coral atolls of the Pacific Ocean itself, are also some of the most vulnerable to future disasters that may be associated with the changing climate and most are within the Ring of Fire - the globally most geologically active region.²

¹ The five most lethal events in Pacific Rim (1970-2008) were all initiated by earthquakes: China 1976, Indonesia 2004, China 2008, Peru 1970 and Guatemala 1976. In these five events, 585,000 people died.

² The Ring of Fire is an inverted U-shape region, whose Western tip is New Zealand. The region then encompasses the archipelagos of Indonesia, the Philippines, and Japan, the Russian Far East, the Aleutian Islands, Alaska, and then down the Western Coast of the Americas all the way to Tierra Del Fuego at the very southern tip of the continent. This region experiences by far most of the volcanic activity and earth movements recorded worldwide.

Robert Barro has argued that the infrequent occurrence of economic disasters has much larger welfare costs than continuous economic fluctuations of lesser amplitude (Barro 2006 and 2009). He estimated that for the typical advanced economy, the welfare cost associated with large economic disasters such as those experienced in the twentieth century amounted to about 20 percent of annual GDP, while normal business cycle volatility only amounted to a still substantial 1.5 percent of GDP. For developing countries, which usually suffer from more frequent natural disasters of all types, and of even greater magnitude than in advanced economies, these events have an even greater effect on the welfare of the average citizen.

Understanding the history of disasters in the Pacific Rim, their impact on development, on the spatial evolution of income, and the risks that the Pacific Rim region faces in terms of future events and their likely consequences all seem to be important components of an understanding of the region's economy. After all, the disruptions in many multinationals' supply chains that occurred after the 2011 Tohoku earthquake/tsunami demonstrated persuasively the potentially global impact of these types of disasters, an impact which is especially acutely felt in the Pacific region – whose countries' level of trade integration within the global economy is very high.

I employ a typology of disaster impacts that distinguishes between direct and indirect damages. Direct damages are the damage to fixed assets and capital (including inventories), damages to raw materials and extractable natural resources, and of course mortality and morbidity that are a direct consequence of the natural phenomenon. Indirect damages refer to the economic activity, in particular the production of goods and services, that will not take place following the disaster and because of it. These indirect damages may be caused by the

direct damages to physical infrastructure or harm to labor, or because reconstruction pulls resources away from the usual production practices. These indirect damages also include the additional costs that are incurred because of the need to use alternative and potentially inferior means of production and/or distribution for the provision of normal goods and services (Pelling et al., 2002).

These costs can be accounted for in the aggregate by examining the overall performance of the economy, as measured through the most relevant macroeconomic variables, in particular GDP, the fiscal accounts, consumption, investment, and, especially important for the comparatively globalized countries of the Pacific Rim, the balance of trade and the balance of payments. These costs can also be further divided, following the standard distinction in macroeconomics, between the short run (up to several years) and the long run (typically considered to be at least five years, but sometimes also measured in decades). I use these distinctions in the discussion that follows.

2. Data on Disasters in the Pacific Rim

2.1 The Past

The Emergency Events Database (EM-DAT), maintained by CRED at the Catholic University of Louvain, is the most frequently used resource for disaster data.³ EM-DAT defines a disaster as an event which overwhelms local capacity and/or necessitates a request for external assistance. For a disaster to be entered into the EM-DAT database, at least one of the following criteria must be met: (1) 10 or more people are reported killed; (2) 100 people are reported

³ The data is publicly available at: <http://www.emdat.be/>

affected; (3) a state of emergency is declared; or (4) a call for international assistance is issued. Natural disasters can be hydro-meteorological, including floods, wave surges, storms, droughts, landslides and avalanches; geophysical, including earthquakes, tsunamis and volcanic eruptions; and biological, covering epidemics and insect infestations (these are much less frequent). The data report the number of people killed, the number of people affected, and the amount of direct damages in each disaster. Since biological events are much more anthropogenic, and the data collected on them are much less reliable; we will not discuss these in what follows.

We present disaster data for all the countries of the Pacific Rim, but exclude the small island-nations of the Pacific itself.⁴ The disaster-types we include are earthquakes, temperature extremes, floods, storms, volcanic events, and wildfires.

In the Pacific Rim, natural disasters, as defined in the EM-DAT database, are common events. Overall, we have some data on 3221 natural disaster events in the Pacific Rim for 1970-2008, but many of these do not include the full data on mortality, the number of people affected and property damages; and many are quite small and would have no large economic consequences. The five worst disasters (in terms of the three measures of disaster magnitude) are given in table 1. In the Pacific Rim region, the five disasters with the highest mortality are all earthquakes, with a total of almost 600,000 people killed. In terms of people affected, floods in China dominate the list, although aggregate mortality for these is fairly low (about 10,000 people in total). Hurricane Katrina in the U.S., and the Kobe earthquake in Japan were by far the costliest disasters (in terms of damage to infrastructure) until the March 2011

⁴ The following are included: Australia, Canada, Chile, China PR, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Indonesia, Japan, Korea (South), Malaysia, Mexico, New Zealand, Nicaragua, Panama, Papua New Guinea, Peru, Philippines, Russia, Taiwan, United States, and Vietnam.

earthquake/tsunami in Tohoku, which dwarfs both disasters with damages estimated at 300 billion US\$, more than twice as much as the amount estimated for Katrina.

A list of the three worst disasters for each Pacific Rim country and their aggregate toll (in terms of mortality), provided in table 2, provide some limited insight into what are the vulnerabilities of each country both in terms of the kinds of disasters that are likely to wreak the most damages and how big these damages are likely to be. Not surprisingly, there are very few Pacific Rim countries for which earthquakes are not part of the most dangerous disaster list: Australia, Canada, Honduras, Korea, New Zealand, the U.S. and Vietnam. But, after the 2011 earthquake in Christchurch, New Zealand can no longer be considered relatively earthquake safe, and most predictions are that a large West Coast quake in the U.S. will also dwarf any impact from other American disasters. Thus, past recent experiences is only of limited use in assessing future vulnerabilities in the face of catastrophic but rare events.

The last column in table 2 measures vulnerability differently, by counting the number of large events in the past 40 years. In this case, we adopt a threshold that is ten times higher than the one used by EM-DAT, since the dataset includes many relatively minor events (from a macroeconomic perspective). Using this measure, Indonesia, China and the Philippines stand out as highly vulnerable.

Figure 1, taken from Cavallo and Noy (2011), plots the average number of natural disaster events (hydro-meteorological and geophysical) per country 1970-2008. The figure shows that the incidence of disasters has been growing over time everywhere in the world. In the Asia-Pacific region for example, which is the region with the most events, the incidence has grown from an average of 11 events per country in the 1970s to over 28 events in the 2000s. In other

regions, while the increase is less dramatic, the trend is similar. However, these patterns appear to be driven to some extent by improved recording of milder events, rather than by an increase in the frequency of disasters. Furthermore, truly large events—i.e., conceivably more catastrophic—are rarer. At this point, there is no credible evidence the frequency of catastrophic events is increasing, though that is most clearly a possible prediction given the projected evolution of climatic conditions in the next century.

2.2 The Future

A recently announced Intergovernmental Panel on Climate Change (IPCC) summary of a *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* concludes, after a review of the scientific literature, that there will be a “likely increase heat wave frequency and very likely increase in warm days and nights across Europe....likely increase in average maximum wind speed and associated heavy rainfall (although not in all regions).... very likely contribution of sea level rise to extreme coastal high water levels (such as storm surges)....[but] low confidence in drought projections for West Africa.” (IPCC, 2011).⁵ While the 2011 report is fairly skeptical about the robustness of the much of the predictions available in the scientific literature about catastrophic high-risk low-probability natural disasters, it does argue that “For exposed and vulnerable communities, even non-extreme weather and climate events can have extreme impacts”.

In its latest comprehensive report from 2007, the IPCC states that: “Warming of the climate system is unequivocal, as is now evident from observations of increases in global

⁵ By ‘very likely’ the IPCC refers to 90-100% probability, while ‘likely’ means 66-100% probability (IPCC, 2011).

average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level” (IPCC, 2007). The IPCC report projects that by year 2100, average global surface warming will increase by between 1.8° Celsius and 4° Celsius depending on the success of emissions mitigation strategies.⁶

The projected increase in sea surface temperatures will potentially impact both the frequency and intensity of tropical storms, though there is limited understanding of these effects. One of the necessary conditions for hurricane formation is ocean water temperature greater than 26°C to a depth of about 50 meters. Several studies posit that, as global sea surface temperatures rise, hurricanes may become more numerous or intense, the range of hurricanes will increase to the north and south of the current “hurricane belt”, or their location and typical paths will change (e.g., Webster et al., 2005 and Li et al., 2010).

While admittedly coupling climate models with storm-generation models is fraught with unknowns and maybe unknowables, Emanuel et al. (2008), for example, find that “Basin-wide power dissipation and storm intensity generally increase with global warming, but the results vary from model to model and from basin to basin. Storm frequency decreases in the Southern Hemisphere and north Indian Ocean, increases in the western North Pacific, and is indeterminate elsewhere” while Mendelsohn et al. (2009) also predict increased frequency and intensity of storms in the North Atlantic. Elsner et al. (2008) suggest that warming temperatures allow for already strong storms to get even stronger.

The 2007 IPCC report predicts that sea levels will rise between 0.18 and 0.59 meters by 2100. However, like predictions on temperature changes, more recent predictions of global sea

⁶ Different climate models, yield somewhat different results, but the consensus is well represented by this range.

level rise are considerably more drastic as more information on glacial melting has become available. Rahmstorf (2007), for example, predicts a sea level rise of 0.5 to 1.4 meters by 2100 while Vermeer and Rahmstorf (2009) predict rises of up to 1.9 meters. These sea level rises, besides posing ongoing difficulties to low-lying areas, will certainly also increase the damages caused by storm wave surges and earthquake induced tsunamis.

Other changes associated with climate change may also contribute to disaster occurrence and damage. For example, the absorption of carbon in the ocean has led to increased acidity and has resulted in widespread coral reef bleaching. This coral bleaching in turn leads to destruction of reef systems that protect coastal areas from storm surges.

Whatever climate models are used, however,, there is wider agreement that the combination of sea level rise and deteriorated coral reef ecosystems will make coastal areas considerably more vulnerable to storms, regardless of whether storms will indeed be more frequent or more intense (or both).

The impact of global climate change on the incidence of other types of natural disasters is even less well understood., but there is some preliminary evidence, mostly from model exercises, that droughts and floods will become more common and more severe (e.g., IPCC, 2007). For now, we have no evidence that the incidence of geophysical disasters is likely to change over time or be affected by any of the climatic changes that are predicted to occur. The frequency of large earthquakes appear to be fairly constant with, on average 17 large earthquakes (magnitude 7.0-7.9) and about one mega earthquake (magnitude 8.0 and above) a

year.⁷ However, as we already observed about the future damages from earthquake-generated tsunami waves, one can easily conclude that even if the probability of geophysical events will not be impacted, the ways in which these natural events will interact with the local economy may clearly change over time. For example, if climate change will induce longer and more widespread droughts, then the soil erosion that will result will increase the damage incurred when earthquakes generate a mud-slides (as is frequent in Central America).

3. Determinants of Initial Disaster Costs

When evaluating the determinants of disasters' direct costs, most research papers estimated a model of the form: $DIS_{it} = \alpha + \beta X_{it} + \varepsilon_{it}$; where DIS_{it} is a measure of direct damages of all disasters in country i and time t ; using measures of primary initial damage such as mortality, morbidity, or capital losses. X_{it} is a vector of control variables of interest with each research effort distinguishing different independent variables. Typically X_{it} will include a measure of the disaster magnitude (e.g., Richter scale for earthquakes or wind speed for hurricanes) and variables that capture the "vulnerability" of the country to disasters (i.e., the conditions which increase the susceptibility of a country to the impact of natural hazards). ε_{it} is generally assumed to be independently and identically distributed (iid) error term.

Kahn (2005) estimates a version of this model and concludes that while richer countries do not experience fewer or less severe natural disasters, their death toll is substantially lower.

⁷ A one point increase in earthquake magnitude entails a 10 time increase in earth movement and a 32 times increase in the amount of energy released, so a 9.0 earthquake is dramatically different from an 8.0 one. For historical information about earthquake frequencies, see: <http://earthquake.usgs.gov/earthquakes/eqarchives/>.

In 1990, a poor country (per capita GDP<2000 US\$) typically experienced 9.4 deaths per million people per year, while a richer country (per capita GDP>14,000 US\$) would have had only 1.8 deaths. This difference is most likely due to the greater amount of resources spent on prevention efforts and legal enforcement of mitigation rules (e.g., building codes). In particular, some of the policy interventions likely to ameliorate disaster impact, including land-use zoning, building codes and engineering interventions are rarer in less developed countries.

This finding, however, does not imply that higher damages in developing countries are inevitable. The contrast between storm preparedness in Cuba vs. Haiti, or in Burma vs. Bangladesh, clearly demonstrates that even poor countries can adopt successful mitigation policies and that successful mitigation does not only depend on financial resources and the ability to mobilize them. Even in wealthier countries, there are dramatic differences in the degree of preparedness; Japan, for example, has constructed a nation-wide earthquake warning system that has successfully managed to stop all high-speed rail a few seconds before the damaging earthquake shock waves arrived in the Sendai region on March 11th, 2011 – no other country has installed such a system.

A consistent finding of several studies (i.e., Kahn, 2005; Skidmore and Toya, 2007; Raschky, 2008; Strömberg, 2007) is that better institutions—understood, for instance, as more stable democratic regimes or greater security of property rights—reduce disaster impact. Typhoon Nargis that hit Burma in May 2008 provides a tragic contrast to this insight. Apparently, the Burmese government was warned about the nearing storm two days before it arrived, but did little to warn coastal residents. In addition, the government interrupted post-disaster relief efforts and restricted access by international NGOs to the affected area; more

than 138,000 people were killed. Nargis is an extreme case, but other countries that experience periodic storms and flooding, such as the Philippines, also appear comparatively unprepared.

Anbarci et al. (2005) elaborate on the political economy of disaster prevention. They conclude that inequality is important as a determinant of prevention efforts: more unequal societies tend to have fewer resources spent on prevention, as they are unable to resolve the collective action problem of implementing preventive and mitigating costly measures.

Besley and Burgess (2002), using data from floods in India, observe that disaster impacts are lower when newspaper circulation is higher, which leads to more accountable politicians and a government that is more active in preventing and mitigating impacts. Compounding this question of accountability is the apparent unwillingness of the electorate to punish politicians who had under-invested in preparedness while failure to provide generous post-disaster reconstruction funds does appear to be an important determinant of post-disaster electoral success (Healy and Malhotra. 2009). Thus, even in democracies, politicians rarely face the optimal incentives in terms of disaster prevention and/or mitigation.

To summarize, while the damage caused by disasters is naturally related to the physical intensity of the event, a series of economic, social, and political characteristics also affect vulnerability. A by-product of this analysis, of course, is that these characteristics are therefore potentially amenable to policy action. In particular, the collective action problems that the literature identifies can potentially be overcome with the design of decision-making mechanisms that take these problems into account. There is growing awareness among the Pacific Rim countries' policymakers of the importance of not only mitigation but in reducing vulnerability to the economic pain that is likely in a disaster's aftermath. In the November 2011

ministerial meeting of Asia-Pacific Economic Cooperation (APEC), leaders issued a statement that details these concerns and describes the steps that APEC countries are encouraged to take in order to become more resilient (APEC, 2011).

4. Economic Impacts – Are Disasters a Poverty Trap?

A disaster's initial impact causes mortality, morbidity, and loss of physical infrastructure (residential housing, roads, telecommunication, and electricity networks, and other infrastructure). These initial impacts are followed by consequent impacts on the economy (in terms of income, employment, sectoral composition of production, inflation, etc.). These indirect impacts, of course, are not pre-ordained, and the policy choices made in a catastrophic disaster's aftermath can have significant economic consequences. For example, by using a non-equilibrium dynamic growth model, Hallegatte et al. (2007) show that a country experiencing disastrous events may find itself unable to adequately reconstruct and may remain stuck in a post-disaster poverty trap. Thus, while post-disaster policy choices clearly have a direct economic impact in the short run, these potentially also have long-run consequences.

4.1 Short-run

The short-run impacts of disasters are usually evaluated in a regression framework of the form: $Y_{it} = \alpha + \beta X_{it} + \gamma DIS_{it} + \varepsilon_{it}$; where Y_{it} is the measured variable of interest (e.g., per capita GDP), DIS_{it} is a measure of the disaster's immediate impact on country i at time t , X_{it} is a vector of control variables that potentially affect Y_{it} , and ε_{it} is an error term. Noy (2009) estimates a version of this equation and, in addition to the adverse short-run effect already

described in Raddatz (2007), he describes some of the structural and institutional details that make this negative effect worse. Noy (2009) concludes that countries with a higher literacy rate, better institutions, higher per capita income, higher degree of openness to trade, higher levels of government spending, more foreign exchange reserves, and higher levels of domestic credit but with less open capital accounts are better able to withstand the initial disaster shock and prevent further spillovers into the macro-economy. These findings suggest that access to reconstruction resources and the capacity to utilize them effectively are of paramount importance in determining the speed and success of recovery.

Raddatz (2009) uses vector autoregressions (VARs) to conclude that smaller and poorer states are more vulnerable to these spillovers, and that most of the output cost of climatic events occurs during the year of the disaster. His evidence, together with Becerra et al. (2010), also suggests that, historically, aid flows have done little to attenuate the output consequences of climatic disasters.⁸

Even if aid inflows are typically not substantial enough to assist in complete reconstruction, bigger countries may be capable of engineering the inter-sectoral and inter-regional transfers required to fully mitigate the economic impact of natural disasters (Coffman and Noy, 2010, and Auffret, 2003). The importance of inter-regional transfers was highlighted by the massive mobilization of reconstruction resources following the catastrophic Sichuan earthquake of 2008. The Chinese government spent lavishly on reconstruction, with about 90%

⁸ Loayza et al. (2009) notes that while small disasters may, on average, have a positive impact (as a result of the reconstruction stimulus), large disasters always pose severe negative consequences for the economy in their immediate aftermath.

coming from the central government and only 10% financed locally in Sichuan.⁹ The rebuilt infrastructure in the destroyed counties (which were remote and under-developed pre-quake) appears to be significantly superior to its previous state. Therefore, while direct losses may be high in large countries because of the increased wealth exposure, the greater capacity to absorb shocks means that indirect losses may be lower, and/or that the size of the damage may be lower relative to the size of the country.

Noy and Vu (2010) further focus on the importance of inter-regional transfers in a developing country, Vietnam, and find that the post-disaster impact on economic activity across Vietnamese provinces appears to be determined by the provincial ability to attract reconstruction resources from the central government.

Very little research has attempted to examine household data and determine the effects of natural disasters on household expenditures. An important exception is Sawada and Shimizutani (2008) who examine household data after the 1995 Kobe earthquake in Japan. They find that, even in a rich country, credit-constrained households experienced significant reductions in consumption, while households with access to credit did not. Further evidence on the importance of credit is suggested by the Rodriguez-Oreggia et al. (2009) findings of a significant increase in poverty in disaster-affected municipalities in Mexico.

4.2 Long-run

⁹ Data obtained from http://www.china.org.cn/china/earthquake_reconstruction/2010-01/25/content_19302110.htm (accessed on 11/11/11).

Theoretically, the likely impact of natural disasters on growth dynamics is not clear. Standard neo-classical frameworks that view technical progress as exogenous—e.g. the Solow-Swan model with exogenous saving rates and the Ramsey-Cass-Koopman model with consumer optimization—all predict that the destruction of physical capital will enhance growth since it will drive countries away from their balanced-growth steady states. In contrast, endogenous growth frameworks do not suggest such clear-cut predictions with respect to output dynamics depending on the approach used to explain the endogeneity of technological change. For example, models based on Schumpeter’s creative destruction process may also ascribe higher growth as a result of negative shocks (Hallegatte and Dumas, 2009), as these shocks can be catalysts for re-investment and upgrading of capital goods. Yet, the AK-type endogenous growth models in which the technology exhibits constant returns to capital, predict no change in the growth rate following a negative capital shock; though the economy that experiences a destruction of the capital stock will never go back to its previous growth trajectory. Endogenous growth models that have increasing returns to scale production generally predict that a destruction of part of the physical or human capital stock results in a lower growth path and consequently a permanent deviation from the previous growth trajectory.

To date, the empirical work on this question has also failed to reach a consensus. Skidmore and Toya (2002) uses the frequency of natural disasters in a cross-sectional dataset to examine long-run growth impacts of disasters, while Noy and Nualsri (2007) uses a panel of five-year country observations, as in the extensive literature that followed the work by Barro (1997). Intriguingly, they reach diametrically opposing conclusions, with the former identifying

expansionary and the latter contractionary disaster effects. More recently, Jaramillo (2009) finds qualified support for the Noy and Nualsri (2007) conclusion.

Skidmore and Toya (2002) explain their somewhat counterintuitive finding by suggesting that disasters may be speeding up the Schumpeterian “creative destruction” process that is at the heart of the development of market economies. Cuaresma et al. (2008), however, find that for developing countries, disaster occurrence is associated with less knowledge spillover and a reduction in the amount of new technology being introduced rather than with an acceleration of these processes.

Cavallo et al. (2010) provide the most recent attempt to resolve this debate. They implement a new methodology based on constructing synthetic controls—i.e., a counterfactual that measures what would have happened to the path of the variable-of-interest in the affected country in the absence of the natural disaster. Using this methodology, they don’t find any significant long-run effect of even very large disasters, except for very large events that were then followed by political upheavals. For these events, they find economically very substantial and statistically significant negative long run effects on per capita GDP.

Another possibility is suggested in Coffman and Noy (2011), where the question is the impact of a specific event (a hurricane) on an isolated Hawaiian island. In this instance, the authors conclude that while there was no long-term impact on per-capita variables, this is largely because the disaster led to an out-migration from which the island has never completely recovered (the net population loss was a very significant 15%). Whether this pattern can be observed for other catastrophic events is not well established, though casual observation suggests that these irreversible out-migrations also happened in the case of New Orleans after

hurricane Katrina, while in the city of Kobe after the earthquake of 1995 the population did not move away in spite of persistent decreases in incomes (see Vigdor, 2008 and Dupont and Noy, 2012, respectively). There is much speculation that the same will be true for the Tohoku region of Japan that was hit by the March 2011 tsunami.

4.3 Fiscal Impacts

As we observed previously, disasters are likely to generate significant inter-regional transfers and/or international aid. Accurate estimates of the likely fiscal costs of disasters are useful in enabling better cost-benefit evaluation of various mitigation programs and to determine the appropriate level of insurance against disaster losses.¹⁰

On the expenditure side, publicly financed reconstruction costs may be very different from the original magnitude of destruction of capital; while on the revenue side of the fiscal ledger, the impact of disasters on tax and other public revenue sources has also seldom been quantitatively examined. Using panel VAR methodology, Noy and Nualsri (2011) and Melecky and Raddatz (2011) estimate the fiscal dynamics likely in an “average” disaster; however, they acknowledge that the impacts of disasters on revenue and spending depend on the country-specific macroeconomic dynamics occurring following the disaster shock, the unique structure of revenue sources (income taxes, consumption taxes, custom duties, etc.), insurance coverage and the size of the financial sector, and government indebtedness.

¹⁰ Insurance could be purchased directly (maybe through re-insurance companies), indirectly through the issuance of catastrophic bonds (CAT bonds), or through precautionary savings

Borensztein et al. (2009) utilize data from Belize to estimate in a calibrated model the likely fiscal insurance needs of a government that is susceptible to large adverse shocks (hurricanes in the case of Belize) while Barnichon (2008) calculates the optimal amount of international reserves for a country facing external disaster shocks using a similar methodology.

The implications of these findings to the Pacific Rim region are quite obvious given the high degree of vulnerability of almost all countries in the region. Mexico's FONDEN provides an example of an ex-ante fiscal provisioning for disaster reconstruction, but this, while prudent, amounts to a form of self-insurance, which may be very costly in the case of a developing economy with substantial borrowing costs.¹¹ Chile, in contrast, has used some of the funds available in its Sovereign Wealth Fund (the Copper Fund) to pay for reconstruction following the destructive earthquake of February, 2010. Japan, which can easily pursue counter-cyclical fiscal policy,¹² resorted to additional borrowing to pay for the 2011 Tohoku earthquake reconstruction costs.

As we have already observed in section 3, political reluctance to engage in insurance purchase derives from the fact that there is little short-run benefit to be gained from entering into insurance contracts. Insurance involves costs today and a possible payoff in the undetermined future, by that time the government may have already changed hands. In addition to these time-incentive problems, disasters are widely considered as "acts of God" (or

¹¹ In addition to FONDEN, Mexico is also one of the biggest issuers of CAT bonds. Even so, the provisioning of FONDEN has recently been insufficient to cover the costs of disasters in 2010 (see <http://www.artemis.bm/blog/2010/09/16/fonden-mexicos-disaster-fund-exceeds-its-annual-budget/> accessed 11/12/11).

¹² For some insights into why some countries can or cannot pursue counter-cyclical fiscal policy see, for example, Ilzetzki (2011).

natural phenomena), and politicians are often not blamed for their occurrence and the damages they inflict. Politicians and policy-makers therefore face very weak incentives for adopting relatively complex measures, such as purchasing market insurance, to offset hypothetical post-disaster costs.

One way to overcome this problem is for countries to mutually insure each other. While this is difficult to envision politically within any Pacific-Rim-wide grouping such as APEC, it may be more politically palatable and therefore practical in smaller and more geographically concentrated groups like ASEAN.

4.4 International Impacts: Trade, Financial Flows, and Emigration?

Odell and Weidenmeir (2004), in a historical investigation of the international impacts of the 1906 earthquake and fire in San Francisco, describe how the shock propagated to Europe since about 40% of city's fire insurance policies were issued by European firms (majority from the UK). Under the Gold Standard, these insurance payments required gold to flow across the Atlantic, and this eventually led to higher interest rates in Europe and restrictions on capital flows placed by European banks. This turmoil culminated with the 1907 U.S. financial panic. The earthquake and tsunami of March 2011 in Tohoku, Japan, was also propagated internationally. While a careful tabulation of that propagation is impossible at this time, preliminary reports frequently detail the difficulties in vertical production networks that was experienced after the

tsunami destroyed manufacturers of key components.¹³ Similar reports about interruption in vertical networks also surfaced after the Greater Bangkok floods of late 2011.

Several other papers examine various aspects of the international propagation of the economic shock that follow a natural disaster. For example, Gassebner et al. (2010) examine the impact of natural disasters on trade flows, while Yang (2008) and Bluedorn (2005) investigate the evolution of capital flows following disasters. Yet all these find fairly small impacts (if any). Even for foreign aid flows, Becerra et al. (2010) find that the increase in aid inflows following a disaster is on average substantially lower than the amount required to cover much of the cost of replacing destroyed property. All this suggests that international concern about disasters should focus not on the standard channels of trade and capital flows, but rather on production networks and contractual obligations through various financial instruments (e.g., large holders of CAT bonds), and is probably only relevant to the biggest economies in the global system.¹⁴

Whether disasters can potentially lead to migrations has not been studied thoroughly, and the likely impact may well be very different across time and circumstances (Hunter, 2005). The Irish Famine was, for example, a trigger for a dramatic out-migration from Ireland; and that migration turned out to be irreversible and initiated a long-term decline in the Irish population (Ó Gráda and O'Rourke, 1997). On the other hand, Halliday (2006) finds that the very large 2001 earthquake in El Salvador actually changed the household calculus of migration and led to a

¹³ The post-tsunami worldwide shortage of bismaleimide triazine resin—important in smartphones and other similar devices and produced almost exclusively by Mitsubishi Gas Chemical—is a relevant example (Noy, 2011).

¹⁴ The recent financial crisis that started in September, 2008, however, suggests that even smaller problems can percolate through the financial system and threaten the stability of larger markets.

reduction in the number of people leaving El Salvador for the United States since the returns to staying increased.

4.5 Disaster as an Opportunity?

Some argue that disasters provide an impetus for change, which can bring on positive economic changes that have long-term beneficial dynamic impact on the economy. Change can lead to “creative destruction” dynamics that entail replacing the old with new technologies and with upgrades of superior equipment, infrastructure, and production processes. The rapid growth of Germany and Japan after the destruction they experienced in World War II is widely used as an example of such beneficial dynamics. However, even for both these cases, empirical research failed to identify a long-term beneficial effect; but at best found a return to the pre-shock equilibrium (Davis and Weinstein, 2002, and Brakman et al., 2004).¹⁵

Besides the potential ‘creative’ introduction of new technologies to replace the ones that had previously been destroyed, a large natural disaster changes political power dynamics in ways that may facilitate radical change. Rahm Emanuel, Barak Obama’s former chief of staff, is often quoted as saying, “you never want a serious disaster to go to waste . . . it’s an opportunity to do things you could not do before”.¹⁶ The evidence to date, however, does not suggest that after accounting for the loss of life and property, one can identify beneficial aspects to the destruction wrought by natural disasters.

¹⁵ In a related project, Miguel and Roland (2011) find that post-war Vietnam (a low-income country) also reverted to its pre-shock equilibrium with little evidence of a negative long-term effect (a poverty trap).

¹⁶ Emanuel, at a Wall Street Journal event (see WSJ, Nov. 21, 2008).

5. Policies and Open Questions

Perrow (2007) argues that public policy should focus on the need to “shrink” the targets: lower population concentration in vulnerable (especially coastal) areas, and lower concentration of utilities and other infrastructure in disaster-prone locations. This advice also stems from the awareness that more *ex-post* assistance to damaged communities generates a “Samaritan’s dilemma,” i.e., an increase in risk-taking and a reluctance to purchase insurance when taking into account the help that is likely to be provided should a disaster strike.¹⁷ However, apart from these *ex-ante* ‘shrink-the-target’ policies, many other *ex-ante* and *ex-post* policies that can alleviate or worsen the economic impact of disasters will necessarily be weighed before and after any large event.

The need to construct efficient and timely warning systems is clearly a policy target that is less controversial and more easily implementable. The 2004 South-East Asian tsunami, for example, led to an extension of the Pacific Tsunami Warning System to regions of Indonesia and the Indian Ocean that were previously unprotected. Operating warning systems, however, remains a long-term goal that can still be improved in cost-effective ways in most countries of the Pacific Rim region.¹⁸

Scientific experts repeatedly describe the likelihood of future disasters in terms of one-in-X-year events. We have recently observed several one-in-500-year events, which suggest that this framing may not be very instructive given the shifting climatic conditions worldwide.

¹⁷ See, for example, the discussion in Raschky and Weck-Hannemann (2007).

¹⁸ That is one of future policy goals in the region as stated in the Hyogo Framework for Action adopted by the UN General Assembly in 2005. A recent review of progress in the Asia Pacific concluded that in preparing early warning systems: “achievement [in most countries] are neither comprehensive nor substantial.” (UNISDR, 2011, p. 8).

This framing creates the lack of preparedness we have seen most recently in the Fukushima nuclear power plant. With hindsight, it is obvious that the operators of the seaside power plant should have had contingency plans in place for a failure in the electricity supply of both the grid and the emergency generators that were made inoperable by the tsunami. More generally, post-disaster energy supply difficulties and the collapse of communication networks seem to be two aspects of this and other recent disasters that were not planned for adequately. Vulnerability of industrial production, as exposed after this disaster, is a result of a dramatic increase in the vertical integration of production networks and the just-in-time supply chain management. These create vulnerabilities that can easily spread to unaffected regions, and is compounded by trends toward very specific specializations.

Beyond lack of preparedness and adequate mitigation of risks, Kunreuther and Pauly (2009) survey some of the problems associated with *ex-ante* insurance coverage for large natural events: uncertainty with regard to the magnitude of potential losses, highly correlated risk among the insured, moral hazard that leads to excessive risk taking by the insured, and an adverse selection of insured parties caused by imperfect information. As we already pointed out, many large disasters have very small probabilities associated with them and these make it difficult to develop relevant mitigation policies and likely also lead to under-insurance. In all recent disasters, even in ones that happened in heavily insured countries like the United States, only a relatively small portion of actual damages was insured. For example, Hurricane Katrina

led to insurance claims totaling \$46.3 billion; while the estimated damage of the storm was \$158.2 billion.¹⁹

Implementing disaster insurance in many Pacific Rim countries, however, faces three types of obstacles: paucity of markets, political resistance and inadequate institutional framework. For a number of reasons, markets have traditionally been insufficiently developed or simply nonexistent.

Private capital markets offer some complementary alternatives that may increase the availability of financing options as they continue to develop. The first capital market instrument linked to catastrophe risk (“CAT bonds”) was introduced in 1994 as a means for reinsurers to transfer some of their own risks to capital markets, and these have since been used by various issuers, including governments. A typical structure of a CAT bond is one in which the investors purchase a highly-rated bond for the desired amount of coverage and deposit it with a Special Purpose Vehicle (SPV) institution, which is legally distinct from the parties. The investors collect the interest on the bond plus the insurance premium that is paid by the insured party while the disaster does not occur. If the disaster strikes, however, their claim is extinguished and the SPV sells the bond and transfers the funds to the insured. While these are encouraging developments, the private and government CAT bond market is still in its infancy.²⁰

Equally promising, but as yet even more undeveloped, are the possibilities for micro-insurance schemes that are indexed to measureable weather or other easily observable

¹⁹ Katrina insurance claim data are from Kunreuther and Pauly (2009), while the figure for total damages is taken from EM-DAT.

²⁰ In January-November 2011, there were 21 different issues of CAT bonds, all but one issued by either insurance or re-insurance companies (the exception being the California Earthquake Authority). Information taken from: http://www.artemis.bm/deal_directory/

outcomes (rainfall, seismographic reading, river level rise, etc.). Instruments that, for example, tie insurance payments to measureable floods would have simplified immensely the difficult and prolonged sorting out of insurance claims that will likely follow the Greater Bangkok floods of October-November 2011—estimated at 13B US\$, it may be the costliest flood event in the last decade in terms of insured losses.

Yet, even if the supply side of risk financing instruments becomes fully developed, many important questions remain unanswered. What is the optimal level of insurance for rare but catastrophic events? What is the optimal combination of alternative financing options? How are these answers tied to country-specific characteristics? What are the appropriate institutional arrangements that ensure the proper functioning of insurance schemes while minimizing moral hazard and adverse selection? What is the appropriate role of the government vis-à-vis the private sector in catastrophe insurance markets?

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Table 1: Worst Disasters in the Pacific Rim 1970-2008

Worst Disasters (# of people killed)				
Country (year)	Type	# Killed	# Affected	Damages
China PR (1976)	Earthquake	242000	164000	5600
Indonesia (2004)	Earthquake	165708	532898	4451.6
China PR (2008)	Earthquake	87476	45976596	30000
Peru (1970)	Earthquake	66794	3216240	530
Guatemala (1976)	Earthquake	23000	4993000	1000
Worst Disasters (# of people affected)				
China PR (1998)	Flood	3656	238973000	30000
China PR (1991)	Flood	1729	210232227	7500
China PR (1996)	Flood	2775	154634000	12600
China PR (2003)	Flood	430	150146000	7890
China PR (1995)	Flood	1437	114470249	6720
Worst Disasters (damages in US\$ million)				
United States (2005)	Storm	1833	500000	125000
Japan (1995)	Earthquake	5297	541636	100000
China PR (1998)	Flood	3656	238973000	30000
China PR (2008)	Earthquake	87476	45976596	30000
United States (1994)	Earthquake	60	27000	30000

Source: author's calculations from EMDAT.

Table 2: Vulnerability A - Worst Disasters per country:

Country	Worst Three Disasters (1970-2008) ¹			# killed ²	# of large disasters ³
Australia	wildfire 1983	Storm 1974	Flood 1984	176	0
Canada	Storm 1998	Storm 1987	Storm 1975	68	0
Chile	Earthquake 1971	Earthquake 1985	Flood 1993	374	1
China	Earthquake 1976	Earthquake 1974	Earthquake 2008	349476	84
Colombia	volcano 1985	Earthquake 1970	Earthquake 1999	23416	10
Costa Rica	Storm 1988	Storm 1996	Earthquake 1991	126	0
Ecuador	Earthquake 1987	Flood 1983	Flood 1998	5525	3
El Salvador	Earthquake 1986	Earthquake 2001	Flood 1982	2444	5
Guatemala	Earthquake 1976	Storm 2005	Flood 1982	25133	4
Honduras	Storm 1998	Storm 1974	Flood 1993	22974	4
Indonesia	Earthquake 2004	Earthquake 2006	Earthquake 1992	173986	20
Japan	Earthquake 1995	Flood 1972	Flood 1982	6100	10
Korea	Flood 1972	Flood 1998	Storm 1987	1558	9
Malaysia	Storm 1996	Earthquake 2004	Flood 1970	411	0
Mexico	Earthquake 1985	Flood 1999	Storm 1976	1736	22
N Zealand	Storm 1988	Flood 1985	Storm 1997	13	0
Nicaragua	Earthquake 1972	Storm 1998	Storm 2007	13520	4
Panama	Flood 1970	Earthquake 1991	Storm 1988	108	0
Papua NG	Earthquake 1998	Storm 2007	Earthquake 1993	2407	2
Peru	Earthquake 1970	Earthquake 2007	Storm 1998	67831	6
Philippines	Earthquake 1976	Storm 1991	Earthquake 1990	14368	17
Russia	Earthquake 1995	Ex temp 2001	Ex temp 2001	2597	3
Taiwan	Earthquake 1999	Storm 2001	Storm 2000	2453	2
U. S.	Storm 2005	Ex temp 1980	Ex temp 1995	3763	19
Vietnam	Storm 1997	Storm 1985	Storm 1989	5231	20

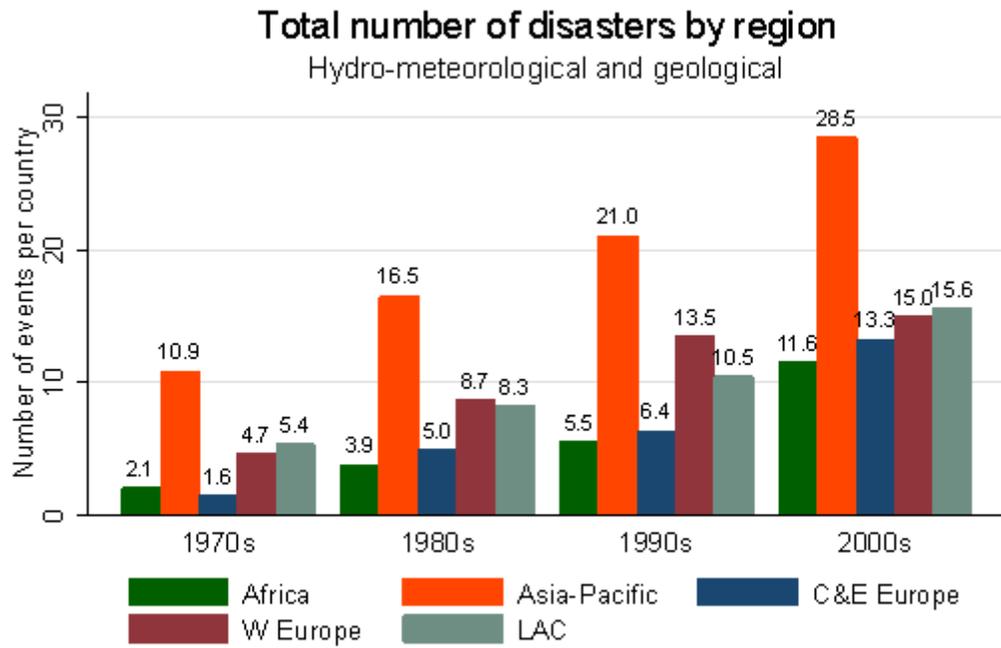
Source: author's calculations from EMDAT.

¹ The worst three disasters in terms of the number of fatalities.

² Measures the sum of fatalities in the three worst disasters experienced in each country.

³ Measures the number of disaster events for which there were more than 100 fatalities, more than a thousand people affected, and damages of more than a million US\$ (this is a significantly higher threshold than the one used by EMDAT – we further did not count disasters for which the number of fatalities was unavailable).

Figure 1: Frequency of Disasters by Geographic Region



Source: Cavallo and Noy (2011).