Chapter 11
Natural Disaster and Economic Policy for ASEAN and the Pacific Rim: A Proposal for a Disaster Risk Reduction 'Seal of Approval' Fund

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1 Disasters in South–East Asia

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), or the Mexico City earthquake of 1985, 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 nations (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

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Robert Barro has argued that the infrequent occurrence of economic disasters leads to much larger welfare costs than continuous economic fluctuations of lesser amplitude (Barro 2006, 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 % of annual GDP, while normal business cycle volatility only amounted to a still substantial 15 % 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 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 and the 2011 Bangkok floods demonstrated persuasively the potentially global impact of these types of disasters—especially for a 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. These are 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 5 years, but sometimes also measured in decades). I use these distinctions in the discussion that follows.

Tierra Del Fuego at the very southern tip of the continent. This region experiences by far the majority of the volcanic activity and earth movements recorded worldwide.

2 Data on Regional Disasters

2.1 The Past

The Emergency Events Database (EM-DAT), maintained by the Centre for Research on the Epidemiology of Disasters (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 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. Natural disasters, as defined in the EM-DAT database, are common events. The five worst disasters (in terms of the three measures of disaster magnitude) are given in Table 11.1. 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 earthquake/tsunami in Tohoku, which dwarfs both disasters with damages estimated at more than US$200 billion, about 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), is provided in Table 11.2. It provides some limited insight into 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: these are Australia,

[3] The data is publicly available at: http://www.emdat.be/

[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.

Table 11.1 Worst disasters in the Pacific Rim 1970–2008

Country (year)	Type	# Killed	# Affected	Damages
Worst disasters (# of people killed)				
China PR (1976)	Earthquake	242,000	164,000	5,600
Indonesia (2004)	Earthquake	165,708	532,898	4,451.6
China PR (2008)	Earthquake	87,476	45,976,596	30,000
Peru (1970)	Earthquake	66,794	3,216,240	530
Guatemala (1976)	Earthquake	23,000	4,993,000	1,000
Worst disasters (# of people affected)				
China PR (1998)	Flood	3,656	238,973,000	30,000
China PR (1991)	Flood	1,729	210,232,227	7,500
China PR (1996)	Flood	2,775	154,634,000	12,600
China PR (2003)	Flood	430	150,146,000	7,890
China PR (1995)	Flood	1,437	114,470,249	6,720
Worst disasters (damages in US$ million)				
United States (2005)	Storm	1,833	500,000	125,000
Japan (1995)	Earthquake	5,297	541,636	100,000
China PR (1998)	Flood	3,656	238,973,000	30,000
China PR (2008	Earthquake	87,476	45,976,596	30,000
United States (1994)	Earthquake	60	27,000	30,000

Source: Author's calculations from EMDAT

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 11.2 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 11.1, taken from Cavallo and Noy (2011), plots the average number of natural disaster events (hydro-meteorological and geophysical) per country in the period 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

Table 11.2 Vulnerability A—worst disasters per country

Country	Worst three disasters (1970–2008)[a]			# Killed[b]	# of large disasters[c]
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	349,476	84
Colombia	Volcano 1985	Earthquake 1970	Earthquake 1999	23,416	10
Costa Rica	Storm 1988	Storm 1996	Earthquake 1991	126	0
Ecuador	Earthquake 1987	Flood 1983	Flood 1998	5,525	3
El Salvador	Earthquake 1986	Earthquake 2001	Flood 1982	2,444	5
Guatemala	Earthquake 1976	Storm 2005	Flood 1982	25,133	4
Honduras	Storm 1998	Storm 1974	Flood 1993	22,974	4
Indonesia	Earthquake 2004	Earthquake 2006	Earthquake 1992	173,986	20
Japan	Earthquake 1995	Flood 1972	Flood 1982	6,100	10
Korea	Flood 1972	Flood 1998	Storm 1987	1,558	9
Malaysia	Storm 1996	Earthquake 2004	Flood 1970	411	0
Mexico	Earthquake 1985	Flood 1999	Storm 1976	1,736	22
N Zealand	Storm 1988	Flood 1985	Storm 1997	13	0
Nicaragua	Earthquake 1972	Storm 1998	Storm 2007	13,520	4
Panama	Flood 1970	Earthquake 1991	Storm 1988	108	0
Papua NG	Earthquake 1998	Storm 2007	Earthquake 1993	2,407	2
Peru	Earthquake 1970	Earthquake 2007	Storm 1998	67,831	6
Philippines	Earthquake 1976	Storm 1991	Earthquake 1990	14,368	17
Russia	Earthquake 1995	Ex temp 2001	Ex temp 2001	2,597	3
Taiwan	Earthquake 1999	Storm 2001	Storm 2000	2,453	2
U. S.	Storm 2005	Ex temp 1980	Ex temp 1995	3,763	19
Vietnam	Storm 1997	Storm 1985	Storm 1989	5,231	20

Note:
[a]The worst three disasters in terms of the number of fatalities
[b]Measures the sum of fatalities in the three worst disasters experienced in each country
[c]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)
Source: Author's calculations from EMDAT

events—i.e., conceivably more catastrophic—are rarer. At this point, there is no credible evidence that 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.

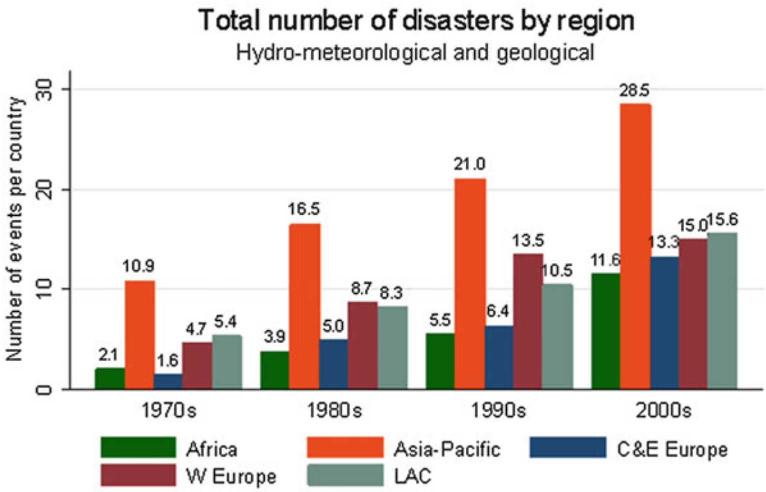

Fig. 11.1 Frequency of disasters by geographic region. *Source*: Cavallo and Noy (2011)

2.2 The Future

A recent report by the Intergovernmental Panel on Climate Change (IPCC 2012), the *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* concludes 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). . .." (IPCC 2012).[5] While the report is fairly skeptical about the robustness of many 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 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 the year 2100, average global surface temperature will increase by between 1.8° Celsius and 4° Celsius depending on the success of emissions mitigation strategies.[6]

[5] By 'very likely' the IPCC refers to 90–100 % probability, while 'likely' means 66–100 % probability (IPCC 2011).

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

The projected increase in sea surface temperatures will potentially impact both the frequency and intensity of tropical storms. 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; Li et al. 2010; Mendelsohn et al. 2012; Elsner et al. 2008; Emanuel et al. 2008).

More recent predictions than the 2007 IPCC report regarding global sea level rise are considerably more alarming as more information on glacial melting has become available. Rahmstorf (2007), for example, predicts a sea level rise of 0.5–1.4 m by 2100 while Vermeer and Rahmstorf (2009) predict rises of up to 1.9 m. 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. Whatever climate models are used, however, there is wider agreement that the combination of sea level rise and deterioration in 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 appears 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) per 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.

3 Determinants of Initial Disaster Costs

When evaluating the determinants of disasters' direct costs, most research papers estimated a model of the form: $DIS_{it} = \alpha + \beta \mathbf{X}_{it} + \varepsilon_{it}$; 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. $\mathbf{X}_{it}$ is a vector of control variables of interest with each research effort distinguishing different

[7] A one point increase in earthquake magnitude entails a 10 times 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/.

independent variables. Typically $\mathbf{X}_{it}$ 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 an 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. In 1990, a poor country (per capita GDP $<$ US$2,000) typically experienced 9.4 deaths per million people per year, while a richer country (per capita GDP $>$ US$14,000) 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 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; 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 2 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 costly preventive and mitigation measures. Collective action difficulties may be overcome in communities whose inter-communal ties are stronger. As Aldrich (2012 and Chap. 2) discusses, when people feel an affinity with their neighbors, organizing them to act communally both in preparing for disasters, mitigating their consequences and reconstructing are all done more easily.

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.[8] 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, 2010). The benefits of generous post-disaster government intervention also appear to be long-lasting (Bechtel and Hainmueller 2011). Not surprisingly, politicians respond to these incentives, and thus increase their generosity in allocating post-disaster assistance in election years (Cole et al. 2012). 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. Political incentives are probably more difficult to alter, but robust public scrutiny with the assistance of an activist and investigative media can assist in that process. There is growing awareness among the Pacific Rim countries' policymakers of the importance of not only mitigation but of 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), the 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).

In addition to all these incentive problems that inhibit the desire to act, the resources needed are also typically only provided ex post rather than ex ante. Both private donations channeled through NGOs and public sector resources (from foreign or domestic sources, or both) generally become available only in the aftermath of catastrophic events, and are not available beforehand to prevent or mitigate any likely event.

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

[8] An equally plausible explanation for this finding is that newspaper circulation is a representation of more cohesive communities with higher 'social capital' (see Aldrich 2012).

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, they 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: $Y_{it} = \alpha + \beta \mathbf{X}_{it} + \gamma DIS_{it} + \varepsilon_{it}$; 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, $\mathbf{X}_{it}$ 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 is 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.[9]

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; 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

[9] 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.

spent lavishly on reconstruction, with about 90 % coming from the central government and only 10 % financed locally in Sichuan.[10] 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 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

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 rate sand 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

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

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 (2012), 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; 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 in determining the appropriate level of insurance against disaster losses.[11]

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; they acknowledge, however, 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.

The implications of these findings for the Pacific Rim region are quite obvious given the high degree of vulnerability of almost all countries in the region. Mexico's FONDEN (a disaster fund) provides an example of an ex-ante fiscal provisioning for disaster reconstruction, but this, while prudent, amount to a form of self-insurance, which may be very costly in the case of a developing economy with substantial borrowing costs.[12] 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, resorted to additional borrowing to pay for the 2011 Tohoku earthquake reconstruction costs.

One way to overcome this lack of sufficient explicit insurance 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 well-defined groupings like ASEAN (or ASEAN+3).

4.4 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

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

[12] 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).

destruction they experienced in World War II is widely used as an example of such beneficial dynamics. Even in these cases, however, empirical research failed to identify a long-term beneficial effect, at best finding a return to the pre-shock equilibrium (Davis and Weinstein 2002; Brakman et al. 2004).

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, was 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".[13] 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.

5 A Disaster Risk Reduction Fund

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.[14]

Constructing efficient and timely warning systems is clearly a desirable policy 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, and progress towards it can still be improved in cost-effective ways in most countries. A recent review of progress under the Hyogo Framework for Action adopted by the UN in 2005 concluded that in preparing early warning systems in the Asia Pacific: "achievement[s] are neither comprehensive nor substantial." (UNISDR 2011, p. 8).

The difficulty of developing an effective early-warning-system should not be underestimated. On April 11, 2012, a powerful earthquake (8.6 on the Richter scale) occurred not far offshore Banda Aceh, the city that was inundated by the 2004 South-East Asian tsunami with about 25,000 people killed (Doocy et al. 2007). By 2012, there was an early warning system in place for tsunami hazard in Aceh, but since everyone attempted to evacuate at the same time, roads became gridlocked very quickly as people were frantically trying to flee (Rondonuwu 2012). There were also wide-spread reports of various operational failures of the warning system

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

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

in this instance. Luckily, no significant tsunami was generated by the earthquake, but the inadequacy of a system developed specifically to prevent mortality if a repeat of the 2004 catastrophe were to occur was demonstrated quite starkly. Investment in effective mitigation and risk reduction is neither cheap nor easy as it also requires securing an effective response to the warnings that are supplied. Yet, the magnitude of benefits, in terms of life saved per dollar spent, are very large if these systems manage to prevent the very catastrophic disasters that occur all too frequently.[15]

If early-warning systems are indeed cost effective, why are they not being implemented wholeheartedly? As we discussed previously in analyzing the general underinvestment in preparedness, the answer is most likely political. In many cases, initiating the development of a disaster risk reduction (DRR) policy is clearly needed, and this can probably be best carried out with external support/incentives from the multilateral organizations. The World Bank, in particular, has been working on this front, but a dedicated fund, a Global Fund for DRR (GF-DRR), that will incentivize and support this work can and should result in the optimal allocation of resources for this task. Many developing countries lack coherent planning for disaster preparedness and risk reduction, and the knowledge collected by the international organizations (especially the World Bank), together with the funds to support this planning, can lead to a very cost effective implementation of a much more global DRR policy.

An appropriate DRR policy may primarily involve the funding of early warning systems in most cases, but may also involve other preparatory steps; DRR may mean retrofitting essential infrastructure for earthquakes (especially hospitals and other building where many people reside or work), moving people permanently away from wave-surge prone coastal regions or river flood-plains, or establishing more robust communication networks that will not collapse in the aftermath of a catastrophic event. Beyond costs, the appropriate steps needed depend on the broadly-defined institutional details, the current state of the economy, and predictions regarding likely future disaster risks.

Since all three factors (institutions, economy and disaster risk) are inherently local and widely varying, it would be difficult to attempt to devise a universally appropriate policy menu, or to argue for a universal implementation of any specific policy. Preparation of DRR is taking place, but much more needs to be done; especially since economic conditions are changing, and risk patterns are appearing to change as well. Future economic exposure to tropical storms, for example, is predicted to quadruple by 2100, with roughly half of this increase associated with higher population and property in vulnerable areas and half resulting from changing

[15] Kydland, Finn E., Robert Mundell, Thomas Schelling, Vernon Smith, and Nancy Stokey, 2012. Copenhagen Consensus: Expert Panel Findings. http://www.copenhagenconsensus.com/Admin/Public/DWSDownload.aspx?File = %2fFiles%2fFiler%2fCC12 + papers%2fOutcome_Document_Updated_1105.pdf

patterns in terms of new predicted storm tracks and storm intensities (Mendelsohn et al. 2012).

The International Monetary Fund (IMF) has been involved in post-crisis intervention for several decades. The lessons the IMF has learned, in terms of avoiding perverse incentives—e.g., moral hazard and adverse selection—and leading countries to adopt ex-ante sound policies, are as relevant to natural disasters. Essentially, the idea is that countries will be constantly evaluated for their DRR plans, and given 'Seals of Approval.' A country whose plans are favorably evaluated will have access to support for DRR projects and in addition will have access to an Emergency Disaster Fund should it be required (one can establish triggers that automatically provide affected countries access to pre-specified sums as grants or concessional loans). The evaluation process already undergoing through the Hyogo Framework umbrella may serve as a good starting point for developing the evaluation and scoring mechanisms that would allow a 'grading' of DRR policy and the allocation of the contingent 'seal of approval' for these policies.

An additional positive externality from such fund with its associated monitoring and evaluation functions, would be enabling countries who receive this DRR 'seal of approval' to more easily insure themselves explicitly (with re-insurers) or implicitly by issuing Catastrophic Bonds (CAT bonds) and further enable multi-year insurance. All three developments (re-insurance, CAT bonds and multi-year) will be made easier by having a 'seal of approval' since that seal will alleviate investors/insurers concerns regarding the moral hazard generated by the disaster-contingent financial support.

While macro-level explicit or implicit insurance has been growing in popularity in the last decade (see the discussion of a rice index insurance in a companion paper in this volume), the vast majority of CAT bonds, for example, are still issued by local organizations in developed countries or specialized insurance companies. Governments, at the local or national level, do not yet appear to avail themselves of these insurance opportunities, and the establishment of a 'seal of approval' may be the catalyst that will increase utilization of these new financial tools for handling catastrophic risk.

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