Comparing the Direct Human Impact of Natural Disasters for Two Cases in 2011: the Christchurch Earthquake and the Bangkok Flood

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Abstract: The standard way in which disaster damages are measured involves examining separately the number of fatalities, of injuries, of people otherwise affected, and the financial damage that natural disasters cause. Here, we implement a novel way to aggregate these separate measures of disaster impact and apply it to two catastrophic events from 2011: the Christchurch (New Zealand) earthquakes and the Greater Bangkok (Thailand) flood. This new measure, which is similar to the World Health Organization's calculation of Disability Adjusted Life Years (DALYs) lost due to the burden of diseases and injuries, is described in detail in Noy (2014). It allows us to conclude that New Zealand lost 180 thousand lifeyears as a result of the 2011 events, and Thailand lost 2,644 thousand lifeyears. In per capita terms, the loss is similar, with both countries losing about 15 days per person due to the 2011 catastrophic events in these two countries.

Keywords: Christchurch, earthquake, DALY, Bangkok, flood, disaster impact

1. Introduction

The standard way in which disaster damages are measured involves examining separately the number of fatalities, of injuries, of people otherwise affected, and the financial damage that natural disasters, such as earthquakes or floods, cause. This classification dates back to a 1970s UN-sponsored project, at the Economic Commission for Latin America and the Caribbean. It was further developed and refined, and is now referred to as the Damage and Loss Assessment Methodology (see Guha-Sapir and Hoyois, 2012).

As the UN notes: "Part of the reason why disaster losses have not created the same political or economic imperative to address the risks of disease or financial risks may be the way in which they are measured. In reality, disasters affect households, communities and countries due to the combined impact of mortality, morbidity and damaged or destroyed housing, infrastructure and agriculture. Separate measurements of mortality and economic loss fail to capture the full dimensions of disaster." (UNISDR, 2015, p. 40).

Noy (2014) proposes a way to aggregate measures of disaster impact that overcomes some of the methodological difficulties inherent in any attempt to generalize from the separate measures. This measure is similar to the calculation of Disability Adjusted Life Years (DALYs) that is frequently used when comparing the efficacy of health interventions. The World Health Organization (WHO) uses this methodology to calculate the DALYs that are lost from the burden of diseases and injuries (WHO, 2014). As in the WHO's calculations of DALYs, the unit of measurement in the index used here is also 'lifeyears'.

The one conceptual difference between the WHO's approach measuring the 'burden of disease' and our approach is that the DALYs measure the impact of diseases exclusively on health, while our measurement is aimed at accounting for the impact of disasters on human welfare more generally. In order to to do that, we also need to incorporate the impact of financial losses on human well-being. Put differently, the loss of capital assets implies a need to devote further human effort in order to rebuild, reconstruct, or recreate these destroyed assets. Without this need, the effort and resources needed to rebuild would have been available for use in other ways to improve human welfare. The measure used here thus includes not only an accounting of the time lost because of mortality and morbidity, but also the time communities will need to devote to rebuilding their lives and the assets that they have lost.[1]

Here, we focus on two of the most catastrophic disasters in the most catastrophic year on record for disaster risk, at least in terms of financial losses.[2] These two events, the 22/2/2011 earthquake in Christchurch, New Zealand, and the post-monsoon floods in Thailand, are also quite different both in terms of the main characteristics of the hazard (a sudden and very supervising earthquake, and a slow-moving and anticipated flood) and, as we already noted, in the countries in which they occurred. These two events were also unique in that the data required to complete the calculations presented here was available (from various sources detailed below).

[1] At alternative literature converts human lives into monetary terms using value-of-statistical-life measurements (e.g., UNU and UNEP, 2014).

[2] Unfortunetly, obtaining detailed data on the most catastrophic event of 2011, the Great East-Japan earthquake/tsunami/nuclear failure, proved to be beyond the scope of this project, especially as the direct effects of this event are still ongoing.

2. *A Description of the Two Events*

The series of earthquakes in the Canterbury region of the South Island of New Zealand began on 4/9/2010. While some damage was caused by this first event, no fatalities occurred, and no major urban centre was directly affected. Another Canterbury earthquake with a magnitude of 6.1 struck closer to the City of Christchurch on 22/2/2011, and because of its location and physical characteristics, significantly more damage was caused to infrastructure and buildings and 185 lives were lost. Widespread liquefaction also added to the damage of the earthquake. About 80,000 housing units were significantly damaged. The 2011 earthquake was largely unexpected since it occurred in a previously little-known fault (Wills et al., 2011). For a much fuller description, see Potter et al. (2015).

In the latter part of 2011, Thailand experienced its worst flooding in decades. The World Bank (2012) estimated there were 800 fatalities and a total loss of THB 1.43 trillion (USD 46.5 billion) associated directly with the flooding. Flooding affected many provinces, including most importantly the commercial hub of Bangkok, and had an estimated duration of 6 months. Mean annual rainfall reached its peak in 2011 representing a 24% increase from normal. Alongside record-breaking rainfall, Poapongsakorn (2012) attributes the extensive damage to Thailand's inefficient water management, unplanned urbanisation and lack of reliable warning systems.[3]

3. *The Lifeyears Index*

Some of the basic assumptions used in the construction of the index were previously

[3] Noy and Patel (2014) provide more detail. Haraguchi and Lall (2015) identify another unique aspect of this event; they observe that the affected region served as an important link in many global supply chains.

adopted by the WHO in their constructon of the burden of disease measures. When calculating lifeyears lost due to moratlity and morbidity, as in the Burden of Disease project, one simply aggregate the number of years lost per person by simple linear summations and the mortality and morbidity sums are also added together.[4]

In the DALY literature, the value of monetary damages is not accounted for. The lifeyears meaure, however, assumes that a dollar worth of destroyed assets lost in a high-income country such as New Zealand imposes a less adverse impact on society than a similr dollar asset lost in a lower-income country like Thailand; income per capita in 2011, in the two countries was USD 5,192 and 37,192, respectively.[5] The index we use here converts all damage indicators — including mortality, morbidity, other impacts on human lives (e.g. displacement), and damage to infrastructure and housing — into an aggregate measure of lifeyears lost, not of less easily interpretable currency/monetary units.

The index proposed here, based on a modified version of Noy (2014), consists of the following:

$$Lifeyears_i = L_i(M, A^{death}, A^{exp}) + I_i(N) + DAM_i(Y, INC)$$

where $L(M, A^{death}, A^{exp})$ is the number of years lost due to event (*i*) mortality, calculated as the difference between the age at death and life expectancy.[6] $L(M, A^{death}, A^{exp})$ requires not only information on the number of people who died

[4] Fox-Rushby and Hanson (2001) discuss the accepted ways of calculating DALYs, including the possibility of time-discounting (whereby the future is discounted as playing a reduced role in current consideration).

[5] While in the value-of-statistical-life approach, the monetary damages are aggregated at 'face value, with the implied assumption that a dollar is worth the same everywhere.

[6] Henceforth, we supress the subscript i - the indicator for the event being analysed.

(M), but also the vectors of their age profile (A^{death}), and the projected life expectancy for each individual (A^{exp}). For life expectancy, we follow the WHO's approach in measuring DALYs. The WHO uses a uniform life expectancy of 92 years ($A^{exp} = 92$ for all m). This number originates from projections made by the United Nations regarding the likely average life expectancy at birth in the year 2050 (WHO, 2013, p. 5). The rationale for using this value for life expectancy, and one that is uniform across countries, is that the number represents a viable estimate of the possible frontier of human longevity in the foreseeable future.[7] This assumption also removes another a potential difference in our measure between the Thailand and New Zealand disasters, as actual life expectancy in New Zealand is somewhat higher. Thus, our measure for the number of lifeyears lost due to disaster mortality is $L = \sum_{m=1}^{M}(92 - A_m^{death})$.

$I(N)$ is the cost function associated with the people who were injured, or otherwise affected by the disaster. In principle, this should includes serious injuries, and the cost of their care, time spent in hospital and later rehabilitation, impact on people's mental health, impact on those whose houses were destroyed or livelihoods were adversely affected, impact on those who were displaced (temporarily or permanently), and any other direct human impact. *N*, in this framework, is all the information available for each disaster that allows us to calculate, as closely as is possible, this component of the overall index. The complete information set is never

[7] It could be argued that a theoretically more attractive option is to use the life expectancy at the time of death. There is a practical challenge here, as the life expenctancy at different ages varies significantly and information on the age profile of life expectancy is less reliable. There is also an ethical challenge, since this implies placing more weight on disasters occurring in wealthier regions, where life expectancy is higher. We note, however, that life expectancy at the median age is significantly higher than life expectancy at birth, especially for countries with lower life expectancy at birth, so that this choice of 92 does not exaggerate the impact of mortality to a very significant extent.

available, however. For global measures, one can typically only find information about the number of people injured and otherwise affected, though this count includes a wide range of syndromes and impacts.

The EMDAT dataset, the most frequently used global dataset, includes only information on the number of people affected, but not on the nature of this impact. Desinventar, an alternative global dataset maintained by UNISDR, includes separately data on injuries, and people affected, but without further distinctions. In the cases we investigate here, we have additional information, which we use as well. Following the WHO methodology in calculating DALYs, we assume that the impact function is defined as $I(N) = eTN$.

The coefficient, *e*, is the 'welfare-reduction weight' that is associated with being exposed to a disaster. There is no precedent to determining the magnitude of this weight, and there is much debate about the appropriate methodology to determine such weights (see the discussion about the 'disability weights' in determining DALYs; WHO, 2013, p. 11). Since we do not have information about how each individual was affected, we adopt the WHO's weight for disability associated with "generic uncomplicated disease: anxiety about diagnosis" (*e*=0.054).[8] *T* is the time it takes an affected person to return back to normality, or for the impact of the disaster to disappear; while *N* is the number of affected people. Our benchmark calculations are based on a two- or three-year horizon for return to normality (*T*=3 for Christchurch and *T*=2 for Bangkok, given their very different experieces in the post-disaster period, and the more rapid recovery in Thailand). Since we also have access to more

[8] See, WHO (2013, p. 80) for the list of disability weights used in calculating DALYs.

specific data on hospitalizations associated with disaster-caused injuries in the two events examined here, we add that measure, though we note that this variable is typically unavailable for most disasters.

The last component of the index, $DAM(Y, INC)$, attempts to account for the number of human years lost as a result of the damage to capital assets and infrastructure — including residential and commercial buildings, public buildings, and other types of infrastructure such as roads, water, seweage, electricity and communication systems. In principle, we aim to measure the opportunity cost of spending resources (especially human effort) on the reconstruction of these destroyed assets. *Y*, the amount of financial damages, should therefore only include the value of the destroyed or damaged capital, rather than the cost of replacement.[9] *INC* is the monetary amount obtained in a full year of human effort. We use income per capita as an indicator of the cost of human effort, but discount this measure by 75% (*d*) in our benchmark calculations to account for the observation that much of our time is spent not in work-related activities. Thus, $DAM(Y, INC) = (1-d)Y * INC^{-1}$.

Given the assumptions detailed above, our benchmark index is calculated as:

$$Lifeyears = \sum_{m=1}^{M}(92 - A_m^{death}) + eTN + (1-d)Y * INC^{-1}.$$

The data on the relevant measures for the Christchurch and Bangkok events are taken from Thai and New Zealand national sources, at the most detailed level we could obtain. Data on per capita GDP are taken from the World Bank's *World Development Indicators.* The detailed data and all the calculations are available for

[9] In cases where the only data available is the cost of replacement, we further discount the data by using a measure that accounts for the age of the physical assets destroyed.

download at: https://sites.google.com/site/noyeconomics/research/natural-disasters.

4. Christchurch Earthquake Estimates

We obtain the age of death for all the 182 people whose death is associated with the 22 February 2011 event. The total number of lifeyears lost due to mortality is thus $L = \sum_{1}^{182}(92 - A^{death})$ = 9,593.

The injuries to the 308 people who were hospitalized after the quake, and for whom we have hospital records, resulted in 2,930 days of hospitalization (8 lifeyears), and total cost of care of NZD 3.2 million. We use the NZ income per capita NZD 44,739 (for year ending March 2011) and the 75% discounting, to calculate the total cost as valued at 18 years. Further, there were 6,863 people who had reported injuries but had not been hospitalized (or hospital record were unavailable). We assume each of these cases resulted in a loss of 1 week. Aggregated, that amount to a loss of 132 years. The total loss due to direct morbidity, therefore, is 158 years.

EMDAT lists that 300,000 people were affected. As mentioned earlier, we assume a DALY coefficient of 0.054, and duration of impact of three years given the slow recovery in Christchurch. These assumptions imply a total of 48,600 lifeyears lost as a direct result of the disaster's impact.

The most current estimate for the cost of replacement of all the damaged capital, which we were able to construct, is NZD 32,875 million (see appendix table for details). However, the replacement value is not identical to the damage, given the age of the capital that was destroyed. We assume that the damaged capital was one third through its life cycle, so the actual damage was around NZD 21,917 million. We further discount the amount by 75%, as explained above, and use the per capita income in New Zealand in 2011 of NZD 44,739 to obtain a total of 122,470 years lost due to damaged assets and capital.

Thus, the estimated total number of lifeyears lost because of the 2011 Christchurch earthquake is 180,821 years.

5. Bangkok Flood Estimates

Data on the age at death associated with the flooding is not available, but we were able to obtain the distribution of mortality by decadal cohort. We use the mid-point of each cohort and the other assumptions details above to conclude that 39,282 lifeyears were directly lost directly due to mortality.

The Thai government reported that 1,825,486 people experienced some injuries but the vast majority has not been hospitalized (hospital records associated with the floods are not available). Since it is reported that the top three causes for injuries are very minor, we assume that each of these cases only resulted in a loss of 2 days. Aggregated, that amount to a loss of 10,003 years.

The EMDAT database reports 9,500,000 being affected by the riverine flood in Thailand in 2011. As detailed earlier, we assume a DALY coefficient of 0.054, and a shorter duration of two years, given the much faster recovery, to obtain the aggregate number of lifeyears lost as 1,026,000.

The available estimate for the cost of replacement of all the damaged capital is THB 1,490,458 Million. However, the replacement value is not identical to the damage, given the age of the capital and the reduced quality of infrastructure that was destroyed (relative to what will be reconstructed). As for the Christchurch event, we assume that the damaged capital was one-third through its life-cycle. Per capita income in Thailad in 2011 was THB 158,317. Together with our assumption of a 75% discounting, the total number of lifeyears lost due to the direct damage to capital and assets is therefore 1,569,065 lifeyears.

Thus, the estimated total number of years lost because of the Bangkok floods of 2011 is 2,644,350 years.

6. Comparisons and Discussion

Disaster losses worldwide are dominated by low-probability high-impact events (a small subset of the whole range of natural hazards affecting most countries adversely on a regular basis. The disasters reported here were unusually catastrophic for both New Zealand and Thailand, amounting to a loss of about 15 days per person in each country, but comparing them to a few other recent disasters might be instructive. For example, the loss experienced by Sri Lanka in the 2004 Boxing Day tsunami was significantly higher in per capita terms (53 days), while the Haiti (Port-au-Prince) earthquake of 2010 was both much larger in absolute terms (20.9 million lifeyears lost) and in per capita terms (771 days) – more than 2 years lost per every single person living in country.

The approach proposed here has several advantages, including: (1) emphasis on the loss of human potential associated with mortality; (2) emphasis on the tangible impact on people who were affected by disasters (but were not directly injured); (3)

a full-information index, for specific disaster events, allows one to place a stronger emphasis on the death of children[10]; (4) a greater emphasis on the financial costs of disasters in lower income countries such as Thailand; and (5) perhaps most importantly, the fact that any of these assumptions can easily be modified, depending on the ultimate aim of the data analysis.[11]

This measure focuses exclusively on the direct impact of disasters; even though there are significant socioeconomic impacts that are indirect in nature. Such indirect impacts can also be potentially long lasting (more discussion of this typology is available in Cavallo and Noy, 2011 and Meyer et al., 2013). Current knowledge appears to indicate that these impacts can indeed be long lasting (Cavallo et al., 2013), most adverse for the geographical areas directly impacted, and that the magnitude of indirect impacts may be a significant multiple of the direct adverse impact.

Furthermore, all existing attempts to measure disaster impacts, including the one described here, do not account for the direct impacts that are more difficult to quantify, especially the effect on natural capital (e.g. on the natural environment and the ecosystem services it provides us). For all these reasons, our quantification here should be viewed as significantly underestimating the overall impact of of the Christchurch earthquake(s) and the Greater Bangkok floods on human activity.

[10] Observing the public consternation with the high death toll among school age children in the Wenchuan Earthquake of 2008 suggests that the pubic, broadly speaking, shares this emphasys.
[11] In order to facilitate this, the data, including the calculations used to produce the table and figures, are posted at: https://sites.google.com/site/noyeconomics/research/natural-disasters.

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Figure 1: The 2011 Christchurch Earthquake

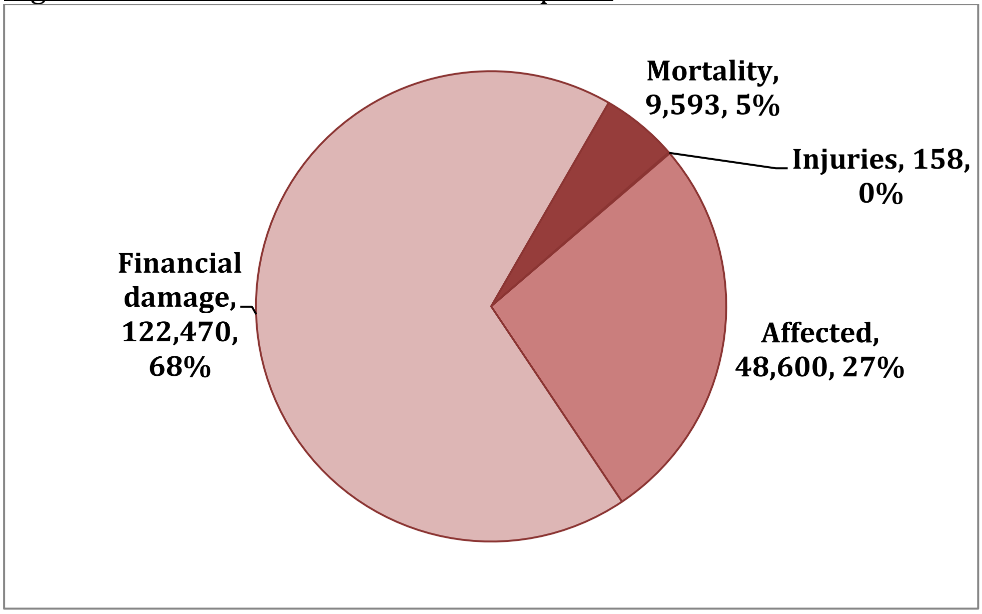

Figure 2: The 2011 Thailand Floods

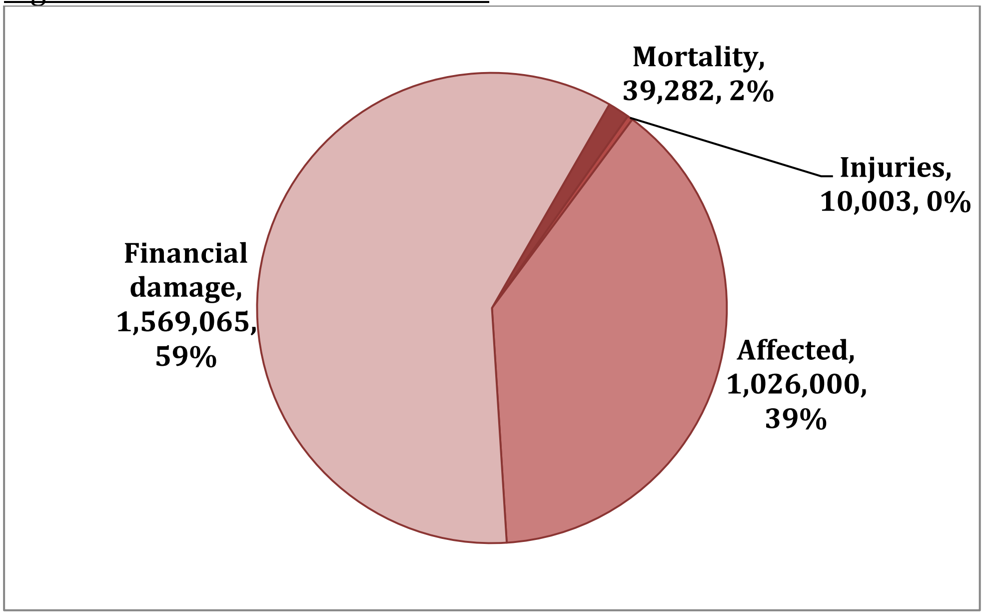

Table 1: The Events in Detail

	New Zealand		Thailand	
	Raw data	**Lifeyears**	Raw data	**Lifeyears**
Mortality	182 [1]	9,593	899 [6]	39,282
Morbidity (Total)				
Hospitalized days	2930 [2]	8		
Hospitalization costs	NZD 3,271,385 [2]	18		
Injuries (no hospital)	6,863 [3]	132	1,825,486 [7]	10,003
Affected	300,000 [4]	48,600	9,500,000 [8]	1,026,000
Damage (in million)	NZD 32,875 [5]	122,470	THB 1,490,458 [9]	1,569,065
TOTAL		**180,821**		**2,644,350**
Per capita (days per person)		**15.0**		**14.5**

1. Christchurch Earthquake : List of the deceased persons – http://earthquake-report.com/2011/03/08/christchurch-earthquake-list-of-the-deceaced-persons/.
2. Personal correspondence from the Ministry of Health, Government of New Zealand.
3. Source: Johnston D, et al. (2014). The 2010/2011 Canterbury earthquakes: context and cause of injury. *Natural Hazards* 73:627–637; we subtracted the 308 people for which we have hospital records.
4. EMDAT
5. See appendix table for sources for this observation.
6. Source: "Epidemiology of Drowning Death Identified from Flood - Related Surveillance during the Worst Flood in Thailand, August 2011 - January 2012." Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand. Volume 45 Number 19 : May 23, 2014
7. The total number of injured persons we report is the sum of persons experiencing physical injuries, from the Bureau of Information, Office of the Permanent Secretary (as at 13 November 2011), and the number of people reported to need mental health treatment, from the Department of Mental Health, Ministry of Public Health, Public Health, 2011.
8. The stated figure is from EMDAT. A Thai governemtn source lists a higher number (12,860,946), but given the ambiguouity in the definition of being affected, we prefer to use a consistent source for the two events. The governement source: "Statistical report of natural disasters in 2011", September 2012, Department of Disaster Prevention and Mitigation (DDPM), Ministry of Interior, Thailand.
9. Source: World Bank (2012). *Thai Floods 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning*. GFDRR Paper.