Abstract

Since 1967, the Insurance Council of Australia has maintained a database of significant insured losses. Apart from five geological events, all others are the result of meteorological hazards – tropical cyclones, floods, thunderstorms, hailstorms and wildfires. In this study, we normalize these weather-related losses to estimate the insured loss that would be sustained if these events were to recur under year 2006 societal conditions. Conceptually equivalent to the population, inflation and wealth adjustments of Pielke and Landsea (1998), we use two surrogate factors to normalize losses – changes in both the number and nominal value of dwellings over time, where nominal dwelling values exclude land value. An additional factor is included for tropical cyclone-related losses to account for the influence of enhanced building standards in tropical cyclone-prone areas since the early 1980s, standards that have markedly reduced the vulnerability of newer construction.

Insured losses often comprise about 50% of the total direct cost of natural disasters. This being the case and once the weather-related insured losses have been normalized in the manner described above, we have a rational means to compare the relative cost to the nation of the various natural perils. Hailstorms and tropical cyclones have been mostly costly with each contributing roughly 35% of the total normalized losses from all weather-related events over this 40-year time period; bushfire, flood and thunderstorm each contribute another 10%. It is possible that the flood risk has been underestimated due to the fact that it has not been consistently insured and that at least one major flooding event has been attributed to a tropical cyclone (Cyclone Wanda 1974).

Interestingly, the normalized losses exhibit no obvious trend over time that might be attributed to other factors, including human-induced climate change. Given this result, we echo Pielke (2005) and others in suggesting that practical steps taken to reduce the vulnerability of communities to today’s weather would alleviate the impact of any future climate; the success of improved building standards in reducing average annual tropical cyclone-related losses by 35% shows what can be done when there is a demonstrated need and political will.

Keywords: normalization; disaster losses; climate change

1. Introduction

Worldwide, increases in insured losses from natural hazards have risen dramatically (Swiss Reinsurance Company, 2006; Munich Re Group, 2005)
leading to concerns that human-induced climate change is contributing to this trend. A critical step before drawing this conclusion is to first filter out other influences known to contribute to increased disaster losses. And so as others have done previously for a variety of natural disaster losses in other locations, here we normalize (index) Australian insured disaster losses, in this case to year 2006 values. In other words, we are interested in the loss if these historical events were to impact society in 2006. Related studies include those of Changnon and Changnon (1992a, 1992b) – U.S. storm (hurricane, winter storm, thunderstorm and windstorm); Pielke and Landsea (1998), Pielke et al. (2007) and Collins and Lowe (2001) – U.S. hurricane; Pielke and Downton (2000), Downton et al. (2005) – U.S. flood; Brooks and Doswell (2001) – U.S. tornado; Vranes (2006) – U.S. earthquake; Pielke et al. (2003) – Caribbean and Latin American hurricane, and Raghavan and Rajesh (2003) – Indian tropical cyclones.

Our starting point is the Insurance Council of Australia’s Natural Disaster Event List (hereafter “Disaster List”). This comprises a catalogue of natural hazard events in Australia that have caused significant insured losses. The Disaster List contains details of each event including date, areas affected, and the industry-wide insured loss in “original” dollars. The Hobart Bushfires of 1967 were chosen as a starting point because this event was the first significant natural disaster for which credible insured industry loss figures were available. The threshold for inclusion has changed over time but most events exceed a nominal value of AUD$10 million. Spanning 40 years, it is one of the more comprehensive disaster loss records in the world. It has been previously analysed for trends and patterns (Blong, 1991; Walker, 2003) and was an important input to a national study of the economic cost of natural hazards in Australia (Bureau of Transport Economics, 2001). It is widely used by the insurance industry to estimate future losses and provide sanity checks on the output of catastrophe loss models. Many applications require normalized losses and this study attempts a rigorous methodology for doing this.

A defensible normalization process must adjust for changes in population and wealth, as well as inflation (Pielke and Landsea, 1998). An additional factor that can not be neglected under Australian conditions is the impact of improved building standards that stipulate more wind resistant construction in tropical cyclone prone areas (Walker, 1999). These enhancements were introduced in the early 1980s in the wake of devastating losses caused by Tropical Cyclones Althea in 1971 and Tracy, which almost completely destroyed Darwin, the State capital of the Northern Territory, in 1974. As a result of these changes, specified in Standard Association of Australia (1989), now superseded by Standard Australia/Standards New Zealand (2002), hereafter referred to as the “Wind Code”, newer construction is much less vulnerable to wind damage. Given that roughly one third of the total number of building losses over the last century due to natural hazards in Australia have been a result of tropical cyclones (Blong, 2004; Crompton et al., 2007), failure to properly account for the reduced vulnerability of newer construction would lead to unrealistic normalized values. No other natural hazard in Australia has invoked comparable responses in terms of building standards.
The paper is constructed as follows: we begin by describing our normalization approach followed by a brief discussion of the resulting values. We further analyze normalized losses and loss frequency by peril and seek out trends in the normalized losses over time. In particular, we shall look for any evidence that might suggest the increasing trend in original losses is due to other factors such as human-induced climate change. A Discussion section follows listing limitations common to most normalization methodologies including our own and the paper concludes with implications for policy.

2. Normalization Methodology

2.1. Adjusting for changes in population, wealth and inflation

A range of surrogate indices are available to adjust for these factors. Our preferred approach converts original losses in year $i$ ($L_i$) to 2006 values ($L_{06}$) according to the following equation:

\[ L_{06} = L_i \times N_{i,j} \times D_{i,k} \]  

(1)

where $j$ is the Urban Centre/Locality (UCL) impacted by the event; $N_{i,j}$ is the dwelling number factor defined as the ratio of the number of dwellings in 2006 in UCL $j$ to the number in year $i$; $k$ is the State or Territory that contains the impacted UCL and $D_{i,k}$ the dwelling value factor, defined by the ratio of the State/Territory average nominal value of new dwellings in 2006 to that of year $i$. Equation (1) provides very similar outcomes to the Pielke and Landsea (1998) methodology.

The UCL structure is one of the seven interrelated classification structures of the Australian Standard Geographical Classification that groups Census Collection Districts together to form areas defined according to population size (Australian Bureau of Statistics (ABS) - http://www.abs.gov.au). In broad terms, an Urban Centre is a population cluster of 1000 or more people while a Locality comprises a cluster of between 200 and 999 people. The numbers of occupied dwellings in the UCL at 2006 and when the event occurred ($N_{i,j}$) was determined by interpolation and/or extrapolation from the numbers in the 1966 and 2001 Census of Population and Housing (ABS - http://www.abs.gov.au). Only one UCL was used for each event and when more than one was impacted, the UCL experiencing most damage was used where possible.

The dwelling value factor ($D_{i,k}$) was calculated for the State or Territory containing the impacted UCL. Average nominal values of new dwelling units increase over time in an exponential fashion as shown in Figure 1 for Western Australia. State/Territory values are calculated by dividing the value of building work completed within a year by the number of completions within the same year with relevant values taken from Building Activity reports (ABS - http://www.abs.gov.au). The increase in $D_{i,k}$ is in part due to increasing average dwelling size as well as improvements in the quality of the housing stock. The average dwelling value excludes the price of land and as the nominal value is already adjusted for inflation (by definition), no further adjustment for this variable is required.
2.2. Tropical cyclone loss adjustment

As has been explained already, consideration of enhanced building standards as specified by the Wind Code needs to be included in the normalization of tropical cyclone-related losses. We adopt 1981 as a threshold year to discriminate between new and improved construction; this year also coincides with the reporting of Australian Census information.

The adjustment required is unique to each tropical cyclone event loss and incorporates the proportion of the loss attributable to wind damage (as opposed to flooding or storm surge); the proportion of pre- and post-1981 residential buildings in the impacted UCL both in the year the event occurred and in 2006; and pre- and post-1981 residential building loss ratios (ratios of insured losses to insured value), which are a function of peak gust speed (Walker 1995; Holmes 2001). This loss ratio also includes damage due to wind driven rain following wind damage to the outer envelope of the dwelling. These variables are combined to further adjust the partially normalized tropical cyclone losses as determined from Equation (1). The approach is based entirely on residential structures and assumes the post-1981 buildings were built in line with the Wind Code, i.e. no more or less vulnerable than the Wind Code prescribes. Full details of this correction can be found in Crompton and McAneney (2007).

An illustrative example follows:

![Figure 1: Time changes in the average nominal new dwelling value (AUD$ thousands) in Western Australia. Similar curves were developed for all States and Territories.](image)

- Average Nominal Value (AUD$ thousands): 0, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200
- Wind damage: 100%
- Pre-1981 residential building distribution:
  - 1970 100%
  - 2006 44%
- Notional maximum gust speed at landfall: 61 m/s
- Residential building loss ratio:
  - Pre-1981 78%
  - Post-1981 10%
- Original Loss (1970): AUD$200 million
- Partially Normalized Loss (Equation (1)): AUD$8040 million
- Normalized Loss (2006): AUD$4120 million

The importance of accounting for the reduced vulnerability of post-1981 construction is evident.

3. Results

Figures 2(a) and (b) show annual aggregated original and normalized losses for the weather-related events in the Disaster List. Annual losses have been calculated for years beginning 1 July to take account of the southern hemisphere seasonality of the meteorological hazards. The most salient observation is that the time series of normalized losses exhibit no obvious trend over time. We conclude that the increasing trend in original losses is largely attributable to changes in dwelling numbers and nominal dwelling values and that there is no discernable evidence that human-induced climate change is significantly impacting insured losses, at least in Australia and to the present time. Further work is required to determine the influence of human-induced climate change on any one particular hazard and to identify patterns of behaviour characteristic of meteorological cycles such as El Niño-Southern Oscillation.

The ten highest ranked weather-related normalized losses are presented in Table 1 with Tropical Cyclone Tracy heading the list. There is a wide spread of natural disasters with four different hazard types represented in the top ten. If geological hazards are also included then the normalized loss from the 1989 Newcastle earthquake would top the list with a cost comparable to that from Tropical Cyclone Tracy.
Figure 2(a): Original annual aggregate insured losses (AUD$ million) for weather-related events in the Disaster List for years beginning 1 July.

Figure 2(b): As for (a) but with losses normalized to 2006 values.
**Table 1:** Ten highest ranked weather-related normalized losses (AUD$ million).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Event</th>
<th>Year</th>
<th>Location</th>
<th>State</th>
<th>Original Loss (AUD$ million)</th>
<th>Normalized Loss (2006) (AUD$ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tropical Cyclone Tracy</td>
<td>1974</td>
<td>Darwin</td>
<td>NT</td>
<td>200</td>
<td>4120</td>
</tr>
<tr>
<td>2</td>
<td>Hailstorm</td>
<td>1999</td>
<td>Sydney</td>
<td>NSW</td>
<td>1700</td>
<td>3300</td>
</tr>
<tr>
<td>3</td>
<td>Tropical Cyclone Wanda</td>
<td>1974</td>
<td>Brisbane</td>
<td>QLD</td>
<td>68</td>
<td>1790</td>
</tr>
<tr>
<td>4</td>
<td>Ash Wednesday Bushfires¹</td>
<td>1983</td>
<td>Multiple</td>
<td>VIC / SA</td>
<td>176</td>
<td>1610</td>
</tr>
<tr>
<td>5</td>
<td>Hailstorm</td>
<td>1990</td>
<td>Sydney</td>
<td>NSW</td>
<td>319</td>
<td>1480</td>
</tr>
<tr>
<td>6</td>
<td>Hailstorm</td>
<td>1985</td>
<td>Brisbane</td>
<td>QLD</td>
<td>180</td>
<td>1430</td>
</tr>
<tr>
<td>7</td>
<td>Tropical Cyclone Madge</td>
<td>1973</td>
<td>Multiple</td>
<td>QLD / NT / WA</td>
<td>30</td>
<td>820</td>
</tr>
<tr>
<td>8</td>
<td>Hailstorm</td>
<td>1976</td>
<td>Sydney</td>
<td>NSW</td>
<td>40</td>
<td>740</td>
</tr>
<tr>
<td>9</td>
<td>Hailstorm</td>
<td>1986</td>
<td>Sydney</td>
<td>NSW</td>
<td>104</td>
<td>710</td>
</tr>
<tr>
<td>10</td>
<td>Flood</td>
<td>1984</td>
<td>Sydney</td>
<td>NSW</td>
<td>80</td>
<td>670</td>
</tr>
</tbody>
</table>

¹ The two separate loss entries in the Disaster List for this event have been combined into a single loss.

![Figure 3(a): Percentage of the number of weather-related events in the Disaster List classified by hazard type.](image)
Figures 3(a) and (b) classify the weather-related losses by hazard type showing their contribution to relative event frequency and the total normalized loss. Floods and thunderstorms combined account for half the total number of events, but only 20% of the total loss. Conversely, tropical cyclone and hailstorms together represent 40% of the total number of events but almost 70% of the total normalized loss. Floods are likely under-represented in this analysis because this peril has not been uniformly insured and some predominantly flood events were attributed to tropical cyclones, e.g. Tropical Cyclone Wanda (1974).

The average annual weather-related normalized damage over the 40-year period is AUD$790 million with a standard deviation of AUD$970 million. In normalized values, tropical cyclone-related losses average AUD$260 million per year, and would rise to AUD$400 million had the building standard adjustment not been incorporated. Moreover, had the Wind Code forced existing structures to be retrofitted the tropical cyclone average annual normalized loss would be even less than AUD$260 million. This result highlights just how effective risk-reduction measures can be in terms of reducing losses from natural disasters, a point that we will return to in later discussion.

Figure 4 shows successive normalized loss event frequencies above given thresholds summed over five-year periods. The increasing number of small events (>AUD$10 million) is attributed to population growth: as population grows and new areas are developed for housing, so does the

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**Figure 3(b):** Percentage of the total normalized loss from all weather-related events in the Disaster List by hazard type.
number of potential ‘targets’. The frequency of the most severe events (>AUD$1 billion) exhibits no distinct trend over time though the reliability of this result is limited owing to the small number of events. Moderate sized events (>AUD$100 million), on the other hand, show a slight decrease over time. This serves as a reminder that the recent past has been relatively benign in terms of weather-related loss activity. The most recent of the ten highest ranked event losses (Table 1) – the April 1999 Sydney hailstorm – occurred almost 10 years ago. The annual damage over the most recent five years averages AUD$380 million, less than half the average annual loss over the entire period of the Disaster List. Not included in this list is the 2007 Queen’s Birthday Weekend floods on the NSW Central Coast and Hunter Valley, which are anticipated to cost the insurance industry around $1.6 billion.

**Figure 4:** Five-year frequencies of normalized losses exceeding a given loss threshold.

### 4. Discussion

Equation (1) is conceptually equivalent to the Pielke and Landsea (1998) normalization but follows the approach described in Changnon and Changnon (1992a, 1992b) in so far as it is based on dwellings rather than population. The change in the number of dwellings is substituted for population change and change in the nominal value of new dwellings for inflation and wealth. A necessary assumption is that each line of business (residential, commercial, motor, aviation hulls, marine craft, etc.) contributing to the disaster loss behaves proportionally and can be normalized using the same factors.

While the most important factors have been quantified, it is important to recognize that our approach, like all normalization methods, has limitations. Some of these relate to changing demographics whereby it’s now possible for a loss to be registered in an area where there may not have been people
living in the past. Pielke and Landsea (1998) consider this possibility in their normalization of U.S. hurricane losses and conclude that their omission did not materially alter their findings. In our analysis of all Australian weather-related losses, it is less clear that this is the case, especially for hailstorms where there is no record of an event unless it impacted a populated area. This may in part explain the increasing frequency of small losses in the Disaster List (Figure 4). Offsetting this to some degree is the fact that a repeat of some historical bushfire loss events may now be physically impossible where original bushlands have been converted to suburbs. Nonetheless it would be naïve to think that similarly large bushfire losses will not recur (McAneney, 2005).

Adjusting for demographic changes is also problematic if damage resulting from the natural hazard was confined to a small area. For example, the April 1999 Sydney hailstorm impacted an already highly developed part of Sydney, yet the dwelling number factor still adjusts for growth characteristic of the entire Sydney UCL. The reverse is also possible had the hailstorm impacted a less developed part of Sydney. This influence on the normalized values is constrained however as it is the nominal value of dwellings that has been largely responsible for the escalation of Australian disaster losses. In the case of Tropical Cyclone Tracy, for example, the number of dwellings in Darwin tripled between 1974 and 2006 whereas the average nominal value of new dwellings in Northern Territory increased from AUD$18 500 to around AUD$240 000, a factor of thirteen.

Notwithstanding these and other cautions, the methodology presented here provides a relatively simple and effective way of normalizing original natural hazard event losses to 2006 values. The focus on dwelling values alone (i.e. land value excluded) ensures reasonable alignment to insured losses. These losses represent roughly 50% of the total direct losses to impacted communities.

5. Policy Implications

The collective evidence reviewed above suggests that societal factors – dwelling numbers and values - are the predominant reasons for increasing insured losses due to natural hazards in Australia. The role of human-induced climate change is not detectable at this time. This being the case, it seems logical that in addition to efforts undertaken to reduce global greenhouse gas emissions, significant investments be made to reduce society’s vulnerability to current and future climate and associated variability. Employing both mitigation and adaptation concurrently will benefit society now and into the future.

We are aware of few policies explicitly developed to help Australian communities adapt to a changing climate (Leigh et al., 1998). One positive related example is improved building standards introduced in the early 1980’s as part of a National Building Code of Australia. These enhancements have been mentioned already and as a result, dramatic reductions in wind-induced losses were observed following Tropical Cyclones Winifred (1986) and Aivu (1989) (Walker, 1999) and most recently, Larry (2006) (Guy Carpenter, 2006;
Henderson et al., 2006). While these measures were introduced in response to natural variability, the benefits will hold true under any future climate.

An increased threat from wildfires (bushfires) under human-induced climate change is often assumed. Indeed Pitman et al. (2006) and others anticipate an increase in conditions favouring wildfires. However, analyses by McAneney (2005) and Crompton et al. (2007) suggest that the main wildfire menace to building losses will continue to be extreme fires and that the threat to the most at-risk homes on the bushland-urban interface can only be diminished by improved planning regulations that restrict where and how people build with respect to distance from the forest. Social governance of this kind would immediately reduce current and future society’s vulnerability to natural hazards.
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References


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