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Natural Disaster Costs in Australia

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Natural Disaster Costs in Australia

Liam Dillon

Abstract

As climate change continues to amplify the incidence of extreme weather events, policymakers are increasingly cognizant of the mounting financial burdens brought by a warming world. This paper examines the costs which have followed natural disasters in Australia between 1970-2022, utilising data from the Insurance Council of Australia and the Australian Institute for Disaster Resilience. The financial impact of disasters is estimated by applying loss ratios to insurance claim data and overlaying mortality and injury costs. An autoregressive integrated moving average model is then applied to forecast these costs out to 2030. The results show an average annual cost of between $2.9 billion to $6.7 billion between 1970-2022 and highlight the tendency for large-scale events to drive the majority of losses, with events in the top decile of costs accounting for 68% of all losses incurred in the period. The scale and volatility of costs following extreme weather events reinforces the need for both physical and fiscal preparedness of governments in meeting the economic challenges presented by climate change.

JEL Classifications: Q51, Q54, Q58

Keywords: Climate Change, Global Warming, Natural Disaster, Economic Costs, Disaster Management, Climate Policy, Environmental Policy

1. Introduction

Like many of its peers, Australia finds itself caught in the debate not of whether climate change is taking hold, but rather how fast it is happening, and more crucially, how to respond. Despite its vaunted position as the lucky country, Australia has not been able to escape the impacts of a changing climate, with droughts, floods and fires imposing significant costs with increasing regularity on state and federal governments.

With global temperature rises kept within 1.5 degrees, scientists anticipate that intense heatwaves will happen at four times their historical rate, and droughts and floods at almost twice their historical average (Milman et al., 2021). For temperature rises of 2 degrees between now and 2050, bushfires of the calamitous scale of the Black Summer season are anticipated to be four times as likely to occur (Milman et al., 2021).

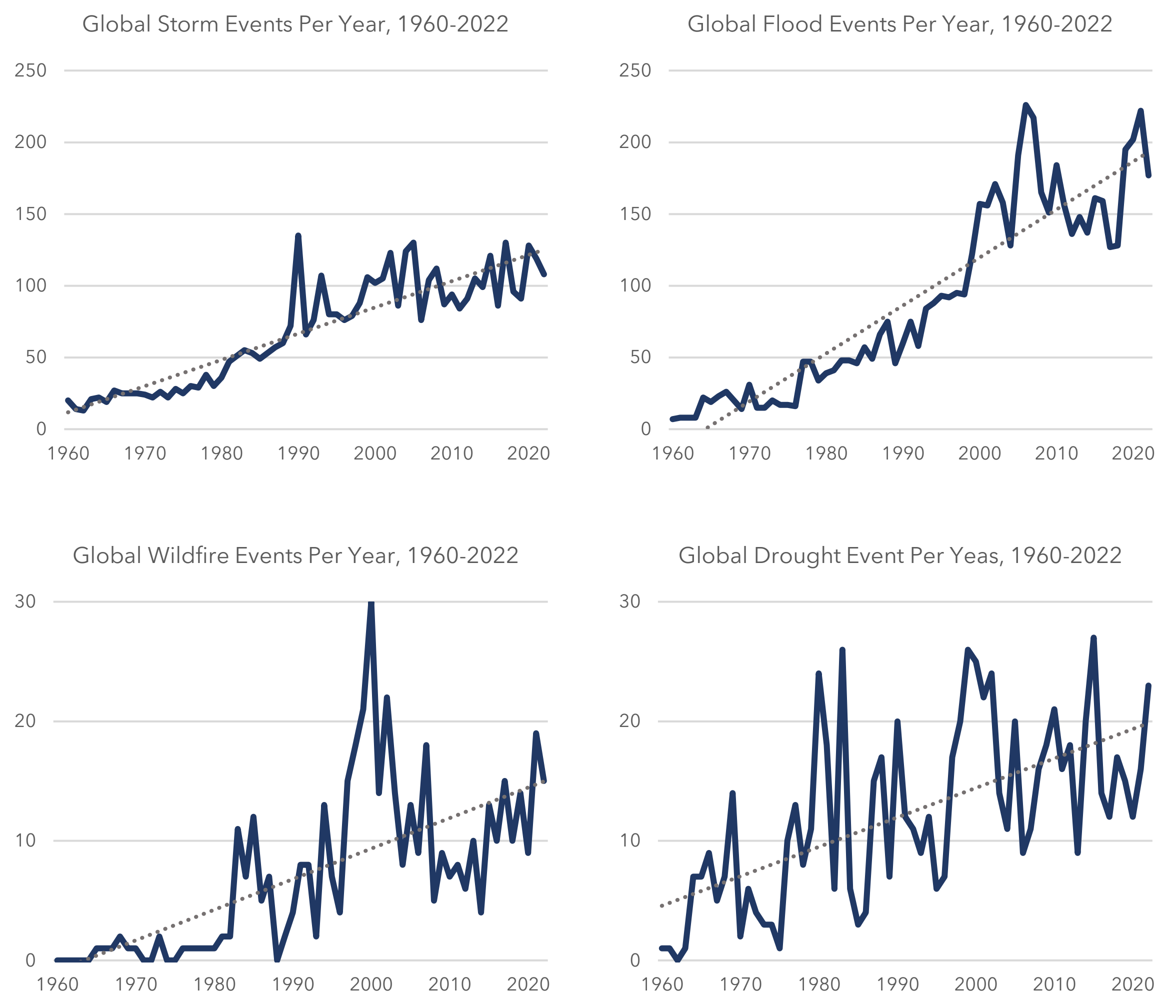
Natural disasters impose significant costs on the economy which are borne across multiple dimensions. In addition to the immediate physical damage they cause, social, psychological and productivity costs are also incurred. In an environment of escalating frequency and intensity for such events, fiscal responsibility demands that policymakers have a robust and complete understanding of the financial risk which natural disasters pose. Accordingly, this report seeks to estimate the costs incurred from natural disasters across the past several decades, highlight trends across disaster types, and provide indicative forecasts of future costs.

Section two provides some context around the incidence of natural disasters globally and in Australia across recent decades, while section three examines previous studies aiming to quantify the economic losses of natural disaster within the literature. Sections four and five discuss the data and methodology used in this report respectively, while sections six and seven introduce the analysis and provide a discussion of results.

2. Meteorological Trends in Australia and Globally

Australia is a country uniquely prone to a range of natural disasters, and has a long history of dealing with their far-reaching impacts (CSIRO, 2022). The health and welfare of Australian communities and ecosystems are significantly affected by shifts in extreme weather and climate events such as intense heat, heavy rainfall, coastal flooding, fire conditions and drought. While such events have always formed an essential part of Australia's ecology and natural environmental processes, a number of highly visible and destructive events have coalesced with growing awareness and concern regarding broader climate trends to bring natural disasters to the forefront of the public mind.

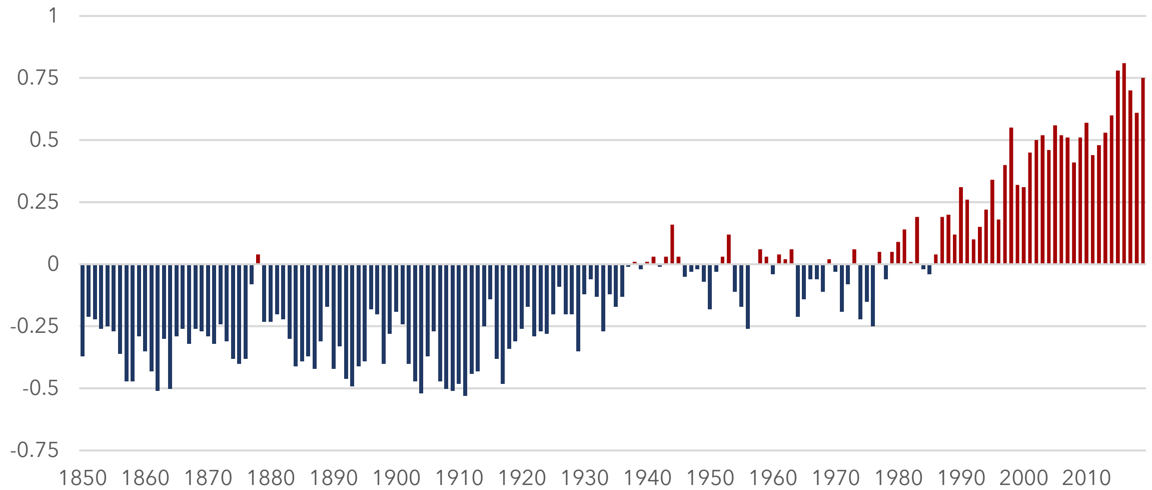
Figure 1. Trends in Global Hazard Events



Source: EM-DAT, 2023

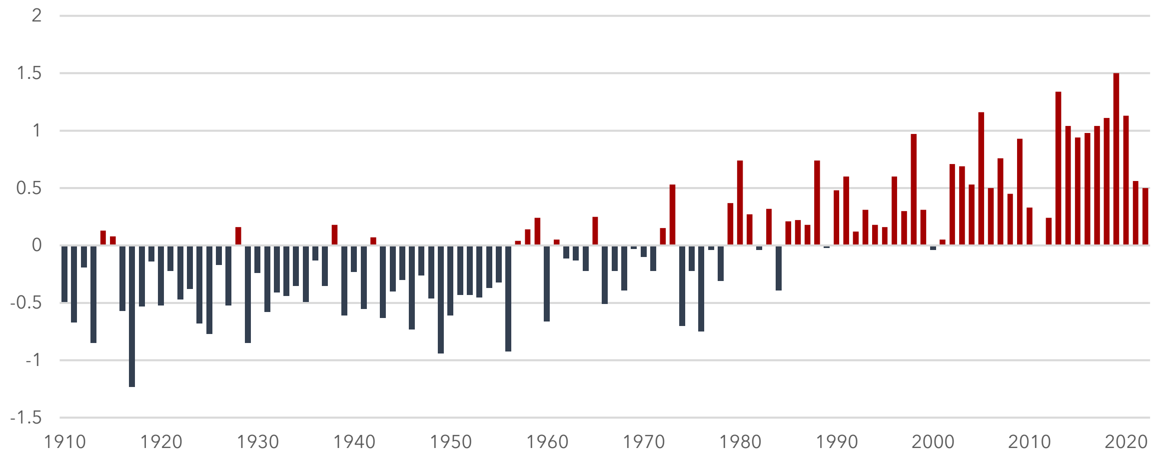
Evidence suggests that extreme weather and natural disasters are becoming more frequent and intense, with anthropogenic-led climate trends contributing to worsened natural disasters (IPCC, 2023). According to the World Meteorological Organisation (2021), there were 11,072 weather and climate-related natural hazards which crossed disaster-reporting thresholds between 1970 through to 2019. The cumulative impact of these disasters was estimated to be US$3.64 trillion in economic losses in 2021 dollars, with over two million associated deaths (Centre for Research on the Epidemiology of Disasters, 2022). Put differently, natural disasters cost the global economy an average of US$202 million per day over the fifty year period assessed by the World Meteorological Organisation.

Figure 2. Global average temperature anomaly (˚C) relative to 1961-1990



Source: Bureau of Meteorology, 2022

Figure 3. Australian average temperature anomaly (˚C) relative to 1961-1990

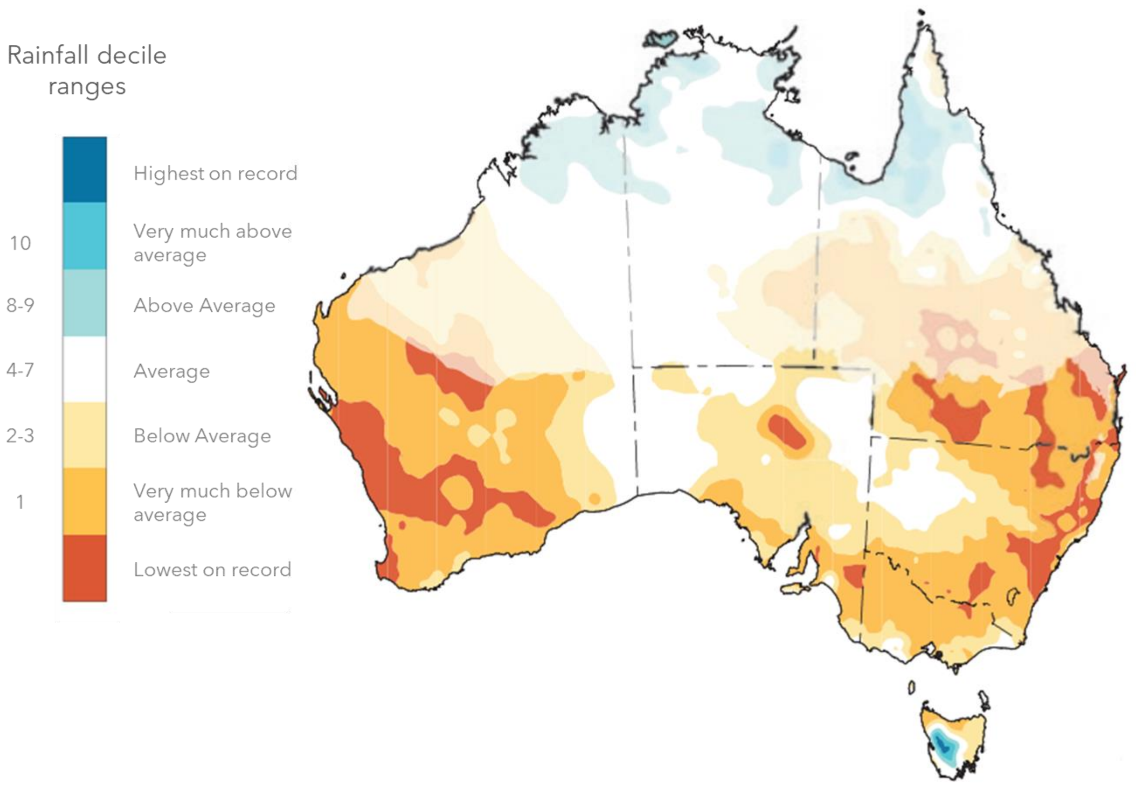


Source: Bureau of Meteorology, 2022

According to the CSIRO (2022), Australia's ecology has undergone drastic changes across a number of meteorological indicators over recent decades, many of which have incurred adverse economic impacts. As highlighted in figure 3, Australia's climate has mirrored the global trend and is estimated to have warmed by 1.4°C since 1910, while sea surface temperatures have increased by 1.05°C (CSIRO, 2022). The corollary of these trends interacting has been to create an environment more conducive for severe storms, droughts, and bushfires.

One climatic shift keenly felt by Australia's agricultural sector has been changes to seasonal rainfall. The southwest of Australia has experienced a decline of approximately 15% in rainfall between April to October since 1970, while the period from May to July within the same region saw a reduction of around 19% since 1970 (Bureau of Meteorology, 2022). Meanwhile, the southeast of Australia has seen a decrease in rainfall of approximately 10% in April to October since the late 1990s (Bureau of Meteorology, 2022). Ortiz-Bobea et al. (2021) estimate that the cumulative impact of Australia's changing climate and meteorological trends was a 20-25% loss of agricultural productivity between 1961 – 2015.

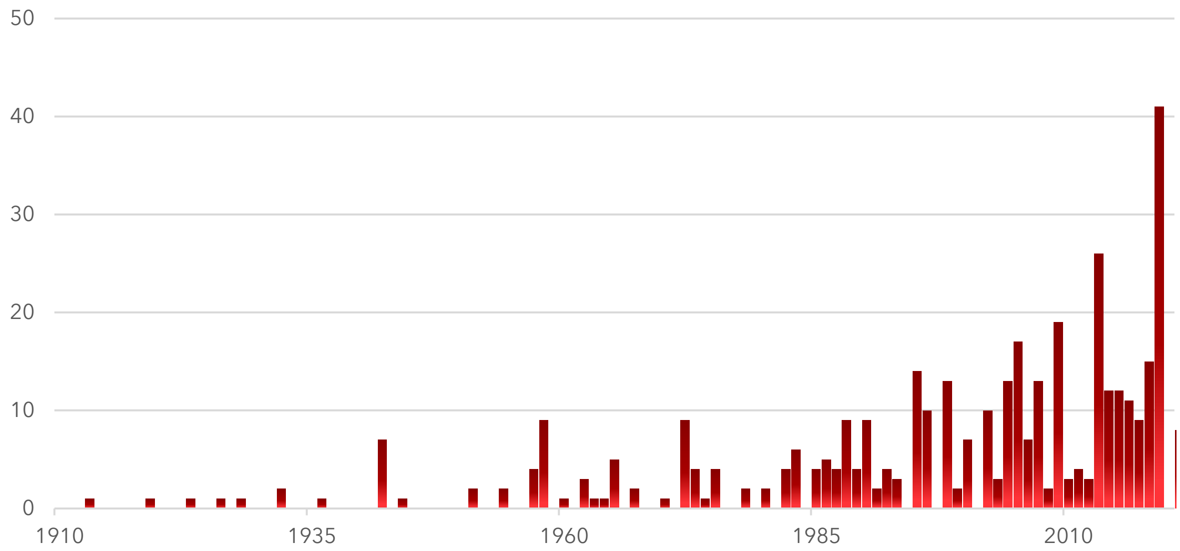
Figure 4. April to October Rainfall Deciles, 2000-21



Source: Bureau of Meteorology, 2021

Accompanying rising sea and surface level temperatures has been a marked increase of extreme heat days experienced in Australia, defined as days with temperature over 39°C (Bureau of Meteorology, 2022). In 2019, Australia experienced 33 days when the national daily average maximum temperature exceeded this threshold, a larger result than the combined 59 years between 1960–2018 (CSIRO, 2022). This increase in the incidence of extreme heat has also seen a prolonging of the fire season and increase in extreme fire weather versus the pre-1950s average (CSIRO, 2022).

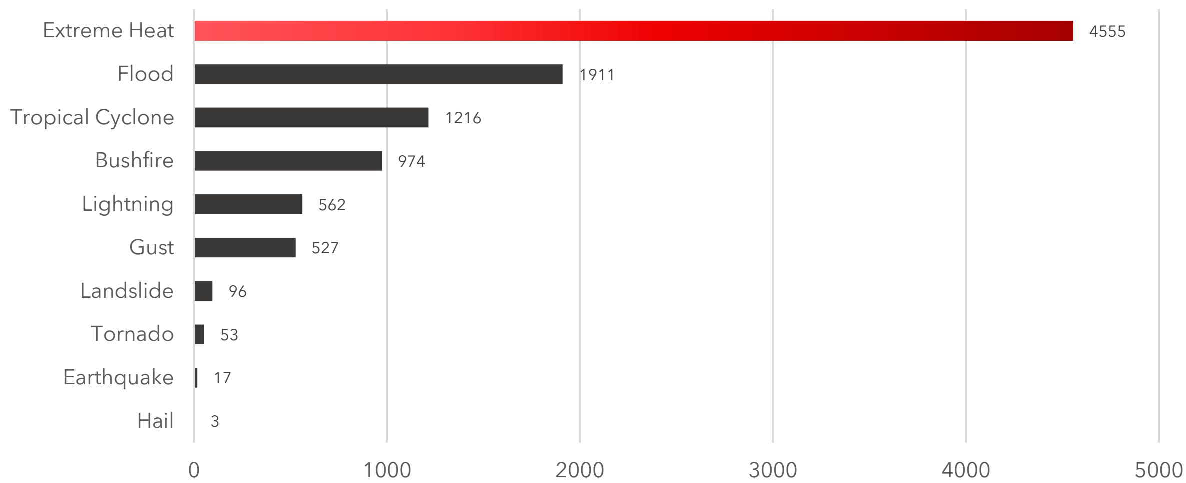
Figure 5. Number of Days Average Temperatures Were in Warmest 1% of Records, 1910-2020



Source: CSIRO, 2022

The Royal Commission into Natural Disasters (2019) estimated that between 1900 and 2015, extreme heat was the most lethal type of natural hazard in Australia. Indeed, analysis of these estimates shows that extreme heat was 11 per cent more lethal than the next four hazard types combined.

Figure 6. Australian Fatalities by Hazard Type, 1900 - 2015

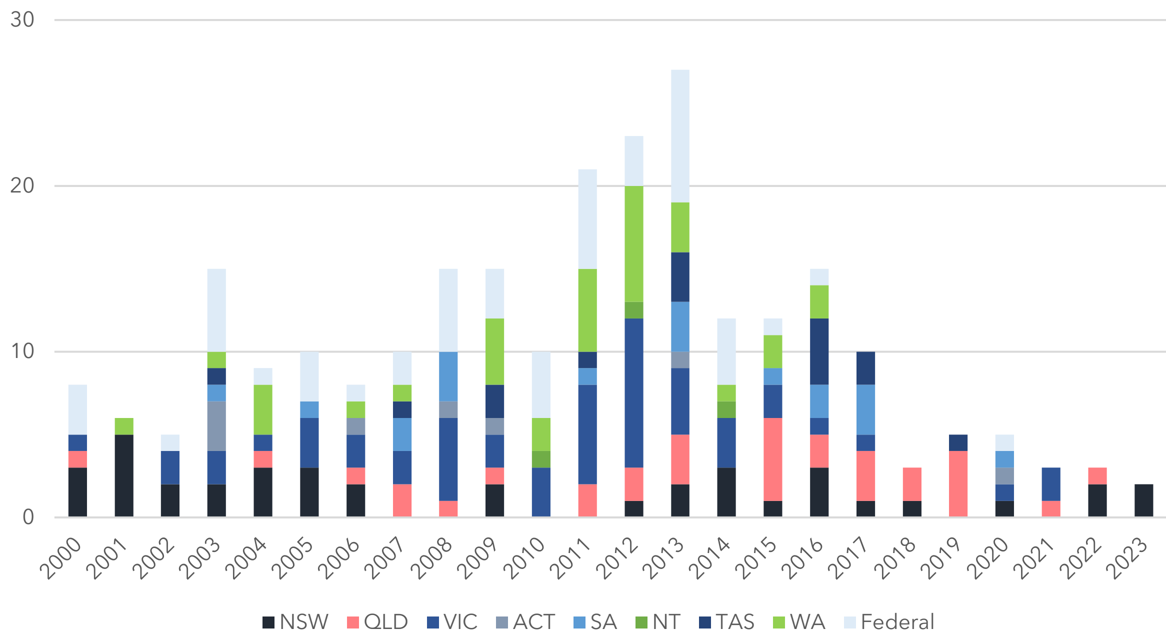


Source: Royal Commission into Natural Disasters, 2019

While meteorological trends are worrying both individually and collectively, a distinction must be made between extreme weather and natural disasters. The latter of these, which are key to this report, refer to natural events which cause harm or loss to people and units of economic value, while the phrase extreme weather within the literature is used as a catch-all for both, and can also encompass extreme natural events which occur remotely and do not have any human impact (Productivity Commission, 2014).

The destructive and highly visible nature of natural disasters in Australia has made the exercise of assessing their costs one which has attracted both academic and political attention over the past two decades. Indeed, since 2000 there have been nearly 250 inquiries and reviews into disasters within Australia, and 324 since records commenced in 1886 (Bushfire and Natural Hazards CRC, 2023).

Figure 7: Natural Disaster Inquiries and Reviews in Australia



Source: Bushfire and Natural Hazards CRC, 2023

While Australia is fortunate in that it is a rich country which is comparatively well-equipped to respond to disasters, globally recognised projections for increased frequency and intensity of such events carry portentous implications for the potential of natural disasters to impose substantial costs and constrain economic growth in the years to come.

3. Literature Review

Enquiry in the field of disaster research has been approached from multiple perspectives and with varying motives, with some studies focusing on individual or localised impacts arising from disasters, and others focusing on the aggregate financial consequences of natural hazards as they occur. This section evaluates contributions which have focused on both the financial and economic implications of natural disasters in Australia at a national scale.

What is clear within the literature is that despite the level of interest for this subject, there is no consensus on how to measure the economic costs of natural disasters, either domestically and internationally. The inconsistency of approaches adopted among researchers is summarised well by Hallegatte and Przyluski (2010, p. 2) who state that that:

> '… these various assessments are based on different methodologies and approaches, and they often reach quite different results. Beside technical problems, these discrepancies are due to the multi-dimensionality in disaster impacts and their large redistributive effects, which make it unclear what is included or not in disaster cost assessments. But most importantly, the purpose of these assessments is rarely specified, even though different purposes correspond to different perimeters of analysis and different definitions of what a cost is.'

Indeed, it is commonplace to see different researchers utilise various measures such as fiscal costs, financial costs, economic costs, insurance losses, or a combination of these when estimating the costs of natural disasters (Royal Commission, 2012). Further compounding disparities among cost estimates are the different adjustment methods applied to financial data series, with adjustments to cost ranging between no transformations at all, to complex modifications which factor in a wide range of economic indicators (Latham et al., 2010). The corollary of this trend has been the publication of significantly varying estimates for the same event. For instance, ranges for the economic costs of the 2009 Black Saturday bushfires have been reported between $1.4 billion to $4.4 billion in different publications (Latham et al., 2010; Stephenson et al., 2012; VBRC, 2010).

Despite different methods of calculation, common to most research both domestically and abroad is the use of insurance data as a baseline for estimating the costs of natural disasters. This approach has been favoured locally as the Insurance Council of Australia has made public records of insured disaster losses (further detail regarding this data is provided in section four). The availability of this data and absence of consistently reported, more general disaster data has also led to the widespread adoption of insurance loss ratios (ILRs) within the literature as a means of calculating a fuller picture of costs. These ratios attempt to capture the relationship between insured and uninsured losses arising from natural disasters (Productivity Commission, 2014).

While the use of simple adjustments such as ILRs as a means of calculating total financial losses likely represents a poor reflection of the complex and multi-faceted damages stemming from disaster, the practice is not unique to Australia and has also been adopted overseas. For example, Pielke et al. (2008) detail that the National Hurricane Centre in the United States makes the assumption that direct economic losses are approximately twice the insured loss incurred.

Despite these ratios acting as the lynchpin of all contemporary analysis, the multiples most regularly applied within an Australian context stem from research which is over three decades old by Joy (1991). Commissioned by and working in tandem with in-house researchers at the Insurance Council of Australia, Joy (1991) attempted to approximate the ratio of insured to uninsured losses arising from several categories of natural hazard, summarised in table one below.

Table 1. Proportion of Insured Loss to Total Loss, Joy (1991, p. 4.)

Disaster Type	Proportion of insured to total loss
Severe Storm	35%
Tropical Cyclone	20%
Flood	10%
Earthquake	25%
Bushfire	35%

These ILRs made use of proprietary data held by the Insurance Council of Australia, and the estimates have been subsequently regarded as difficult to analytically verify (Ladds et al., 2017). Nevertheless, the Productivity Commission (2014) considered that 'while the relevance of these ILRs 20 years later is questionable, they can nevertheless be useful as an input in determining a plausible range for the economic costs of natural disasters' (p. 519).

The Bureau of Transport Economics (2001) offered what was the first and perhaps remains the most comprehensive economic analysis of natural hazards in Australia. Despite being published over two decades ago, this report consistently forms the foundation of almost all recent research and analysis within this field in the Australian context. The report had the goal of establishing the costs of natural disasters and their trends in Australia over time, as well as to develop a framework for future analysis. The research was motivated by a view that an authoritative insight into the cost of natural hazards would enable a more robust understanding of the effectiveness of expenditure on the disaster mitigation and response measures in place.

The Bureau considered the impact of floods, cyclones, tsunamis, storm surges, bushfires and earthquakes in their analysis, following the classifications used by Commonwealth for the purposes of the Natural Disaster Relief Arrangements, and analysed disasters which had occurred between 1967 through to 1999 on the basis of credible data availability.

The Bureau made clear that the focus of the analysis was predicated not on financial costs, but rather on the economic costs associated with natural disasters. While the former was classified as being concerned purely with the cash value of resources affected by the disaster, with market prices used to value all costs and benefits, economic costs were identified as those which incorporate the broader social effects of a disaster, and were considered more aligned with the concerns of governments in responding to such crises.

The Bureau's analysis utilised data maintained by Emergency Management Australia (EMA), which had publicly available records of disasters spanning back to the 1800s. While the Bureau considered that the EMA database was the best available source for analysis in Australia at the time, it identified several limitations. These included the use of insurance data as a baseline for cost estimates, a reliance on sometimes conflicting media reports for documenting disasters, and inaccurate indexing of costs within the database.

To arrive at cost estimates, the Bureau utilised insured costs identified in the EMA database and applied multiples identified by Joy (1991) per disaster type to arrive at an indicative total disaster cost. The Bureau then added the cost of deaths and injuries to the data, with these being considered to be the only intangible impact of disasters which were able to be reliably estimated and incorporated into the available data. Utilising guidance from its own previous research, the Bureau applied a value of $1.3 million as the cost of a fatality, $317,000 as the cost of a serious injury, and $10,600 for the cost of a minor injury (in 1999 dollars). While records of fatalities within the EMA database were considered reliable, the distinction between serious and minor injuries was not always complete. In such instances, the Bureau assumed a 1:3 ratio, based on the distribution observed in other events with injury records.

The report found that disasters cost Australia $37.8 billion in 1999 prices between 1967 – 1999, equivalent to an average annual cost of $1.14 billion, or $85 per person. The cumulative costs of deaths and injuries associated with the disasters were estimated to be $1.4 billion. Ultimately, the Bureau caveated its findings by identifying that because indirect and intangible costs have been subject to different approaches and data limitations, the conclusions derived from the data analysis must be interpreted as indicative or approximate only, with any conclusions drawn regarded as tentative.

Because insurance data was only included from 1967 onwards the period of analysis was limited and frustrated the Bureau's ability to identify long term trends. As an example, the Bureau noted that it was possible to derive an increasing or decreasing trend in costs depending on the time frame chosen, illustrating the need for caution when drawing conclusions from a short time series.

While the Bureau's estimates were based on the application of ILRs to insurance data, it also provided a detailed framework which it hoped could be used in future analyses should more comprehensive hazard data become available. This framework identified that best practice for costing such events would be to collectively identify and sum both direct and indirect costs associated with disasters. The Bureau considered that 'the more inclusive these cost estimates are of intangible factors like death and injury, the better the opportunities for more informed decision-making. Inclusion of these costs allows a more thorough evaluation of the cost-effectiveness of funding which aims to reduce or mitigate the impacts of natural disasters' (p. 127).

A comprehensive and more recent contribution to the literature was made by the Productivity Commission (2014) as part of an inquiry into natural disaster funding arrangements. The supplementary paper examined natural disasters from 1970 through to 2013, utilising data provided by the Insurance Council of Australia. Analysing this data led the Commission to conclude that natural disasters were occurring more regularly, with 74 disasters recorded in the first half of the sample (1970-1991) versus 126 in the second half (1992-2013).

The Commission projected insured and economic costs from 2014-23, with the 2014-18 period defined as the medium term and 2014-23 defined as the long term. The estimates suggested that over the projection period, the average growth rate of nominal insurance losses was expected to fall between 5-6% per year, while annual economic costs were projected to fall between $2.4 billion and $14.6 billion in the medium term and $2.6 - $15.1 billion in the long term.

In arriving at its estimates, the Commission considered two alternate approaches. The first drew from the conceptual framework put forward by the BTE (2001) and entailed directly estimating as many components of economic costs associated with natural disasters as practical, while omitting transfers. While the Commission considered that estimates of direct costs like damage to public infrastructure, residential property and commercial buildings were possible to obtain, time series data on indirect and intangible costs were largely not available. Overall the Commission did not include these costs in its quantitative analysis 'because of the inherent difficulties in valuing indirect and intangible costs' (p. 506).

Instead, the Commission followed the approach taken in earlier work and applied ILRs to scale insured losses to direct costs, with a view that this approach leveraged aggregate insurance loss data which was of publicly available and of high quality.

A major contribution of the Commission's work was to evaluate the application of Joy's (1991) ILRs and incorporate more recent data points to test their credibility. The Commission found that compared with the 2009 Black Saturday Bushfires, Joy's ILR of 35% was close to estimates from the Victorian Bushfires Royal Commission (2010b) of 27% and Stephenson et al.'s (2012) estimate of 38%. After incorporating these and other findings, the Commission ultimately decided to opt for loss estimate ranges which saw insured losses representing between 20-50% of total direct losses.

Another key finding from the Commission's work related to the outsized impact of large events. From a policy perspective, the Commission considered that these highlighted the importance of natural disaster funding arrangements designed to deal with costly natural disasters, asserting that their findings supported an argument that 'the goal of funding arrangements is not to provide support for every natural disaster – disaster damage cannot be entirely prevented – but for those at the high end of the cost and community impact spectrum' (p. 283).

Outside of reports provided by public entities, one of the most prevalent series of commercially commissioned analyses has been contributed by Deloitte Access Economics for the Australian Business Roundtable for Disaster Resilience and Safer Communities (2011, 2013, 2017, 2021). With a stronger emphasis on incorporating potential climate change effects, these reports enjoy regular citation in media reports as well as government enquiries.

Deloitte's most recent approach to cost modelling builds on the use of ILRs and incorporates proprietary data not publicly accessible in conjunction with climate modelling sourced from the IPCC (Deloitte, 2021). The data utilised is provided to Deloitte by the Insurance Australia Group, and distinguishes itself from the ICA disaster database by capturing smaller natural disaster events and the inclusion of localised cost estimates. Using these data as a baseline, Deloitte then applies modified ILRs to capture other financial and social costs associated with disasters, and combines these with meteorological data to project losses through to 2060 under low, medium and high emissions scenarios.

The research concludes that natural disasters as of 2021 cost the Australian economy $38 billion per year on average, with these costs estimated to rise to $73 billion per year by 2060, discounted to 2021 dollars (Deloitte, 2021).

Despite being regularly published in news media, Deloitte's estimates are hard to objectively assess due to the private nature of the data used, as well as the specific ILRs and their adjustment mechanisms having not been provided within the report. Additionally, while the majority of research in this area considers the wide variability of costs year over year and uncertain feedback systems associated with global climate trends as significant constraints in conducting meaningful long-run cost forecasting, Deloitte's report provides few caveats to its estimates, and indeed does not include any confidence intervals in reporting potential costs under different emissions scenarios. Deloitte's report and results reinforce the earlier point regarding how different data sources and methodologies can lead to disparate results in cost estimates.

A common theme within the literature which binds many reports together is for researchers to assert that increases in the costs of natural disasters are driven by the increasing size of population centres exposed to natural hazards, rising asset values and adoption of insurance policies. This relationship was analytically tested by McAneney et al. (2017), who developed a normalisation method to identify the quantum of change which could be attributed to increases across socio-economic dimensions, as opposed to anthropogenic related global climate trends. The authors posited that increased severity of hazards should manifest as an upward trend in normalised loss data. After accounting for changes to wealth levels, changes in population and structural quality of buildings, the authors found that there was no discernible increase in normalised losses from natural disasters, lending empirical support to the theoretical view held by many other researchers. This view was reinforced by work conducted by the Actuaries Institute (2010) which arrived at much the same conclusion after applying similar tests to their own data.

While many studies and reports highlight the human cost as a significant driver of overall natural disaster losses, few consider the impact of extreme heat, despite the recent trends highlighted in section two. Indeed, overlooking the costs of heatwaves may represent a significant omission from the existing literature. While less visible than other natural disasters, heatwaves can exact a more significant human toll – as an example, it was estimated that the heatwave which coincided with the Black Saturday bushfires of 2009 yielded more than twice as many deaths as those arising directly from the fires (Victorian Bushfires Royal Commission, 2010). In submissions to the Productivity Commission's inquiry, the Government of South Australia expressed that:

> 'Heatwaves are becoming more significant within the emergency management arrangements as the South East of Australia experiences more frequent and extreme weather events. Heatwave is known as the 'silent killer' and the morbidity and mortality rates are higher than any other natural hazard in Australia. Heatwaves also impact essential infrastructure … it is recommended that heatwave is included as an eligible measure under the NDRRA' (p.270).

Nevertheless, neither Deloitte, BTE or the Productivity Commission included heatwaves within their analysis, despite the latter emphasising '… their potential significant and negative impacts on the community' (Productivity Commission, 2014, p.270).

While there can be many effects associated with severe heatwave events such as loss of productivity or damage to infrastructure, the most well researched aspect is excess mortality. Despite this element of heat being well studied, estimates of mortality within Australia are widely disparate, driven largely by the fact that heat generally acts as an exacerbating factor for other co-morbidities and is seldom reported as the sole cause of death (Cowan and Purich, 2014).

One comprehensive analysis was conducted by Coates et al. (2022), who examined fatalities between 2001 through to 2018. In conducting their analysis, the authors were granted special access to the closely guarded national coronial information system, and utilised specific mortality coding searches in conjunction with keyword and phrase searches in accompanying medical reports to explicitly identify heat-related deaths. The study found that in the assessed period, there were at least 473 heat-related deaths reported to a coroner. Significantly, the research identified that the data exhibited generally low levels of heat mortality, with a small number of events contributing the majority of deaths. In particular, the authors found that just two heatwaves (2009 and 2014) delivered 63% of total deaths.

Within the context of overall disaster cost estimates, Handmer et al. (2017) present one of the only studies which incorporates the cost of heatwave mortality in indirect cost estimates. Though the authors identify that heatwave inclusion is important 'because increasing heatwave severity and frequency are virtually certain with climate change' (p. 42), there is little information given on the method for identifying heatwave fatalities, a significant limitation given the difficulties associated with clearly identifying them. A component of this research was developing a new disaster database, called AUS-DIS which included observations between 1967 to 2013 and integrated insurance data, international cost estimates, and accompanying metadata. However, at the time of writing, this dataset was not publicly available.

Extreme heat can also incur costs outside of those associated with mortality. Despite the challenges in estimating their costs, Zander et al. (2015) estimated that heat stress can cause annual costs in Australia of between US$5.2–7.3 billion in lost productivity associated with absenteeism and reductions in work performance. This analysis relied on a representative survey of 1,726 working Australians and calculated loss based on reported income figures multiplied against self-reported days absent as well as lost productivity while working during heat-stressed days.

4. Data

There are two primary sources of publicly accessible data in Australia regarding natural disasters: the Insurance Council of Australia (ICA) and the Australian Institute for Disaster Resilience (AIDR). The ICA gathers information from general insurance companies after significant events that affect both the community and insurers, and documents events where the nominal insured loss surpasses $10 million. Like many other studies, the ICA dataset is utilised in this report because it is relatively comprehensive, providing both nominal and normalised estimates of insurance losses for a large number of disasters.

The AIDR hosts the Emergency Management Australia disasters database which was initially utilised by the BTE in conducting its analysis. The database provided by AIDR is useful in that it provides additional statistics for disasters outside of cost measures such as the number of injuries and fatalities, descriptions of events, and other qualitative information. However, the data collection for these statistics is inconsistent, and not all disasters have recorded costs. In order to be included in AIDR's database, natural disasters must have carried at least three deaths, twenty injuries or illnesses, or significant damage estimated at a cost of $10 million or higher. While the cost information within the AIDR dataset is not relied on for this report, information regarding injuries and fatalities have been cross-referenced as supplementary data points to the ICA database.

As highlighted in section three, comprehensive proprietary datasets exist however are not publicly available. These include the PerilAus database developed by Risk Frontiers which contains data on over 14,000 events in Australia since 1900, as well as data provided by Insurance Australia Group utilised by Deloitte (2021).

Limited disaster statistics are also obtainable from international sources like the United Nations' Emergency Events Database (CRED, 2023) and Swiss Re Sigma reports (Swiss Re 2022). Nevertheless, these sources are not generally amenable for comprehensive analysis within an Australian context due to the sporadic recording of natural disasters and the limited availability of consistent time series data on natural disaster costs in Australia.

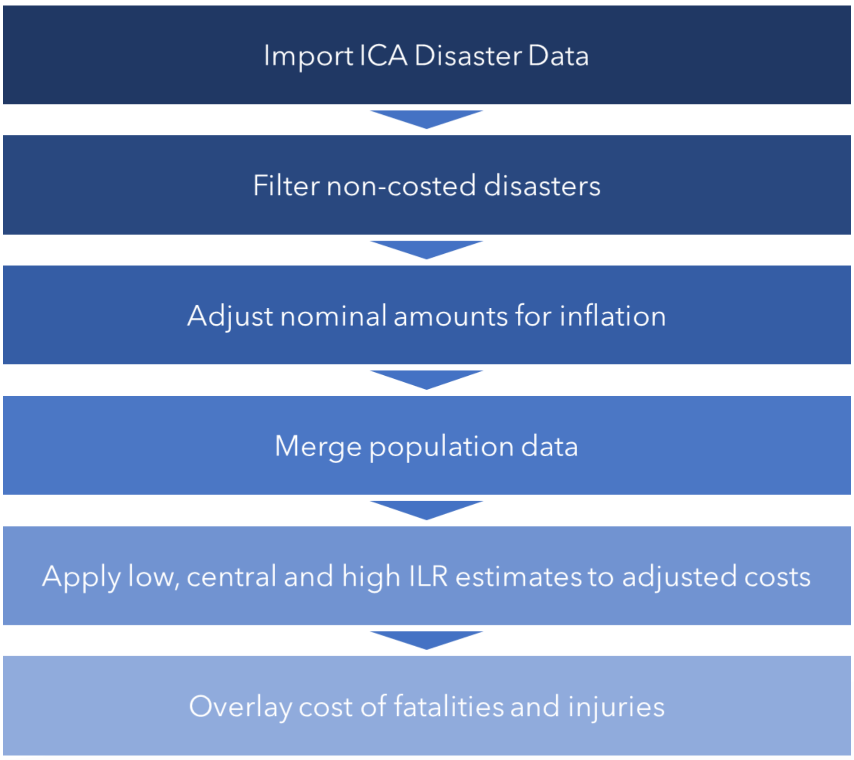
5. Methodology

As identified in the Bureau of Transport Economics' conceptual framework (2001), a comprehensive analysis of the full economic cost of natural disasters would ideally include all direct, indirect and intangible costs associated with disasters, as well as any positive impacts (such as income from construction and clean up work). However the primary challenge in conducting such an analysis arises from inadequate data availability across disasters, particularly surrounding indirect and intangible costs like lost productivity, psychological harm, damage to cultural heritage and harm to ecosystems.

As such, the approach taken in this report follows the example set in other works, in utilising insured losses reported by the ICA's disaster database as a baseline, applying the Productivity Commission's ILR updates, and finally overlaying the indirect costs of deaths and injuries to arrive at an indicative estimate for economic costs.

The steps taken for analysis are summarised in figure 8. The use of financial as opposed to calendar years follows the convention within the literature, and is done so as to better capture costs which can fall within Australia's summer months. The timeframe applied for this analysis is the financial years commencing 1970-2022.

Figure 8. Loss Estimation Process



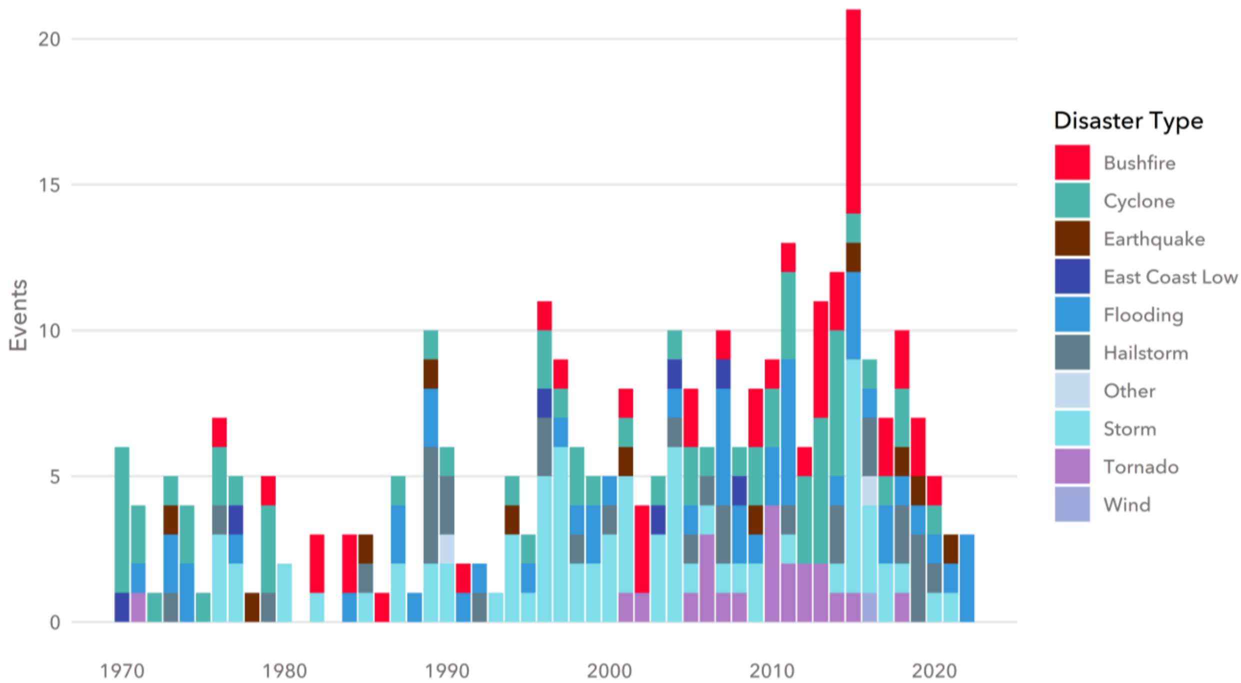
Within the frame of this analysis, fatalities and injuries represent the only indirect economic cost which can be reliably apportioned. The costing methodology for fatalities and injuries uses the latest estimate from the Office of Best Practice Regulation (2022) for the value of statistical life, which is $5.3m in 2022 dollars. Research from the Bureau of Transport Economics (2001) indicates that serious injuries resulting from natural disasters are on average 25% of the value of a fatality, and minor injuries represent approximately 0.8% of the value of a fatality. The Bureau's (2001) research also indicated that the ratio between serious and minor injuries from disasters was approximately 1:3. To arrive at an annual estimate for the 'human cost' of disasters, the below formula was applied:

$$Annual\ Human\ Cost_t = (Deaths_t * \$5.3m) + \left(Injuries_t * \frac{1}{3} * \$1.325m\right) + \left(Injuries_t * \frac{2}{3} * \$0.0425m\right)$$

6. Analysis

Since 1970 through to 2022, ICA data indicates that there have been 669 natural disasters in Australia, 303 of which have been attributed costs. Among the disasters which have costs attributed to them, bushfires, storms and cyclones are the most prevalent, as highlighted in figure 8, whereas flooding, hailstorms and cyclones have incurred the greatest insured losses over the assessed period.

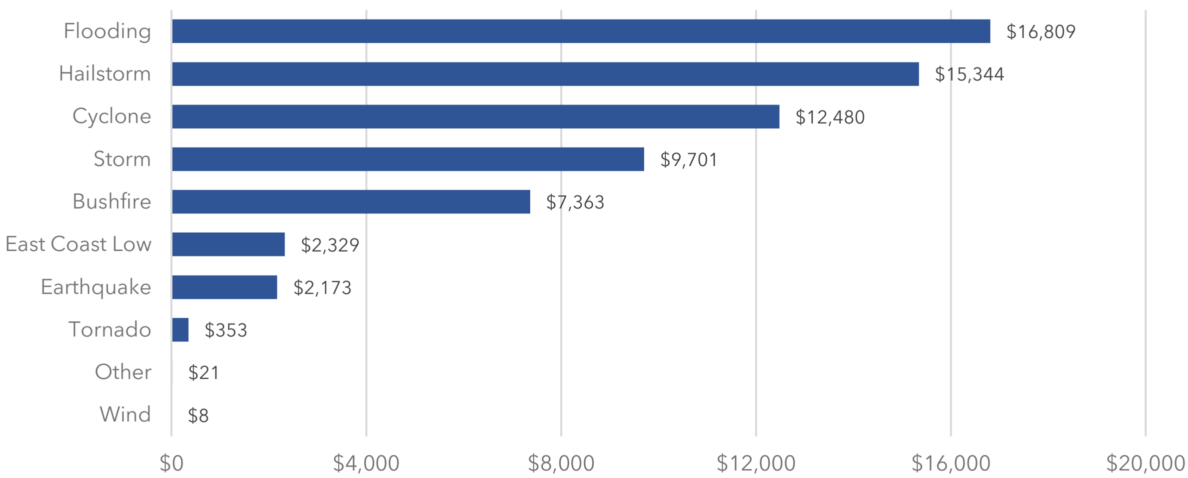
Figure 8. Number of Disasters by Type and Financial Year[a]



(a): 'Other' is a native categorisation within the ICA database and refers to storm events which arose from fires.

Source: Insurance Council of Australia, 2023

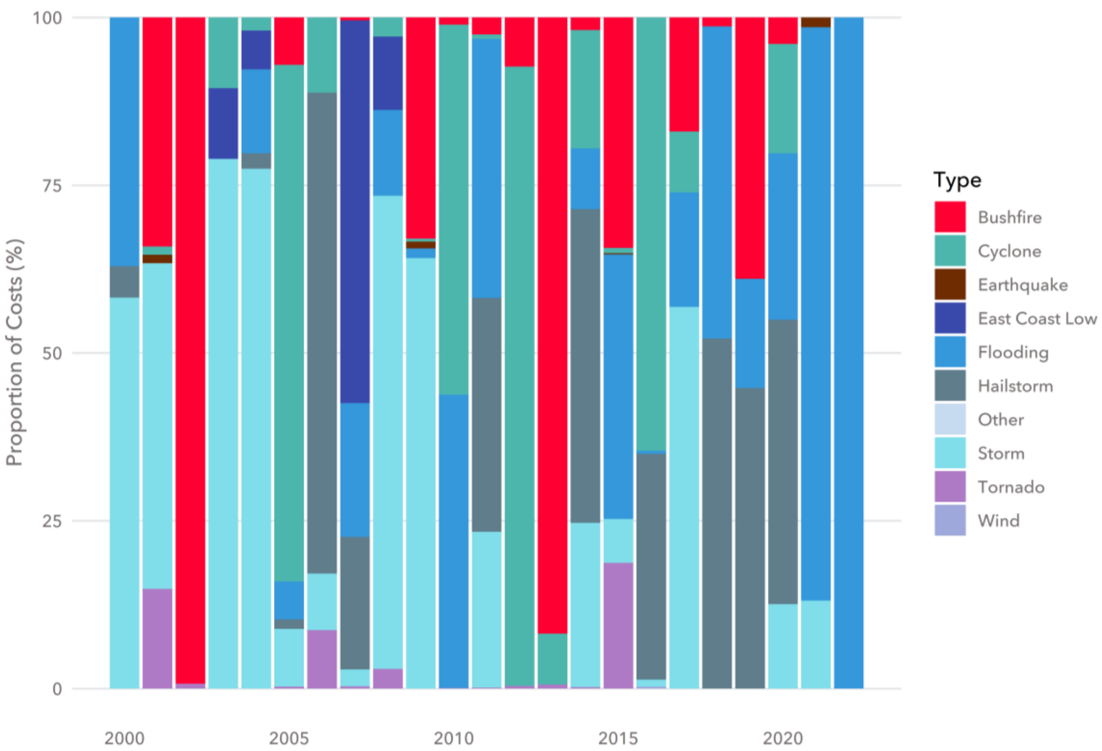
Figure 9. Cumulative Insured Costs by Disaster Type in 2022 Dollars ($m), 1970-2022



Source: Insurance Council of Australia, 2023

Year over year cost contributions demonstrate strong variability of disaster prevalence, with no disaster type emerging as a consistent annual contributor to costs, as shown in figure 10. Indeed, there appears to be an alternating pattern among wet weather disasters such as storms, flooding and cyclones versus bushfires, likely reflecting Australia's exposure to extreme weather during La Niña and El Niño cycles.

Figure 10. Contribution to Insured Losses by Disaster Type

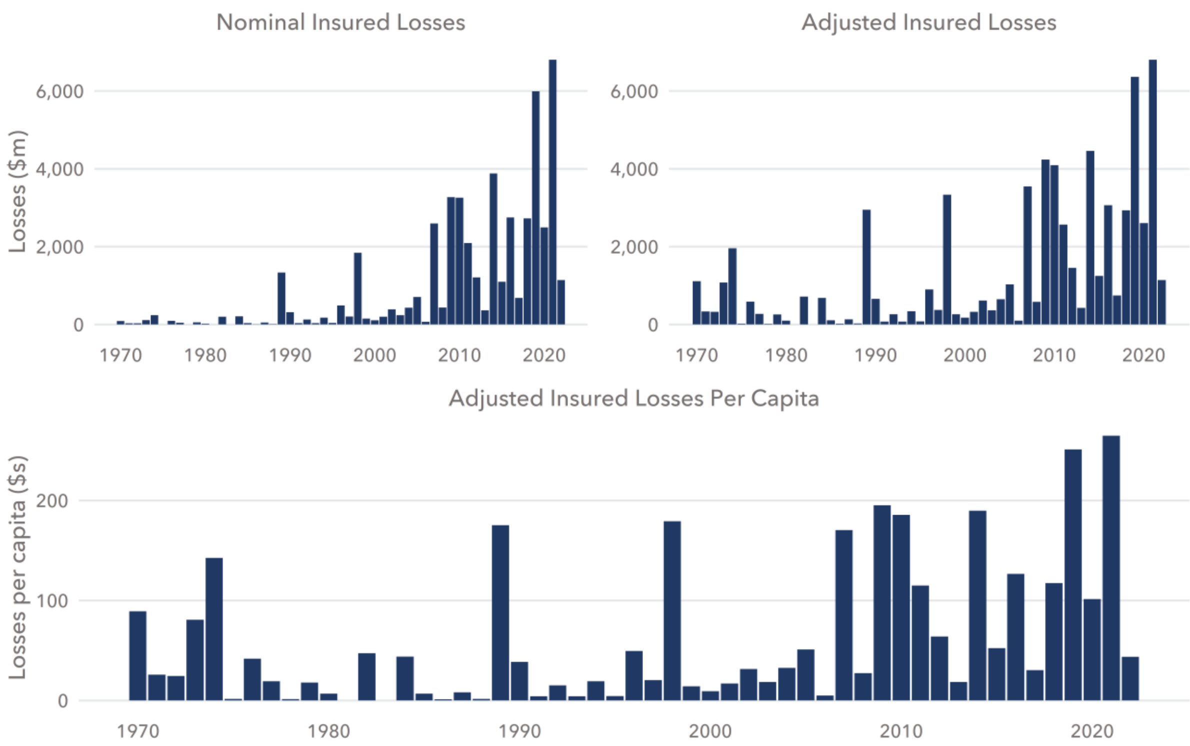


Source: Insurance Council of Australia, 2023

Figure 11 highlights insured costs over time presented in nominal, adjusted, and adjusted per capita terms. When adjusted amounts are applied reduced to a per capita basis as shown in the bottom panel, the results reflect McAneney et al.'s (2017) normalised results, which show little evidence of an increasing trend over time. This reinforces the position that any increases in costs are largely being driven by socio-economic metrics, as opposed to an increasing intensity of disaster, per se. An important distinction here is that intensity in this context relates to cost-intensity, as opposed to meteorological intensity.

Between 1970 through to 2022, adjusted insured losses from disasters totaled $66.6 billion, or $1.26 billion per year on average. Examining adjusted insured losses in the top right panel of figure 11, significant variability of damages between years is observed, with some years experiencing losses in excess of $2 billion and others incurring costs in the hundreds or tens of millions range.

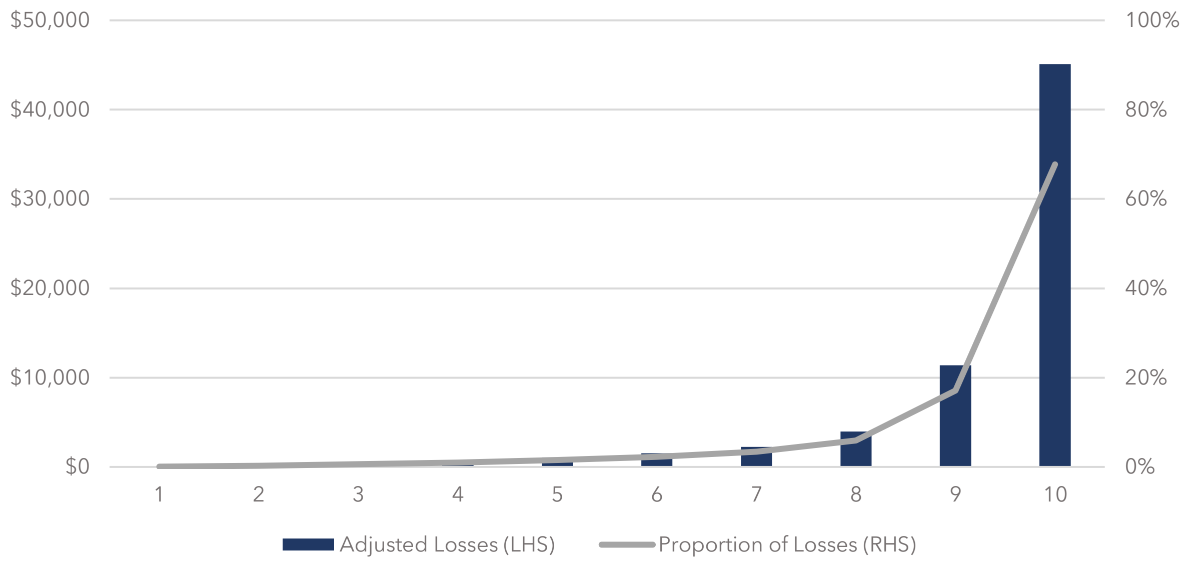
Figure 11. Insured Losses Over Time



Source: Insurance Council of Australia, 2023

In addition to the variability of insured losses year over year, another theme is the propensity for large scale events to drive significant proportions of losses, as shown in figure 12. Indeed, disaster events falling within the top decile of costs accounted for 68% of all insured losses incurred in the time assessed.

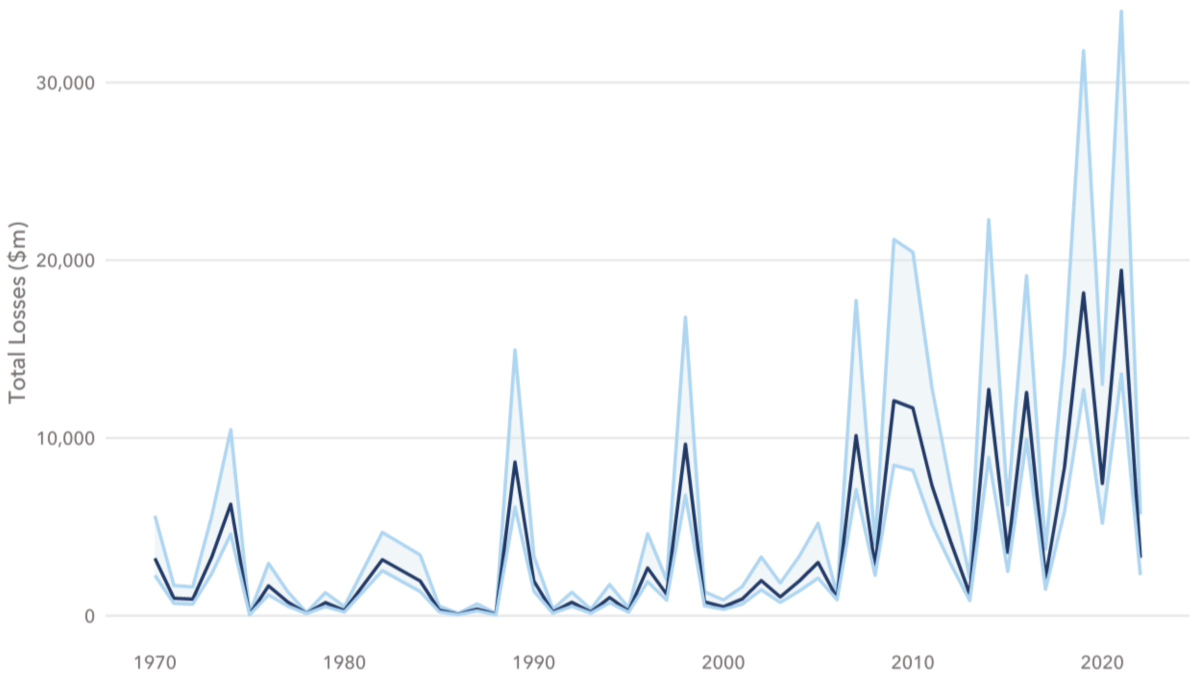
Figure 12. Adjusted Insurance Losses by Decile ($m), 1970-2022



Source: Insurance Council of Australia, 2023

Expanding the analysis beyond insured losses, ILRs as identified by the Productivity Commission (2014) are applied to inflation-adjusted figures to arrive at low, central and high estimates for total direct costs, with the results shown in figure 13.

Figure 13. Estimated Total Losses from Natural Disasters (2022 dollars), 1970 – 2022



Source: Insurance Council of Australia, 2023

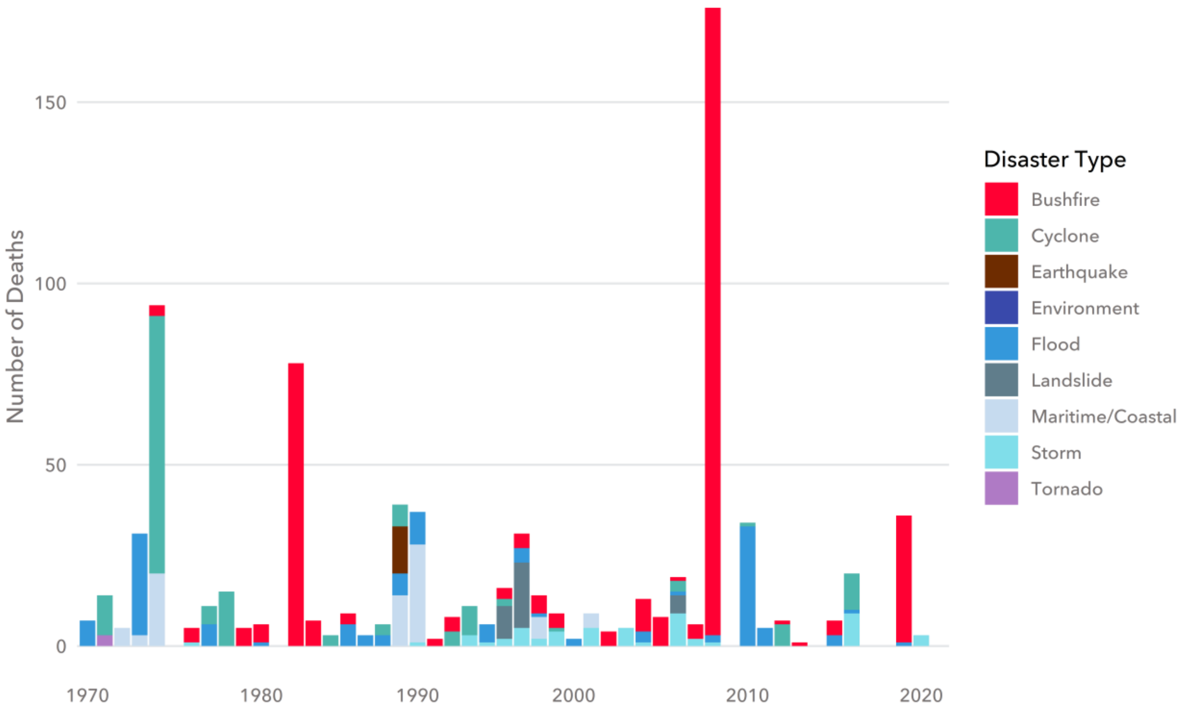
Table 2. ILRs and Estimated Loss Ranges

Estimate Range	Ratio Between Insured Losses and Total Losses	Average Loss Per Year ($m), 1970 - 2022	Total Losses ($m), 1970 - 2022
Low	20%	$6,703	$341,829
Central	35%	$3,905	$199,153
High	50%	$2,786	$142,083

Source: Productivity Commission, 2014; Insurance Council of Australia, 2023; Australian Institute for Distaster Resilience, 2023

In addition to insured losses having been augmented by ILR estimates, the above results also incorporate indirect costs in the form of deaths and injuries. Data provided by the AIDR (2023) indicate that within the assessed period, there were 827 fatalities and 14,246 injuries attributed to natural disasters in Australia, with the distribution shown in figure 14. The cumulative cost of these is estimated to be approximately $8.9 billion.

Figure 14. Distribution of Fatalities by Disaster Type, 1970 – 2022



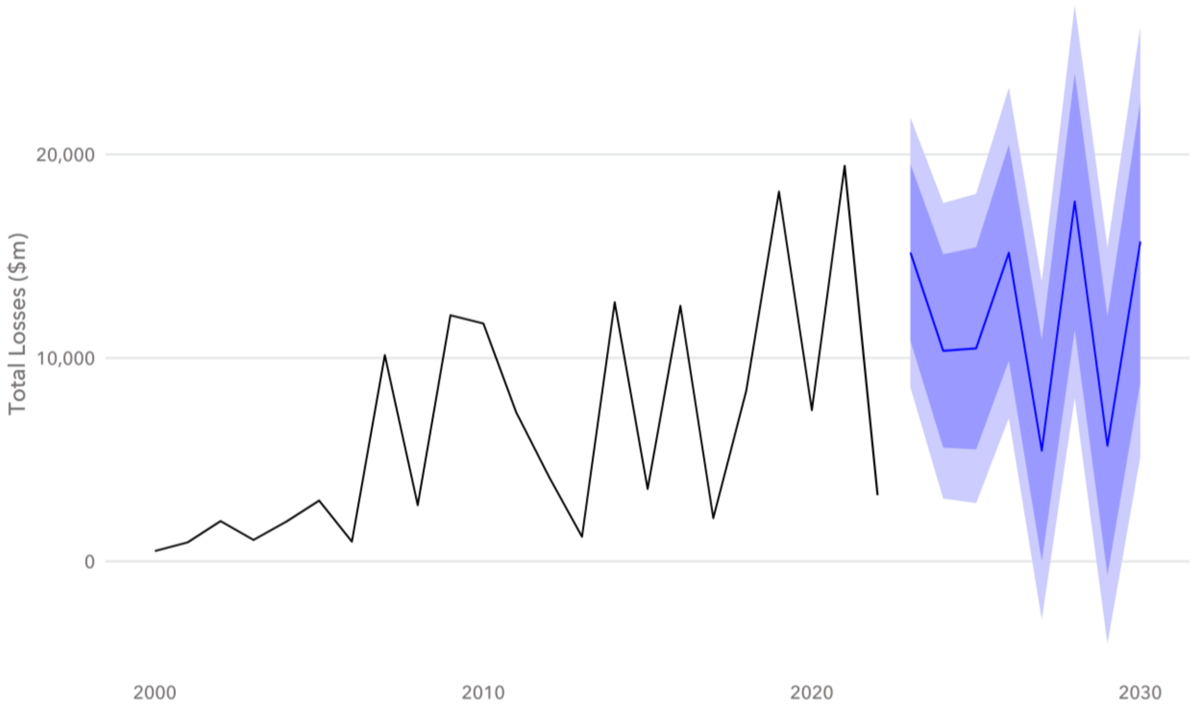
Source: Australian Institute for Distaster Resilience, 2023

One notable omission from both the above estimates and generally within the literature is the cost of heatwaves. As indicated in section two, rising temperatures within Australia and globally have been well documented, and stand to impose material costs on the economy as their frequency increases. The human cost of heatwaves in Australia is elusive, and is not captured within the AIDR or ICA data. However, research by Coates et al. (2022) included anonymised data for mortalities explicitly associated with extreme heat between 2001 and 2018, which estimated that there were 473 deaths within the period. Applying the value of statistical life ascribed by the Office of Best Practice Regulation (2022), these fatalities equate to an indicative $2.5 billion. While these costs have been omitted from the above estimates as methods for identifying heatwave mortalities remain contested (see Longden, 2019, who estimated 37,000 deaths in a shorter period), this simple calculation illustrates the potentially significant limitation of analyses within this field which ignore the costs of extreme heat.

To produce forecasts, ARIMA models were fitted against the central adjusted cost estimate. ARIMA models were considered most appropriate as they were able to capture the volatility of the time series. After conducting residual analysis and evaluating AICC scores for multiple model specifications, an ARIMA(4,1,1) model was found to fit the data best, with the forecast to 2030 presented in figure 15.

While prediction intervals for any forecast expand in tandem with the horizon window, climate-related events are particularly susceptible to imprecise forecasts, due to the unknown impact of positive feedback loops in climate science. Acknowledging that large scale disaster events have the capacity to significantly impact annual costs and the inherent inability to predict such events with any degree of certainty, forecasts beyond 2030 were not considered instructive, and the below estimates should be regarded as illustrative only.

Figure 15. Total Loss Forecasts, 2022-2030



Source: Insurance Council of Australia, 2023; Australian Institute for Disaster Resilience, 2023

Table 3. ARIMA(4,1,1) Forecast Estimates for Total Losses to 2030

Year	Forecast Point Estimate ($m)
2023	$15,176
2024	$10,345
2025	$10,466
2026	$15,166
2027	$5,448
2028	$17,683
2029	$5,693
2030	$15,721

Source: Insurance Council of Australia, 2023; Australian Institute for Disaster Resilience, 2023

7. Discussion and Concluding Remarks

The results of this analysis can be contextualised by contrasting them in proportion to other economic indicators. The BTE (2001) did this by comparing their average annual results to the annual costs of car crashes, and highlighted that while not insignificant, the costs were small in comparison ($1.14 billion versus $15 billion, in 1999 dollars). The estimates presented in section 5 indicate that disaster costs for the 2021-22 financial year fell between $13-34 billion. Even taking into account the significant flooding and associated losses which occurred on Australia's east coast during this timeframe, this result represents just 0.6-1.5% of GDP.

As has been consistently noted within the literature, analysis of natural disasters and their costs is regularly constrained by information which is incomplete, out of date, or privately held and prohibitively expensive to access (Productivity Commission, 2014). The workaround for research in this space has been to utilise publicly available datasets such as those provided by the ICA and AIDR. Such an approach however brings with it material drawbacks which must be addressed.

A valid critique of this and other work in this field is that a reliance on insured losses and ILRs to estimate costs comes with significant limitations. One such limitation is that insurance policies typically provide full replacement costs for assets that are total losses. However, unless the asset in question is close to the beginning of its expected life, the resulting payout may significantly overstate the economic value of the loss. As an example, if the assumption that assets destroyed in a disaster are half way through their economic life is a reasonable reflection of reality, then insurance payout figures will overstate the economic cost by up to 100 per cent.

Another limitation of this data is adoption of insurance policies as well as coverage protocols. IBISWorld (2023) highlights that insurance firms have responded proactively to extreme disaster events by increasing premiums and fine-tuning inclusions within coverage policies. Both of these factors may influence and obfuscate broader loss estimates which rely on insurance costs as a baseline by conflating consumer adoption behaviours with trends in disaster costs. For instance, a growing concern for the threats posed by climate change may cause an increase in adoption of insurance policies, which could ostensibly drive up loss estimates. Inversely, increases in premium costs may diminish policy adoption rates over time.

While a mainstay of research in this area, the use of ILRs to arrive at estimates for the full direct costs of disasters also constrains the analytical robustness of this exercise. As indicated in other research, there are wide range of factors which influence the full costs borne following a natural disaster, many of which are likely to be location or event-specific. Such factors could include the regulations which govern building standards in the affected region or the meteorological characteristics of a particular event, and it is unlikely that the nuances of individual disasters and their attendant costs can be generalised by a single ratio, or even a range of ratio estimates as were applied in this report.

Nevertheless, the estimates generated through this method are considered to still offer value in that they likely represent a middle ground between insured losses, and the full economic costs which are presently unable to be fully captured. This reflects the fact that there are a number of intangible impacts not recorded with any level of consistency across disasters which are likely to represent substantial costs. This category includes lost productivity associated with disasters, long-run health complications, and environmental damage. As an example, Bloomberg (2023) recently reported that a number of children born during the bushfires between July 2019 and March 2020 have begun to exhibit chronic health problems associated with shortness of breath. At present, despite their significant impact, costs such as these are not captured at the aggregate level.

Other questions that are becoming increasingly important concern the 'just in time' nature of supply chains and the heavy dependence of Australian society and economic activity on uninterrupted electricity supply, which can serve to heighten disaster vulnerabilities. Failure of such a critical supply chain could incur significant costs, and should be examined as part of further analysis of indirect losses.

The individual and aggregate impacts of natural disasters are compounded by growing populations, urban development, human concentration in disaster-prone areas, as well as increased asset values. In addition, global trends suggest that natural disasters are increasing in frequency and intensity. The consequences of these changes increasingly impact the lives and economic stability of all Australians. Accordingly, it is crucial for Australia to proactively prepare for and adjust to the evolving nature of climate-related risks both presently and in the future.

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