# Catastrophic Fat Tails and Non-smooth Damage Functions-Fire Economics and Climate Change Adaptation for Public Policy[1]

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## Abstract

South-eastern Australia is one of the most fire prone environments on earth. Devastating fires in February 2009 appear to have been off the charts climatically and economically, they led to a new category of fire danger aptly called 'catastrophic'. Almost all wildfire losses have been associated with these extreme conditions and climate change will see an increase in these catastrophic fire danger days. Estimating the economic impacts of these fires is a key input into climate change adaptation decision-making for three key reasons: 1) a fattening of the tail of the fire disaster probability distribution, is widely held to be a significant climate change impact; 2) extrapolating current bushfire costs assumed to be a convenient and straightforward starting point for adaptation cost estimation, however a paucity of data means this assumption is over ambitious; and 3) fire disaster risk reduction is a low-regrets climate change adaptation policy, meaning it is believed to have a positive net benefits regardless of the actual future climate scenario, thereby bypassing the risks associated with uncertainty regarding future climate. This focus poses key challenges for fire economics in regards to full valuation of disaster impacts, particularly in regard to indirect and intangible impacts. Furthermore, extrapolating current impact estimates under future climatic and socio-demographic conditions is complicated by nonlinearity in the damage function with the majority of damages occurring during extreme conditions, changes to which are less certain than projections regarding means.


*Key Words: adaptation, bushfire, climate change, damage function, extremes, wildfire.*

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is these conditions that pose the greatest difficulty to contemporary fire-fighting and that frequently overwhelm them regardless of the resources and technology used. Almost all wildfire losses have been associated with these extreme conditions. Such conditions, and the associated serious impacts, have historically been rare, but are precisely the conditions that will be more common under climate change and are the subject of interest for public policy. Coming to grips with complex uncertainties inherent in extremes is a key challenge for climate change adaptation economics.

Climate change will see an increase in these catastrophic fire danger days (Lucas and others 2007, IPCC 2012) and estimating the economic impacts of these fires is a key input into climate change adaptation decision-making. We propose that the extrapolation of the economic impacts of bushfire under climate change scenarios is complicated by several factors, in particular the nature of the damage function, which we suggest is neither linear nor smooth. We propose a theoretical stepped (or staged) damage function where damages become less predictable as dangerous fire conditions increase, and blow out significantly and unpredictably at levels of catastrophic fire danger.

Climate change adaptation is increasingly becoming a local and regional policy focus and is raising challenging questions in disaster economics. The IPCC (2012, pg. 3) defines adaptation: “In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.”[3] UNFCCC (2009, pg. 3) defines the costs of adaptation as “the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs” and the benefits of adaptation as “the avoided damage costs of the accrued benefits following the implementation of adaptation measure”. In this context the costs and benefits are not only financial but consider wider economic, societal and environmental impacts.

Considering the above definitions the standard economic approach to climate change adaptation is to estimate the cost of climate change with no adaptation and weigh it against the cost of climate change under various adaptation investments minus the cost of those investments. Hence the benefits of climate change adaptation investment are the climate change impact costs avoided due to the adaptation[4]. As such the first step in an economic assessment of climate change adaptation is to

[3] Here adaptation does not include climate engineering initiatives such as carbon sequestration or ocean fertilization.

[4] This definition of the benefits of adaptation being equal to the avoided impact costs is standard but not uncontested. Dobes (2009) identifies several issues with damage avoided methods, significantly that benefits are likely to be underestimated and the use of willingness to pay methods would more accurately capture the full benefit of the adaptation.

estimate the costs of climate change impacts in the future by estimating current costs and extrapolating under future social, economic and climatic conditions. Estimating the current and future costs of bushfires is seen as an important first step in climate change adaptation decision-making for three key reasons as outlined below.

Firstly, increases in the frequency and severity of extreme and catastrophic fire weather, or a fattening of the tail of the fire disaster probability distribution, is widely held to be a significant climate change impact (IPCC 2012). The probability distribution function (PDF) of bushfire events is predicted to change, with more fire and more extreme fires. Lucas and others (2007) predict that for southeast Australia, several factors influencing fire probability, not just temperature, are likely to increase under climate change. Catastrophic fire danger days are predicted to become more frequent.

Secondly, recent work in Australia has shown that the significant uncertainties associated with climate change adaptation economics have led to a perception that extrapolating current bushfire costs is a convenient and straightforward starting point for cost estimation. A paucity of data on the current costs of bushfire (Keating and Handmer 2011) and significant methodological challenges as described here mean that this perception is, unfortunately, overly ambitious.

Finally fire disaster risk reduction is a low-regrets climate change adaptation policy. Low-regrets adaptations are favoured in climate adaptation policy because they have positive net benefits regardless of the actual future climate scenario, thereby bypassing the risks associated with uncertainty regarding future climate (Ackerman & Stanton 2011). In the case of bushfire there are thought to be positive net benefits to fire disaster mitigation, prevention and preparedness (adaptation) regardless of the climate scenario that eventuates. Indeed Crompton and McAneney (2008) find that the current cost of disasters in Australia currently warrants increased investment in mitigation and prevention because they are likely to have significant payoffs.

A renewed focus on fire economics with a view to inform climate change adaptation decision-making presents challenges in regards to the valuation of indirect impacts and intangible assets. A full economic assessment of the impact of bushfire includes valuation of direct impacts such as loss of property or livestock, indirect impacts such as loss of business revenue and intangible impacts such as ecosystem services and cultural heritage. A significant proportion of data regarding the cost of bushfire comes from the insurance industry and as such accounts for only direct costs that are frequently insured (Keating and Handmer 2011). Therefore these estimates frequently omit significant impacts, with some authors estimating that indirect and intangible impacts equal 2-3 times that of direct impacts (IPCC 2012). While economists have established methods for estimating indirect and intangible impacts, these are rarely utilised due to resource constraints.

A further significant challenge for fire economics in relation to climate change adaptation is how current estimates are extrapolated under future conditions. Empirically we can observe that the relationship between the FFDI on the day of a fire and the resulting damage is not linear. In Australia relatively very little damage is done on days where FFDI is below 50, the very majority of damage is done on days where FFDI exceeds 100 (Blanchi and others 2010). This nonlinearity needs to be taken into account when extrapolating future fire risk. The majority of future risk is based on increased frequency and severity of extreme temperatures and conditions rather than mean temperatures and conditions. Unfortunately projections regarding extremes are more uncertain than those projecting means.

The record-breaking fires of February 2009 in Victoria, Australia are thought to foreshadow the increase in frequency and severity of extreme weather events that is projected to occur under climate change. What this event shows is that when conditions facilitate a catastrophic situation conventional preparedness and response can often be seriously inadequate. These types of 'extreme extremes' are not well accounted for in traditional cost-benefit analysis because they have a low probability and imbue multiple uncertainties. However it is just this sort of event that is driving the impetus for climate change adaptation.

## References

**Ackerman, F., Stanton, E. A. 2011.** Climate Economics: The State of the Art, Stockholm Environment Institute-U.S. Center, http://www.sei-international.org

**Blanchi, R., Chris L., Justin L., Klara, F. 2010.** Meteorological conditions and wildfire-related house loss in Australia. International Journal of Wildland Fire **19**, 914–926.

**Crompton, R.P., McAneney, K.J. 2008.** Normalised Australian insured losses from meteorological hazards: 1967-2006, Environmental Science and Policy, **11**: 371-378.

**Dobes, L.** 2009. People versus planners: Social Preferences for Adaptation to Climate Change, Environmental Economics Research Hub Research Reports No. 41, December 2009, ISSN 1835-9728

**IPCC 2012,** Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.

**Keating, A., Handmer, J. 2011.** The cost of disasters to Victoria and Australia – No straightforward answers, VCCCAR Project: Framing Adaptation in the Victorian Context Working Paper 3, http://www.vcccar.org.au/files/vcccar/Framing_project_workingpaper3_210611.pdf Accessed 29 November 2011.

**Lucas, C., Hennessy, K., Mills, G., Bathols, J. 2007.** Bushfire weather in southeast Australia: recent trends and projected climate change impacts. Consultancy report prepared for the Climate Institute of Australia. Bushfire CRC and CSIRO: Melbourne.

**UNFCCC. 2009.** Potential costs and benefits of adaptation options: A review of existing literature, Frakemwork Convention on Climate Change, United Nations, Technical Paper 2009/2.