The hedonistic cost of the Black Saturday bushfires

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Abstract

This study employs the experienced preference method to quantify the hedonistic cost of the Black Saturday bushfires, which started on and around the 7th of February 2009 in Victoria, Australia. Using data from the Household, Income and Labour Dynamics in Australia (HILDA) survey and data from Geographic Information Systems (GIS) this study explores the spatial and temporal dimensions of the hedonistic costs of the Black Saturday Bushfires, a natural experiment. Specifically, this study reveals the size and nature of the psychological cost borne by those living near fire effected land. In doing so, this study makes a distinct contribution to both the non-market valuation literature and the economics of happiness literature. It is envisaged that the findings of this study will help inform decision makers, public debate and public policy on the magnitude and characteristics of the psychological costs associated with Black Saturday bushfires. Furthermore, these findings are more generally pertinent to understanding how the increased risks of bushfires caused by anthropogenic climate change may adversely affect human welfare.

Keywords: Bushfires; Experienced Preference Method (EPM); Happiness; Household, Income and Labour Dynamics in Australia (HILDA) survey; Life satisfaction

JEL: I31; Q51; Q57

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1.   Introduction

Globally, impacts from climate change-related extremes, such as heat waves, droughts, floods, cyclones and wildfires, highlight significant vulnerabilities and exposures to current climate variability (IPCC, 2014). In recent times, in many parts of the world, an exceptionally large number of record-breaking and destructive heatwaves have been observed. This trend is expected to continue to increase due to human-induced climate change (Coumou & Rahmstorf, 2012). Across the United States, it is anticipated that climatic change will increase the frequency, extent and uncertainty surrounding the occurrence of wildfires (Stavros, Abatzoglou, McKenzie, & Larkin, 2014; Westerling et al., 2011). Not only do these sustained periods of extreme heat have significant human health risks for instance, in terms of rates of mortality, particularly for the young and elderly (McMichael, Woodruff, & Hales, 2006); the bushfires[1] these conditions precipitate have disastrous and all too familiar impacts on human life, property and ecosystems.

Already containing one of the three most bushfire prone areas in the world, along with southern California and southern France (cf. Commonwealth Scientific and Industrial Research Organisation, 2005) Australia shares these broader global trends experiencing record hot and dry conditions and longer fire seasons (Climate Council of Australia Limited, 2013). Australia suffered its worst bushfires on record following an unprecedented heatwave, the devastating 'Black Saturday' bushfires (Karoly, 2009). This ravaged many parts of the State of Victoria and indirectly impacted many millions of in the State, throughout the rest of Australia and beyond. In all, one hundred and seventy three people died, thousands of homes and other dwellings were destroyed and over 400,000 hectares were burnt (Country Fire Authority, 2012). While the costs associated with mitigating bushfire risk are relatively clear, the non-market values associated with bushfires avoided are far less clear cut. More complete estimates of the social and economic costs of bushfires permit a more socially optimal allocation of resources (Clayton, Mylek, Schirmer, Cary, & Dovers, 2014; Venn & Calkin, 2011).

Unsurprisingly, a tremendous amount of research effort has been devoted over many decades to understanding the complex relationship between bushfires and societal welfare. Revealed preference and stated preference (mostly stated preference) techniques have been employed to provide monetary estimates of utility lost due to bushfires. One earlier cost-benefit analysis of a Fire Management Program in Victoria estimates the net benefits of the fire suppression and prevention at approximately $1.5 billion.[2] This result however is likely a considerable underestimate. It estimates the non-use conservation value of forested public land at $135 per hectare using hardwood timber losses as a conservative measure of the opportunity cost (cf. Loane & Gould, 1986). A more recent study calculates the health cost of defensive expenditures (private costs) at USD$84.42 per exposed person per day for the Station Fire of 2009, the largest wildfire in Los Angeles County's modern history. These costs however still fall short of capturing the social costs (Richardson, Champ, & Loomis, 2012). Generally, there remains a dearth of fire-specific studies and few studies that have been able to elicit more intangible values such as use and non-use values (Bennetton, Cashin, Jones, & Soligo, 1998).

In a recent critical review and synthesis of 60 economic studies on the costs and benefits of wildfires the authors reported that uncertainty and data limitations present key challenges to undertaking economic evaluations. Furthermore, there is paucity of research in other geographic contexts outside of the United States (Milne, Clayton, Dovers, & Cary, 2014). Also, in order to support efficient bushfire management strategies there is a need for *ex post* evaluation to capture the *total* changes to social welfare. Given the current state of knowledge this goal continues to remains elusive, although, choice modelling experiments are thought to offer great potential (Venn & Calkin, 2011).

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[1] Also known as 'forest fires', 'wildfires' or 'brushfires', these terms are used synonymously.
[2] Unless otherwise stated dollars ($) refers to Australian dollars. As at the 22nd of January 2016, AUD$1 = USD$0.70 or £0.49 or €0.65.

Fundamentally though, both revealed preference and stated preference methods rely on the notion of *ex ante* decision utility which may differ starkly from *ex post* experienced utility (Dolan & Kahneman, 2008; Kahneman & Sugden, 2005). One means by which many of these difficulties can be circumvented is to redirect attention to *experienced utility*. In this respect, one of the main applications of emerging from the economics of happiness is the monetisation of non-market factors (Ferrer-i-Carbonell, 2013). This is where the literature on the economics of happiness intersects with the non-market valuation literature yielding a novel non-market valuation technique, which has been termed the life satisfaction approach (cf. Frey, Luechinger, & Stutzer, 2010), yet might be more generally be called, the experienced preference method (cf. Welsch & Ferreira, 2013). This method sheds light on the psychosocial or hedonistic costs that have remained elusive from most earlier investigations of the social welfare implications of bushfires (Gibbs et al., 2015).

There are is some limited research applying this type of approach to the case of bushfires (cf. Kaval & Loomis, 2007; Kountouris & Remoundou, 2011). This is despite well-documented evidence on the psychological impacts of bushfires, for instance, in terms of post-traumatic stress and depression (Maida, Gordon, Steinberg, & Gordon, 1989). In the case of the Black Saturday bushfires there is evidence that roughly two and a half years after the event and even five years after the event wellbeing remains is not significantly different than the normal range (Gibbs, 2014; Weinberg & Cummins, 2012). This did not appear to differ depending on whether or not you had personally suffered home damage or knew someone who had died (Weinberg & Cummins, 2012). However, Beyond Bushfires, a five-year study exploring the medium to long term impacts of the Victorian 2009 bushfires on individuals and communities found, among a number of other things, that one's psychological wellbeing post the bushfires is greatly dependent on one's social connectedness (Gallagher et al., 2016; Gibbs, 2014).

While informative these studies have not sought to quantify these hedonistic costs of the Black Saturday bushfires in monetary terms. The purpose of this study is to employ the experienced preference method to estimate the hedonistic costs associated with the Black Saturday bushfires. In doing so, this study makes a distinct contribution to the non-market valuation and wellbeing literature. Furthermore, these findings are more generally pertinent to understanding how bushfires caused by anthropogenic climate change may adversely affect human welfare.

Section 1.1 briefly revisits earlier conventional non-market valuation studies of bushfires. Section 1.2 describes the experienced preference method. Section 2 outlines the method and data. Section 3 reports the results. Finally, Section 4 discusses these results and concludes.

1.1.   The social and economic costs of bushfires

A voluminous body of literature exists employing traditional non-market valuation techniques to quantify the non-market values or costs or bushfires. For instance, evidence from hedonic property pricing for the town of Pine in Colorado indicates that following the Buffalo Creek fire in 1996 house prices dropped 15% in the unburned community (Loomis, 2004). Later evidence for northwestern Montana reveals that for bushfire risk, when a burned area is not visible from a home, it is out of sight and thus out of mind of home buyers (Stetler, Venn, & Calkin, 2010). Other studies have applied stated preference methods. For instance, a contingent valuation study indicates a median $52 willingness-to-pay to for forest preservation in East Gippsland, Australia (Lockwood, Loomis, & DeLacy, 1993). While a choice modelling experiment for Flathead County indicates that an average household is only willing-to-pay USD$0.24 per annum for the next 10 years to avoid one home evacuation per year for the next 10 years but USD$13.28 per annum for the next 10 years to avoid one unhealthy smoke day per year for the next 10 years (O'Donnell, Venn, & Calkin, 2014). A subset of studies have concerned themselves with the economic valuation of the health impacts of bushfires have been reviewed (cf. Kochi, Donovan, Champ, & Loomis, 2010). A number of significant reviews of the non-market valuation literature related to bushfires generally are provided by Hesseln (2000), Venn and Calkin (2011) and Milne et al. (2014).

1.2. The experienced preference method

An approach to develop at the intersection of the economics of happiness and the existing non-market valuation literature is the experienced preference method to non-market valuation. This approach which may supplement or even supplant (cf. Bronsteen, Buccafusco, & Masur, 2013) existing cost-benefit analysis (Welsch, 2009) is described by Frey et al. (2010) as entailing the inclusion of a non-market good as explanatory variables within a micro-econometric function of life satisfaction along with income and other covariates. The estimated coefficient for the non-market good yields first, a direct valuation in terms of life satisfaction, and second, when compared to the estimated coefficient for income, the implicit willingness-to-pay for the non-market good in monetary terms. Welsch and Ferreira (2013) provide a recent discussion of the conceptual underpinnings of this approach, discusses recent methodological innovations and what insights may be gleaned with the help of data on wellbeing.

Most pertinent to this study is the appreciation of psychosocial costs which despite being well reported have not featured in conventional non-market valuation studies concerning bushfires (Gibbs et al., 2015). In this respect, this study extends that part of social welfare falls within the measuring rod of money (Pigou, 1932), reintroduces the hedonistic link, something Robbins removed from economics (Hands, 2010) and thus permitting inferences regarding social welfare may be much richer permitting the discovery of helpful insights into many important questions (Ng, 1997; van Praag & Frijters, 1999).

The research which applies this method to the case of bushfires is limited. Using repeated cross-sections from the Eurobarometer Survey Series for Portugal, Spain, Italy and the Mediterranean provinces of France, Kountouris and Remoundou (2011) find evidence that the incidence of forest fires and fire extent both have a significant negative effect on individual wellbeing. The authors report an income equivalent or willingness-to-pay figure (in terms of average monthly household income) of around €2.03 for a reduction of the burnt area in the region by 100 hectares and a WTP of €0.20 to reduce the number of fire incidences by one.

Using a hybrid contingent valuation-life satisfaction approach Kaval and Loomis (2007) find at the wildland-urban interface in Colorado, that a greater frequency of wildfire occurrence was associated with lower levels of wellbeing whether or not other things were held constant. Further, after a wildfire, the frequency of wildfire occurrence was found to be more strongly linked to wellbeing than other variables in the model. This hybrid approach introduces some of the challenges of traditional stated preference methods at the expense of some of the revealed preference-like advantages of the more usual experienced preference method. Nevertheless, the study points to a miniscule, even negligible link between house prices and wellbeing informing the debate (cf. Ferreira & Moro, 2010; van Praag & Baarsma, 2005) in the literature regarding the nature of the relationship between the hedonic pricing and experienced preference method. The results suggest that the observed willingness-to-pay estimates are largely distinct from hedonic property pricing estimates.

2. Method and data

The model takes the general form of an indirect utility function illustrated in Equation 1:

$$U_{i,k,t} = \omega + \alpha_1 ln y_{i,k,t} + \alpha_2 ln f_{1_{k,t}} + \sum_{j=1}^{m} \beta_j z_{j_{i,k,t}} + u_i \kappa_k + \tau_t + \varepsilon_{i,k,t} \tag{1}$$

Where $U_{i,k,t}$ represents the utility of individual i, at location k, at time t; $y_{i,k,t}$ is household income;[3] $f_{1_{k,t}}$ is percentage of bushfires in the area; $z_{j_{i,k,t}}$ denotes socio-economic and demographic characteristics $j...m$, including, marital status, employment status, education and so forth; $u_i \kappa_k$ are the individual-specific × location (e.g. Local Government Area)-specific fixed effects and τ_t time or year fixed effects. Finally, $\varepsilon_{i,k,t}$ is the error term.

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[3] Ambrey and Fleming (2014a) provide further details on the virtues of using this income measure.

In the model, the individual's true utility is unobservable. In the place of utility is a measure of life satisfaction. This model is estimated using the relatively new 'blow-up and cluster' (BUC) estimator (cf. Baetschmann, Staub, & Winkelmann, 2015). Table 1 provides a description of the variables employed.

[Table 1 here]

As shown elsewhere (cf. Ferreira & Moro, 2010; Frey et al., 2010; Welsch, 2007, 2009; Welsch & Ferreira, 2013) it is possible to estimate the implicit willingness-to-pay (denoted WTP) by taking the partial derivative of Equation 1 with respect to the variable of interest ($f_{1_{i,k,t}}$) and the partial derivative Equation 1 with respect to the income variable, as follows:

$$WTP_{f_{1_{i,k,t}}} = \frac{\frac{\partial U_{i,k,t}}{\partial f_{1_{i,k,t}}}}{\frac{\partial U_{i,k,t}}{\partial y_{i,k,t}}} = -\frac{\bar{y}\widehat{\alpha_2}}{\bar{f_1}\widehat{\alpha_1}} \tag{2}$$

Where $\bar{y}$ is the mean household income and $\bar{f_1}$ is the mean percentage of an individual's CD affected by the Black Saturday bushfires. While the estimated coefficients from the BUC (or fixed effects ordered logit) model have no meaningful interpretation (as they refer to an underlying latent variable), the ratios between any two coefficients can be interpreted (Frey et al., 2010).

2.1. Household, Income and Labour Dynamics in Australia survey data

In terms of the socio-economic data on residents this is obtained from waves 1 to 13 (for years 2001 to 2013) of the Household, Income and Labour Dynamics in Australia (HILDA) survey. The HILDA survey is a national probability sample which takes the form of an indefinite life panel following individuals over time. The sampling design of the survey involves the selection of households into the sample by a multi-stage process. To begin with, a random sample of 488 Census Collection Districts (CDs) based on the 1996 census boundaries was selected from across Australia, stratified by State, and within the five largest States in terms of population, by metropolitan and non-metropolitan regions, each CD consisting of approximately 200 to 250 households. The CDs were sampled with probability proportional to their size as measured by the number of dwellings (unoccupied and occupied) recorded in the 1996 Census with some adjustments for population growth since the Census. Within each of these CDs, all dwellings were fully enumerated and a sample of 22 to 34 dwellings randomly sampled based on the expected response and occupancy rates within each area (Watson & Wooden, 2002).

The life satisfaction dependent variable is obtained from the HILDA survey, from responses to the question: *'All things considered, how satisfied are you with your life?'* The life satisfaction variable is an ordinal variable, the individual choosing a number between 0 (totally dissatisfied with life) and 10 (totally satisfied with life).

2.2. Geographic Information Systems data

The Geographic Information Systems (GIS) data employed in this investigation is obtained from the Victorian Bushfires Severity Map 2009 provided by the Victorian Government's Department of Environment, Land, Water and Planning. The vector (polygon) dataset is based on the filtered version (3×3 pixel filter) of the class fire severity classification raster product as derived from a classification of a SPOT and Landsat TM woodlands fire severity indexes to map the fire severity of the February 2009 Victorian bushfires using ground control and air photograph analysis provided by Department of Sustainability and Environment to Ecowise Environmental Pty Ltd for validation. The area covered by the classification is clipped to the extents of the fire effected lands (approximately 400 000 hectares). Class 1 is *most severe* and Class 5 is *least serve*. (The State of Victoria, 2016). The bushfires extent variable takes the value 0 before the 7th of February 2009 and then the percentage an individual's CD which is fire effected thereafter. Figure 1 provides a map of the study area.

[Figure 1 here]

3. Results

To begin with, it is worth noting that the variance inflation factors provide no indication of worrisome multicollinearity.[4] Table 2 presents the results for the estimation of Equation 1. The socio-economic characteristics are broadly consistent with findings for Australia reported elsewhere (cf. Ambrey & Fleming, 2014b; Manning, Ambrey, & Fleming, forthcoming; Shields, Price, & Wooden, 2009; Ulichny, Ambrey, & Fleming, forthcoming). Particularly important for this investigation, the natural log of bushfire extent (the percentage of an individual's CD that was effected by the Black Saturday bushfires) is found to be negatively associated with life satisfaction (coefficient = -0.18, p-value = 0.06) and statistically significant at the 10% level. Using Equation 2 this life satisfaction effect is equivalent to $50,198.55[5] (or $17,430 per capita) in terms of household income. This mean figure is not without uncertainty. The 90% confidence intervals for the bushfire extent variable point to a lower bound of $5,577.62 and an upper bound of $92,030.68.

It is worth remembering that this estimate relates to areas effected by the bushfires, experienced by individuals over the period from 2009 through to 2013. One individual was interviewed directly after the bushfires although most individuals in 2009 were interviewed approximately 200 to 250 days after Black Saturday (the 9th of February 2009). As such, this result includes the hedonistic cost to individuals who may have moved to the area sometime later. This distinction raises an interesting question, how might the hedonistic cost of the bushfires differ among those who decided to move or stay following the bushfires?

[Table 2 here]

3.1. Post-Black Saturday pathways, moving or staying?

Unlike the Beyond Bushfires study conducted by researchers at The University of Melbourne, the HILDA survey does not specifically target groups impacted by the bushfires. As such, only those individuals who; stayed (604 observations), moved among bushfire effected areas (8 observations) or moved to the bushfire effected areas (39 observations) are observed in the sample. In order to investigate differences among these groups Equation 1 is augmented to include exhaustive group-specific bushfire extent variables. The results of the model estimation are reported in Table 3. The socio-economic characteristics are almost identical, at two decimal places, to those reported in Table 2. As might be expected, the coefficient is strongest and most precise for individuals who did not move from the bushfire effected areas (coefficient = -0.29, p-value = 0.02), statistically significant at the 5% level. This yields an estimated implicit willingness-to-pay of $62,222.14,[6] with a lower bound of $19,310.32 and an upper bound of $102,988.36.

This result is independent of an individual's social connectedness with others. Gibbs (2014) and Gallagher et al. (2016) report that the psychological wellbeing of individuals' in communities effected by the Black Saturday bushfires depends greatly on this, with more socially connected individuals generally experiencing better outcomes. Consistent with these findings, omitting the social connectedness variables from the model the results reveal a larger still coefficient estimate (coefficient = -0.33, p-value = 0.01), statistically significant at the 5% level. Diverging from these average results relating to the period from 2009 to 2013 it might be hypothesised that the impact of the Black Saturday bushfires diminishes over time. Colloquially, it might be said that, 'time heals all wounds'. This hypothesis can be tested with the available data.

[Table 3 here]

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[4] The highest variance inflation factor of 3.51 'Age (60 years and over)'. 'ln(Bushfire)' has a variance inflation factor of 1.02.

[5] $-1.00 \times ((73,624.54 \times -0.18)/(8.80 \times 0.03)) = \$50,198.55$

[6] $-1.00 \times ((75,524.80 \times -0.29)/(8.80 \times 0.04)) = \$62,222.14$

3.2. 'Time heals all wounds', or does it?

The often heard and perfunctory statement 'time heals all wounds' suggests that the passage of time alone will allow the pain of past life events to dissipate. Although, as has been shown for the case of divorce, this may not necessarily be the case (Lucas, 2005). The hypothesis that time may diminish the negative psychological effects associated with the Black Saturday bushfires can be tested using time-varying variables. The estimates of a further augmented Equation 1 are presented in Table 4. Again, the socio-economic variables are little changed from the base model. The key results tend to support the notion that over time the psychological effects of the Black Saturday bushfires diminish. Although, it may not simply be the passage of time itself that leads to a diminishing of the negative effect associated with the bushfires, instead it may be what an individual actually does with that time. For individuals who did not move from the bushfire effected areas the most severe impact is experienced in 2009, the year of the Black Saturday bushfires. Although, most of the individuals in the sample were interviewed approximately 200 to 250 days after Black Saturday (the 9th of February 2009). The coefficient estimate does not differ greatly to earlier estimates (coefficient = -0.25, p-value = 0.09). These estimates accord with an implied willingness-to-pay of $53,639.77[7] with a lower bound of $2,145.59 and an upper bound of $105,133.95.

[Table 4 here]

3.3. Decisions to access psychological support services

Individuals experiencing psychological distress may seek out or be directed to psychological support services. Hence, it would also be expected that there is some convergence between the relationships between: the Black Saturday bushfires and life satisfaction; and the Black Saturday bushfires and an individual's decision to access mental health support services. The HILDA data contains information useful for making this comparison. In the HILDA survey the question is asked:

'During the last 12 months, have you seen any of these health care providers about your health?

- *A hospital doctor (i.e., in outpatients or casualty)*
- *A specialist doctor (excluding in outpatients or casualty of a hospital)*
- *A mental health professional, such as a psychiatrist or psychologist*
- *A podiatrist (foot doctor)*
- *A chiropractor or osteopath*
- *A physiotherapist*
- *An optometrist*
- *Any other allied health provider, such as a speech therapist, audiologist or occupational therapist*
- *An alternative health practitioner, such as a naturopath, acupuncturist or herbalist*
- *A community nurse, practice nurse, nurse practitioner or midwife'*

Where the individual may provide multiple responses. The dependent variable takes a value 1 if the individual responses that they have seen *'A mental health professional, such as a psychiatrist or psychologist'* and 0 if they have not. This variable is only available for 2009 and 2013. As such, a pooled logit model is estimated, using the same socio-economic variables as earlier regressions. The results are reported in Table 5. The coefficient estimate, aligns with the findings reported in the base model (Table 2). The bushfire extent variable is associated with a greater likelihood of seeing a psychiatrist or psychologist (coefficient = 0.20, p-value = 0.04), statistically significant at the 5% level.

[Table 5 here]

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[7] $-1.00 \times ((75,524.80 \times -0.25)/(8.80 \times 0.04)) = \$53,639.77$

4. Discussion

In line with global human-induced climate change, Australia is experiencing record hot and dry conditions and longer fire seasons (Climate Council of Australia Limited, 2013). Australia suffered its worst bushfires on record following an unprecedented heatwave, the devastating 'Black Saturday' bushfires (Karoly, 2009). This disaster is unparalleled in Australia's history and yet the all too well known hedonistic burden associated with the bushfires remains conspicuously absent from conventional non-market valuation (Gibbs et al., 2015). The purpose of this study is to employ the experienced preference method to estimate the hedonistic costs associated with the Black Saturday bushfires. The results of this investigation reveal a mean implicit willingness-to-pay of $50,198.55 in terms of annual household income for a one percent increase the extent of an individual's CD that is bushfire effected. This estimate is not without some uncertainty. Nevertheless, the effect remains sizeable. This effect appears most pronounced for those individuals who did not move from bushfire effected areas and seems to be experienced most prominently in year of the bushfires. Furthermore, a one percent increase the extent of an individual's CD that is bushfire effected is associated with a greater likelihood of having seen a psychiatrist or psychologist, lending confidence to the validity of these estimates. The evidence reported in this study sheds light on how the widely reported psychological distress associated with traumatic events such as the Black Saturday bushfires may be estimated. This study not only makes a contribution to the non-market valuation literature it also extends the blossoming economics of happiness literature. These findings also provide policy makers with insights into the implications of extreme climate change-related events for human wellbeing.

Similar to earlier findings an individual's social connectedness was found to depend markedly on one's psychological outcome following the bushfires. Furthermore, several years after the bushfires individual's psychological wellbeing was not statistically significantly different from that of people outside of bushfire effected areas (Gallagher et al., 2016; Gibbs, 2014; Weinberg & Cummins, 2012). Comparing these findings to a recent cost-benefit analysis of the Community Fireguard Program coordinated by the Country Fire Authority in Victoria, Australia, based on experiences from the Black Saturday bushfires is imperfect but nonetheless telling. The evaluation of Community Fireguard groups yielded an estimated $217,116 per group, in terms of avoided loss of human life and property alone, if a bushfire was to occur once every 100 years (cf. Gibbs et al., 2015). The Community Fireguard groups average about 10-12 households living in close proximity to one another (mostly neighbours) in high bushfire risk areas assuming approximately 2.88 people per household (as was found to be the average in the sample for our own study) this equates to a per capita benefit of $6,853.41, more than 2.5 times our estimated per capita benefit ($17,430 per capita) for a one percent change in the bushfire extent. Whether or not one considers the differences in the units underlying these valuations, the hedonistic costs of the Black Saturday bushfires are significantly higher in magnitude than avoided costs measured by more tangible factors.

This investigation while seeking to extend on earlier research is not without its own limitations shared with other stochastic models estimated in naturalistic settings. Specifically, the estimated implicit willingness-to-pay estimate relies on an unbiased estimate of the income and bushfire extent coefficients. The income coefficient may be biased in an unknown degree and to an unknown extent due to reverse causality between income and life satisfaction. Defensible instrumental variables to address this problem continue to remain elusive. Further, the income coefficient is thought to be biased downwards because individual's compare their own income with their past income and with the income of others. Paul and Guilbert (2013) offer a way forward that would capture comparisons of one's own household income with that of others. With regards to adaption to past income or changes in aspirations that, "...no court in the world would grant compensation for..." (Ng, 1978, p. 581), if these are present (Paul and Guilbert (2013) provide evidence which suggests they are not) the results reveal the extra money that would be required in the long-run to secure an extra util of happiness (Layard, 2006).

In terms of the bushfire extent coefficient, it is unlikely that self-selection afflicts the link between bushfire extent and life satisfaction. Further, if any such bias existed it would tend to lead to an underestimate of the negative effect. Evidence for northwestern Montana suggests that self-selection may not be a significant issue. It reveals that for bushfire risk, when a burned area is not visible from a home, it is out of sight and thus out of mind of home buyers (Stetler et al., 2010). In this respect, the 'Black Saturday' bushfires represent a natural experiment.

Despite the battery of socio-economic controls and plethora of fixed effects there is the perennial risk of omitted variable bias common to probabilistic models in the social sciences where observed data is used. Nevertheless, the results presented here provide a meaningful indication of the hedonistic costs associated with the bushfires.

The size of the estimates may have been larger were it not for government intervention which coincided with the bushfires. Anticipating significant hardship at the time of the bushfires the Australian Government provided $7.5 million to support the mental health and wellbeing of individuals and communities in the bushfire effected areas. This financial contribution was part of a broader and comprehensive Recovery Assistance Package provided by the Australian Government which totalled more than $465 million for reconstruction and recovery (Commonwealth of Australia, 2015). The support of the Australian Government in a time when people are in need is heartening, as is the 2009 Victorian Bushfires Royal Commission's exhortation to policy makers to make living in bushfire-prone areas safer (Parliament of Victoria, 2010). However, allowing or inadvertently encouraging homes to be built in bushfire-prone areas generates a moral hazard problem whereby the benefits of living in an area are privatised while the risks are socialised and borne by the government (Loomis, 2004). For this reason, there is a need to inform people on the risks of living in bushfire prone areas and to improve land use planning decisions.

Acknowledgements

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Table 1: Descriptive statistics

Variable name	Definition	Mean (std. dev.)	%
Dependent variable			
Life satisfaction	Individual's self-reported life satisfaction (0-10)	7.92 (1.46)	
Independent variables			
Age and ethnicity measures			
Age (15-19)	Individual is between 15 and 19 years of age		7.5%
Age (20-29)	Individual is between 20 and 29 years of age		16.9%
Age (40-49)	Individual is between 40 and 49 years of age		19.6%
Age (50-59)	Individual is between 50 and 59 years of age		16.2%
Age (60 or greater)	Individual is 60 years of age or greater		21.9%
Poor English	Individual speaks English either not well or not at all		0.8%
Marital status measures			
Married	Individual is legally married		51.4%
Defacto	Individual is in a defacto relationship		13.3%
Separated	Individual is separated		2.7%
Divorced	Individual is divorced		6.0%
Widowed	Individual is a widow		4.6%
Parenting measures			
Lone parent	Individual is a lone parent		1.5%
Number of children	Number of individual's own resident children in individual's household at least 50 per cent of the time and number of own children who usually live in a non-private dwelling but spend the rest of the time mainly with the individual	0.73 (1.10)	
Health measures			
Severe health condition	Individual has a long-term health condition and cannot work		0.8%
Moderate health condition	Individual has a long-term health condition limiting the amount or type of work that the individual can do		17.2%
Mild health condition	Individual has a long-term health condition, that is a condition that has lasted or is likely to last for more than six months and this condition does not limit the type or amount of work the individual can do		8.3%
Educational attainment measures			
Bachelors degree or higher	Individual's highest level of education is a Bachelors degree or higher		22.5%
Certificate or diploma	Individual's highest level of education is a certificate or diploma		29.0%
Year 12	Individual's highest level of education is Year 12		15.4%

Employment status		
Employed part-time	Individual is employed and works less than 35 hours per week	21.2%
Unemployed	Individual is not employed but is looking for work	3.3%
Non-participant	Individual is a non-participant in the labour force, including retirees, those performing home duties, non-working students and individuals less than 15 years old at the end of the last financial year	31.5%
Income measures		
Disposable income	Individual's disposable household income	$73,624.54 ($56,331.88)
Comparison income	Individual's comparison disposable household income following Paul and Guilbert (2013) we define peer groups by age and education, whereby all those who are within 15% of the individual's age and have attained the same level of education form the peer group[8]	$73,272.98 ($23,566.48)
Richer	If disposable household income is greater than comparison disposable household income then Richer = ln(comparison income) Else if disposable household income is less than or equal to comparison disposable household income then Richer = 0 (cf. Paul & Guilbert, 2013)	4.61 (5.50)
Leisure or free time measure		
Free time satisfaction	Individuals' self-reported satisfaction with the amount of free time they have (scale 0-10)	6.66 (2.51)
Social connectedness measures[9]		
Hobby	Individual is currently an active member of a sporting, hobby or community-based club or association	38.5%
Frequent social interaction	Individual gets together socially with friends or relatives no living with them either daily, several times a week or once a week	60.4%
Sense of belonging	Individual's sense of belonging (scale 0-5)	3.54 (0.90)
Tangible support	Individual's sense of tangible support (scale 0-5)	3.87 (1.06)
Social desirability / learning bias measures		
Others present	Someone other than the individual was	37.5%

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[8] As explained by Paul and Guilbert (2013) this means, for instance, that a 20 year old male compares himself only with those people aged between 17-23 years, while a 50 year old male will compare himself only with those people aged between 43-57 years within his education category. Somewhat differently to Paul and Guilbert (2013) an individual's education level is categorised into: year 11 or below, year 12, certificate or diploma and bachelors degree or higher.

[9] As analysed in detail by Ulichny et al. (forthcoming).

	present during the interview	
Years interviewed	Number of years the individual has been interviewed	6.00 (3.79)
Locational measures		
Inner	Individual resides in an inner regional area as defined by the Accessibility/Remoteness Index of Australia	24.7%
Outer	Individual resides in an outer regional area as defined by the Accessibility/Remoteness Index of Australia	11.2%
Remote	Individual resides in a remote area as defined by the Accessibility/Remoteness Index of Australia.	1.8%
Black Saturday bushfire measure		
Bushfire extent	The percentage of an individual's CD which was effected by bushfires in the Black Saturday bushfires.	8.8%

Table 2: Blow-up and cluster, base model life satisfaction results

Variable name	Coefficient (standard error)	Variable name	Coefficient (standard error)
Age and ethnicity measures		Health measures	
Age (15-19)	0.25***	Severe health condition	-0.74***
	(0.08)		(0.09)
Age (20-29)	0.01	Moderate health condition	-0.53***
	(0.05)		(0.03)
Age (40-49)	-0.09**	Mild health condition	-0.13***
	(0.04)		(0.03)
Age (50-59)	-0.08	Educational attainment measures	
	(0.07)	Bachelors degree or higher	-0.54***
			(0.11)
Age (60 or greater)	0.23***		
	(0.09)	Certificate or diploma	-0.27***
			(0.07)
Poor English	-0.15		
	(0.14)	Year 12	-0.33***
			(0.06)
Marital status measures			
Married	0.51***	Employment status	
	(0.07)	Employed part-time	-0.12***
			(0.03)
Defacto	0.51***		
	(0.06)	Unemployed	-0.74***
			(0.05)
Separated	-0.59***		
	(0.10)	Non-participant	-0.28***
			(0.04)
Divorced	-0.12		
	(0.09)	Income measures	
		ln(Disposable income)	0.03**
Widowed	-0.25**		(0.01)
	(0.11)		
		ln(Comparison income)	0.30*
Parenting measures			(0.18)
Lone parent	-0.04		
	(0.07)	Richer	0.01***
			(0.00)
Number of children	-0.01		
	(0.02)	Leisure or free time measure	
		Free time satisfaction	0.27***
			(0.00)

18

Variable	Coefficient	Year	Coefficient
Social connectedness measures		2003	0.11^{*}
Hobby	0.07^{***}		(0.06)
	(0.02)		
		2004	0.04
Frequent social interaction	0.07^{***}		(0.07)
	(0.02)		
		2005	-0.13^{*}
Sense of belonging	0.42^{***}		(0.08)
	(0.01)		
		2006	-0.20^{**}
Tangible support	0.11^{***}		(0.08)
	(0.01)		
		2007	-0.21^{**}
Social desirability / learning bias measures			(0.09)
Others present	0.07^{***}		
	(0.02)	2008	-0.28^{***}
			(0.10)
Years interviewed^{-1}	0.20^{***}		
	(0.08)	2009	-0.29^{***}
			(0.11)
Locational measures			
Inner	0.16	2010	-0.33^{***}
	(0.15)		(0.11)
Outer	0.28	2011	-0.34^{***}
	(0.29)		(0.11)
Remote	-0.11	2012	-0.34^{***}
	(0.68)		(0.12)
Black Saturday bushfire measure		2013	-0.37^{***}
ln(Bushfire extent)	-0.18^{*}		(0.12)
	(0.09)		
Year dummies			
2002	-0.09^{*}		
	(0.05)		
Observations	309,074		
Wald test	Wald $\chi^{2}(48) =$ 6,132.28		
p-value	0.00		
Pseudo R^{2}	0.09		

Standard errors in parentheses
$^{*}\ p < 0.10,\ ^{**}\ p < 0.05,\ ^{***}\ p < 0.01$

Table 3: Blow-up and cluster, moving and staying interaction effects

Variable name	Coefficient (standard error)	Variable name	Coefficient (standard error)
Age and ethnicity measures		Health measures	
Age (15-19)	0.21^{**}	Severe health condition	-0.78^{***}
	(0.08)		(0.09)
Age (20-29)	-0.03	Moderate health condition	-0.54^{***}
	(0.06)		(0.03)
Age (40-49)	-0.04	Mild health condition	-0.12^{***}
	(0.05)		(0.03)
Age (50-59)	-0.05	Educational attainment measures	
	(0.07)	Bachelors degree or higher	-0.63^{***}
			(0.12)
Age (60 or greater)	0.20^{**}		
	(0.09)	Certificate or diploma	-0.30^{***}
			(0.08)
Poor English	-0.32^{**}		
	(0.16)	Year 12	-0.39^{***}
			(0.06)
Marital status measures			
Married	0.47^{***}	Employment status	
	(0.07)	Employed part-time	-0.12^{***}
			(0.03)
Defacto	0.46^{***}		
	(0.06)	Unemployed	-0.73^{***}
			(0.06)
Separated	-0.68^{***}		
	(0.10)	Non-participant	-0.30^{***}
			(0.04)
Divorced	-0.19^{*}		
	(0.10)	Income measures	
		ln(Disposable income)	0.04^{**}
Widowed	-0.33^{***}		(0.01)
	(0.13)		
		ln(Comparison income)	0.29
Parenting measures			(0.20)
Lone parent	-0.06		
	(0.08)	Richer	0.01^{***}
			(0.00)
Number of children	-0.02		
	(0.02)	Leisure or free time measure	
		Free time satisfaction	0.28^{***}
			(0.01)

Social connectedness measures		ln(Bushfire to bushfire)[c]	0.01
Hobby	0.07***		(0.37)
	(0.02)		
		Year dummies	
Frequent social interaction	0.07***	2003	0.27***
	(0.02)		(0.05)
Sense of belonging	0.42***	2004	0.22***
	(0.02)		(0.07)
Tangible support	0.11***	2005	0.06
	(0.01)		(0.09)
Social desirability / learning bias measures		2006	0.01
Others present	0.06***		(0.10)
	(0.02)		
		2007	-0.00
Years interviewed^{-1}	0.57**		(0.11)
	(0.26)		
		2008	-0.06
Locational measures			(0.12)
Inner	0.29*		
	(0.16)	2009	-0.06
			(0.13)
Outer	0.49		
	(0.33)	2010	-0.09
			(0.13)
Remote	1.13*		
	(0.64)	2011	-0.10
			(0.14)
Black Saturday bushfire measures			
ln(No bushfire to bushfire)[a]	-0.06	2012	-0.11
	(0.16)		(0.14)
ln(Stay bushfire)[b]	-0.29**	2013	-0.12
	(0.12)		(0.15)
Observations	255,199		
Wald test	Wald $\chi^2(49)$ = 5,222.44		
p-value	0.00		
Pseudo R^2	0.09		

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
[a] This variable is the natural log of the percentage of the CD that is bushfire effected for individuals who have moved from an area uneffected by the bushfires to effected areas. It takes a value 0 otherwise. [b] This variable is the natural log of the percentage of the CD that is bushfire effected for individuals who have not moved and

remain in an area effected by the bushfires. It takes a value 0 otherwise. [c] This variable is the natural log of the percentage of the CD that is bushfire effected for individuals who have moved from an area effected by the bushfires to another bushfire effected area. It takes a value 0 otherwise.

Table 4: Blow-up and cluster, time decay interaction effects

Variable name	Coefficient (standard error)	Variable name	Coefficient (standard error)
Age and ethnicity measures		Health measures	
Age (15-19)	0.21**	Severe health condition	-0.78***
	(0.08)		(0.09)
Age (20-29)	-0.03	Moderate health condition	-0.54***
	(0.06)		(0.03)
Age (40-49)	-0.04	Mild health condition	-0.12***
	(0.05)		(0.03)
Age (50-59)	-0.05	Educational attainment measures	
	(0.07)	Bachelors degree or higher	-0.63***
			(0.12)
Age (60 or greater)	0.20**		
	(0.09)	Certificate or diploma	-0.30***
			(0.08)
Poor English	-0.32**		
	(0.16)	Year 12	-0.39***
			(0.06)
Marital status measures			
Married	0.47***	Employment status	
	(0.07)	Employed part-time	-0.12***
			(0.03)
Defacto	0.46***		
	(0.06)	Unemployed	-0.73***
			(0.06)
Separated	-0.68***		
	(0.10)	Non-participant	-0.30***
			(0.04)
Divorced	-0.19*		
	(0.10)	Income measures	
		ln(Disposable income)	0.04**
Widowed	-0.32***		(0.01)
	(0.13)		
		ln(Comparison income)	0.29
Parenting measures			(0.20)
Lone parent	-0.06		
	(0.08)	Richer	0.01***
			(0.00)
Number of children	-0.02		
	(0.02)	Leisure or free time measure	
		Free time satisfaction	0.28***
			(0.01)

Social connectedness measures		ln(Stay bushfire)[b] × 2011	-0.14
Hobby	0.07***		(0.13)
	(0.02)		
		ln(Stay bushfire)[b] × 2012	-0.05
Frequent social interaction	0.07***		(0.14)
	(0.02)		
		ln(Stay bushfire)[b] × 2013	-0.05
Sense of belonging	0.42***		(0.13)
	(0.02)		
		ln(Bushfire to bushfire)[c]	0.23
Tangible support	0.11***		(0.37)
	(0.01)		
		Year dummies	
Social desirability / learning bias measures		2003	0.27***
Others present	0.06***		(0.05)
	(0.02)		
		2004	0.22***
Years interviewed⁻¹	0.57**		(0.07)
	(0.26)		
		2005	0.06
Locational measures			(0.09)
Inner	0.27*		
	(0.16)	2006	0.01
			(0.10)
Outer	0.49		
	(0.33)	2007	-0.00
			(0.11)
Remote	1.13*		
	(0.63)	2008	-0.06
			(0.12)
Black Saturday bushfire measures			
ln(No bushfire to bushfire)[a]	0.07	2009	-0.06
	(0.16)		(0.13)
ln(Stay bushfire)[b] × 2009	-0.25*	2010	-0.09
	(0.15)		(0.13)
ln(Stay bushfire)[b] × 2010	-0.10	2011	-0.10
	(0.10)		(0.14)

2012	-0.11
	(0.14)
2013	-0.13
	(0.15)
Observations	255,199
Wald test	Wald $\chi^2(53) =$
	5,219.66
p-value	0.00
Pseudo R^2	0.09

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[a] This variable is the natural log of the percentage of the CD that is bushfire effected for individuals who have moved from an area uneffected by the bushfires to an effected areas. It takes a value 0 otherwise. [b] This variable is the natural log of the percentage of the CD that is bushfire effected for individuals who have not moved and remain in an area effected by the bushfires. It takes a value 0 otherwise. [c] This variable is the natural log of the percentage of the CD that is bushfire effected for individuals who have moved from an area effected by the bushfires to another bushfire effected area. It takes a value 0 otherwise.
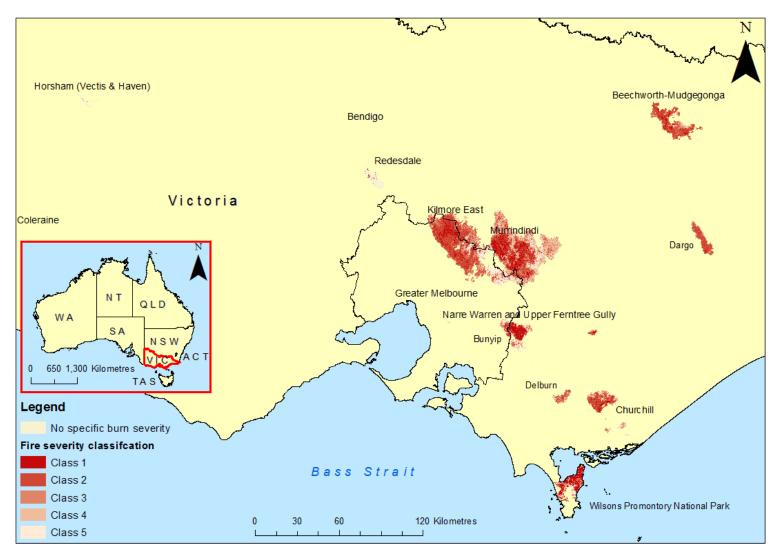
Table 5: Pooled logit model, having seen a psychiatrist or psychologist in the last 12 months

Variable name	Coefficient (standard error)	Variable name	Coefficient (standard error)
Age and ethnicity measures		Health measures	
Age (15-19)	-0.59***	Severe health condition	1.04***
	(0.16)		(0.22)
Age (20-29)	-0.08	Moderate health condition	1.04***
	(0.10)		(0.07)
Age (40-49)	-0.29***	Mild health condition	0.75***
	(0.09)		(0.08)
Age (50-59)	-0.77***	Educational attainment measures	
	(0.10)	Bachelors degree or higher	-0.50***
			(0.16)
Age (60 or greater)	-1.14***		
	(0.14)	Certificate or diploma	-0.16
			(0.11)
Poor English	0.41		
	(0.34)	Year 12	-0.29**
			(0.13)
Marital status measures			
Married	-0.45***	Employment status	
	(0.10)	Employed part-time	0.40***
			(0.08)
Defacto	-0.02		
	(0.10)	Unemployed	1.01***
			(0.13)
Separated	0.38**		
	(0.16)	Non-participant	0.59***
			(0.08)
Divorced	0.10		
	(0.13)	Income measures	

		ln(Disposable income)	-0.04
Widowed	-0.42*		(0.03)
	(0.22)		
		ln(Comparison income)	1.95***
Parenting measures			(0.31)
Lone parent	-0.26		
	(0.23)	Richer	-0.01
			(0.01)
Number of children	-0.09**		
	(0.04)	Leisure or free time measure	
		Free time satisfaction	-0.02*
			(0.01)
Social connectedness measures			
Hobby	-0.16**	Locational measures	
	(0.07)	Inner	-0.35***
			(0.08)
Frequent social interaction	0.05		
	(0.06)	Outer	-0.59***
			(0.12)
Sense of belonging	-0.30***		
	(0.04)	Black Saturday bushfire measure	
		ln(Bushfire extent)	0.20**
Tangible support	-0.12***		(0.09)
	(0.03)		
		Year dummy	
Social desirability / learning bias measures		2013	-0.01
Others present	-0.07		(0.06)
	(0.06)		
Years interviewed^{-1}	-0.10		
	(0.15)		
Observations	16,804		
Wald test	Wald $\chi^2(36)$ = 1,137.42		
p-value	0.00		

Pseudo R^2	0.13

Standard errors in parentheses
[*] $p < 0.10$, [**] $p < 0.05$, [***] $p < 0.01$

Figure 1: Black Saturday bushfires

Source: Department of Environment, Land, Water and Planning