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DISASTERS AND ECONOMIC RESILIENCE IN SMALL REGIONAL COMMUNITIES: THE CASE OF TOODYAY

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ACKNOWLEDGEMENTS

As academic researchers, our primary focus is to produce high quality research and rigorously examine the effects that disasters have on our communities and economies.

To deliver socially meaningful and impactful research, we need to work closely with our government and research counterparts, so that our research is holistic, directly answers questions policy makers are grappling with, and makes our Australian communities safer and more resilient to natural disasters.

Our partnership with the Bushfire and Natural Hazards CRC (BNHCRC) has been a fantastic avenue for doing just that. We are grateful to the BNHCRC not only for generously funding this project, but also for their dedication and passionate support which has facilitated conversations and pushed for greater utilisation of our research among end-users and beyond.

We thank Ed Pikusa, our lead end-user from the Department for Environment and Water (SA), who has steadfastly promoted the value of our research. We are particularly grateful to Tim McNaught for his suggestions, guidance, and support in undertaking this case study. We also warmly thank all end-users who have at various stages contributed their insights and expertise; collaborated on research design and informed the utilisation direction of the *Optimising Post-Disaster Recovery Interventions in Australia* research program. These organisations in alphabetical order are: Department of Environment, Land, Water and Planning (VIC), Department for Environment and Water (SA), Department of Fire and Emergency Services (WA), Emergency Management Australia, Emergency Management Victoria, IGEM South Australia, IGEM Victoria, and Queensland Reconstruction Authority.

We are also thankful to fellow BNHCRC research project leads Dr Melissa Parsons and Dr Veronique Florec, who kindly provided information from their own respective BNHCRC research projects (*Australian Natural Disaster Resilience Index,* and *Economics of Natural Hazards,* respectively). This information has strengthened the evidence base for our own research and provided opportunities for broader research utilisation.

We also thank the Australian Bureau of Statistics' DataLab team, especially Barry Tynan, for patiently uploading our program files and clearing outputs following countless sessions. We are also grateful to Talei Parker, Kim McCosker, and Salma Mujagic-Horvat from the same team, who provided significant support in different ways and on different occasions.

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END-USER STATEMENT

Tim McNaught, *Office of Bushfire Risk Management, WA*

In a fire-prone landscape like Australia, as the climate warms and dries, the likelihood of more severe bushfires impacting communities is increasing. The scale of 2019/2020 summer bushfires on the East Coast of Australia demonstrate how integrated the economic elements of communities are and the interconnectedness between towns and communities themselves are to the impacts of natural disasters. Government and non-government organisations that support communities are endeavouring to gain an insight into plausible futures to assist policy, planning and investment decisions that can ensure the most efficient and effective allocation of increasingly stretched resources to protect communities from hazards before, during and afterwards.

One such way to crystal ball a possible future is to understand the past and this research methodology provides an insight into one such method that follows the economic effect on one community impacted by a relatively short-lived, small scale but intense bushfire in Western Australia in 2009. Appreciating the shocks that something like a short-lived bushfire can have on a small community, like Toodyay, measured by economic effect over a longer period can provide some important insight and justify investment in a community's preparedness and prevention activities that reduce the short-term and longer-term shocks and impacts a bushfire could have.

It is hoped that lessons of the past can inform behaviours and choices in the future. The Shire of Toodyay has made some significant changes in response to the 2009 bushfire. It is hoped such a case study may assist government and non-government organisations with a role in managing the hazards an opportunity to consider measures that may mitigate the impacts of future events. It is clear that those communities that are prepared, have undertaken mitigation activities to reduce the impacts of a hazard and are able to respond accordingly have a greater chance of recovering. I hope this case study can demonstrate a methodology that captures the tangible impacts one event can have over time and may be of interest to other communities faced with similar hazards and potential impacts, ultimately guiding decisions about mitigating the impacts of those hazards.

PRODUCT USER TESTIMONIALS

Marcin Pius, Emergency Management Australia, ACT

Emergency Management Australia (EMA), as the national emergency management coordinating body, including national recovery policy, may have an opportunity to use findings from these reports at various national recovery fora, encouraging the recovery community to consider the findings in the design of future recovery policy and programs. EMA is often involved in reviewing national recovery handbooks, development of guidelines and frameworks and could use the report findings to guide the content of the resources being developed. Finally, in respect of sharing the results of this research, EMA will include these reports in its knowledge management repositories making it available to recovery communities across all jurisdictions.

KEY TERMS USED IN THIS REPORT

TABLE 1 ACRONYMS USED IN THIS REPORT

Acronym	Explanation
ABS	Australian Bureau of Statistics
ACLD	Australian Census Longitudinal Dataset
ANZSIC	The Australian and New Zealand Standard Industrial Classification (ANZSIC) provides a basis for the standardised collection, analysis and dissemination of economic data on an industry basis for Australia and New Zealand
GDP	Gross Domestic Product
LGA	Local Government Area
NDRRA	Natural Disaster Relief and Recovery Arrangements
DRFA	Disaster Recovery Funding Arrangements
SA2	Under the Australian Statistical Geography Standard framework used by the Australian Bureau of Statistics, Statistical Areas Level 2 (SA2) are medium-sized general purpose areas built up from whole Statistical Areas Level 1. Their purpose is to represent a community that interacts together socially and economically.

TABLE 2 DEFINITIONS OF KEY TERMS

Term	Definition	Definition Source
Difference in differences modelling	Difference-in-differences modelling is a quasi-experimental method that allows for evaluating the impact of a "treatment" on a group of interest. It is a natural experiment, in which one group has experienced the treatment, whereas another comparable group has not. The impact of the treatment is estimated by looking at the difference between the changes experienced by the two groups before and after the treatment.	Kennedy, 2003
Disaster risk	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. Annotation: The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socioeconomic development, disaster risks can be assessed and mapped, in broad terms at least. It is important to consider the social and economic contexts in which disaster risks occur and that people do not necessarily share the same perceptions of risk and their underlying risk factors.	UNISDR, 2018
Economic resilience	At the macrolevel, static economic resilience refers to the ability or capacity of a system to maintain function (continue production) when shocked, while dynamic economic resilience is the ability and speed of a system to recover from a shock.	Xi et al., 2018
	At an individual level, this study considers an individual's income stream as effectively representing their economic resilience of to external shocks.	Author
Natural disaster	Disasters caused by natural hazards. Natural hazards only lead to 'disaster' if they intersect with an exposed and vulnerable society (interrupting these systems) and when the consequences exceed people's capacity to cope.	Commonwealth of Australia, 2018a

Natural hazard	A natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation	UNISDR
Tangible impact	Impacts on items that are normally bought or sold and that are therefore easy to assess in monetary terms	Stephenson, 2010
Intangible impact	Impacts on items that are not normally bought or sold. Social and environmental impacts are considered to be intangible	Stephenson, 2010
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and function through risk management.	UNISDR, 2018
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.	UNISDR, 2018

1. EXECUTIVE SUMMARY

Natural disasters in Australia are very costly, and often have devastating socioeconomic effects on impacted communities. Examples in the past decade include the Victorian Black Saturday Bushfires 2009 and the Queensland Floods 2010-11, which caused significant loss of life, losses across multiple sectors (including mining and agriculture), and damage to countless homes and properties. With the severity and frequency of natural disasters expected to increase (Kitching et al., 2014), there is growing academic and policy effort towards better understanding: the risks such disasters pose on Australian communities; the impacts they have on different industry sectors and community groups; and the role that disaster risk reduction can play in minimising such impacts and building disaster resilience.

Estimating the total economic costs of natural disasters can be difficult, owing to the lack of complete and systematic data, conceptual difficulties (Kousky, 2014) and divergent predictions from growth theory about the effects of natural disasters on economic growth (Loayza et al., 2012). While the literature is inconclusive, with some studies reporting negative effects and others positive or insignificant effects (Loayza et al., 2012), a recent meta-analysis of the literature showed evidence of negative impacts in terms of direct costs (Lazzaroni and van Bergeijk, 2014), with more severe disasters causing the highest damage and increasing the likelihood of long-term and/or negative consequences (Boustan et al., 2017; Kousky, 2014).

There is also evidence of distributional effects. Economic and human losses shown to be more pronounced in poorer countries (Schumacher and Strobl, 2011), and institutional factors and educational attainment levels found to be important determinants that influence resilience and recovery (Kousky, 2014; Felbermayra and Gröschl, 2014). Economic diversity also matters. Relying on a single economic sector for income heightens community vulnerability and elongates disaster recovery time compared to diversified economies (Cutter et al., 2008). The type and interlinkages of economic sectors also play a significant role. Due to its land-intensive nature, the agricultural sector is often adversely affected (FAO, 2015). Locally, a study of major Victorian bushfires found that industries most susceptible to direct or indirect impacts are the Agriculture, forestry and fishing sector and retail trade (Stephenson, 2010). Conversely, the construction sector may experience a boom in the immediate aftermath of the disaster as households redirect expenditure towards rebuilding that they otherwise would have deferred, only to experience a lull in the next few years once that expenditure subsides (Kousky, 2014). Even with a diversified economy structure, the interdependence of sectors can have knock-on effects (Yu et al., 2014). Thus, industries more heavily reliant on inputs from the agricultural sector are likely to experience adverse effects to their production.

While these broader examinations are useful, aggregated numbers can mask or hide very large distributive impacts, as the typical instruments used (GDP and aggregated consumption) can be misleading measures of actual welfare losses (Hallegatte S, 2014). What is missing is a systematic understanding of how these broader economic impacts of natural disasters translate to the individual level vis-à-vis income effects; how long these effects persist; and which individuals

within the community bear the brunt of these costs. Indeed, regardless of a country's economic development, a lower socioeconomic status has been consistently associated with greater post-disaster hardship (Norris et al., 2002), with the poor suffering significant disaster losses due to lower financial capacity and limited access to public and private (e.g. insurance) recovery assets (Blaikie et al. 1994; Gladwin and Peacock 1997). For example, while storm damage from Hurricane Katrina was uniform across demographic groups, it was lower income individuals who were less likely to have evacuated or own cover for flood insurance (Masozera et al. 2007). Many other known vulnerabilities to disasters, such as being female, old age, or with lower educational attainment (McKenzie and Canterford, 2016), are highly correlated or interdependent with income. The link between income and disasters also extends to mental health outcomes: In the case of bushfires, the longevity of disruptions to income post-disaster has been shown to materially affect the mental health of those affected by bushfires (Gibbs et al., 2016). Thus quantifying the effects of disasters based on these social and economic dimensions can help policymakers better target and evaluate disaster mitigation recovery programs.

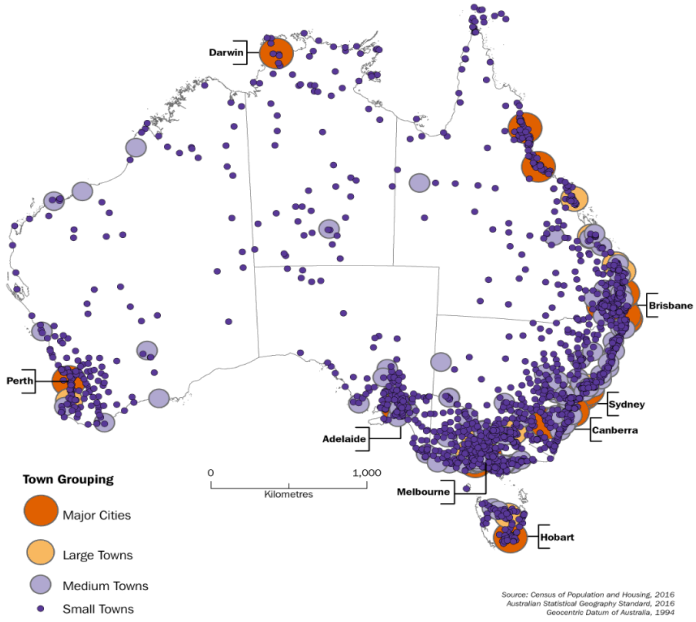
To that end, our research program explores the impact of a number of Australian natural disasters, of various types (fires, flood and cyclone), scales (small, large), and locational settings (regional, metropolitan) on the disaster-hit individuals' economic resilience (measured through their income stream). It disaggregates these impacts on individuals based on who they are (their demographic attributes), if they work (unemployed, employed), how much they work (part-time, full-time) and the industries they work for.

This report investigates the income effects of the 2009 Toodyay bushfire on the income trajectory of residents of Toodyay – a small regional town in Western Australia with a population of 4,450 around the time of the bushfire. The fire conditions were some of the worst seen in Western Australia at the time, and burnt around 2,900 hectares, the equivalent of 2% of the Shire of Toodyay's total area. While no casualties were reported, the total cost of damages was estimated at $100 million (FESA, 2010b).

From a policy perspective, this report contributes to a greater understanding of the potential economic effects of natural disasters on individuals and communities living in small regional towns within Australia (FIGURE 1). Toodyay is fairly typical of such small, regional Australian towns, having an ageing population within the 1,000–4,999 population range, and an economy historically linked to agriculture, mining and manufacturing; industries which are known to be sensitive to natural disasters (Ulubasoglu et al., 2019). Such towns (~1,700 in 2016) form 9.7% of Australia's population and are mostly concentrated around Australia's eastern seaboard (ABS, 2018).

For Western Australia in particular, it is expected that agricultural businesses in currently marginal areas, such as the Wheatbelt region (in which Toodyay is located) are most at risk from climate change (Sudmeyer et al., 2016), and so deserve particular attention when considering disaster resilience in the state.

FIGURE 1 AUSTRALIAN TOWNS, BY POPULATION SIZE GROUPINGS 2016



SOURCE: ABS, 2018

1.1 KEY INSIGHTS

1. **We find that Toodyay bushfire 2009 did not adversely affect the overall income trajectory of individuals who were in the labour force in 2006.**

We find that the Toodyay bushfire did not adversely affect the *overall* income trajectory of the workforce residing within Toodyay in the 2006 Census period. In other words, the changes in incomes of the bushfire-hit residents between 2006 and 2011 censuses are not statistically different than the changes observed in individual incomes in our control groups -Northam and Chittering-, which are comparable areas not struck by the disaster. This finding can be attributed to the relatively smaller size of the bushfires and/or the 2.5 years of time interval between the Toodyay bushfires 2009 and the 2011 Census. Another explanation is that, arguably, Toodyay residents continued to access neighbouring unaffected areas for work, which is likely to have contributed to reducing or eliminating any persistent income losses they would have experienced otherwise.

2. **Low-income earners and female employees are vulnerable to bushfires**

Consistent with the existing literature, low-income earners seem to be the most vulnerable groups to the Toodyay bushfire, given that they seem to have experienced some income losses. It also emerges that females are more vulnerable than males given the relatively weaker income change they experienced compared to males.

3. **Government disaster relief and recovery programs play an important role in supporting regional economies recover from disasters**

The Shire of Toodyay following the disaster was provided with $1.7M worth of recovery assistance over the subsequent three-year period. While these recovery packages may have helped an average person, hence explaining the statistically insignificant effect, financially vulnerable demographic and income groups within the community seem to have suffered income losses.

Even though other market-based recovery means such as insurance payments are available, flood insurance uptake in Australia is rare, with significant rates of under-insurance or no insurance compared to residential insurance (Commonwealth of Australia, 2011). This makes small regional communities particularly reliant on government disaster relief and recovery efforts.

As the income losses arising from the Toodyay bushfire are net losses, this means that the significant post-disaster government relief and recovery efforts could not fully mitigate the disaster's impact on incomes of low-income individuals in the medium-term.

However, as with many natural disasters, government support to reconstruction and rebuild have been critical to support community recovery and in the case of Toodyay, we consider that without government prioritisation of economically critical rebuilding efforts, it is likely that income losses for low income individuals would have been far greater.

4. Economic impact analysis requires a larger sample size

The size of our benchmark sample includes a total of 447 observations in treatment and control groups in 2006 and 2011. This is relatively small to obtain precise estimates for income losses, as small samples may result in high standard errors. Thus, we refrain from making statements about the amount of income losses in this report. However, we believe that the direction of the effects found (such as negative income effects for low-income groups) is informative. Whilst income is an important determinant of economic wellbeing, so is crucial for small communities following natural shocks, future studies should obtain larger and representative samples to offer precise estimates for income changes.

1.2 WHERE TO FROM HERE?

Disasters and Economic Resilience in Small Regional Communities: the Case of Toodyay is one of four natural disaster case studies explored as part of the Optimising Post-Disaster Recovery Interventions in Australia research program, which were chosen to unpack the economic effects that disasters of different types and scales can have on metropolitan and regional communities:

- The Victorian Black Saturday Bushfires 2009,
- The Western Australian Toodyay Bushfire 2009 (this study),
- The Queensland Floods 2010-11,
- Cyclone Oswald 2013.

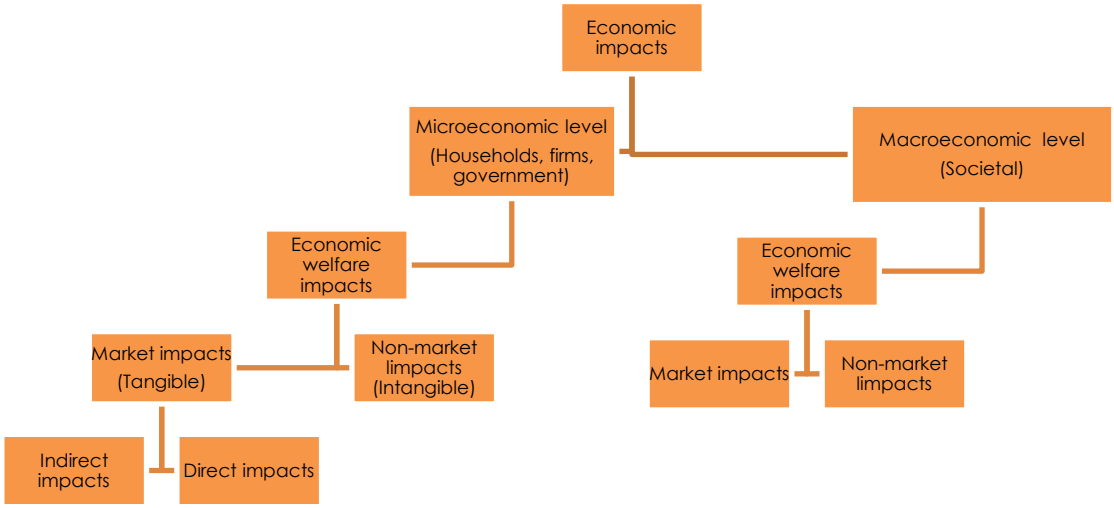
This report aims to shed light on the income effects associated with a bushfire on a relatively small regional community.

2. INTRODUCTION

Disasters and Economic Resilience in Small Regional Communities: the Case of Toodyay measures the average income changes of individuals who were in the labour force in 2006 Census and living within the boundaries of Toodyay.

In this report, we use difference-in-differences modelling[1] to estimate these income effects. The Australian Census Longitudinal Dataset[2] (ACLD) is our primary dataset.

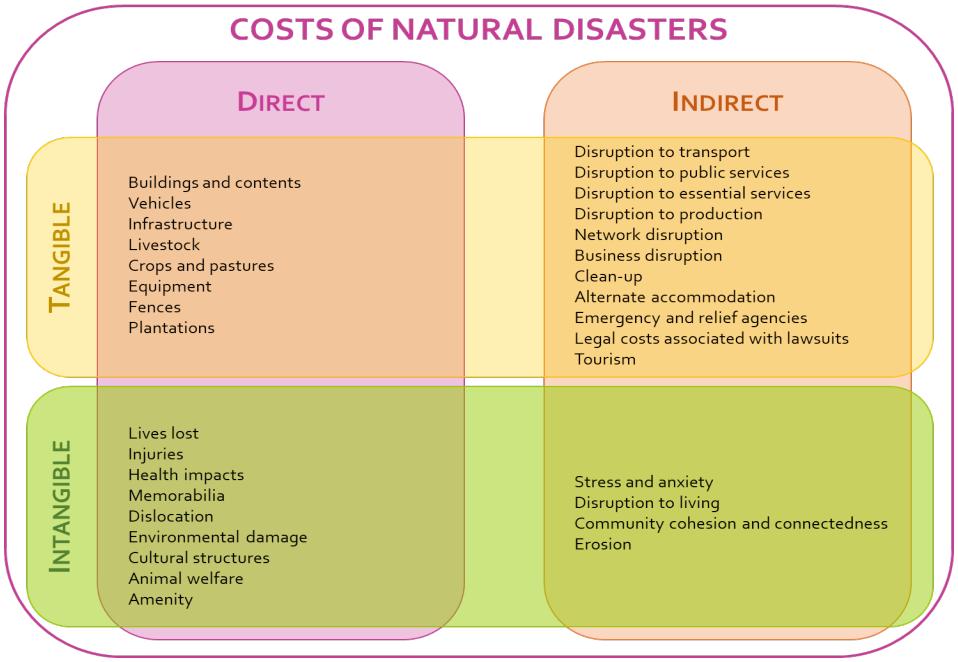
FIGURE 2 WHERE OUR PROJECT SITS WITHIN THE BROADER ECONOMIC IMPACTS ASSESSMENT OF NATURAL DISASTERS



Out of scope are any other indirect effects[3] or other economic costs described in FIGURE 2. The project also does not assess the role insurance could have played in reducing or mitigating the effects of the bushfires. This is predominantly because of the dearth of insurance data at the Statistical Area- 2 (SA2), and is listed as a limitation of this study.

FIGURE 3 ECONOMIC COSTS OF NATURAL DISASTERS

[1] See Table 2 for definition.
[2] Available through the Australian Bureau of Statistics (ABS) DataLab.
[3] See Table 2 for definitions of these terms.



SOURCE: PENMAN ET AL. (2019)

The rest of this report is organised as follows. We set the scene by providing an overall socioeconomic profile of Toodyay and contextual information on the Toodyay bushfire 2009. We then outline our methodology, incorporating our sample construction and descriptive statistics. Following our results, we offer conclusions on how this study can be utilised to inform disaster mitigation and recovery activities.

3. SMALL FIRES IN TOODYAY, WESTERN AUSTRALIA

3.1 SOCIOECONOMIC PROFILE

Toodyay is a regional town located in the northern Wheatbelt region of Western Australia, approximately 80km North/East of the state capital Perth. It is characterised by agricultural activities and low population density, with 2.7 persons per square kilometre.

Toodyay has a small population, which grew from 4,330 in 2006 to 4,707 in 2013, before declining to 4,500 in 2016, placing it within the ~1,700 small towns scattered across Australia. The population is relatively older and ageing – Toodyay's median age reached 51 years in 2016, with the share of residents aged 65 or older increasing from 12.8% to 23.3% over the decade.

Since 2006-07, there have around 400 businesses on average located in the Shire of Toodyay (FIGURE 4). A significant share of these businesses are non-employing (i.e. either sole-proprietorships or partnerships with no employees; (FIGURE 5), and are mostly concentrated in the agricultural and construction sectors (FIGURE 6). Owing to this, over 60% of Toodyay's employed residents typically work outside the Toodyay Shire (FIGURE 7), mostly in Perth (~28%) and neighbouring Northam (~16%).

FIGURE 4 TOODYAY SHIRE BUSINESSES, OVERALL AND PER 1000 PERSONS

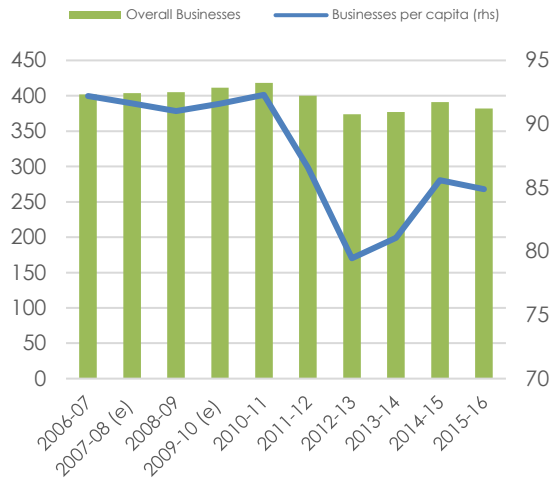


FIGURE 5 TOODYAY SHIRE BUSINESSES, OVERALL AND PER 1000 PERSONS

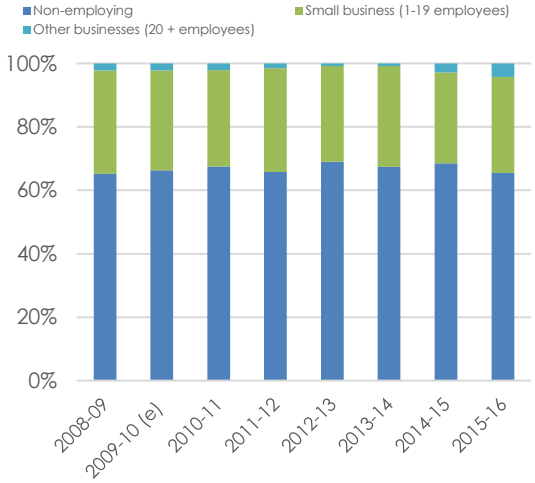


FIGURE 6 TOODYAY SHIRE NON-EMPLOYING AGRICULTURAL AND CONSTRUCTION BUSINESSES (% OF TOTAL NON-EMPLOYING)

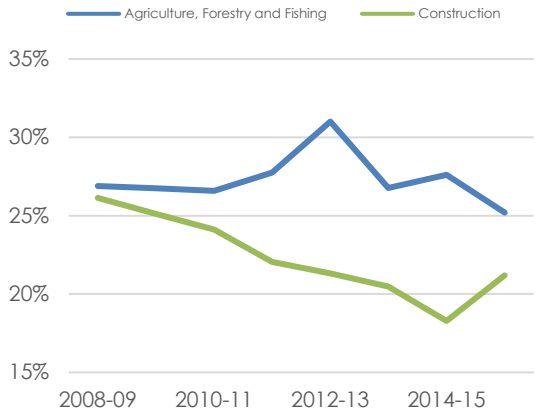
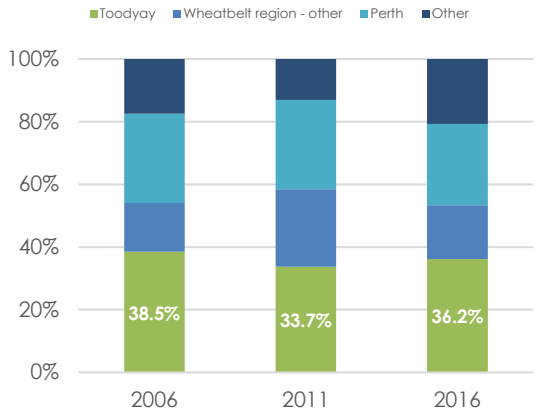


FIGURE 7 TOODYAY SHIRE RESIDENTS PLACE OF WORK (%)



SOURCE: FIGURE 3 - FIGURE 6: ABS, CAT 8165.0 COUNTS OF AUSTRALIAN BUSINESSES, INCLUDING ENTRIES AND EXITS; FIGURE 2: ABS, CAT 3218.0 REGIONAL POPULATION GROWTH; FIGURE 5: ABS CENSUS OF POPULATION AND HOUSING (2006, 2011, 2016) (USUAL RESIDENCE DATA) RETRIEVED VIA TABLE BUILDER. FIGURE 5 EXCLUDES PLACE OF WORK "NOT STATED" OR "NOT APPLICABLE".

More broadly, and compared to the Wheatbelt region, Toodyay's overall employed workforce has seen a greater shift away from manufacturing and the agricultural sector, which dropped from the largest employer in 2001 and 2006, to become the sixth largest employing industry in 2016 (FIGURE 8). Health care and social assistance became the top employer in 2011, while mining also exhibited the strongest gain, most notably over the 2011-2016 period. Based on ABS Census data (at the SA2 level), the top 5 employing industries have typically accounted for 49% of employment. While the overall rankings are different, the common top industries of employment between 2001 and 2016 were Health care and social assistance and Construction.

FIGURE 8 Top 5 industries of employment 2001-2016

						2001-2016
Top 5 Industries of Employment	**2001**	**2006**	**2011**	**2016**	**Trendline**	**Annualised Δ**
Toodyay						
Agriculture, forestry and fishing	12.56%	11.10%	7.73%	7.69%		-3.22%
Construction	10.22%	10.97%	10.81%	9.84%		-0.25%
Manufacturing	9.16%	8.17%	6.28%	5.88%		-2.91%
Health care and social assistance	9.01%	9.48%	11.40%	10.06%		0.74%
Public administration and safety	8.52%	8.04%	8.60%	9.89%		1.00%
Retail trade	8.02%	9.10%	9.53%	7.86%		-0.14%
Education and training	7.45%	8.35%	8.02%	8.42%		0.82%
Mining	1.99%	3.62%	6.22%	8.59%		10.25%
Wheatbelt region						
Agriculture, forestry and fishing	29.19%	25.70%	20.28%	20.78%		-2.24%
Retail trade	9.25%	10.01%	9.54%	8.82%		-0.31%
Education and training	7.78%	8.00%	8.54%	8.97%		0.96%
Health care and social assistance	7.19%	8.36%	9.21%	10.02%		2.24%
Construction	6.33%	7.03%	8.28%	7.72%		1.34%

SOURCE: ABS CENSUS OF POPULATION AND HOUSING (2006, 2011, 2016) (USUAL RESIDENCE DATA). GENERATED 17 DECEMBER 2018 USING AUSTRALIAN BUREAU OF STATISTICS TABLE BUILDER

3.2 DISASTER PROFILE

3.2.1 Disaster resilience

Not all Australian communities have the same capacity for disaster resilience (Parsons et al., 2019). Communities with lower capacity to deal with disasters will need more assistance so that they – and the local economies that support their social and economic wellbeing – can recover.

Here, the Australian Natural Disaster Resilience Index (ANDRI) is a national scale composite index that provides an evidence-based snapshot of the disaster resilience of SA2s across Australia. It defines resilience to disasters arising from natural hazards as: "the capacity of communities to prepare for, absorb and recover from natural hazard events and to learn, adapt and transform in ways that enhance these capacities in the face of future events." (Parsons et al., 2019).

ANDRI scores are available for Toodyay. Compared to other Australian SA2s, Toodyay was ranked within the bottom quartile of SA2s and thus assessed as having low capacity for disaster resilience. Communities in areas assessed as having low disaster resilience "may be limited in their capacity to use available resources to cope with adverse events, and are limited in their capacity to adjust to change through learning, adaptation and transformation. Limitations to disaster resilience may be contributed by entrenched social and economic disadvantage, less access to or provision of resources and services, lower community cohesion and limited opportunities for adaptive learning and problem solving" (Parsons et al., 2019).

3.3 TOODYAY BUSHFIRES 2009 EVENTS

The 29 December 2009 Toodyay Bushfire burnt around 2,900 hectares, the equivalent of 2% of the Shire of Toodyay's total area. According to 2008-09 ABS estimates, 4,450 residents and 405 businesses would have been residing/located within the Shire at the time of the fire.

The fire conditions were some of the worst seen in Western Australia at the time. The total cost of damages was estimated at $100 million (FESA, 2010b), though no breakdown is provided. The fire's ignition point was close to the rural-urban interface, destroying 38 houses and damaging over 170 properties (FESA, 2010a; FESA, 2010c). Some of the properties lost were holiday or second homes (Barnett, 2010). One-thirds of affected residents did not have adequate insurance (Parliament of Western Australia, 2010). The fires caused material damage to the agricultural sector. 18 cows (Lampathakis, 2011) and 100 sheep were killed (FESA 2010b), with damage to 20 sheds, fencing, farming machinery, crops, orchards, vineyards, dairies and olive groves (Moylan, 2010). There was also considerable damage to electricity distribution lines, with repair and restoration of public assets totalling around $443,000. While costly, the Toodyay fire was relatively small in size (FESA, 2010a), with no fatalities and only 4 injuries recorded (FESA, 2010b).

The Toodyay fire was declared a natural disaster, with Category A and B assistance provided by the Federal Government totalling $1.7 million as provided in TABLE 3.

TABLE 3 FEDERAL GOVERNMENT ASSISTANCE (NDRRA)

NDRRA Measure	2009-10	2010-11	2011-12	Total
Category A assistance	$299,285	$139,065	$208,414	$646,764
Emergency Food, Clothing or temporary accommodation	$2,343	$ 37,431	$3,065	$ 42,839
Removal of debris from residential properties	$170,699	$3,880	$ 29,228	$203,807
Counter Disaster Operations assistance to individuals	$ 87,593	$ 32,478	$ 11,477	$131,548
Personal and financial counselling		$616	$3,247	$3,863
Extraordinary costs of delivering Category A assistance	$ 38,650	$ 64,660	$161,397	$264,707
Category B assistance	$646,205	$370,878	$ 46,370	$1,063,453
Restoration or repair of essential public asset	$131,452	$311,392		$442,844
Counter Disaster Operations assistance to the general public	$514,753	$ 59,486	$ 46,370	$620,609
Annual totals	$ 945,490	$ 509,943	$ 254,784	$1,710,217

SOURCE: DFES, supplied

4. RESEARCH APPROACH

4.1 MODEL

At its core, the research aims to determine the disruptive effects of a natural disaster on individuals' income trajectory. We use a statistical technique called difference-in-differences (DID) modelling to analyse the effect of Toodyay bushfire on the income of individuals in the workforce who resided in Toodyay in 2006. The model mimics experimental research design by comparing the effect of a treatment (i.e. natural disaster) on a 'treatment group' relative to a 'control group'. That is, it computes the effect of this treatment on an outcome (individual income) by comparing the changes in income in the treatment group before and after the disaster, relative to similar changes in the control group.

We exploit the rich individual-level Australian Census Longitudinal Dataset (ACLD) available through ABS Datalab, which not only provides a convenient 'baseline' (2006) and 'end-line' (2011) surveys for our DID design but also allows us to explore the differential effect of the disaster on demographic groups. As we're interested in the impacts on income, we refine our sample to incorporate only Toodyay residents who were in the labour force and reported non-negative income (n=889). We further restrict our sample to those who did not move between the census years (non-movers; n=447). This is because, in the absence of a full analysis of the migration decisions (which is difficult with the ABS Census being conducted only once every five years), we cannot understand what motivated this movement and what happened to movers.

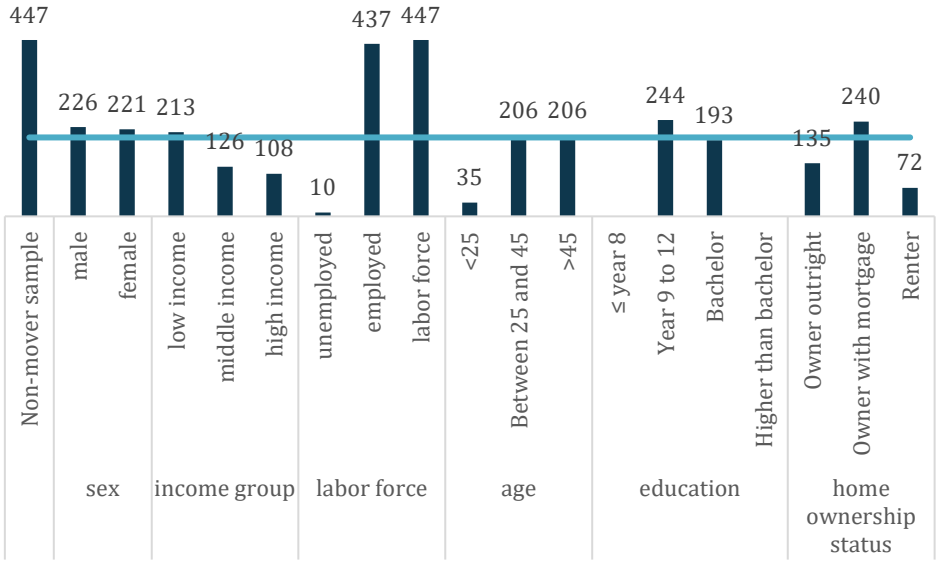
Our modelling considers Toodyay residents as the members of the treatment group and residents of the two of its immediate neighbours, Northam and Chittering, as the members of the control group. The socioeconomic characteristics of Northam and Chittering closely resemble those of Toodyay. The data from ACLD show that, in 2006, our treatment and control groups have an average income of around 38,200 AUD, age of around 39, home ownership of around 70%, unemployment rate of 3.5%, and highly similar educational attainment, thus meeting the necessary condition of this model, and enabling us to pinpoint any bushfire-driven effects. In addition to the overall income effects, we further explore four key dimensions across which one might expect to observe differences in impact of the fire on individuals:

- gender,
- income level,
- education, and
- age.

While our modelling approach generally enables disaggregating the sectoral and demographic effects, the small, regional nature of Toodyay presents challenges for statistical computations as the non-mover sample size is less than 500. This means that achieving statistical power in our analysis is difficult. The small sample size also limits what we could normally report in regard to sectoral and several demographic groups due to ABS confidentiality constraints. For these reasons, analysis was limited to demographic attributes that had a sample size

of 200 or greater (represented by the horizontal blue line in FIGURE 9) and met the ABS confidentiality constraints. Unfortunately, these limitations meant we could not present a disaggregated analysis at the sectoral level (i.e. by an individual's industry of employment), which we were able to do in the other case studies of our research program.

FIGURE 9 TOODYAY NON-MOVER SAMPLE SIZES (NO.), BY DEMOGRAPHIC ATTRIBUTES



The model is formally defined as:

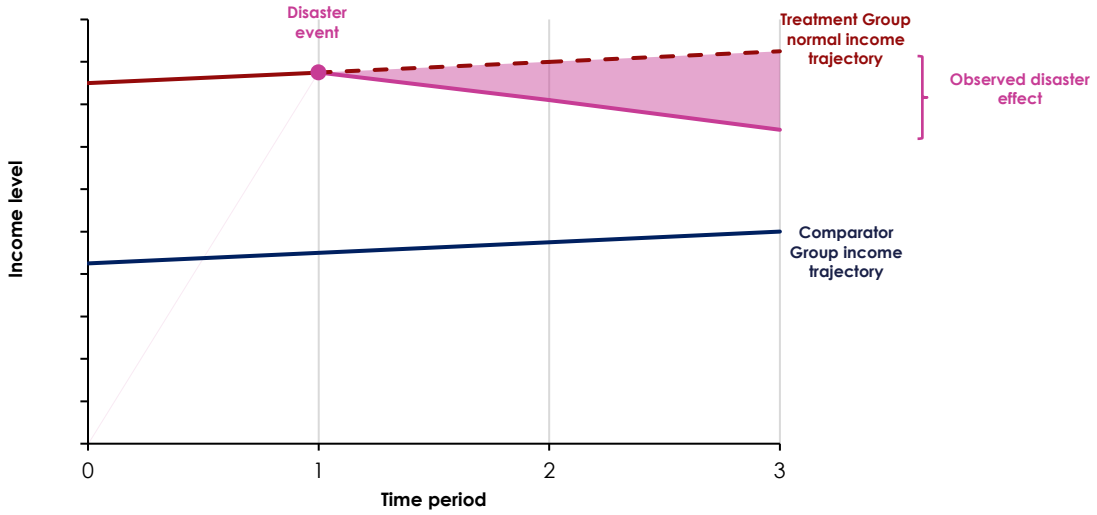
$$\boldsymbol{Y_{ist} = \beta_1 T_i + \beta_2 Post_t + \beta_3 T_i \times Post_t + \alpha_i + S_s + \varepsilon_{ist}}$$

where:

$\boldsymbol{Y_{ist}}$ = Log of income
$\boldsymbol{i}$ = Individuals
$\boldsymbol{s}$ = Indicates the SA2 in which an individual lives in 2006
$\boldsymbol{t}$ = Census dates for 2006 and 2011
$\boldsymbol{T}$ = Treatment variable; becomes one if individual *i* resided in Toodyay in 2006.
$\boldsymbol{Post}$ = Post BSB indicator variable that equals one if the time period is 2011.
$\boldsymbol{\alpha}$ = Individual fixed effect
$\boldsymbol{S}$ = SA2 fixed effect
$\boldsymbol{\beta_3}$ = Coefficient of interest
$\boldsymbol{\varepsilon}$ = Disturbance Term

FIGURE 10 illustrates a hypothetical case of how the difference-in-differences calculates a negative disaster effect on income where the y-axis denotes the income level and x-axis denotes the time period.

FIGURE 10 ILLUSTRATIVE DIFFERENCE-IN-DIFFERENCES MODEL SHOWING A HYPOTHETICAL NEGATIVE DISASTER EFFECT



As time progresses, the treatment group is subject to a disaster shock at point 1. The pink solid line portrays the *observed* income trajectory in the treatment group following the disaster and the dashed pink line represents the counterfactual income in the treatment group, had the disaster not occurred at point 1. This counterfactual income trajectory is provided by the control group (the dark blue line). The vertical difference between the pink dashed and solid lines at point 2 reflect the disaster's income effect in the shorter term, while the distance at point 3 reflects the fully realised income effect of the disaster.

4.2 DATASET

We utilise the rich, anonymised, individual-level Australian Census Longitudinal Dataset (ACLD) available through the ABS DataLab. This dataset includes a nationally representative 5% sample from each of the 2006 and 2011 Censuses, and links the individual records in the 2006 and 2011 Censuses. In other words, an individual can be tracked over time, including changes in their economic, demographic, and other characteristics.

While there are several limitations of this dataset (see section 6.2.2), compared to alternative sources, the ACLD has the largest sample size available for empirical research, and collects information on the location of individuals, allowing us to track individuals who did not move between two Census dates.

4.3 SAMPLE CONSTRUCTION

4.3.1 Sample construction

As we are interested in individual income, we refine our sample to incorporate only individuals who were in the labour force. We construct our panel data by excluding the following individuals from our sample in the following order:

(i) individuals that are not within the working age,
(ii) individuals who were not in the labour force in 2006,

(iii) individuals who reported to have negative income or chose not to report any sort of income, and
(iv) individuals who moved before 2011 Census.

The rationale behind this sample construction is as follows. It is a common practice in the literature on the economic effects of disasters caused by natural disasters to focus on individuals who are between 15 to 65 years of age. This means children and the retired people are not the focus of attention. From a policy perspective, we wish to know how to allocate scarce relief and recovery assistance for a sample of those who are part of market dynamics, and hence, those whose economic resilience may need to be supported by the government. For practical purposes, individuals who are not in the labour force are mostly those who are aged 15-20. These individuals could be subject to a separate analysis, and/or their relief and recovery assistance could be set on other grounds (i.e. youth allowance) than supporting their economic resilience.

Because respondents tick a box that corresponds with an income range (e.g. $1-$7799), this provides interval-based annual income data.[4] We take the mid-point of the respective interval class as the actual income of individuals. To adjust for inflation, we then deflate this income measure using the Consumer Price Index of Perth between 2006 and 2011.

We exclude those who reported negative income as the ABS Census data report "-1" (i.e., minus 1) for these individuals' income. This information is practically unusable from the analysis perspective. This is a limitation of the ABS Census data. We note that these individuals constitute only a small portion of the sample, so we consider that their exclusion is unlikely to impact our results.

4.3.2 Treatment group

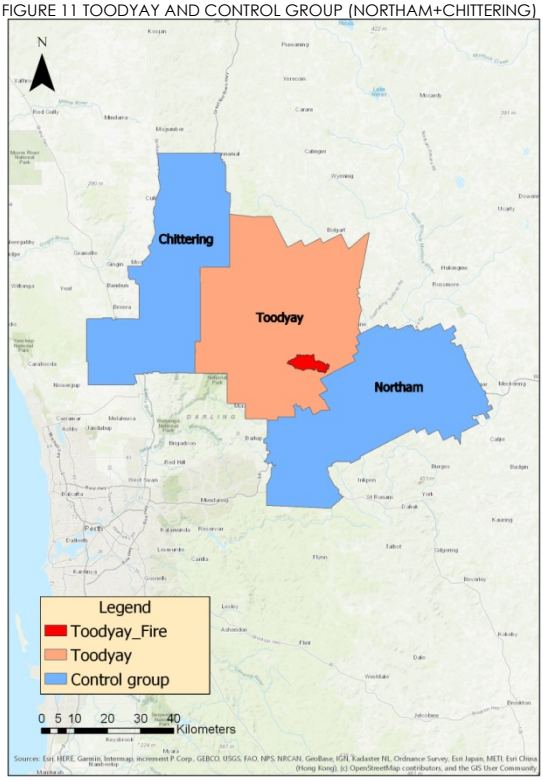
The selected treatment group is individuals who lived in Toodyay (SA2 area) during the 2006 Census. Red coloured area in FIGURE 11 shows the bushfire area within Toodyay SA2. Our treatment group comprises individuals who lived in pink coloured area.

4.3.3 Control (comparator) group

Our comparator SA2s are Northam and Chittering. The residents living in blue areas in FIGURE 11 constitute our control group.

[4] $0, $1-$7799, $7800-$12999, $13000-$20799, $20800-$31199, $31200-$41599, $41600-$51999, $52000-$67599, $67600-$83199, $83200-$103999, and $104000 or more.

FIGURE 11 TOODYAY AND CONTROL GROUP (NORTHAM+CHITTERING)



4.3.4 Sample descriptive statistics

We present the descriptive statistics for our benchmark (i.e. non-mover) sample in TABLE 4 and TABLE 5. Northam and Chittering turn out to have highly similar income earnings to that of Toodyay in 2006. In addition, important socioeconomic characteristics, such as average age, home ownership status, employment and education level, present striking similarities. For instance, both our treatment and control groups have average incomes of around 38,200 AUD. Both groups have average age of around 39 years and strikingly both groups have highly similar home ownership status; 79% of individuals are home owners in Toodyay while this figure is 74% for Northam and Chittering. All these characteristics ensure that our control group is comparable to Toodyay for a reliable DID analysis.

TABLE 4 2006 SAMPLE DESCRIPTIVE STATISTICS FOR NON-MOVER SAMPLE: DEMOGRAPHIC AND EMPLOYMENT ATTRIBUTES

	Full sample (2006)			Toodyay (2006)			Northam + Chittering (2006)		
	Mean	Median	Std. dev	Mean	Median	Std. dev	Mean	Median	Std. dev
Income (AU)	$38,070	$36,400	$25,056	$38,298	$36,400	$24,733	$38,204	$36,400	$24,840
Age	39.4	41.0	11.7	38.7	41.0	12.2	39.0	41.0	12.0
Home ownership status									
Owner (outright) (%)	0.232	0.000	0.423	0.243	0.000	0.430	0.239	0.000	0.427

Owner (with mortgage) (%)	0.429	0.000	0.496	0.548	1.000	0.499	0.500	0.500	0.501
Renter (%)	0.293	0.000	0.456	0.158	0.000	0.365	0.212	0.000	0.409
Employment status									
Employed (%)	0.955	1.000	0.209	0.966	1.000	0.182	0.961	1.000	0.193
Unemployed (%)	0.046	0.000	0.209	0.034	0.000	0.182	0.039	0.000	0.193
Education level									
Year 8 or lower	0.000	0.000	0.000	0.010	0.000	0.101	0.006	0.000	0.078
Year 9 to 12	0.460	0.000	0.500	0.555	1.000	0.498	0.516	1.000	0.500
Bachelor Degree	0.470	0.000	0.500	0.377	0.000	0.485	0.414	0.000	0.493
Higher than Bachelor	0.141	0.000	0.349	0.099	0.000	0.300	0.116	0.000	0.321

NOTE: % REFERS TO THE SHARE OF THE GROUP IN THE RELATED SAMPLE.

TABLE 5 2011 SAMPLE DESCRIPTIVE STATISTICS FOR NON-MOVER SAMPLE: DEMOGRAPHIC AND EMPLOYMENT ATTRIBUTES

	Full sample (2011)			Toodyay (2011)			Northam + Chittering (2011)		
	Mean	Median	Std. dev	Mean	Median	Std. dev	Mean	Median	Std. dev
Income (AU)	$41,458	$40,610	$25,722	$41,603	$40,610	$25,704	$41,553	$40,610	$25,679
Age	41.5*	53.0	n.a.	43.9*	47.0	11.3	41.3*	49.0	n.a.
Home ownership status									
Owner (outright) (%)	0.245	0.000	0.431	0.234	0.000	0.424	0.239	0.000	0.427
Owner (with mortgage) (%)	0.482	0.000	0.501	0.515	1.000	0.501	0.500	0.500	0.501
Renter (%)	0.208	0.000	0.407	0.215	0.000	0.412	0.212	0.000	0.409
Employment status									
Employed (%)	0.954	1.000	0.211	0.967	1.000	0.179	0.961	1.000	0.193
Unemployed (%)	0.046	0.000	0.211	0.033	0.000	0.179	0.039	0.000	0.193
Education level									
Year 8 or lower	0.005	0.000	0.068	0.015	0.000	0.120	0.010	0.000	0.101
Year 9 to 12	0.569	1.000	0.496	0.562	1.000	0.497	0.565	1.000	0.496

Bachelor Degree	0.495	0.000	0.501	0.518	1.000	0.501	0.508	1.000	0.500
Higher than Bachelor	0.120	0.000	0.326	0.113	0.000	0.317	0.116	0.000	0.321

NOTE: % REFERS TO THE SHARE OF THE GROUP IN THE RELATED SAMPLE.*THESE VALUES ARE OBTAINED FROM PUBLICLY AVAILABLE ABS CENSUS DATA.

4.4 CHECKS AND CONTROLS

We perform the necessary robustness checks and sensitivity analyses. We also check and control for many factors that, aside from the bushfires, could have affected individual income in our treatment and control groups. These include:

- Eliminating any factors at both the SA2 level and the individual level that do not vary with time, but could also drive income differences between our treatment and control group[5]
- Eliminating factors at the individual level that *do* vary with time and could also create non-bushfire related income deviations between the groups

4.4.1 Controlling for other shocks that hit the region

Other shocks that occurred in the treatment and control groups in between the Census periods could also contribute to observed income deviations between the two groups.

Aside from these more generalised shocks, we need to be mindful of whether disaster shocks in either the treatment group or the control group bias our observed income effects.

We know that disasters arising from natural hazards are a regular event in the Australian context. Thus, it is more extreme events that would likely have a material effect on incomes, and cause income deviations between our treatment and control group. Here, we can rely on assistance classifications under the Australian disaster relief and recovery arrangements[6] to isolate more severe disasters requiring special assistance (i.e. Category D, which requires Prime Minister approval) from more "regular" events (Categories A to C).

To that end, Toodyay experienced two natural disaster events in 2011. None of these events required significant (Category D) assistance. Northam and Chittering, which form our control group, each experienced relatively mild disasters in 2011. Details of these disasters are provided in the Appendix (see TABLE 13 and TABLE 14).

[5] At the SA2 level, this includes eliminating any differences in topography, climate and institutional structure. At the individual level, this includes netting out any characteristics, like risk-taking behaviour and psychological resilience that could also influence their coping mechanism with economic shocks.

[6] For events prior to 1 November 2018, i.e. our study period, this would be covered under the Natural Disaster Relief and Recovery Arrangements, or NDRRA. New events are covered by the Disaster Recovery Funding Arrangements (DRFA).

4.5 ASSUMPTIONS AND LIMITATIONS

4.5.1 Assumptions

4.5.1.1 Assumption 1: Parallel trends assumption

Our results are sensitive to the selection of the control group, and so a key difference-in-differences model assumption we need to meet is that treatment and control group incomes were growing in parallel before the bushfires associated with Toodyay.

Put simply, if we know that the control and treatment groups were growing along similar trends prior to the disaster, and we have properly accounted for other potential reasons for variations in income, including socioeconomic characteristics and topography, this gives more confidence that the Toodyay fires alone was responsible for any deviations of the treatment group from its expected trajectory post disaster. For the ABS five-year interval dataset, this means examining income patterns between 2001 and 2006. However, unfortunately, 2001 Census is not linked to 2006-2011 Censuses. Thus, we cannot formally check whether parallel trend assumption hold. Instead, we compare income levels and socioeconomic characteristics of treatment and control groups to ensure that they have similar features. Characteristics presented in Table 4 and 5 give us comfort that our results are reliable in this regard.

4.5.1.2 Assumption 2: Government intervention mechanisms played a role in mitigating the bushfire's effects on individual income

Our results include the bushfire's effect on income plus any disaster relief and recovery effect on income.[7] This assumption is critical for us to examine the role that government relief and recovery programs played in supporting individuals in the disaster area.

The wording of the Census question is unlikely to prompt Census respondents to report government assistance received or insurance pay-outs as part of their annual income. Rather, we know from the economics literature that when large and unexpected natural shocks hit the economic system, a negative wealth and income effect may appear. If the intervention mechanisms are strong enough (such as insurance markets and government programs), the negative income is smoothed and potential losses are mitigated. In this case, the income effect is likely to be transient.

However, when the economy cannot resume its activities effectively and if the intervention mechanisms are not effective enough, the income trajectory remains lower than the pre-disasters levels, so that the effect is permanent.

So for instance, by speedily rebuilding roads, repairing critical assets, and reconnecting essential services, government recovery programs minimise disruptions to businesses and therefore reduce or fully mitigate any economic losses. Thus, well-designed interventions provide the supportive environment to enable the continuation of the income trajectory, which would be reflected in the results reported.

[7] This includes post-disaster income and recovery assistance by the government, disaster insurance, reconstruction efforts and infrastructure investments.

While we cannot directly test this due to data limitations, we are satisfied based on available evidence that the government post-disaster relief and recovery assistance are the primary intervention mechanism over the course of our study period, and so are the primary driver of the relief and recovery effect that are detectable within the scope of our analysis. We explain this below.

The Toodyay fire was declared a natural disaster, with Category A and B assistance provided by the Federal Government totalling $1.7 million. Over half of this assistance was provided within six months of the disaster (TABLE 6).

TABLE 6 FEDERAL GOVERNMENT ASSISTANCE (NDRRA)

NDRRA Measure	2009-10	2010-11	2011-12	Total
Category A assistance	$299,285	$139,065	$208,414	$646,764
Emergency Food, Clothing or Temporary accommodation	$2,343	$ 37,431	$3,065	$ 42,839
Removal of debris from residential properties	$170,699	$3,880	$ 29,228	$203,807
Counter Disaster Operations assistance to individuals	$ 87,593	$ 32,478	$ 11,477	$131,548
Personal and financial counselling		$616	$3,247	$3,863
Extraordinary costs of delivering Category A assistance	$ 38,650	$ 64,660	$161,397	$264,707
Category B assistance	$646,205	$370,878	$ 46,370	$1,063,453
Restoration or repair of essential public asset	$131,452	$311,392		$442,844
Counter Disaster Operations assistance to the general public	$514,753	$ 59,486	$ 46,370	$620,609
Annual totals	$ 945,490	$ 509,943	$ 254,784	$1,710,217

SOURCE: DFES, supplied

Apart from the federal assistance, the State Government, in conjunction with Western Energy, announced a $10 million financial assistance package for affected individuals on 11 October 2010 (TABLE 7).

TABLE 7 TOODYAY BUSHFIRE DISASTER ASSISTANCE PACKAGE

Category	Description	Maximum payment	
Residential buildings	Established homes which were damaged or destroyed	$945,490	
External Structures	Sheds, fences and other external structures	—	
Site Clean-up	Cost of site clean-up and rubbish removal	$193,000	
Home Contents	Home contents	$1,100,000	$190,000 total payment for each property
Tools of Trade	Items used for employment purposes (tools and equipment)	—	
Private Motor Vehicles	Private motor vehicles including cars, motor homes and motorbikes.	$ 64,660	

SOURCE: BARNETT (2010)

It is noted that the payments were provided regardless of insurance cover (Parliament of Western Australia, 2010) and were directed at assisting with residential rather than commercial losses. The first payments were reported in

December 2010 (Farm Weekly, 2010), with less than half of the funds paid as at 24 October 2012 (Parliament of Western Australia, 2012). Combined with public bushfire appeals and Western Power settlements, monetary assistance for the Toodyay bushfires totalled $16.5 million, with up to $10.6 million distributed as at October 2012 (TABLE 8).

TABLE 8 TOODYAY BUSHFIRE DISASTER ASSISTANCE

Assistance	Total allocated	2009-10	2010-11	2011-12	As of October 2012
NDRRA (a)	$ 1,710,217	$945,490	$509,943	$254,784	$1,710,217
Toodyay Financial Assistance Package (b, c)	$10,000,000	—	$4,084,280	—	$4,084,280
Lord Mayor Disaster Relief Fund - Toodyay Bushfires (d)	$193,000	$193,000	—	—	$193,000
Salvation Army Toodyay Bushfire Appeal (e)	$1,626,000	$1,100,000	$526,000	—	$1,626,000
Western Power settlements (f)	$3,000,000	—	—	—	< $ 3,000,000

SOURCE: (A) DFES, SUPPLIED; (B) BARNETT, 2010; (C) PARLIAMENT OF WESTERN AUSTRALIA 2011; (D) LORD MAYOR DISASTER RELIEF FUND, 2010; (E) SALVATION ARMY, 2010; (F) PARLIAMENT OF WESTERN AUSTRALIA 2012.

4.5.2 Limitations

As with any study, multiple limitations constrain the applicability of our findings.

As acknowledged in the 2018 National Disaster Risk Reduction Framework, "disaster risk data and information is not always available to those who need it and it does not adequately integrate climate science" (Commonwealth of Australia, 2018, p. 12).

Related to this, information useful to:

- constructing measures such as disaster severity (including infrastructure and insurance data),
- estimating effects of government assistance on income, and
- estimating the effects of insurance pay-outs on income.

is not readily available and/or requires significant consultation lead time before being made available. This has limited the scope of the project. These data limitations are general in nature and would affect other similar studies.

Even if we could completely address these limitations, our choice of measure (income) adds further limitations in how our results can be interpreted. Here, other financial dimensions are also likely to influence individuals' financial capacity to economically cope and recover from the disasters. This includes access to credit cards, business loans, and ability to draw loans on existing assets.

Additionally, the results reported are average point estimates, which do not give the complete distribution of effects of the bushfires. This means there will always be certain individuals who are more (less) severely impacted than what we report.

5. RESULTS AND CONCLUSIONS

5.1 RESULTS

We find that the Toodyay bushfire 2009 did not adversely affect the *overall* income trajectory of workforce residents within Toodyay. In other words, the difference in income changes of the bushfire-hit residents between 2006 and 2011 and those in control groups (i.e. the coefficient of post×D) is not significant (TABLE 9).

TABLE 9 IMPACT OF TOODYAY BUSHFIRES ON INDIVIDUAL INCOME TRAJECTORY

	Non-mover sample
post × *D*	
2006-11	0.1281
	(0.2077)
Observations	447
R-squared	0.013

post ×D is the difference-in-differences estimate. Standard errors in parenthesis. For significant results, significance levels are denoted by: *p <0.10, ** p <0.05, *** p <0.01. Findings are based on use of ACLD Microdata.

While this is likely due to our small sample size (n=447), we note that the fire was relatively small and quickly contained (within 14 hours) (2% share of burnt area). This is in contrast to our other regional bushfire study of the Victorian Black Saturday Bushfires 2009, which occurred over a longer period (7 February – 14 March 2009), with the share of burnt area at the SA2 level ranging from 0.1 to 72.2 percent. For the Victorian bushfires we found significant and relatively persistent negative effects on the overall income trajectories of individuals residing within the bushfire-hit areas (Ulubasoglu and Onder, 2020).

5.1.1 Social characteristics

We now turn to how the bushfires correlate with changes in individual income of different demographic groups within our sample. We first consider individuals with respect to their income groups (low, middle or high) and gender. [8]

5.1.1.1 Income group

This analysis decomposes the overall income effects documented above into low, middle and high income earners (TABLE 10).

[8] For low income group, we compare the individuals whose income belongs to bottom 33rd percentile both in the treatment and control groups in 2006, while for middle income group, we do the same for middle 33rd percentile, and for high income group, the upper 33rd percentile. So we track these individuals' income changes within these groups and report the differential impact of the disaster on this group. In essence, this way of definition ensures that we compare the low income group of the treatment group with the low income group of the control group. Middle income group is comprised of individuals that belong to the middle 33rd percentile.

TABLE 10 RESULTS BY INCOME GROUP: INDIVIDUAL INCOME CHANGES ASSOCIATED WITH THE BSB (RELATIVE TO 2006 AND CONTROL GROUP)

	Income group (in 2006)		
	Low income	Middle income	High income
post × *D*			
2006-2011	-0.30089	0.71114***	0.29742
	(0.22829)	(0.02536)	(0.34642)
Observations	213	126	108
R-squared	0.003	0.061	0.078

post ×D is the difference-in-differences estimate. Standard errors are in parenthesis and clustered at SA2 level, Significance levels are denoted by: *p <0.10, ** p <0.05, *** p <0.01. Findings are based on use of ABS Microdata.

As of 2011, the Toodyay bushfire was associated with income losses among low-income earners (by 30%). That is, poor individuals became poorer.

Middle-income and high-income results are presented in the table for completeness, but due to even smaller sample size, we are hesitant to make any interpretations about the associated effects.[9]

These findings, particularly for low-income earners, provide some evidence to support existing literature. A lower socioeconomic status has been consistently associated with greater post-disaster hardship, with the poor suffering significant disaster losses due to lower financial capacity and limited access to public and private (e.g. insurance) recovery assets. Yet, one should be cautious on interpreting the magnitudes as number of observations is small.

One may wonder why we have wildly different observations for each income group as they are grouped into lower, middle and upper 33rd percentiles. Recall that Census respondents tick a box that corresponds with an income range (e.g. $1-$7,799), which provides interval-based annual income data. Thus, income variable is not continuous.

[9] It is difficult to read the positive coefficient of the middle income group, which is quite high (suggesting a 71% income gain). We interpret this estimate to be an unstable coefficient due to small sample size.

5.1.1.2 Gender

Breaking down income changes by gender yields interesting results (TABLE 11).

TABLE 11 RESULTS BY GENDER: INDIVIDUAL INCOME CHANGES ASSOCIATED WITH THE BSB (RELATIVE TO 2006 AND CONTROL GROUP)

	Gender	
	Male	Female
post $\times$ *Intensity*		
2006-2011	0.1662	0.02588
	(0.06008)	(0.45821)
Observations	226	221
R-squared	0.002	0.033

post ×Intensity is the difference-in-differences estimate. Standard errors are in parenthesis and clustered at SA2 level, Significance levels are denoted by: *p <0.10, ** p <0.05, *** p <0.01. Findings are based on use of ABS Microdata.

Our estimates imply that female and male residents are likely to be differentially affected by bushfires. While male residents seem to have experienced a higher income level (as seen through a positive coefficient with a relatively small standard error), female residents do not seem to have experienced such a gain. In other words, their income levels are estimated to be unchanged. Overall, this points to the relatively weaker economic position of female workers relative to males. Drawing parallel from our other case study on Black Saturday Bushfires, our analysis documents that female workers are heavily represented within the part-time (or casualised) workforce or certain sectors such as private health care and social assistance (17.7%), retail trade (13.2%) and private education and training (11.8 %), with the figures in parentheses indicating the percentage share of working females in the respective sector. These sectoral and demographic groups are also adversely impacted/affected by the bushfires.

5.2 ANALYSIS OF RESULTS

From our demographic profiling of the Toodyay region, we note that the degree of economic exposure and speed of recovery activities are likely to have also influenced economic resilience to the fire:

- Recovery assistance: Combined with public bushfire appeals and Western Power settlements, available monetary assistance for the Toodyay Bushfires totalled $16.5 million, with up to $10.6 million distributed as at October 2012
- Degree of economic exposure: With a significant number of non-employing local businesses, employed residents mostly work outside Toodyay. This fact, and the historical shift away from disaster-sensitive industries like agriculture naturally limits the fire's effect on the overall income trajectory
- Speed of recovery activities: Compared to bushfires with significant effects (e.g. Victorian Black Saturday bushfires), the Toodyay fire was

relatively small and quickly contained (14 hours), with 29% of public assistance distributed within first three months.

Thus while individuals, particularly sole traders, within this community may have suffered significant income losses, this does not appear to have translated into any persistent changes to the income trajectory of the broader Toodyay community (in comparison to our control groups).

Arguably, Toodyay residents' continued access to neighbouring unaffected areas they were economically dependent on and is likely to have significantly contributed to reducing or eliminating any persistent income losses they could have experienced. This also has an added and material benefit: in the case of bushfires, the longevity of disruptions to income post-disaster has been shown to materially affect the mental health of those affected by bushfires (Gibbs et al., 2016).

Turning to our demographic modelling, while our point estimates suggest that we have some heterogeneities, their standard errors are high due to the small sample size (n=447). As such, we do not report these point estimates.

Nevertheless, the signs of the point estimates are likely to inform us about the potential impacts of the bushfire on different groups within the Toodyay community had the sample size been larger. Here, we do find some differences between these demographic groups, which largely coincide with our observations in other case studies within our research program:

- Gender: Male residents experienced some income increase, while female residents' income changes were insignificant. This is a similar pattern to our Victorian Black Saturday Bushfire case study, where we found female individuals lost on average -7%, whereas the income trajectory of male workers was not affected (Ulubasoglu and Onder, 2020).
- Income group: Low-income individuals also experienced some income decrease, consistent with results obtained in the Victorian Black Saturday Bushfire case study (Ulubasoglu and Onder, 2020).

These groups coincide with those noted in the literature as being more vulnerable to natural disasters (McKenzie and Canterford, 2016) and are likely to be more sensitive to disruptions in income generating activities, particularly if they are working in part-time or seasonal occupations in the agricultural sector. Unfortunately, due to the small sample size and confidentiality constraints, we are unable to explore sectors of employment to determine this.

5.3 CONCLUSIONS

Overall, we find that the Toodyay Bushfire 2009 did not have a significant effect on the *overall* income trajectory of individuals residing in Toodyay who were in the labour force in 2006 and did not move between the census years. These findings could be attributed to sample size limitations, but it must be noted that there was also significant public assistance provided.

While the large standard errors mean we cannot report point estimates, the signs of the point estimates inform us that there are likely to be heterogeneous impacts

on different demographic groups, with females and low-income individuals. That is, these groups are relatively more disadvantaged than others within their demographic groupings. These patterns not only coincide with our other regional bushfire case study (Victorian Black Saturday Bushfires 2009), but also with groups noted in the literature as being more vulnerable to natural disasters (Masozera et al., 2007; McKenzie and Canterford, 2016). These results are therefore informative for policymakers interested in better understanding the distributive effects of disasters.

From the literature we know that limiting the longevity of income disruptions post-disasters is incredibly important for the mental health of individuals within disaster-affected communities (Gibbs et al., 2016). From our demographic profiling, we observed that a significant number of Toodyay residents commuted to Perth and neighbouring areas for work, which likely helped mitigate overall income losses. Ensuring that these areas remain/are quickly made accessible to community members if such disasters were to strike is critical not only for survival, but also for their longer-term health and economic prosperity.

For regional communities in particular, where there are challenges in obtaining sufficient sample size for statistical computations, our study reveals that detailed demographic profiling, using publicly available data, could be undertaken as part of disaster risk reduction exercises to help policy makers build disaster resilience and better direct post-recovery interventions to minimise disruptions to important income streams.

6. KEY MILESTONES

TABLE 12 TOODYAY BUSHFIRE CASE STUDY AND RELEVANT RESEARCH PROGRAM MILESTONES

Year	Milestone	Milestone date	Status
2019-20	Submit the final report on the Cyclone Oswald 2010-11 Case Study, including economic profiling	31 January 2020	Completed
2019-20	Submit Policy briefing for the Cyclone Oswald 2013 Case Study	31 March 2020	Upcoming
2019-20	A national seminar to sensitise the policymakers on the economic and social effects of disasters	30 May 2020	Upcoming
2019-20	Submit guidance note on the methodology of estimating economic and social impacts of natural disasters	30 June 2020	Upcoming
2019-20	Submit a research brief to facilitate the adoption of research findings at agency level	30 June 2020	Upcoming

7. UTILISATION OUTPUTS

ACHIEVEMENTS

End-User Engagement

Opportunities

Impacts

Tracking

Tim McNaught, *Office of Bushfire Risk Management*, WA

This research will complement existing strategies to develop policies and programs that support the building of community resilience from bushfire and other natural hazards. The future enhancements of methodologies that can provide communities with structured programs to assess risk and develop strategies to manage that risk rely on research such as this.

For Western Australia this research will provide some valuable Input for the development of a State Bushfire Management Policy and enhancement to existing local government level bushfire risk management planning programs.

8. WHERE TO FROM HERE

Disasters and Economic Resilience in Small Regional Communities: The Case of Toodyay report has investigated the income impacts associated with a bushfire that afflicted a small, regional community.

In doing so, the research has provided policymakers with a valuable insight into the effects of mild disaster-induced economic shocks on individuals using national accounts records. Here, we note that a future deliverable of our research program is to provide guidance material that can assist policymakers in replicating our modelling approach.

The main limitation of our research set up is the low number of observations as the disaster-hit area itself is sparsely populated. Thus, we refrain ourselves from undertaking sectoral level analysis as the number of observations are often fewer than 50. Thus, in order not to mislead policymakers, we mainly conduct an overall analysis for the region and some demographic groups that provided the minimum necessary sample size.

9. PUBLICATIONS LIST

4.1 PEER REVIEWED JOURNAL ARTICLES

1 Ulubasoglu M, Rahman MH, Önder Y, Chen Y, Rajabifard A, *Floods, bushfires and sectoral economic output in Australia, 1978-2014,* 2019: 1-23, Economic Record, Chichester, Eng., C1.

2 Rahman MH. *Earthquakes don't kill, built environment does: Evidence from cross-country data*, Economic Modelling 2018; 70: 458–468.

3 Rahman MH, Anbarci N, Bhattacharya P, Ulubasoglu M, *Can Extreme Rainfall Trigger Democratic Change? The Role of Flood-Induced Corruption*, Public Choice, March 2017;171:331–358.

4 Rahman MH, Anbarci N, Bhattacharya P, Ulubasoglu M, *The Shocking Origins of Political Transitions? Evidence from Earthquakes*, Southern Economic Journal, January 2017;83: 796–823.

4.2 PAPERS

4.2.1 Refereed Conference papers

1 Rahman, M.H., M. Ulubasoglu, P. Bhattacharya, K. Potts, Y. Chen, M. Kalantari and A. Rajabifard (2015). "Natural Disasters and Economic Development: Evidence from Australia", Australian Conference of Economists, 7-10 July 2015, Brisbane.

4.2.2 Non-Refereed Conference Papers

2 Ulubasoglu, M. *Disasters and economic resilience: income effects of the Black Saturday bushfires on disaster-hit individuals*. AFAC18 (Bushfire and Natural Hazards CRC, 2018).Google Scholar BibTeX XML

3 Ulubasoglu M, Önder YK, Rahman MH, *Evaporative Heating: The Negative Income Effects of the Black Saturday Bushfires in Disaster-Hit Areas*, The 2018 Annual Conference of the Australasian Fire and Emergency Service Authorities Council, 5-8 September 2018, Perth.

4 Ulubasoglu M, Rahman MH, *Unpacking the Sectoral Income Effects of Natural Disasters: Evidence from the 2010-11 Queensland Floods*, The 2017 Annual Conference of the Australasian Fire and Emergency Service Authorities Council, , 3-5 September 2017, Sydney.

5 Rahman MH, Chen Y, Potts K, Bhattachary P, Rajabifard A, Ulubasoglu M, Kalantari M, *Bringing hazard and economic modellers together: A spatial platform for damage and losses visualisation*, 2015, Research proceedings from the Bushfire and Natural Hazards CRC and AFAC conference, Report No. 2015.084, Adelaide.

6 Rajabifard A, Ulubasoglu M, Potts K, Rahman MH, Kalantari M, Bhattacharya P. "*A pre-disaster multi-hazard damage and economic loss estimation model for Australia*", The 2014 Annual Conference of the Australasian Fire and Emergency Service Authorities Council, 2-5 Sep 2014 Wellington.

4.2.3 Working papers

In the coming year, we will also be progressing several working papers. These papers, while strictly outside the scope of our project, nevertheless have greatly benefited from and been informed by our BNHCRC research program methodology and learnings, underscoring the positive externalities that CRCs such as the BNHCRC effect on the quality and relevance of Australian research:

- Önder, Rahman, Ulubasoglu: *The Spillover Effects of Black Saturday Bushfires: A Network Approach*
- Önder, Rahman, Ulubasoglu: *Droughts and Crop Yield in Australia*
- Rahman, Anbarci, Ulubasoglu: *"Storm Autocracies": Islands as Natural Experiments*
- Rahman, Guven, Ulubasoglu: *Floods and Agricultural Productivity: Natural Field Experimental Evidence from Micro Plot-Level Data on Sri Lanka*.

4.2.4 Other

1 Ulubasoglu M, Beaini F. 2019. *Black Saturday bushfires: counting the cost*, Australian Journal of Emergency Management, 2019:5–6.

2 Beaini F, Ulubasoglu M. 2019. *Demographic profiling:* Toodyay Bushfire 2009 case study, Bushfire and Natural Hazards CRC, 2019.

3 Beaini F, Ulubasoglu M. 2018. *Demographic profiling: Victorian bushfires 2009 case study*, Bushfire and Natural Hazards CRC, 2018, https://www.bnhcrc.com.au/node/5214.

4 Beaini F, Ulubasoglu M. 2018. *Demographic profiling: Queensland Floods 2010-11 case study*, Bushfire and Natural Hazards CRC, 2018.

5 Ulubasoglu M, Beaini F. 2020. *Disasters and Economic Resilience: The effects of the Queensland Floods 2010-11 on individual income. A Case Study on the Brisbane River Catchment Area.* February 2020. Bushfire and Natural Hazards CRC.

6 Ulubasoglu M. 2020. *Disasters and Economic Resilience: The income effects of Cyclone Oswald on Small business owners. A Case Study on the Burnett River Catchment Area.* January 2020. Bushfire and Natural Hazards CRC.

7 Ulubasoglu M., Onder Y.K 2020. *Disasters and Economic Resilience: The effects of Black Saturday Bushfires on individual income.* March 2020. Bushfire and Natural Hazards CRC.

10. TEAM MEMBERS

Professor Mehmet Ulubasoglu – Project lead

Professor Mehmet Ulubasoglu is the Head of the Department of Economics and the Director of the Centre for Energy, the Environment and Natural Disasters at Deakin University. Professor Ulubasoglu is one of Australia's foremost experts on the economic impacts of natural disasters, with many years' experience working on these questions with governments in Australia, through his work with the Bushfire and Natural Hazards Cooperative Research Centre, and in South-East Asia with the Asia Disaster Preparedness Centre.

His current BNHCRC research project *Optimising Post-disaster Recovery Interventions in Australia* fills a major gap by estimating economic impacts of several Australian natural disasters on economic sectors and vulnerable groups.

He has published extensively in leading international journals, including the Review of Economics and Statistics, Journal of Development Economics, American Journal of Agricultural Economics, European Economic Review, and American Journal of Political Science.

Ms Farah Beaini – Research fellow

Farah Beaini was a member of the team until 31 January 2020 as a Research Fellow in the Department of Economics at Deakin University, and the Industry Program and Research Coordinator at the Deakin Business School's Centre for Energy, the Environment and Natural Disasters.

Farah brought in a wealth of stakeholder engagement and project management experience from her previous state and Commonwealth government roles in digital transformation, service delivery, administrative law and economic research. As part of the BNHCRC project, Farah oversaw the stakeholder management and end-user engagement.

Other

In addition to the core research team, there are a number of casual members who contribute valuably to the project by working on the ArcGIS, statistical programming, and performing regressions as part of the Australian Bureau of Statistics visits.

11. APPENDICES

11.1 NORTHAM AND CHITTERING DISASTER INFORMATION

TABLE 13 DECLARED NATURAL DISASTER EVENTS NORTHAM AND CHITTERING SA2s THROUGHOUT STUDY PERIOD (2006-11)

Date	Disaster event	NDRRA Category activated	NDRRA assistance activated for SA2		Source
			Chittering	Northam	
29 January 2011	Western Australia severe thunderstorm: 29 January 2011	• Certain counter disaster operations (Category A/B) • Personal hardship and distress assistance (Category A) • Restoration of essential public assets (Category B) • Interest rate subsidies for small businesses and primary producers (Category B) • Professional advice grants and freight subsidies for primary producers (Category B)	No	Yes	Disaster Assist
5 February 2011	Western Australia bushfire: 5 February 2011	• Certain counter disaster operations (Category A/B) • Personal hardship and distress assistance (Category A) • Restoration of essential public assets (Category B) • Interest rate subsidies for small businesses and primary producers (Category B) • Professional advice grants and freight subsidies for primary producers (Category B)	Yes	No	Disaster Assist

11.2 TOODYAY DISASTER INFORMATION

TABLE 14 DECLARED NATURAL DISASTER EVENTS TOODYAY SA2 THROUGHOUT STUDY PERIOD (2006-11)

Date	Disaster event	NDRRA Category activated	Source
29 December 2009	Western Australia bushfires: 29 December 2009	• Personal hardship and distress (PHD) grants where principal residences had been damaged, based on need (Category A) • Support to local governments in the restoration of essential public infrastructure (Category B) • Assistance for primary producers, including road and rail freight subsidies and other re-establishment costs (Category B) • Interest rate subsidies for small businesses (Category B)	Disaster Assist
29 January 2011	Western Australia severe thunderstorm: 29 January 2011	• Certain counter disaster operations (Category A/B) • Personal hardship and distress assistance (Category A) • Restoration of essential public assets (Category B) • Interest rate subsidies for small businesses and primary producers (Category B) • Professional advice grants and freight subsidies for primary producers (Category B)	Disaster Assist
21 March 2011	Western Australia severe thunderstorm: 21 March 2011	• Certain counter disaster operations (Category A/B) • Personal hardship and distress assistance (Category A) • Restoration of essential public assets (Category B) • Interest rate subsidies for small businesses and primary producers (Category B) • Professional advice grants and freight subsidies for primary producers (Category B)	Disaster Assist

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