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Delving into the eye of the cyclone to quantify the cascading impacts of natural disasters on life satisfaction

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Research Summary

Why was the research done?

Natural disasters have a profound impact on various facets of society, including social dynamics, health outcomes, and economic stability. As concerns over increasing natural disaster risks intensify, there is a corresponding rise in research examining the effects of these events on life satisfaction. However, there remains a significant gap in strong causal evidence regarding the indirect and direct influences of natural disasters on various domains of life satisfaction. This underscores the need for more robust studies that can provide a deeper understanding of these complex relationships.

What were the key findings?

This study pioneers a causal analysis of cyclones' impacts on Australians' life satisfaction, using local cyclones as natural experiments. Analysing over two decades of data, individual fixed-effects models reveal that cyclones, particularly category 5 (highest severity) cyclones in close proximity to residences, significantly reduce overall life satisfaction and specific domains like community, personal safety, and health satisfaction. Notably, these cyclones have a lasting impact on community and personal safety satisfaction. Our findings withstand rigorous sensitivity assessments, including a falsification test demonstrating no impact of future cyclones on current life satisfaction. Moreover, extensive heterogeneous analysis uncovers significant variations in cyclone impact based on life satisfaction domains and individual, household, and regional characteristics. Additionally, this study shows that cyclone-induced home damage, especially from the most severe cyclones, significantly diminishes the aforementioned life satisfaction outcomes, but to a much greater magnitude.

What does this mean for policy and practice?

The results presented in this study have important methodological and policy implications. Methodologically, our findings highlight the importance of accounting for individual time-invariant unobservable characteristics when quantifying the effects of cyclones on life satisfaction. Failure to do so may lead to biased estimates of the true impacts. Similarly, addressing the endogeneity of self-reported natural disaster-related damage is crucial to avoid biased estimates of its true impact on life satisfaction. From a policy perspective, our novel finding of negative and substantial impacts of cyclones on life satisfaction provides valuable information for crafting effective policies and interventions aimed at supporting affected populations, especially those disproportionately negatively affected by cyclones.

Citation

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Delving into the eye of the cyclone to quantify the cascading impacts of natural disasters on life satisfaction

Ha Trong Nguyen*, † Francis Mitrou†

The catastrophic effects of natural disasters on social and economic systems are well-documented; however, their impacts on individual life satisfaction remain insufficiently understood. This study pioneers a causal analysis of cyclones' impacts on Australians' life satisfaction, using local cyclones as natural experiments. Analysing over two decades of data, individual fixed-effects models reveal that cyclones, particularly category 5 (highest severity) cyclones in close proximity to residences, significantly reduce overall life satisfaction and specific domains like community, personal safety, and health satisfaction. Notably, these cyclones have a lasting impact on community and personal safety satisfaction. Our findings withstand rigorous sensitivity assessments, including a falsification test demonstrating no impact of future cyclones on current life satisfaction. Moreover, extensive heterogeneous analysis uncovers significant variations in cyclone impact based on life satisfaction domains and individual, household, and regional characteristics. Additionally, this study shows that cyclone-induced home damage, especially from the most severe cyclones, significantly diminishes the aforementioned life satisfaction outcomes, but to a much greater magnitude.

Keywords: Natural Disasters; Life Satisfaction; Happiness; Wellbeing; Australia.

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1. Introduction

Natural disasters have a profound impact on various facets of society, including social dynamics, health outcomes, and economic stability (Dell *et al.* 2014; Carleton & Hsiang 2016). As concerns over increasing natural disaster risks intensify (Elsner *et al.* 2008; Fischer *et al.* 2021), there is a corresponding rise in research examining the effects of these events on life satisfaction (Carroll *et al.* 2009; Gunby & Coupé 2023). However, there remains a significant gap in strong causal evidence regarding the indirect and direct influences of natural disasters on various domains of life satisfaction. This underscores the need for more robust studies that can provide a deeper understanding of these complex relationships.

Establishing the causal impact of natural disasters on life satisfaction remains a challenge. Existing studies often rely on cross-sectional individual-level data (see Section 2 for a literature review). These data limitations make it difficult to account for unobserved individual time-invariant factors, such as residential preferences, which may be correlated with both natural disaster exposure and life satisfaction (Dell *et al.* 2014; Botzen *et al.* 2019). This is particularly concerning given prior research suggesting individuals residing in disaster-prone regions tend to have more disadvantaged backgrounds (Currie & Rossin-Slater 2013; Nguyen & Mitrou 2024c). Consequently, the validity of existing findings hinges on the ability to address the potential confounding influence of these unobserved characteristics.

Moreover, the current literature primarily focuses on the indirect effects of natural disasters. Individuals are typically classified as affected based on their residence in an area, such as a county as in US studies (Ahmadiani & Ferreira 2021; Frijters *et al.* 2023), that has experienced a disaster. While a few studies have employed proxy measures for direct exposure, captured by material and psychological damages as self-reported by individuals (Calvo *et al.* 2015; Gunby & Coupé 2023), these approaches often rely on self-reported measures, which can be susceptible to endogeneity bias and hinder causal inference.

To address these limitations, this study leverages over two decades of nationally representative longitudinal data from the Household, Income and Labour Dynamics in Australia (HILDA) survey, linked to historical cyclone records. Employing various exogenously measured exposures to local cyclones as natural experiments and individual fixed-effects models, this study causally quantifies both the indirect and direct impacts of cyclones on life satisfaction among Australians. The present study contributes to the existing literature in four important ways.

First, our research provides the first comprehensive analysis of cyclone effects on life satisfaction in Australia. While cyclones are a significant threat in this nation, no prior study has documented their impact on life satisfaction. A fresh examination is crucial given the catastrophic nature of cyclones, ranking among the most devastating extreme weather events with the potential to inflict widespread disruption and damage (Krichene *et al.* 2023; Nguyen & Mitrou 2024a). Understanding the ramifications of cyclones on life satisfaction is imperative for crafting effective policies to support affected populations.

Second, this study is one of a few employing longitudinal individual-level data and exogenously constructed natural disaster exposure measures to examine the effect of natural disasters on life satisfaction (refer to Section 2 for a literature review). Specifically, the HILDA dataset permits us to employ an individual fixed-effects model, effectively controlling for unobserved individual time-invariant factors (Dell *et al.* 2014; Botzen *et al.* 2019). Additionally, our study utilizes various cyclone exposure metrics identified exogenously by combining the distance from the individual's residing postcode centroid to the eye of the cyclone and the cyclone category. By incorporating these exogenous measures within the individual fixed-effects framework, our empirical strategy effectively addresses potential biases arising from unobserved individual factors. Moreover, this extensive and long-term panel dataset facilitates an investigation of the dynamic impacts of cyclones on life satisfaction.

Third, our extensive longitudinal data facilitates an exceptionally rich heterogeneous analysis. Spanning 22 years and encompassing over 80 cyclones of varying severity, the dataset offers a unique opportunity to explore the differential impact of natural disasters with various levels of severity. As a result, our findings can be generalized to a broader range of cyclones. Moreover, the richness of our linked datasets allows us to explore the impacts of cyclones for diverse sub-populations, identified by numerous individual, household and regional characteristics. Furthermore, this study considers not only overall life satisfaction, as most prior studies did, but also a comprehensive list of seven life satisfaction domains, including home, community, financial, personal safety and health satisfaction. This comprehensive heterogeneous analysis illuminates the channels through which cyclones influence overall life satisfaction as well as various life satisfaction domains and identifies vulnerable groups and regions for targeted support and resilience-building strategies.

Fourth, this study advances the field by employing an individual fixed-effects instrumental variable (FE-IV) model to address potential endogeneity concerns associated with self-reported direct exposure to natural disasters. Previous studies have used self-reported weather-related home damage as a proxy for direct exposure but often struggle to account for endogeneity bias (Calvo *et al.* 2015; Gunby & Coupé 2023). Although Gunby and Coupé (2023) utilize HILDA data and an individual fixed-effects model, which is the most robust method employed thus far in this literature, we extend this approach. Our FE-IV methodology specifically targets the endogeneity concerns related to self-reported home damage.

Our study finds four main sets of results. Firstly, the individual fixed-effects model reveals a substantial decrease in overall life satisfaction attributed to cyclones, particularly category 5 (the highest severity) cyclones located near residences. These severe cyclones also exert adverse effects on specific satisfaction domains, including community, personal safety, and health satisfaction. Remarkably, the identified impacts of cyclones on life satisfaction parallel or even exceed documented effects of the devastating 2009 Black Saturday Bushfires in Australia (Johnston *et al.* 2021). Additionally, our findings suggest a sustained impact of cyclones on community and personal safety satisfaction.

Secondly, our thorough heterogeneous analysis uncovers significant variations in the impacts of cyclones on life satisfaction, depending on diverse factors such as gender, age, prior homeownership, income levels, residential insurance coverage, rural or urban residency, coastal proximity, and community cyclone history. The impacts vary across various life satisfaction domains, with a prevailing trend indicating more pronounced effects among males, younger individuals, and those lacking previous residential insurance.

Thirdly, the instrumental variable approach, addressing potential endogeneity of self-reported weather-related home damage, reveals that cyclone-induced home damage, particularly stemming from more severe cyclones, significantly diminishes overall life satisfaction and specific domains like community, personal safety and health satisfaction. Notably, the direct impacts of cyclones on life satisfaction derived from this model substantially exceed (by up to twelve times) the indirect impacts calculated from an individual fixed-effects model.

Finally, our findings demonstrate robustness through a series of sensitivity assessments, including a falsification test that confirms the absence of current life satisfaction impacts from future cyclones. Furthermore, our results highlight the importance of accounting for individual time-invariant unobservable characteristics and addressing the endogeneity of self-reported natural disaster-related damage when quantifying the indirect and direct impacts of cyclones on life satisfaction.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature, providing context for our research question. Section 3 details the data employed in our analysis. Section 4 presents the empirical models utilized to investigate the relationship between cyclones and life satisfaction. Section 5 then outlines our key findings. To establish the robustness of our results, Section 6 details the various sensitivity tests conducted. Section 7 explores the heterogeneous impacts of cyclones on life satisfaction across different sub-populations. Next, Section 8 focuses on the empirical models used to examine the effects of weather-related home damage on life satisfaction, presenting the main results obtained from these models. Finally, Section 9 concludes the paper.

2. Literature review

By examining the effects of cyclones on life satisfaction, this study intersects with two distinct lines of research. The first line, a substantial body of work, focuses on the social and economic impacts of natural disasters (Dell *et al.* 2014; Carleton & Hsiang 2016). Within this domain, our study is closely related to an increasing number of investigations evaluating the effects of cyclones/hurricanes/typhoons on various factors, including economic growth (Hsiang & Jina 2014), migration (Gröger & Zylberberg 2016; Mahajan & Yang 2020; Nguyen & Mitrou 2024c), income (Deryugina *et al.* 2018; Groen *et al.* 2020), health (Currie & Rossin-Slater 2013; Bakkensen & Mendelsohn 2016), or insurance acquisition (Nguyen & Mitrou 2024b, c).

Our research also contributes to a rich line of inquiry examining the role of various factors affecting life satisfaction/subjective wellbeing/happiness.[1] These factors include income (Frijters *et al.* 2004), life events (Nguyen *et al.* 2020), pollution (Levinson 2012; Zhang *et al.* 2017), weather (Feddersen *et al.* 2016), and macroeconomic conditions (Di Tella *et al.* 2003; Nguyen & Duncan 2020). Within this literature, our study is particularly related to a growing number of studies focusing on the effects of natural disasters on life satisfaction.

Appendix Table B1 summarises the literature on natural disasters and life satisfaction. Research in this narrower field has explored the life satisfaction impacts of various types of natural disasters, including droughts (Carroll *et al.* 2009; Lohmann *et al.* 2019; Berlemann & Eurich 2021), floods (Luechinger & Raschky 2009; Sekulova & Van den Bergh 2016; Van Ootegem & Verhofstadt 2016; Hudson *et al.* 2019), wildfires (Kountouris & Remoundou 2011;

[1] Life satisfaction, subjective wellbeing and happiness have been used interchangeably in this literature (for reviews, see Frey and Stutzer (2002) or Ferrer-i-Carbonell (2013)).

Johnston *et al.* 2021), hurricanes (Calvo *et al.* 2015; Berlemann 2016), and multiple natural disasters (Ahmadiani & Ferreira 2021; Frijters *et al.* 2023).

The majority of studies in this literature have examined the effects of "indirect" exposure to natural disasters, classifying individuals as affected based on their residence in an area that has experienced a disaster. An increasing number of studies have employed proxy measures for "direct" exposure, captured by material and psychological damages as self-reported by individuals (Calvo *et al.* 2015; Sekulova & Van den Bergh 2016; Van Ootegem & Verhofstadt 2016; Hudson *et al.* 2019; Lohmann *et al.* 2019; Gunby & Coupé 2023). However, these self-reported measures can be susceptible to endogeneity bias, hindering causal inference.

Most studies within this literature grapple with one or both of two primary issues, undermining the interpretability of their findings as causal (Dell *et al.* 2014; Botzen *et al.* 2019). The first issue pertains to the utilization of cross-sectional data, which lack the capacity to control for individual unobservable factors that may correlate with both natural disaster exposure and life satisfaction. The second issue arises from the reliance on natural disaster exposure measures contingent upon human behaviours, which may confound the natural disaster estimates (Wooldridge 2010). Examples of such measures include individuals' self-reported experiences of natural disasters, employed by studies using them as proxies for direct natural disaster exposure (Calvo *et al.* 2015; Gunby & Coupé 2023). Additionally, some studies classify regions as disaster-affected areas following official declarations (Luechinger & Raschky 2009; Frijters *et al.* 2023). Others have utilized indirect natural disaster exposure measures based on actual damage incurred by such disasters (von Möllendorff & Hirschfeld 2016; Ahmadiani & Ferreira 2021).

Two notable studies utilizing individual panel data and exogenously measured exposure to natural disasters are Rehdanz *et al.* (2015) and Johnston *et al.* (2021). Rehdanz *et al.* (2015) investigate the impact of the tsunami and nuclear accident at Fukushima, Japan, in 2011, while Johnston *et al.* (2021) examine the Black Saturday Bushfires in Victoria, Australia, in 2009. Both studies employ panel data and individual fixed-effects models, measuring exposure by the distance from the individual's residing region to the disaster event.

Building upon the methodologies of these studies, our current research utilizes various cyclone exposure metrics identified exogenously. These metrics combine the distance from the individual's residing postcode centroid to the eye of the cyclone and the cyclone category. As advocated by Dell *et al.* (2014) or Botzen *et al.* (2019), these geophysical or meteorological metrics are independent of human behaviours. By integrating these exogenous measures within the individual fixed-effects framework, our empirical strategy effectively addresses potential biases arising from unobserved individual factors. Consequently, it enables a robust quantification of the causal impacts of cyclones on various life satisfaction domains.

Appendix Table B1 also shows that Australian studies have explored the effects of droughts (Carroll *et al.* 2009), bushfires (Johnston *et al.* 2021) or weather-related home damage (Gunby & Coupé 2023) on life satisfaction. However, no study has examined the impact of cyclones on life satisfaction in Australia, a cyclone-prone country. This study thus contributes as the first to explore the effects of cyclones on life satisfaction in Australia. Moreover, none of the surveyed studies have addressed the potential endogeneity of individuals' self-reported natural disaster exposure, including self-reported home damage as in the Australian study by Gunby and Coupé (2023),[2] as this study does.

3. Data and sample

3.1. Data

Our study draws upon two primary data sources. The first dataset originates from the Household, Income, and Labour Dynamics in Australia (HILDA) survey (Summerfield *et al.* 2023). This nationally representative survey, initiated in 2001, tracks individuals in private households over time, providing detailed individual and household-level data, including residential information, health outcomes, and life satisfaction. A notable advantage lies in HILDA's ability to follow individuals who relocate, ensuring the sample's representativeness and facilitating the utilization of an individual fixed effects model to robustly quantify the effects of cyclones on life satisfaction. We utilize the latest release of HILDA, spanning 22 waves from 2001 to 2022.

The second dataset comprises a publicly available historical cyclone database sourced from the Australian Bureau of Meteorology (BOM). This database furnishes comprehensive information regarding tropical cyclones occurring south of the equator within longitudes 90E and 160E (BOM 2023). For each documented cyclone, it delineates the track (longitude, latitude, and time) and strength measures such as wind speed.

[2] Indeed, Gunby and Coupé (2023) acknowledge that their employed individual fixed-effects model may not fully address the potential endogeneity of self-reported home damage, which could lead to a null impact of home damage on life satisfaction.

We establish a connection between the two datasets by aligning the cyclone path and timing from the historical database with the individual's residential postcode centroid and interview date from HILDA. We utilize the restricted version of HILDA containing postcodes, as they provide the finest geographical granularity available. Appendix Figure A1 graphically depicts the cyclone hit map during the study period.

3.2. Cyclone exposure measures

Following the methodology outlined by Nguyen and Mitrou (2024c), we determine an individual's exposure to cyclones within a given year by considering the distance to the cyclone's eye and its category. Initially, we ascertain the closest distance between the individual's residential postcode centroid and the cyclone's eye, where areas directly beneath its path typically experience the severest damage (BOM 2024). To ensure the analysis remains manageable and informative, we utilize two distance bands - 40 km and 100 km - to assess exposure. A similar approach has been previously employed in studies conducted in the United States (Currie & Rossin-Slater 2013; Deryugina & Marx 2021).

In addition to distance, we gauge exposure to a cyclone by its category, which ranges from 1 (weakest) to 5 (strongest). Specifically, we adopt the BOM's recommended cutoffs to classify a cyclone based on its maximum mean wind speed (BOM 2024). The respective maximum mean wind speed cutoffs for each cyclone category are as follows (in km/h): Category 1 (≤88), 2 (>88 and ≤117), 3 (>117 and ≤159), 4 (>159 and ≤199), 5 (>199). Other studies have also utilized maximum wind speed to assess cyclone exposure (Currie & Rossin-Slater 2013; Hsiang & Jina 2014).

To facilitate analysis given the relative rarity of yearly cyclones, we aggregate several categories into three overlapping groups: all cyclones, categories 3-4, and category 5 only. Each group is then paired with the nearest cyclone path distance to the individual’s residing postcode centroid. Consequently, we obtain a set of six variables measuring cyclone exposure, each identified by the cyclone category and distance to the cyclone eye. Furthermore, due to the infrequent occurrence of yearly cyclones during the study period, we incorporate a dummy variable indicating whether a cyclone was recorded within the individual's residential postcode in the 12 months preceding the survey date.[3] Given that survey dates vary among individuals

[3] Appendix Table A1 further details variable descriptions and summary statistics. Appendix Figure A2 displays the distribution of cyclone occurrences and HILDA interview dates. The bulk of HILDA interviews (90%) took place during the concentrated period of August to October. Almost all observed cyclones (95%) transpired within the November-April timeframe throughout the study period.

within the same survey wave, individuals residing in the same postcode may experience different exposures to the same cyclone during the same survey wave.

3.3. Outcome variables

This study utilizes an individual's overall satisfaction with their life as the primary measure of subjective well-being. This outcome is derived from the direct question: "All things considered, how satisfied are you with your life?" Respondents select a point on a scale ranging from 0 (completely dissatisfied) to 10 (completely satisfied), with higher scores indicating greater life satisfaction. Beyond the overall life satisfaction indicator, the study explores respondents' satisfaction with other life domains available in the data. These domains are obtained from responses to questions asking the respondents about their satisfaction with their employment opportunity (thereafter called "employment opportunity", applicable only to employed individuals), financial situation ("financial situation"), the home in which they live ("home"), feeling part of their local community ("community"), the neighbourhood in which they live ("neighbourhood"), how safe they feel ("personal safety"), and their health ("health").

The selection of specific life satisfaction domains was informed by their perceived sensitivity to cyclones, as noted in prior research (Currie & Rossin-Slater 2013; Bakkensen & Mendelsohn 2016; Nguyen & Mitrou 2024a).[4] These life satisfaction measures have been extensively utilized in Australian studies in different contexts (Nguyen & Duncan 2020; Nguyen *et al.* 2020; Johnston *et al.* 2021). Appendix Table A2 presents the correlation matrix for the key life satisfaction variables, revealing positive associations between overall life satisfaction and the individual domain-specific measures. However, the strengths of these associations vary between 0.2 and 0.5, indicating that each life satisfaction domain contributes uniquely to the construct of overall life satisfaction. This supports the rationale for conducting separate investigations of each domain.

3.4. Sample

The paper's unit of analysis is the individual due to the availability of all life satisfaction measures at the individual level. Our baseline analysis is centred on states and territories affected by at least one cyclone during the study period, a restriction that enhances the

[4] The study does not incorporate some other measures due to theoretical or practical limitations. For instance, we do not use another aspect of life satisfaction asking respondents about "the amount of free time that they have" due to a lack of established theoretical and empirical frameworks connecting natural disasters to free time satisfaction (Nguyen *et al.* 2020). Similarly, we do not consider some other aspects of wellbeing such as the respondents' satisfaction about their relationship with partner or children since responses are only available to specific sub-populations (e.g., partnered individuals, parents).

efficiency of individual fixed effects estimates for exposed individuals. This is because cyclone exposure remains constant over time for those in unaffected regions (Wooldridge 2010). As a result, New South Wales, Queensland, Western Australia, and the Northern Territory constitute our baseline sample.

Furthermore, we stipulate that individuals must be observed at least twice within the study period, as our primary empirical model relies on an individual fixed effects model. By combining these restrictions, the final sample size varies depending on the outcome. For instance, to examine the impact of cyclones on overall life satisfaction, we have a longitudinal sample comprising 204,389 individual-year observations from 21,811 unique individuals across 22 years of data. This represents the largest sample size in the study.

4. Empirical model

We follow Nguyen and Mitrou (2024c, 2024b) to employ an individual fixed effects (FE) model to examine the effects of cyclones on outcome Y for individual i, residing in postcode p, at time t:

$$Y_{it} = \alpha_1 + \beta_1 Z_{i(p)t} + X_{it}\gamma_1 + \delta_i + \varepsilon_{1,it} \qquad (1)$$

where $Z_{i(p)t}$ is a binary variable denoting whether the individual i living in postcode p experienced a cyclone in the 12 months prior to the survey time. X_{it} represents a set of time-variant explanatory variables. δ_i denotes individual time-invariant unobservable factors, and $\varepsilon_{1,it}$ is the usual random error term. α_1, β_1 and γ_1 are parameters to be estimated, with β_1 serving as our parameter of interest.

We incorporate a minimum number of individual and household-level time-variant variables into X_{it} to mitigate potential confounding effects. These variables encompass the individual's age (and its square), marital status, education level, household size, and residency in major cities. Additionally, we address temporal disparities in outcomes by including dummy variables for survey month and year separately. Regional discrepancies are accounted for through the inclusion of state/territory dummy variables in Equation (1). Furthermore, we consider local socio-economic contexts that may influence individual behaviours by integrating regional unemployment rates and a relative socio-economic disadvantage index.

We employ an individual FE regression to account for individual heterogeneity, including residential preferences, in Equation (1). This approach is crucial as it enables us to control for individual unobservable time-invariant factors, which is particularly relevant given findings suggesting that areas more prone to natural disasters tend to exhibit higher levels of disadvantage (Dell *et al.* 2014; Botzen *et al.* 2019). Our estimates of the cyclone impact (β_1) are derived from yearly variations in cyclone occurrences within a postcode for the same individuals. This, coupled with the stochastic nature of cyclone impacts despite spatial clustering and our exogenously identified natural disaster measures, enhances the strength of causal inference.

As outlined in Section 3, cyclone exposure is defined within 12 months preceding the survey date. This synchronization of survey dates with cyclone occurrences bolsters identification assumptions. It's crucial to note that discrepancies in survey and cyclone dates may result in individuals residing in the same postcode experiencing varying degrees of cyclone exposure from the same cyclone within the same survey year (refer to Appendix Figure A2 for the distribution of survey and cyclone timing). To address potential serial correlation issues, we cluster standard errors at the individual level, given that the treatment varies for the same individual over time (Cameron & Miller 2015). As a robustness check, we also present results with standard errors clustered at the postcode level or with additional postcode fixed effects, which yield largely similar findings.

5. Results

5.1. Descriptive results

Table 1 presents descriptive statistics for key variables, stratified by cyclone exposure status. Within our final sample, 8,598 individuals from 5,951 unique persons experienced at least one cyclone within a 100 km radius annually, constituting our "treated" group. Although a relatively small proportion of the study population (4.20%) was affected by a cyclone, the substantial number of individuals affected during the study period ensures that we can detect any impact of cyclones on life satisfaction (Wooldridge 2010).[5]

Comparatively, individuals in the "treated" group exhibit distinct sociodemographic characteristics in contrast to the unexposed "control" group. They are statistically significantly younger, possess lower levels of educational attainment, have smaller family units, and predominantly reside in rural areas. Notably, while unemployment rates are lower in regions

[5] Furthermore, the final column in Appendix Table A1 illustrates that despite the relatively infrequent occurrence of yearly cyclones during the study period, our sample comprises a substantial number of individuals exposed to various cyclones, thus enabling the reliable detection of potential effects. However, it is important to note that the number of individuals affected by more severe cyclones, especially those in closer proximity, is comparatively small. For instance, the minimum count of individuals affected is 662, exposed to a category 5 cyclone within 40 km. Therefore, prudence is advised when interpreting results related to such cyclone exposure measures.

encompassing the “treated” group, these areas exhibit lower overall socioeconomic status as measured by the SEIFA index. This corroborates previous research (Dell *et al.* 2014; Botzen *et al.* 2019), suggesting that populations vulnerable to natural disasters, as defined by education and socioeconomic disadvantage measured by the SEIFA index, are disproportionately susceptible to their impacts. Consequently, rigorous methodological approaches that account for individual fixed effects are imperative when investigating the consequences of cyclones.

This table reveals statistically significant ($p < 0.05$) differences in selected life satisfaction outcomes between cyclone-exposed and unaffected individuals. Unexpectedly, exposed individuals report higher levels of overall life satisfaction, as well as in domains of employment opportunity, financial situation, and personal safety satisfaction. However, as discussed in Section 4, these disparities may not solely reflect direct cyclone impacts but rather pre-existing differences influencing both exposure and satisfaction outcomes. The subsequent analysis addresses this critical issue by employing an individual FE model to control for potentially confounding factors.

5.2. Main regression results

5.2.1. Contemporary impacts of cyclones on life satisfaction

Table 2 presents estimates of the effects of cyclones derived from individual fixed-effects regressions, accounting for both observable time-variant and unobservable time-invariant factors. The results highlight significant contemporaneous impacts of cyclones on selected life satisfaction measures, particularly for more severe cyclones. For example, the estimates for all category 5 cyclone exposure measures, regardless of distance, indicate a negative and statistically significant (at the 5% level) effect on overall life satisfaction (see Panel A in Table 2). This suggests that individuals affected by any category 5 cyclone experience decreased overall life satisfaction.

Furthermore, the detrimental impact of cyclones on overall life satisfaction increases with their intensity. Specifically, only the estimates for category 5 cyclones are statistically significant. Conversely, the effect of distance mitigates the impact, as the estimate is approximately 25% greater in absolute value for individuals residing within 40 km of a category 5 cyclone's eye compared to those within 100 km. When statistically significant, the estimates are considerable in magnitude. For instance, the largest estimate is (minus) 0.10, observed for a category 5 cyclone within 40 km of its eye, which accounts for 1.26% of the mean overall life satisfaction of all individuals in our sample.

Further reflecting the escalating scale of cyclone impact, our findings reveal a nuanced relationship between cyclone exposure and individual community satisfaction (Panel E in Table 2). Specifically, only individuals exposed to category 5 cyclones exhibit a statistically significant decrease in community satisfaction (at the 5% level). The distance-dependent effect on community satisfaction is evident, as the estimated impact of cyclones diminishes substantially with increased distance from the eye. For instance, the estimate is 30% greater for individuals residing within 40 km of the eye compared to those within 100 km of a category 5 cyclone.

In contrast, the estimate for category 3 to 4 cyclones within 100 km of their eye is positive and marginally statistically significant at the 10% level (Panel E - Column 5), suggesting that individuals affected by such cyclones display a slightly higher level of community satisfaction. Similarly, some positive and statistically significant (at the 5% level) estimates of exposure to category 3 to 4 cyclones, irrespective of distance, are observed for neighbourhood satisfaction (Panel F), indicating that individuals affected by these cyclones show a greater level of neighbourhood satisfaction. This finding aligns with anecdotal evidence suggesting that neighbours help each other during natural disasters in Australia (Longman *et al.* 2023). It is also consistent with Johnston *et al.* (2021), who used the same HILDA dataset to find that individuals affected by the Black Saturday Bushfires in Victoria, Australia, in 2009 showed increased community satisfaction in the wake of the disaster. However, this positive estimate is only observed for category 3 or 4 cyclones, whereas the opposite is true for more severe category 5 cyclones. This suggests that the impacts of cyclones on community or neighbourhood satisfaction vary by their severity.

Panel G in Table 2 indicates that the estimated impact of cyclones on personal safety satisfaction is negative and highly statistically significant (at the 1% level) exclusively for individuals exposed to the most severe cyclones considered in this study. Specifically, the findings reveal that individuals within a 40 km radius of the eye of any category 5 cyclone report significantly lower levels of personal safety satisfaction. This estimate represents approximately 1.82% of the sample mean for personal safety satisfaction.

Panel H in Table 2 continues to demonstrate the detrimental impact of cyclone exposure on individual health satisfaction. Specifically, the negative and statistically significant estimates (at the 5% level) for all category 5 cyclone exposure measures, regardless of distance, indicate that individuals affected by any category 5 cyclone experience decreased health satisfaction. Furthermore, the results underscore the critical importance of geographical proximity, as the impact of the cyclone is 11% greater for individuals residing within 40 km of the eye compared to those within 100 km of a category 5 cyclone. When statistically significant, the estimates are substantial. For example, the largest estimate is -0.10, observed for a category 5 cyclone within 40 km of its eye, accounting for 1.38% of the mean health satisfaction of all individuals in our sample.

Overall, the analysis demonstrates that cyclones, particularly category 5 cyclones in close proximity to homes, substantially decrease overall life satisfaction. These severe cyclones also negatively impact specific satisfaction domains, including community, personal safety, and health satisfaction. An exception to this pattern is observed among individuals affected by less severe cyclones, characterized by a lower category or greater distance from homes, who exhibit higher levels of community and neighbourhood satisfaction.

Our findings of a statistically significant impact of category 5 cyclones on selected indicators of life satisfaction align relatively well with some findings in previous research by Johnston *et al.* (2021), who used the same HILDA dataset to document the impacts of the 2009 Black Saturday Bushfires (BSB), one of the worst natural disasters on record in Australia, on life satisfaction.[6] For instance, Johnston *et al.* (2021) found that the BSB reduced overall life satisfaction by between 0.15 and 0.19 points on a 0-10 scale, similar to the scale used in this study. This estimate is slightly higher than our largest estimate of (minus) 0.10 points, observed for exposure to a category 5 cyclone within 40 km from homes. Additionally, our highly statistically significant (at the 1% level) estimate of -0.15 points for personal safety satisfaction due to the same cyclone exposure is slightly smaller (in absolute terms) than their marginally statistically significant (at the 10% level) estimate of -0.17 points for the immediate impact of the BSB on this domain.

However, unlike their finding of an insignificant effect of the BSB on health satisfaction, our study shows a substantial negative impact of exposure to a category 5 cyclone, either within 40 km or 100 km from homes, on health satisfaction. Furthermore, while Johnston *et al.* (2021) identified a positive impact of the BSB on community satisfaction, this study finds a statistically significant (at the 5% level) negative effect of exposure to a category 5 cyclone on this analogous life satisfaction domain. These differences in findings suggest that different types of natural disasters may affect overall life satisfaction and its domains in distinct ways.

[6] We refrain from comparing our results with those of other studies which use different datasets, life satisfaction measures, or empirical models.

5.2.2. Dynamic impacts of cyclones on life satisfaction

Recognizing the potential for delayed effects on life satisfaction, this study delves into the dynamic influence of cyclones. To account for this temporal dimension, we incorporate an additional variable into Equation (1). This variable captures exposure to cyclones one year preceding the measurement of life satisfaction outcomes. The estimated coefficients for both concurrent and lagged cyclone exposure are presented in Table 3. Notably, the results for concurrent exposure closely correspond to the baseline findings in Table 2, thus solidifying our prior conclusions.

Furthermore, the estimates for certain lagged cyclone exposure measures are negative and statistically significant, indicating delayed impacts of cyclones on community and personal safety satisfaction. Specifically, individuals residing within 40 km or 100 km of the path of a previous category 5 cyclone exhibit lower levels of community satisfaction ($p < 0.1$, Panel E) in the subsequent survey wave. Similarly, individuals affected by any category 5 cyclone, regardless of proximity to its eye, report substantially lower personal safety satisfaction in the subsequent survey wave ($p < 0.05$, Panel G). Additionally, consistent with the observed trends in the immediate aftermath of cyclones, the estimates suggest an amplified influence of cyclones on future both community and personal safety satisfaction for more proximate cyclones. For example, in absolute value, the estimate on personal safety satisfaction increases by 30% (from -0.10 to -0.13) when comparing individuals residing within 100 km and 40 km of the eye of a category 5 cyclone.

6. Robustness checks

To bolster confidence in the reliability of our results, we implemented a series of sampling and specification tests. Due to brevity constraints, we focus on presenting results based on one key concurrent cyclone exposure measure: experiencing a category 5 cyclone within 100 km of the eye. This measure has been shown to have statistically significant effects on various life satisfaction domains.

Our initial sampling test involved restricting the regression analysis to individuals residing in Local Government Areas (LGAs) directly impacted by at least one cyclone within 100 km during the study period. This test aimed to address concerns regarding potential limitations in the baseline sample's cyclone exposure variation. The results obtained from this more restricted sample are reported in Panel B1 of Appendix Table A3. Reassuringly, these results closely mirrored the baseline findings (re-reported in Panel A) in terms of both magnitude and statistical significance. To further solidify the validity of our findings, we additionally analysed the entire dataset (Panel B2) and again observed similar outcomes.

To enhance the robustness of our model, we conducted five additional specification checks. First, we incorporated postcode fixed effects to account for unobserved time-invariant factors potentially influencing both cyclone exposure and life satisfaction outcomes within a specific locality (Panel C1). Second, we clustered standard errors at the postcode level to acknowledge potential spatial correlation within geographic units (Panel C2). Third, we compared the results from our baseline individual fixed effects model with pooled Ordinary Least Squares (OLS) and Random Effects (RE) models, which do not control for individual fixed effects (Panels C3 and C4).[7] The pooled OLS estimates (Panel C3) deviated noticeably from the baseline (Panel A),[8] highlighting the importance of controlling for individual-specific factors through fixed effects. Fourth, we conducted analyses where we excluded potentially cyclone-influenced time-varying control variables (Panel C5) and separate analyses where we controlled for additional time-varying variables potentially co-affected by cyclones (e.g., irregular income - Panel C6, and health - Panel C7 (Nguyen & Mitrou 2024a)). Throughout these checks, the core findings remained consistent, demonstrating resilience to methodological variations.

To further solidify the causal relationship between cyclone exposure and life satisfaction, we conducted a falsification test. This test involved incorporating lagged (one year prior) and lead (one year future) cyclone exposures into the model with individual fixed effects. We hypothesized that since future cyclones are unexpected, they should not exert any influence on current life satisfaction when controlling for individual characteristics and past cyclones. The results confirmed this hypothesis (Appendix Table A4). Specifically, estimates for current and lagged cyclones closely mirrored the baseline findings (Table 3), suggesting robust causal inferences. Additionally, the lack of statistical significance for future cyclones reinforces the exogeneity of cyclone exposure.

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[7] To address potential confounding effects, we included time-invariant variables, such as gender and migration status, in these specifications.

[8] Particularly, cyclone estimates on overall life satisfaction, community satisfaction, and health satisfaction mirror those from the FE regressions in terms of magnitude but lose statistical significance. The fact that the standard errors obtained from the FE regressions are smaller than those from the pooled regressions indicates that there are sufficient within-individual variations in both cyclone exposure and life satisfaction outcomes to justify the use of an individual FE model (Wooldridge 2010). Conversely, estimates for employment opportunity, neighbourhood satisfaction, and personal safety satisfaction become statistically significant (at least at the 10% level) and of a larger magnitude (i.e., the pooled OLS estimate is more negative than the baseline individual FE estimate). This noticeable shift in results, alongside the unreported Hausman test suggesting strong correlation within individual error terms, further strengthens the case for using the individual FE model to quantify the cyclone effects on life satisfaction.

Overall, this comprehensive sensitivity analysis strengthens our confidence in the causal relationship observed between cyclone exposure and life satisfaction. The findings demonstrate resilience to various sampling and specification tests, bolstering the internal and external validity of the study.

7. Heterogeneity

To explore potential mechanisms through which cyclones influence life satisfaction and identify vulnerable sub-populations, we follow Nguyen and Mitrou (2024c, 2024b) to employ the individual FE model (i.e., Equation (1)) to estimate effects within distinct groups defined by eight individual, household, or regional characteristics. These characteristics encompass gender (male vs. female), age group (young vs. old, categorized relative to the median population age), homeownership status (renters vs. homeowners), income group (lower income vs. higher income households, defined relative to the median), residential insurance status (insured vs. uninsured)[9], urban/rural residence (major city vs. rural area), distance to the coast (coastal areas vs. inland areas), and whether the individual resides in a "cyclone-prone area" (postcode experiencing a cyclone within 100 km in the past 30 years) or a "cyclone-free area".

To mitigate concerns regarding the influence of cyclones on sub-population classification, individuals are categorized based on the values of time-variant variables (excluding age) observed at their first appearance in the sample. For conciseness and illustrative clarity, this section utilizes a singular cyclone exposure indicator (exposure to a category 5 cyclone within 100 km) due to its robust statistical impact in the pooled regression (Table 2) and to ensure adequate sample size for robust heterogeneous analysis across sub-populations.

Figure 1 graphically represents subgroup results for the eight life satisfaction domains, with each domain presented in a separate panel. Each panel displays regression estimates visually, depicting both the impact of cyclones and the average life satisfaction within each subgroup. Figure 1 reveals the heterogeneous effects of cyclones across subgroups for various life satisfaction outcomes.

Panel A indicates that cyclones exert a more substantial negative impact on the overall life satisfaction of specific subgroups. This is evidenced by larger (in absolute term) or statistically

[9] Building on Nguyen and Mitrou (2024c), this study classifies individuals as "insured" if their reported annual household expenditure on combined home, contents, and motor vehicle insurance exceeds $1,250 (adjusted to 2010 prices). Conversely, those reporting lower expenditures are categorized as "uninsured". Data on home and contents insurance is sourced from Wave 6 onwards, leveraging responses to the "other insurance (home/contents/motor vehicle)" spending question.

significant cyclone estimates for males, younger individuals, homeowners, individuals from higher-income households, those without prior residential insurance, and residents of rural, coastal, or cyclone-prone areas. Our finding of a more pronounced negative impact of cyclones on the overall life satisfaction of rural residents aligns with other studies, which also report a heightened negative impact of droughts on rural residents in Australia (Carroll *et al.* 2009) and forest fires in Europe (Kountouris & Remoundou 2011). Conversely, our finding of more pronounced cyclone effects for males, younger individuals, and individuals from higher-income households contrasts with the evidence by Johnston *et al.* (2021), who used the same HILDA data to demonstrate that bushfires have a more pronounced impact on females, older individuals, and lower-income individuals.[10] These differing impacts of cyclones and bushfires on selected sub-populations suggest that the life satisfaction effects of these two natural disasters are not uniform, underscoring the necessity for separate analyses for each type of natural disaster.

Panels C and D reveal that while cyclones do not significantly influence financial situation and home satisfaction for the entire population (as shown by the horizontal dashed line representing the cyclone estimate for the whole population), they do reduce these life satisfaction domains for residents of historically cyclone-free areas. This is due to negative and statistically significant cyclone estimates ($p < 0.05$) for these subgroups. Notably, the cyclone estimates are large, accounting for 7.69% and 6.35% of the subgroup sample mean of the financial situation and home satisfaction outcome, respectively. This finding aligns with evidence in Nguyen and Mitrou (2024c) that residents in historically cyclone-free areas are more likely to relocate following a cyclone. Together, these results suggest that individuals lacking prior experience with extreme weather events may be particularly susceptible to increased vulnerability to damages when encountering them for the first time (Dell *et al.* 2014). This underscores the role of natural disaster readiness in protecting individuals in historically natural disaster-free regions from future disasters.

Panel E suggests that cyclones disproportionately reduce the community satisfaction of specific subgroups, as shown by larger (in absolute terms) or more statistically significant cyclone estimates for males, younger individuals, individuals from higher income households, those without prior residential insurance, and residents of coastal areas or historically cyclone-free areas.

[10] Unfortunately, Johnston *et al.* (2021) did not report heterogeneous results for other life satisfaction domains, preventing a comparison of our findings with theirs.

Panel G reveals that while category 5 cyclones within 100km from homes do not significantly affect overall feelings of personal safety for the entire population, they do reduce this domain for males, younger individuals, and individuals from poorer households. This is indicated by negative and statistically significant cyclone estimates (at least at the 10% level) for these subgroups, suggesting a heightened sense of vulnerability in the aftermath of this cyclone event.

Finally, Panel H demonstrates a disproportionate reduction in health satisfaction for specific subgroups following cyclones. This is evidenced by larger effect sizes (in absolute value) or statistically more significant estimates for males, younger individuals, individuals from higher income households, those lacking prior residential insurance, and residents of rural, inland, or historically cyclone-free areas.

Overall, the aforementioned heterogeneous analysis highlights substantial differential cyclone impacts on life satisfaction among various socio-demographic groups. The extent of this heterogeneity varies across life satisfaction domains. However, a general finding is that individuals with specific characteristics - males, younger individuals, and those lacking prior residential insurance - are more negatively affected. This underscores the necessity for targeted support policies aimed at building resilience and assisting vulnerable populations. Additionally, the finding that life satisfaction is disproportionately diminished among individuals without prior residential insurance, when viewed alongside evidence presented by Nguyen and Mitrou (2024c) that acquiring residential insurance serves as an effective coping mechanism, emphasizes its importance. Together, our findings demonstrate that residential insurance not only mitigates future home-related repair costs but also helps maintain life satisfaction when exposed to future natural disasters.

8. Impacts of weather-related home damage on life satisfaction

8.1. Empirical models

We proceed to investigate the "direct" impact of cyclones on life satisfaction. Consistent with prior Australian studies utilizing the same HILDA dataset (Baryshnikova & Pham 2019; Johar *et al.* 2022; Gunby & Coupé 2023), individuals are categorized as directly impacted by a natural disaster if they self-report that their residence suffered damage or destruction due to a weather-related disaster such as a flood, bushfire, or cyclone within the preceding 12 months. This categorization stems from responses to a survey question querying, "Did any of these events occur to you in the past 12 months?" accompanied by the specific prompt, "A weather-related disaster (e.g., flood, bushfire, cyclone) damaged or destroyed your home". Australian research has frequently utilized this variable as a proxy for direct exposure to natural disasters, examining its effects on mental health (Baryshnikova & Pham 2019), economic outcomes (Johar *et al.* 2022), life satisfaction (Gunby & Coupé 2023), and residential responses (Nguyen & Mitrou 2024c). Hence, in this study, we employ this variable as a proxy for the direct impact of cyclones, given the explicit mention of cyclones in the questionnaire prompt.

To explore the direct influence of weather-related home damage on life satisfaction outcome Y_{it} of individual i at time t, we utilize the following individual fixed effects equation:

$$Y_{it} = \alpha_2 + \sigma D_{it} + X_{it}\gamma_2 + \delta_i + \varepsilon_{2,it} \qquad (2)$$

where D_{it} is a binary variable indicating whether the individual's home was damaged or destroyed by a weather-related disaster. X_{it} and δ_i are described as in Equation (1). $\varepsilon_{2,it}$ is an error term, and α_2, σ and γ_2 are vectors of parameters to be estimated. In Equation (2), σ is the parameter of interest, capturing the effect of weather-related home damage on an individual's life satisfaction.

While the above fixed-effects model controls for unobservable time-invariant individual characteristics, it does not address potential endogeneity of self-reported home damage arising from time-varying factors that simultaneously correlate with home damage and life satisfaction (Wooldridge 2010; Nguyen *et al.* 2024). To further tackle this potential endogeneity issue, we employ an instrumental variable method, introducing an additional instrumental variable equation for the weather-related home damage. This equation resembles Equation (1), with home damage now acting as the dependent variable (i.e., Y_{it} is replaced by D_{it} in Equation (1)). In particular, we introduce the home damage equation of the following form:

$$D_{it} = \alpha_3 + \beta_3 Z_{i(p)t} + X_{it}\gamma_3 + \delta_i + \varepsilon_{3,it} \qquad (3)$$

In Equation (3), $Z_{i(p)t}$ is an instrument which is not included in the life satisfaction equation (2). X_{it} and δ_i are as described as in Equation (1). $\varepsilon_{3,it}$ is an error term and α_3, β_3, and γ_3 are parameters to be estimated.

We follow Nguyen and Mitrou (2024c) in employing within-individual time-variant exogenous exposure to local cyclones as an instrument to identify the home damage equation. Specifically, $Z_{i(p)t}$ denotes whether individual i residing in postcode p experienced a cyclone in the 12 months prior to the survey time. This variable is considered a suitable instrument for several reasons. First, consistent with expectations and previous Australian research by Nguyen and

Mitrou (2024c), cyclones, particularly those of greater severity and closer proximity to homes, substantially increase self-reported weather-related home damage. Second, the instrument is theoretically sound: the plausibly exogenous exposure to cyclones directly impacts individuals' weather-related home damage, indirectly influencing their life satisfaction via the home damage channel. Third, our previous falsification test provides empirical evidence validating that cyclone exposure is plausibly exogenous, as future cyclone exposure does not influence current life satisfaction. Fourth, this instrument varies over time for the same individuals, facilitating its application in individual fixed-effects models, effectively controlling for both time-invariant and time-varying unobservable factors. Fifth, we will empirically assess the strength of this instrument against concerns of correlation with individual time-varying unobservable factors by additionally controlling for variables such as income and health.

We alternatively adopt four cyclone exposure-based instruments, identified by two cut-offs for distance to the cyclone eye (i.e., 40 km and 100 km) and two cyclone categories (i.e., any category and category 5).[11] We utilize these four instruments separately. These instruments are selected based on prior research indicating their substantial impacts on home damage (Nguyen & Mitrou 2024c). Moreover, they mirror those employed previously in Table 2, enabling comparison with the indirect cyclone impacts presented in Subsection 5.2.1. By employing instruments with varying severity levels, we aim to address the inherent uncertainty regarding the extent of home damage severity in the HILDA dataset. Specifically, we acknowledge the possibility that home damage resulting from more severe cyclones may evoke a stronger impact on life satisfaction.

Given that we utilize a cyclone-driven instrument, the estimate of home damage obtained from this FE-IV framework can be interpreted as the direct impact of cyclones (via their effect on home damage) on life satisfaction (Wooldridge 2010). To estimate the FE-IV model, we employ a Two-Stage Least Squares (2SLS) method. Similar to the baseline analysis, we focus on states and territories impacted by at least one cyclone during the study period to ensure estimation efficiency. We necessarily restrict the analysis to a smaller sample (i.e., the largest sample encompasses 123,908 observations from 14,241 unique individuals, as observed in the FE-IV regression of overall life satisfaction) compared to that used in Section 4 because

[11] We refrain from utilizing category 1 to 2 cyclone exposure as an instrument due to its limited capacity to induce home damage, thus rendering it a weak instrument (i.e., the F statistic from the first-stage regression is smaller than 10). Similarly, we abstain from employing category 3 to 4 cyclone exposure as an instrument because the relatively small number of individuals affected by such cyclones during the study period results in a weak instrument.

information on weather-related home damage is only available from wave 9 of HILDA (Summerfield *et al.* 2023).

8.2. Descriptive results

Table 4 presents descriptive statistics for key variables, disaggregated by the status of weather-related home damage. In our final sample, 2,530 individuals from 2,016 unique persons reported that their homes were damaged or destroyed by a weather-related disaster. Although only a small proportion of the sample (2.05%) reported home damage, the substantial number of affected individuals allows for the detection of any impact of home damage on life satisfaction. Compared to individuals without self-reported home damage, those with home damage tend to have lower levels of education and are more likely to reside in rural areas or regions with lower unemployment rates and socio-economic conditions.

Additionally, individuals reporting weather-related home damage exhibit higher levels of overall life satisfaction and satisfaction in selected domains such as employment opportunity, financial situation, and home satisfaction. Conversely, they report lower levels of community, neighbourhood, personal safety, and health satisfaction. Unexpectedly, they are less likely to be affected by cyclones. However, as discussed above, these differences do not account for observable and unobservable factors that may correlate with both home damage and life satisfaction outcomes. The subsequent analysis addresses this critical issue by employing an FE-IV model to control for potentially confounding factors.

8.3. Empirical results

Table 5 presents estimates of the home damage variable derived from both the FE and FE-IV models. The FE results (Column 1) reveal a negative and statistically significant (at least at the 5% level) association between home damage and selected life satisfaction domains, including employment opportunity, financial situation, and personal safety satisfaction.[12] This negative correlation suggests that individuals whose homes were damaged or destroyed by a weather-related event have lower levels of satisfaction in these domains.

The FE-IV results (Columns 2 to 5) unveil notable findings. Firstly, the estimates of all cyclone exposure measures from the first-stage regressions, reported in Appendix Table A6, are positive and highly statistically significant (at the 1% level), suggesting that individuals

[12] The FE results indicate an insignificant association between weather-related home damage and both overall life satisfaction and home satisfaction. This finding aligns with the results reported by Gunby and Coupé (2023), who also use the HILDA dataset and employ a similar FE model, focusing specifically on overall life satisfaction and home satisfaction.

affected by cyclones are more likely to report weather-related home damage, consistent with the findings by Nguyen and Mitrou (2024c). Moreover, in line with Nguyen and Mitrou (2024c), we observe that the impact of cyclones on home damage increases with the cyclone category and decreases with the distance from the cyclone eye. For example, holding distance to the eye constant at 100 km, the estimated probability of home damage increases approximately four-fold from 1.86 percentage points (pp) for a cyclone of any category to 7.48 pp for a category 5 cyclone. Importantly, the first-stage F-statistic, reported at the bottom of each panel in Table 5, surpasses 80 in all regressions, robustly rejecting the null hypothesis of a weak instrument (Stock & Yogo 2005).

Secondly, the FE-IV estimates for the home damage variable, reported in Columns 2 to 5 of Table 5, demonstrate significant changes in magnitude and statistical significance compared to the FE results for selected life satisfaction outcomes, with the degree of these changes depending on the instruments employed. For instance, the FE-IV estimate of home damage on overall life satisfaction or health satisfaction becomes statistically significant (at least at the 10% level, as can be seen in Panels A and H - Columns 3 and 5) in FE-IV regressions that use a category 5 cyclone exposure, regardless of the distance, as an instrument. Likewise, the home damage estimate on community satisfaction gains statistical significance at the 10% level only in the FE-IV regression when the least severe cyclone exposure measure (i.e., a cyclone of any category within 100 km, Panel E - Column 4) is used as an instrument. By contrast, the FE-IV estimate of home damage becomes less statistically significant or, in most cases, statistically insignificant for employment opportunity, financial situation, and home satisfaction. Thus, the FE-IV estimates indicate that weather-related home damage does not affect employment opportunity, financial situation, home and neighbourhood satisfaction.

Thirdly, the FE-IV estimates, when statistically significant, demonstrate a substantial negative impact of weather-related home damage on various life satisfaction domains. For instance, the statistically significant (at the 5% level) estimate of home damage on overall life satisfaction obtained from the FE-IV regression, which uses exposure to a category 5 cyclone within 40 km from its eye as an instrument, is (minus) 0.88 (see Panel A – Column 3). This represents 11% of the mean overall life satisfaction in our sample. Similarly, the marginally statistically significant (at the 10% level) FE-IV estimate of home damage on community satisfaction, obtained from a regression using the same instrument, indicates a substantial negative impact, with cyclone-driven home damage reducing community satisfaction by 1.13, which accounts for 17% of the sample mean (Panel E – Column 3).

Similarly, the marginally statistically significant (at the 10% level) estimate of home damage on personal safety satisfaction obtained from the FE-IV regression using the same instrument is (minus) 0.87, which is 12 times greater than the statistically significant (at the 5% level) FE estimate of just (minus) 0.07 and represents roughly 11% of the sample mean for personal safety satisfaction (Panel G). Moreover, using a similar instrument in the FE-IV regression of health satisfaction produces a statistically significant (at the 5% level) estimate of (minus) 1.21, which accounts for about 17% of the sample mean for health satisfaction (Panel H – Column 3).

The negative FE-IV estimates of home damage suggest that cyclones, when they damage homes, considerably reduce overall life satisfaction and specific domains like community, personal safety, and health satisfaction. The results also show a stronger damaging impact of weather-related home damage on these life satisfaction outcomes compared to the FE results (reported in Column 1 of Table 5). Notably, this pattern of amplified negative effects in the FE-IV model is only observed when utilizing exposure to the most severe cyclones (category 5 or within 40 km) as an instrument. It is worth reiterating that Section 5 employed the FE model (Equation (1)) to quantify the "indirect" impact of cyclone exposure on life satisfaction. In that analysis, only category 5 cyclones yielded statistically significant results (Table 2). This consistency in significance between the two models (the "reduced form" of Equation 1 and the FE-IV model) further strengthens the credibility of our findings.

The preceding analysis elucidates that while nearly all statistically significant FE-IV estimates exhibit negativity, denoting a profound impact of cyclone-induced home damage on the aforementioned life satisfaction domains, a notable exception arises concerning community satisfaction. This exception emerges from the estimate of home damage derived from an FE-IV regression utilizing exposure to any cyclone within 100 km as an instrument (Panel E - Column 4). Specifically, the positive and statistically significant (at the 5% level) FE-IV estimate of home damage is 2.91, implying that cyclone-induced home damage augments community satisfaction among affected individuals. Furthermore, the estimate bears substantial significance, constituting approximately 43% of the sample mean for community satisfaction. It should be noted that, as documented above, home damage caused by the most severe cyclones (i.e., a category 5 cyclone within 40 km from homes, as shown in Panel E - Column 3) still exerts a statistically significant (at the 10% level) negative impact on this same community satisfaction. These findings suggest that the direct impacts of cyclones on community satisfaction vary by their severity.

It is pertinent to underscore that this positive and statistically significant FE-IV estimate is solely evident when employing the least severe cyclone exposure (i.e., any cyclone within 100 km from homes) as an instrument. Recollecting our earlier discussion in Section 5, which documented the indirect impact of cyclones, we similarly note a positive and marginally statistically significant estimate for the least severe cyclone measure on this same life satisfaction domain (see Table 2 - Panel E - Column 4). Once more, the congruence between the direct and indirect outcomes observed within this life satisfaction domain serves to bolster the validity of our findings.[13]

8.4. Discussion

In summary, the above results emphasize the significant impact of home damage, particularly when induced by category 5 cyclones, on various domains of life satisfaction. The identification of a statistically significant correlation between home damage linked to the most severe cyclones aligns with the Australian Bureau of Meteorology's classification of escalating cyclone impact on property, ranging from "negligible house damage" for category 1 cyclones to "extremely dangerous with widespread destruction of buildings" for category 5 cyclones (BOM 2024). This concordance reinforces the validity of our empirical strategy, which leverages exposure to cyclones of varying severity levels to address the inherent ambiguity in the severity of home damage present in the dataset.

Moreover, the FE-IV estimates, which delineate the direct influence of cyclones on life satisfaction, manifest a conspicuous discrepancy when juxtaposed with the indirect ramifications of cyclones expounded upon in Section 5. Specifically, when both indirect and direct estimations achieve statistical significance, the ascertained direct effects evince significantly larger magnitudes (in absolute terms). For instance, the direct repercussion on overall life satisfaction derived from the FE-IV regression utilizing exposure to any category 5 cyclone within a 40-km radius from residences as an instrumental variable supersedes the indirect impact of the same cyclone exposure measure on overall life satisfaction by a factor exceeding 8-fold (≈-0.88/-0.10). Additionally, employing the identical instrument, the FE-IV assessment concerning personal safety satisfaction surpasses the indirect appraisal of exposure

[13] In alignment with the methodology outlined in Section 6, this section similarly undertook various sampling and specification tests to validate the credibility of our conclusions concerning the repercussions of weather-related home damage on life satisfaction. The outcomes of these tests, as detailed in Appendix Table A7, substantiate the robustness of our findings. Furthermore, we abstain from conducting a heterogeneous analysis on the effects of home damage. The rationale behind this decision lies in the inadequacy of the considerably reduced sample size within this section to support a comprehensive and reliable analysis.

to the same cyclone on the analogous life satisfaction domain by more than five-fold (≈-0.87/-0.15). Similarly, employing the same instrumental variable, the FE-IV evaluation of health satisfaction eclipses the indirect assessment of exposure to the same cyclone on the corresponding life satisfaction domain by more than twelve-fold (≈-1.21/-0.10).

There are several factors contributing to the notably greater direct impacts of cyclones on life satisfaction compared to the indirect impacts. First, the estimate of β_1 in Equation (1) can be interpreted as the estimated impact of "intention-to-treat" (ITT) of cyclone exposure, as discussed by Wooldridge (2010). Conceptually, residing in a region affected by a cyclone does not necessarily imply that all individuals residing therein are directly affected by the cyclone itself (Johar *et al.* 2022; Gunby & Coupé 2023). Consequently, the "indirect impact" of cyclone exposure derived from Equation (1) tends to be smaller than the direct impact.

Second, akin to other Australian studies utilizing the same HILDA dataset (Baryshnikova & Pham 2019; Johar *et al.* 2022; Gunby & Coupé 2023), this study employs weather-related residential damage or destruction as a proxy for the direct impact of cyclone exposure. Residential damage or destruction is arguably among the most severe physical consequences of cyclones (Dell *et al.* 2014; Nguyen & Mitrou 2024c), thus employing it as a proxy for the direct impact amplifies the observed direct impact.

Third, as documented above, the more pronounced direct estimates are only observed when they are obtained from an FE-IV regression which uses the most severe cyclone exposure as an instrument. These most severe cyclones may cause more extensive home damage, resulting in greater direct impacts of cyclones on life satisfaction compared to the indirect impacts.

Fourth, analogous to other IV studies, the estimates from our IV approach capture a Local Average Treatment Effect (LATE) of home damage on life satisfaction (Imbens & Angrist 1994). Specifically, LATE pertains to individuals who experienced home damage due to cyclone strikes, often referred to as "compliers".

In summary, the findings from this section highlight that cyclone-induced home damage, particularly damage caused by more severe cyclones, substantially reduces various life satisfaction outcomes. This underscores the importance of addressing the endogeneity of self-reported home damage, as failure to do so may result in biased estimates of its true impact on life satisfaction.

9. Conclusion

This study offers the first investigation into the causal impacts of cyclones on various life satisfaction domains in Australia. Utilizing an individual fixed effects model to assess the effects of various exogenously determined cyclone exposure measures, our results demonstrate that cyclones, particularly category 5 cyclones in close proximity to homes, substantially decrease overall life satisfaction. These severe cyclones also negatively affect specific satisfaction domains, including community, personal safety, and health satisfaction. The newly identified indirect impacts of cyclones on life satisfaction align with or even surpass the documented effects of one of the worst natural disasters on record in Australia - the 2009 Black Saturday Bushfires (Johnston *et al.* 2021).

Our findings further indicate that these cyclones have a lasting impact on community and personal safety satisfaction. Additionally, the robustness of our results is confirmed through a series of sensitivity assessments, including a falsification test that shows future cyclones do not impact current life satisfaction. Our extensive heterogeneous analysis reveals significant differential impacts of cyclones on life satisfaction based on various individual, household, or regional characteristics. This heterogeneity varies across life satisfaction domains, with a general trend showing more pronounced impacts for males, younger individuals, and those lacking prior residential insurance.

This study also employs within-individual time-variant exogenous exposure to local cyclones of varying severity levels as an instrument in an individual fixed effects instrumental variable model. This approach allows us to pioneer an investigation into the causal impacts of weather-related home damage on life satisfaction. Our results indicate that weather-related home damage, especially when caused by category 5 cyclones within a 40-km radius from residences, significantly reduces overall life satisfaction and specific domains such as community, personal safety and health satisfaction. Moreover, the direct impacts of cyclones on life satisfaction, as derived from the fixed effects instrumental variable model, are much greater (up to twelve times) than the indirect impacts of the same cyclone exposure measure derived from an individual fixed effects model.

The results presented in this study have important methodological and policy implications. Methodologically, our findings highlight the importance of accounting for individual time-invariant unobservable characteristics when quantifying the effects of cyclones on life satisfaction. Failure to do so may lead to biased estimates of the true impacts. Similarly, addressing the endogeneity of self-reported natural disaster-related damage is crucial to avoid biased estimates of its true impact on life satisfaction. From a policy perspective, our novel finding of negative and substantial impacts of cyclones on life satisfaction provides valuable information for crafting effective policies and interventions aimed at supporting affected populations, especially those disproportionately negatively affected by cyclones.

This study provides novel and robust evidence on the indirect and direct impacts of cyclone exposure on life satisfaction. However, several limitations suggest directions for future research. First, it is beyond the scope of this study to investigate the impact of other natural disasters, such as floods, on life satisfaction. Further research into the distinct impacts of various natural disasters would offer a more comprehensive understanding of their effects on life satisfaction. Second, this study identifies that exposure to less severe cyclones enhances community satisfaction among affected individuals. The mechanisms through which cyclones improve the sense of community remain unclear. Further research into these potential mechanisms, such as the role of neighbourly assistance during natural disasters, would be beneficial. Additionally, exploring the pathways through which cyclones influence other domains of life satisfaction would be valuable, as collectively, these insights could inform strategies to mitigate the negative impacts of natural disasters on life satisfaction.

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Table 1: Sample means of key variables by cyclone exposure status

	Affected by any cyclone	Unaffected	Affected - Unaffected (1) - (2)
	(1)	(2)	(3)
Age (years)	44.099	44.842	-0.743***
Married/De facto [(a)]	0.630	0.625	0.005
Separated/divorced/widowed [(a)]	0.132	0.140	-0.008**
Year 12 [(a)]	0.158	0.152	0.007*
Vocational or Training qualification [(a)]	0.402	0.355	0.047***
Bachelor or higher [(a)]	0.168	0.180	-0.012***
Household size	2.849	2.884	-0.035**
Major city [(a)]	0.345	0.611	-0.266***
Local area unemployment rate (%)	4.993	5.162	-0.169***
Local area SEIFA index	5.147	5.460	-0.313***
Overall life satisfaction	7.956	7.920	0.036**
Employment opportunity satisfaction	7.149	7.046	0.104***
Financial situation satisfaction	6.696	6.555	0.141***
Home satisfaction	8.007	8.017	-0.010
Community satisfaction	6.754	6.762	-0.009
Neighbourhood satisfaction	7.874	7.881	-0.007
Personal safety satisfaction	8.327	8.224	0.103***
Health satisfaction	7.238	7.265	-0.027
Observations	8,598	196,000	

Notes: Figures are sample means. Estimated sample from the regression of "Overall life satisfaction" as an outcome. [(a)] indicates a binary variable. Tests are performed on the significance of the difference between the sample mean for "affected" individuals (identified as those living in a postcode affected by any cyclone within 100km from the cyclone eye) and "unaffected" individuals (remaining individuals). The symbol * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 2: Concurrent impacts of cyclone exposure on life satisfaction

Distance to cyclone eye:	Within 40 km			Within 100 km		
Cyclone category:	Any	Cat 3 - 4	Cat 5	Any	Cat 3 - 4	Cat 5
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A:	Overall life satisfaction (N: 204,389; P: 21,811; M: 7.92)					
Cyclone estimate	0.02	0.02	-0.10**	0.00	-0.01	-0.08**
	[0.02]	[0.03]	[0.04]	[0.01]	[0.02]	[0.03]
Proportion affected (%)	1.51	0.75	0.32	4.21	1.88	0.59
Panel B:	Employment opportunity satisfaction (N: 161,600; P: 20,396; M: 7.05)					
Cyclone estimate	0.02	0.05	-0.04	0.02	0.03	-0.04
	[0.04]	[0.05]	[0.08]	[0.03]	[0.04]	[0.06]
Panel C:	Financial situation satisfaction (N: 204,235; P: 21,802; M: 6.56)					
Cyclone estimate	-0.01	-0.06	-0.02	-0.02	-0.04	0.00
	[0.03]	[0.04]	[0.06]	[0.02]	[0.03]	[0.05]
Panel D:	Home satisfaction (N: 204,330; P: 21,811; M: 8.02)					
Cyclone estimate	-0.03	-0.03	-0.05	-0.01	-0.01	-0.01
	[0.03]	[0.04]	[0.06]	[0.02]	[0.03]	[0.04]
Panel E:	Community satisfaction (N: 204,018; P: 21,796; M: 6.76)					
Cyclone estimate	0.01	0.05	-0.13**	0.04*	0.06*	-0.10**
	[0.03]	[0.05]	[0.06]	[0.02]	[0.03]	[0.05]
Panel F:	Neighbourhood satisfaction (N: 204,176; P: 21,801; M: 7.88)					
Cyclone estimate	0.03	0.08**	-0.08	0.03	0.06**	-0.05
	[0.03]	[0.04]	[0.06]	[0.02]	[0.02]	[0.05]
Panel G:	Personal safety satisfaction (N: 204,326; P: 21,811; M: 8.23)					
Cyclone estimate	-0.03	0.00	-0.15***	0.00	0.02	-0.05
	[0.02]	[0.03]	[0.05]	[0.02]	[0.02]	[0.04]
Panel H:	Health satisfaction (N: 204,409; P: 21,812; M: 7.26)					
Cyclone estimate	-0.01	0.00	-0.10**	-0.01	0.00	-0.09**
	[0.03]	[0.04]	[0.05]	[0.02]	[0.02]	[0.04]

Notes: Results reported in each column and panel are from a separate FE regression. "Cyclone estimate" refers to the FE estimate of the cyclone exposure variable, which is identified by the distance from the cyclone eye as mentioned in the first row of this table and by the cyclone category as noted in the second row. "N", "P", and "M" refer to "Number of observations", "Number of unique persons", and "Mean of the dependent variable", respectively. Other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Table 3: Dynamic impacts of cyclone exposure on life satisfaction

Distance to cyclone eye:	Within 40 km	Within 100 km
	(1)	(2)
Panel A:	Overall life satisfaction (N: 179,217; P: 18,061; M: 7.92)	
Current cyclone	-0.14***	-0.10***
	[0.05]	[0.04]
Lagged cyclone	-0.03	0.02
	[0.05]	[0.03]
Panel B:	Employment opportunity satisfaction (N: 140,104; P: 16,734; M: 7.08)	
Current cyclone	-0.05	-0.08
	[0.08]	[0.07]
Lagged cyclone	-0.06	-0.09
	[0.09]	[0.07]
Panel C:	Financial situation satisfaction (N: 179,119; P: 18,063; M: 6.63)	
Current cyclone	-0.04	-0.04
	[0.07]	[0.05]
Lagged cyclone	-0.06	-0.02
	[0.07]	[0.05]
Panel D:	Home satisfaction (N: 179,153; P: 18,062; M: 8.01)	
Current cyclone	-0.10	-0.04
	[0.06]	[0.05]
Lagged cyclone	-0.07	-0.05
	[0.06]	[0.05]
Panel E:	Community satisfaction (N: 178,902; P: 18,054; M: 6.78)	
Current cyclone	-0.17**	-0.11**
	[0.07]	[0.05]
Lagged cyclone	-0.12*	-0.10**
	[0.06]	[0.05]
Panel F:	Neighbourhood satisfaction (N: 179,029; P: 18,059; M: 7.88)	
Current cyclone	-0.11*	-0.07
	[0.06]	[0.05]
Lagged cyclone	-0.08	-0.07
	[0.06]	[0.04]
Panel G:	Personal safety satisfaction (N: 179,150; P: 18,060; M: 8.23)	
Current cyclone	-0.17***	-0.05
	[0.05]	[0.04]
Lagged cyclone	-0.13**	-0.10***
	[0.05]	[0.04]
Panel H:	Health satisfaction (N: 179,228; P: 18,064; M: 7.22)	
Current cyclone	-0.12**	-0.12***
	[0.06]	[0.04]
Lagged cyclone	-0.03	-0.01
	[0.06]	[0.04]

Notes: Results reported in each column and panel are from a separate FE regression. Cyclone exposure measure is captured by exposure to any category 5 cyclone within a distance from the cyclone eye as mentioned on the first row of this table. "N", "P", and "M" refer to "Number of observations", "Number of unique persons", and "Mean of the dependent variable", respectively. Other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Table 4: Sample means of key variables by weather-related home damage status

	Home damage	No home damage	Home damage - No home damage (1) - (2)
	(1)	(2)	(3)
Age (years)	45.377	46.108	-0.732*
Married/De facto [(a)]	0.653	0.644	0.009
Separated/divorced/widowed [(a)]	0.134	0.135	-0.002
Year 12 [(a)]	0.138	0.152	-0.014*
Vocational or Training qualification [(a)]	0.416	0.380	0.036***
Bachelor or higher [(a)]	0.164	0.202	-0.038***
Household size	2.928	2.861	0.067**
Major city [(a)]	0.448	0.609	-0.161***
Local area unemployment rate (%)	4.911	5.243	-0.332***
Local area SEIFA index	4.683	5.474	-0.791***
Overall life satisfaction	0.060	0.020	0.04***
Employment opportunity satisfaction	0.028	0.003	0.025***
Financial situation satisfaction	0.108	0.055	0.053***
Home satisfaction	0.038	0.007	0.031***
Community satisfaction	7.751	7.953	-0.201***
Neighbourhood satisfaction	6.822	7.091	-0.269***
Personal safety satisfaction	6.292	6.720	-0.429***
Health satisfaction	7.840	8.070	-0.229***
Any cyclone within 40 km (%)	6.686	6.798	-0.112***
Any category 5 cyclone within 40 km (%)	7.693	7.887	-0.193***
Any cyclone within 100 km (%)	8.172	8.323	-0.151***
Any category 5 cyclone within 100 km (%)	6.966	7.228	-0.261***
Observations	2,530	121,000	

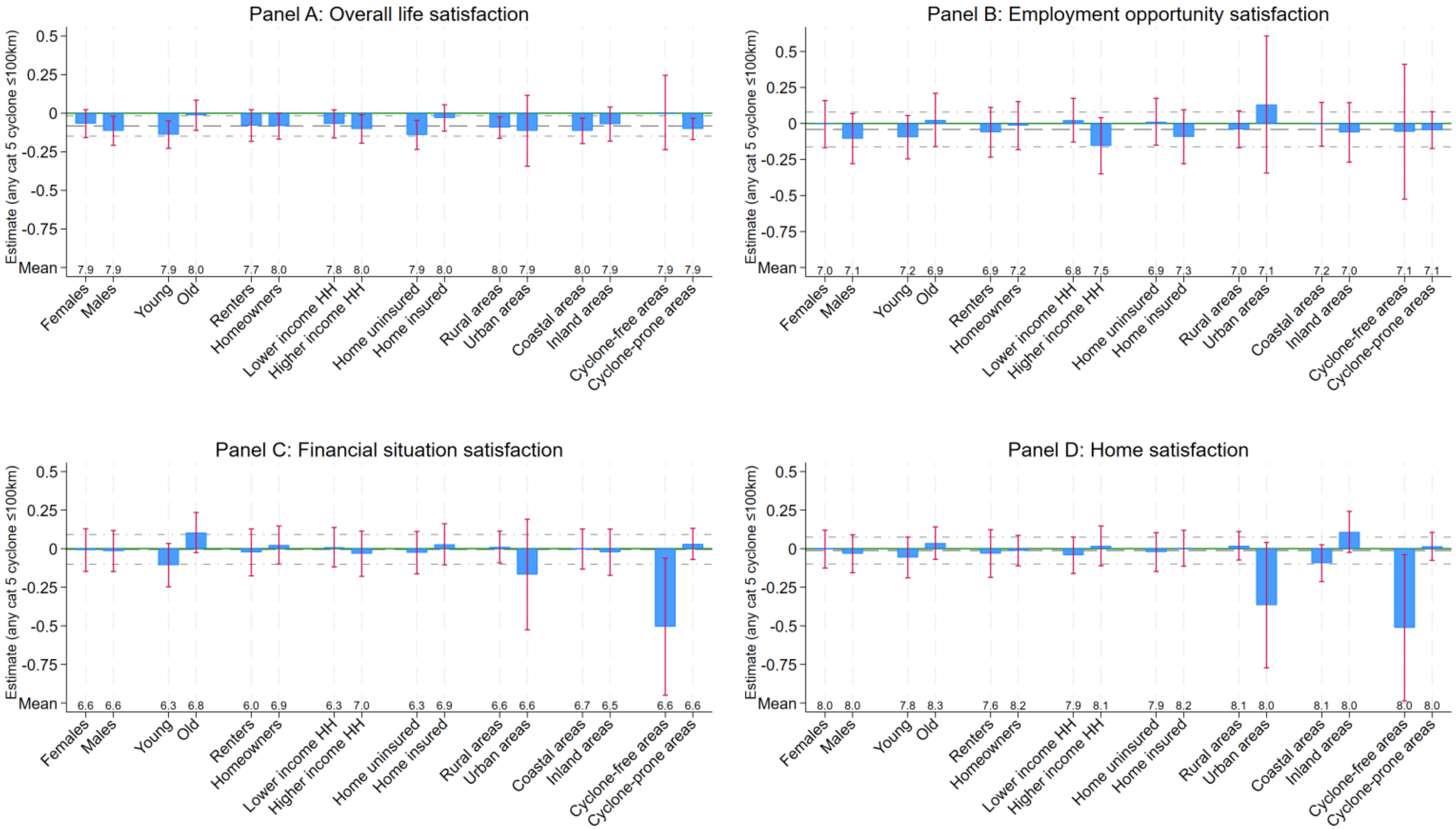
Notes: Figures are sample means. Estimated sample from the FE-IV regression of "Overall life satisfaction" as an outcome. [(a)] indicates a binary variable. Tests are performed on the significance of the difference between the sample mean for two groups of individuals with and without weather-related home damage. The symbol * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 5: Impacts of weather-related home damage on life satisfaction

Estimation method:	FE	FE-IV			
Distance to the cyclone eye:		Within 40 km		Within 100 km	
Cyclone category:		Any	Cat 5	Any	Cat 5
	(1)	(2)	(3)	(4)	(5)
Panel A:	Overall life satisfaction (N: 123,908; P: 14,241; M: 7.95)				
Current home damage	-0.03	0.52	-0.88**	-0.12	-0.86*
	[0.03]	[0.53]	[0.41]	[0.76]	[0.50]
F statistic		176.66	322.06	85.39	224.93
Panel B:	Employment opportunity satisfaction (N: 97,413; P: 12,815; M: 7.09)				
Current home damage	-0.12***	0.74	-0.53	2.06	-0.46
	[0.04]	[0.97]	[0.74]	[1.45]	[0.86]
F statistic		173.36	307.94	80.27	225.28
Panel C:	Financial situation satisfaction (N: 123,817; P: 14,231; M: 6.71)				
Current home damage	-0.07**	-0.22	-0.26	-1.43	-0.35
	[0.04]	[0.82]	[0.56]	[1.20]	[0.73]
F statistic		176.82	321.30	85.70	224.08
Panel D:	Home satisfaction (N: 123,841; P: 14,239; M: 8.06)				
Current home damage	-0.06*	-1.07	-0.13	-0.35	0.81
	[0.03]	[0.77]	[0.54]	[1.05]	[0.66]
F statistic		176.45	322.15	85.58	224.53
Panel E:	Community satisfaction (N: 123,637; P: 14,232; M: 6.8)				
Current home damage	-0.01	-0.02	-1.13*	2.91**	-0.85
	[0.04]	[0.87]	[0.63]	[1.29]	[0.73]
F statistic		174.39	322.74	85.79	225.36
Panel F:	Neighbourhood satisfaction (N: 123,744; P: 14,234; M: 7.88)				
Current home damage	-0.02	0.52	-0.56	1.09	0.18
	[0.03]	[0.70]	[0.55]	[1.00]	[0.64]
F statistic		179.97	325.16	86.68	226.89
Panel G:	Personal safety satisfaction (N: 123,840; P: 14,238; M: 8.32)				
Current home damage	-0.07**	-0.49	-0.87*	0.69	0.39
	[0.03]	[0.62]	[0.45]	[0.89]	[0.52]
F statistic		176.67	321.97	85.32	224.65
Panel H:	Health satisfaction (N: 123,914; P: 14,241; M: 7.22)				
Current home damage	0.00	0.16	-1.21**	0.00	-1.60**
	[0.03]	[0.69]	[0.52]	[0.98]	[0.63]
F statistic		176.94	322.38	85.71	225.17

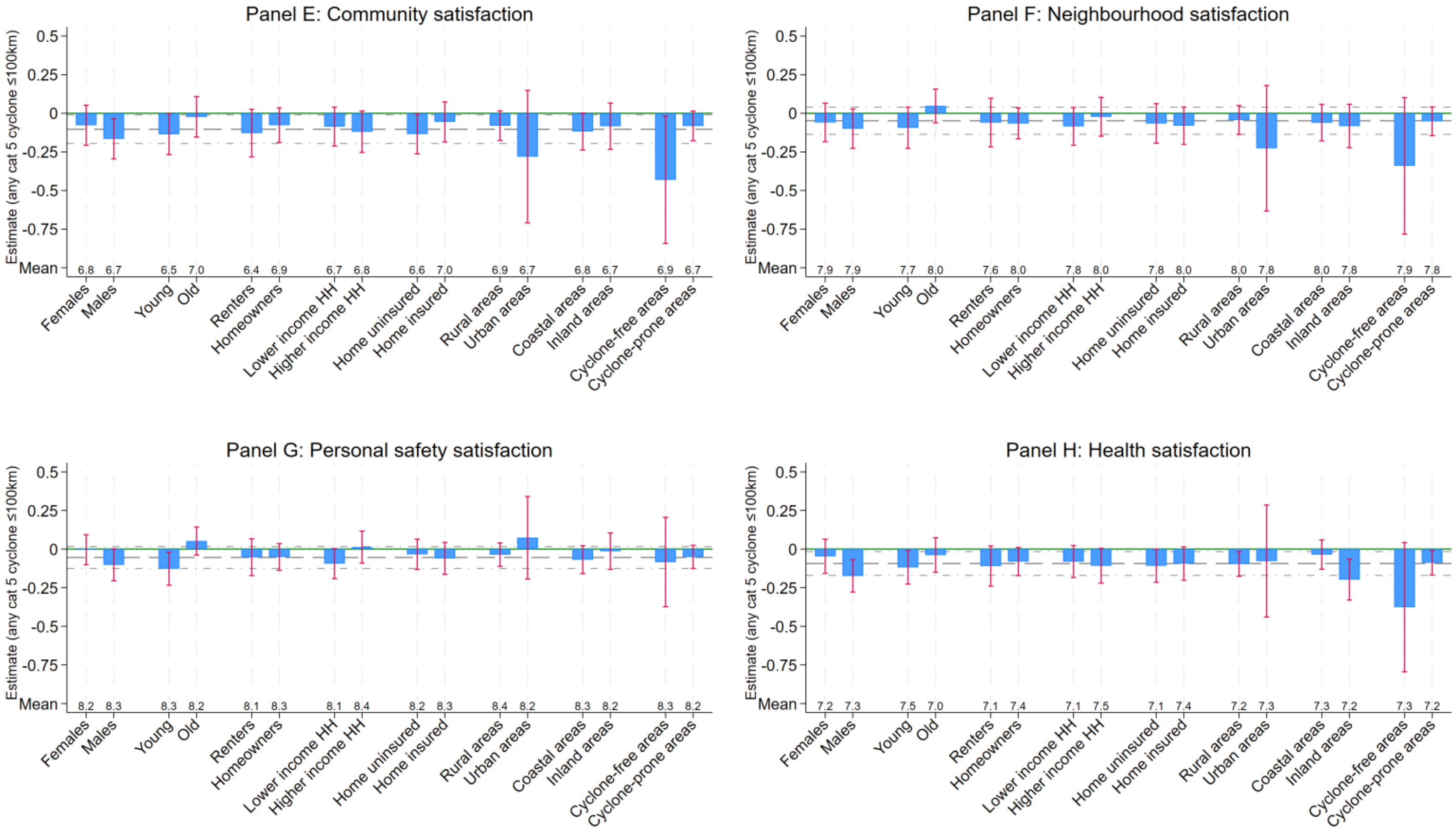
Notes: Results reported in each column and panel are from a separate regression. FE results are from the regression (2) while FE-IV results from an FE-IV regression. “F-statistic” denotes the F statistic for the strength of the respective instrument, identified by distance to the cyclone eye and cyclone category as mentioned on the second and third row of this table, in the first stage regression. “N”, “P”, and “M” refer to “Number of observations”, “Number of unique persons”, and “Mean of the dependent variable”, respectively. Other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Figure 1: Heterogeneity in the cyclone impact on life satisfaction



Notes: Results for different sub-populations are obtained from a separate FE regression. The dash (short dash dot) horizontal line shows the cyclone exposure coefficient (95% confidence interval) estimates for the whole population. “Mean” indicates the mean of the dependent variable for each sub-population printed below the bars. Detailed regression results are reported in Appendix Table A5.

Figure 1: Heterogeneity in the cyclone impact on life satisfaction (continued)



Notes: Results for different sub-populations are obtained from a separate FE regression. The dash (short dash dot) horizontal line shows the cyclone exposure coefficient (95% confidence interval) estimates for the whole population. “Mean” indicates the mean of the dependent variable for each sub-population printed below the bars. Detailed regression results are reported in Appendix Table A5.

Online Appendix

for refereeing purposes and to be published online

Appendix Table A1: Variable description and summary statistics

Variable	Description	Mean	Min	Max	Standard deviations		
					Overall	Between	Within
Age (years)	The respondent's age at the survey time (years)	44.81	14.00	101.00	18.85	19.14	4.93
Married/De facto	Dummy variable: = 1 if the individual is married or in de factor relationship at the survey time and zero otherwise	0.63	0.00	1.00	0.48	0.45	0.25
Separated/divorced/widowed	Dummy variable: = 1 if the individual is separated/divorced/widowed at the survey time and zero otherwise	0.14	0.00	1.00	0.35	0.30	0.16
Year 12	Dummy: = 1 if the individual completes Year 12 and zero otherwise	0.15	0.00	1.00	0.36	0.34	0.17
Vocational or Training qualification	Dummy: = 1 if the individual has a vocational or training qualification and zero otherwise	0.36	0.00	1.00	0.48	0.45	0.16
Bachelor or higher	Dummy: = 1 if the individual has a bachelor degree or higher and zero otherwise	0.18	0.00	1.00	0.38	0.35	0.13
Household size	Number of household members	2.88	1.00	17.00	1.49	1.38	0.85
Major city	Dummy variable: = 1 if the individual lives in a major city and zero otherwise	0.60	0.00	1.00	0.49	0.47	0.18
Local area unemployment rate	Yearly unemployment rate at the individual's residing local government area (%)	5.15	2.10	8.10	1.16	0.83	1.02
Local area SEIFA decile	Socio-Economic Indexes for Areas (SEIFA) decile at the individual's residing local government area	5.45	1.00	10.00	2.88	2.68	1.24
Overall life satisfaction	Responses to a question “All things considered, how satisfied are you with your life?”	7.92	0.00	10.00	1.47	1.29	1.00
Employment opportunity satisfaction	Responses to a question asking the respondents about their satisfaction with their employment opportunity	7.05	0.00	10.00	2.37	2.15	1.66
Financial situation satisfaction	Responses to a question asking the respondents about their satisfaction with their financial situation	6.56	0.00	10.00	2.24	1.94	1.51
Home satisfaction	Responses to a question asking the respondents about their satisfaction with the home in which they live	8.02	0.00	10.00	1.79	1.48	1.33
Community satisfaction	Responses to a question asking the respondents about their satisfaction with feeling part of their local community	6.76	0.00	10.00	2.18	1.86	1.52
Neighbourhood satisfaction	Responses to a question asking the respondents about their satisfaction with the neighbourhood in which they live	7.88	0.00	10.00	1.76	1.51	1.27
Personal safety satisfaction	Responses to a question asking the respondents about their satisfaction with how safe they feel	8.23	0.00	10.00	1.60	1.37	1.14
Health satisfaction	Responses to a question asking the respondents about their satisfaction with their health	7.26	0.00	10.00	1.96	1.72	1.23

Notes: Sample size include 204,389 observations.

Appendix Table A1: Variable description and summary statistics (continued)

Variable	Description	Mean	Min	Max	Standard deviations			Number of observations affected
					Overall	Between	Within	
Any cyclone within 40 km	Dummy variable: = 1 if an individual's residential postcode was within 40 km of any cyclone eye last year and zero otherwise	0.015	0.00	1.00	0.12	0.07	0.11	3,080
Any category 1 or 2 cyclone within 40 km	Dummy variable: = 1 if an individual's residential postcode was within 40 km of any category 1 or 2 cyclone's eye last year and zero otherwise	0.004	0.00	1.00	0.07	0.05	0.06	888
Any category 3 or 4 cyclone within 40 km	Dummy variable: = 1 if an individual's residential postcode was within 40 km of any category 3 or 4 cyclone's eye last year and zero otherwise	0.007	0.00	1.00	0.09	0.04	0.08	1,532
Any category 5 cyclone within 40 km	Dummy variable: = 1 if an individual's residential postcode was within 40 km of any category 5 cyclone's eye last year and zero otherwise	0.003	0.00	1.00	0.06	0.03	0.05	662
Any cyclone within 100 km	Dummy variable: = 1 if an individual's residential postcode was within 100 km of any cyclone eye last year and zero otherwise	0.042	0.00	1.00	0.20	0.12	0.18	8,598
Any category 1 or 2 cyclone within 100 km	Dummy variable: = 1 if an individual's residential postcode was within 100 km of any category 1 or 2 cyclone's eye last year and zero otherwise	0.019	0.00	1.00	0.14	0.09	0.12	3,802
Any category 3 or 4 cyclone within 100 km	Dummy variable: = 1 if an individual's residential postcode was within 100 km of any category 3 or 4 cyclone's eye last year and zero otherwise	0.019	0.00	1.00	0.14	0.07	0.13	3,846
Any category 5 cyclone within 100 km	Dummy variable: = 1 if an individual's residential postcode was within 100 km of any category 5 cyclone's eye last year and zero otherwise	0.006	0.00	1.00	0.08	0.04	0.07	1,196

Notes: Sample size include 204,389 observations.

Appendix Table A2: Correlation structure among life satisfaction variables

	Life satisfaction	Employment opportunity satisfaction	Financial satisfaction	Home satisfaction	Community satisfaction	Neighbourhood satisfaction	Personal safety satisfaction	Health satisfaction
Life satisfaction	1.00							
Employment opportunity satisfaction	0.38	1.00						
Financial satisfaction	0.46	0.47	1.00					
Home satisfaction	0.44	0.24	0.34	1.00				
Community satisfaction	0.39	0.27	0.31	0.31	1.00			
Neighbourhood satisfaction	0.41	0.25	0.29	0.44	0.51	1.00		
Personal safety satisfaction	0.46	0.30	0.36	0.36	0.38	0.46	1.00	
Health satisfaction	0.49	0.34	0.33	0.23	0.30	0.33	0.34	1.00

Notes: All correlations are statistically significant at the 1% level.

Appendix Table A3: Robustness checks for the impacts of cyclone on life satisfaction

	Overall life satisfaction	Employment opportunity satisfaction	Financial situation satisfaction	Home satisfaction	Community satisfaction	Neighbourhood satisfaction	Personal safety satisfaction	Health satisfaction
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Baseline								
Any category 5 cyclone within 100 km	-0.08**	-0.04	0.00	-0.01	-0.10**	-0.05	-0.05	-0.09**
	[0.03]	[0.06]	[0.05]	[0.04]	[0.05]	[0.05]	[0.04]	[0.04]
Observations	204,389	161,600	204,235	204,330	204,018	204,176	204,326	204,409
Num of unique persons	21,811	20,396	21,802	21,811	21,796	21,801	21,811	21,812
Panel B1: Different sample - Including only local government areas with at least one cyclone within 100 km								
Any category 5 cyclone within 100 km	-0.08**	-0.08	0.01	-0.02	-0.08	-0.03	-0.06	-0.10**
	[0.03]	[0.06]	[0.05]	[0.04]	[0.05]	[0.05]	[0.04]	[0.04]
Observations	72,290	58,098	72,225	72,253	72,136	72,212	72,259	72,293
Num of unique persons	8,543	8,039	8,541	8,542	8,534	8,539	8,542	8,546
Panel B2: Different sample - Using a sample of all individuals observed in the data								
Any category 5 cyclone within 100 km	-0.09***	-0.05	-0.01	-0.01	-0.12**	-0.08*	-0.05	-0.11***
	[0.03]	[0.06]	[0.05]	[0.04]	[0.05]	[0.05]	[0.04]	[0.04]
Observations	337,276	268,380	337,006	337,150	336,718	336,945	337,190	337,302
Num of unique persons	34,494	32,150	34,479	34,492	34,477	34,484	34,497	34,497
Panel C1: Different specification - Controlling for postcode dummies								
Any category 5 cyclone within 100 km	-0.08**	-0.04	0.01	0.00	-0.07	-0.03	-0.04	-0.09**
	[0.03]	[0.06]	[0.05]	[0.04]	[0.05]	[0.04]	[0.04]	[0.04]
Observations	204,341	161,566	204,188	204,282	203,971	204,132	204,278	204,361
Num of unique persons	21,811	20,396	21,802	21,811	21,796	21,801	21,811	21,812
Panel C2: Different specification - Clustering at the postcode level								
Any category 5 cyclone within 100 km	-0.08*	-0.04	0.00	-0.01	-0.10**	-0.05	-0.05	-0.09*
	[0.04]	[0.09]	[0.06]	[0.06]	[0.05]	[0.05]	[0.05]	[0.05]
Observations	204,341	161,566	204,188	204,282	203,971	204,132	204,278	204,361
Num of unique persons	21,811	20,396	21,802	21,811	21,796	21,801	21,811	21,812

Notes: The results presented in each column and panel are based on separate FE regression, unless otherwise specified. Unless stated otherwise, other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level, unless indicated otherwise, in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A3: Robustness checks for the impacts of cyclone on life satisfaction (continued)

	Overall life satisfaction	Employment opportunity satisfaction	Financial situation satisfaction	Home satisfaction	Community satisfaction	Neighbourhood satisfaction	Personal safety satisfaction	Health satisfaction
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C3: Different specification - Using a pooled cross sectional OLS model								
Any category 5 cyclone within 100 km	-0.08*	-0.14*	0.01	-0.05	-0.10*	-0.12**	-0.13***	-0.09
	[0.04]	[0.07]	[0.06]	[0.05]	[0.06]	[0.05]	[0.04]	[0.05]
Observations	204,389	161,600	204,235	204,330	204,018	204,176	204,326	204,409
Panel C4: Different specification - Using a Random Effects model								
Any category 5 cyclone within 100 km	-0.08**	-0.05	0.00	-0.01	-0.10**	-0.05	-0.06*	-0.09**
	[0.03]	[0.06]	[0.05]	[0.04]	[0.05]	[0.04]	[0.04]	[0.04]
Observations	204,389	161,600	204,235	204,330	204,018	204,176	204,326	204,409
Num of unique persons	21,811	20,396	21,802	21,811	21,796	21,801	21,811	21,812
Panel C5: Different specification - Excluding some time variant variables such as education, marital status, household size and major city								
Any category 5 cyclone within 100 km	-0.09***	-0.08	-0.03	-0.01	-0.11**	-0.05	-0.06	-0.10**
	[0.03]	[0.06]	[0.05]	[0.04]	[0.05]	[0.05]	[0.04]	[0.04]
Observations	204,389	161,600	204,235	204,330	204,018	204,176	204,326	204,409
Num of unique persons	21,811	20,396	21,802	21,811	21,796	21,801	21,811	21,812
Panel C6: Different specification - Including a time variant variable: non-wage income								
Any category 5 cyclone within 100 km	-0.08**	-0.04	-0.01	-0.01	-0.10**	-0.05	-0.05	-0.09**
	[0.03]	[0.06]	[0.05]	[0.04]	[0.05]	[0.05]	[0.04]	[0.04]
Observations	204,152	161,438	204,005	204,093	203,784	203,941	204,090	204,173
Num of unique persons	21,807	20,390	21,798	21,807	21,791	21,797	21,807	21,808
Panel C7: Different specification - Including a time variant variable: SF 36 general health summary								
Any category 5 cyclone within 100 km	-0.07**	-0.03	0.02	0.02	-0.11**	-0.04	-0.01	-0.08**
	[0.04]	[0.07]	[0.05]	[0.05]	[0.05]	[0.05]	[0.04]	[0.04]
Observations	181,874	143,467	181,795	181,820	181,601	181,710	181,819	181,894
Num of unique persons	20,600	19,196	20,594	20,601	20,588	20,591	20,600	20,602

Notes: The results presented in each column and panel are based on separate FE regression, unless otherwise specified. Unless stated otherwise, other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level, unless indicated otherwise, in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A4: Falsification test for the cyclone impact on life satisfaction

Distance to cyclone eye:	Within 40 km	Within 100 km
	(1)	(2)
Panel A:	Overall life satisfaction (N: 159,524; P: 15,991; M: 7.92)	
Current cyclone	-0.15***	-0.11***
	[0.05]	[0.04]
Lagged cyclone	-0.05	0.01
	[0.05]	[0.04]
Lead cyclone	-0.06	-0.05
	[0.04]	[0.03]
Panel B:	Employment opportunity satisfaction (N: 124,905; P: 14,784; M: 7.06)	
Current cyclone	-0.06	-0.08
	[0.09]	[0.07]
Lagged cyclone	-0.04	-0.06
	[0.09]	[0.07]
Lead cyclone	-0.06	0.01
	[0.09]	[0.07]
Panel C:	Financial situation satisfaction (N: 159,455; P: 15,989; M: 6.61)	
Current cyclone	-0.05	-0.05
	[0.07]	[0.05]
Lagged cyclone	-0.08	-0.02
	[0.07]	[0.05]
Lead cyclone	-0.11	-0.01
	[0.07]	[0.06]
Panel D:	Home satisfaction (N: 159,480; P: 15,990; M: 8.01)	
Current cyclone	-0.14**	-0.06
	[0.07]	[0.05]
Lagged cyclone	-0.09	-0.04
	[0.06]	[0.05]
Lead cyclone	-0.10	-0.01
	[0.07]	[0.05]

Notes: Results reported in each column and panel are from a separate FE regression. Cyclone exposure measure is captured by exposure to any category 5 cyclone within a distance from the cyclone eye as mentioned on the first row of this table. “N”, “P”, and “M” refer to “Number of observations”, “Number of unique persons”, and “Mean of the dependent variable”, respectively. Other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A4: Falsification test for the cyclone impact on life satisfaction (continued)

Distance to cyclone eye:	Within 40 km	Within 100 km
	(1)	(2)
Panel E:	Community satisfaction (N: 159,283; P: 15,984; M: 6.79)	
Current cyclone	-0.17**	-0.11**
	[0.07]	[0.05]
Lagged cyclone	-0.13*	-0.11**
	[0.07]	[0.05]
Lead cyclone	-0.05	-0.01
	[0.07]	[0.06]
Panel F:	Neighbourhood satisfaction (N: 159,375; P: 15,990; M: 7.89)	
Current cyclone	-0.15**	-0.10**
	[0.07]	[0.05]
Lagged cyclone	-0.10	-0.08*
	[0.06]	[0.04]
Lead cyclone	-0.11	-0.03
	[0.07]	[0.05]
Panel G:	Personal safety satisfaction (N: 159,475; P: 15,992; M: 8.22)	
Current cyclone	-0.19***	-0.06
	[0.05]	[0.04]
Lagged cyclone	-0.17***	-0.12***
	[0.05]	[0.04]
Lead cyclone	-0.09	0.01
	[0.06]	[0.04]
Panel H:	Health satisfaction (N: 159,533; P: 15,990; M: 7.23)	
Current cyclone	-0.14**	-0.12***
	[0.06]	[0.04]
Lagged cyclone	-0.04	-0.01
	[0.06]	[0.04]
Lead cyclone	-0.05	-0.03
	[0.06]	[0.04]

Notes: Results reported in each column and panel are from a separate FE regression. Cyclone exposure measure is captured by exposure to any category 5 cyclone within a distance from the cyclone eye as mentioned on the first row of this table. “N”, “P”, and “M” refer to “Number of observations”, “Number of unique persons”, and “Mean of the dependent variable”, respectively. Other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A5: Heterogeneity in the cyclone impact on life satisfaction

Separate by:	Gender		Age		Home ownership		Household income		Residential insurance		Rural/urban		Distance to coast		Locality cyclone history	
	Female	Male	Young	Old	Renter	Owner	Poorer	Richer	Uninsured	Insured	Rural areas	Urban areas	Coastal areas	Inland areas	Cyclone-free areas	Cyclone-prone areas
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Panel A:	Overall life satisfaction															
Any category 5 cyclone within 100 km	-0.07	-0.11**	-0.14***	-0.01	-0.08	-0.08*	-0.07	-0.10**	-0.14***	-0.03	-0.09***	-0.11	-0.11***	-0.07	0.00	-0.10***
	[0.05]	[0.05]	[0.05]	[0.05]	[0.05]	[0.04]	[0.05]	[0.05]	[0.05]	[0.04]	[0.04]	[0.12]	[0.04]	[0.06]	[0.12]	[0.04]
Observations	177,709	159,567	103,297	97,384	73,724	136,873	121,190	89,407	109,978	86,139	78,411	117,706	98,468	97,649	101,369	94,748
Num of unique persons	17,759	16,735	12,537	8,938	6,988	11,115	10,024	8,079	8,704	6,374	5,955	9,123	7,580	7,498	7,876	7,202
Mean of dep. variable	7.95	7.90	7.88	7.97	7.75	8.01	7.84	8.03	7.86	8.01	7.99	7.88	7.96	7.89	7.93	7.92
Proportion affected (%)	0.35	0.36	0.63	0.54	0.70	0.48	0.57	0.55	0.62	0.53	1.36	0.06	0.70	0.46	0.06	1.13
Panel B:	Employment opportunity satisfaction															
Any category 5 cyclone within 100 km	0.00	-0.11	-0.10	0.02	-0.06	-0.01	0.02	-0.15	0.01	-0.09	-0.04	0.13	-0.01	-0.06	-0.06	-0.05
	[0.08]	[0.09]	[0.08]	[0.09]	[0.09]	[0.08]	[0.08]	[0.10]	[0.08]	[0.10]	[0.07]	[0.24]	[0.08]	[0.11]	[0.24]	[0.06]
Observations	136,544	131,836	78,813	78,731	63,270	102,720	102,010	63,980	83,731	69,982	58,822	94,891	77,350	76,363	78,629	75,084
Num of unique persons	16,369	15,781	10,678	8,872	6,544	9,796	9,815	6,525	7,650	5,895	5,202	8,343	6,816	6,729	7,023	6,522
Mean of dep. variable	7.02	7.13	7.19	6.94	6.87	7.20	6.84	7.46	6.92	7.30	7.03	7.13	7.18	7.00	7.07	7.11
Proportion affected (%)	0.39	0.39	0.66	0.65	0.75	0.54	0.65	0.57	0.67	0.62	1.57	0.07	0.78	0.50	0.08	1.24
Panel C:	Financial situation satisfaction															
Any category 5 cyclone within 100 km	-0.01	-0.02	-0.11	0.10	-0.02	0.02	0.01	-0.03	-0.03	0.03	0.01	-0.17	0.00	-0.02	-0.51**	0.03
	[0.07]	[0.07]	[0.07]	[0.07]	[0.08]	[0.06]	[0.07]	[0.07]	[0.07]	[0.07]	[0.05]	[0.18]	[0.07]	[0.08]	[0.23]	[0.05]
Observations	177,566	159,440	103,198	97,334	73,713	136,749	121,092	89,370	109,844	86,123	78,313	117,654	98,398	97,569	101,312	94,655
Num of unique persons	17,747	16,732	12,531	8,939	6,988	11,111	10,021	8,078	8,695	6,374	5,947	9,122	7,576	7,493	7,873	7,196
Mean of dep. variable	6.60	6.58	6.33	6.84	6.05	6.85	6.29	6.96	6.33	6.92	6.56	6.61	6.69	6.49	6.63	6.55
Proportion affected (%)	0.35	0.36	0.64	0.54	0.70	0.48	0.57	0.55	0.62	0.53	1.36	0.06	0.70	0.46	0.06	1.14
Panel D:	Home satisfaction															
Any category 5 cyclone within 100 km	0.00	-0.03	-0.06	0.04	-0.03	-0.01	-0.04	0.02	-0.02	0.00	0.02	-0.37*	-0.09	0.11	-0.51**	0.02
	[0.06]	[0.06]	[0.07]	[0.05]	[0.08]	[0.05]	[0.06]	[0.07]	[0.06]	[0.06]	[0.05]	[0.21]	[0.06]	[0.07]	[0.24]	[0.05]
Observations	177,658	159,492	103,261	97,363	73,736	136,813	121,188	89,361	109,932	86,107	78,373	117,666	98,435	97,604	101,350	94,689
Num of unique persons	17,759	16,733	12,537	8,939	6,989	11,116	10,026	8,079	8,703	6,373	5,952	9,124	7,579	7,497	7,875	7,201
Mean of dep. variable	8.03	7.99	7.79	8.26	7.64	8.20	7.92	8.12	7.89	8.15	8.06	7.97	8.06	7.95	8.03	7.99
Proportion affected (%)	0.35	0.36	0.64	0.54	0.70	0.49	0.57	0.55	0.62	0.53	1.36	0.06	0.70	0.46	0.06	1.14

Notes: The results presented in each column and panel are based on a separate FE regression. Other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A5: Heterogeneity in the cyclone impact on life satisfaction (continued)

Separate by:	Gender		Age		Home ownership		Household income		Residential insurance		Rural/urban		Distance to coast		Locality cyclone history	
	Female	Male	Young	Old	Renter	Owner	Poorer	Richer	Uninsured	Insured	Rural areas	Urban areas	Coastal areas	Inland areas	Cyclone-free areas	Cyclone-prone areas
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Panel E:	Community satisfaction															
Any category 5 cyclone within 100 km	-0.08	-0.17**	-0.14**	-0.02	-0.13	-0.08	-0.09	-0.12*	-0.13**	-0.06	-0.08	-0.28	-0.12*	-0.08	-0.43**	-0.08*
	[0.07]	[0.07]	[0.07]	[0.07]	[0.08]	[0.06]	[0.06]	[0.07]	[0.07]	[0.07]	[0.05]	[0.22]	[0.06]	[0.08]	[0.21]	[0.05]
Observations	177,391	159,327	103,101	97,214	73,544	136,673	121,007	89,210	109,685	86,018	78,222	117,481	98,324	97,379	101,179	94,524
Num of unique persons	17,748	16,729	12,528	8,934	6,982	11,111	10,025	8,068	8,697	6,369	5,948	9,118	7,577	7,489	7,870	7,196
Mean of dep. variable	6.82	6.68	6.54	7.01	6.42	6.94	6.69	6.84	6.61	6.97	6.92	6.67	6.80	6.73	6.86	6.66
Proportion affected (%)	0.35	0.36	0.64	0.54	0.70	0.49	0.57	0.55	0.62	0.53	1.36	0.06	0.70	0.46	0.06	1.13
Panel F:	Neighbourhood satisfaction															
Any category 5 cyclone within 100 km	-0.06	-0.10	-0.09	0.05	-0.06	-0.07	-0.08	-0.02	-0.07	-0.08	-0.04	-0.23	-0.06	-0.08	-0.34	-0.05
	[0.06]	[0.06]	[0.07]	[0.06]	[0.08]	[0.05]	[0.06]	[0.06]	[0.07]	[0.06]	[0.05]	[0.21]	[0.06]	[0.07]	[0.23]	[0.05]
Observations	177,531	159,414	103,198	97,276	73,627	136,753	121,100	89,280	109,840	86,051	78,315	117,576	98,370	97,521	101,267	94,624
Num of unique persons	17,751	16,733	12,534	8,937	6,984	11,115	10,025	8,074	8,704	6,370	5,953	9,121	7,579	7,495	7,874	7,200
Mean of dep. variable	7.92	7.86	7.75	8.03	7.61	8.03	7.77	8.03	7.76	8.04	7.96	7.84	7.97	7.80	7.92	7.84
Proportion affected (%)	0.35	0.36	0.64	0.54	0.70	0.48	0.57	0.55	0.62	0.53	1.36	0.06	0.70	0.46	0.06	1.14
Panel G:	Personal safety satisfaction															
Any category 5 cyclone within 100 km	0.00	-0.10*	-0.13**	0.05	-0.05	-0.05	-0.09*	0.01	-0.03	-0.06	-0.04	0.07	-0.07	-0.01	-0.08	-0.05
	[0.05]	[0.05]	[0.05]	[0.05]	[0.06]	[0.04]	[0.05]	[0.05]	[0.05]	[0.05]	[0.04]	[0.14]	[0.05]	[0.06]	[0.15]	[0.04]
Observations	177,684	159,506	103,255	97,364	73,734	136,819	121,194	89,359	109,947	86,100	78,364	117,683	98,447	97,600	101,347	94,700
Num of unique persons	17,761	16,736	12,536	8,940	6,989	11,115	10,026	8,078	8,704	6,372	5,952	9,124	7,581	7,495	7,875	7,201
Mean of dep. variable	8.18	8.32	8.26	8.20	8.11	8.29	8.12	8.39	8.18	8.33	8.37	8.17	8.28	8.21	8.27	8.22
Proportion affected (%)	0.35	0.36	0.64	0.54	0.70	0.49	0.57	0.55	0.62	0.53	1.36	0.06	0.70	0.46	0.06	1.14
Panel H:	Health satisfaction															
Any category 5 cyclone within 100 km	-0.05	-0.17***	-0.12**	-0.04	-0.11*	-0.08*	-0.08	-0.11*	-0.11**	-0.09*	-0.10**	-0.08	-0.04	-0.20***	-0.38*	-0.09**
	[0.06]	[0.05]	[0.06]	[0.06]	[0.07]	[0.05]	[0.05]	[0.06]	[0.05]	[0.06]	[0.04]	[0.18]	[0.05]	[0.07]	[0.21]	[0.04]
Observations	177,737	159,565	103,287	97,418	73,764	136,877	121,222	89,419	109,984	86,154	78,417	117,721	98,477	97,661	101,386	94,752
Num of unique persons	17,761	16,736	12,540	8,940	6,992	11,116	10,028	8,080	8,706	6,374	5,956	9,124	7,581	7,499	7,877	7,203
Mean of dep. variable	7.22	7.31	7.55	6.96	7.11	7.35	7.09	7.51	7.13	7.44	7.23	7.29	7.35	7.18	7.29	7.24
Proportion affected (%)	0.35	0.36	0.64	0.54	0.70	0.49	0.57	0.55	0.62	0.53	1.36	0.06	0.70	0.46	0.06	1.14

Notes: The results presented in each column and panel are based on a separate FE regression. Other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A6: First stage regression results

Distance to cyclone eye:	Within 40 km		Within 100 km	
Cyclone category:	Any	Category 5	Any	Category 5
	(1)	(2)	(3)	(4)
Cyclone exposure measure	4.16***	12.12***	1.86***	7.48***
	[0.48]	[1.57]	[0.24]	[1.00]
Age	0.49	0.41	0.47	0.44
	[0.72]	[0.72]	[0.72]	[0.72]
Age squared	-0.00*	-0.00*	-0.00*	-0.00*
	[0.00]	[0.00]	[0.00]	[0.00]
Married [(a)]	0.14	0.14	0.15	0.14
	[0.28]	[0.28]	[0.28]	[0.28]
Separated [(a)]	0.16	0.16	0.17	0.17
	[0.43]	[0.43]	[0.43]	[0.43]
Year 12 [(b)]	-0.41	-0.44	-0.40	-0.42
	[0.30]	[0.30]	[0.30]	[0.30]
Vocational or training qualification [(b)]	-0.38	-0.40	-0.37	-0.38
	[0.39]	[0.39]	[0.39]	[0.39]
Bachelor degree or higher [(b)]	-1.01**	-1.03**	-0.99**	-1.02**
	[0.43]	[0.43]	[0.43]	[0.43]
Household size	0.00	0.00	0.00	0.00
	[0.06]	[0.06]	[0.06]	[0.06]
Major city	-1.32***	-1.27***	-1.31***	-1.26***
	[0.30]	[0.30]	[0.30]	[0.30]
Local area unemployment rate	-0.13*	-0.22***	-0.11	-0.21***
	[0.07]	[0.06]	[0.07]	[0.06]
Local area SEIFA index	-0.09**	-0.09**	-0.08**	-0.09**
	[0.04]	[0.04]	[0.04]	[0.04]
Observations	123,908	123,908	123,908	123,908
Number of unique persons	14,241	14,241	14,241	14,241
F statistic	176.66	322.06	85.39	224.93

Notes: Results in each column are from a separate first stage regression of "overall life satisfaction" as an outcome. Results (coefficient estimates and standard errors) are multiplied by 100 for aesthetic purposes. Other explanatory variables include state/territory dummies, year dummies, and survey month dummies. [(a)] and [(b)] indicates "Never married" and "Under year 12 qualification" as the comparison group, respectively. "F-statistic" denotes the F statistic for the strength of the respective instrument, identified by distance to the cyclone eye and cyclone category as mentioned on the first and second row of this table, in the first stage regression. Robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A7: Robustness checks for the impacts of weather-related home damage on life satisfaction

	Overall life satisfaction	Employment opportunity satisfaction	Financial situation satisfaction	Home satisfaction	Community satisfaction	Neighbourhood satisfaction	Personal safety satisfaction	Health satisfaction
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Baseline								
Home damage	-0.86*	-0.46	-0.35	0.81	-0.85	0.18	0.39	-1.60**
	[0.50]	[0.86]	[0.73]	[0.66]	[0.73]	[0.64]	[0.52]	[0.63]
Observations	123,908	97,413	123,817	123,841	123,637	123,744	123,840	123,914
Num of unique persons	14,241	12,815	14,231	14,239	14,232	14,234	14,238	14,241
F statistic	224.93	225.28	224.08	224.53	225.36	226.89	224.65	225.17
Panel B1: Different sample - Including only local government areas with at least one cyclone within 100 km								
Home damage	-0.83*	-0.70	0.11	0.56	-0.23	0.34	0.27	-1.63***
	[0.49]	[0.82]	[0.71]	[0.63]	[0.68]	[0.60]	[0.51]	[0.61]
Observations	44,906	35,508	44,867	44,869	44,799	44,854	44,876	44,907
Num of unique persons	5,451	4,922	5,448	5,450	5,446	5,451	5,450	5,452
F statistic	187.67	188.42	187.45	187.37	187.84	189.41	187.6	187.66
Panel B2: Different sample - Using a sample of all individuals observed in the data								
Home damage	-0.99*	-0.59	-0.38	0.80	-1.24	-0.36	0.37	-1.77***
	[0.52]	[0.88]	[0.75]	[0.67]	[0.77]	[0.67]	[0.53]	[0.66]
Observations	204,937	163,098	204,745	204,808	204,527	204,673	204,830	204,932
Num of unique persons	22,885	20,646	22,864	22,882	22,870	22,876	22,880	22,882
F statistic	264.17	266.76	263.12	263.62	264.8	266.27	263.8	264.21
Panel C1: Different specification - Employing an instrumental variable model without controlling for individual fixed effects								
Home damage	-0.33	-1.41	-0.05	0.43	-0.57	-0.36	-0.19	-0.54
	[0.56]	[0.95]	[0.83]	[0.63]	[0.79]	[0.68]	[0.53]	[0.72]
Observations	126,277	100,092	126,189	126,210	125,999	126,103	126,208	126,281
F statistic	314.03	289.55	313.62	313.26	306.68	315.09	313.05	313.66

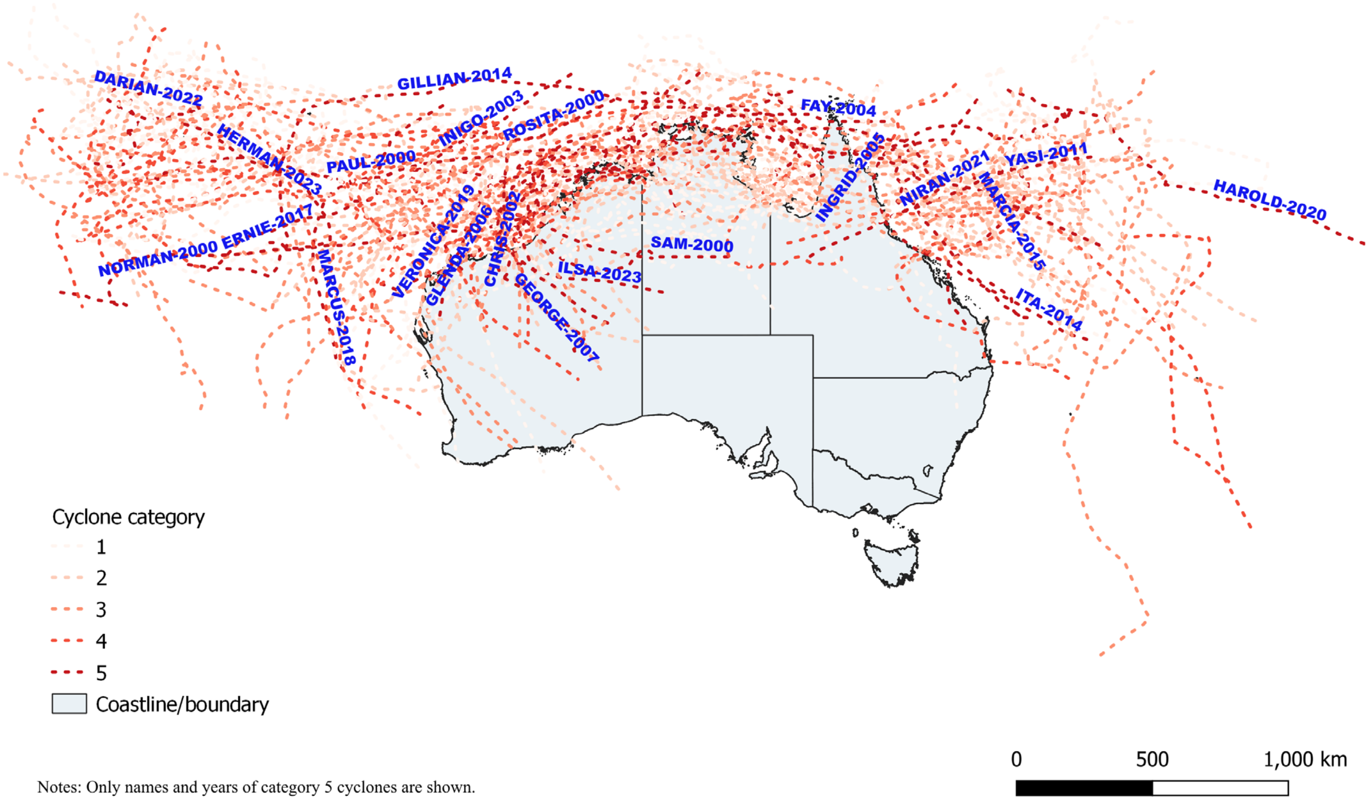
Notes: Results reported in each column and panel are from a separate FE-IV regression, unless indicated otherwise. Instrument: Exposure to a category 5 cyclone within 100 km. "F-statistic" denotes the F statistic for the strength of the instrument. Unless stated otherwise, other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Unless indicated otherwise, robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A7: Robustness checks for the impacts of weather-related home damage on life satisfaction (continued)

	Overall life satisfaction	Employment opportunity satisfaction	Financial situation satisfaction	Home satisfaction	Community satisfaction	Neighbourhood satisfaction	Personal safety satisfaction	Health satisfaction
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C2: Different specification - Employing a Random Effects instrumental variable model								
Home damage	-0.69	-0.48	-0.27	0.86	-0.87	0.17	0.45	-1.45**
	[0.49]	[0.86]	[0.72]	[0.63]	[0.72]	[0.63]	[0.50]	[0.62]
Observations	126,277	100,092	126,189	126,210	125,999	126,103	126,208	126,281
Num of unique persons	16,610	15,494	16,603	16,608	16,594	16,593	16,606	16,608
F statistic	65.25	61.83	65.33	65.23	64.32	65.58	65.26	65.3
Panel C3: Different specification - Excluding some time variant variables such as education, marital status, household size and major city								
Home damage	-0.98*	-0.88	-0.62	0.78	-0.85	0.09	0.26	-1.61**
	[0.52]	[0.87]	[0.74]	[0.66]	[0.74]	[0.65]	[0.52]	[0.64]
Observations	123,908	97,413	123,817	123,841	123,637	123,744	123,840	123,914
Num of unique persons	14,241	12,815	14,231	14,239	14,232	14,234	14,238	14,241
F statistic	219.79	221.37	218.93	219.33	220.24	221.68	219.46	219.96
Panel C4: Different specification - Including a time variant variable: non-wage income								
Home damage	-0.85*	-0.48	-0.36	0.80	-0.85	0.16	0.37	-1.61**
	[0.51]	[0.86]	[0.73]	[0.66]	[0.74]	[0.64]	[0.52]	[0.64]
Observations	123,753	97,312	123,664	123,686	123,486	123,589	123,685	123,759
Num of unique persons	14,234	12,812	14,224	14,232	14,226	14,227	14,231	14,234
F statistic	223.2	224.65	222.61	222.8	223.63	225.15	222.91	223.43
Panel C5: Different specification - Including a time variant variable: SF 36 general health summary								
Home damage	-0.76	-0.48	-0.28	0.77	-0.80	0.12	0.31	-1.46**
	[0.49]	[0.86]	[0.72]	[0.66]	[0.73]	[0.64]	[0.52]	[0.58]
Observations	122,805	96,747	122,717	122,738	122,537	122,641	122,737	122,810
Num of unique persons	14,205	12,774	14,196	14,203	14,196	14,197	14,202	14,205
F statistic	225.26	227.6	224.35	224.8	225.65	227.24	224.92	225.44

Notes: Results reported in each column and panel are from a separate FE-IV regression, unless indicated otherwise. Instrument: Exposure to a category 5 cyclone within 100 km. "F-statistic" denotes the F statistic for the strength of the instrument. Unless stated otherwise, other explanatory variables include age (and its square), marital status, education, household size, local area socio-economic variables, state/territory dummies, year dummies, and survey month dummies. Unless indicated otherwise, robust standard errors clustered at the individual level in parentheses. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

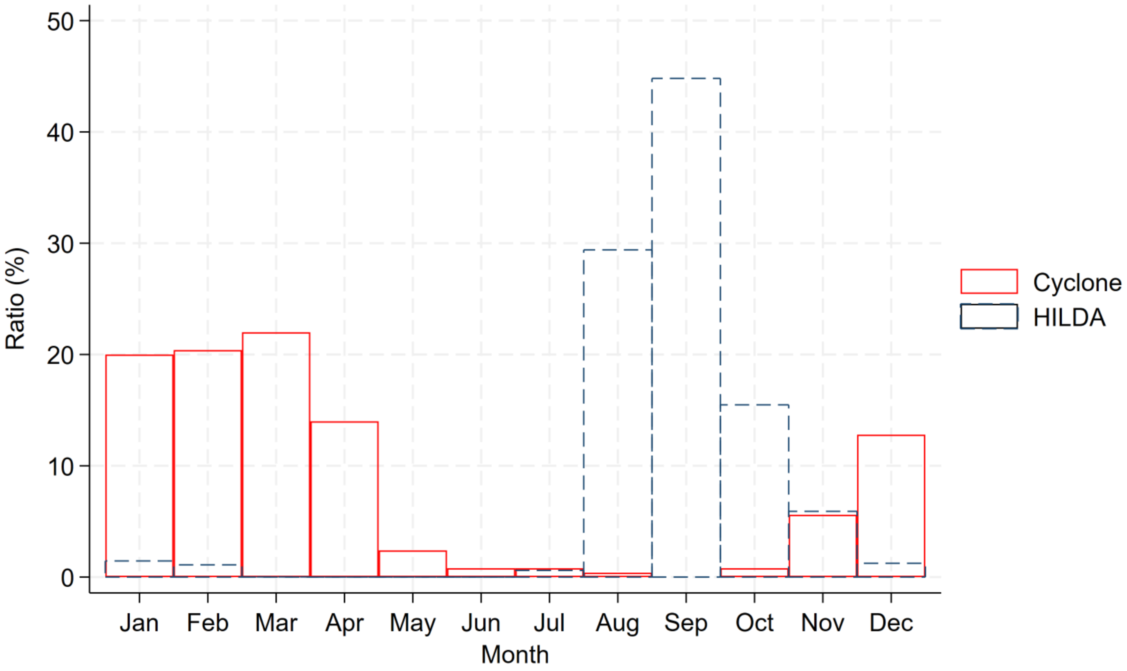
Appendix Figure A1: Tropical cyclone hit map between 2000 and 2023



Notes: Only names and years of category 5 cyclones are shown.

Notes: Cyclone category is classified using the maximum wind speed cut-offs from BOM. Only names and years of category 5 cyclones are listed.

Appendix Figure A2: Distribution of cyclone occurrence and HILDA interview dates



Notes: Data from historical tropical cyclone observed from 2000 to November 2023 and HILDA Release 22.

Appendix Table B1: Summary of the literature on natural disasters and life satisfaction/subjective wellbeing/happiness

Study	**Dependent variable**	**Disaster event and main exposure measure**	**Level of disaster exposure measure**	**Location**	**Main micro dataset and panel nature**	**Main findings**
Carroll *et al.* (2009)	Life satisfaction (10-point scale)	Event: Droughts Measure: Meteorological drought	Regional (Postcode level)	Australia	Dataset: Australian Unity Wellbeing Index survey with about 2,000 individuals surveyed each wave Data type: Repeated cross-sectional	Negative only for rural residents
Luechinger and Raschky (2009)	Life satisfaction (4-point scale)	Event: Floods Measure: Events are included if they fulfill at least one of the following criteria: 10 or more people reported killed, 100 people reported affected, declaration of a state of emergency or call for international assistance	Regional (NUTS 2 level)	Europe	Dataset: Eurobarometer Survey Series Data type: Repeated cross-sectional	Negative
Kountouris and Remoundou (2011)	Life satisfaction (4-point scale)	Event: Forest fires Measure: Number of forest fire incidents and the forest area affected	Regional (NUTS 2 level)	Europe	Dataset: Eurobarometer Survey Series Data type: Repeated cross-sectional	Negative only for rural residents
Calvo *et al.* (2015)	Happiness (4-point scale)	Event: Hurricane Katrina Measure: Self-reported hurricane stressors, bereavement, and property damage	Individual	US	Dataset: 491 women affected by Hurricane Katrina Data type: Panel	Negative
Rehdanz *et al.* (2015)	Self-reported wellbeing (11-point scale)	Event: Tsunami and nuclear accident at Fukushima in 2011 Measure: Distance from the individual's residing municipality to the disaster	Regional (municipality level)	Japan	Dataset: Panel data for 5,979 individuals interviewed in Japan before and after the disaster Data type: Panel	- Negative - More pronounced for residents in greater proximity to the disaster
Berlemann (2016)	Happiness (4-point scale) and life satisfaction (10-point scale)	Event: Hurricanes Measure: Annual number of hurricanes whose centres pass a country's borders up to a 160 km distance	Country	Multiple countries	Dataset: European/World Values Survey Data type: Repeated cross-sectional	- Negative - More pronounced for lower income countries - No lasting impact
Sekulova and Van den Bergh (2016)	Life satisfaction (10-point scale)	Event: Floods Measure: Self-reported material and psychological damages	Individual	Bulgaria	Dataset: Survey about 600 respondents Data type: Cross-sectional	Negative

Study	Dependent variable	Disaster event and main exposure measure	Level of disaster exposure measure	Location	Main micro dataset and panel nature	Main findings
Van Ootegem and Verhofstadt (2016)	Life satisfaction (11-point scale)	Event: Floods Measure: Self-reported severity of the flood, the recurrence of floods and their fear of future flooding	Individual	Belgium	Dataset: Survey about 1,000 respondents Data type: Cross-sectional	Insignificant impact
von Möllendorff and Hirschfeld (2016)	Life satisfaction (11-point scale)	Event: Multiple natural disasters Measure: Events are based on their intensity which is approximated by the claims expenditure they caused for insurances	Regional (NUTS 3 regions)	Germany	Dataset: German Socio-Economic Panel Study (SOEP) Data type: Panel	- Negative - Floods have a lasting impact
Hudson *et al.* (2019)	Subjective wellbeing (11-point scale) and 7 domains	Event: Floods Measure: Self-reported flood experiences	Individual	France	Dataset: Survey of 900 flood-prone households in France Data type: Cross-sectional	Negative
Lohmann *et al.* (2019)	Life satisfaction (10-point scale)	Event: Heavy storms and droughts Measure: Self-reported past experienced events, damage suffered, perceived vulnerability and expectations for future events to occur	Individual	Papua New Guinea	Dataset: Survey 515 respondents Data type: Cross-sectional	Negative for droughts
Ahmadiani and Ferreira (2021)	Life satisfaction (4-point scale)	Type: Multiple extreme weather events. Measure: Number of deaths and estimated monetary damages	Regional (county level)	US	Dataset: Behavioral Risk Factor Surveillance System Data type: Repeated cross-sectional	Negative
Berlemann and Eurich (2021)	Expected future wellbeing (10-point scale)	Event: Droughts Measure: Drought severity and drought risk are measured at a 5 km-grid-level	Regional (Zip code)	US	Dataset: Gallup Daily Tracking Survey Data type: Repeated cross-sectional	- Negative - More pronounced for poorer individuals
Johnston *et al.* (2021)	Life satisfaction (11-point scale) and 6 satisfaction domains	Event: The 2009 Black Saturday Bushfires Measure: Distance from individual's residing region to wildfires	Regional (Statistical Areas Level 1 (SA1))	Australia	Dataset: Household, Income and Labour Dynamics in Australia (HILDA) Data type: Panel	- Negative - More pronounced for females, older, unmarried, or lower income individuals - No lasting impact
Frijters *et al.* (2023)	Wellbeing (11-point scale)	Type: Multiple natural disasters Measure: County is identified as affected if it received a presidential Major Disaster Declaration	Regional (county level)	US	Dataset: Gallup Polls Data type: Repeated cross-sectional	- Negative - More pronounced for white, older, and economically advantaged subpopulations.

Study	**Dependent variable**	**Disaster event and main exposure measure**	**Level of disaster exposure measure**	**Location**	**Main micro dataset and panel nature**	**Main findings**
Gunby and Coupé (2023)	Life satisfaction (11-point scale) and home satisfaction	Event: Weather-related home damage Measure: Self-reported home damage	Individual	Australia	Dataset: Household, Income and Labour Dynamics in Australia (HILDA) Data type: Panel	Insignificant impact

Notes: The studies are listed chronologically and alphabetically.