The Exposure of Australia's Housing Stock to Climate Risks

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Abstract:

Climate change has significantly influenced the intensity and frequency of extreme weather events impacting the globe, including Australia. This has implications for various sectors, including the housing market. Utilizing postcode-level climate risk data—including for cyclones, fires, floods, and droughts—and data from the 2006, 2011, 2016, and 2021 censuses, we scrutinize the susceptibility of Australia's stock of dwellings to such hazards. Our investigation focuses on three main questions. First, we try to understand how the exposure of the housing sector to different climate hazards is dispersed geographically and how the vulnerability to extreme weather events evolved over time. Second, we investigate the extent to which the location of new homes throughout this period has raised or lowered the vulnerability of the housing stock. Third, we outline the historical trajectory of the housing sector's climate susceptibility and use our data to estimate how this is likely to evolve out to 2100. Our analysis reveals that the Australian housing stock displays pronounced susceptibility to water stress, a moderate degree of vulnerability to wildfires, and only a slight susceptibility to floods, cyclones, and heatwaves. Furthermore, our findings indicate that growth in the Australian housing stock shows an inverse correlation with the risk posed by heatwaves and the anticipated shifts in wildfire risk, whereas they exhibit no discernible association with other hazards.

Keywords: Climate Risk, Dwellings, Housing, Australia.

JEL Classification Codes: Q54, R14, R31.

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1. Introduction

Climate change has emerged as a significant and widely discussed subject, captivating numerous scholars not only within Australia but across the globe. According to the latest "State of the Climate" report by the Bureau of Meteorology (BoM 2022), Australia has experienced an increase in average temperatures of approximately 1.5°C since the commencement of national records in 1910. The anticipated future for Australia entails persistent alterations in weather and climate. These changes encompass reduced winter rainfall in agricultural regions located in the southern and eastern parts of the country, an increase in instances of extreme heat, extended fire seasons, and a decrease in the number of tropical cyclones, although they may exhibit higher intensity (BoM 2022). These changes in climatic conditions are likely to impact the cost of building, maintaining, repairing, and replacing properties, their durability and vulnerability to extreme events. Our focus in this research is to provide some insight on the exposure of Australia's housing stock to climatic risks. In doing so, we make use of a novel dataset that provides climate risk measures for a range of hazards.

Climate risks have already exerted substantial influence on the geography of economic activity. For example, Dell et al. (2012) reveal that a 1°C increase in temperature in a given year results in a 1.4 percent decline in per capita income, primarily affecting impoverished nations. Ruth et al. (2007) and Johar et al. (2022) provide a comprehensive report on the economic consequences of climate change and natural disasters, estimating the current output loss caused by forest fires, floods, droughts, and other factors. Stern (2007) emphasizes the substantial risks and costs associated with climate change, projecting that without action, the world could lose at least 5 percent of its global GDP annually, both in the present and perpetuity. In Australia, Garnaut (2008, 2011) offers valuable insights into the severe and expensive effects of climate change on agriculture, infrastructure, biodiversity, and ecosystems.

A growing body of empirical evidence indicates that extreme climatic shocks could exhibit a more profound impact on other aspects such as productivity and change in urbanisation. For example, Sivakumar et al. (2005) show that climate change induces environmental and social strain across many of Asia's rangelands and drylands. In Africa's arid and semi-arid tropics, where environmental stress is already a challenge, climate change poses a significant risk to agriculture, primarily due to an increase in drought frequency. In Latin America, the agricultural sector and water resources are most vulnerable to extreme temperatures (such as excessive heat and frost) and shifts in rainfall patterns, including both droughts and flooding events. Providing evidence on urbanisation effect of climate risks, Barrios et al. (2006) and Henderson et al. (2017) find that climatic conditions have a notable impact on urbanisation rates. Favourable conditions tend to slow down urbanisation, whereas unfavourable conditions contribute to a higher rate of urban population growth.

Several studies have illustrated the response of housing markets to climate hazards like floods, storms, and related events (Severen et al., 2018; Kim, 2020; Nguyen et al., 2022). Nevertheless, there remains a gap in our understanding concerning the impact of climate incidents on housing stocks, particularly in Australia. Our paper explores the following three issues. First, we try to understand how the exposure of the housing sector to different climate hazards is dispersed geographically and how the vulnerability to extreme weather events has evolved over time. Second, we investigate the extent to which the location of new homes has raised or lowered the vulnerability of the housing stock. Third, we outline the historical trajectory of the housing sector's climate susceptibility and use our data to estimate how this is likely to evolve out to 2050.

We combine climate risk data at the Australian postcode level with housing stock and sales data sourced from the Census and CoreLogic respectively. We find that the Australian housing stock, when assessed collectively, exhibits a significant vulnerability to water stress, a moderate vulnerability to wildfires, and a minimal vulnerability to floods, cyclones, and heat waves. Moreover, we find that the changes in Australian housing stock are negatively correlated with heatwave risk and projected changes in wildfire risk and not related to other hazards.

Our research adds to the literature on climate change in Australia. The last decade has seen investigations on the impact of climate incidents on human lives and activities. For example, through the application of the synthetic control method and utilizing Australia's Millennium drought as a case study of an extreme weather event, Sheng and Xu (2019) document that the severe droughts experienced from 2002 to 2010 caused an 18 percent reduction in agricultural total factor productivity over the period. Hutley et al. (2022) from the Climate Council suggest that climate change increases insurance premiums in Australia, causing an insurability crisis. They also note that riverine floods pose the costliest hazard to properties. The most recent study by Kurian et al. (2023) shows that climate change presents financial institutions with a dual landscape, comprising both risks and opportunities. Financial institutions are required to actively monitor and effectively manage both the physical and transition risks originating from climate change. We provide evidence that climate risks, such as heatwaves, affect the Australian housing stock and alter the behaviour of home-builders.

The remainder of the paper proceeds as follows. Section 2 describes the data. Section 3 shows our analysis results and Section 4 concludes the work.

2. Data

Our geographic focus is the postcode level in Australia. Postcodes are useful for analysis because they are consistent through time, cover the whole of Australia, are widely understood, and provide meaningful segmentation of housing markets. Moreover, in most cases they provide a small enough scale to usefully consider climate risks. This is particularly the case for climate risks such as wildfires, heatwaves, and cyclones. The possible exception is flooding, which can be highly localised and reflect the topography of an area.

We use Australian housing stock data at the postcode level from the 5-yearly Census of Population and Housing. This data covers 2515 postcodes (8,446,723 dwellings) in 2006, 2513 postcodes (9,139,685 dwellings) in 2011, 2668 postcodes (9,924,642 dwellings) in 2016, and 2641 postcodes (10,874,664 dwellings) in 2021. Our focus is the number of dwellings in each postcode. This is then linked with data on the exposure of the postcode to climate risks. We also incorporate CoreLogic's monthly housing sales data, spanning 2645 postcodes from 1990 to 2023. To facilitate the analysis, we convert the data into yearly averages. Additionally, we utilize the household income data from the 2021 census, encompassing various income brackets and the corresponding number of households falling within each income range for that year.

Our climate risk metrics are provided by Sust Global[4]. This data encompasses a range of climate hazards such as wildfires, floods, cyclones, heatwaves, and water stress. These hazards are analysed within the context of three prominent Shared Socioeconomic Pathways (SSP1, SSP2, and SSP5) that represent different future trajectories.

SSP1, known as the Green Road (SSP1-RCP2.6), represents an optimistic sustainable path. It encompasses socioeconomic and emissions trajectories that align with a widespread and

[4] Sust Global's metrics are derived from state-of-the-art global climate models participating in the Coupled Model Intercomparison Project phase 6 (CMIP6). Outputs from these models are combined with various observational datasets to bias-correct and downscale these climate simulations to local areas. The methods are outlined in detail in Sust Global (2023) and Erinjippurath and Ballard (2023).

enduring global transition towards a more sustainable future. Starting around 2020, carbon emissions start to decline, and global mean temperatures are projected to increase by approximately 1.8°C by 2100, a crucial objective outlined in the Paris Climate Agreement.

SSP2, known as the Middle Path (SSP2-RCP4.5), presents challenges in terms of climate mitigation. In this scenario, global emissions continue to increase until the middle of the century before gradually declining. Environmental systems suffer significant degradation, and climate change worsens throughout the remainder of the century. This scenario is often regarded as the probable outcome if governments and policies lack a strong sense of urgency towards climate adaptation. Global mean temperatures are projected to rise by approximately 2.4°C by 2100, with higher emissions increasing the risk of reaching tipping points.

SSP5, known as Fossil-Fueled Growth (SSP5-RCP8.5), portrays a future in which the world follows its current trajectory. In this scenario, both the global population and per-capita consumption continue to rise. Emissions reach their peak around 2090, resulting in a global mean temperature increase of approximately 4.3°C by 2100.

Figures 1-5 illustrate the geographic dispersion and temporal evolution of climate risks. We conducted a comparison between two specific years, namely 2021 and 2050, in order to highlight the changes. The intensity of the climate risk is represented by varying shades of orange on the map, with darker shades indicating higher risk levels. The assessment of risks associated with wildfires, floods, and cyclones involves quantifying the probability of these severe events happening within a specific timeframe. On the other hand, water stress is evaluated using a scale that ranges from 0 to 1, representing a weighted average score. Heatwaves are determined by counting the total days in a year when temperatures surpass the historical 98th percentile. Additional information can be found in Appendix 1A.

[Insert Figures 1-5 here]

In Figure 1, we observe the wildfire risk in 2021, ranging from 0.02 to 0.14. Regions most vulnerable to wildfires were identified as Northern Territory and Western Australia. Looking ahead to 2050, the risk level is projected to increase significantly, reaching a maximum of 0.2. Furthermore, the regions that experienced high susceptibility in 2021 are expected to maintain their high vulnerability in 2050. The second most significant climate hazard is heatwaves. In 2021, the maximum number of days with heatwave conditions was recorded as 22. Queensland, Northern Territory, and Western Australia were most susceptible to heatwaves. The risk level is expected to rise dramatically to 50 days by the year 2050. As for other climate incidents, we observed relatively minor fluctuations over the years, suggesting little significant change in their occurrence.

3. Methods and Results

3.1. How is the vulnerability of housing stock to extreme weather events dispersed geographically?

To demonstrate the susceptibility of housing inventory to climate-related incidents, we undertake various statistical analyses. Table 1 presents summary statistics across all postcodes in Australia. Our findings reveal the average risk levels of various natural disasters and environmental challenges spanning the years 2006 to 2021.

[Insert Table 1 here]

We find that the risk of wildfires ranges from 0.017 to 0.019, with an average value across the examined period. Flooding risk falls at 0.002, while the probability for cyclone risk is approximately 0.001. Furthermore, the risk of water stress fluctuates between 0.521 and 0.536. When considering heatwaves, their risk demonstrates significant variation, declining from 7.927 days in 2006 to 6.881 days in 2021.

We then examine the exposure of Australian postcodes and housing stock to climate risks and report the results in Tables 2 and 3, respectively. Risks are classified into high, medium, and low ranges based on Sust Global’s breakpoints (see Appendix 1A). We find that Australian housing stock, when assessed collectively, exhibits a significant vulnerability to water stress, a moderate vulnerability to wildfires, and a minimal vulnerability to floods, cyclones, and heatwaves.

[Insert Table 2, 3 here]

Specifically, as shown in Table 3, in 2021, approximately 70.18% of Australian properties were situated in areas with a medium risk of wildfires, while 95.41% were located in low-risk flooding areas. Additionally, 94.34% of properties were situated in low-risk cyclone areas, and 55.89% faced a high risk of water stress. These findings emphasize the importance of understanding the existing geographical distribution of postcodes and properties exposed to various levels of susceptibility to climate hazards.

Subsequently, we compute the Gini index to quantify whether there was increasing or decreasing polarization in the impacts of climate change. It ranges between 0 and 1. A higher Gini index suggests greater inequality in the distribution of climate risks, indicating that a few postcodes bear a disproportionate share of the risks, while others have relatively lower exposure. A lower Gini index indicates a more balanced distribution of climate risks across the postcodes.

[Insert Figure 6 here]

As shown in Figure 6, over the surveyed years, the Gini coefficients for cyclones and floods are really high indicating a great deal of inequality across postcodes. This phenomenon aligns with our earlier findings, as a majority of postcodes are characterized by minimal or zero risks. In contrast, the Gini index is comparatively lower for other cases suggesting that all postcodes entail some level of risk. This emphasizes the need for targeted interventions in regions marked by heightened risk inequality, while also emphasizing the importance of comprehensive risk management strategies across the board.

3.2. Are climate risks focused in affluent or poorer areas?

In this section, we examine whether climate risks are concentrated in affluent or poorer areas. Firstly, we collect the Australian housing sales data from CoreLogic. To conduct a cross-sectional analysis, we divide the sample into three equal parts, or terciles, based on the annual average sale price. Within each of these groups, we count the number of postcodes categorized as facing high, medium, or low risk. The results for the year 2021 are summarized in Table 4[5]. Our analysis reveals that a significant portion of the expensive postcodes demonstrates a moderate susceptibility to wildfires, but they exhibit a high susceptibility to water stress. Additionally, we observe a consistent pattern concerning cyclones, aligning with the widely held notion that areas with minimal vulnerability are valued higher due to reduced housing damage.

[Insert Table 4 here]

Secondly, we address the disparities in climate risk exposure among different income groups. The census provides us with household income data, which we use to calculate the average annual household income specifically for the year 2021. Afterward, we integrate this data with

[5] To save space, we do not report the results for other years in this paper.

climate risk information sourced from Sust Global. Our subsequent step involves dividing the sample into three terciles based on the average income. Within each of these groups, we assess the count of postcodes falling under high, medium, and low-risk categories. The findings are documented in Table 5. Similar to the previous results, we observe a pattern where high-income households tend to cluster in regions with moderate vulnerability to wildfires, low vulnerability to floods, cyclones, and heatwaves, but relatively higher risk of water stress. This suggests that wealthier communities may be more resilient to certain climate hazards while facing specific challenges related to water availability and stress. In contrast, households with lower incomes face a greater-than-proportionate susceptibility to wildfire risk. Similarly, albeit to a lesser degree, these households are also subject to increased cyclone risk to a greater extent. This highlights the notable imbalance in the vulnerability of low-income communities to climate-related hazards due to their relatively limited capacity to adapt.

[Insert Table 5 here]

3.3. Have changes to the housing stock increased or decreased the climate vulnerability of Australia's homes?

The quantity of newly constructed dwellings exposed to climate risks has predominantly risen in comparison to a block of the previous five years, as shown in Table 6. For example, in contrast to the figures from 2016, there is a notable increase in the proportion of properties facing varying degrees of susceptibility to wildfires in 2021. This includes 28.49% (equivalent to 271,922) new properties categorized as highly susceptible, 71.49% (equivalent to 682,340) new properties classified as moderately susceptible, and 0.02% (equivalent to 216) new properties identified as minimally susceptible to wildfires.

[Insert Table 6 here]

Recent additions to the housing stock in Australia have increased the climate vulnerability of homes. The rise in properties facing varying degrees of susceptibility to climate hazards indicates a growing concern for housing resilience in the face of climate change impacts. The findings from the cross-sectional analysis further underscore the significance of considering climate risk when evaluating property markets, particularly in high-value areas, to ensure appropriate measures are taken to address and adapt to the escalating climate challenges.

In order to assess the impact of climate hazards on Australian housing stock, we conducted the following regression analysis of the changes in the number of dwellings on lagged values of various climate hazard measures, including wildfires, cyclones, floods, heatwaves, and water stress scores:

$$\triangle Ln(Dwellings)_{it} = a_0 + \sum_{k=1}^{6} \beta_{ki} ClimateRisks_{kit-5} + Postcode\ FE + Time\ FE + \varepsilon_{it} \quad (1)$$

Where $\triangle Ln(Dwellings)_{it}$ denotes the change in log of the number of dwellings in postcode *i* in year *t*. $ClimateRisks_{kit-5}$ is a vector of six climate risks including *wildfire, flood, cyclone, heatwave, and water stress* in the past 5 years. Postcode-fixed effects and time-fixed effects are included in the regression. The *β's* are the coefficients of interest.

We present the regression result in Table 7. Our findings indicate that, out of the six climate threats analysed, only heatwaves have a significant influence on the quantity of Australian properties. Specifically, while the coefficients for other climate risk measures are not statistically significant, the coefficient for heatwaves is negative and statistically significant at the 1% level. This outcome aligns with the current situation in Australia. Coates et al. (2014) highlight heatwaves have been the most significant hazard, causing more fatalities in Australia over the past two centuries than other natural disasters. In fact, heatwaves accounted for 55% of all recorded natural hazard fatalities in PerilAUS from 1900 to 2011, surpassing the combined total of all other listed hazards. Additionally, the 2022 Intergovernmental Panel on Climate Change (IPCC) report predicts a four-fold increase in urban heat-related excess deaths in Melbourne, Sydney, and Brisbane between 2031 and 2080 compared to the period of 1971-2020.

[Insert Table 7 here]

Next, we conduct a regression analysis, examining the relationship between the total number of properties sold (scaled by the total listed properties) and the lagged values of the five climate threats. The results of this analysis are presented in Table 8.

Our findings reveal that the majority of the coefficients exhibit negative values, indicating an inverse association between climate threats and property sales. Notably, three coefficients are statistically significant at the 1% level. Specifically, the coefficients for *Cyclone*, *Heatwave*, and W*ater stress* are -10,599.290 *(t = -4.682)*, -7.773 *(t = -14.244)*, and -112.643 *(t = -10.720)* respectively.

[Insert Table 8 here]

These results align with our initial expectation that higher levels of climate risk, particularly cyclones, heatwaves, and water stress, are linked to a reduction in the number of properties sold in the corresponding areas. The presence of significant coefficients emphasizes the importance of considering climate threats as influential factors when analysing property sales trends and underscores the potential impact of climate risk on real estate markets.

Finally, our analysis focuses on investigating the relationship between the changing landscape of Australian housing and projected climate risks. With the assistance of Sust Global, which offers future climate risk predictions at the postcode level, we aim to determine whether these forecasts influence people's decisions regarding new property construction. We utilize risk levels associated with climate hazards over the next 5, 15, and 30 years which are categorized as high, medium, and low as regressors. Our regression is as follows:

$$\triangle\, Ln(Dwellings)_{i2021} = a_0 + \sum_{k=1}^{6} \beta_{ki}\, Projected\_ClimateRisks_{ki} + \varepsilon_i \qquad (2)$$

We present the result in Table 9. Our findings reveal that two primary risk factors, namely floods, and wildfires, significantly contribute to changes in the current number of dwellings. Specifically, the statistically significant coefficient on *MEDIUM_flood* demonstrates that concerningly the number of new buildings grew more rapidly in this category than in the low-risk category.

Conversely, both *MEDIUM_wildfire* and *HIGH_wildfire* consistently exhibit negative and statistically significant associations at the 1% significance level across all three specifications. This means that as the susceptibility to wildfires increases, there is a decrease in the construction of new properties. This trend can be attributed to Australia's susceptibility to frequent and severe bushfires, particularly in recent times. The bushfires that occurred during the 2019/2020 period were of an unprecedented scale, both within Australia and potentially on an international level, resulting in catastrophic consequences for extensive regions of the country. By March 2020, over 11 million hectares (110,000 square kilometres) had been ravaged, causing the loss of 33 human lives and an estimated billion birds, mammals, reptiles, insects, amphibians, and fish[6].

[Insert Table 9 here]

3.4. What is the historical trajectory of the climate vulnerability of Australia's homes and how will it evolve out to 2100?

Next, we create a trajectory of how the vulnerability of Australian housing stock to different climate risks will evolve over time. We estimate a weighted average of the probability of each of the extreme climate incidents across all postcodes for each year starting from 1980. We use the fraction of dwellings in each postcode relative to the total dwellings in the country in 2006 for all the years prior to 2011, the fraction of dwellings in 2011 for the years 2011-2015, the fraction of dwellings in 2016 for the years 2016-2020, and the fraction of dwellings in 2021 for all the years afterward. We assume these proportions remain stable over the surveyed periods. Using these proportions as weights, we combine them with forecasted risk measures to calculate the weighted average risks for Australia. The resulting numbers show the fraction of our total housing stocks at risk of various climate hazards over time. We first plot the historical trajectories during the period of 1980-2021 and report them in Figure 7.

[Insert Figure 7 here]

We show that Australian housing stock was increasingly affected by climate hazards over the past four decades, especially after 2010. The findings align with the "State of Climate 2022" report which provides compelling evidence of climate change in Australia. The report reveals a substantial increase in very high monthly maximum temperatures, which were only around 2 per cent during 1960-89 but have surged to over 11 per cent between 2007 and 2021—a remarkable sixfold escalation. Additionally, mainland Australia has been subject to persistent and significant rainfall variability, consistently falling far below average in recent decades. These climate events have significantly elevated the risk of bushfires throughout the country. Moreover, it is noteworthy that eastern Australia has experienced several major flood events, including those in 1974, 2010-11, and 2021-22, which are often linked to strong La Niña events. This emphasizes the intricate and unpredictable nature of weather patterns and their

[6] https://www.bbc.com/news/world-australia-50951043

potential impact on flooding. These findings underscore the urgent need to address climate change and its impacts on Australia's housing and infrastructure. Proper adaptation and mitigation strategies are essential to safeguard communities and ensure long-term resilience in the face of changing climate conditions.

Second, we present our predictions of housing stocks that will be at risk over the coming decades in Figure 8.

[Insert Figure 8 here]

According to our projections, the weighted average probability of wildfire impacting household dwellings across Australia is expected to increase gradually, starting at 1.1% in 2023 and reaching 1.6% by the year 2100. This indicates a potential rise in the susceptibility of residential properties to wildfire-related risks over the coming decades. In contrast, the curve illustrating the probability of flooding presents a more complex pattern, making it challenging to explain. It shows a decline in the next three decades, followed by a subsequent upward trend. This fluctuation in flood risk probabilities warrants further investigation and analysis to understand the underlying factors driving such changes. Regarding cyclone and water stress risks, both demonstrate similar patterns in their respective probabilities over time.

Overall, our findings indicate that all the examined climate risks—wildfires, flooding, cyclones, water stress—are projected to increase over time, potentially posing significant challenges for housing stock and infrastructure across Australia. These findings emphasize the importance of proactive measures and adaptive strategies to mitigate and address the escalating risks associated with climate change in the coming decades.

4. Conclusion

In conclusion, our research has provided a comprehensive and critical examination of the potential impacts of climate change on the housing sector in Australia. We have illuminated the changing landscape of climate risks and their implications for residential properties across the country. Our findings underscore the urgent need for proactive measures to address the growing threats posed by climate change. The evidence presented in this paper highlights the most susceptible regions to various climate hazards, such as wildfires, cyclones, floods, water stress, and heatwaves. Understanding the effect of these risks is essential for developing effective adaptation and mitigation strategies to safeguard our housing stock and communities.

Moreover, our study emphasizes the significance of incorporating climate resilience into housing development and urban planning policies. By adopting sustainable construction practices, improving infrastructure, and enhancing disaster preparedness, we can enhance the long-term viability and durability of Australia's housing sector in the face of climate-induced challenges.

As climate change continues to evolve, ongoing research and monitoring are crucial to keep abreast of emerging risks and trends. The insights provided in this paper can serve as a foundation for future studies and policymaking efforts aimed at bolstering the resilience of Australia's housing stock.

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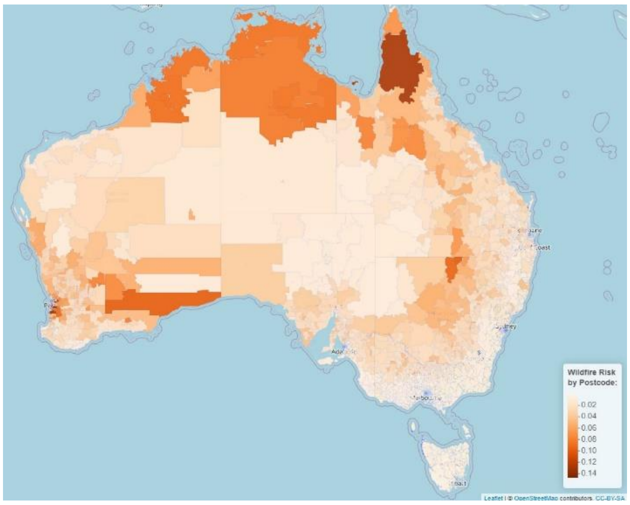
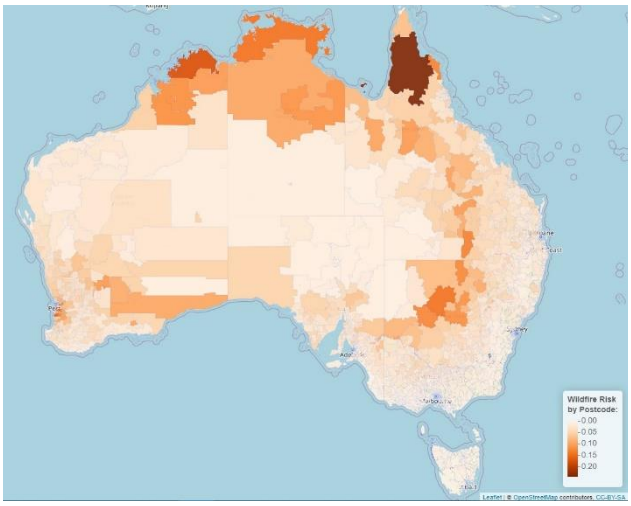
The Working Group II contribution, *Climate Change 2022: Impacts, Adaptation and Vulnerability* was released on 28 February 2022.

Figure 1: Change in wildfire risk

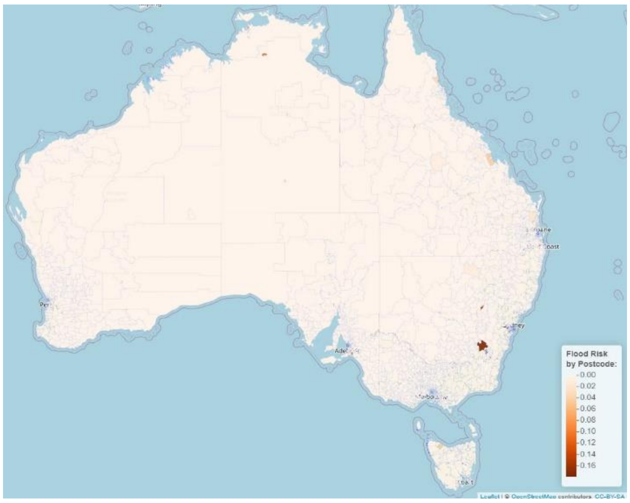


Wildfire Risk in 2021



Wildfire Risk in 2050

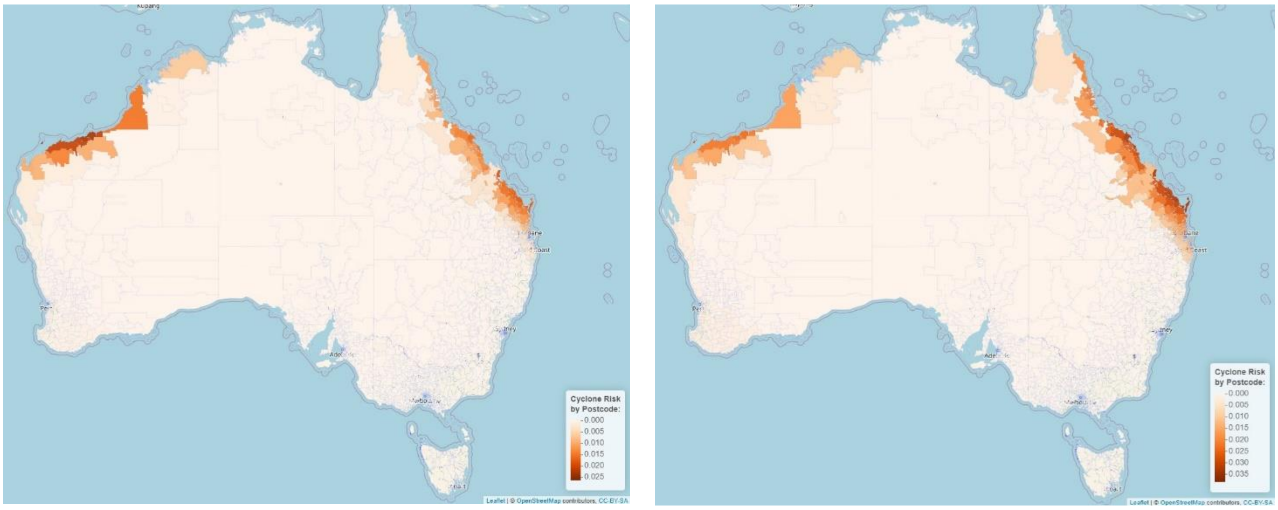
Figure 2: Change in flood risk



Flood Risk in 2021

Flood Risk in 2050

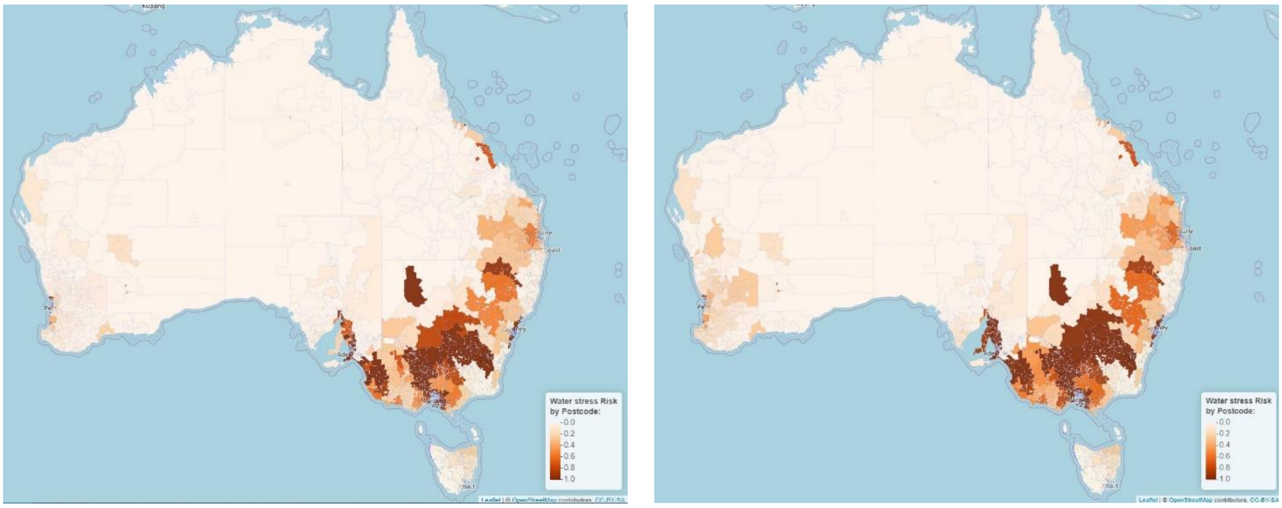
Figure 3: Change in cyclone risk



Cyclone Risk in 2021

Cyclone Risk in 2050

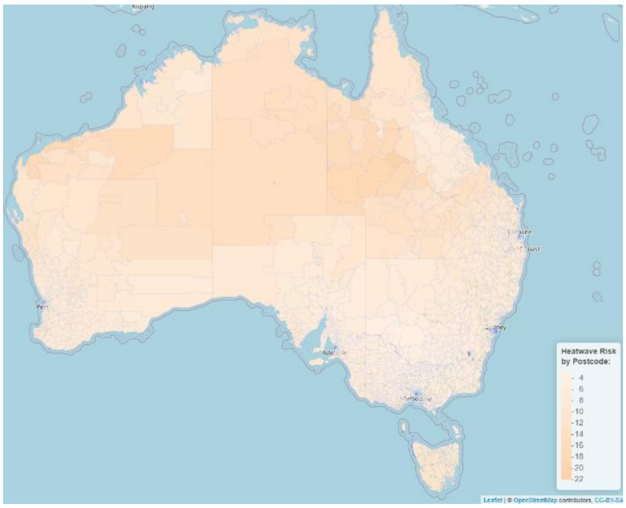
Figure 4: Change in water stress risk



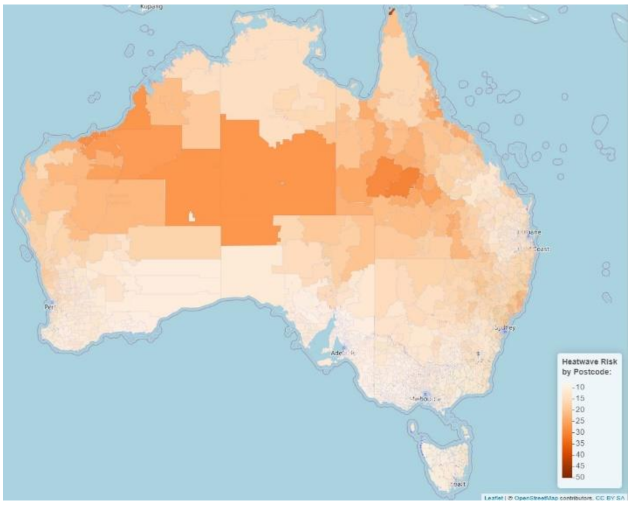
Water Stress Risk in 2021

Water Stress Risk in 2050

Figure 5: Change in heatwave risk



Heatwave Risk in 2021



Heatwave Risk in 2050

Figure 6: Gini coefficient

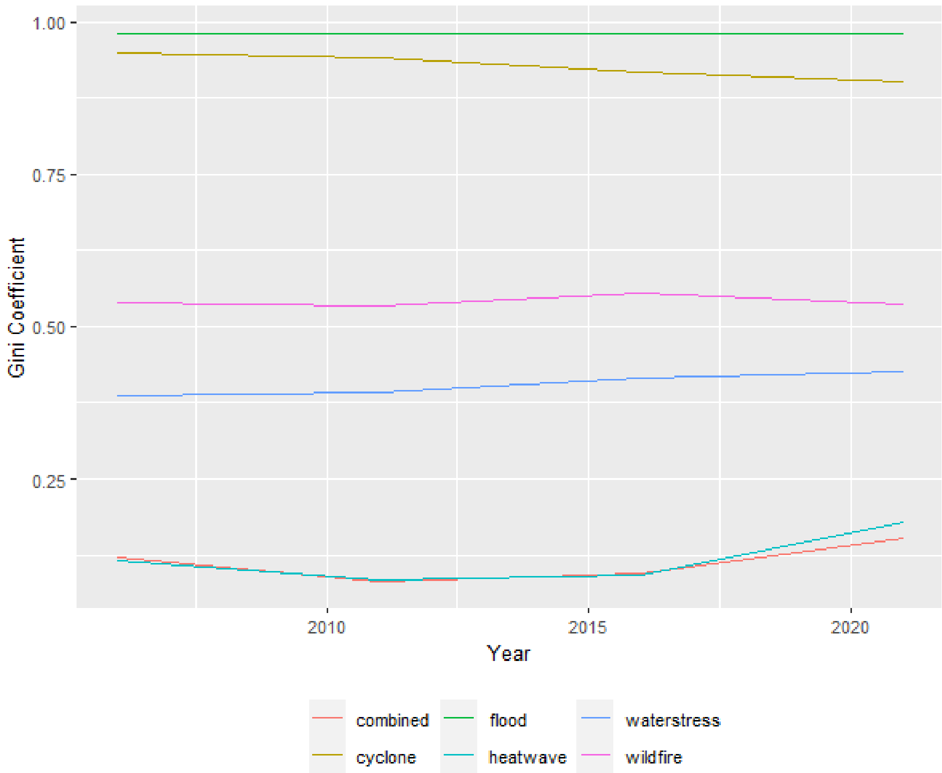
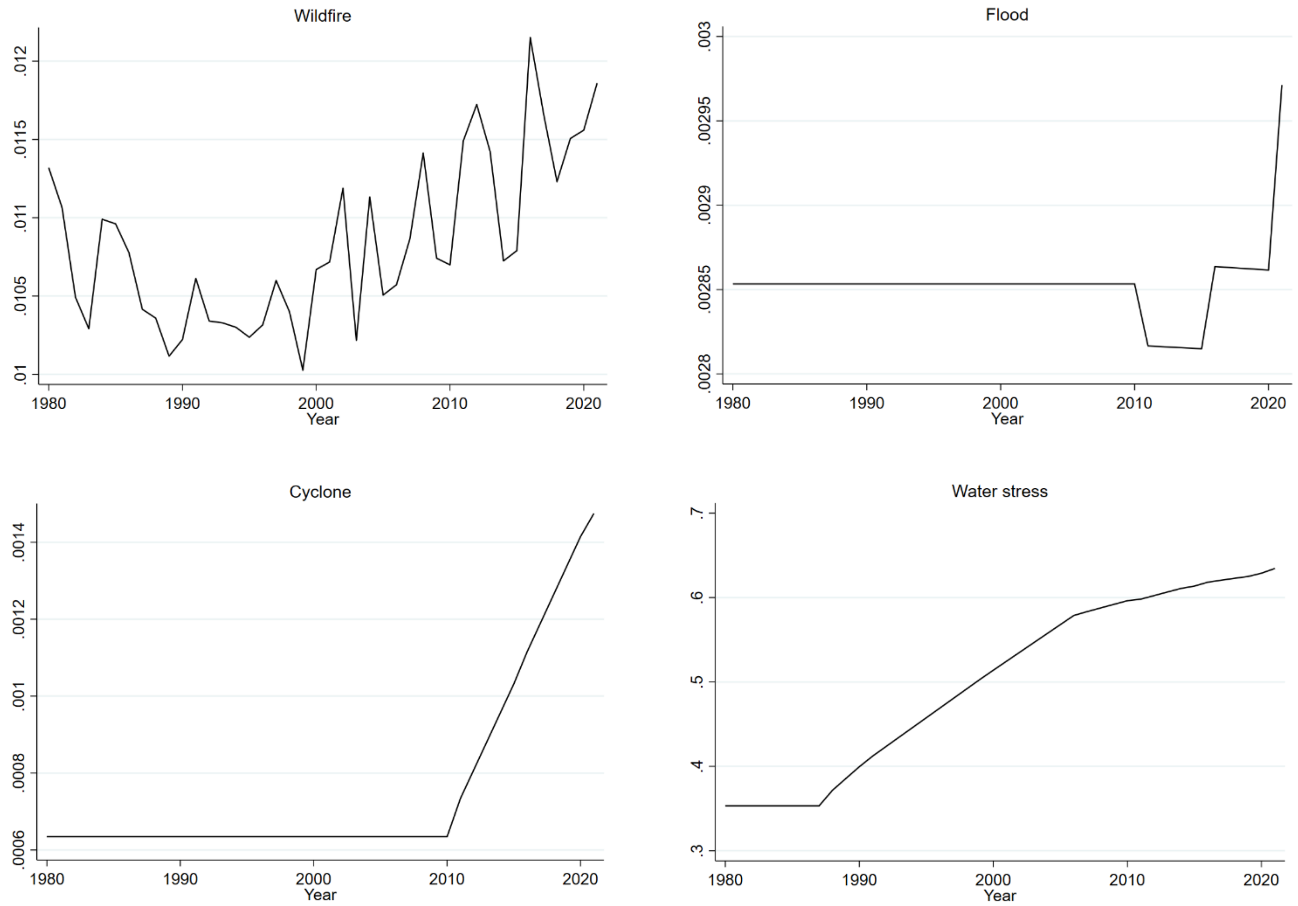
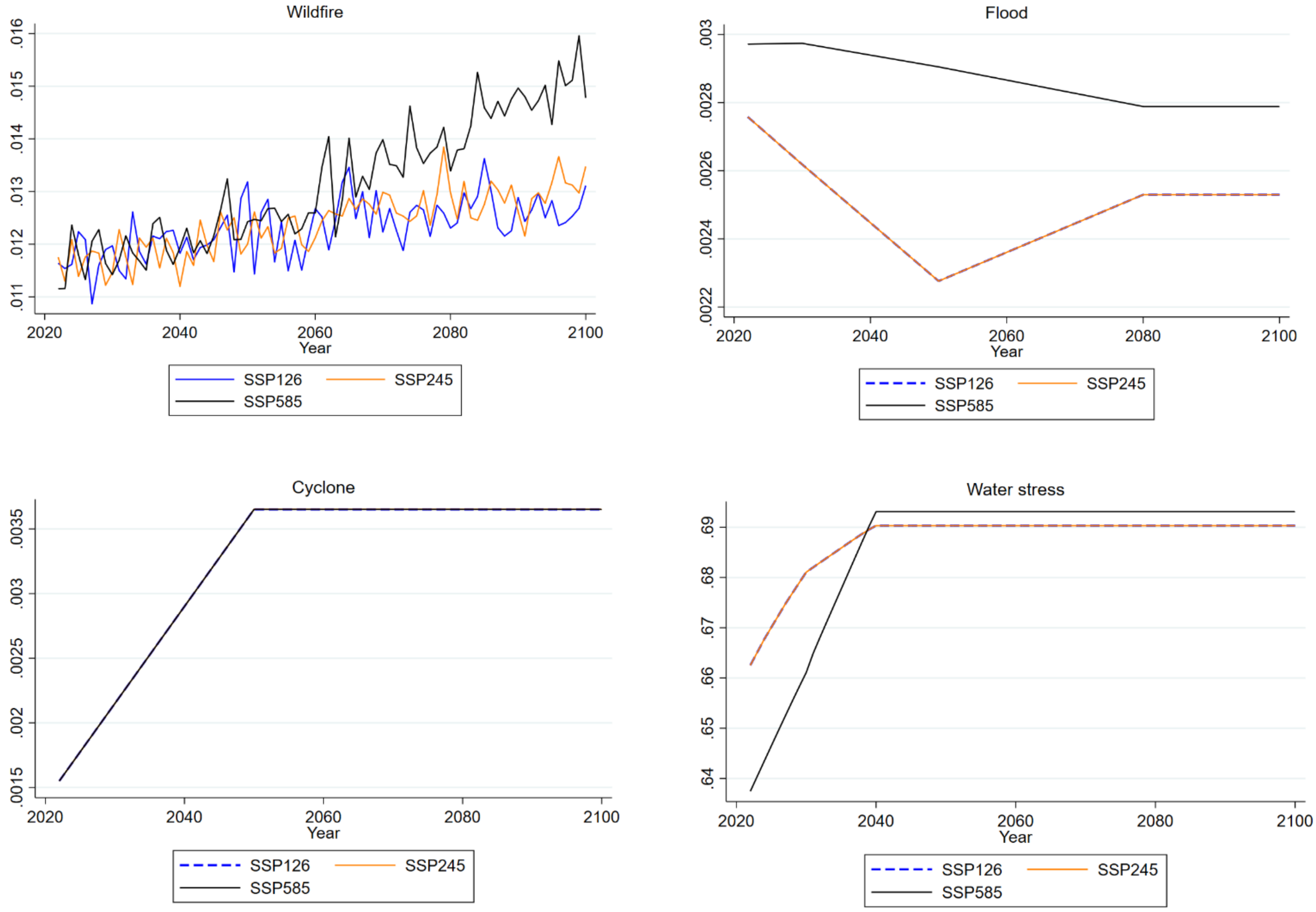


Figure 7: Historical Trajectory of Vulnerability of Housing Stocks



Note: The lines show the proportion of housing stocks that were at risk of any particular kind of climate event under the SSP 585.

Figure 8: Projected Vulnerability of Housing Stocks



Note: The lines show the projected proportion of housing stocks that are at risk of any particular kind of climate event under the different SSPs. SSP1 and SSP2 for cyclones are not available in Sust Global.

Table 1: Summary Statistics

Risk type	Risk characteristics	2006	2011	2016	2021
Wildfire	Mean	0.017	0.018	0.019	0.018
	P25	0.005	0.005	0.005	0.005
	Median	0.01	0.011	0.010	0.011
	P75	0.024	0.026	0.024	0.025
Flood	Mean	0.002	0.002	0.002	0.002
	P25	0	0	0	0
	Median	0	0	0	0
	P75	0	0	0	0
Cyclone	Mean	0.001	0.001	0.001	0.001
	P25	0	0	0	0
	Median	0	0	0	0
	P75	0	0	0	0
Water stress	Mean	0.521	0.536	0.527	0.531
	P25	0.177	0.179	0.147	0.102
	Median	0.46	0.457	0.460	0.494
	P75	0.942	1	1	1
Heatwave	Mean	7.919	9.125	8.678	6.885
	P25	7	8	8	5
	Median	8	9	9	7
	P75	9	10	10	8

Note: This table reports the descriptive statistics for climate risks used in our paper, including the mean, 25^{th} percentile, median, and 75^{th} percentile. Our investigated years include 2006, 2011, 2016, and 2021 as the Census only provides data on housing stocks in these years. The risk measures are provided in Appendix 1A.

Table 2: Distribution of postcodes facing climate risks

Risk type	Risk range	2006	2011	2016	2021
Wildfire (%)	High[7]	49.48	51.81	50.51	50.66
	Medium	50.40	48.07	49.34	49.19
	Low	0.12	0.12	0.15	0.15
Flood (%)	High	1.01	1.05	0.91	0.76
	Medium	1.61	1.85	1.97	2.12
	Low	97.38	97.10	97.12	97.12
Cyclone (%)	High				
	Medium	1.65	1.77	3.00	4.62
	Low	98.35	98.23	97.00	95.38
Water stress (%)	High	40.10	42.68	42.31	43.77
	Medium	26.61	20.62	14.19	13.44
	Low	33.29	36.70	43.49	42.79
Heatwave (%)	High				
	Medium				
	Low	100	100	100	100

Note: This table reports the distribution of postcodes facing different levels of climate risks. The figure (%) is calculated by dividing the number of postcodes exposed to high/medium/low risks by the total postcodes in Australia in a particular year. The risk measures are provided in Appendix 1A.

[7] Risks are classified into high, medium and low levels based on the breakpoints in Table 1A.

Table 3: The exposure of Australian properties to climate risks

Risk type	Risk range	2006	2011	2016	2021
Wildfire (%)	High	29.19	31.19	29.92	29.80
	Medium	70.80	68.80	70.06	70.18
	Low	0.01	0.01	0.02	0.02
Flood (%)	High	1.25	1.22	1.22	1.12
	Medium	2.67	3.02	3.27	3.47
	Low	96.08	95.76	95.51	95.41
Cyclone (%)	High				
	Medium	2.70	2.93	3.89	5.66
	Low	97.30	97.07	96.11	94.34
Water stress (%)	High	50.91	53.67	54.67	55.89
	Medium	23.99	19.56	14.77	14.92
	Low	25.10	26.77	30.57	29.19
Heatwave (%)	High				
	Medium				
	Low	100	100	100	100

Note: This table reports the distribution of Australian housing stocks facing different levels of climate risks. The figure (%) is calculated by dividing the number of dwellings exposed to high/medium/low risks by the total dwellings in Australia in a particular year. The risk measures are provided in Appendix 1A.

Table 4: Australian expensive postcodes in climate risks in 2021

Risk type	Risk range	High price	Medium price	Low price
Wildfire	High	156	362	715
	Medium	681	476	123
	Low	1		1
Flood	High	4	11	4
	Medium	26	20	8
	Low	808	807	827
Cyclone	High			
	Medium	17	45	58
	Low	821	793	781
Water stress	High	565	330	240
	Medium	89	164	95
	Low	184	344	504
Heatwave	High			
	Medium			
	Low	839	838	838

Note: This table reports the distribution of Australian expensive postcodes exposed to climate risks in 2021. We gather the pricing data from CoreLogic and merge it with climate data from Sust Global. This process enables us to have a time series of climate risks and housing prices. The sample is then split into three terciles based on the average housing price and ranged by the level of climate hazards.

Table 5: High-income postcodes in climate risks in 2021

Risk type	Risk range	High income	Medium income	Low income
Wildfire	High	265	456	602
	Medium	607	417	271
	Low	2	1	1
Flood	High	6	9	4
	Medium	22	18	16
	Low	846	847	854
Cyclone	High			
	Medium	21	52	48
	Low	853	822	826
Water stress	High	527	370	252
	Medium	100	142	112
	Low	247	362	510
Heatwave	High			
	Medium			
	Low	874	874	874

Note: This table reports the distribution of high-income postcodes exposed to climate risks in 2021. We gather the income data from the census and merge it with climate data from Sust Global. This process enables us to have a time series of climate risks and housing prices. The sample is then split into three terciles based on the annual average income and ranged by the level of climate hazards.

Table 6: The number of new homes exposed to climate risks

Risk type	Risk range	2011 vs 2006	2016 vs 2011	2021 vs 2016
Wildfire	High	384,622	119,624	271,922
	Medium	308,268	665,057	682,340
	Low	-21	1,075	216
Flood	High	6,435	9,318	1,024
	Medium	49,905	48,725	53,072
	Low	636,529	727,713	900,382
Cyclone	High			
	Medium	39,619	117,683	230,387
	Low	653,250	668,073	724,091
Water stress	High	604,735	520,461	655,329
	Medium	-238,057	-321,832	157,177
	Low	326,191	587,127	141,972
Heatwave	High			
	Medium			
	Low	692,869	785,756	954,478

Note: This table reports the number of new homes facing different levels of climate risks. We compare the current year with the last 5 years, that is 2011 vs 2006, 2016 vs 2011, and 2021 vs 2016. We count the number of new properties constructed in high/medium/low-risk areas.

Table 7: The effect of climate risks on housing stock

Variables	Coefficients
Cyclone	-8.026
	(-0.911)
Wildfire	-0.911
	(-0.971)
Flood	-0.979
	(-0.356)
Heatwave	-0.010***
	(-4.202)
Water stress	-0.034
	(-0.545)
Observations	7,578
Number of postcodes	2,628
R-squared	0.004
Postcode FE	Yes
Year FE	Yes

Note: This table reports the baseline results of the relationship between climate risks and housing stock. The housing stock is measured by changes in the log of the number of dwellings. Climate risk variables in Column (1) are in lagged values and under the SSP 126 scenario[8]. Climate risk variables (t+1) in Column (2) are future values in year t+1 under the SSP 126 scenario. Postcode and year-fixed effects are included in the regression. Robust t-statistics are presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

[8] Our scenarios (SSP 245 and SSP 585) experienced similar results. Therefore, we do not report them in this paper.

Table 8: The effect of climate risks on housing stock sold

Variables	Coefficients
Cyclone	-10,599.290***
	(-4.682)
Wildfire	-433.977
	(-1.270)
Flood	632.729
	(1.066)
Heatwave	-7.773***
	(-14.244)
Water stress	-112.643***
	(-10.720)
Observations	57,816
Number of postcodes	2,553
R-squared	0.008
Postcode FE	Yes
Year FE	Yes

Note: This table reports the results of the relationship between climate risks and property sold. The property sold is measured by the number of properties sold over the total number of listings. Climate risk variables are in lagged values and under the SSP 126 scenario. Postcode Postcode and year-fixed effects are included in the regression. Robust t-statistics are presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9: Future climate risk projection and current housing stock

Variables	Coefficients		
	5 years	15 years	30 years
MEDIUM_flood	0.049**	0.050**	0.047**
	(2.274)	(2.349)	(2.310)
HIGH_flood	0.084	0.079	0.075
	(1.104)	(1.050)	(1.080)
MEDIUM_heatwave	0.010	0.043	0.058
	(0.746)	(0.571)	(1.388)
HIGH_heatwave	-	0.017*	-0.002
		(1.649)	(-0.123)
MEDIUM_cyclone	0.465	0.069*	0.001
	(1.568)	(1.696)	(0.062)
MEDIUM_wildfire	-0.044***	-0.038***	-0.036***
	(-6.245)	(-5.461)	(-5.092)
HIGH_wildfire	-0.052***	-0.052***	-0.058***
	(-4.050)	(-4.047)	(-4.514)
MEDIUM_water_stress	-0.004	-0.011	-0.008
	(-0.516)	(-1.129)	(-0.878)
HIGH_water_stress	0.012	0.011	0.010
	(1.368)	(1.352)	(1.357)
Observations	2,626	2,626	2,626
R-squared	0.026	0.022	0.022

Note: This table reports the effect of future climate risk projection on the current housing market. Climate risks are classified into high/medium/low under the SSP 126 scenario. The housing stock is measured by changes in the log of the number of dwellings. The investigated year in this session is 2021. Postcode and year-fixed effects are included in the regression. Robust t-statistics are presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix

1A. Constructing climate hazard exposure

According to Sust Global, the data on annualized hazard exposure is obtained from various climate models, utilizing advanced technologies and methodologies:

- *Wildfire:* The annual probability of wildfire at an asset location. This information is generated using AI technology that has undergone rigorous peer review[9].
- *Flood:* The annual probability of a flood with a depth exceeding 0.5 meters at an asset location, encompassing both inland and coastal flooding. The data is derived from WRI's Aqueduct Flood Hazard Maps.
- *Cyclone:* The annual probability of a Category 1 cyclone or stronger, with sustained wind speeds of 34–47 knots, occurring at an asset location. The data is derived from the STORM cyclone model.
- *Heatwave:* The total number of days in a given year that exceed the historic 98th percentile for temperature. NASA Global Downscaled Daily Projections are used to calculate this information.
- *Water stress:* The unitless water stress score, which combines SPEI (Standardized Precipitation Evapotranspiration Index) and WRI Aqueduct data. Higher values indicate more significant water stress, with values exceeding 0.7 generally considered as being at high-stress levels. The score is computed using a weighted mean, with weights derived from the methodology designed by the World Resources Institute in their Global Aqueduct Methodology (Page 35, Table 3).

Table 1A: Climate Risks' Breakpoints

Hazard	Unit	Low Range	Medium Range	High Range
Wildfire	Probability	0.0 - 0.000075	0.000075 - 0.01	0.01 - 1.0
Inland Flood	Probability	0.0 - 0.01	0.01 - 0.05	0.05 - 1.0
Cyclone	Probability	0.0 - 0.01	0.01 - 0.05	0.05 - 1.0
Water Stress	Score	0.0 - 0.3	0.3 - 0.6	0.6 - 1.0
Heatwave	Number of days in year	0 - 30	30 - 50	50 - 366

Source: Sust Global website

[9] See Ballard, T., Cooper, M., Lowrie, C., & Erinjippurath, G. (2023). Widespread Increases in Future Wildfire Risk to Global Forest Carbon Offset Projects Revealed by Explainable AI. *arXiv preprint arXiv:2305.02397*.