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The financial burden of climate disasters on household's health expenditure: evidence from Australia

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Introduction: Climate change is increasing the frequency and intensity of natural disasters. While a growing literature documents their effects on psychological well-being, less is known about their implications for household medical expenditure. This study examines the relationship between direct exposure to weather-related disasters and out-of-pocket pharmaceutical expenditure.

Methods: We use nationally representative longitudinal data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey covering 2009-2021. Individual fixed-effects models account for time-invariant unobserved heterogeneity and control for a rich set of socioeconomic and demographic characteristics.

Results: Exposure to weather-related disasters is associated with significantly higher out-of-pocket pharmaceutical expenditure. This association is concentrated among individuals without private health insurance. An analysis of potential transmission mechanisms further shows that disaster exposure increases the likelihood of reporting several physical and mental health conditions.

Discussion: The findings suggest that the economic costs of climate-related disasters extend beyond physical damage and public reconstruction spending, affecting household welfare through higher pharmaceutical expenditure. The concentration of this burden among individuals without private health insurance highlights the potential role of insurance coverage in shaping the financial consequences of climate-related shocks.

KEYWORDS
natural disasters, out-of-pocket medical expenditure, panel regression analyses, pharmaceutical expenditure, private health insurance

1 Introduction

Natural disasters have become one of the most visible channels through which climate change affects human welfare. Floods, bushfires, cyclones, droughts, heatwaves and other extreme weather events expose households not only to physical destruction, but also to displacement, health deterioration, income losses and financial insecurity. The scale of the challenge is substantial: recent assessments indicate that approximately 3.3–3.6 billion people live in contexts highly vulnerable to climate change, making the identification of exposed and economically vulnerable populations a central concern for public health and social policy (1, 2). In economic and social research, natural disasters have gained

increasing attention because of their multidimensional effects on mental health, life satisfaction, poverty, employment, income and broader household wellbeing (3–6).

Despite this growing evidence, the household financial burden associated with post-disaster healthcare needs remains comparatively underexplored. Existing assessments of disaster costs have largely focused on property damage, infrastructure losses, labor market disruption, migration responses, public transfers and aggregate fiscal costs (7–9). Yet disasters may also generate new or intensified health needs through physical injury, psychological distress, exposure to smoke or contaminated water, and disruption of regular healthcare access (2, 10, 11). These health effects may translate into additional household expenditure on medicines, consultations, treatments and other medical services. In this sense, medical expenditure constitutes a key but often overlooked channel through which climate-related shocks may become household financial shocks.

Building on this gap, this paper addresses three related research questions. First, do individuals whose homes are damaged or destroyed by weather-related disasters experience higher household pharmaceutical expenditure? Second, does private health insurance coverage moderate this relationship, reducing the extent to which disaster-induced healthcare needs translate into private spending? Third, are these expenditure effects consistent with a deterioration in physical and mental health after disaster exposure? These questions are directly linked to the broader issue of who ultimately bears the private financial burden of climate-related health shocks.

We answer these questions using longitudinal data from the Household, Income and Labor Dynamics in Australia (HILDA) Survey for the period 2009–2021. To address the first question, we estimate the association between direct disaster exposure and household pharmaceutical expenditure, controlling for time-invariant unobserved heterogeneity and a set of socioeconomic and demographic characteristics. Disaster exposure is measured by whether, during the previous 12 months, a weather-related disaster (flood, bushfire or cyclone) damaged or destroyed the respondent's home. This measure allows us to focus on direct household-level exposure rather than relying exclusively on aggregate regional indicators of disaster occurrence. To address the second question, we examine whether the effect of disaster exposure differs between individuals with and without private health insurance. This allows us to test whether insurance coverage acts as a buffer against disaster-induced healthcare costs. To address the third question, we analyse whether disaster exposure is associated with the onset or worsening of a broad range of physical and mental health conditions, providing evidence on the health mechanisms through which disasters may translate into higher medical spending.

Australia provides a particularly useful empirical setting for this analysis. It is regularly exposed to weather-related disasters such as floods, bushfires and cyclones, which correspond closely to the disaster measure available in HILDA (12). At the same time, Australia is a high-income country with a mixed healthcare system in which private health insurance coexists with public provision (13). This institutional configuration makes it possible to examine whether disaster-related medical costs are absorbed equally across the population or whether they are concentrated among individuals without private coverage. In this sense, Australia offers an informative laboratory for understanding how climate-related shocks interact with healthcare protection mechanisms in a developed economy.

Evidence linking climate shocks to medical expenditure comes mostly from developing and middle-income countries, where extreme heat and drought raise out-of-pocket health spending (14–17). This relationship is not mechanical, however: evidence from Peru and the United States shows that households may instead defer or forgo care after a disaster, reducing rather than increasing observed spending (18, 19). A separate literature on household finance after disasters, concentrated in high-income countries and particularly the United States, examines outcomes other than healthcare spending: income and social-insurance transfers such as disability and unemployment benefits (20), consumer credit, debt, and mortgage distress (21, 22), and the role of insurance in financial resilience [(23, 24); Spencer and Strobl (25)] propose broader frameworks for household adjustment to climate shocks.

This study contributes to the literature in several ways. First, while previous research has primarily focused on property damage, infrastructure losses, labor market disruptions and income shocks, much less attention has been paid to the additional financial burden arising from increased pharmaceutical needs. This omission is important because out-of-pocket medical spending represents an immediate and often unavoidable expense that can undermine household financial resilience long after the disaster itself. Using longitudinal household data, we show that natural disasters are associated with an approximately 6.3 per cent increase in pharmaceutical expenditures.

Second, our findings reveal substantial heterogeneity in the distribution of these costs. Rather than affecting all households equally, disaster-related pharmaceutical expenditures are disproportionately concentrated among individuals without private health insurance, for whom healthcare spending increases by 12.6 per cent. This observation suggests that insurance coverage plays an important role in shaping households' financial vulnerability to climate-related shocks, and that natural disasters may exacerbate existing economic inequalities.

Third, we provide evidence on one of the mechanisms underlying these higher healthcare costs. We show that disaster exposure is associated with deteriorations in both physical and mental health, including reduced mobility and poorer mental health outcomes. These results provide a plausible explanation for how extreme weather events translate into persistent economic costs for households.

The remainder of the paper is organized as follows. Section 2 reviews the literature on natural disasters, household financial burden, healthcare expenditure and insurance as a protection mechanism. Section 3 outlines the econometric model employed in the analysis. Section 4 introduces the HILDA data and describes the key variables, including disaster exposure, pharmaceutical expenditure, health outcomes and private health insurance coverage. Section 5 presents the main empirical results and examines potential transmission mechanisms. Section 6 concludes with a discussion of policy implications and recommendations.

2 Literature review

A growing body of evidence shows that the consequences of natural disasters extend well beyond immediate physical destruction, reducing subjective wellbeing across very different empirical settings. Qualitative evidence from the 2005 Carlisle floods documents severe psychological distress among displaced residents (26), while cross-country panel data for Europe show a sizeable, robust decline in life satisfaction after floods, one that is substantially mitigated where mandatory insurance is in place (27). The same pattern extends to the United States, where effects vary by hazard type and intensity (28), and to Australia, where weather-related home damage—the exposure measure closest to the one used in this paper—produces significant declines in wellbeing (6). Individual-level analyses show that direct losses such as housing damage generate substantially larger declines in wellbeing than indirect exposure alone (29–31). Recent reviews attribute this pattern to differences in hazard characteristics, exposure intensity, and households' vulnerability (32–34).

These welfare losses are not purely psychological. A global epidemiological review documents that floods increase mortality, injuries, infectious disease, and mental health disorders (35). More broadly, disasters can worsen chronic conditions and expose individuals to smoke, contaminated water, or heat stress, disrupting regular access to care. Australian evidence from the 2019–20 "Black Summer" bushfires documents a substantial smoke-related health burden, including excess respiratory hospitalisations, cardiovascular hospitalisations and asthma-related emergency department presentations, highlighting the considerable health impacts of extreme wildfire smoke (36).

In the Australian context, Baryshnikova and Pham (4) use panel data from HILDA to show that natural disaster damage lowers mental health scores among homeowners, with a particularly strong negative effect concentrated in the lowest quantiles of the distribution for non-owners. This literature establishes that disasters affect health through well-documented physical and psychological channels; what it does not establish is whether, and how much, these health effects translate into additional healthcare spending, the question this paper addresses.

A separate literature examines the financial mechanisms through which households cope with disasters, largely using US administrative data. Deryugina et al. (37) track Hurricane Katrina victims through individual tax records and find only small, transitory effects on income and employment. Using consumer credit files, Gallagher and Hartley (21) show that the most flooded Katrina victims experienced modest, short-lived spikes in credit card debt and delinquency, and that flood-insurance payouts were used primarily to pay down mortgage debt rather than to rebuild. At the county level, Deryugina (20) finds that non-disaster social insurance transfers, driven largely by medical spending, income maintenance, and unemployment insurance, exceed direct disaster aid several times over within a decade of a hurricane. An et al. (22) show that wildfire smoke exposure affects credit-card balances, mortgage distress, and house prices, while Spencer and Strobl (25) propose general empirical frameworks for the multiple margins through which households adjust to climate shocks. Complementary evidence points to formal and informal support networks as an additional buffering mechanism (38). Taken together, this literature is concentrated in high-income countries (predominantly the United States) and documents outcomes such as income, employment, relocation, debt, and delinquency, or aggregate public medical transfers; none of it examines individual out-of-pocket medical expenditure or whether private health insurance moderates it.

A distinct and more recent literature estimates the effect of climate shocks directly on medical expenditure. The evidence comes almost entirely from developing and middle-income countries. Li et al. (14), using longitudinal data from the China Family Panel Studies matched to daily county-level weather records, find that an additional day above 32 °C raises individual out-of-pocket medical spending by 2.8%, and a day below −12 °C by 3.6%, relative to a mild day, with larger effects among men, outdoor workers, and rural and poorer groups. These extra costs operate through channels such as doctor visits, chronic disease, and sleep disruption. Li et al. (15) find that each additional heatwave in the previous month raises outpatient expenditure among older Chinese adults, with stronger effects for those with chronic conditions, in rural areas, or without air conditioning. In rural Vietnam, drought exposure raises household health expenditure by 11% of median annual per-capita consumption (16), while in Sri Lanka, floods and droughts generate at least USD 19 million a year in healthcare costs for the public and private sectors (17). A systematic review of 15 studies on out-of-pocket health expenditure published between 2016 and 2022 finds that only a small minority cover high-income countries (39), and even in Europe the topic remains comparatively unstudied. A Spanish study using Household Budget Survey data finds that 21.3% of households devoted more than 10% of monthly income to healthcare out-of-pocket payments in 2008, and 4.4% exceeded 40%, amounting to a national catastrophic gap of 0.82% of GDP (40).

Methodologically, these studies differ considerably in their ability to isolate the effect of climate exposure from unobserved confounders. Li et al. (14) exploit a panel matched to daily county-level weather records, while Lohmann and Lechtenfeld (16) use rainfall-based drought severity as an instrument for household illness in a panel IV-Tobit framework; both designs net out time-invariant household and locality characteristics and address potential reverse causality. Li et al. (15) combine generalized estimating equations with community and month fixed effects, which purge time-invariant community-level confounders and common monthly shocks, though, unlike an individual fixed-effects design, they do not rule out unobserved heterogeneity at the individual level. By contrast, De Alwis and Noy (17) rely on a single cross-section, and López-López et al. (40) analyse repeated cross-sections without a panel link across years, so in both cases the reported associations cannot fully rule out unobserved heterogeneity correlated with both climate exposure and healthcare spending.

The relationship between disaster exposure and observed medical expenditure is not necessarily mechanical. Higher expenditure may reflect greater healthcare needs. However, lower expenditure does not imply better health, for it may simply reflect deferred care, liquidity constraints, or an inability to pay. In

rural Peru, households affected by the 2017 El Niño reduced per-capita spending on medicines and procedures by 29.3% and on medical services by 24.7%, consistent with an agricultural income shock crowding out health spending (18). In the US healthcare outflows fell by more than half in the week Hurricanes Harvey and Irma made landfall, and remained below average 12 weeks later, suggestive of postponed rather than reduced care (19). Both studies rely on designs well suited to isolate a short-run causal response: Malpartida and Guembes (18) use a difference-in-differences approach comparing panel households affected and unaffected by the 2017 El Niño, while Farrell and Greig (19) exploit high-frequency, transaction-level account data to trace spending around the exact week of hurricane landfall.

Conceptually, the relationship between natural disasters and household medical expenditure can be interpreted through Grossman's (41) health-capital model, which views health as a stock of capital that depreciates over time and following adverse shocks. Within this framework, medical expenditure is a derived demand: individuals do not consume healthcare for its own sake but as an investment to restore health following adverse shocks. Consequently, exogenous events that deteriorate health increase the demand for healthcare and, where access and financial resources permit, out-of-pocket medical expenditure. Weather-related disasters constitute precisely this type of depreciation shock, operating through several channels including physical injuries sustained during the event, exposure to smoke, contaminated water and extreme temperatures, psychological distress associated with trauma, loss or displacement, and disruptions to routine healthcare that exacerbate pre-existing chronic conditions.

As illustrated in Figure 1, the magnitude and composition of this investment response depend not only on healthcare needs but also on households' financial resources and the institutional arrangements governing access to healthcare. Under Australia's Pharmaceutical Benefits Scheme (PBS), prescription medicines are subsidized independently of private insurance coverage, whereas access to specialist consultations, rehabilitation and allied health services is more closely linked to insurance status. Consequently, insured households are more likely to substitute toward services covered by private insurance, whereas uninsured households may rely more heavily on pharmaceutical treatment to manage persistent health conditions.

The conceptual framework gives rise to three empirical predictions. First, disaster exposure should increase pharmaceutical expenditure on average. Second, this increase should be more pronounced among individuals without private health insurance. Third, the expenditure response should be explained by the onset of specific physical and mental health conditions following disaster exposure (see Figure 1). These predictions motivate the empirical analyses presented in Sections 4 and 5, with Section 5.1 providing direct evidence on the proposed transmission mechanism.

Against this conceptual background, the existing empirical literature leaves three important questions unanswered. First, evidence on climate shocks and medical expenditure comes almost exclusively from developing or middle-income countries, where healthcare systems, insurance coverage and access to care differ substantially from high-income settings. Second, most studies focus on a single hazard (heatwaves, droughts or floods) rather than on direct measures of household exposure to weather-related disasters. Third, and most importantly for this paper, to the best of our knowledge, there is limited empirical evidence on whether private health insurance moderates the relationship between direct disaster exposure and out-of-pocket pharmaceutical expenditure. While the household-finance literature reviewed above studies insurance and credit outcomes other than healthcare, largely in the United States, the medical-expenditure literature focuses primarily on developing-country settings where private health insurance is relatively uncommon.

3 Empirical framework

We assume the amount spent on pharmaceutical expenses is a function of individual characteristics. Let I be a set of individuals, with an element i, $i \in I$, and T be a set of time periods, $t \in T$, representing a specific moment when the surveys were conducted.

$$ME_{it} = \vec{\alpha}\,\vec{X}_{it} + \beta_1 D_{it} + c_i + u_{it};\ t \in T,\ \ i \in I_t \tag{1}$$

where ME_{it} is pharmaceutical expenditure, X_{it} is a vector of relevant confounders, c_i stands for unobservable heterogeneity and u_{it} is white noise. We define D_{it} as taking a value of one if a weather-related disaster (flood, bushfire, cyclone) occurred at time t and "damaged or destroyed" the home of respondent i.

Equation 1 is estimated using an individual fixed-effects estimator. This approach controls for all time-invariant unobserved characteristics that may confound the relationship between disaster exposure and medical expenditure, including innate health endowments, long-standing behavioral traits, genetic predispositions, persistent socioeconomic characteristics and fixed locational attributes. Consequently, identification relies on within-individual variation in disaster exposure over time rather than on comparisons across different individuals.

3.1 Identification strategy

Our identification strategy exploits changes in disaster exposure experienced by the same individual across survey waves. By removing all time-invariant individual heterogeneity, the fixed-effects estimator substantially reduces omitted-variable bias arising from persistent differences across individuals. This feature is particularly important in our context, since households residing in disaster-prone areas may differ systematically from the rest of the population in ways that are difficult to observe but potentially correlated with healthcare expenditure.

Identification requires that, conditional on the included time-varying covariates, regional fixed effects and wave fixed effects, no remaining time-varying unobserved factors jointly determine both disaster exposure and medical expenditure. Although this assumption cannot be tested directly, the rich set of socioeconomic and demographic controls included in the model helps mitigate this concern.

The choice of fixed effects over random effects is supported by a Hausman specification test, which rejects the null hypothesis

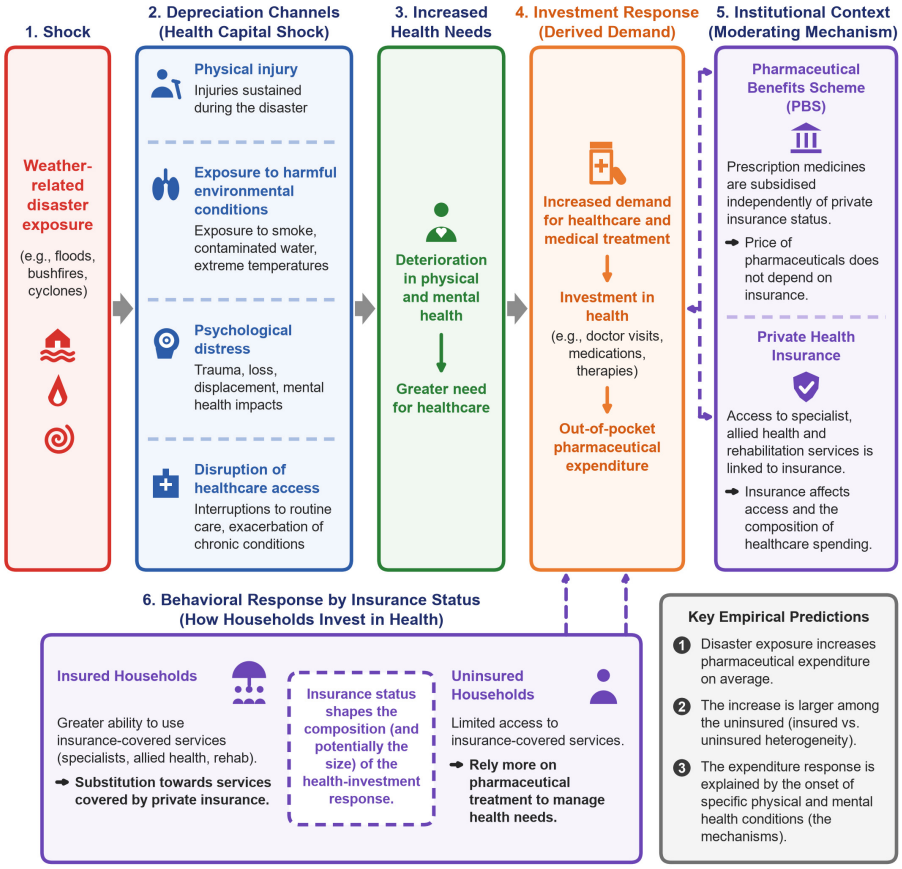


FIGURE 1
Conceptual framework linking weather-related disasters to out-of-pocket pharmaceutical expenditure. The conceptual framework is based on Grossman's (41) health-capital model, in which health is viewed as a stock of capital that depreciates following adverse shocks. Weather-related disasters (floods, bushfires and cyclones) are conceptualized as exogenous health shocks that increase healthcare needs and induce healthcare investment.

that the random-effects estimator is consistent [$\chi^2(25) = 553.16$, $p < 0.001$], indicating that unobserved individual heterogeneity is correlated with the explanatory variables.

Weather-related disaster exposure is treated as plausibly exogenous from the individual's perspective because households do not determine the timing or occurrence of floods, bushfires or cyclones. Although residential location may influence exposure to natural hazards, the fixed-effects specification removes all time-invariant locational characteristics, while regional and wave fixed effects absorb common regional and temporal shocks. Consequently, identification is based on within-individual changes in disaster exposure rather than on cross-sectional differences between households.

Nevertheless, some endogeneity concerns may remain. Disaster exposure could still be correlated with unobserved time-varying factors, such as residential relocation, changes in socioeconomic circumstances or other shocks affecting both health and disaster vulnerability. While the inclusion of a comprehensive set of time-varying controls substantially reduces these concerns, they cannot be completely eliminated. Accordingly, our estimates should be interpreted as identifying associations conditional on the maintained identifying assumptions rather than definitive causal effects.

4 Data and definition of variables

We use the 2009–2021 waves of the Household, Income, and Labor Dynamics in Australia (HILDA) Survey, a comprehensive, nationally representative longitudinal study that examines the economic, social, and demographic dynamics of Australian households. Initiated in 2001 and conducted annually, it tracks individuals and households over time. The survey combines objective data on income, labor market activities, health, education, and housing, among others, with subjective measures, such as mental health and satisfaction with various areas of life, offering a rich dataset for understanding Australia's social fabric. The original 2001 sample included approximately 7,600 households and 13,000 individuals, with periodic updates to account for attrition.

Since 2009, HILDA asks each respondent whether, within the last 12 months, a weather-related disaster (flood, bushfire, cyclone) damaged or destroyed' the respondent's home. These responses are further broken down by quarter, albeit with a reduced response rate. We therefore focus on the annual data. After excluding cases with item non-response, which represented 2.4% of the original dataset, the final estimation sample comprises 171,301 observations from 29,658 individuals. Although retention rates are remarkably high in

the HILDA database (yearly average = 90%), the non-random exit and entry of individuals in panel data is a potential concern.

Each individual in our sample belongs to a household, and, since the HILDA dataset contains both individual- and household-level information, we can identify the pharmaceutical expenditure of the household in which each individual lives. Hence, our dependent variable is the logarithm of annual household out-of-pocket expenditure on medicines, prescriptions, pharmaceuticals, and alternative medicines.

This measure captures out-of-pocket medical spending and provides a direct indicator of the financial burden associated with healthcare consumption. We focus on out-of-pocket pharmaceutical expenditure, rather than total out-of-pocket health expenditure, for two reasons. First, focusing on pharmaceutical expenditure is institutionally meaningful in Australia: under the Pharmaceutical Benefits Scheme (PBS), most prescription medicines are subsidized regardless of private insurance status. This allows us to interpret differences in this specific expenditure margin across insurance groups as informative about how households substitute between medicines and other, less price-regulated forms of care. Second, because PBS co-payments are regulated and only weakly linked to private insurance coverage, pharmaceutical expenditure provides a relatively clean out-of-pocket margin through which to examine how insured and uninsured households adjust healthcare spending following a disaster. By contrast, expenditure on specialist consultations, allied health services and hospital treatment is more directly influenced by differences in private insurance coverage, making it more difficult to distinguish behavioral responses from differences in insurance generosity. The dataset also contains information on whether respondents hold private health insurance, allowing us to explore heterogeneity in the relationship between disaster exposure and medical expenditure according to insurance coverage.

The empirical analysis includes a rich set of time-varying individual and household characteristics commonly associated with healthcare expenditure. These controls capture several economic and demographic factors that may influence both the need for pharmaceutical products and households' ability to afford them. Age and health status are expected to be particularly relevant, as healthcare needs and medication use generally increase with age and poorer health. Educational attainment may affect health-related behaviors, health awareness, and the ability to navigate the healthcare system, while marital status and the number of children capture differences in household composition, care needs, and the allocation of household resources. Labor market status may influence pharmaceutical expenditure through income, employment-related access to healthcare, and the time and resources available for seeking treatment. Household income captures differences in households' ability to meet medical expenses and may also be associated with differences in healthcare consumption.

Household income is equivalized using the OECD-modified equivalence scale and converted into real terms using the Consumer Price Index (42). Health status is measured through respondents' self-assessed health, reported on a five-point scale ranging from excellent to poor. Following previous studies, we construct an indicator variable equal to one when individuals report poor or fair health. Self-assessed health has been widely validated in the literature and shown to be strongly associated with objective health measures, physician assessments, labor market outcomes, and mortality risk (43, 44). Finally, all specifications include controls for remoteness and region of residence in order to account for geographical disparities in healthcare access and service availability, which may affect both the use and cost of pharmaceutical products. Wave fixed effects are also incorporated to absorb common macroeconomic shocks, business cycle fluctuations, policy changes, and other time-specific factors affecting medical expenditure.

A common challenge when analyzing household-level outcomes is that many explanatory variables are measured at the individual level. In this respect, we follow the literature on health outcomes and medical expenditures, which typically examines how the characteristics of adult household members (e.g., education, marital status, and gender) are associated with household-level outcomes. However, we cannot determine to what extent each individual is solely or jointly responsible for the household-level outcomes, as the allocation of responsibilities within the family may vary considerably depending on household circumstances. We therefore assume that each adult in the household contributes, either directly or indirectly, to household financial decisions, including the payment of bills and pharmaceutical expenditures.

5 Results

Table 1 reports the summary statistics for the main variables used in the analysis. Weather-related disasters are relatively infrequent events in the sample, affecting approximately 0.9% of person-year observations. Nevertheless, among the 29,658 individuals in our sample, 1,867 (6.29%) reported experiencing at least one weather-related disaster during the observation period. Average annual household expenditure on medicines, prescriptions, pharmaceuticals, and alternative medicines amounts to AUD 447, although the large standard deviation indicates substantial heterogeneity in healthcare spending across households. Private health insurance is widespread in the sample, with approximately 67% of respondents reporting coverage. This relatively high prevalence provides an appropriate setting to investigate whether insurance coverage moderates the financial consequences of disaster exposure. The average equivalized household income is around AUD 97,000 per year, while respondents report an average educational attainment of 12.6 years. Approximately 24% of individuals report poor or fair health. The average respondent is 40 years old, and around two-thirds are married. Divorced and widowed individuals represent 8.7% and 1.2% of the sample, respectively. Labor market participation is high, with 75.5% of respondents employed and only 4.2% unemployed. Finally, households report an average of 1.5 children.

Figure 2 presents coefficient plots of the estimated effects, while Table A1 in the Appendix reports the corresponding numerical estimates. The results suggest that exposure to natural disasters is associated with higher individual pharmaceutical expenditure. In the pooled specification, the coefficient associated with disaster exposure is positive and statistically significant, indicating that

TABLE 1 Sample averages and standard deviations.

Natural disaster	0.0088 (0.0931)
House hold expenditure on medicines	446.68 (875.44)
Private insurance	0.6661 (0.471)
House hold income	97021.45 (82528.9)
Years of education	12.62 (2.39)
Ill–health	0.2399 (0.427)
Age	40.33 (13.50)
Married	0.6578 (0.474)
Divorced	0.0872 (0.282)
Widowed	0.0117 (0.108)
Employed	0.7550 (0.430)
Unemployed	0.0421 (0.200)
Number of children	1.507 (1.489)

(i) Source: 2009-2021 waves of HILDA; (ii) Standard errors in parenthesis.

individuals who experience a natural disaster incur 6.3 percent higher annual household pharmaceutical expenditure than those who do not experience a natural disaster. This finding is consistent with the notion that natural disasters may generate both immediate and persistent health burdens through injuries, the exacerbation of pre-existing medical conditions, disruptions in access to healthcare services and increased exposure to environmental hazards. Collectively, these effects are likely to increase the demand for pharmaceutical treatment and other forms of healthcare, leading to higher out-of-pocket medical expenditure.

However, the most notable finding emerges when the sample is divided according to private health insurance status. The positive association between disaster exposure and medical expenditure disappears entirely among individuals holding private health insurance, whereas it remains positive, statistically significant, and substantially larger among those without private coverage (12.6 percent). This pattern suggests that the average effect observed in the pooled sample is driven almost exclusively by individuals lacking private health insurance. In other words, while disasters appear to increase healthcare-related financial burdens in the population as a whole, these additional costs are concentrated among households without access to supplementary insurance protection.

Several mechanisms may explain this heterogeneity. First, private health insurance may reduce the out-of-pocket consequences of health shocks by facilitating faster access to specialist care, rehabilitation services, elective procedures, and mental health treatment. Earlier intervention may prevent health conditions from worsening and reduce subsequent dependence on pharmaceutical treatment, even if the initial health shock is similar across insured and uninsured individuals. Within this context, private insurance may therefore lower the need for prolonged medication through more timely healthcare.

Second, the composition of healthcare utilization following a disaster may differ across insurance groups. Our expenditure measure captures spending on medicines, prescriptions, pharmaceuticals, and alternative medicines, but does not include several healthcare services that are more readily accessible through private insurance, such as physiotherapy, rehabilitation programmes, psychological counseling, or hospital treatments. Hence, insured individuals may substitute pharmaceutical treatment with other forms of care. In contrast, uninsured individuals may rely more heavily on medications and alternative medicines to manage similar health conditions.

A further explanation relates to the institutional features of the Australian healthcare system. Under the PBS, most prescription medicines are subsidized by the Australian Government irrespective of private health insurance status. This implies that insured and uninsured individuals generally face similar co-payments for PBS-listed medicines. As a result, the absence of higher pharmaceutical expenditure among insured individuals should not be interpreted as evidence that private insurers directly finance prescription drugs. Instead, one possibility is that insured individuals receive more intensive medical care following disaster exposure, leading to a greater number of consultations and prescriptions without substantially increasing their out-of-pocket pharmaceutical spending because PBS co-payments remain regulated. By contrast, uninsured households may rely relatively more on non-PBS medicines, over-the-counter pharmaceuticals, and alternative medicines, all of which are included in our expenditure measure and generally involve larger out-of-pocket payments.

The estimated coefficients for the remaining variables are broadly consistent with theoretical expectations and previous empirical evidence (Figure 2b). Household income is positively and significantly associated with medical expenditure across all specifications, suggesting that healthcare behaves, at least partially, as a normal good. Individuals with greater financial resources are more likely to consume healthcare services and face fewer budget constraints when seeking medical treatment. As expected, ill-health is a strong predictor of medical expenditure. The positive and highly significant coefficients indicate that poorer health status translates into greater healthcare spending. Moreover, the effect is larger among individuals without private insurance, reinforcing the view that insurance coverage cushions households from the financial consequences of adverse health shocks. Age exhibits a nonlinear relationship with medical expenditure. The negative coefficient on age and the positive coefficient on age squared indicate a convex age profile, with expenditure declining over early adulthood and rising at older ages, the latter being consistent with the increasing prevalence of chronic conditions and healthcare needs at older ages. Education displays heterogeneous effects across groups. Among individuals with private insurance,

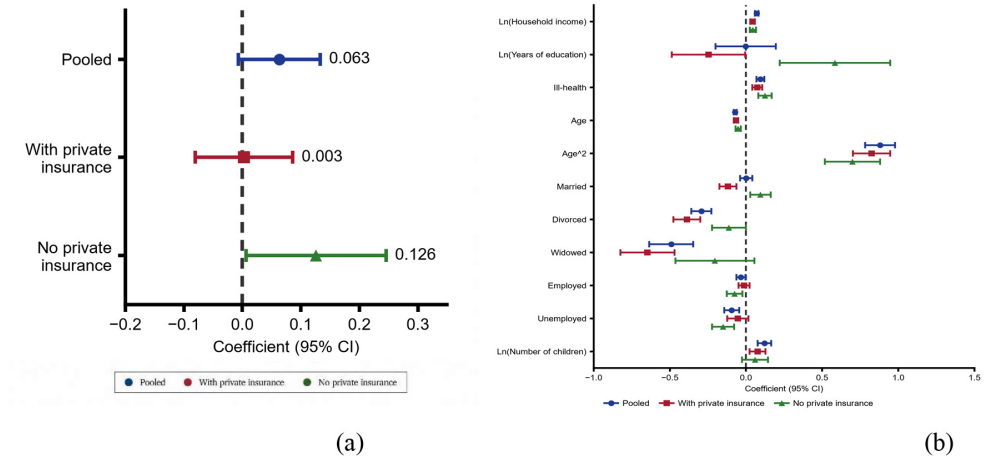


FIGURE 2
Association between disaster exposure, household characteristics, and annual household pharmaceutical expenditure — by private health insurance status. **(a)** Coefficient on disaster exposure; **(b)** coefficients on other covariates.

higher educational attainment is associated with lower medical expenditure, possibly reflecting healthier lifestyles and more effective preventive behaviors. In contrast, education is positively associated with expenditure among the uninsured, suggesting that more educated individuals may be more willing or able to invest in healthcare despite facing higher out-of-pocket costs.

Marital status also produces mixed results. Marriage is associated with lower expenditure among insured individuals but higher expenditure among those without private coverage. This observation may reflect differences in household support networks and healthcare utilization patterns. Divorced and widowed individuals tend to report lower spending relative to the reference category. Finally, employment status is negatively associated with medical expenditure, particularly among the uninsured. Relative to the omitted category, employed and unemployed individuals exhibit lower healthcare spending, possibly because the reference group includes retirees or economically inactive individuals with greater healthcare needs.

5.1 Sensitivity checks

To assess the robustness of our main findings, we conduct a series of additional sensitivity and falsification exercises. These checks are designed to examine whether our results are driven by repeated disaster exposure, old individuals, residential mobility, the COVID-19 period, or the contemporaneous specification of disaster exposure.

First, we re-estimate the baseline specification excluding individuals who experienced two or more disaster events during the observation period. In our sample, 15.9% of individuals who experienced a natural disaster experienced more than one event. Given the relatively low prevalence of repeated exposure, we expect our binary indicator to capture primarily the contemporaneous exposure to a disaster rather than cumulative exposure across multiple events. Nevertheless, to address this concern, Table 2 shows that excluding individuals with multiple disaster events does not alter our results.

TABLE 2 Determinants of annual household pharmaceutical expenditure—sensitivity checks.

Natural disaster	With private insurance	No private insurance
Excluding multiple disaster events	0.0169 (0.0495)	0.142** (0.0701)
Obs.	99,787	68,101
Natural disaster	0.0342 (0.0634)	0.1208** (0.0130)
Natural disaster × Age >45	0.0567 (0.0849)	0.0139 (0.1242)
Obs.	1,01,553	69,748
Excluding COVID−19years (2020–2021)	−0.0122 (0.0441)	0.130** (0.0649)
Obs.	88,107	60,323
Natural disaster (t−1)	−0.0071 (0.0347)	−0.0153 (0.0256)
Obs.	101,553	69,748
Natural disaster (t+1)	0.0185 (0.0452)	−0.0206 (0.0666)
Obs.	101,553	69,748

(i) Source: 2009-2021 waves of HILDA; (ii) Standard errors in parenthesis; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Second, we test whether the results are driven by older adults in the sample. Disaster-related health shocks could potentially have different consequences for younger and older individuals. Older adults generally have higher healthcare needs and a greater prevalence of chronic conditions, which could make them more vulnerable to disruptions in healthcare following a disaster. We

therefore introduce an interaction between the natural disaster indicator and a dummy variable identifying individuals aged 65 or older. This threshold is based on the Australian Bureau of Statistics', National Health Survey definition of "older people" (45). The results do not provide evidence of significant age heterogeneity. The interaction term between natural disaster exposure and the age indicator is statistically insignificant in both insurance groups. At the same time, the coefficient on natural disaster exposure remains positive and statistically significant among individuals without private health insurance, while it remains statistically insignificant among those with private insurance.

Third, we exclude the 2020–2021 waves, given that the COVID-19 pandemic may have generated unusual disruptions in healthcare utilization and disaster response that could affect the estimated relationship. The estimated effect remains statistically insignificant for individuals with private insurance (−0.0122), while remaining positive and statistically significant for those without private insurance (0.130).

Fourth, we introduce a one-wave lag of disaster exposure to examine whether the effects extend beyond the year in which the disaster occurs. The lagged coefficient is statistically non-significant in both groups (−0.0071 and −0.0153, respectively), suggesting that the increase in pharmaceutical expenditure is concentrated in the period of disaster exposure and does not reflect a delayed expenditure response.

Finally, we conduct a placebo/falsification test using a one-wave lead of disaster exposure. Since future disaster exposure should not affect current pharmaceutical expenditure, the absence of a statistically significant association in this specification provides additional support for the temporal ordering underlying our main results.

5.2 Potential transmission mechanisms

Following the conceptual framework presented in Section 2, we next examine the potential transmission mechanism through which disaster exposure translates into higher pharmaceutical expenditure. Under Grossman's (1972) health-capital model, adverse shocks depreciate individuals' stock of health, increasing healthcare needs and, consequently, the demand for healthcare investment. Where access to care and financial resources permit, this process should be reflected in higher out-of-pocket medical expenditure. We therefore test whether disaster exposure is associated with the onset of specific health conditions that can account for the observed increase in pharmaceutical expenditure. The conceptual framework predicts that, if natural disasters increase healthcare spending, part of this effect should operate through a deterioration in individuals' physical or mental health.

The HILDA Survey contains detailed information on respondents' physical and mental health, covering a broad range of long-term conditions and disabilities. These include chronic pain, limitations in physical functioning (e.g., mobility and manual dexterity), respiratory and cardiovascular conditions, neurological disorders, sensory impairments and cognitive conditions, among others. The richness of these health measures allows us to explore which specific conditions are more likely to emerge following disaster exposure and, in turn, may contribute to higher medical expenditure. To that purpose, we estimate a series of regressions in which the dependent variable is a binary indicator for the presence of a specific health condition, HC_{it},

$$HC_{it} = \vec{\alpha}\,\vec{X}_{it} + \beta_1 D_{it} + c_i + u_{it};\ t \in T,\ \ i \in I_t$$

All specifications include the same set of controls as the baseline models, including individual fixed effects, regional controls, and wave fixed effects. We use a linear probability formulation because it allows the inclusion of individual fixed effects and provides coefficients that can be interpreted directly as percentage-point changes in the probability of reporting the relevant condition. This framework allows us to assess whether exposure to natural disasters is associated with the onset of new physical and mental health conditions.

Table 3 shows that disaster exposure is associated with an increased likelihood of newly reporting specific health conditions. Rather than generating a generalized deterioration across all health domains, the effects concentrate in a subset of physical and mental impairments. These are compatible with the direct and indirect consequences of extreme weather events, and include i) difficulties gripping objects, ii) long-term consequences resulting from head injuries, strokes, or other forms of brain damage, iii) limited use of arms or fingers, iv) mental health problems requiring assistance or supervision, v) shortness of breath or breathing difficulties, and vi) speech problems. These problems are likely to arise from injuries sustained during disasters, disruptions in access to healthcare, heightened psychological distress, or the worsening of pre-existing medical conditions. This evidence also helps explain why the expenditure response differs according to insurance status. Mental health disorders and mobility impairments frequently require multidisciplinary care involving specialist consultations, physiotherapy, rehabilitation, and psychological treatment in addition to medication. Individuals with private health insurance may be able to access these services more rapidly and with lower financial barriers, reducing their dependence on prolonged pharmaceutical treatment. Conversely, uninsured individuals may have fewer treatment options available and therefore rely more heavily on medications and alternative therapies to manage persistent symptoms, resulting in higher out-of-pocket pharmaceutical expenditure following disaster exposure.

Overall, the estimates provide a plausible micro-level mechanism linking climate-related shocks to household pharmaceutical burdens and help explain why disaster exposure translates into higher medical spending, particularly among individuals lacking private health insurance.

6 Conclusions and policy recommendations

Natural disasters are becoming increasingly frequent and severe in many parts of the world, raising concerns about their economic and social consequences. While a growing literature has documented their effects on income, employment, subjective

TABLE 3 Natural disasters and the onset of physical and mental conditions.

Variables	Coefficient
Blackouts, fits or loss of consciousness	0.0105
	(0.0072)
Chronic or recurring pain	0.0146
	(0.0092)
Restricted physical activity or physical work (e.g. back problems, migraines)	0.01463
	(0.0092)
Difficulty gripping objects	0.0145*
	(0.0078)
Disfigurement or deformity	0.0110
	(0.0071)
Hearing problems	0.0076
	(0.0081)
Long term effects as a result of a head injury, stroke or other brain damage	0.0141**
	(0.0072)
Limited use of arms or fingers	0.0158**
	(0.0079)
Limited use of feet or legs	0.01339
	(0.0082)
Any mental illness which requires help or supervision	0.01314*
	(0.0079)
Athritis, astoma, heart disease, Alzheimers, dementia etc	0.0146
	(0.0101)
Shortness of breath or difficulty breathing	0.0146*
	(0.0101)
Speech problems	0.01203*
	(0.0071)
Sight problems not corrected by glasses/lenses	0.00879
	(0.0078)
Year fixed effects	Yes
State fixed effects	Yes
Observations	171,301
Number of id	23,912

(i) Source: 2009-2021 waves of HILDA; (ii) Standard errors in parenthesis; *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

well-being, and physical and mental health, considerably less attention has been paid to their impact on household healthcare expenditures. Using longitudinal data from the HILDA Survey for the period 2009–2021 and individual fixed-effects models, we showed that exposure to a weather-related disaster is associated with higher medical expenditure. However, this effect is not evenly distributed across the population. The increase in pharmaceutical spending is concentrated almost entirely among individuals without private health insurance, whereas no statistically significant effect is observed among those with private coverage. Rather than indicating that private insurers directly absorb pharmaceutical costs, these findings suggest that the financial consequences of disaster-related health shocks depend on how individuals access and utilize healthcare services. In the Australian institutional context, private health insurance appears to modify the pathway through which health needs translate into out-of-pocket pharmaceutical expenditure. This observation highlights the importance of healthcare access and treatment patterns in shaping households' financial vulnerability to climate-related shocks.

Moreover, we showed that natural disasters are associated with a higher likelihood of reporting several physical and mental impairments, including difficulties gripping objects, limitations in the use of arms and fingers, speech problems, breathing difficulties, long-term neurological consequences, and mental health conditions requiring assistance or supervision. In other words, the increase in medical expenditure following disaster exposure reflects a genuine deterioration in health status rather than purely behavioral or reporting effects.

The findings contribute to the literature on the household financial consequences of climate-related shocks in several ways. First, they provide evidence from a high-income setting where private health insurance is relatively widespread, complementing the predominantly developing-country evidence on disaster-related healthcare expenditure. Second, rather than focusing on a single type of climate hazard, we examined direct household exposure to weather-related disasters. Third, whereas much of the household-finance literature examines outcomes such as income, credit, debt or insurance, our analysis focused on the medical-spending channel through which disaster-related health shocks can translate into additional household financial burdens. Our results therefore extend this literature by, first, highlighting the role of pharmaceutical expenditure and private health insurance in shaping the financial consequences of disaster-related health shocks and, second, providing evidence on the health mechanisms through which disasters translate into higher medical spending.

The study has several limitations that should be acknowledged. First, our expenditure measure mainly captures pharmaceutical costs, and therefore does not capture the full spectrum of healthcare costs that may arise following natural disasters (emergency care, specialist consultations, diagnostic tests, rehabilitation services, psychological counseling, home care, etc.) that may constitute an important component of post-disaster healthcare utilization. Consequently, our estimates should be interpreted as capturing only one dimension of the broader economic costs associated with disaster-related health shocks. Second, although our individual fixed-effects specification substantially reduces concerns about unobserved heterogeneity, disaster exposure may still be correlated with time-varying factors related to residential location or other unobserved characteristics. Third, our measure of disaster exposure is based on self-reported damage to the respondent's home. As such, it does not provide information on the intensity of the event, the magnitude of property damage, the duration of displacement, or the specific type of disaster experienced. Future research combining household survey data with geocoded information on disaster severity could provide a more detailed understanding of how different types and intensities of climate events affect healthcare expenditure. Fourth, we have assumed a contemporaneous relationship between the relevant variables.

However, some health conditions may emerge or persist over time, implying that the effects of natural disasters on healthcare spending could extend well beyond the year of exposure. Future research should examine these potential dynamic effects. Finally, we cannot distinguish between different types of private health insurance coverage or identify whether higher pharmaceutical expenditure reflects greater healthcare utilization or differences in treatment intensity. Addressing these limitations represents a promising avenue for future research. Finally, we cannot distinguish between different types of private health insurance coverage or identify whether higher pharmaceutical expenditure reflects greater healthcare utilization or differences in treatment intensity. Addressing these limitations represents a promising avenue for future research.

Despite these challenges for future research, our findings have important implications for climate adaptation policy. First, discussions of climate resilience have traditionally focused on physical infrastructure, disaster preparedness and emergency response systems. While these interventions remain essential, our results indicate that the financial consequences of disaster-related health shocks depend not only on healthcare needs but also on households' ability to access and finance healthcare. Healthcare protection should therefore be regarded as an integral component of climate resilience strategies. In the Australian context, this suggests several policy priorities. Second, because the increase in out-of-pocket expenditure is concentrated in pharmaceutical spending among uninsured individuals, temporary reductions or waivers of PBS co-payments in officially declared disaster areas could provide targeted financial protection during the immediate post-disaster period. Third, the Disaster Recovery Funding Arrangements (DRFA) and the Disaster Recovery Allowance, which currently address income loss, could incorporate a specific pharmaceutical or medical expense supplement for affected households lacking private health insurance. Fourth, the health conditions identified in our mechanism analysis suggest that disaster response should prioritize early access to mental health services, rehabilitation and allied-health support, particularly for uninsured individuals who may otherwise rely disproportionately on pharmaceutical treatment. Finally, because the expenditure effect is concentrated among uninsured households, targeted, means-tested policies aimed at improving access to private health insurance among residents of officially designated high-risk bushfire, flood and cyclone zones may help reduce this unequal financial burden. All in all, the findings highlight the potential contribution of insurance coverage to broader climate-adaptation and social-protection strategies.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: This paper uses unit record data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey. The HILDA Project was initiated and is funded by the Australian Government Department of Social Services (DSS) and is managed by the Melbourne Institute of Applied Economic and Social Research (Melbourne Institute). The findings and views reported in this paper, however, are those of the authors and should not be attributed to either DSS or the Melbourne Institute. Requests to access these datasets should be directed to melb-inst@unimelb.edu.au.

Author contributions

AB-O: Data curation, Supervision, Writing – review & editing, Software, Investigation, Visualization, Validation. MF: Formal analysis, Methodology, Writing – original draft, Validation, Resources, Conceptualization, Supervision. SB: Formal analysis, Writing – original draft, Data curation, Investigation, Supervision, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

TABLE A1 Determinants of annual household pharmaceutical expenditure.

Variables	(1) Pooled	(2) With private insurance	(3) No private insurance
Natural disaster	0.0631*	0.00272	0.126**
	(0.0356)	(0.0425)	(0.0610)
Ln (Household income)	0.0706***	0.0432***	0.0453***
	(0.0061)	(0.00746)	(0.0107)
Ln (Years of education)	−0.00203	−0.246**	0.584***
	(0.1010)	(0.123)	(0.185)
Ill–health	0.0946***	0.0745***	0.125***
	(0.0134)	(0.0166)	(0.0225)
Age	−0.0711***	−0.0659***	−0.0516***
	(0.00485)	(0.00618)	(0.00867)
Age^2	0.881***	0.825***	0.699***
	(0.0501)	(0.0625)	(0.0925)
Married	0.00152	−0.118***	0.0952***
	(0.0206)	(0.0285)	(0.0346)
Divorced	−0.293***	−0.388***	−0.112**
	(0.0337)	(0.0451)	(0.0569)
Widowed	−0.491***	−0.647***	−0.204
	(0.0736)	(0.0904)	(0.132)
Employed	−0.0332**	−0.0127	−0.0749***
	(0.0153)	(0.0187)	(0.0261)
Unemployed	−0.0940***	−0.0537	−0.151***
	(0.0249)	(0.0355)	(0.0370)
Ln (Number of children)	0.121***	0.0763***	0.0592
	(0.0227)	(0.0266)	(0.0434)
Constant	4.751***	6.128***	2.465***
	(0.257)	(0.318)	(0.470)
Year fixed effects	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes
Observations	171,301	101,553	69,748
R–squared	0.010	0.011	0.008
Number of id	23,912	15,793	14,122

(i) Source: 2009-2021 waves of HILDA; (ii) Standard errors in parenthesis; *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.