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Insuring Homes Against Extreme Weather Events: A Systematic Review of the Research

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Abstract

Home insurance for extreme weather events is a significant security mechanism not only for individual households, but for global finance. As extreme weather events become more frequent and intense, home insurance has been identified by governments as a critical tool for climate adaptation and disaster resilience. However, the growing research literature on the interactions between household insurance and climate-related disaster events has not previously been systematically reviewed. In this paper, we analyse 175 original peer-reviewed empirical research papers on this subject, published between 2009 and 2018. We identify areas of research focus, themes, spatial and temporal patterns, and knowledge gaps, and examine policy implications of these findings. We find that an overall focus on flood insurance leaves unanswered questions about the different insurantial challenges posed by storms, wildfire and coastal erosion. We suggest existing technocratic and calculative insurance narratives obscure the political and moral assumptions embedded within them, and that these assumptions warrant further investigation in the context of socially legitimate insurance against the impact of extreme weather events.

Keywords: climate change, insurance, disaster, extreme weather, systematic review.

1.0 Introduction

In an overheated climate, catastrophes are becoming commonplace. Rises in the number and severity of extreme weather events due to global warming, together with increasing development and financial exposure in high-risk areas, are responsible for highly significant increases in material and human loss

over the last 50 years (Hoeppe 2016). Residential development in areas at high risk from flood, wind or fire shows no sign of flagging, and the stakes are rising. The five-year average for weather related global financial losses grew ten-fold between 1974 and 2018 (see Figure 1). More than 60% of global losses from weather-related events are identified as uninsured (US $602 000 million of US $964 000 million total losses between 2013-2018, according to Munich Re.'s NatCatService). In response, governments, who have traditionally contributed to uninsured costs of natural disasters, are advocating further privatisation of risk management at a household scale, through the medium of insurance (Booth and Tranter 2018).

The application of insurance is extensive and varied, and as such, it has been the subject of research across multiple disciplines. To better understand the contribution of this diverse and variegated research, in this paper, we conduct a systematic review of the empirical literature on home insurance for extreme weather events. This approach has the benefits of being explicit and reproducible: it can provide methodological rigour and transparency, and is thus particularly appropriate for synthesis of fast-growing and interdisciplinary literatures such as those related to climate change adaptation (Berrang-Ford et al. 2015). Using quantitative and qualitative analysis of a corpus of 175 original peer-reviewed research papers published between 2009 and 2018, we identify key themes, patterns, and gaps in knowledge, and highlight the policy implications of this research.

We have chosen to focus on home insurance for two reasons. One, in market-based economies, households are now seen as key to maintaining global financial stability (Bryan and Rafferty 2018). Homes are not only the location for personal and familial well-being and sustainability. Their budgets and asset bases – if these are secure – are now understood as contributing to the global economy (Bryan et al. 2016). In this context, insurance as a mechanism for household security is increasingly significant for not only individuals but global finances. This has led to households being positioned as the nexus for climate change adaptation, through a government and industry led process of individual responsibilisation for climatic risk (Lucas and Booth 2020). While other forms of insurance (notably catastrophe bonds or index insurance) are important in relation to extreme weather, the social dimensions of household insurance make it distinct from these and worthy of independent research. Two, the existing body of work on home insurance is currently manageable within the parameters of a system literature review. Given this literature appears to be rapidly expanding, this appears to be an ideal time to critically engage with emerging themes and associated implications.

The overarching aim of this paper is to critically review the literature about interactions between household insurance and extreme weather events. In doing so, we aim to draw together research published across diverse disciplines, situating qualitative and analytical work on insurance in relation to quantitative and behavioural insurance research. In the following section, we describe the quantitative and qualitative methods of analysis used in this study, and its limitations. We then present the results of quantitative analysis showing disciplinary, conceptual, geographical and temporal patterns and foci of the literature reviewed. In the subsequent discussion, we consider these data in relation to seven qualitatively identified research themes: the drivers of insurance uptake; the encouragement and enabling of behaviours to mitigate risk through insurance; the relationship between government policies and private insurance; geographic and demographic patterns of insurance inequality; opportunities for new insurance markets or models; the development of new methods for risk modelling and measurement; and the lived experience insurance (or uninsurance) following extreme weather losses. In conclusion, we argue that political and moral logics are both embedded within, and obscured by, the technical and actuarial decisions made in applying household insurance policies. These logics tend to generate and exacerbate disparities in financial and community resilience.

2.0 Methods

2.1 Identifying the corpus for analysis

Literature for the review was identified using a systematic review process (Moher et al. 2009) as detailed in Figure 1. The initial search was performed on Scopus, which claims to be the largest abstract and citation database of peer-reviewed literature, in January 2019. Academic databases Mendeley and Researchgate were also searched using the same terms. To limit the body of literature returned, only articles from peer-reviewed journals in English were searched, within a ten-year publication window of 2009-2018. The search term was developed iteratively, to include all common descriptors of home insurance, and all major descriptors of climate-related extreme weather events. The final search term identified papers that contained the following in their title, and/or abstract:

insurance AND (resident* or house* or home*) AND (natural disaster OR extreme weather OR climate change OR bushfire OR wildfire OR storm OR cyclone OR hurricane OR typhoon OR flood)

The result is a comprehensive corpus of interdisciplinary literature comprising 175 articles. Figure 1 shows a flow chart adapted from the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) developed by Moher et al. (2009) describing the process used to identify and screen papers for inclusion in the corpus.

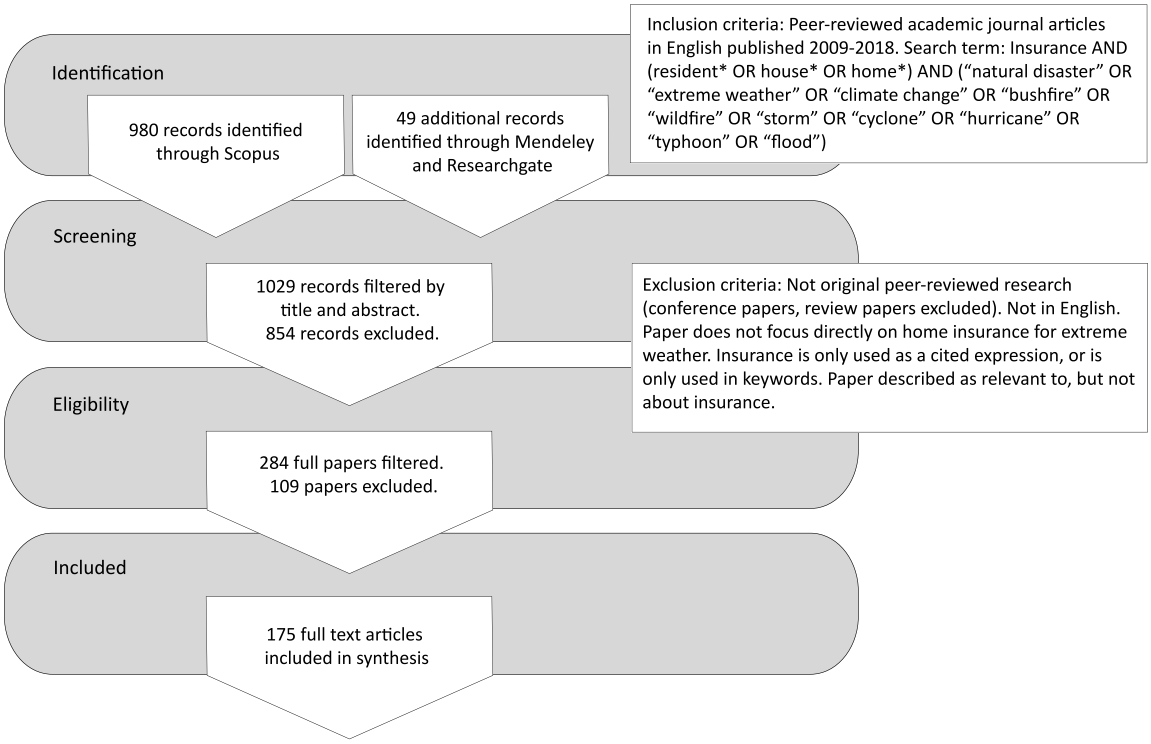

Figure 1. PRISMA statement (adapted from Moher et al. 2009)

2.2 Coding and analysis

The article database was coded in Excel (see supplementary material Table S1), using the method described by Pickering and Byrne (2014). Information recorded for each article included author, date, journal, title, keywords and abstract. Articles were coded according to quantitative categories, addressing fields of research, types of extreme weather, and geographical and temporal patterns. The 175 papers in the corpus were published across 94 academic journals. Eighty-seven of these journals are indexed according to broad fields of research, and specific subject area categories, by Scimago (https://www.scimagojr.com). We used these indices to classify each journal article in the corpus according to the indexed subject areas

of the publishing journal. Other quantitative categories included location of study (where data was collected, rather than where study was produced), data type, research methods used, and type of extreme weather event studied.

Mixed methods were used to analyse the data. To explore the relationships between key concepts in the research, we used semantic network analysis of keywords. Keywords are used by authors to codify their subject matter for other readers. Keywords may be used to indicate a conceptual, disciplinary or methodological framework, and to signal where a paper 'fits' within a broad literature. They therefore provide useful data through which to map the important concepts of a field of literature. Of the 175 papers in the corpus, 127 contained author-coded keywords. Some keywords were simple (eg. 'adaptation') and others more complex phrases containing more than one concept (eg. 'climate change adaptation', 'adaptive capacity' or 'adaptive governance'). In order to represent each individual concept, phrases were split into single words, and multiple semantic forms of individual words were grouped together, so that, for example, 'adaptive governance' was recorded both under 'adapt*' and 'govern*'. Some phrases were kept as single words, where their meaning would be lost if they were split, or if they did not appear in the keywords in other forms. Examples of such phrases include 'willingness to pay' and 'climate change'. Altogether the resulting keyword database contained 1057 words. Keywords used three or more times each were then included in a list of 72 'core concepts' for semantic network analysis. This analysis, using UCINET, examined the co-occurrence of keywords within papers to investigate the connectedness of concepts within the corpus (Borgatti et al. 2002). The keywords 'insurance' and those describing the overall context of the study (eg. type of extreme weather impact studied, that it was a climate change related event or that it was a natural disaster or hazard) were excluded from the analysis so that the relationship between the concepts framing the studies could be more clearly seen. To find the most important words connecting different components of the graph, bi-component analysis and lambda sets (dataset dichotomised for co-occurrences 3 and more) were used (Borgatti et al. 1990). Betweenness centrality (Freeman 1979) was used to choose the most important cutpoints and to identify sub-groups within the network. Graphs were produced using gephi.

We used an inductive process to identify, organise and describe themes present in the corpus. This form of analysis was used in order to generate data-driven themes, rather than fitting them to a pre-existing framework (Nowell et al. 2017). Themes were identified by reading the papers with the process of

categorising themes being iterative: 23 themes were identified in the process of analysing the first 50 papers. These papers were then re-analysed, along with the rest of the corpus, using the complete set of themes. Once analysis of the full corpus was complete, six of the themes were found to be redundant, because they fitted entirely within the scope of other themes identified, or were present in less than three articles, and so were removed from analysis. The remaining 17 themes were grouped into seven higher-order themes for the purposes of review: for example, themes relating to 'psychological drivers of insurance uptake', 'socio-economic drivers of insurance uptake', and 'willingness-to-pay' were grouped into a higher order theme called 'drivers of insurance uptake' (see Table 1). The use of qualitative thematic review methods enables us to contextualise and interpret the quantitative findings of the systematic review (Dixon-Woods et al. 2006). In the Discussion we describe these themes in detail, also drawing on evidence from the preceding analyses, to identify gaps in the literature, and policy implications of the study.

2.3 Limitations

We have used mixed methods to investigate this corpus, in order to generate complementary analyses that elaborate and enhance one another (Greene et al. 1989). However, the systematic review process and the methods used to analyse this corpus are limited in their capacity to tell the full story of research on this subject. In particular, the corpus includes only papers written in English. This may exclude important strands of insurance research, especially given burgeoning insurance markets in the developing world including China, India and Latin America. Our decision to limit the scope of the review by including only papers with the keywords *resident*, *house*, or *home* may also exclude research relevant to insurance for extreme weather events that is not framed in the context of residential insurance. In addition, neither quantitative methods nor the qualitative summaries undertaken are conducive to deep engagement with conceptual nuances and complex discourses. However, overall, we feel confident that given the size and breadth of our corpus and our use of a well-established systematic review method, we have identified key themes and associated gaps and thus, provide a strong evidence base for our reflections pertaining to policy and associated conclusions.

3.0 Data and results

In this section, we present the results of our analysis in relation to the subject areas, fields of research and extreme weather events represented in the research; geographical and temporal patterns in these; and the

relationships between key concepts in the literature. In the subsequent discussion, we then discuss these in relation to the research themes, identifying interlinkages and divergences in relation to each, as well as implications for future research and policy.

3.1 Field of research

While insurance is traditionally the subject of financial and economic research, the corpus provides evidence that it is of interest to a broad range of subject areas. In fact, only 19% of the literature reviewed was published in economics or business journals. Papers published in the fields of Environmental Sciences and Geography & Social Sciences made up half of the corpus (see Figure 2).

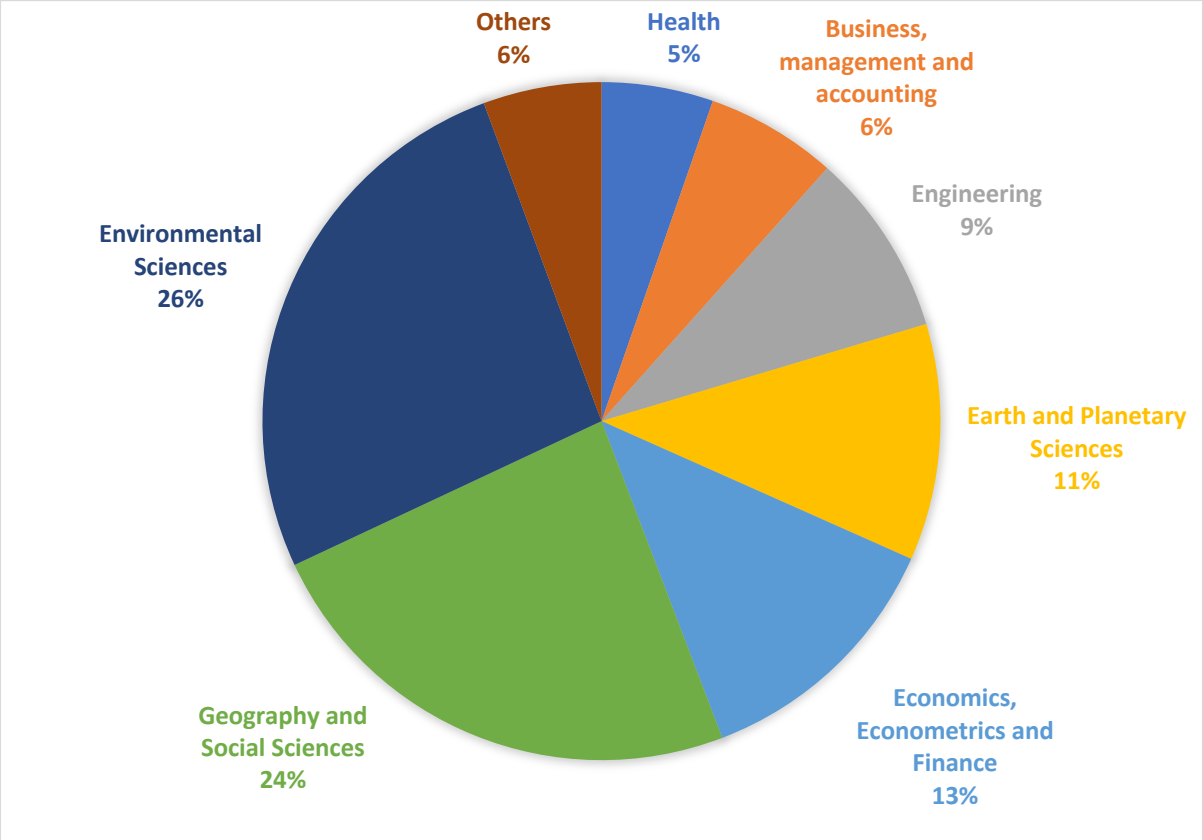

Figure 2. Proportion of papers in the corpus published in each field of research (journal subject areas indexed by Scimago)

A closer look at the subject areas represented within each broad field of research shows the variety of insurance research being undertaken (see supplementary materials). Economics and econometrics accounted for the largest focus on insurance, closely followed by geography. There is also a predominance of science-based research, with high numbers of papers accounted for in atmospheric science and water science and technology. Somewhat surprisingly, there is a low number of papers in law, despite the legalistic dimensions of insurance in relation to disasters.

3.2 Geographical range of the corpus

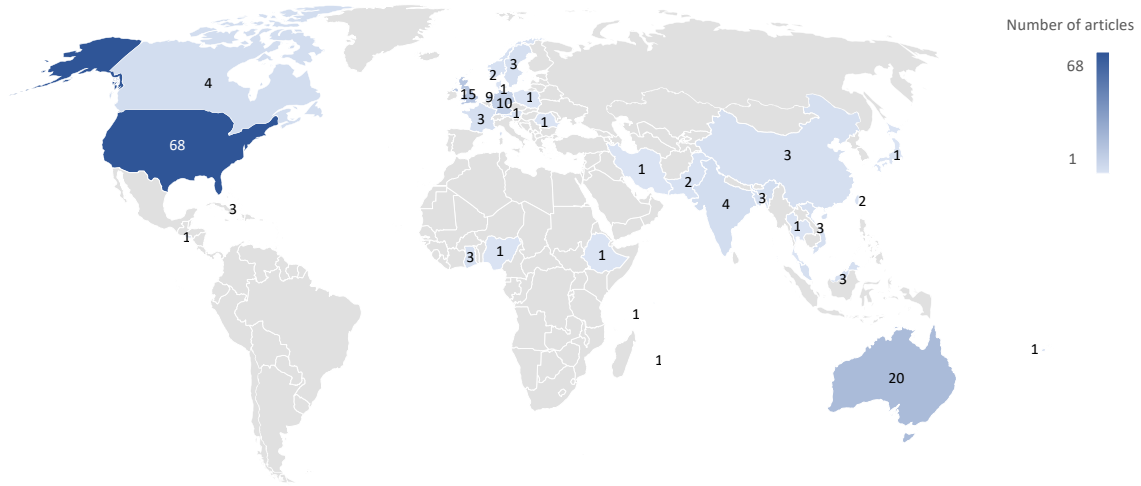

Figure 3. Map of number of articles by country of study focus

The map shown in Figure 3 attests to the dominance of studies undertaken in the USA – American studies account for more than a third of the literature in the study. Australia, the UK, Germany and the Netherlands are also strongly represented. Interestingly, the research includes a number of island states – including Caribbean states, the Seychelles, Mauritius, Fiji, Taiwan and Japan. These studies appear to reflect the growing risk of extreme weather on coastal populations, particularly in tropical regions affected by cyclones (e.g. Chandra and Gaganis 2016; Leatherman 2018).

3.3 Types of extreme weather

Literature on home insurance for extreme weather events grew rapidly between 2011 and 2013, and has since levelled off at around 22 papers per year. Despite flood insurance being unavailable in many countries, the predominance of research focussing on flood has grown since 2012, rising to 73% of all papers in the corpus in 2018. Although storm events are clearly of major importance, by comparison, the corpus shows a bias toward research on flood, which is responsible for 59% of the total research focus, compared to storm at 17% and wildfire at 3%. As well as its high cost to the insurance industry, the focus on flood may in part be attributable to the availability of improved risk mapping for flood affected areas. Fluvial floods are more geographically predictable than storms or wildfires, tending to re-occur in the same places (with increasing frequency thanks to climate change). Insurers are therefore able to factor in the risk of flood more easily than other hazards. This has led to home insurance in areas at high risk of flooding becoming increasingly unaffordable. In the US and the UK, governments subsidise flood insurance

through the long-running National Flood Insurance Program (NFIP) in the US, and its newer counterpart Flood Re in the UK. The NFIP is the focus of a large proportion of research in this corpus. This may in part be because, as a federal government insurance program, the NFIP has publicly available data. This is unusual in insurance research, as most private insurers are not inclined to share their data, which could be both commercially and politically sensitive. The NFIP has also been subject to much criticism and modification, particularly in recent years. Figure 4 shows the dominance of flood research increasing over the ten years represented in the corpus. This may also reflect an increase in flood risk due to climate change (Jongman 2018). Storm research counts for a smaller, but growing proportion of studies, while all-hazards research has slightly dwindled over the ten years represented. Wildfire research is represented in only four of the ten years examined.

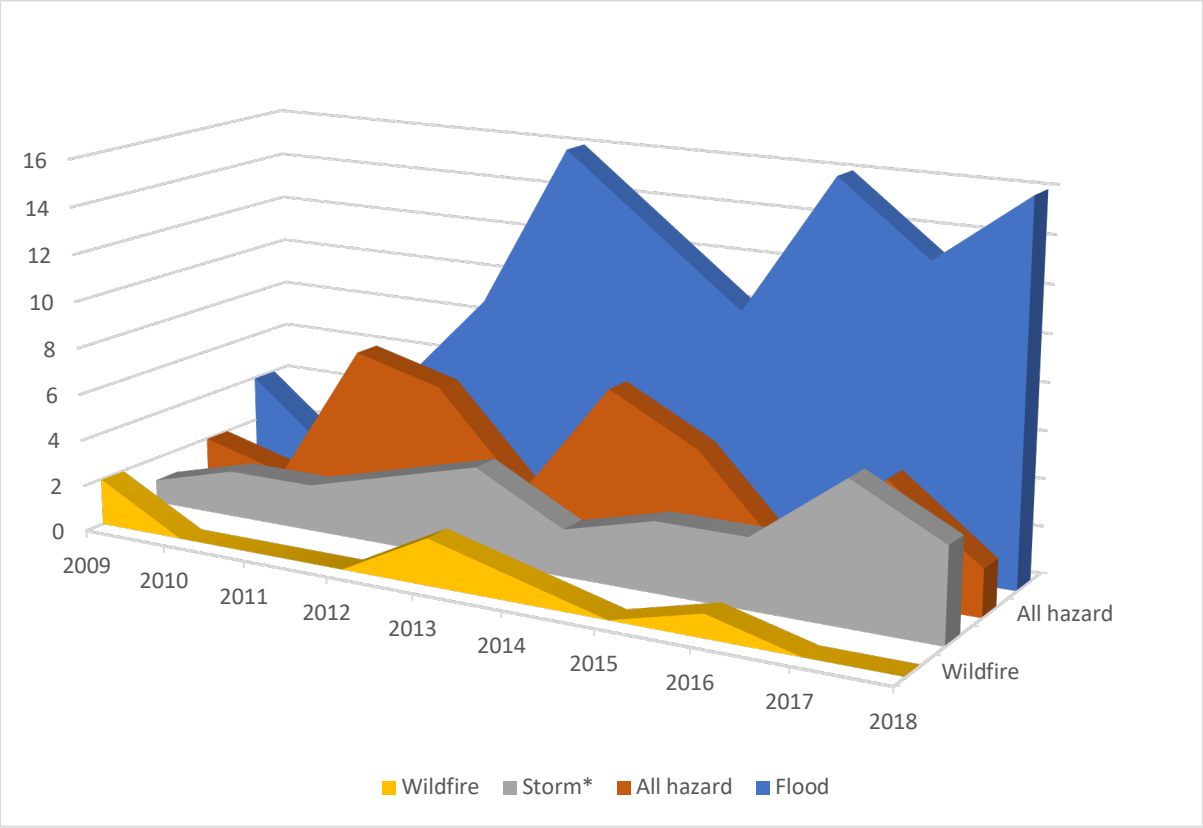

Figure 4: Number of publications per year by hazard type

3.4 Key concepts

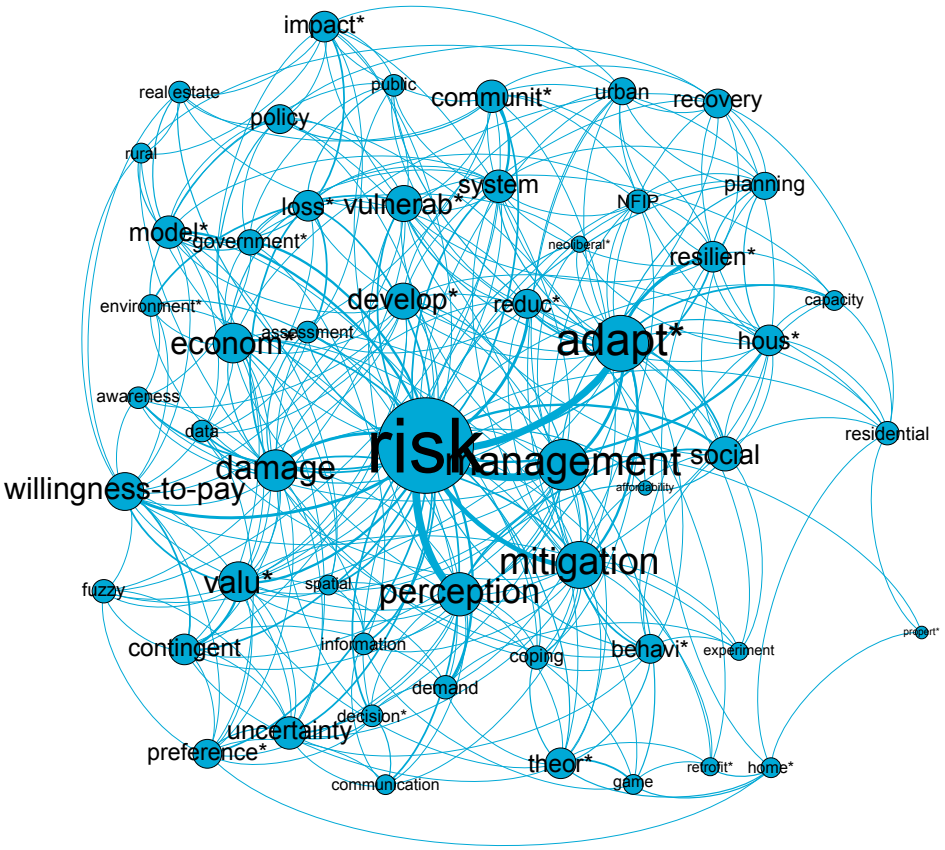

*Figure 5: Network diagram of concepts present in keywords with three or more occurrences, after the search terms 'insurance', 'climate change' and those describing the type of impact ('flood', 'hurricane', '*fire', catastroph*, 'natural', 'disaster', 'hazard', 'extreme', 'event', 'storm', 'weather') were excluded.*

Figure 5 shows the co-occurrence of concepts represented in the keywords. The size of each 'node' (the circle behind each concept) represents the number of times the concept occurs in the keywords, and thickness of lines represents the number of connections. In this highly centralised network and perhaps unsurprisingly, 'risk' is the central concept connecting 54 other conceptual nodes.

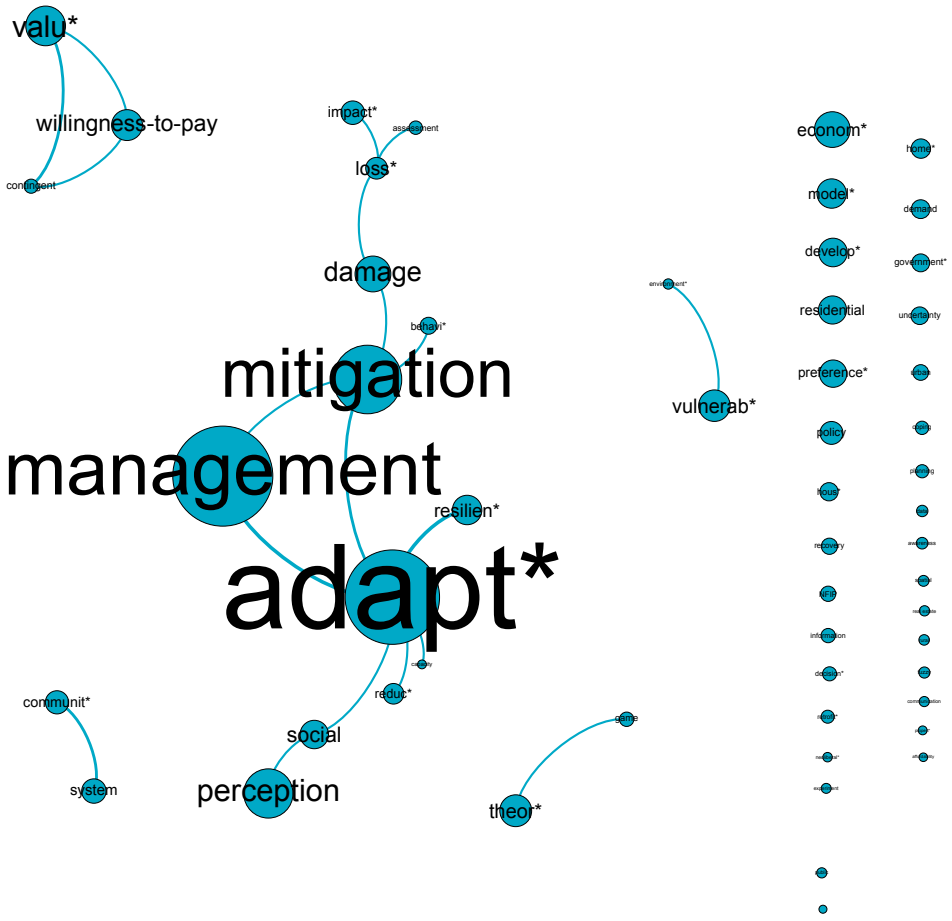

Figure 6: Network diagram of concepts present in keywords with three or more occurrences, after further removing the term 'risk'.

In order to examine the conceptual relationships within this semantic network independent of the concept of risk, we looked at the relationships between the same 54 concepts once 'risk' is excluded (see Figure 6). Adapting to, mitigating, and managing risk from extreme weather events are the central concepts in this network.[i] The analysis shows that adaptation is closely related to human concepts – 'social', 'perception', 'capacity', 'resilience' – while mitigation is more allied to concepts relating to property – 'damage', 'loss', 'impact' and 'assessment'. 'Behaviour' is, however, more closely related to mitigation, and 'reduction' (largely used in the context of risk reduction) most connected to adaptation. 'Management' appears often in relation to both adaptation and mitigation, but does not strongly link to other concepts. Within the corpus management often refers to broader collective efforts, especially by governments, to handle extreme weather impacts, for example in relation to disaster management, or management of coastal zones. Four other conceptual groupings emerge in Figure 6 as strongly internally connected. One is a set of concepts relating to financial methodology: 'willingness-to-pay', 'valuation', and 'contingent'. While the

concept of valuation was used in multiple ways within the corpus, it occurred four times in the corpus keywords in the context of 'contingent valuation' which is a method of estimating the value that a person places on a good. This is often used as a way to calculate willingness-to-pay. Another methodological group of concepts connects 'game' and 'theory'. While multiple theoretical approaches were used in the corpus, game theory was mentioned three times in the corpus keywords. 'Community' and 'system' are related by virtue of four papers investigating the NFIP Community Rating System. The final grouping links the concept of 'vulnerability' to 'environment'. It is interesting given that vulnerability is most often examined in relation to environmental, rather than economic factors. Also of note is that the concept of vulnerability is not strongly associated with resilience in this literature.

3.5 Themes

Seven overarching themes were identified within the corpus, with each of the 175 papers representing one or more theme (see Table 1). These themes were identified inductively, through an iterative process, and reflect the foci of the literature, rather than the authors' interests (see Methods). Each theme relates either to the measurement or risk modelling of extreme weather events, or to the relationships between insurers, homeowners, and governments, and the mechanisms through which these relationships are managed. These themes are interlinked, and thus papers often cross multiple themes. In the next section we discuss these themes in order of prevalence and in relation to the data and results pertaining to field of research, geographical location and key concepts, outlining the main arguments, the evidence presented, and any disciplinary, methodological or geographical foci.

4.0 Discussion

The predominant patterns of geography and subject focus in the corpus of this insurance research correspond to the history of private insurance – its emergence and prevalence in the western world is reflected by most of the research being located in places like the US and Europe. It also reflects one of the limitations of this review – an exclusion of non-English papers that potentially contributes to the western bias in our analysis. The dominance of the idea of risk also reflects the lineage of insurance and insurance research. Its roots in actuarialism assume a direct calculable correlation between insurability and risk. In other words, risk is 'calculable, it is collective, and it is capital' (Ewald, 1991, p.201) and anything that is

insurable is a risk and *vice versa*. This provides a scientific imperative to much insurance research, an imperative that tends to assume insurance to be a benign tool that is premised on rational decision-making. As we discuss here in relation to each of our identified themes, the lineage of these types of ideas continue to resonate throughout insurance research. However, we also identify in the corpus how more subjective and human dimensions of adaptation are garnering new insights and perspectives that are adding nuance and complexity to existing and future research directions with significant policy implications.

Our most commonly represented theme examined the **drivers of insurance uptake**. This research investigates the psychological and socio-economic factors affecting insurance purchase. The geographical range of these papers is very wide, and it includes studies in countries where home insurance is not currently widely available, such as Bangladesh, Vietnam, China, Ghana and Pakistan (see also the theme *Opportunities for new markets/models of insurance*, below). Two thirds of the papers in this theme focus on flood insurance. Flood is a Several studies found that more affluent people were more likely to buy insurance (Hung 2009; Ghanbarpour et al. 2014; Browne et al. 2015; Brody et al. 2017; Wang et al. 2017; Yiannakoulias et al. 2018) – and that lack of affordability of premiums was a strong barrier to purchase (Aliagha et al. 2015; Kuo 2016). None of the papers in the corpus presented evidence to the contrary.

Householders' perception of risk was a more controversial theme, with evidence presented both for and against the importance of understanding the level of risk in making decisions about insurance. Some studies suggest that level of risk is not an important factor in deciding to insure (Browne et al. 2015; Brody et al. 2017), while others identify evidence that it is (Kousky 2011; Aliagha et al. 2015). In general, and as introduced above, research on insurance tends to assume the existence of an objective measure of risk, which can be mapped or calculated using scientific methods. Booth (2018) points out that insurance logics assume a level playing field of individual rational agency, in which high insurance prices are signals of risk that lead to adaptive responses in insurance customers are at odds with the complex life circumstances that contribute to insurance decisions. Kousky and Michel-Kerjan (2017) also cast doubt on the importance of rational decision-making, finding that individuals have limited ability to understand the risk of low probability events. A meta-analysis by Bubeck et al. (2012) found no evidence that risk perception was a positive factor in insurance uptake.

Previous experience of extreme weather may have a different effect on decision-making to that of abstract risk information. Several studies examined how personal experience of extreme weather events affects

people's likelihood of purchasing insurance. Five studies found that such experience increased likelihood of insurance purchase (Hung 2009; Petrolia et al. 2011; Wang et al. 2012; Seifert et al. 2013; Chatterjee and Mozumder 2014) but this was questioned by Harries (2012), who found that experience of flood can reduce confidence in the usefulness of insurance for recovery, and can also lead to denial of risk as a self-protective mechanism. Kousky (2017) found that insurance uptake increases in the 3 years after a major flood event, and then decreases. Other studies found similar effects of event immediacy (Gallagher 2014; Dumm et al. 2017; Wang et al. 2017). Individual risk perceptions may have an indirect effect on insurance purchase through their contribution to social norms (Lo 2013a). In a study of flooded households in Australia, Lo (2013b) found that norms have a greater effect than on whether people buy insurance than individual risk perception or economic factors. Neighbours' decisions were also found to affect insurance uptake in Florida (Torres et al. 2018), Thailand (Allaire 2016), and the Caribbean (Grislain-Letrémy 2014).

While the use of **insurance incentives to encourage and enable risk mitigation (or adaptation) behaviour** (our second theme) has been discussed in the literature across the ten years represented in this study, in practice insurers offer such incentives irregularly. As governments place increasing emphasis on insurance as a means for adaptation, insurance mechanisms through which risk mitigation can be rewarded are a growing subject of discussion in both academic and grey literature. This is reflected in the semantic network analysis that shows adaptation and risk mitigation are pivotal concepts in this corpus. Risk mitigation tends to be conceptually linked to technical and physical actions – for example construction of flood defences or use of fire or cyclone-proof building materials. Adaptation, however, is linked to social and psychological drivers in this literature. Studies examining how insurance can incentivise adaptation primarily looked at decreases in premiums for lower risk properties through risk reflective pricing, or subsidies for particular risk mitigation activities (e.g. Harwood et al. 2016), although adaptive retreat from high risk areas due to a negative effect on house prices was also considered (e.g. Belanger and Bourdeau-Brien 2018). A number of studies using econometric models suggest that risk-reflexive pricing, where premiums are adjusted to reflect the modelled risk of individual properties, is likely to incentivise adaptive behaviour (Peng et al. 2014; Hudson et al. 2016). In a study of wildfire in Texas, USA, Collins and Bolin (2009) found that such incentives were effective in encouraging about 10% of residents to retrofit their houses in order to reduce the risk. However, subsidies offered were not sufficient to enable lower income households to undertake mitigation, and higher income amenity migrants, whose properties were often

second homes, tended to see insurance as a substitute for risk mitigation. Other studies echo the finding that insurance incentives are only effective in encouraging risk mitigation by the relatively affluent (Li and Landry 2014; Paille et al. 2016; Osberghaus 2017).

The problem of 'moral hazard', where being insured reduces the incentive to mitigate risk, as with Collins and Bolin's Texan amenity migrants, is also discussed by a number of papers in this theme. Cameron and Proverbs (2014) describe moral hazard as the outcome of widely available insurance, together with insurance rather than mitigation being the norm. It may be much cheaper to insure, and then rebuild in the case of disaster, than to mitigate the risk, as retrofitting older houses can be extremely costly (Burrus et al. 2011). Nevertheless, Botzen et al. (2013) found that investing in adaptation can be more appealing than facing the need to rebuild after a disaster. Some researchers argue that concern about moral hazard is misplaced: for example, Osberghaus (2015) found no evidence that insured residents reduce their level of mitigation in a study of 4200 householders in Germany. Finally, there is evidence that insurance incentives are imperfectly applied: Torres et al. (2018) attest to poor communication by insurers of the incentives available to customers, and Antwi-Boasiako (2016) offers evidence that undertaking risk mitigation may not lead to reduction in premiums. Given the increasing emphasis being placed on insurance as a mechanism for individual climate adaptation, the apparent failure of this project, particularly in high-risk, low-income places, is an important focus for future research.

A third theme reflects on the **relationships between government policies and private insurance**. Adger et al. (2013) suggest that adaptation to climate change occurs primarily in response to extreme weather events, during which the social contract between states and individuals evolve. Neoliberal governments are progressively withdrawing from risk management, which is increasingly framed as an individual responsibility (Booth 2018, Lucas and Booth 2020). This move brings issues of inequality and vulnerability to the fore. The fundamental challenge is to protect the vulnerable, while avoiding subsidising residence in high-risk, unmitigated environments (Green and Olshansky 2012). For example, Zahran et al. (2009) criticise The US government-subsidised National Flood Insurance Project for increasing the affordability of living in high risk areas – the argument being that the absence of affordable insurance might incentivise people to leave these areas. Roche et al. (2010) find that government policies in developed countries fail to encourage individual mitigation, or to deter development in high risk areas. They suggest insurance subsidies should be available only to those who already live in high risk areas.

Several papers in this theme find evidence of 'charity hazard': that the existence of post-disaster funding by governments reduces people's willingness to buy insurance (Shughart II 2011; Botzen and van den Bergh 2012; Seifert et al. 2013; Davlasheridze and Miao 2018; Kousky et al. 2018). This may be exacerbated where government support is more efficient than that provided by private insurers (Kammerbauer and Wamsler 2017). Comparing different models of insurance across the EU, Porrini and Schwarze (2014) argue that countries with free market insurance and government disaster funding (such as Italy, Austria and Australia) perform worse than those with other models, such as public monopoly insurance, because they are subject to both adverse selection (in which insurance pools contain too many high risk, compared to low risk customers) and charity hazard.

The idea of equitability is taken further in a theme examining the **geography and demography of insurance inequality**, which pays particular attention to the spatial aspects of vulnerability that can be exacerbated by insurance. For example, Gearing (2018) shows how rising insurance premiums (due to increasing use of risk-reflective pricing) in Australia lead to people becoming 'stuck' in risky places. Oulahen et al. (2015) give a Canadian example of how insurance interacts with income inequality and other determinants of vulnerability to allow powerful groups of people to live in hazardous places without taking on the full risk. Receiving insurance payments post-disaster may not contribute to recovery where there are other social pressures – Gallagher and Hartley (2017) describe the case of Hurricane Katrina in which mortgagees were pressured to use payments to repay banks, rather than to rebuild.

Opportunities for new markets/models of insurance are discussed with reference to countries where household insurance for extreme weather damage is less common. Countries represented by papers in this theme include from Vietnam, Malaysia, India, Bangladesh, Ethiopia, Nigeria, Fiji, the Seychelles, Mauritius, and China. Research investigating the opportunities for new insurance markets in low-income countries identifies a complex range of factors limiting current interest in home insurance (Abbas et al. 2014). Households in these countries often have existing strategies to support each other through kinship networks, in place of commercial insurance. For instance, in a study of household recovery from flooding in Bangladesh, Islam and Nguyen (2018) found that many households have informal resource-sharing networks of neighbours and relatives that contribute to their recovery from natural disasters. People with these informal arrangements are less likely to take out formal insurance (Mahmud and Barbier 2016). The longevity and success of such existing informal insurances, together with lack of trust in corporate

insurance systems are limiting factors – in Vietnam, for example, people do not see a need for formal insurance markets (Reynaud et al. 2018). However, as evidenced by several papers in this theme, these arrangements can lead to asset depletion in high risk areas (Patnaik and Narayanan 2015; Islam and Nguyen 2018; Wuepper et al. 2018). People whose homes and possessions are of low relative cost are more likely to prioritise forms of insurance that protect their health, or pay a premium if they should die as a result of a catastrophic event (Reynaud et al. 2018). However, in countries with increasingly affluent populations, risk exposure is growing as people invest in higher quality housing. Ren and Wang (2016) found that two-thirds of rural Chinese people whose home was their only major asset were willing to purchase flood insurance, which is not currently available in these areas. James and Yearwood (2014, p. 8) call for new forms of insurance that do not fall into the 'traps' of insurance present in developed countries: namely "high premiums in high risk areas where the most vulnerable are located; incentivising settlement in high risk areas and dis-incentivising the adoption of mitigation measures; limited coverage by private insurers in high-risk zones; and inefficiency of publicly funded programs." Some researchers see micro-insurance as an answer to these problems in developing countries. For example, Calis et al. (Calis et al. 2017) find that micro-insurance was successful in reducing the impact on Indian households of Cyclone Phailin in 2013. The opportunities and limitations of Catastrophe funds, often used by insurers and governments as ways to reinsure against liability for household insurance after extreme weather events (Aggarwal 2012; Grove 2012; Medders and Nicholson 2018) are also discussed in this theme. While these kinds of mechanisms offer new ways of off-setting financial risk, questions remain about the political effects of a mechanism in which uncertainty is rationalised as catastrophe in order to be leveraged as capital (Grove 2012). Another group of papers in this theme examine the financial cost of natural disasters in order to highlight examples where insurance is not currently used, or to see how it could be used more effectively. The remainder of papers in this theme take the perspective of the private insurance industry in examining opportunities to develop new markets, looking in particular at willingness-to-pay for insurance in different international contexts. Future research on insurance in low-income countries could examine the benefits of existing informal systems of insurance, and investigate the potential for hybrid models in which these socially networked transactions could be formalised and levels of protection increased.

A group of papers discuss the **development of methods for risk modelling and measurement**. These are mostly technical quantitative studies of relevance to the insurance industry, and a number of them use data

from insurers. This is interesting in itself, as insurance company data is rarely made available for independent research. Several focus on the need for better prediction of changing patterns of extreme weather events, and insurers' exposure to risk in relation to the cost of insured property in high risk areas. Finally, a small group papers in the corpus investigate the **lived experience of extreme weather losses and insurance**. These are mostly qualitative, or mixed methods studies, using information given by people who have lived through the experience of an extreme weather event that has impacted their home. Overall, papers in this theme are critical of insurance from the perspective of the insured. For example, Sneath et al. (2009) found that the stress caused by loss of possessions is not mitigated by having insurance. Trust, or distrust, of insurers (and in government responses to disaster) is an important thread in this theme, with lack of trust, due to either personal experience or broader social narratives about insurance, contributing to decisions not to insure (Booth and Tranter 2018; Torres et al. 2018). Evidence of poor practice by insurers, and the impact on the insured, is described in relation to Hurricane Katrina (Strangia 2010; Young 2011). Sakurai et al. (2011) describe the importance of perceptions of procedural and distributive justice, and ensuring that insurance customers' voices are heard. Booth and Harwood (2016) describe the experience of insurance as itself potentially catastrophic: noting specifically that a lack of transparency on behalf of insurers causes uncertainty and anxiety, while the individualisation of risk and objectification of household possessions through the insurance process undermines everyday logics and reduces the incentive to insure. Several of these papers find that insurance itself is not sufficient for disaster recovery. For example, Keogh et al. (2011) in a case study of flood-affected Charleville, USA, found that while one third of residents impacted by the floods were uninsured for flooding, strong social networks and a high proportion of longterm residents helped the community to be resilient, and recover quickly.

Table 1: Thematic summary of papers (n=175, papers may include more than one theme). Full database is available in the supplementary materials

Paper code	Data (no.)	Methods used	Country/ Region (no.)	Hazard studied (no.)	Description
Drivers of insurance uptake (65)					
2, 11, 12, 13, 15, 16, 17, 22, 26, 28, 31, 33, 36, 37, 39, 42, 43, 48, 50, 51, 52, 53, 54, 59, 61, 66, 67, 68, 70, 72, 74, 80, 81, 82, 84, 85, 87, 88, 92, 93, 94, 95, 97, 98, 101, 103, 108, 109, 115, 116, 124, 125, 135, 137, 138, 146, 147, 151, 152, 154, 155, 169, 170, 171, 174	Quant (55) Qual (6) Mixed (3)	Surveys, statistical analysis, insurance data analysis, document analysis, spatial analysis, econometric modelling, demographic analysis, psychology experiment, interviews, participant observation, focus groups, case studies, meta-analysis	USA (24) Europe (14) Asia (9) Australia (8) Canada (2) India (2) Africa (2) Middle East (1) International (3)	Flood (44) Storm (9) Wildfire (3) Coastal erosion (1) All-hazards (8)	A large body of research investigates the psychological and socio-economic factors affecting insurance purchase. These papers overwhelmingly focus on flood insurance. Many papers in this theme model willingness-to-pay under different conditions. Another group of papers focus on data from the US National Flood Insurance Program. A small group of these papers examine the role of subjective perceptions of risk in determining likelihood of insurance purchase.
Encouraging and enabling mitigation behaviour (vs moral hazard) (36)					
10, 30, 31, 35, 41, 60, 76, 78, 82, 84, 88, 91, 93, 94, 96, 97, 98, 103, 108, 118, 119, 128, 132, 135, 137, 142, 146, 148, 153, 154, 155, 159, 167, 171, 174, 175	Quant (27) Qual (6) Mixed (3)	Surveys, participant observation, focus groups, psychology experiment, interviews, case studies, document analysis, statistical analysis, econometric modelling	USA (16) Europe (13) Australia (1) Asia (1) International (5)	Flood (25) Storm (5) Wildfire (3) All-hazards (3)	Many of these papers discuss the perceived problem of 'moral hazard' ie. That being insured reduces incentives to undertake risk minimisation behaviour. Another stream of papers within this theme examine predictors of mitigation behaviour, while a third examines options available to insurers to encourage and enable mitigation of the risk of extreme weather events on households.
Relationships between government policies and private insurance (38)					
3, 4, 6, 8, 9, 20, 27, 57, 61, 77, 78, 82, 89, 95, 98, 99, 101, 102, 104, 106, 107, 110, 116, 119, 121, 128, 132, 138, 142, 143, 144, 154, 157, 158, 160, 161, 162, 166, 174	Quant (24) Qual (11) Mixed (4)	Surveys, case studies, document analysis, focus groups, interviews, econometric modelling, statistical analysis	USA (23) Europe (9) Australia (3) Canada (1) Asia (1) International (2)	Flood (26) Storm (7) Wildfire (3) All-hazards (3)	These papers discuss the implications of varying roles and relationships between private insurers and government agencies, including for individuals and communities. They describe, compare and analyse different models of government involvement in planning for, and responding to extreme weather events.
Geography and demography of insurance inequality (30)					
2, 5, 9, 15, 17, 23, 27, 36, 49, 51, 58, 59, 61,	Quant (18) Qual (8)	Spatial analysis, surveys, insurance data analysis,	USA (19) Australia (4) Canada (3)	Flood (16) Storm (6)	A large proportion of these papers are concerned with spatially distinct forms of social inequality, exploring ways in which

62, 63, 69, 77, 83, 107, 118, 122, 124, 125, 137, 147, 153, 157, 160, 161, 165	Mixed (4)	document analysis, interviews, case studies, demographic analysis, statistical analysis, econometric modelling	Europe (2) India (1) International (1)	Coastal erosion (1) Wildfire (1) All-hazards (6)	insurance interacts with social and economic power and vulnerability. These papers also examine the social geographies of high risk environments.
Opportunities for new markets/models of insurance (22)					
7, 12, 14, 18, 19, 32, 34, 38, 43, 45, 47, 48, 54, 73, 75, 79, 100, 111, 129, 140, 156, 157, 168	Quant (17) Qual (4) Mixed (1)	Surveys, econometric modelling, interviews, case studies, spatial analysis, climatological analysis, statistical analysis and modelling.	Asia (7) India and Indo-pacific (5) Africa (3) South America (1) Oceania (1) Europe (1) USA (2) Canada (1) International (1)	Flood (9) Storm (3) All-hazards (10)	A large proportion of these papers call for forms of home insurance to alleviate the cost of extreme weather damage for households in developing countries. Some of them look at need in relation to vulnerability to natural hazards, while others examine how communities manage without insurance. Several papers in this theme explore the potential for micro-insurance, or different forms of private or government insurance to those currently available in developed countries.
Development of methods for risk modelling and measurement (20)					
11, 12, 24, 25, 29, 55, 64, 71, 86, 90, 105, 112, 113, 114, 136, 145, 149, 150, 172, 173	Quant (20)	Climatological analysis, spatial analysis, insurance data analysis, statistical and econometric modelling, meta-analysis	Europe (8) USA (9) Australia (1) Unspecified (2)	Flood (8) Storm (7) Coastal erosion (1) All-hazard (4)	High use of insurance data. These papers often designed to help improve risk management processes for insurance companies, and had high levels of co-operation and collaboration with the industry.
Lived experience of extreme weather losses and insurance (9)					
36, 165, 174, 130, 139, 127, 133, 141, 123	Qual (5) Mixed (9) Quant (1)	Surveys, focus groups, case studies, interviews, participant observation	USA (6) Australia (2) Europe (1)	Storm (3) Flood (2) Wildfire (1) All-hazards (3)	This small group of mostly qualitative papers examine the effect of extreme weather events on perceptions about insurance; experiences of interactions with insurers during claims, including discussion about trust in insurers; and accounts of the psychological effects of being insured or not after a disaster.

5.0 Conclusion

Our review of this corpus of insurance research highlights both gaps and opportunities for insurance research. There appears to be a need for studies that question the embedded rationalistic and positivist assumptions of much existing insurance research. The majority of the corpus was made up of quantitative studies. Qualitative and mixed-method approaches offer greater depth of insight into decision-making processes and the complexity of both cognitive and emotional processes of householders, insurers and governments. Gaps include studies of householder expectation and experience of insurance; studies exploring how insurance industry decision-makers design policies to meet the needs of markets; studies

examining the processes of government insurance policy development; and legal studies of insurance equitability and justice. With insurers paying much closer attention to markets in places like China, India and Latin America, engagement with the cultural and social nuances of household experiences and perceptions of insurance both within and between nations would likely deepen understandings of this important feature of contemporary life. This includes more research and/or a dissolving of language barriers through international collaborations. Another area ripe for further research is the comparison in terms of social legitimacy and equitability of different models of insurance, from unfettered insurance markets, to government partnerships, microinsurance, index insurance, and solidarity funds.

In terms of the hazards faced, the literature on wildfire insurance is still nascent, and in need of further study given the relative unpredictability of wildfire events, together with their propensity to cause total loss of property, which exacerbates the issue of household underinsurance. The effects of climate change, on both the capacity of insurers to provide suitable and equitable cover to households, and on the relationships between insurers, insured and governments was not definitively addressed in this literature. Given the increasing frequency and intensification of extreme weather events, and increasing financial exposure through continued development in high risk areas, these are important areas for further research.

A number of policy implications stem from this review. Overall, while affordability was a barrier to insurance purchase, risk perception appeared not to drive uptake, except in the immediate aftermath of a disaster. Insurers and governments attempting to increase insurance uptake should focus on activating social norms, rather than concentrating solely on providing risk information. However, given the ubiquity of risk-reflective pricing, this is unlikely to be successful in encouraging uptake in less affluent high-risk areas. Households in these areas are likely to miss out on insurance protection unless it is mandated by government. Social legitimacy should be a focus of policy development. Purely market-based models of insurance for extreme weather events are unlikely to address the problem of new development in high risk areas, or of people becoming trapped by negative equity without a safety net, because they cannot afford either to move from these areas, or to insure. In this context, risk reflexive pricing should not be unquestioningly applied as best practice. It is important to recognise that what are often presented as technical and actuarial decisions made in applying insurance obscure the political and moral logics embedded within them. Governments should ensure that insurance logics do not disadvantage the least

privileged members of society, even if such protection involves regulation and unwelcome intervention in the insurance industry.

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[i] It should be noted that in the context of insurance (and papers in this corpus) 'mitigation' tends to refer to localised activities to mitigate the risk of extreme weather events on property, rather than to climate change mitigation, for example through reducing greenhouse gas emissions. 'Adaptation' in the corpus is more often used in the broader context of climate change, in relation to expected increase in extreme weather events. Adaptation and mitigation are therefore more closely related concepts within the insurance literature than in the wider literature on climate change.