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# ECONOMIC EXPERIMENTS, HYPOTHETICAL SURVEYS AND MARKET DATA STUDIES OF INSURANCE DEMAND AGAINST LOW-PROBABILITY/HIGH-IMPACT RISKS: A SYSTEMATIC REVIEW OF DESIGNS, THEORETICAL INSIGHTS AND DETERMINANTS OF DEMAND

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**Abstract.** This paper provides a systematic review of the literature on 80 experimental, hypothetical survey and market data studies of insurance demand against low-probability/high-impact risks. The objective of the review is to extract lessons from these studies and to outline an agenda for future research. We contrast the results of experimental and survey studies to findings from market data. We focus on experimental design methods, insurance characteristics, as well as results about theories, heuristics, behavioural biases and explanatory variables. Lessons for policymakers are drawn which can facilitate disaster preparedness.

**Keywords.** Economic experiment; Hypothetical survey; Insurance demand; Low-probability/high-impact events; Market data

## 1. Introduction

This paper reviews the literature on economic experiments, hypothetical surveys and market data studies of insurance demand against low-probability/high-impact (LPHI) events. These events, which are catastrophic losses for an individual, are difficult to predict and can have a large societal impact (Kunreuther, 1996; Browne *et al.*, 2015). There is an increased interest in LPHI risks by academic researchers and policymakers (Barberis, 2013). The recent incidence of natural disasters, terrorist attacks and financial crises are examples that LPHI events occur around the world. Such events are likely to become more prevalent with the impact of climate change and globalization (Taleb *et al.*, 2009; Bouwer,

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2013). Risk management solutions for LPHI events have become a societal priority in which insurance can play an important role (Kunreuther, 2015).

Over the past few decades, there has been some progress in understanding the psychology of behaviour towards tail events, as summarized in Barberis (2013). Expected utility theory, first axiomized by von Neumann and Morgenstern (1944), is used as the benchmark for analysing behaviour under risk. Expected utility theory tends to perform well under medium to high-probability/low-impact (HPLI) risks; however, in the domain of LPHI risk the theory sometimes fails to give an adequate explanation of behaviour (Browne *et al.*, 2015).

In light of this, Kahneman and Tversky (1979) developed Prospect Theory, later modified to a version called cumulative prospect theory (Tversky and Kahneman, 1992). Both original prospect theory and cumulative prospect theory account for increased sensitivity to decisions framed as losses relative to gains due to loss aversion and the tendency for low probabilities assigned to the worst outcomes to be over-weighted by incorporating probability weighting. A variety of alternative non-expected utility models have also been developed to explain individual decision making under risk, including dual theory, as well as to explain decision making under uncertainty and ambiguity (see Section 4.2). Moreover, it has been well recognized that individuals find it difficult to process information about LPHI risk (Kunreuther *et al.*, 2001). To cope with these complexities, individuals often apply intuitive thinking processes and use heuristics or rules of thumb (Gilovich *et al.*, 2002; Slovic *et al.*, 2007). Heuristics and intuitive thinking may explain observed deviations of subjective probabilities and losses from their objective counterparts (Botzen *et al.*, 2015). Moreover, heuristics may provide a short cut to decision making which is easier than mental calculations based on probability estimates.

Theory and heuristics provide a platform for hypothesis testing in experimental studies about insurance decision making. An advantage of experiments is that they allow for studying regularities in decision making in a controlled setting, which enables rigorous testing of behavioural economic theories and for analysing policy solutions for increasing insurance uptake (Laury *et al.*, 2009).

Jaspersen (2016) offers some critical remarks about using insurance decisions to test theories of decision making in experiment tasks. Insurance decisions do not correlate strongly with the way individuals make other financial decisions (Einav *et al.*, 2012). Jaspersen (2016) questions whether insurance decisions can offer insights for general theories other than whether or not they hold in the insurance domain. We conduct a review focused on insurance decisions and do not claim that findings from this literature can be generalized to other contexts. We adopt Jaspersen (2016) and Smith's (1982) terminology regarding the difference between experimental studies and hypothetical surveys. The former employs salient reward structures, where payoffs are determined by outcomes of the experiment. The latter may include fixed payment structures, but these do not constitute salient experiments according to Smith (1982).

Our review paper builds upon Jaspersen (2016) who gave a general review of insurance demand studies for all kinds of risks, focusing on topics studied and some design methods employed. We think it is beneficial to have a focused study on LPHI risk, because decision making is markedly different than under HPLI risk. Our study differs from Jaspersen (2016) in that we focus more prominently on LPHI risks, discuss findings in relation to theory and heuristics and interpret prior studies relative to natural world catastrophic loss. Therefore, in addition to results of LPHI risk in the experimental and survey study domain, we review the literature on market insurance data regarding catastrophic losses.

Relevant to our comparison of experimental studies to market data studies is Smith's (1982) discussion of parallelism, which refers to the applicability of conjectures about individual behaviour tested in experimental settings to the field, under similar ceteris paribus conditions. Parallelism therefore implies that if differences between subjects in experimental studies and homeowners on which market data is based (or other apparent differences between the lab and the field) could be controlled for, insurance decision making would be the same. We take the position that experimental studies of LPHI risk can offer insights into the influence of important variables which are present in the field, but are perhaps difficult to study with market data. In this respect, experimental findings can supplement market data research and vice versa. For example, it is typically difficult to control for confounding variables in market data studies, but in experiments such control is possible. Whereas, high-impact losses are challenging to incentivize in the lab (Etchart-Vincent, 2004), market data examinations on LPHI risk are useful because they are based on revealed preferences in an actual LPHI risk context.

We conduct a systematic review of this literature based on some selection criteria. The aim of our literature review is to draw lessons learned from the studies about demand for insurance and for outlining an agenda for future research. This is done by inquiring: sample designs and insurance characteristics, as well as, results regarding certain explanatory variables and tested theories and heuristics.

The remainder of this paper is structured as follows: Section 2 outlines the method used to conduct the review, including our selection criteria. Section 3 examines the types of studies included in the review, country focus, incentives, samples as well as insurance characteristics in terms of the insurance context, deductibles and loading factors. Section 4 presents key results in relation to theories tested. Section 5 provides main results about behavioural biases and heuristics. Section 6 discusses findings of variables of influence on insurance demand and Section 7 concludes.

## 2. Literature Review Method

In this section, we outline the method and selection criteria used to review the literature. We conduct a systematic literature review with the aim to provide an objective representation of the overall literature on our topic of interest. We first elaborate upon our selection criteria regarding the experimental and survey papers. The following combination of keywords was used to search academic journal databases Google Scholar and Scopus: insurance demand; experiment; low probability. This resulted in 46 potential papers. The review also includes papers which compare behaviour under risk, where the probability of loss is known and uncertainty or ambiguity. Another search was performed with the combination of keywords: insurance demand; experiment; risk; ambiguity; uncertainty. This resulted in 19 additional potential papers. Based on these two searches and 11 papers found by cross-checking references, 41 experimental study and hypothetical survey papers are included in this review because they meet the following selection criteria.

At least one study treatment must include a decision about a LPHI event. Low probability is defined here as equal to or below 0.05, which is consistent with experiments framed in the context of catastrophic risk (Kunreuther and Michel-Kerjan, 2015). Moreover, this value is close to the highest yearly probability of suffering damage from typical low-probability events like a flood, hurricane and earthquake. It is difficult to define a cut-off value for the loss at stake due to cross-study differences in currencies used. Furthermore, many studies do not specify a particular currency in their definition of loss and use some abstract value instead, for example, points and tokens. Thus, an unambiguous cut-off point cannot be defined for this review. Despite this, a conscious effort has been made to contain studies which present sizeable losses in LPHI treatments, at least in numeric form. Moreover, papers which explicitly state the context of their study to be LPHI risk are included, regardless of the size of losses they incorporate. Studies comparing the behaviour of participants facing either LPHI or HPLI risk are also included, because they offer relevant theoretical insights. However, studies solely focusing on HPLI events are excluded. In total, 10 experimental and survey papers are included in this review which were not reviewed by Jaspersen (2016) who also did not review studies based on market data.

Regarding the selection of papers about real market insurance purchases against catastrophic risk by homeowners, we used the following combination of keywords to search the same academic journal databases as those used for the experimental and survey papers: insurance data; household; insurance demand; low probability. Using Jaffee and Russell's (1997) characterization of catastrophic risk (i.e. insurance companies receive regular premiums, but losses are paid out infrequently), resulted in the inclusion of 14 papers for the review.

We quality screened the papers by only including those published in international peer-reviewed journals. Therefore, working papers as well as papers which appear in conference proceedings are not included. A sizeable proportion of papers are in *Journal of Risk and Insurance* and *Journal of Risk and Uncertainty* (26), but papers can also be found in other journals covering risk and behavioural economic studies. Moreover, a large variety of researchers and groups have collected the study data, which may be seen as contributing to an independent evidence base.

We acknowledge that some relevant studies may have been excluded because the keyword searches failed to retrieve them. Moreover, we do not include the large number of general contingent valuation survey studies, where probability distributions pertaining to insurance decisions are not provided. To do so would not be feasible. The included studies should however provide an overview of the literature regarding study and insurance characteristics as well as key study results.

## 3. Study and Insurance Characteristics

In this section, we provide an overview of the types of studies included in the review with regard to country focus, samples utilized and incentives as well as insurance characteristics in terms of the insurance context, deductibles and loading factors used. This is based on an overview of the 41 experimental and survey papers in Table 1 and information provided about the 14 market data studies in Table 2. In total, the review is based on 80 studies, because multiple experimental and survey papers reported several studies.

It is notable that all but one study using market data, as well as most of the experimental and survey studies were conducted in the USA. In addition, the data is collected within developed countries and countries which are members of the Organisation for Economic Co-operation and Development (OECD), where insurance is more commonly available. For future studies, it may be interesting to focus on non-OECD countries.[1] These are usually developing countries, which suffer more often losses from LPHI events, like natural disasters (Intergovernmental Panel on Climate Change, 2012) and have growth potential for insurance businesses (Han *et al.*, 2010), for example, through offering micro-insurance (Hamid *et al.*, 2011).

Of the experimental and survey studies, the majority utilized hypothetical incentives. In this review, we focus on discussing study results (Sections 4–6) based on incentive compatible rewards, where incentives are structured in a way that aim to reveal subjects' true preferences. Results which may arise because studies have utilized hypothetical incentives or non-incentive compatible rewards are also discussed in order to highlight consequences of using non-incentive compatible rewards.[2] However, results which are solely based on hypothetical incentives do not appear in the descriptions of main findings in the text on the basis of which our conclusions are based, although these results are retained in the overview tables. We believe that these restrictions are necessary given that incentive compatible rewards better align choices with incentives faced in actual market decisions and have been shown to influence insurance choices as well as random decision making (Irwin *et al.*, 1992; Laury *et al.*, 2009).

Some studies have implemented large incentive compatible rewards by randomly selecting one or a few subjects to receive payment, contingent on one or a few randomly selected choices. Of the reviewed studies, Schade *et al.* (2012), Kunreuther and Michel-Kerjan (2015) and Zimmer *et al.* (2018) incorporate such payments. Jaspersen (2016) is sceptical about this procedure due to evidence provided by Herrero *et al.* (2006), who showed that subjects prefer more complete insurance when everybody is paid compared to when only 2 of 54 subjects are paid. The latter used a payment mechanism which is not incentive compatible, and payment was not scaled up in the case where only few subjects were paid. It is therefore unclear whether paying a potentially large amount to a small set of randomly selected subjects affects insurance decision making, compared to paying everybody smaller sums of money based on more common payment methods like the random problem selection mechanism.

**Table 1.** Type of Study, Country Where the Study Was Conducted, Sample Types Used and Insurance Conditions (Insurance Context, Deductibles and Loading Factors).

| Author | Study | Study type[a] | Country[b] | Sample | Context of insurance | Deductibles; Coinsurance[c] | Loading factors[d] |
|---|---|---|---|---|---|---|---|
| Murray (1971) | 1 of 1 | Hypothetical | USA | 3 academics; 7 students | General | N/A | N/S |
| Neter and Williams (1971) | 1 of 1 | Hypothetical | USA | 36 insurance employees | Commercial property and liability insurance | 500; 1,000 H | N/S |
| Murray (1972) | 1 of 1 | Hypothetical[e] | USA | 14 non-students; 16 students | General | N/A | Two (others N/S) |
| Slovic *et al.* (1977) | 1–8 of 10 | Hypothetical | USA | ~700 subjects divided over the 8 studies | General | N/A | 1 (and 0.5; 0.8; 1.2; 1.5 in fourth study and 1.4625 in eighth study) |
| | 9 of 10 | Hypothetical | | 30 subjects | Agriculture crop and natural hazard insurance | | 1.01 |
| | 10 of 10 | Experiment | | 31 subjects | Agriculture crop and natural hazard insurance | | 1.01 |
| Schoemaker and Kunreuther (1979) | 2 of 5 | Hypothetical | USA | 202 students; 101 insurance clients in all studies | General. | 100; 200; 500 H | Undefined subsidized insurance |
| | 3 of 5 | | | | | 500 H | N/A |
| | 4 of 5 | | | | | N/A | N/A |
| | 5 of 5 | | | | | N/A | 0.8 |
| Hershey and Schoemaker (1980) | 1 of 1 | Hypothetical | USA | 127 students | General | N/A | 1 |
| Einhorn and Hogarth (1986) | 2 of 3 | Hypothetical | USA | 112 students | Commercial insurance for a defective product | N/A | N/A |
| | 3 of 3 | | | 136 insurance employees | Individual warranty insurance for a personal computer | | |
| Camerer and Kunreuther (1989) | 1 of 1 | Experiment | USA | 133 students | General | N/A | N/A |
| Hogarth and Kunreuther (1989) | 1 of 2 | Hypothetical | USA | 101 actuaries; 116 students | Commercial insurance for a defective product | N/A | N/A |
| | 2 of 2 | | | 85 students; 139 insurance employees; 48 planners; 78 actuaries; 186 students and business executives | Commercial insurance for a defective product and flood | | 1.1; 1.5; 2.5; 3 |

(*Continued*)

**Table 1.** *Continued.*

| Author | Study | Study type[a] | Country[b] | Sample | Context of insurance | Deductibles; Coinsurance[c] | Loading factors[d] |
|---|---|---|---|---|---|---|---|
| Shogren (1990) | 1 of 1 | Experiment; hypothetical | USA | 120 students | General | N/A | N/A |
| Irwin *et al.* (1992) | 1 of 1 | Experiment; hypothetical | USA | 160 students | General | N/A | N/A |
| McClelland *et al.* (1993) | 1 of 2 | Experiment; hypothetical | USA | 64 students | General | N/A | N/A |
| | 2 of 2 | Experiment | | 48 students | | | |
| Connor (1996) | 1 of 1 | Hypothetical | USA | 154 students | Travel, business interruption and theft insurance | N/A | 1 |
| Di Mauro and Maffioletti (1996) | 1 of 1 | Experiment | UK | 82 students | General | N/A | N/A |
| Wakker *et al.* (1997) | 1 of 4 | Hypothetical | USA | 86 students | Fire insurance | N/A | N/A |
| | 2 of 4 | | | 144 students | Car insurance | N/A | |
| | 3 of 4 | | | 75 money managers | International investment | N/A | |
| | 4 of 4 | | | 57 students | Fire insurance | 1,250 H | |
| Kunreuther *et al.* (1998) | 1 of 2 | Hypothetical | USA | 85 students | Renter buying lock against theft | N/A | N/A |
| | 2 of 2 | | | 252 subjects | Renter buying lock against theft; buying steering-wheel club for a leased car; bracing the foundation of a house to protect against earthquake | | |
| Loehman (1998) | 1 of 1 | Hypothetical | USA | 21 academics | General | N/A | 1 |
| Shapira and Venezia (1999) | 1 of 4 | Hypothetical | USA | 177 students | Fire and theft insurance | 100 H | 1; 1.09 |
| Ganderton *et al.* (2000) | 1 of 1 | Experiment | USA | 449 students | General | N/A | 0.07–55 |

(*Continued*)

**Table 1.** *Continued.*

| Author | Study | Study type[a] | Country[b] | Sample | Context of insurance | Deductibles; Coinsurance[c] | Loading factors[d] |
|---|---|---|---|---|---|---|---|
| Theil (2000) | 1 of 1 | Hypothetical | Austria | 118 students | General | N/A | 1 (and undefined subsidized/commercial insurance) |
| Di Mauro and Maffioletti (2001) | 1 of 1 | Experiment | UK | 88 students | General | N/A | N/A |
| Loubergé and Outreville (2001) | 1 of 1 | Hypothetical | Canada; Switzerland; Singapore; Netherlands | 502 students | General | N/A | 1 |
| Kruse and Thompson (2003) | 1 of 2 | Experiment | USA | 93 students in all studies | General | N/A | 0.25; 0.75; 1; 2; 2.5; 5; 10; 20 |
| | 2 of 2 | Hypothetical | | | Renter buying lock against theft | | N/A |
| Laury and McInnes (2003 | 1 of 1 | Experiment | USA | 88 students | General | N/A | 1 |
| Fehr-Duda *et al.* (2006) | 1 of 1 | Experiment | Switzerland | 204 students | Computer insurance | N/A | N/S[f] |
| Papon (2008) | 1 of 1 | Experiment | France | 64 students | General | Coinsurance rate: 0.5; 0.7; 0.9 | 1.5 |
| Kusev *et al.* (2009) | 1 and 2 of 5 | Hypothetical | UK; Japan | 60 students, 15 of which participated in both studies | Travel insurance | N/A | N/S[g] |
| | 3 of 5 | | | 128 students | Theft insurance | | |
| | 4 of 5 | | | 90 students | Variety of insurance types, including for accident; theft; travel; transport and natural hazards | | |
| | 5 of 5 | | | 75 students | | | |
| Laury *et al.* (2009) | 1 of 2 | Hypothetical | USA | 34 subjects | General | N/A | 1 |
| | 2 of 2 | Experiment | | 108 subjects | | | 0.8; 1; 1.5; 2; 3; 4 |
| Fehr-Duda *et al.* (2011) | 1 of 1 | Experiment | Switzerland | 107 students | Property insurance | N/A | N/S |

(*Continued*)

**Table 1.** *Continued.*

| Author | Study | Study type[a] | Country[b] | Sample | Context of insurance | Deductibles; Coinsurance[c] | Loading factors[d] |
|---|---|---|---|---|---|---|---|
| Schram and Sonnemans (2011) | 1 of 1 | Experiment | The Netherlands | 148 students | General | 20; 50 points | N/S |
| Shafran (2011) | 1 of 1 | Experiment | USA | 58 students | General | N/A | 0.67; 1 |
| Schade *et al.* (2012) | 1 of 1 | Experiment | Germany | 263 students | Fire and theft insurance for art | N/A | N/A |
| Brunette *et al.* (2013) | 1 of 1 | Hypothetical | France | 42 forest owners; 36 students | Forest fire insurance | N/A | N/A |
| Krieger and Felder (2013) | 1 of 1 | Experiment | Germany. | 89 students | Health insurance | Coinsurance rate: 0.5; 0.6; 0.7; 0.8 | 1.05; 1.1; 1.14375; 1.15; 1.2; 1.25 |
| Ozdemir and Morone (2014) | 1 of 1 | Experiment | Germany | 96 students | General | N/A | 1 |
| Petrova *et al.* (2014) | 1 of 1 | Hypothetical | The Netherlands | 148 students | Loss and theft insurance for a camera | N/A | N/A |
| Bajtelsmit *et al.* (2015) | 1 of 1 | Experiment | USA | 60 students | General | N/A | 0.83; 1; 1.01; 3; 3.22; 3.33 |
| Jindal (2015) | 1 of 1 | Hypothetical | USA | 562 subjects | Washing machine warranty | N/A | N/S |
| Kunreuther and Michel-Kerjan (2015) | 1 of 1 | Experiment | USA | 445 subjects | Homeowner hurricane insurance | N/A | 1; 1.05; 1.1 |
| Kunreuther and Pauly (2018) | 1 of 1 | Hypothetical | USA | 1,346 subjects | Homeowner hurricane insurance | N/A | 0.8; 1; 1.2 |
| Zimmer *et al.* (2018) | 1 of 1 | Experiment | Germany | 181 students | Theft insurance | N/A | N/A |

[a]Our paper uses a higher level of disaggregation when discussing study characteristics compared to Jaspersen (2016). For example, Jaspersen (2016) discusses Laury *et al.* (2009) and Wakker *et al.* (1997) as one study, and Slovic *et al.* (1977) as three studies.
[b]Refers to the country the study took place. If this is not specified, it refers to the research institute of the primary author.
[c]H: Hypothetical currency.
[d]N/A: Not available; N/S: Not specified.
[e]Insurance decisions are hypothetical, but separate valuation questions are rewarded based on a first-price mechanism, which is not incentive compatible.
[f]Loading factors were based on sure amounts (premiums in the insurance loss context) of risky prospects, where sure amounts were linearly spaced between 1 Swiss franc and the highest absolute prospect outcome, as in Fehr-Duda *et al.* (2011).
[g]See [f] except monetary units are British pounds and sure amounts were logarithmically spaced for the first and second study, and linearly spaced in the third, fourth and fifth.

**Table 2.** Studies of Insurance Demand Using Market Data.

| Author | Topic | Results |
|---|---|---|
| Browne and Hoyt (2000) | Influence of various factors on flood insurance demand between 1983 and 1993 in 50 U.S. states | Expenditures by Federal Emergency Management Agency on emergency planning, preparedness and mitigation (ns), disaster relief expenditures by Federal Emergency Management Agency (+$^*$), insurance price (–$^*$), income (+$^*$), federally backed mortgage (–$^*$), total flood damage in the previous year (+$^*$) |
| Grace *et al.* (2004) | Influence of various factors on insurance demand against catastrophic and non-catastrophic risk between 1995 and 1998 in Florida and New York | Insurance price (–$^*$)[a], income (m)[b], above median loss costs for both catastrophic and non-catastrophic risks (+$^*$), less fire resistant homes (+$^*$ in Florida, m in New York), public service quality (–$^*$), comprehensiveness of coverage (m), policies with wind exclusion (+$^*$ only applies to Florida), per cent of policies with replacement cost coverage (m), per cent of policies with ordinance or law coverage (m in Florida, +$^{**}$ in New York), replacement cost of home (m in Florida, +$^*$ in New York), wind deductible (m), fire deductible (m), per cent with wind protection device (m only applies to Florida)[c], per cent off-premises theft coverage exclusion (m only applies to New York), regulatory price suppression (+$^*$ in Florida, m in New York), type of company offering coverage (m), auto insurance offered by same company (+$^*$ in Florida, m in New York), life insurance offered by associated company (+$^*$), insurance company size (m), insurance company financial security (m) |
| Kriesel and Landry (2004) | Influence of various factors on flood insurance demand between 1998 and 1999 in nine US counties | Insurance price (–$^*$), income (+$^*$), distance of house from erosion reference feature (–$^*$), house has seawall, groin, or nourished beach protection (+$^*$), federally backed mortgage (+$^*$), interval, in years, between hurricane landfalls (–$^*$) |
| Zahran *et al.* (2009) | Influence of various factors on flood insurance demand between 1999 and 2005 in Florida | CRS[d] rating (+$^*$), home value (+$^*$), education (+$^*$), proportion of area in floodplain (+$^*$), length of streams divided by area (ns), coastal area (+$^*$), 10 year average of flood frequency (+$^*$), 10 year average of flood damage (+$^*$) |

(*Continued*)

**Table 2.** *Continued.*

| Author | Topic | Results |
|---|---|---|
| Michel-Kerjan and Kousky (2010) | Flood insurance buyer characteristics, deductibles and coverage levels purchased, as well as the influence of various factors on claims payments between 2000 and 2005 in Florida | - Most policyholders purchased the lowest deductible policy available<br>- Severe storms led to higher flood insurance demand and lower deductibles purchased<br>- Claims payments are positively affected by: being in a high risk area; and negatively affected by: the house having more than one floor, the house being elevated, the house having a basement and the house being in the best CRS class ($p < 0.05$ in all cases apart from CRS class, which depends on the dependent variable used in the regression analysis) |
| Athavale and Avila (2011) | Influence of various factors on earthquake insurance demand between 2001 and 2008 in Missouri | Insurance price (ns)[e], income ($+^*$), higher risk ($+^*$), time ($-^*$) |
| Kousky (2011) | Influence of various factors on flood insurance demand between 2000 and 2006 in St. Louis County, Missouri | Income (m)[f], value of homes (m)[g], percentage of land in 100 year floodplain (m), percentage of land in 500 year floodplain (m)[h], living along major river (m)[i], protected by levee (m)[j], filed a claim for 1993 flood (ns), filed claim for previous year flood (m)[k], insurance price (m)[l], percentage with higher education (ns), percentage white (m)[m], percentage aged 65 and older (ns), percentage owner occupied (ns), percentage with a mortgage (ns) |
| Landry and Jahan-Parvar (2011) | Influence of various factors on flood insurance demand between 1998 and 1999 in nine US counties | Insurance price ($-^*$), subsidy ($+^*$), higher risk areas ($+^*$), lower risk areas (m)[n], higher erosion hazard ($+^*$), higher shoreline accretion ($+^*$), hurricane return interval (m), location manages coastal erosion through beach replenishment ($+^*$), location employs coastal armouring (ns), mortgage holder (ns)[o], lower education ($-^*$), income (m), retired (ns) |

(*Continued*)

**Table 2.** *Continued.*

| Author | Topic | Results |
|---|---|---|
| Michel-Kerjan *et al.* (2012) | Flood insurance tenure and the influence of various factors on flood insurance demand between 2001 and 2009 in the USA | - Median tenure of policies issued between 2001 and 2006 is between two and four years.<br>- Residents with high risks have relatively small differences in tenure compared to those with low risks.<br>- A small (large) insurance claim in the first year of coverage leads to longer (shorter) policy tenure |
| Gallagher (2014) | Influence of a presidential disaster declared flood on flood insurance demand between 1980 and 2007 in the USA | Lagged presidential disaster declared flood (+*)[p] |
| Atreya *et al.* (2015) | Influence of various factors on flood insurance demand between 1978 and 2010 in 153 counties in Georgia | Insurance price (–*), income (+*), recent flood (+*), flood mitigation assistance (ns), proportion of area in floodplain (+*), proportion of area not participating in the National Flood Insurance Program (ns), African American (+*), white (ns), education (+*), age (+*), home occupancy type (ns), coastal areas (+*) |
| Browne *et al.* (2015) | Preference for purchasing flood insurance vs. bicycle theft insurance and the influence of various factors on flood insurance and bicycle theft insurance demand in 2010 in Germany | Higher risk areas (m)[q], insurance agent (m), living space (+*), GDP per capita (ns), sum insured per square meter (m)[r], public sector employment (m)[s], direct debit (m), male (m)[t], age (–*).<br>- More policyholders purchase insurance against bicycle theft than purchase insurance against flood risk |
| Kousky (2017) | Influence of various factors on flood insurance demand between 2001 and 2010 in all states along the Atlantic and Gulf coasts | Number of storm tracks crossing area (+*), coastal area (+*), only one storm (ns), more than one storm (+*), hit by at least one hurricane (+*), category of strongest hurricane (+*), at least one coastal storm, flood, or hurricane disaster declared (+*), at least one non-flood disaster declared (ns), individual assistance declared for coastal storm, flooding, or hurricane (m)[u], any damage (m), National Flood Insurance Program claims (+*), income (m)[v], income squared (m), population (ns), annual time trend (+*)[w] |

(*Continued*)

**Table 2.** *Continued.*

| Author | Topic | Results |
|---|---|---|
| Kousky *et al.* (2018) | Influence of various factors on flood insurance demand between 2000 and 2011 in the USA | One-year lagged positive individual assistance (m)[x], one-year lagged receipt of Small business administration loan (m), insurance price (–*), one-year lagged average claim (m), income (m), population (–*), higher education (m) |

*These results are significant at the 5% level. + or –: direction of impact on insurance demand. Not significant: ns. Mixed findings: m.
[a]Price elasticity of demand is elastic for catastrophe coverage and inelastic for non-catastrophe coverage.
[b]Income elasticity is positive in Florida and inelastic for both catastrophe and non-catastrophe coverage. It is positive in New York for catastrophe coverage and negative for non-catastrophe coverage.
[c]Coefficient estimates are negative for catastrophe coverage (the device is a substitute for insurance) and positive for non-catastrophe coverage.
[d]Community Rating System acronym. Communities that undertake mitigating activities have a better CRS classification and are rewarded with lower premiums.
[e]The estimated coefficient on price suggests that the demand for earthquake insurance is almost perfectly price inelastic.
[f]Income does not relate to take-up rates, but has a positive impact on the level of coverage for those who do actually insure.
[g]The value of the home is positively related to coverage levels, but unrelated with take-up rates.
[h]The two floodplain variables have a positive influence on take-up rates, but are unrelated with coverage levels.
[i]The variable lowers take-up rates, but increases coverage amounts on one of the two rivers.
[j]The variable lowers take-up rates, but does not influence coverage levels.
[k]The variable positively affects coverage levels, but has little influence on take-up rates.
[l]Price has no effect on coverage levels, but a positive influence on take-up rates.
[m]Take-up rates decline for white homeowners, but there is no influence of ethnicity on coverage levels.
[n]The effect is only statistically significant at the 5% level in a low premium model (where households elect higher deductibles).
[o]There is a positive interaction between mortgage holder and premium, indicating that mortgage holders have lower price elasticity.
[p]The impact persists for between 9 and 15 years (depending on the panel data used) after the flood, after which the effect becomes insignificant.
[q]Risk has an insignificant effect on bicycle theft insurance demand. Moderate risk impacts flood insurance demand positively compared to low risk; however, high risk does not impact flood insurance demand compared to low risk.
[r]The effect is positive for flood insurance demand and insignificant for bicycle theft insurance demand.
[s]The effect is negative for flood insurance demand and positive for bicycle theft insurance demand.
[t]Being male has an insignificant effect on flood insurance demand, but a positive effect on bicycle theft insurance demand.
[u]The impact of this variable is positive if we consider all policies, but not if we consider only voluntary purchases.
[v]The impact of this variable is positive if we consider only voluntary purchases.
[w]The study used 1-year lagged variables. Using longer lags of the hurricane variable results in insignificant coefficient estimates.
[x]The variable has a negative impact on coverage levels (the effect persists until the third lag), but an insignificant effect on policies in force which were not required to be purchased as a condition for disaster aid.

Risk operationalization methods have been used by studies to communicate risks to subjects, to visualize the consequences of insurance decisions and to resolve incentivized payments. Of the risk operationalized studies, approximately half conducted random drawings of a ball or chip from a container, where the proportion of balls or chips corresponds to the potential uninsured loss probability. In other studies, risk is based on a computerized random mechanism, which may become more prevalent in future research given the increasing use of online experiments.[3] To our knowledge, no study has compared the influence of different risk operationalization methods on decisions to insure against LPHI events, while this is relevant given the difficulties individuals have understanding LPHI risks (Kunreuther *et al.*, 2001).

Out of a total of ∼9608 subjects sampled in the experimental and survey studies, over half are students. Apart from hypothetical studies (Schoemaker and Kunreuther, 1979; Brunette *et al.*, 2013), there is a lack of systematic research into the generalizability of student sample results to non-students such as homeowners at risk of catastrophic losses. Such research is necessary given that there are systematic differences between students and other populations (Feltovich, 2011).

Concerning insurance characteristics, a general context is given in the majority of experimental and survey studies, which implies that demand for insurance is elicited for general probability and loss combinations without specifying the hazard covered. Neutral framing is suitable for studies performing controlled theoretical tests, because specific context framing may add noise to results due to uncontrolled responses of subjects to certain wording (Schram and Sonnemans, 2011). Nevertheless, framing insurance in a specific context may add external validity, because individuals are seldom required to make insurance decisions which are neutrally framed (Elabed and Carter, 2015), and in the absence of a frame individuals may make up their own (Cardenas and Carpenter, 2008). Most of the market data papers focus on flood insurance demand, using data from the US National Flood Insurance Program.

Moreover, only a minority of the experimental and survey studies incorporate fixed deductibles and coinsurance, while such risk sharing is common in practice. It is notable that fixed deductibles are small relative to loss (the highest is 2.5% of the maximum loss), suggesting that little is known about the impact of higher and more realistic deductibles on demand for insurance.

Another important characteristic of the insurance product is the loading factor $\lambda$, which is the premium surcharge on top of the expected value of risk, and reflects the insurer's administration costs and profit. Actuarially fair insurance $\lambda = 1$ is offered in most experimental and survey studies for which we could derive $\lambda$. Subsidized ($\lambda < 1$) and commercial ($\lambda > 1$) insurance appear less often, and the values are lower than the high $\lambda$ for insurance against LPHI events observed in practice (Kunreuther and Michel-Kerjan, 2004), which can reach up to 18.9 as discussed in Pollner *et al.* (2001). Loading factors are generally higher for LPHI events than HPLI events because of a higher loss variance and costs of capital needed for reimbursing claims caused by disasters (Pakdel-Lahiji *et al.*, 2015). The low loading factors in most of the reviewed experimental and survey studies are representative of historically subsidized public insurance, like the US National Flood Insurance Program (Browne and Hoyt, 2000). Exceptions are experiments utilizing a wide variety of $\lambda$, for example, Ganderton *et al.* (2000) and Kruse and Thompson (2003).

To summarize the findings of this section, all of the reviewed studies on LPHI risk are conducted in the USA and other developed countries, and most of the experimental and survey data is collected from student samples with general context framing. There are also more hypothetical surveys than incentivized experimental studies in the review, and few of the experimental and survey studies have incorporated high fixed deductibles and loading factors, despite this being a common feature of LPHI risk insurance in practice.

## 4. Results about Theories of Decision Making under Risk, Uncertainty and Ambiguity

This section describes main findings of the reviewed studies with respect to theories under risk (Section 4.1) with known loss probabilities as well as uncertainty and ambiguity (Section 4.2) with unknown loss probabilities. We aim to provide an intuitive description of such theories. For a more detailed exposition, see Etner *et al.* (2012) and Wakker (2010). The section will provide details about results in relation to these theories based on an overview of detailed results per paper provided in Tables 2 and 3.

### 4.1 *Theories of Decision Making under Risk*

The benchmark expected utility theory (EUT) model (von Neumann and Morgenstern, 1944) obtains expected utilities by weighting utility transformed outcomes by their objective probabilities of occurrence. Risk aversion implies a strictly increasing concave utility function defined on final wealth. A risk averse individual will purchase actuarially fair insurance ($\lambda = 1$), although the decision to purchase commercial ($\lambda > 1$) insurance will depend on the premium surcharge and their degree of risk aversion.

Risk aversion under EUT is also implied as a result of aversion to mean-preserving spreads. A mean-preserving spread is obtained by increasing the variance of a given (insurance) prospect, while keeping its expectation constant. For example, Laury *et al.* (2009) compared insurance decisions for uninsured loss amount $60 with 0.01 probability of occurrence (LPHI risk) to $6 uninsured loss amount with 0.1 probability of occurrence (HPLI risk).[4] Higher insurance demand against the LPHI risk than the HPLI risk indicates aversion to mean-preserving spreads, and therefore risk aversion under EUT. Whereas hypothetical examinations on this matter show EUT inconsistent behaviour assuming the utility function is strictly concave (Slovic *et al.*, 1977), Laury *et al.* (2009) showed in an incentive compatible experimental setting that EUT is not violated, that is individuals demand more insurance against LPHI events than HPLI events with the same expected value of loss.

In contrast to Laury *et al.* (2009), an experiment by Shafran (2011) showed that individuals prefer more probabilistic insurance against HPLI events than LPHI events with the same expected value of loss. Whereas full indemnifying insurance, which reduces the potential loss to zero was featured in Laury *et al.* (2009), probabilistic insurance reduces the probability of loss to some lower value (often above zero), like investing in a lock to prevent burglary (Kahneman and Tversky, 1979). The results are also not comparable since the greatest loss amount included in Shafran (2011) is $3, which is substantially below the losses in Laury *et al.* (2009).

Other counter evidence to the Laury *et al.* (2009) result can be found in the market data. Browne *et al.* (2015) found that more policyholders purchase add-on coverage to homeowner's policies for bicycle theft (HPLI event) insurance than for flood (LPHI event) insurance. Nevertheless, a market data study on violations of EUT in terms of aversion to mean-preserving spreads is likely to suffer from the obvious problem that it is difficult to control for the expected value of insurance prospects.

An example of an incentive compatible experiment showing results which contrast EUT is Zimmer *et al.* (2018). The authors find a high degree of individual aversion to probabilistic insurance (in the form of insurer default risk) than that which could be reasonably accommodated by EUT. Under expected utility, an individual who is willing to pay $c$ for full insurance against a potential loss, should be willing to pay approximately $(1 - d)c$ for probabilistic insurance, where $d$ is the probability of insurer default (Starmer, 2000). Individuals are willing to pay a lot less for probabilistic insurance in their experiment, which may instead be explained by over-weighting of the low probability of insurer default.

The experiment by McClelland *et al.* (1993) also finds results which may suggest that individuals weigh probabilities. They conclude that there is a bimodal response to low-probability risks: Either subjects significantly over-weight the probability and have a high willingness-to-pay (WTP) for insurance, or under-weight the likelihood and deem insurance as unnecessary. Although the finding does not violate EUT directly because any one observation of insurance demand can be reconciled with utility curvature, for the magnitude of losses incorporated in their study, WTP should approximately equal expected value. Empirically, utility should be linear for small outcomes, because if marginal utility of wealth were to diminish sufficiently to make individuals risk averse for small outcomes, it would imply implausible

**Table 3.** Main Results per Study and Support Provided for Theories, Heuristics and Behavioural Biases.

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| Murray (1971) | -EUT predicts insurance preferences correctly 58% of the time. The theory performs very poorly when loss probabilities are $\leq 0.01$ | EUT (N) |
| Neter and Williams (1971) | -Subjects ranked the Comparison Method most acceptable to elicit insurance preferences, the Worry Method is second and the expected utility method is third | EUT (N) |
| Murray (1972) | -EUT predicts insurance preferences correctly 45.3% of the time | EUT (N) |
| Slovic *et al.* (1977) | -Subjects are more willing to buy insurance against HPLI compared to LPHI losses with the same expected value<br>-Nine per cent of policies for hazards which just occurred were cancelled and only 2.5% were cancelled otherwise | EUT (P); gambler's fallacy (Y), threshold model (Y) |
| Schoemaker and Kunreuther (1979) | -Low deductibles are preferred in an insurance frame compared to the equivalent context with no reference to insurance ($p < 0.0001$ for students and $p < 0.0007$ for clients)<br>-WTP is lower for bundled insurance than the sum of each policy component offered separately ($p < 0.005$ for students and $p < 0.05$ for clients)<br>-Risk taking preferences prevail in the loss domain | EUT (N), PT (P); framing effect (Y), threshold model (Y) |
| Hershey and Schoemaker (1980) | -Subjects prefer more insurance in the insurance frame than in the equivalent context with no reference to insurance<br>-Subjects are more willing to buy insurance against LPHI losses compared to HPLI losses with the same expected value of loss | EUT (N), Markowitz-type utility theory (P), PT (P); framing effect (Y) |
| Einhorn and Hogarth (1986) | -WTP for insurance is higher at low probabilities when the probability of loss is ambiguous compared to non-ambiguous. As the probability of loss increases, aversion to ambiguity falls and subjects exhibit ambiguity seeking for large probabilities | Einhorn–Hogarth anchoring and adjustment model (Y) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| Camerer and Kunreuther (1989) | -Previous losses do not impact WTP for insurance in the current period ($p > 0.05$)* <br>-Uncertainty in the loss probability does not affect WTP for insurance in most cases ($p > 0.05$)* <br>-Market prices for insurance converge to expected value over experimental rounds | EUT (P), PT (P), Segal's anticipated utility model (N); availability heuristic (N), gambler's fallacy (N) |
| Hogarth and Kunreuther (1989) | -There is a downward trend in the mean ambiguous to non-ambiguous WTP for insurance ratio from low to high probabilities ($p < 0.0001$) | Bayesian EUT (N), Einhorn–Hogarth anchoring and adjustment model (Y) |
| Shogren (1990) | -Experienced hypothetical mean WTP for private self-protection exceeds that of self-insurance ($p < 0.05$) <br>-Subjects initially overestimate loss probability 0.01 but this effect diminishes with experience | EUT (P); framing effect (Y) |
| Irwin *et al.* (1992) | -Hypothetical treatment data is more variable than incentivized treatment data ($p < 0.005$) <br>-The number of very high and zero insurance WTP bids is higher in the hypothetical than in the incentivized condition ($p < 0.03$ and $p < 0.003$, respectively) <br>-There is no effect of experiment length on the number of very high and zero insurance WTP bids ($p > 0.05$) | N/A |
| McClelland *et al.* (1993) | -On average, the ratio of WTP for insurance to expected value >1 at loss probability 0.01. However, at the disaggregated individual level, WTP for insurance is either zero, or significantly higher than expected value <br>-Prior to loss, demand for insurance declines over time. Immediately after a loss, demand does not change very much, but thereafter subjects bid increasingly more for insurance over successive rounds without a loss | EUT (P), PT (Y); gambler's fallacy (P) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| | -On average, over-bidding for insurance is prominent in the first hypothetical round, however, this effect diminishes with experience of the experiment mechanism, bringing insurance bids closer to expected value | |
| Connor (1996) | -Subjects are risk averse in insurance and investment frames ($p < 0.0001$ and $p < 0.0001$, respectively). Risk reduction, recovery and overcoming frames have no effect on risk preferences ($p > 0.05$, $p > 0.05$ and $p > 0.05$, respectively)[b] | EUT (N); framing effect (Y) |
| Di Mauro and Maffioletti (1996) | -Valuation of self-protection does not differ from self-insurance under most experimental conditions ($p > 0.05$)<br>-The ratio of ambiguous to non-ambiguous probability WTP for insurance bids is not monotonically decreasing as the probability increases<br>-There is ambiguity aversion at loss probability 0.03, but the results are mixed for higher loss probabilities<br>-There is no effect on WTP for insurance of the different definitions of ambiguity | Einhorn–Hogarth anchoring and adjustment model (N), Gardenfors and Sahlin's maximin model (N); framing effect (N). |
| Wakker *et al.* (1997) | -Subjects demand a 30% premium reduction to counter 1% default risk | EUT (N), PT (Y) |
| Kunreuther *et al.* (1998) | -In the first study, between 21% and 24% of subjects are consistent with discounted EUT with a low rate of discounting. Between 23% and 43% of subjects are myopic (high rate of discounting). Many view their decision to invest in a lock as either a one-shot investment or a two-stage process, where WTP does not change between the 5-year leasing period compared to the 1-year leasing period (between 56% and 33%)<br>-Subjects are more likely to have a lower rate of discounting when investing in an energy efficient refrigerator with known annual savings compared to the risk reduction measures with unknown benefits | Discounted EUT (N); myopia (N) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| Loehman (1998) | -Risk preferences are most successfully predicted by PT and rank-dependent utility<br>-PT and rank-dependent utility predict insurance purchase in all decisions (as opposed to the actual variety of purchase decisions which prevail) | Chew model (N), EUT (N), PT (N), rank-dependent utility (N), subjective distribution model (N) |
| Shapira and Venezia (1999) | -High risk subjects self-select in to buying full insurance over deductible insurance, whereas low risk subjects are evenly split between the two, despite expectations of self-selection in to deductible insurance | N/A |
| Ganderton *et al.* (2000) | -Uninsured loss experience negatively affects insurance purchase ($p < 0.05$)* <br>-On average, the WTP for insurance to the expected value of loss ratio >1 at low loss probabilities. There is no bimodality in responses | EUT (N); Gambler's fallacy (Y), Reference dependence (Y) |
| Theil (2000) | -Subjects are more willing to buy insurance against LPHI compared to HPLI losses with the same expected value | N/A |
| Di Mauro and Maffioletti (2001) | -The distribution of risky to ambiguous insurance bids at the 0.5 loss probability is not different, which represents a switching point between ambiguity aversion and ambiguity seeking. There is mostly an effect of ambiguity at every other probability level<br>-The ratio of ambiguous to risky WTP insurance bids are not different between the vague description of ambiguous loss probability and ambiguity as a second-order probability distribution ($p > 0.05$) | Einhorn–Hogarth anchoring and adjustment model (Y), Gardenfors and Sahlin's maximin model (N), Segal's anticipated utility model (N), subjective EUT (N) |
| Loubergé and Outreville (2001 | -More subjects are willing to buy insurance against LPHI compared to HPLI losses with the same expected value<br>-Very low loss probabilities are often neglected<br>-The results are robust across samples | EUT (P) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| Kruse and Thompson (2003) | -31% of subjects have decision processes consistent with Discounted EUT with low discounting and 37% with myopia<br>-On average, minimum rejected insurance price in the experiment is greater than WTP for insurance in the survey ($p = 0.02$), and maximum accepted price in the experiment is less than WTP in the survey ($p = 0.03$)<br>-The distributions of male and female insurance purchases are not different ($p = 0.7$). The same holds for WTP in the one year and two year lease treatments ($p = 0.7428$ and $p = 0.7$, respectively) | Discounted EUT (N); myopia (N) |
| Laury and McInnes (2003) | -A lower percentage of subjects buy insurance when the posterior probability = 0.5 than when the posterior probability shows an inclination towards one cup. So subjects buy more insurance when the posterior probability is high (and the loss probability is low) | PT/CPT (Y)[c] |
| Fehr-Duda *et al.* (2006) | -Females exhibit more curved probability weighting functions compared to males ($p < 0.01$)<br>-Probability weighting functions do not differ between contexts in the loss domain ($p > 0.05$) | CPT (P); framing effect (N) |
| Papon (2008) | -Average levels of coverage in the long commitment period are higher than in the short commitment period ($p < 0.05$)<br>-Subjects are either likely to choose full insurance or zero coverage. More subjects are in the upper (lower) mode over the long (short) commitment period<br>-Some subjects are more likely to choose a higher level of insurance after an uninsured loss<br>-Some subjects are increasingly more likely to buy insurance over successive rounds without a loss | Dual theory (Y), EUT (N), PT/CPT (Y); availability heuristic (P), gambler's fallacy (P), regret (Y) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| Kusev *et al.* (2009) | -The probability weighting function is more elevated in the high-frequency insurance condition compared to the abstract gamble condition and the low-frequency insurance condition | EUT (N), PT/CPT (P); framing effect (Y) |
| Laury *et al.* (2009) | -More subjects are willing to buy insurance against LPHI compared to HPLI losses with the same expected value | Framing effect (Y), threshold model (N) |
| Fehr-Duda *et al.* (2011) | -Males are more likely to calculate expected values when making insurance decisions than females ($p < 0.001$)<br>-For females good mood is associated with less elevated probability weighting ($p < 0.05$)[*]<br>-For males good mood is associated with less elevated probability weighting but only for males who do not calculate expected values ($p < 0.05$). Those who use expected values as a decision criterion have more linear probability weighting ($p < 0.05$)[*] | CPT (P) |
| Schram and Sonnemans (2011) | -There are more policy switches when more policies are made available ($p < 0.05$)[*]<br>-There are less policy switches when there are higher switching costs ($p < 0.01$)[*]<br>-Gradual changes in the loss probability do not change the likelihood of switching policy ($p > 0.05$)[*]<br>-Sudden changes in the loss probability increase the probability of a switch ($p < 0.01$)[*]<br>-Subjects sometimes switch policy even when their current policy is optimal | Boiling frog effect (Y), status quo bias (N) |
| Shafran (2011) | -A higher proportion of subjects buy probabilistic insurance against HPLI than LPHI losses ($p < 0.05$)<br>-There is no difference in choice for the median subject between the one-shot and repeated game without feedback ($p = 0.439$) | EUT (P), PT (P) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| | -There is no difference in the proportion of subjects buying probabilistic insurance between the low- and high-cost treatments in the one-shot and repeated game ($p = 1.00$ and $p = 0.79$, respectively). But subjects are more likely to protect themselves in the low-cost treatments in the repeated game with feedback ($p = 0.007$) | |
| Schade *et al.* (2012) | -Subjects have a WTP for insurance which is higher under uncertainty/ambiguity than risk, both for separate policies and one bundled policy ($p = 0.0001$ and $p = 0.0002$, respectively)<br>-Some subjects have a WTP for insurance equal to zero, but more so under risk than uncertainty/ambiguity, both for separate policies and one bundled policy ($p = 0.001$ and $p = 0.04$, respectively)<br>-Both worry and subjective probability estimates are positively related to insurance WTP under uncertainty/ambiguity ($p = 0$ and $p = 0.04$, respectively), but worry has a greater influence* | EUT (P) |
| Brunette *et al.* (2013) | -Subjects have a lower WTP for insurance under fixed public support compared to no public support under uncertainty and risk ($p = 0.001$ and $p = 0.039$, respectively). There is no difference in WTP for insurance under fixed public support compared to contingent fixed public support under uncertainty and risk ($p = 0.213$ and $p = 0.121$, respectively). WTP for insurance is smaller under the subsidy as opposed to no public support under uncertainty and risk ($p = 0.034$ and $p = 0.000$)<br>-WTP is higher for insurance under uncertainty compared to no uncertainty ($p = 0.042$) | Brunette and Couture model of decision making under risk (P), Klibanoff *et al.* smooth model of decision making (P) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| Krieger and Felder (2013) | -In the first and second periods, subjects assigned to full insurance as a status quo chose less coinsurance than those assigned to no status quo ($p = 0.017$ and $p = 0.042$, respectively), but this effect diminishes over time* | Framing effect (P), status quo bias (P) |
| Ozdemir and Morone (2014) | -When loss increases from half to all of the subject's endowment with loss probability 0.01, payment decisions differ ($p = 0.043$)<br>-When losses are half of the subject's endowment, and the loss probability decreases from 0.01 to 0.05, buying decisions differ ($p = 0.025$)<br>-Threshold probabilities have no impact on either insurance payment or purchase ($p = 0.548$ and $p = 0.672$)*<br>-Subjects are consistent with the PT fourfold pattern of risk preferences | PT (Y); threshold model (N) |
| Petrova *et al.* (2014) | -Probability weighting functions exhibit inverse-S shape<br>-Probability weights for small loss probabilities (0.01 to 0.25) are larger in the affective condition than in the neutral context ($p = 0.04$)<br>-Probability weighting function elevation is larger in the affective context than in the loss coping context, and discriminability is lower in the affective context compared to the loss coping context<br>-In the reappraisal condition the elevation parameter falls and for more numerate participants discriminability increases | PT (Y) |
| Bajtelsmit *et al.* (2015) | -Subjects who prefer full precaution when insurance is unavailable are more likely to buy insurance when it is available ($p < 0.01$)*<br>-Subjects purchase more insurance under uncertain/ambiguous loss probabilities compared to known probabilities ($p < 0.01$)* | N/A |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| | -More subjects are willing to buy insurance against LPHI compared to HPLI losses with the same expected value | |
| Jindal (2015) | -Loss aversion is more important than probability weighting and utility function curvature for explaining warranty purchases | EUT (N), PT/CPT (Y) |
| Kunreuther and Michel-Kerjan (2015) | -Increasing the price of two-period coverage 5% raises the likelihood of choosing one-period coverage ($p = 0$)[*]<br>-Increasing the price of two-period coverage 10% raises the likelihood of choosing one-period coverage ($p = 0$), and decreases the likelihood of choosing two-period coverage ($p = 0.03$)[*]<br>-The two-period contract is favoured to a one-period contract at actuarially fair premiums The same qualitative conclusion remains for most subjects when the two-period contract premium is increased by 5% and 10%, with the one-period contract premium remaining actuarially fair<br>-On average 27.2% of subjects bought no insurance across all treatments and rounds | EUT (Y), PT/CPT (Y); threshold model (P) |
| Kunreuther and Pauly (2018) | -Ex post negative feelings following a loss have a positive effect on insurance purchase ($p < 0.0001$)<br>-Some subjects bought insurance consistently at subsidized (64.9%), actuarially fair (58.6%) and commercial (56.7%) rates<br>-Other subjects remained uninsured (7.5%, 9.8% and 9.3%, respectively) | EUT (P); Regret (Y), threshold model (P) |

(*Continued*)

**Table 3.** *Continued.*

| Author | Results | Theory; heuristics and behavioural biases[a] |
|---|---|---|
| Zimmer *et al.* (2018) | -Default risk of 1%, 2% and 3% all have a negative impact on the ratio of WTP for probabilistic insurance to the actuarially fair premium ($p < 0.0001$, $p < 0.0001$ and $p < 0.0001$, respectively) and the effect is increasing in default risk[*] | EUT (N), PT/CPT (Y) |

[*]These are results from regression analyses.
[a]We refer to papers finding no support (N) for a given theory when results violate the theory's assumptions, or imply implausible types of behaviour. Studies are said to provide partial support (P) when some of the paper's results are supported, or when assumptions are not directly violated; however, results are contrary to behaviour commonly observed in applications of the theory, or may be explained by other mechanisms not accounted for within the theory. Support for a theory (Y) is assigned to papers which do not violate assumptions and provide an adequate description of findings.
[b]Risk reduction: insurance decision is a standard gamble; recovery: insurance decision is a loss and equal gain; overcoming: insurance decision is a loss and equal gain accomplished by the subject's own effort; investment: insurance decision is an investment; insurance: insurance decision is insurance.
[c]The study describes several heuristics (e.g. representative heuristic, conservative heuristic and Bayes rule), but the focus is on the effect of insurance prices on the use of heuristics, not the use of heuristics in purchasing insurance.

levels of risk aversion for large ones (Rabin, 2000). Note that we also cannot discriminate whether the bimodel response pattern of McClelland *et al.* (1993) is due to bidder fatigue in their 50 repetitions of the fifth-price sealed-bid Vickrey auction, or due to probability weighting, given their aggregated reporting of data.

The probability weighting function, which is a feature of cumulative prospect theory (CPT) (Tversky and Kahneman, 1992),[5] can explain why individuals have a strong aversion to a low probability of insurer default risk (Zimmer *et al.*, 2018) and provides an alternative explanation of the over-/under-weighting of low-probability experimental outcomes for which individuals usually have linear utility (McClelland *et al.*, 1993; Laury and McInnes, 2003). That is, rather than risk attitudes defined by utility curvature under EUT, probabilistic risk attitude under CPT may explain these results.

Nevertheless, probability weighting is not a robust component of individual behaviour. Fehr-Duda *et al.* (2006, 2011), who apply the sign- and rank-dependent model assumed by CPT to experimental insurance choices, find that some of their subjects explicitly report following an expected value calculation decision criteria (mostly males). The latter implies risk neutrality, which can be accommodated by linear probability weighting and utility. Their results are perhaps due to many of their subjects following highly mathematical curricula.

The dual theory framework (Yaari, 1987), which incorporates risk attitudes solely on the basis of probability weighting, has been used to explain individual choices for insurance in which a proportion of losses in relation to actual losses is shared between the insurer and the policyholder (Doherty, 1977), such as coinsurance. The dual theory decision rule is linear in wealth instead of concave/convex for risk averse/seeking persons under EUT, but incorporates non-linear probability weighting compared to EUT. Under risk aversion (convex probability weighting), dual theory implies that for small or zero premium loading, full insurance is preferred, but above some critical loading level, the individual switches to zero insurance assuming a linear coinsurance contract (Doherty and Eeckhoudt, 1995). In contrast, EUT allows for some level of partial insurance given that contract payoffs are transformed non-linearly in utility dependent on risk attitudes.

Regarding the discussion of coinsurance, in an experiment by Papon (2008), subjects most frequently prefer either zero or full coverage to partial coverage given that those options are available in the menu of insurance contracts. This is in agreement with the dual theory implication that subjects either fully insure, or choose to not insure when premiums are positively loaded.

Results in this section can be summarized into three main insights. First, the results suggest that aversion to mean-preserving spreads is found in incentive compatible insurance demand experiments where stakes are sufficiently high, consistent with EUT. Second, theories more general than EUT like CPT, which incorporate additional components of risk preference, like probability weighting, can better explain insurance purchases under insurer default risk and may provide an explanation of over-/under-weighting experimental outcomes for which individuals usually have linear utility. Third, dual theory performs well in explaining why individuals do not demand partial insurance coverage.

In general, it is important to mention that any theory more general than EUT, which incorporates more than a single utility parameter, will better accommodate data. However, it is difficult to estimate additional parameters from data, and therefore perhaps more difficult to make meaningful predictions from models with more than one risk aversion parameter (Wakker, 2010). A general critique of theories that include probability weighting is that few studies have examined the specific reasons why individuals over-/under-weight LPHI insurable risks (Barberis, 2013). This weighting may be explained by heuristics and behavioural biases (Section 5), which can be a fruitful topic to explore in future studies.

### 4.2 *Theories of Decision Making under Uncertainty and Ambiguity*

At this stage, we would like to disentangle the terms uncertainty and ambiguity, based on the terminology used by Harrison (2011) and Jaspersen (2016). A decision under uncertainty is one where subjects have a distribution of beliefs over possible probabilities of each potential outcome. A decision under ambiguity considers the case where the latter information is unavailable, and subjects cannot form subjective belief distributions. Uncertainty is operationalized with multiple equiprobable probabilities of loss (Camerer and Kunreuther, 1989; Brunette *et al.*, 2013), and ambiguity is implemented by providing some incomplete information so that subjects cannot form a comprehensive belief distribution (Einhorn and Hogarth, 1986; Hogarth and Kunreuther, 1989; Di Mauro and Maffioletti, 1996; 2001).

Therefore, theories of decision making under uncertainty and ambiguity explain decision making under imperfect information regarding the loss probability, as is often the case with LPHI risk in practice. EUT assumes that individuals have perfect information about outcome probabilities. Subjective EUT, postulated by Savage (1954), hypothesizes that individuals make decisions based on perceived probabilities when probability information is not provided. Although under subjective EUT subjective probabilities do not deviate from objective ones. Prospects are evaluated in the same way as EUT, except beliefs about probabilities replace known probabilities.

In contrast to subjective EUT, uncertainty and ambiguity may create biases in probability judgment. The Ellsberg paradox (1961) refers to the phenomenon that individuals prefer to bet on known rather than unknown probabilities, which is an anomaly termed uncertainty or ambiguity aversion (Camerer and Weber, 1992). The experiment by Di Mauro and Maffioletti (2001) showed that subjects exhibit some aversion to ambiguity for low probabilities of loss, which violates subjective EUT.

Ambiguity aversion is accounted for in Gardenfors and Sahlin's (1982 1983) maximin model. The model hypothesizes that individuals form subjective probabilities about the likelihood of events which are varying in terms of reliability. The distribution of probabilities is used for evaluating prospects in accordance with the maximin criterion: A prospect is preferred when its minimum expected utility is greater than that of another prospect. In insurance decisions, the individual will place more weight on the highest probability of loss (the lowest expected utility) when deciding her/his maximum WTP for insurance (Di Mauro and Maffioletti, 1996). Therefore, the theory infers that individuals exhibit universal ambiguity aversion. However, Di Mauro and Maffioletti (1996) find only a weak effect of ambiguity on WTP for insurance, so decision making may be more complex than universal ambiguity aversion.

Einhorn and Hogarth (1986) proposed a model of anchoring and adjustment, where individuals form a subjective estimate of the true probability according to some anchor probability. This anchor may be an expert guess, or a probability based on other external information. The subjective estimate is influenced by an adjustment factor, which is a function of the individual's ambiguity perception, their attitude towards ambiguity, and the level of the anchor. For relatively low probabilities, the adjustment will be positive (over-weighting), and for higher probabilities the adjustment will be negative (under-weighting). The model thus predicts that an individual will switch from ambiguity aversion for low probabilities, to ambiguity seeking for higher probabilities. The switching point is variable according to individual attitudes towards ambiguity.

Einhorn and Hogarth (1986), Hogarth and Kunreuther (1989) and Di Mauro and Maffioletti (2001) all find results compatible with the switching behaviour implied by the theory. Nevertheless, Di Mauro and Maffioletti (1996) do not conclude that the majority of subjects exhibit switching behaviour. An important difference between the two sets of findings is that Einhorn and Hogarth (1986) and Hogarth and Kunreuther (1989) utilized hypothetical incentives, whereas Di Mauro and Maffioletti (1996) conduct an incentivized experiment. Di Mauro and Maffioletti (2001) find a significant effect of ambiguity in an incentivized experiment as well, although they stipulate that the effect is weaker than that found in the earlier studies. Therefore, the saliency of the impact of ambiguity may decline when real incentives are used, possibly because individuals make a greater effort in calculating actual probabilities when there is something to be lost.

To summarize, although there is some evidence of individuals exhibiting ambiguity preferences which violate subjective EUT, the impact of ambiguity may decrease in an incentivized experiment. Another important clarification is that all of the reviewed experimental studies examining uncertainty or ambiguity aversion conducted within-subject tests, in which subjects face both situations with risk and uncertainty or ambiguity. This may trigger uncertainty or ambiguity aversion according to Fox and Tversky (1995) when individuals prefer the certainty of risk prospects they experience in the experiment, which may not occur in practice when such risk prospects are absent. Therefore, little is known about the impact of uncertainty or ambiguity between subjects in experimental studies of insurance demand.

## 5. Results about Heuristics and Behavioural Biases

In contrast to theories of decision making, individuals may apply heuristics which are more simple decision rules based on intuitive thinking, and behaviour may be associated with biases (Gilovich *et al.*, 2002). A variety of heuristics and biases are examined in the reviewed studies including framing effects, the availability heuristic and the gambler's fallacy.

### 5.1 *Framing Effects*

The framing effects examined in the reviewed studies include: framing prospects as either insurance purchases or standard gambles and framing of the risk reduction mechanism as either one which reduces the probability of loss to zero (self-protection) or one which reduces the size of the loss to zero (self-insurance). We conjecture that framing effects found in the reviewed studies may in part be related to non-incentive compatible reward structures.

For example, whereas hypothetical surveys find that framing prospects in an insurance context results in a greater degree of risk aversion and insurance demand compared to when equivalent prospects are presented as general probability and loss combinations (Schoemaker and Kunreuther, 1979; Hershey and Schoemaker, 1980; Connor, 1996; Kusev *et al.*, 2009), an incentivized experiment by Fehr-Duda *et al.* (2006) found that such framing does not affect probabilistic risk attitudes in the loss domain.[6]

Moreover, the non-incentive compatible experiment by Shogren (1990) presented subjects insurance decisions where they faced a risk of loss in an unfavourable state and a small gain in a favourable state. Subjects value the mechanism which decreases the probability of loss to zero more (resulting in a payoff of the small gain with certainty) than another instrument that reduces the loss size to zero, which implies that the small gain may not occur in the unfavourable state. It is clear that the observed behaviour is consistent with rationality due to the difference in payoffs. When framing is purely based on different descriptions of the risk reduction mechanism, and an incentive compatible experiment is used, no divergence in behaviour has been observed (Di Mauro and Maffioletti, 1996). However, we cannot disentangle whether the effect found by Shogren (1990) is due to the non-incentive compatible nature of their study or the difference in payoffs.

## 5.2 *Availability Heuristic and Gambler's Fallacy*

Past experience with uninsured losses can significantly affect behavioural patterns according to the gambler's fallacy and the availability heuristic, which have opposite effects on insurance demand. The former implies that experience without a loss for a long time triggers individuals to think a loss is due to occur, which may stimulate insurance purchase. Furthermore, a loss which has just happened may lead individuals to believe that it is now less probable, so purchases may decline (Clotfelter and Cook, 1993). The availability heuristic implies that individuals judge probabilities based on how easy they can recall events (Tversky and Kahneman, 1974). Thus the occurrence of a loss might remind individuals they are vulnerable, which increases their risk perception and insurance demand.

Market data shows that homeowners typically demand more insurance after experiencing a catastrophic loss (Browne and Hoyt, 2000; Kriesel and Landry, 2004; Zahran *et al.*, 2009; Michel-Kerjan and Kousky, 2010; Kousky, 2011, 2017), consistent with the availability heuristic; however, this impact appears to diminish after a few years (Atreya *et al.*, 2015). Gallagher (2014) also finds that a flood increases insurance demand immediately after the event in affected areas, and that media market neighbours (sectors of the population receiving the same television content) to flooded areas have increased flood insurance demand as well. Moreover, geographically close neighbours to flooded areas, who do not share the same media market have little evidence of increased take-up of flood insurance following a flood. This evidence adds credence to an availability heuristic explanation, because insurance demand is increased only for subgroups for which information about flooding became available after the flood event.

Counter evidence can be found in another market data study by Michel-Kerjan *et al.* (2012), who showed that a large insurance claim due to a major flood leads to shorter policy tenure, which may be due to the gambler's fallacy. Nevertheless, we cannot rule out that homeowners may have relocated because of the trauma inflicted by the major flood, which would also reduce policy tenure. Because it is difficult to control for individuals relocating to other areas in large market data studies, it is perhaps useful to study gambler's fallacy in a lab experiment. For example, the experiment by Ganderton *et al.* (2000) finds that subjects experiencing uninsured losses are less likely to purchase insurance subsequently, consistent with the gambler's fallacy. McClelland *et al.* (1993) also find some support for the gambler's fallacy. A contradicting observation is that prior to loss, insurance demand declines over time. Immediately after a loss demand does not change much, but thereafter subjects bid increasingly more for insurance over successive experimental rounds without a loss, which is consistent with the gambler's fallacy.

In sum, there is significant evidence in the market data studies that homeowners make insurance choices consistent with the availability heuristic. The mixed results in the experimental studies may arise because samples consist of subgroups who either follow the gambler's fallacy or the availability heuristic which have opposite effects on insurance demand that may cancel for the total sample, or one effect may dominate depending on which subgroup is largest. For example, Papon (2008) finds that some participants perceive that risk is more likely over several periods without a loss and purchase higher levels of coinsurance as a result (in favour of the gambler's fallacy). Others are more likely to choose higher levels of coinsurance after an uninsured loss, and purchase zero insurance over several experimental rounds without loss which is consistent with the availability heuristic. Only few subjects did not follow these behavioural patterns in Papon (2008).

## 6. Variables Explaining Insurance Demand

The proceeding section examines information provided by Tables 2 and 4 about variables of influence on insurance demand, such as objective risk factors, subjective risk perceptions and insurance market characteristics in terms of policy prices as well as the impact of multi-year insurance contracts and the availability of government compensation. The potential impact of socio-economic characteristics is also described.

Many of the market data papers exploited large geographic study areas to investigate the influence of risk exposure on insurance demand. It has been shown that objective flood risks and flood risk perceptions are correlated (Botzen *et al.*, 2015). Therefore, one can expect that insurance demand is related to objective risk, which is evidenced by most of these studies finding that insurance demand is higher in areas with more risk exposure. Risk perceptions can be examined in studies by eliciting subjective loss probability estimates. These are also positively related to insurance demand in experimental studies (Schade *et al.*, 2012; Bajtelsmit *et al.*, 2015), consistent with expectations. Incentives may also matter for eliciting subjects' best estimates of subjective loss probabilities; however, this examination is missing from the literature.

Difficulties exist when estimating the impact of insurance price on insurance demand against catastrophic risks using market data, due to the correlation between objective risk variables and insurance premiums. Without an exogenous source of variation in the price of insurance, any observed price effect may be confounded by risk levels (Kousky, 2011). Moreover, homeowners with a mortgage backed by a federally regulated lender, who live in floodplains where the annual probability of flooding is 1 in 100, are subject to mandatory coverage requirements in the USA, which can lead to lower price responsiveness (Landry and Jahan-Parvar, 2011). Nevertheless, most of the market data studies examining price find that it has a negative impact on catastrophic risk insurance demand. Experimental studies which can control for the influence of confounding factors, like objective risk levels, also by majority find that insurance prices (loading factors) negatively impact insurance demand.

Empirical evidence suggests that homeowners are reluctant to buy disaster insurance at insurance prices above the expected value of damage (Browne and Hoyt, 2000). Solutions to overcome low uptake of insurance against LPHI risks have been studied, including offering multi-year insurance which has fixed annual premiums each year and does not permit cancellations at the end of any given year. In theory, risk averse individuals should prefer the price stability of multi-year policies compared to annual contracts which are subject to yearly price fluctuations (Kleindorfer *et al.*, 2012), which is supported by the experimental studies by Papon (2008) and Kunreuther and Michel-Kerjan (2015).

Browne and Hoyt (2000) and Kousky *et al.* (2018) studied external influences outside of the private insurance market, like the impact of government relief payments on the demand for flood insurance. Theory suggests that anticipated government relief payments may decrease demand for insurance if the former is used as a substitute for insurance (charity hazard) (Kelly and Kleffner, 2003; Raschky and Weck-Hannemann, 2007). However, Browne and Hoyt (2000) find that disaster relief expenditures are positively related to flood insurance purchases, which may be due to exposure to flooding increasing both insurance demand and receipt of relief payments. There may also exist a reverse causality problem, that is

**Table 4.** Variables Incorporated per Study and Their Effect on Insurance Demand.

| Author | Study | Variables[a] |
|---|---|---|
| Murray (1971) | 1 of 1 | N/A |
| Neter and Williams (1971) | 1 of 1 | N/A |
| Murray (1972) | 1 of 1 | N/A |
| Slovic *et al.* (1977) | 1-3 of 10 | Probability (+)[b] |
| | 4 of 10 | Loading factor (–), probability (+) |
| | 5 of 10 | Presentation of urns [decisions considered one by one vs. decisions made all at once (m)], probability (+). |
| | 6 of 10 | Bundling insurance (+) |
| | 7 of 10 | Commitment period (+$^*$) |
| | 8 of 10 | Bundling refundable insurance (+) |
| | 9 and 10 of 10 | Probability (+)[c] |
| Schoemaker and Kunreuther (1979) | 2 of 5 | Deductible (m) |
| | 3 of 5 | N/A |
| | 4 of 5 | Bundling insurance (–$^*$) |
| | 5 of 5 | Expected loss (m) |
| Hershey and Schoemaker (1980) | 1 of 1 | Expected loss (m), probability (–) |
| Einhorn and Hogarth (1986) | 2 and 3 of 3 | N/A |
| Camerer and Kunreuther (1989) | 1 of 1 | Lagged prices (+$^*$), probability (ns) |
| Hogarth and Kunreuther (1989) | 1 and 2 of 2 | N/A |
| Shogren (1990) | 1 of 1 | N/A |
| Irwin *et al.* (1992) | 1 of 1 | N/A |
| McClelland *et al.* (1993) | 1 of 2 | Probability (–) |
| | 2 of 2 | N/A[d] |
| Connor (1996) | 1 of 1 | N/A |
| Di Mauro and Maffioletti (1996) | 1 of 1 | N/A |
| Wakker *et al.* (1997) | 1-3 of 4 | Default risk (–), expected loss (+) |
| | 4 of 4 | Default risk (–), whether partial insurance is offered (–) |
| Kunreuther *et al.* (1998) | 1 & 2 of 2 | Length of time renting apartment (ns) |
| Loehman (1998) | 1 of 1 | Probability (–) |
| Shapira and Venezia (1999) | 1 of 4 | Probability of loss distribution (ns, for purchase of full insurance compared to deductible insurance) |
| Ganderton *et al.* (2000) | 1 of 1 | Accumulated wealth (–$^*$), expected loss (m), loading factor (–$^*$), probability (+$^*$), risk preference (–$^*$) |
| Theil (2000) | 1 of 1 | Loading factor (–), probability (–) |
| Di Mauro and Maffioletti (2001) | 1 of 1 | N/A |
| Loubergé and Outreville (2001) | 1 of 1 | Probability (–) |
| Kruse and Thompson (2003) | 1 of 2 | Demographics [female (ns)] |
| | 2 of 2 | Length of time renting apartment (+), demographics [female (ns)][e] |

(*Continued*)

**Table 4.** *Continued.*

| Author | Study | Variables[a] |
|---|---|---|
| Laury and McInnes (2003) | 1 of 1 | Posterior probability most likely cup was used (+*), demographics [age (ns), course of study (ns), female (ns), previously purchased insurance outside the lab (ns), year in school (ns)] |
| Fehr-Duda *et al.* (2006) | 1 of 1 | N/A |
| Papon (2008) | 1 of 1 | Commitment period (+*) |
| Kusev *et al.* (2009) | 1 to 5 of 5 | N/A |
| Laury *et al.* (2009) | 1 of 2 | Probability (+) |
| | 2 of 2 | Expected loss (+*), loading factor (–*), probability (–*), quiz score (ns), demographics [age (+*), ethnicity (ns), female (ns), previously purchased insurance outside the lab (ns), US raised (ns)] |
| Fehr-Duda *et al.* (2011) | 1 of 1 | N/A |
| Schram and Sonnemans (2011) | 1 of 1 | N/A |
| Shafran (2011) | 1 of 1 | Feedback (m), loading factor (m), number of gamble repetitions (ns), probability (+*) |
| Schade *et al.* (2012) | 1 of 1 | Bundling insurance (+*, under uncertainty/ambiguity), probability (ns, under uncertainty/ambiguity), subjective probability (+*, under uncertainty/ambiguity), worry (+*, under uncertainty/ambiguity) |
| Brunette *et al.* (2013) | 1 of 1 | Expected loss (m), government assistance [fixed public support vs. no public support (–*), fixed public support vs. contingent fixed public support (ns), insurance subsidy vs. no public support (–*)] |
| Krieger and Felder (2013) | 1 of 1 | Risk preference (m), demographics [age (ns), familiarity with alternative policies (ns), female (ns), insurance status (ns), previously purchased health insurance outside the lab (ns), supplemental insurance ownership (ns)] |
| Ozdemir and Morone (2014) | 1 of 1 | Endowment (m), expected loss (m), probability (m), threshold probability (ns), demographics [age (ns), female (m), income (ns)] |

(*Continued*)

**Table 4.** *Continued.*

| Author | Study | Variables[a] |
|---|---|---|
| Petrova *et al.* (2014) | 1 of 1 | N/A |
| Bajtelsmit *et al.* (2015) | 1 of 1 | Full precaution when insurance unavailable (+*), loading factor (–*), part precaution when insurance unavailable (m), probability (ns), subjective probability (+*) |
| Jindal (2015) | 1 of 1 | Expected repair costs (–*), loading factor (–*), product characteristics [washing machine price (m), front loading vs. top loading (ns)] |
| Kunreuther and Michel-Kerjan (2015) | 1 of 1 | Commitment period (+), loading factor (–*), risk preference (–*), suffer loss early in experiment (+*), demographics [age (+*), education (ns), income (–*)] |
| Kunreuther and Pauly (2018) | 1 of 1 | Ex post negative feelings (+*), loading factor (–), presentation of graphic hurricane images (+), tutorials on deliberative thinking (ns) |
| Zimmer *et al.* (2018) | 1 of 1 | Competence in insurance related questions (ns), default risk (–*), optimism (ns), risk preference (ns), demographics [education (ns), female (ns), study economics (ns)] |

*These results are significant at the 5% level.
[a]+ or –: direction of impact on insurance demand. Not significant: ns. Mixed findings: m. For studies that did not examine the influence of specific variables on insurance demand, results are N/A. Such studies were interested in topics like: the validity of EUT for insurance decisions (Murray, 1971, 1972); the acceptance of various methods to elicit insurance preferences (Neter and Williams, 1971); the impact of framing on insurance decisions (Schoemaker and Kunreuther, 1979; Shogren, 1990; Connor, 1996); the influence of various factors on ambiguity preference (Einhorn and Hogarth, 1986; Hogarth and Kunreuther, 1989; Di Mauro and Maffioletti, 1996, 2001); the influence of experience and incentives on insurance decisions (Shogren, 1990; Irwin *et al.*, 1992; McClelland *et al.*, 1993); the influence of various factors on probability weighting (Fehr-Duda *et al.*, 2006; Kusev *et al.*, 2009, 2011; Petrova *et al.*, 2014) and the influence of various factors on policy switching behaviour (Schram and Sonnemans, 2011).
[b]A different sample was used in the second study, and results were compared to the first study. A different order of urn presentation was used in the third study, and results were compared to the first study. The studies investigate the impact of altering probability on insurance demand, whilst keeping the expected value of loss constant.
[c]Real incentives were used in the tenth study, and the results were compared to the ninth study, where hypothetical incentives were used.
[d]Subjects faced a greater loss, lower fixed probability, a larger number of rounds and more salient incentives compared to the first study.
[e]In the first study real incentives were used and subjects faced binary choices, and in the second study subjects were required to state a hypothetical WTP. Some subjects faced the experiment first and others faced the survey first to control for order effects.

more insured areas need less government aid after a flood. Kousky *et al.* (2018) deal with this endogeneity by employing an instrumental variables analysis. They use an interaction term (as their instrumental variable) between timing of presidential elections and states considered important for the outcome of elections as an exogenous source of variation in government relief payments (Garrett and Sobel, 2003). Their results show that individual assistance grants offered by the government after flood events have a negative impact on flood insurance coverage levels, consistent with theory. Of the reviewed survey and experimental literature, only one hypothetical study incorporates the effect of potential government relief schemes (Brunette *et al.*, 2013). Given the potential confounding problems associated with studying charity hazard with market data, future research should consider examining the impact of government compensation using an incentive compatible experiment setting.

Apart from external forces, like the availability of government compensation, many of the reviewed studies have examined individual drivers, like socio-economic characteristics. Individual disparities in risk attitudes may relate to socio-economic characteristics like income, gender and age (Donkers *et al.*, 2001). Higher income can increase the affordability of and hence the demand for insurance (Browne and Hoyt, 2000; Kriesel and Landry, 2004; Athavale and Avila, 2011; Atreya *et al.*, 2015). Landry and Jahan-Parvar (2011) showed with market data that higher income relates to more insurance demanded, but the relation is not monotonic. Households in the highest income category do not have significantly higher demand compared to those in the lowest, which may indicate that high-income individuals can pay for losses out-of-pocket.

Other socio-economic characteristics like gender, age and education are inconsistent predictors of insurance demand according to the reviewed studies. In addition to the ambiguous influence of socio-economic characteristics, this section has provided the following insights: objective risk and risk perceptions impact insurance demand positively, as one might expect. Moreover, insurance prices tend to negatively affect demand for insurance despite the correlation between objective risk and insurance prices in market data studies. Initial experimental examinations of solutions to underinsurance of LPHI risk, like multi-year insurance, have shown that such insurance contracts increase demand for insurance. Potential causes of underinsurance like the availability of government compensation are difficult to study with market data, but investigations suggest that government compensation may reduce demand for insurance once potentially confounding variables are controlled for.

## 7. Conclusion

This paper has reviewed a large evidence base of 41 experimental and survey papers of insurance demand under LPHI risk in which ~9608 subjects participated, as well as 14 market data studies of insurance demand against catastrophic risk. Publications over time show this is a rapidly growing field. There is a growing concern about how to manage increasing societal impacts from LPHI events, like natural disasters, where insurance can play an important role. Understanding demand for insurance against LPHI risks is important for policy solutions for managing LPHI risks and increasing insurance uptake for these events, which is often low in practice. In this respect, our systematic review is timely by focusing on LPHI risks for which behaviour tends to differ relative to HPLI risk.

The aim of the literature review was to draw lessons learned from the studies about demand for insurance, and for outlining an agenda for future research. Our discussions are based on studies that utilize salient incentive compatible rewards; however, we also highlight results which may arise as a consequence of non-incentive compatible rewards. In this respect, we find that certain theoretical examinations such as ambiguity models predicting ambiguity aversion and EUT which predicts aversion to mean-preserving spreads, as well as framing effects may be influenced by whether studies use incentives. Given that hypothetical incentives may confound results in theoretical studies of insurance demand, we advise that such studies use salient incentive compatible rewards.

A general challenge is how to best operationalize LPHI risk in experimental studies, which are used to resolve incentivized payments, and to communicate risks to subjects. This depends on the method of experiment implementation, such as online via computer, or a laboratory setting with random drawings from an urn. It is well known that individuals have difficulties understanding LPHI risk so the kind of risk operationalization method may matter, but this topic has received insufficient research. It would also be useful to examine whether incentives are needed for eliciting subjects' best estimates of subjective loss probabilities, which proxy risk perceptions in experimental studies.

We supplement insights from the experimental research with results based on market data, given their complementary properties. The confounding problems involved in certain market data examinations, such as the impact of government compensation on insurance demand, suggest that an incentive compatible experiment on the topic of charity hazard is needed. Theoretical investigations unanimously find a charity hazard effect; therefore, it is worth examining which type of government assistance crowds out demand for insurance the least, that is individual assistance grants or loans.

Many of the market data studies find effects consistent with the availability heuristic, so future research could provide a better understanding of subgroups prone to the availability heuristic. We find that risk perceptions influence demand for insurance, so information campaigns that focus on risk awareness may overcome availability effects and low demand in periods when a disaster did not occur for a long time. Probability weighting may also explain low demand for insurance, for example, in the presence of insurer default risk. However, few studies have examined the specific reasons why individuals over-/under-weight low probabilities. Policymakers focused on risk communication could use insights into why individuals are sensitive to probability information when developing their information campaigns.

Moreover, demand for insurance can be increased by offering multi-year insurance, although other measures could provide a better alternative to overcome systematic biases in judgment, like use of the availability heuristic. Another way forward may be to nudge individuals using choice architecture (Thaler and Sunstein, 2003), for example, by framing catastrophic insurance coverage as a default option (Johnson and Goldstein, 2003). However note that more research is needed to determine whether default options can encourage insurance against LPHI risks (Kunreuther, 2015), and the ethical dimension of nudging has been debated in the literature regarding its effect on consumer autonomy and welfare (Smith *et al.*, 2013).

In a world of increasing losses from LPHI risks, it is important to keep prices low since high prices are consistently related to low insurance demand. Affordable insurance is especially important for low-income households because high-income households may pay for losses out-of-pocket. Low-cost insurance can be achieved by for instance offering premium discounts to those who undertake other measures of risk reduction.

Our examination of samples, study designs and insurance context also revealed a variety of gaps in the existing literature, which can be addressed by future experiments. The reviewed experimental and survey studies are conducted in developed countries, most of which are in the OECD, and the large majority of participants are students. Future research should focus on how results from student samples can be generalized to insurance demand for LPHI risks by more common customers, like homeowners. Moreover, regarding the characteristics of insurance products, experiments usually incorporate relatively low deductibles, implying that little is known about the impact of realistic market deductibles on demand for insurance in the experimental literature.

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## Notes

1. One notable exception is the insurance experiment conducted by Turner *et al.* (2014). Their study is not included in the review because the lowest loss probability they incorporate is 0.2.
2. Strategic behaviour is possible in Camerer and Kunreuther (1989) and Shogren (1990); therefore, their reward structures are not incentive compatible. These are the only reviewed salient experimental papers to not include incentive compatible remuneration.
3. Advantages of online computerized experiments include access to a large diverse subject pool, reduced experimenter effects and cost savings; the disadvantages are low control and potentially selective attrition (Horton *et al.*, 2011). In terms of generalizability, Paolacci *et al.* (2010) showed that U.S. samples recruited through Amazon's Mechanical Turk are at least as close to the U.S. population as commonly used student samples.
4. The experiment also incorporated other insurance prospects with lower loss amounts which are mean-preserving spreads, but we use this one as an example.
5. Given the atheoretical properties of the original version of the model (Kahneman and Tversky, 1979), we focus on CPT. It is important to stress that models predicting violations of stochastic dominance like original prospect theory (PT) are undesirable, and such violations are not often observed empirically. When they do occur, they depend on the way decisions are framed (Wakker, 2010). Editing operations of PT have also been criticized because they do not lend well to formal analysis as their application depends on the way choices are elicited (Tversky and Kahneman, 1992).
6. However, they did find a framing effect in the gain domain, where relative to males, females exhibit more probabilistic pessimism when gain prospects are framed as investments.

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