CRESTCENTER FOR RESEARCH IN ECONOMICS AND STATISTICS

Série des Documents de Travail

n° 2017-79
Measuring individual risk-attitudes: an experimental comparison between Holt & Laury measure and an insurance-choices-based procedure

A. CORCOS[1]
F. PANNEQUIN[2]
C. MONTMARQUETTE[3]

[1] CURAPP-ESS UMR 7319; CNRS and Université de Picardie; Pôle Université Cathédrale, E-mail: anne.corcos@u-picardie.fr

[2] CREST; ENS Paris-Saclay; Université Paris-Saclay, E-mail: pannequin@ecogest.ens-cachan.fr

[3] CIRANO; Université de Montréal, E-mail: Claude.Montmarquette@cirano.qc.ca

Measuring individual risk-attitudes: an experimental comparison between Holt & Laury measure and an insurance-choices-based procedure

Anne Corcos,
CURAPP-ESS UMR 7319, CNRS and Université de Picardie,
Pôle Université Cathédrale, 10, placette Lafleur, BP 2716, 80027 Amiens Cedex1, France.
anne.corcos@u-picardie.fr

François Pannequin,
CREST, ENS Paris-Saclay, Université Paris-Saclay
61, avenue du Président Wilson, 94235 Cachan Cedex, France
Telephone: +33 1 47 40 24 83; Mobile: +33 6 20 98 44 96
pannequin@ecogest.ens-cachan.fr

Claude Montmarquette,
CIRANO and Université de Montréal,
CIRANO, 1130 Sherbrooke St. West #1400, Montreal, QC H3A 2M8, Canada.
Claude.Montmarquette@cirano.qc.ca

Preliminary Version - December 2017

Abstract:
This paper compares the Holt and Laury's risk attitude elicitation with a risk attitude classification associated with insurance behavior. The standard Holt and Laury's procedure (2002) is implemented in the loss domain, while the second tool is based on contextualized experimental hedging choices for insurance and loss reduction (secondary prevention).
Our findings highlight the high consistency between the two procedures for more than two-thirds of the subjects, both measures leading to the same risk-attitude assignment. Interestingly, cases where the two measures do not coincide concern the only subjects whose Holt and Laury's risk aversion coefficient is borderline. For these participants, using both measures allows for a more accurate assessment. Finally, the HL-irrational behavior of participants uncovers specific risk-averse behavior signature, while contextualized-irrational behavior reveals a risk-loving behavior.

Keywords: risk-attitude classification, insurance demand, self-insurance demand, loss reduction, secondary prevention, multiple price list method, experimental study
JEL Classification: C91, D81

Section 1. Introduction

Decisions under risk and uncertainty are part of people's daily life: investment in human and financial capital, career choices, choice of marriage partners. Economists have done a great deal to formalize a model that studies those decisions within either the expected utility framework or its alternative theories (prospect theory, rank-dependent expected utility). A common feature is a central role assigned to risk aversion. Relying on the standard EU model and making assumptions on the utility function (CARA, DARA…), economists have strongly deepened the relationship between wealth and risk aversion. In the loss domain, risk aversion also appears to depend on the size of the loss, with subjects exhibiting higher risk aversion when facing higher financial stakes (Holt and Laury, 2002, 2005, Harrison et al., 2005). Another fundamental feature of risk aversion is the reflection effect. According to prospect theory (Kahneman and Tversky, 1979) risk attitude may depend on the nature of the risk exposure: people would tend to exhibit risk aversion in the gain domain but risk loving in the loss domain. Risk-attitudes are therefore difficult to grasp.

Risk-attitude is in particular central to insurance and prevention decisions as it determines the individuals' demand for coverage and hence the associated economic policies. Risk lovers are theoretically not expected to buy insurance, which raises ethical problems (can developed countries leave people without insurance coverage?), fairness issues (will the rest of society take risk lovers over although they did not participate in the market?) resulting in economic policy concerns (which incentive policy for risk lovers?). Therefore identifying individuals' risk attitudes, quantifying risk-lovers and examining their insurance and prevention behavior raise significant issues.

The current article addresses the risk attitude assessment issue in insurance and prevention decisions. It specifically evaluates the risk attitude with the standard Holt and Laury's and a risk hedging-contextualized risk-attitude indicator and compares their consistency. Among the tools developed within the experimental approach, Multiple Price List procedure (Holt and Laury (2002)) is one of the most widely used methods to measure risk-attitudes. When implemented in the loss domain (Chakravarty and Roy, 2009), this measure makes it possible to unravel risk lovers and risk averters.[1] However, while simple to use, Holt and Laury's tool reveals some weaknesses. For example, Lévy-Garboua et al. (2012) found 30% of irrational subjects when using standard Holt and Laury's procedure.[2]

Moreover, risk aversion assessment has proven to be context-dependent. Using hypothetical choices, Hershey and Schoemaker (1980), as well as Lypny (1993) in an experiment, document the fact that individuals are more risk-averse when the choice options are framed as insurance decisions rather than decontextualized risky decisions. In the same way, studies comparing contextualized measures with decontextualized ones (the Holt and Laury measure for example) lead to heterogeneous results: some stress the convergence between the two approaches, while others, highlight their inconsistency. For instance, in a methodological paper, Anderson and Mellor (2008) investigate whether risk preferences measured by Holt and Laury's procedure in experiments correlate with surveyed health-related behaviors. Faff, Mulino, and Chai (2008) study the stability

[1] In the loss domain, risk lovers account for 30 to 40% of the subjects.
[2] For example, with multiple switches between risky and less risky choices of lottery.

of financial risk tolerance (FRT), whether obtained from a psychometrically validated survey or an online lottery choice experiments involving the same nonstudent participants. These two studies exhibit a remarkable coherence between the choice of lottery method and the alternative measures to elicit risk preference. Lusk, and Coble (2005) find that risk-attitudes elicited in a decontextualized lottery choice experiment of Holt and Laury's type are significantly related to subjects' stated willingness to eat and purchase Genetically Modified Food.

On the contrary, comparing risk preferences elicited from a lottery choice task decision (Holt and Laury's task) and eight hypothetical measures, Nielsen, Keil, and Zeller (2013) report that the correlations between the risk preference measures, while statistically significant, are weak. Lönnqvist, Verkasolo, Walkowitz, and Wichardt (2015) obtain same results: comparing two prominent measures of individual risk-attitudes – Holt and Laury's lottery-choice task and the multi-item questionnaire advocated by Dohmen et al. (2011), they suggest that the two risk measures are at best uncorrelated. Similar results are found by Szrek, Chao, Ramlagan, and Peltzer (2012) and contrary to Anderson and Mellor (2008), the Dohmen et al.'s survey question on general risk-taking propensity appears to be a good predictor of actual risky health behavior compared to Holt and Laury's measures.

Our paper relates to the previous papers and focuses specifically on the insurance contextualized issue. We compare two methods of risk-attitudes classification. The first one is Holt and Laury's standard procedure implemented in the loss domain; the second is based on contextualized hedging choices observed in the lab. The joint use of the demands for insurance, I, and prevention (loss reduction or self-insurance), SI to cover a risk will provide a comprehensive measure of risk attitude while permitting to study more realistically the risk hedging behaviors of the participants. In real life, risk hedging choices rely on both insurance and prevention. Managing a risk using only an insurance coverage seems more like a case study than an actual situation. So, for the sake of contextualization, our experimental design offered to subjects to invest simultaneously in insurance and loss reduction.
As a consequence, our experiment allows eliciting risk attitudes through a reduced number of two-decision steps, which mitigates the drawbacks associated with the boring repetition of identical choices. Relying on only three steps, it is possible to observe a wide variety of behaviors. In our experiment, we identify ten different consistent patterns of behavior. In our experiment, in some circumstances depending on the insurance tariff, it may be irrational to invest or not to invest in prevention. Therefore, the simultaneous availability of insurance coverage and loss reduction technology makes it possible to detect inconsistent subjects.

The use of SI will initially allow detecting more robustly the inconsistent behavior of some participants usually present in experimental studies. Also, SI will provide an internal validation tool for the segmentation of our subjects according to their risk attitude. For example, RLs are expected to require significantly fewer SI than RAs.

Our results point out the consistency of the two measurements to assess the risk attitude. Moreover, non-convergent cases highlight a strong complementarity of the two methods to classify, more efficiently, borderline individuals (whose Holt and Laury's-risk-attitude coefficient is located at the splitting point between risk-aversion and risk-loving), and shed a new light on individuals usually qualified as irrational using either method (e.g., the multi-switches issue).

In Section 2, the models used to derive the contextualized measurement of risk-attitude are presented. Section 3 explains the two-step experimental design devoted to the contextualized and decontextualized measurements of risk-attitude. Section 4 examines the consistency of the measures and their robustness. Section 5 concludes.

Section 2. The model ISI

We first present the risk context and its hedging opportunities, before characterizing the optimal and voluntary demands for insurance and self-insurance for risk averters (RAs) and risk lovers (RLs). Finally, we provide an exhaustive description of the consumption behavior depending on risk-attitude and insurance pricing.

1. Risk context and hedging opportunities

Endowed with an initial wealth W_0, the decision maker (DM) is exposed to the probability q of a loss x_0. She can use two risk hedging tools to cope with this risk: insurance (I) and self-insurance (SI).

We consider a two-part insurance tariff: an indemnity I is guaranteed if a loss occurs, in exchange for the payment of an insurance premium P = pI + C, where p stands for the unit insurance price and C for the fixed cost. In line with real life, we excluded over insurance.

The self-insurance technology has diminishing returns to reduce the size of x_0. To make both risk hedging comparable, we distinguish between "*e*," the monetary effort in the technology and SI the demand for self-insurance (i.e., the share of x_0 no longer exposed to risk). Since SI is a function of *e*, we get $x = x(e) = x_0 - SI(e)$, with $SI(0) = 0, SI'(e) > 0, SI''(e) < 0$ and $x(0) = x_0$.

The no-loss state wealth and the loss state wealth are respectively equal to: $W_1 = W_0 - P - e$, and $W_2 = W_0 - P - e - x_0 + SI(e) + I$. The DM maximizes therefore the following expected utility:

$$\max_{I,e} EU(I,e) = (1-q)U(W_0 - pI - C - e) + qU\,(W_0 - pI - C - e - x_0 + SI(e) + I)$$

A positive fixed cost C could deter the DM from participating in the insurance market. This setting calls therefore for the following participation constraint (PC): $EU(I^*, e^*) \geq EU(0, \hat{e})$, where I^* and e^* stand for the optimal choice regarding demand for insurance and self-insurance effort respectively; $\hat{e}$ represents the optimal self-insurance effort when insurance is not involved.[3]

[3] More explicitly, optimal choice for I and *e* needs to respect the following participation constraint (PC): $(1-q)U(W_0 - pI^* - C - e^*) + qU(W_0 - pI^* - C - e^* - x_0 + SI(e^*) + I^*) \geq \max_e\ (1-q)U(W_0 - e) + qU(W_0 - e - x(e))$, and $\hat{e} = \arg\max_e\ (1-q)U(W_0 - e) + qU(W_0 - e - x(e))$.

2. RA

If the DM is risk-averse, her preferences are described by a strictly concave utility function U(W), with U'(W) > 0 and U''(W) < 0. First order conditions characterize optimal choices (see Appendix A for detailed proofs)[4].

From these FOC, we get that a risk-averse DM invests in insurance and self-insurance to equalize marginal returns (MRs) of insurance (on the LHS) and prevention (on the RHS):

$$\frac{1}{p} = SI'(e) \tag{1}$$

A straightforward consequence of this equation is that insurance and self-insurance are substitutes: an increase in the unit price of insurance results in an increase in the demand for self-insurance and a decrease in the demand for insurance.

Moreover, equation (1) and the two FOC (see Appendix A) characterize the risk-bearing behavior of the DM, in response to both the SI technological opportunities (depending on $SI'(0) >$ or $\leq 1/p$) and insurance pricing. Table 1 gives an exhaustive description of the behavior of a risk averter choosing insurance along with self-insurance.

Table 1: Risk hedging behavior of a risk averter

	(1) $p \leq q; C \geq 0$; (PC) satisfied	(2) $p \leq q; C > 0$; (PC) not satisfied	(3) $p > q; C \geq 0$; (PC) satisfied	(4) $p > q; C \geq 0$; (PC) not satisfied
$SI'(0) > \frac{1}{p}$	$\boldsymbol{SI^* > 0}$; $\boldsymbol{I^* > 0}$ $I^* = x_0 - SI^*$	$\boldsymbol{SI^* > 0}$; $\boldsymbol{I^* = 0}$	$\boldsymbol{SI^* > 0}$; $\boldsymbol{I^* > 0}$ $I^* < x_0 - SI^*$	$\boldsymbol{SI^* > 0}$; $\boldsymbol{I^* = 0}$
$SI'(0) \leq \frac{1}{p}$	$\boldsymbol{SI^* = 0}$; $\boldsymbol{I^* > 0}$ $I^* = x_0$	$\boldsymbol{SI^* \geq 0}$; $\boldsymbol{I^* = 0}$ $\left(\text{if } SI'(0) > \frac{1}{q}, \text{ then } SI^* > 0\right)$	$\boldsymbol{SI^* = 0}$; $\boldsymbol{I^* > 0}$ $I^* < x_0$	$\boldsymbol{SI^* \geq 0}$; $\boldsymbol{I^* = 0}$ $\left(\text{if } SI'(0) > \frac{1}{q}, \text{ then } SI^* > 0\right)$

4 cases are displayed in the columns of Table 1 according to the contractual parameters (p and C) and the participation constraint (PC). As over-insurance is not allowed, $0 \leq I^* \leq x_0$. The rows relate to the SI technology and refer to equation (1): if the marginal return (MR) of the 1st monetary unit invested in SI is higher than the MR of insurance ($SI'(0) > 1/p$), then the DM should rely on both hedging means; if $SI'(0) < 1/p$, the MR of insurance is higher and there is no interest in investing in SI, unless the values of p and C violate condition (PC). In this last case, if the 1st unit invested in SI has a positive actuarial return (if $SI'(0) > 1/q$), then $SI^* = SI(\hat{e}) > 0$.

3. RL

[4] These conditions are necessary and sufficient. Second order conditions are developed in Appendix A.

We now turn to the optimal hedging demand for a risk-loving DM. The resulting optimization problem is not convex since the utility function U(W) is convex (U'(W) > 0 and U''(W) > 0). As second-order conditions are violated, only corner solutions are possible. However, we can use first-order conditions to sketch the proofs.

The main finding is that, if the unit price of insurance is sufficiently subsidized ($p < q$), a rational risk lover may invest in insurance. If over-insurance is forbidden, she will arbitrate between full insurance and risk retention ($I^* = x_0 - SI^*$ or $I^* = 0$), and she will equalize the marginal returns of insurance and self-insurance whenever she buys a positive amount of insurance.[5] Otherwise, if $p \geq q$, a risk lover will never buy insurance, but she will invest in self-insurance as soon as the MR of the 1st dollar invested passes a certain threshold ($I^* = 0;\ SI^* > 0$).

The discussion is detailed in Appendix B and leads to the following behavioral predictions:

Table 2: Risk hedging behavior of a risk lover

	$p < q; C \geq 0$; (PC) satisfied	$p < q; C \geq 0$; (PC) not satisfied	$p \geq q; C \geq 0$; (PC) not satisfied
$SI'(0) > \frac{1}{p}$	$\boldsymbol{SI^* \geq 0}$; $\boldsymbol{I^* > 0}$; $I^* = x_0 - SI^*$	$\boldsymbol{SI^* \geq 0}$; $\boldsymbol{I^* = 0}$	$\boldsymbol{SI^* \geq 0}$; $\boldsymbol{I^* = 0}$
$SI'(0) \leq \frac{1}{p}$	$\boldsymbol{SI^* = 0}$; $\boldsymbol{I^* > 0}$; $I^* = x_0$	$\boldsymbol{SI^* = 0}$; $\boldsymbol{I^* = 0}$;	$\boldsymbol{SI^* = 0}$; $\boldsymbol{I^* = 0}$;

Table 2 reports the conditions under which a positive investment in SI is possible: the MR of the 1st unit invested in self-insurance ($SI'(0)$) has to be higher than the MR of insurance (1/p) and it must generate a sufficient actuarial gain to be attractive for a risk lover. Symmetrically, on the insurance side, a subsidized unit price is required but the fixed cost may be deterrent.

Section 3. The experimental design

We use a two-part experimental setting, with both parts being devoted to the measurement of risk attitude. An adapted Holt and Laury's procedure measures the subjects' risk-attitude in a non-contextualized setting (HL), whereas the other part, which elicits the demands for insurance (I) and self-insurance (SI), is designed to fulfill empirically the ISI-contextualized classification presented above. We ensured that both the stakes and domain were controlled so that the two risk-attitude-elicitation procedures essentially differ by the contextual dimension. The order of stakes and domains were drawn at random to counterbalance any possible order effects.

1. The Holt and Laury's decontextualized risk-attitude measure

[5] Obviously, for a RL a fixed cost may induce risk retention even if the price of insurance is highly subsidized.

In Table 3, following Holt & Laury (2002), the participants have to choose between two lotteries, a low-risk lottery (Option A) and a riskier one (Option B). The 10 alternatives only differ about the probabilities associated with the lotteries.

Since insurance decisions deal with loss situations, the HL procedure is implemented in the loss domain, as in Chakravarty and Roy (2009). Moreover, although the HL procedure was not presented in that way to the subjects, it shares common features with insurance choices. Indeed, option A boils down to an insurance coverage while option B corresponds to the no insurance choice. In option B, the outcome $W_1=0$ (resp. $W_2=-10$) refers to the subject's wealth for the no accident (resp. accident) state of the world. Alternatively, by requiring the payment of a premium of 4 dollars to receive an indemnity of 8 dollars in case of an accident, option A is akin to insuring against a 10 dollars loss.

Table 3: Measurement of risk-attitude

Decision	Option A				Option B			
	% likelihood	Loss (in $)	% likelihood	Loss (in $)	% likelihood	Loss (in $)	% likelihood	Loss (in $)
1	10	-4	90	-6	10	0	90	-10
2	20	-4	80	-6	20	0	80	-10
3	30	-4	70	-6	30	0	70	-10
4	40	-4	60	-6	40	0	60	-10
5	50	-4	50	-6	50	0	50	-10
6	60	-4	40	-6	60	0	40	-10
7	70	-4	30	-6	70	0	30	-10
8	80	-4	20	-6	80	0	20	-10
9	90	-4	10	-6	90	0	10	-10
10	100	-4	0	-6	100	0	0	-10

The grid of alternatives has been designed so that the expected gain spread between options (A and B) decreases continuously to become negative from the fifth row to the end. A risk-averse individual (RA) must then choose option A at least from row 1 to row 5 while a risk-loving individual (RL) will choose option A at most from row 1 to row 4.

For ethical and practical reasons in an experiment with losses, participants receive a 10 dollars endowment at the beginning of the experiment to cover for their possible losses. Although there may be a concern that this endowment induces a house money effect causing individuals to take more risk than with their own money, Etchart-Vincent and L'Haridon (2011) show, in a similar setting to ours, that this is not the case.

2. The ISI-contextualized risk-attitude measure

The second part of our experimental protocol, involving three independent rounds, is devoted to the elicitation of the contextualized risk-attitude measure, derived from the hedging choices made by the participants.

At the beginning of each round, the subjects are endowed with 1000 UME that they can entirely lose if an accident occurs during the round. The subjects can buy insurance (I) and invest in a self-insurance activity (SI) to cover the risk of loss (10%). They are aware that they will play three randomly displayed independent rounds corresponding to three different insurance tariffs.

The demand for I

A premium P paid at the beginning of the round allows the subject to receive an indemnity I in the case of an accident during the round. The amount of the premium increases with the desired amount of compensation according to the following relationship: P = pI + C, where p stands for the unit price of insurance and C for the fixed cost. Table 4 below provides the fee schedule for an actuarial insurance price.

The demand for SI

In addition to (or instead of) insurance, individuals can set up a self-insurance activity whose technology is given in Table 5. As for the insurance choice, a self-insurance investment (A) made at the beginning of the round would secure an amount SI if an accident occurs within the round.

Tables 4 and 5 are simultaneously displayed on the subject's computer screen. Subjects can test as many combinations of P and A as they desire, to better adjust their desired final wealth before confirming their choice by clicking the button.
The final wealth can be written as follows, where W_1 stands for the no loss state and W_2 for the loss state:

$$\begin{cases} W_1 = 1000 - P - A \\ W_2 = 1000 - P - A - 1000 + I + SI \end{cases}$$

After the subjects have made her decision, a random draw (specific to each subject) determine whether a damage occurred during the period. Then, the computer calculates their final wealth and displays it on their screen.
All in all, subjects play three rounds involving different insurance tariffs: a lower than actuarial unit price (p = 0.05), an actuarial unit price (p = 0.1) and an over-actuarial price (p = 0.15)).
Because one unit price is less than actuarial, a positive fixed cost has been set at 50 to rule out loss-making insurance contracts.

The rounds are independent, the gains and losses are not cumulated across rounds: at the beginning of each round and regardless of what happened in the previous rounds, the wealth of the subject is a 1000 UME endowment.

Table 4: Insurance premium schedule

Premium P = Total cost of insurance	Indemnity I: Demand for Insurance	Additional indemnity
p = 0.1 C = 50	Reimbursement in the event of damage	from an additional UME of premium
0	0	-
55	50	10
60	100	10
65	150	10
70	200	10
75	250	10
80	300	10
85	350	10
90	400	10
95	450	10
100	500	10
105	550	10
110	600	10
115	650	10
120	700	10
125	750	10
130	800	10
135	850	10
140	900	10
145	950	10
150	1000	10

Table 5: Self-insurance investment

Investment A in the SI activity	Secured amount of wealth *SI*	Additional secured amount of wealth per additional UME of SI
(1)	(2)	(3)
0	0	–
5	90	18
10	170	16
15	240	14
20	305	13
25	365	12
30	415	10
35	460	9
40	500	8
45	535	7
50	570	7
55	600	6
60	630	6
65	655	5
70	680	5
75	700	4
80	715	3
85	725	2
90	730	1
95	730	0
100	730	0

The risk-attitude measurement methodology

We use the elicitation phase of ISI demands to qualify risk loving and risk-averse behaviors. The basic intuition is to categorize our subjects as risk averters (RA) or risk lovers (RL) according to their decisions to buy or not a positive hedging for I and SI.[6] We rely on the characterization of risk-attitudes provided in Tables 1 and 2 and apply it to our experimental setting.

The subject successively face 3 unit prices: p = .05, p = .10, p = .15 with a strictly positive (C = 50) fixed cost, with the self-insurance technology being the same (see Table 5) in each round.[7]

[6] At a second level of characterization, the degree of coverage should reflect the intensity of the identified risk-attitude (and it would also contribute to diagnose a possible behavioral incoherence).

[7] A fixed cost of 50 EMU was necessary to rule out any kind of subsidization of insurance premiums.

Using the three sequential hedging choices of the ISI-step, we identify the "consumption patterns" compatible with each risk attitude, in line with predictions of Table 1 and Table 2. In short, we count the number of times a positive coverage is observed for each type of risk hedging tool (I and SI). Thus, each subject is characterized by a pair of values between 0 and 3.
Only some "consumption patterns" over the three rounds are consistent with the theoretical predictions of Tables 1 and 2. For example, an individual who would always refuse any positive insurance coverage regardless of the decision to self-insure is classified as a risk lover.

We emphasized, as mentioned earlier that the demand for SI provides an internal validation tool for the segmentation of our subjects according to their risk attitude. SI in combination with I permits a complement to H&L measure of the detection of the inconsistent behavior of some participants. As we will discuss in Section 4, following H&L or the ISI model, we observe a highly differentiated reality concerning the irrational behaviors of some participants.

Table 6 displays all the combinations of consistent choices and specifies the rules of classification as RL or RA. Note that any other combination is classified as inconsistent.

Table 6: Contextualized classification of risk lovers and risk averters

Number of times that: I>0	Number of times that: SI>0	Conditions	Risk attitude	Classification Rules	
0	**0**	I=0 ∀p	RL	In our experiment, the insurance tariff is never actuarial except for (I, p) = (x_0; p<q) since C = (q-p) x_0. Therefore, for RLs, **I** = 0 ∀p.	Since the insurance tariff is never actuarially fair, investment in SI remains independent of the unit insurance price. The MR of the 1st unit of SI is unattractive for individuals of this case who never invest in SI.
0	**1**				These 2 cases characterize the behavior of RL subjects who are indifferent as to whether to invest in SI or not. They would never get insured but are likely to invest in SI sometimes.
0	**2**				
0	**3**				In this last case, RLs are attracted by the marginal return of the 1st unit of SI and always invest in SI. Moreover, they should invest the same amount in SI whatever the insurance pricing.[8]
1	**2**	I>0 if p<q SI>0 if p≥q	RA	These three cases account for a perfectly rational RA who equalizes the MRs of SI and I, and should not buy SI when p is less than actuarial	When p<q, an RA chooses a full insurance contract, and SI is crowded out. When p≥q, it is efficient to invest in SI. The intensity of risk aversion determines the extent of the participation in the insurance market.
2	**2**	I>0 if p≤ q SI>0 if p≥q	RA		
3	**2**	I>0 ∀p SI>0 if p≥q	RA		
1	**3**	I>0 if p<q and SI>0 ∀p	RA	These 3 cases relate to imperfectly rational patterns of consumption.	When p=.05, we expect SI to be crowded out. However, as people do not perfectly equalize marginal returns, we find acceptable to include participation in the self-insurance market when p is below the actuarial price when this SI participation is effective in the other cases. At the same time, such behavior can be rationalized for a low level of risk aversion.
2	**3**	I>0 if p≤ q and SI>0 ∀p	RA		
3	**3**	I>0 ∀p SI>0 ∀p	RA		

3. The experimental procedures

The subjects received a 10 dollars show up fee to cover for any losses associated with the HL-risk-attitudes measure and compensation for each experimental step. Moreover, one of the 10 decisions of the HL-part was drawn at random and then played out. Similarly, one of the 3 rounds of the contextualized stage was randomly drawn and played out: the player's gain was then given by her

[8] This case could also characterize the behavior of a risk neutral individual (RN).

wealth at the end of this round, given her coverage decision and the occurrence of an accident or not during the round.
While the subjects were informed in advance of the payment components, their earnings were only revealed at the end of the experiment to avoid any potential house money or wealth effect across steps.
On average, the subjects earned 15 CAD per hour.

Section 4. Results

1. General results

117 individuals aged between 18 and 67 took part in the experiment which was held in Montreal. The sample included an equal proportion of men and women, mostly students.

The HL-decontextualized risk-attitude tool

The inclusion criteria

In most studies referring to HL, subject's HL-risk-attitude coefficient is the number of times Option A (the least risky) is chosen. Individuals would be labeled RAs if the number of times the least risky option is chosen is strictly over 4, RLs otherwise.This criterion allows characterizing all individuals according to their risk-attitude (RA / RL). It also provides a measure of the intensity of their risk aversion (or risk loving): the higher (resp. smaller) the number of choices A, the more risk averse (resp. risk-loving) the individual.

A more restrictive indicator based on an in-depth understanding of the procedure by the subjects was also computed. For her risk-attitude to be assessed, a subject who chooses at first the least risky option (A) should switch only once from option A to option B. If she starts with option B, she is expected never to switch. Any subject that would depart from either of these behavioral patterns would be seen as HL-irrational as she failed to understand the HL-instructions adequately. Assessing any risk attitude for these HL-irrational subjects could be seen as irrelevant and therefore pointless.

In Table 7, col. (1) displays in the breakdown of subjects' risk attitude between RA, RL and irrational behavior according to HL measurement.

Table 7: Risk attitudes breakdown for each measurement tool

		Tool	
		HL	ISI
		(1)	(2)
Rational	RA	44	66
	RL	43	35
	Irrational	30	16

N=117

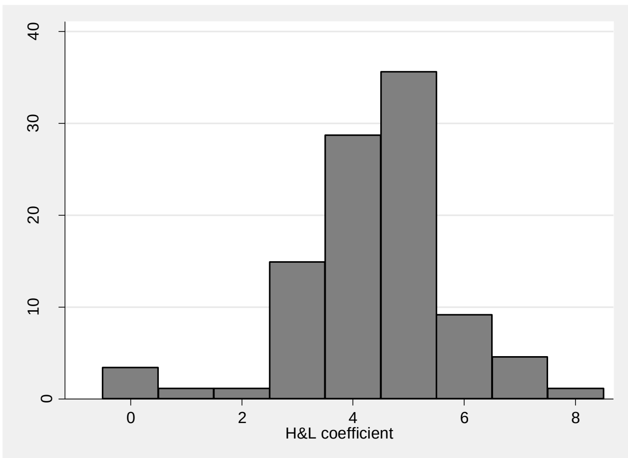
With the HL measure, more than 25% subjects fall into the HL-irrational-class, which is consistent with Lévy-Garboua et al. (2012)'s findings. 4 of these HL-irrational subjects chose at first the riskiest option B and end with option A, switching only once. 3 subjects chose option A all the way along despite the strict domination of option B on option A in the last decision (10th). However, the bulk of HL-irrational subjects (23 participants) are individuals who switched several times, regardless of their first choice. Everything happens as if they did not know which option to choose and opted for a "covering-like behavior" choosing alternately option A and option B.

Ignoring the HL-irrational individuals, the proportion of (HL-rational) RAs and RLs is almost balanced. The most probable reason why individuals are not predominantly RAs is that in the loss domain, individuals are more likely to be RLs (Kahneman and Tversky, 1979). This result supports the use of a loss-domain HL indicator for insurance purpose.

The HL intensity measure

Figure 1 below displays the distribution of HL-coefficients for the 87 HL-rational subjects and shows a strong polarization on the values located at the center of the HL grid: the risk-attitude coefficients of the participants are highly concentrated, and almost 80% of the coefficients range from 3 to 5. Although this finding is consistent with those previously found in the literature, it suggests a weak discriminating power of the HL-risk-attitude procedure for many subjects.

Figure 1: HL-risk-attitude coefficient distribution



This remark is strengthened by the significant number of HL-rational subjects (64%) whose HL-risk-attitude coefficient is 4 or 5. For these subjects, the risk-attitude assessment may be flawed since 4 and 5 values are critical cut points in the risk-attitude assessment. For subjects with a 5-HL-coefficient level, one more choice of option B in the HL schedule would have led to consider them as RLs rather than RAs. In the same way, with a 4 HL-coefficient level, one more choice for option A and the subjects would have been classified as RA instead of RL.

The ISI-contextualized classification

Column (2) in Table 7 provides the breakdown of risk attitudes for the ISI procedure. As for the HL-procedure, an ISI-irrational class was also defined for subjects with an erratic and inconsistent demand for coverage (e.g., buying coverage only when insurance tariff is high). Subjects of this category do not fall into either of the categories depicted in Table 6.

The ISI-contextualized measurement reveals only a small proportion of ISI-irrational individuals and almost twice more RAs than RLs.

HL vs. ISI classifications

These basic descriptive statistics highlight several features. First, we found more RAs with the ISI-measurement than with the HL device. This result is compliant with Hershey and Schoemaker (1980)'s findings. They documented the fact that individuals were more risk-averse when the same decisions were framed as insurance choices than as decontextualized risky choices.

Second, there were many more irrational individuals with HL than with ISI. To the extent that the ISI-measurement tool requires the subjects to understand the articulation between I and SI as well as the role of the contractual parameters, such a discrepancy in the proportion of "irrational" individuals between the two procedures suggests that although the HL's procedure is "only" based on simple choices between lotteries, it could actually be cognitively more demanding.

2. A strong consistency between measures

The cross-tabulate presented in Table 8 provides, for each measurement, the breakdowns into risk attitude for the 74 subjects who rationally behave in both HL and ISI-steps. It shows that HL and ISI risk-attitude assessments match for more than two thirds of the subjects (69%). In support, a Pearson χ^2 tests carried out on these data rejects the independence between the two measurements unambiguously.

Table 8: Cross-tabulate risk-attitude assessments

		ISI typology		
		ISI-RA	ISI-RL	Total
HL typology	HL-RA	30	10	40
	HL-RL	13	21	34
	Total	43	31	74

Pearson χ^2 (1) = 10.2048 p-value = 0.001

In Table 9, we performed one tail-Student test on the 74 subjects who rationally behaved from both parts of the experiment to compare HL-coefficients with ISI-RA and ISI-RL subjects. This test shows that ISI-RA subjects are still significantly more HL-risk averse than ISI-RL subjects. This result bears out the consistency of HL and ISI measures.

Table 9: Student comparison test of HL-risk-attitude coefficients

ISI typology		
ISI-RA	ISI-RL	Mean Student test
HL-coefficient (st) N	HL-coefficient (st) N	T (p-value)
4.88 (1.38) 43	4.00 (1.26) 31	2.808 (0.006)

These features stress the strong consistency between HL and ISI measurements and, regardless of the high proportion of HL-irrational subjects, these elements support the use of an HL-measurement procedure for insurance decisions.

Observation 1: HL and ISI measurements yield highly consistent risk attitude assessments for HL and ISI rational subjects.

3. The RA/RL frontier: a fine-tuning allowed by the complementarity of the two tools

Focusing on the 23 subjects (see Table 8) whose HL and ISI classifications were not concordant (HL-RA; ISI-RL) or (HL-RL; ISI-RA), table 10 below shows that 9 (HL-RA; ISI-RL)-subjects out of 10 have an HL-coefficient equal to 5. Conversely, for 7 (HL-RL; ISI-RA)-subjects out of 13, HL-risk-attitude coefficient is 4. Now, as previously underlined, 4 and 5 are splitting points in the risk-attitude assessment. In both cases, if only one of the subjects' choices in the HL part has been being different, the subjects' risk-attitude HL assessment would have been the reverse.

Therefore, if we requalify the HL measure of these 23 subjects following this argument, the concordance rate between HL and ISI measures increases from 69% to 90%. This result means that, for 90% of the subjects who showed a rational behavior in both measures, the tools lead to a matching risk-attitude classification.

Table 10: HL-coefficient according to ISI-risk-attitudes

	HL-RL				HL-RA				Total
ISI-RA	1	0	5	7	18	8	3	1	43
ISI-RL	1	1	5	4	9	9	1	0	31

Grey areas in the table are for the non-matching ISI-HL-classification

Not only does the ISI measurement appear to be a way of supporting the HL-classification, but it is also a way of clarifying risk attitudes of the subjects whose HL-coefficient is borderline.

Observation 2: In non-matching cases, HL and ISI measurements prove to be complementary. These tools used together allow to better assess the risk attitude of borderline subjects.

4. Irrational behaviors: a highly differentiated reality

Since only three subjects out of 43 have proven to behave irrationally with both ISI and HL measurements, HL-irrationality and ISI-irrationality could uncover different features that deserve to be scrutinized. How does the ISI-tool deal with the risk-attitude assessment of HL-irrational subjects? Conversely, what is the HL-risk-attitude for subjects who exhibited irrational behavior regarding the ISI measure?

How do the HL-irrational subjects split into the ISI typology?

Table 11 below provides the ISI-based breakdown of HL-irrational subjects.

Table 11: ISI risk-attitude assessment for HL irrational subjects

		HL-irrationality
ISI-typology	ISI-RA	23
	ISI-RL	4
	ISI-irrationality	3
	total	30

HL-irrational subjects display an overwhelming ISI-risk-averse insurance behavior with 23 subjects designed as ISI risk averters. It should be recalled that many of them were HL-irrational because of erratic behavior in the lottery task assessment (HL) leading to multi-switches. The question then arises whether such behavior could not be likened to a hedging strategy. In that case, the HL-ISI correspondence should call for an approach of an HL-rationality based on the number of risky choices rather than on a strict understanding of the HL-task.

How do the ISI-irrational subjects split into the HL typology?

Table 12 provides the HL-based breakdown of ISI-irrational subjects.

Table 12: HL risk-attitude assessment for ISI irrational subjects

		ISI-irrationality
HL typology	HL-RA	4
	HL-RL	9
	HL-irrationality	3
	total	16

According to HL-measurement and regardless of the 3 persistent, irrational subjects, ISI-irrational subjects are mainly HL-risk lovers (9 RLs vs. 4 RAs). The results are compliant with those found in Corcos et al. (2017) where HL-RLs were found to behave in a gambling way, meaning that risk-loving behavior does not mean to turn away from insurance but rather to behave strategically. In our data, HL-RLs showed seemingly erratic insurance choices, but strategical one when further scrutinized (for instance, HL-RLs appeared to insure or not depending on the accident to occur in the previous period).

Observation 3: Combining HL and ISI procedures allow us to define irrational behavior more accurately. Our data show that lottery choice (HL) irrationality amounts to a strategic coverage, while ISI-irrationality reshapes insurance risk-loving as gambling with coverage decisions rather than turning away from hedging.

Section 5. Discussion and Conclusion

This article compares two risk attitude classifications. ISI and HL measures are proven to be highly consistent as they provide matching risk attitude assessments for 69% of "rational" subjects. The other 31%, non-consistent appraisals reveal the high complementarity between the tools. Most of the subjects lie on the cutting edge between RA and RL. A joint use of the two methods allows a reclassification of these subjects, increasing the percentage of matching assessment to 90% of rational subjects.

Another feature of this study concerns the subjects classified as "irrational." As fewer than 3% individuals were classified as irrational by both methods, HL-irrationality and ISI-irrationality appear to uncover different realities that can be better grasped by the joint use of the two approaches. The analysis shows that most of the HL-irrational individuals were classified as risk averters with the ISI-measurement. In the HL-procedure, they mainly switched several times from one lottery to another. Such a correspondence calls for this seemingly erratic behavior to be understood as a hedging mechanism.

Symmetrically, most ISI-irrational subjects are RLs when it comes to HL-measurement. ISI-irrationality seems to uncover erratic and inconsistent hedging choices which do not seem to be motivated by pricing considerations. As underlined in Corcos et al. (2017), this insurance behavior appears to characterize RLs' gambling-like behavior. Risk-loving would no longer mean turning away from insurance but rather gambling and betting with insurance.

Therefore, the contextualized and decontextualized elicitations of the risk-attitude exhibit a strong complementarity and allow a considerable enrichment of the use of HL as well as a better understanding of the insurance behavior of risk lovers. HL-procedure made it possible to highlight the gambling dimension of RLs' behavior that the sole contextualized measure would not have been able to provide since RLs individuals are not expected to buy insurance according to ISI-measurement. Conversely, hedging-like HL-irrational behavior calls for a flexible use of the HL-measurement by computing the risk-attitude coefficient by the number of choices for the riskiest lotteries, regardless of the strict understanding of the procedure by the subjects.

The use of the HL-decontextualized measure avoids certain biases related to insurance (for example, mistrust in insurers' likelihood to pay benefits). The measure also makes it possible to focus on the deep nature of risk attitude by overcoming the cyclical nature of particular events (e.g., the presence of an accident in the previous period or a price perceived as too high).

Section 6. References

Andersen, S., Harrison, G., Lau, M. and E. Rutström (2006). "Elicitation using multiple price lists," *Experimental Economics*, 9(4), 383–405.

Arrow K. (1971). *Essays of the Theory of Risk Bearing.* Chicago: Markham Publishing Company.

Camerer C. F., and R. M. Hogarth (1999). "The Effects of Financial Incentives in Experiments: A Review and Capital-Labor-Production Framework," *Journal of Risk and Uncertainty*, 19(1-3), 7-42.

Carson J., McCullough K., and D. Pooser (2013). "Deciding whether to invest in mitigation measures: Evidence from Florida," *The Journal of Risk and Insurance*, 80(2), 309-327.

Chakravarty, S., and J. Roy (2009). "Recursive expected utility and the separation of attitudes towards risk and ambiguity: an experimental study," *Theory and Decision*, 66(3), 199-228.

Corcos A., Pannequin, F., and C. Montmarquette (2017). "Leaving the market or reducing the coverage? A model-based experimental analysis of the demand for insurance," *Experimental Economics*, 20(4), 836–859.

Dohmen T., Falk A., Huffman D., Sunde U., Schupp J., and G. Wagner (2011). "Individual risk attitudes: measurement, determinants and behavioral consequences," *J. Eur. Econ. Assoc.* 9, 522-550.

Etchart-Vincent N., and O. l'Haridon (2011). "Monetary incentives in the loss domain and behavior toward risk: An experimental comparison of three reward schemes including real losses," *Journal of Risk and Uncertainty*, 42:61-83

Fehr-Duda H., Gennaro M., and R. Schubert (2006). "Gender, Financial Risk, and Probability Weights," *Theory and Decision*, 60(2), 283-313.

Harrison G.W., Johnson, E., McInnes M. M., and E.E. Rutström (2005). "Risk aversion and incentive effects: Comment," *American Economic Review,* 95(3), 897-901.

Hershey J.C., and P.J.H. Schoemaker (1980). "Risk taking and problem context in the domain of losses: An expected utility analysis," *The Journal of Risk and Insurance* 47(1), 111-132.

Holt C., and S. Laury (2002). "Risk Aversion and Incentive Effects," *American Economic Review* 92(5), 1644-1655.

Holt C.A., and S.K. Laury (2005). "Risk aversion and incentive effects: New data without order effects." *American Economic Review* 95(3), 902-912.

Kahneman D., and A. Tversky (1979). "Prospect Theory: An Analysis of Decision under Risk," *Econometrica*, 47(2), 263-291.

Kimball M.S. (1990). "Precautionary Saving in the Small and in the Large," *Econometrica*, 58, 53-73.

Kimball M.S. (1993). "Standard Risk Aversion," *Econometrica*, 61, 589-611.

Kroll E.B., Trarback J.N, and B. Vogt (2011). Determining risk preference for pain. Faculty of Economics and Management, Universitat Magdeburg, working paper.

Lévy-Garboua L., Maafi H., Masclet D., and A. Terracol (2012), "Risk aversion and framing effects," *Experimental Economics,* 15, 128-144.

Lypny G.J. (1993). "An Experimental Study of Managerial Pay and Firm Hedging Decisions," *Journal of Risk and Insurance*, 60(2), 208-229.

Lönnqvist J-E., Verkasalo M.G., and P.C. Wichardt (2015). "Measuring individual risk attitudes in the lab: Task or ask? An empirical comparison," *Journal of Economic Behavior & Organization,* 119, 254-266.

Lusk J.L., and K.H. Coble (2005). "Risk Perceptions, Risk Preference, and Acceptance of Risky Food," *American Journal of Agricultural Economics*, 87(2), 393-405.

Nielsen T., Keil A., and M. Zeller (2013). "Assessing farmers' risk preferences and their determinants in a marginal upland area of Vietnam: a comparison of multiple elicitation techniques," *Agricultural Economics*, 44, 255-273.

Pratt, J.W. (1964). "Risk Aversion in the Small and in the Large." *Econometrica,* 32, 122-136.

Szrek H., Chao L,-W., Ramlagan S., and K. Peltzer (2012). "Predicting (un)healthy behavior: A comparison of risk-taking propensity measures," *Judgment and Decision Making,* 7(6), 716-727.

Section 7. Appendix

1. A: Optimal Hedging for a risk averse

A risk-averse EU DM maximizes the following problem:

$$\max_{I,e} EU = (1-q)U(W_0 - pI - C - e) + qU(W_0 - pI - C - e - x_0 + SI(e) + I)$$

Due to the presence of a fixed cost (C), and in addition to the non-negativity conditions for I and e, the insurance contract must satisfy the participation constraint (PC): $EU(I^*, e^*) \geq EU(0, \hat{e})$, where I^* and e^* stand for optimal choices in insurance and self-insurance effort respectively, while $\hat{e}$ represents the optimal self-insurance effort when insurance is not involved.

Developing condition (PC), we obtain:

$$(1-q)U(W_0 - pI^* - C - e^*) + qU(W_0 - pI^* - C - e^* - x_0 + SI(e^*) + I^*) \geq \max_{e} (1-q)U(W_0 - e) + qU\big(W_0 - e - x(e)\big),$$

and $\hat{e} = \arg\max_{e} (1-q)U(W_0 - e) + qU\big(W_0 - e - x(e)\big)$.

To understand the risk-hedging behavior of a risk-averse DM and to use it as a benchmark in our experimental setting, we need to characterize interior and corner solutions.

Interior solutions:

To characterize an interior solution, we assume that condition (PC) is satisfied and we derive the 1st order conditions (FOC):

$$\frac{\partial \mathrm{EU}}{\partial e} = -(1-\mathrm{q})\mathrm{U}'(\mathrm{W}_1) - [1 - \mathrm{SI}'(\mathrm{e})]\mathrm{q}\mathrm{U}'(\mathrm{W}_2) = 0$$

$$\frac{\partial \mathrm{EU}}{\partial \mathrm{I}} = -\mathrm{p}(1-\mathrm{q})\mathrm{U}'(\mathrm{W}_1) + (1-\mathrm{p})\mathrm{q}\mathrm{U}'(\mathrm{W}_2) = 0$$

The second order conditions are checked below:

$$\frac{\partial^2 \mathrm{EU}}{\partial e^2} = (1-q)\, U''(W_1) + [1 - x'(S)]^2 q\, U''(W_2) < 0$$

$$\frac{\partial^2 \mathrm{EU}}{\partial I^2} = p^2(1-q)\, U''(W_1) + (1-p)^2 \mathrm{q}\, U''(W_2) < 0$$

$$\begin{vmatrix} \frac{\partial^2 \mathrm{EU}}{\partial I^2} & \frac{\partial^2 \mathrm{EU}}{\partial \mathrm{I}\, \partial e} \\ \frac{\partial^2 \mathrm{EU}}{\partial \mathrm{I}\, \partial e} & \frac{\partial^2 \mathrm{EU}}{\partial e^2} \end{vmatrix} = q(1-q)[1 - SI'(e)]^2 U''(W_1)\, U''(W_2) > 0$$

From the ratio of the two FOC, after rearrangement, we get that a risk-averse DM invests in insurance and self-insurance to equalize marginal returns (MRs) of insurance (on LHS) and prevention (on RHS):

$$\frac{1}{p} = SI'(e) \quad (1)$$

The DM sets her level of self-insurance (through *e*) at the point that equalizes the MRs, and complements it by buying some insurance coverage (I) for the residual risk. From equation (1), we easily infer the following results:

(RA-**a)** A rational EU risk averse equalizes the marginal returns of insurance and self-insurance.

(RA-**b)** Insurance and self-insurance are substitutes: an increase in the unit price of insurance results in an increase in the demand for self-insurance and a decrease in the demand for insurance.

From equation (1), we readily infer that an increase in the unit price of insurance results in an increase in the demand for self-insurance (SI'(*e*) is increasing with p, so *e* and SI increase with p). In this case, it is trivial that, when SI increases, I decreases (see the 1st FOC).[9]

(RA-**c)** The behavior of insurance demand (I) is consistent with the standard theoretical predictions:

- if p=q, the insurance unit price is actuarial[10] and a full insurance coverage is optimal ($I^* = x_0 - SI(e^*)$);
- if p>q, a partial insurance coverage is optimal ($I^* < x_0 - SI(e^*)$);
- if p<q, the policyholder is subsidized and would prefer to be over-insured (or fully insured if over-insurance is forbidden).

Once the self-insurance investment is induced through equation (1), insurance demand is focusing on the residual loss, $x_0 - SI(e^*)$, and is characterized by the 2nd FOC.

(RA-**d)** While the SI investment of a risk averse is defined by the equalization of MRs (see equation (1)), it is independent of the intensity of risk aversion; the demand for insurance increases with risk aversion.

Corner Solutions:

Corner solutions occur when condition (1) cannot be satisfied and when condition (PC) is not satisfied.[11]
From equation (1), we can infer that if the MR of the 1st unit of money invested in *e* is lower than the MR of insurance, self-insurance is crowded out: if $SI'(0) < \frac{1}{p}$, as $SI''(e) < 0$ then $e = 0$. On the other side, insurance is crowded out if $SI'(\hat{e}) > \frac{1}{p}$; then, the DM relies only on self-insurance opportunity since they dominate insurance opportunities.
Finally, condition (PC) may be violated if the price is more than actuarial and if the fixed cost is too high.

[9] This 1st FOC (the derivative of EU with respect to *e* can be written as follows: $\frac{\partial EU}{\partial e} = -(1-q)U'(W_0 - pI - C - e) - [1 - SI'(e)]qU'(W_0 - pI - C - e + SI(e) + I)$. Following an increase in *e*, the 1st negative term increases (in absolute value) while the 2nd positive term decreases (since SI'(*e*)>1 and SI''(*e*)<0) if we neglect wealth effects (which seems to be acceptable in a Lab context). So, as to avoid that condition be negative, it is necessary to decrease I, which has exactly the opposite effect to that of an increase in *e*.

[10] But not necessarily the insurance premium if C>0.

[11] This point is not fully developed here but the conclusions spring from the study of FOC when one of the non-negativity constraints, either *e*≥*0* or I≥0, is binding.

In short:

- if $SI'(0) < \frac{1}{p}$, e=0 and I≥0;
- if $SI'(\hat{e}) > \frac{1}{p}$, $e=\hat{e}$ and I=0;
- if C>0 and/or p>q, (PC) may be violated and I=0.

2. Appendix B: Optimal Hedging for a risk lover

In this discussion, let us recall that a risk lover will require a positive actuarial return to invest in any risk hedging activity. So, we assume that the marginal return of the first unit of prevention is actuarially favorable: SI'(0)>>1/p. We also assume the marginal return of the last implementable unit of prevention to be actuarially unfavorable: for the last unit of e, SI'(e)<<1/q. Moreover, for the sake of realism, we exclude over-insurance as well as "negative" insurance: ∀a,0 ≤ I ≤ x(e).

Then, on the insurance demand side, two focal points shape the demand for insurance of risk-loving decision makers: risk retention (I* = 0) and full insurance (I* = x(e^*)= x_0-SI(e^*)). Indeed, a risk lover will never buy any insurance coverage if the insurance price is actuarial or more than actuarial. However, even for a less than actuarial price, a risk lover will not necessarily get insured. This is true even if the fixed cost is zero; moreover, as condition (PC) needs to be fulfilled, risk retention may be preferred even if the unit insurance price is highly subsidized. To accept a positive insurance coverage, a risk lover will require a net increase in the mathematical expectation of her final wealth, which means that the insurance price has to be subsidized enough (more explicitly, p and C must satisfy: pI+C<qI, but this is not a sufficient condition). If we evaluate the 2nd FOC (the derivative of EU with respect to I), at the point of no insurance (I=0) and the point of full insurance (I=x_0), we obtain:

$$\left.\frac{\partial EU}{\partial I}\right|_{I=0} = -p(1-q)U'(W_0 - e) + (1-p)qU'(W_0 - e - (x_0 - SI(e))$$

$$\left.\frac{\partial EU}{\partial I}\right|_{I=x_0-SI(e)} = (q-p)U'\big(W_0 - e - p(x_0 - SI(e))\big)$$

If the unit price of insurance is at least actuarial (p ≥ q), these expressions are both negative. In these cases, insurance coverage has no appeal (I*= 0), and this is true whatever the amount invested in self-insurance[12].

If the unit insurance price is less than actuarial (p < q), risk lovers will choose to buy either no insurance (I*= 0) or full insurance (I*= x(e^*)) if the unit price and the fixed cost are sufficiently low (and do not violate condition (PC)). For a given value of "e," the 1st equation can be either negative or positive (if p is sufficiently below q) while the 2nd one is always positive. In this situation, the risk lover would be ready to invest infinitely in insurance coverage, but she is constrained by full insurance. If both equations are positive, she will choose a full coverage; in the other case, she will choose either full insurance or risk retention. Evidently, these conclusions are conditioned by (PC).

To sum up, for a given level of "e," the problem of a risk-loving decision maker always amounts to choose between no insurance and full insurance, to maximize her expected utility.

---

[12] The second order condition, $\frac{\partial^2 EU}{\partial I^2} = p^2(1-q)U''(W_1) + (1-p)^2\, qU''(W_2)$ is strictly positive due to the convexity of the utility function.

Second, on the self-insurance demand side, we focus on the only two values that indemnity may take ($I^*=0$ or $I^*=x(e^*)$) to study the implications directly for the self-insurance demand.
In the presence of full insurance ($I = x(e^*)$), the question of optimal self-insurance becomes trivial. Since final wealth is no longer random, the expected utility can be written as follows: $EU = U(W_0 - px(e^*) - e^*)$. By maximizing this utility with respect to "*e*," we find again equation (1) corresponding to the equalization of the marginal returns of insurance and self-insurance:

$$\left.\frac{\partial EU}{\partial e}\right|_{I=x_0-SI(e)} = -[1-pSI'(e)]U'(W_0 - p(x_0 - SI(e)) - e) = 0$$

This condition implies that $\frac{1}{p} = SI'(e)$ and this solution, considering that $I^* = x(e^*)$, precisely corresponds to a local maximum.[13]
In the case of no insurance ($I^*= 0$), a risk-loving individual will invest in self-insurance only if the marginal return on the first dollar invested passes a certain threshold. This condition is obtained by evaluating the resulting FOC when self-insurance is nil:

$$\left.\frac{\partial EU}{\partial e}\right|_{e=0} = -(1-q)U'(W_0) - q[1-SI'(0)]U'(W_0 - x_0)$$

Then, if this derivative is strictly positive, we obtain a sufficient condition for "a" to be positive:

$$SI'(0) > \frac{(1-q)U'(W_0)}{qU'(W_0 - x_0)} + 1$$

As $EU'=(1-q)U'(W_0)+qU'(W_0-x_0)$ is higher than $U'(W_0-x_0)$ for a risk lover, this inequality implies that the marginal return of the first unit of self-insurance must exceed the marginal return of actuarial insurance: $SI'(0) > \frac{1}{q}$.
For the subsequent units of "e," the risk lovers will pursue her self-insurance investment if the same inequality holds:

$$SI'(e) > \frac{(1-q)U'(W_0 - e)}{qU'(W_0 - e - (x_0 - SI(e))} + 1$$

According to our assumptions, the left-hand side term is decreasing in "e," but due to the convexity of U(.), the right-hand side term is also decreasing in "e." However, SI'(e) decreases and is inferior to 1/q above a certain value $\bar{e}$. Then, for $e \geq \bar{e}$, a risk loving individual will not make any additional investment in self-insurance. So, we guess that equilibrium should be no longer characterized by an inequality, but rather by an equality for a particular value e^*. However, the unicity of such a solution is not guaranteed.[14]

---

[13] The second order derivative of EU with respect to "e" is negative since the 1st term disappears at the optimum: $\frac{\partial^2 EU}{\partial e^2} = [1-pSI'(e)]^2U''(W_0 - px(e) - e) + pSI''(e)U'(W_0 - px(e) - e) < 0$.

[14] In the general case, for a risk lover and when $I^*=0$, the second order derivative of EU with respect to e contains terms of opposite signs so the behavior of the first order derivative is not clear:

$$\frac{\partial^2 EU}{\partial e^2} = (1-q)U''(W_0 - e) - SI''(e)qU'(W_0 - x(e) - e) + [1-SI'(e)]^2qU''(W_0 - (x_0 - SI(e)) - e)$$