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Behavioral foundations of the substitutability between insurance and self-insurance: An experimental study

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Résumé/abstract

In this experimental study, the analysis on two levels of substitution between insurance and self-insurance shows that a higher unit price results in a quantity-based substitution and a between-tools substitution while the only effect of a higher fixed cost is to reduce the insurance market. The optimality of the coverage demands associated with the equalization of marginal returns is not achieved. Instead, individuals chose a stable global amount of coverage. These behavioral insights have a potential impact on public policies related to insurance and self-insurance.

Mots clés/keywords : insurance, self-insurance, substitutability, lab experiment, risk-aversion

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I. Introduction:

Our research belongs to the emerging field of behavioral insurance (Richter et al. (2014), Kunreuther et al. (2013)) and provides the first experimental test of the substitutability property between insurance and self-insurance as emphasized by Ehrlich and Becker (1972). This substitutability property is one of the fundamental results of Risk Management and could be one of the cornerstones of public policies involved in risk mitigation. Therefore, it may seem surprising that, so far, this behavioral prediction has not been examined more closely in the lab. Up to now, the economics of prevention has emphasized the interactions between insurance and self-protection neglecting the relationship between insurance (I) and self-insurance (SI). This can partially be explained by the absence of moral hazard concern in the relationship between insurance and self-insurance: unlike the self-protection activity, the optimal level of self-insurance chosen by a policyholder is the same whether the insurer can observe it or not.[1]

Instead, the theoretical substitutability property between I and SI has generally been assumed to hold and has become a baseline for public policy. This property suggests that a rise in the insurance price enhances the use of self-insurance mechanisms and reduces the size of the insurance market. The dark side of this property is that, symmetrically, a decrease in the insurance price is likely to crowd out self-insurance investments. Therefore, if proved, the substitutability property raises the question of the insurance tariff subsidization and its likely deterrent effect on prevention behavior. To overcome this issue, in the healthcare field, for example, public policies already resort to partial insurance schemes with deductibles or copayments for patients. However, in the current context of the exponential growth of chronic diseases and catastrophic risks, promoting self-insurance activities to reduce risk exposure could also be part of the solution. Therefore, the validity of the substitution property addresses an important issue that could contribute to public policy debates and provide guidelines for insurers' tariff policies.

The demand for self-insurance, alone, has frequently been addressed in the literature, both theoretically and experimentally. In an expected utility setting, several contributions have proved or questioned the robustness of a positive relationship between self-insurance and risk aversion (Dionne and Eeckhoudt (1985), Briys et al. (1990, 1991)). Konrad and Skaperdas (1993) have shown that most of the properties of self-insurance demand remain true with a rank-dependent expected utility. Experimental literature on self-insurance has also emerged, first for the risk context (Shogren (1990), Shogren and Crocker (1994)), then for the case of ambiguity, with several experimental papers (Di Mauro and Maffioletti (1996), Ozdemir (2007)). Recently, a theoretical contribution by Alary *et al.* (2013), has shown how ambiguity aversion may raise the demand for self-insurance.

[1] As shown by Shavell (1979), and also by Ehrlich and Becker (1972), when policyholders may invest in an effort (self-protection or prevention) to modulate their frequency of damage, the optimal choice in prevention is crucially depending on how accurate is the insurer's information about prevention. A first best optimum emerges when the policyholder's self-protection investment is perfectly observable. On the opposite, if prevention is costly and unobservable, a rational policyholder will not exert any effort, since the insurer is unable to condition the premium to effort. Thus, a partial insurance coverage may induce, to some extent, this effort. This has been stressed both in the context of public regulation (Pauly (1974)) and in the context of market equilibrium (Arnott and Stiglitz (1988)).

However, for most contributions, the demand for self-insurance is grasped without considering its interactions with market insurance even if there are some theoretical and empirical exceptions. In their seminal paper, Ehrlich and Becker (1972) show that insurance and self-insurance are substitute and that policyholders equalize the marginal returns of insurance and self-insurance. Therefore, owing the fact that the marginal return of the self-insurance technology is decreasing while it is constant for insurance, the optimal investment in self-insurance is settled through the equalization of marginal returns. From a theoretical point of view, Courbage (2001) has shown the robustness of the substitutability between insurance and self-insurance with the dual theory of choice. Kelly and Kleffner (2003) consider the substitutability property in the context of a monopolistic insurance market and study the impact of loss reduction activities on optimal insurance rates charged by the monopolist. More recently, Carson et al. (2013) found empirical evidence for this substitution in the case of homeowner insurance and catastrophic risks. Using a unique panel dataset from Florida, Kousky et al. (2014) provide an empirical analysis of another kind of substitution: the effect of the federal disaster aid on the demand for insurance. They find a significant crowding out effect on private insurance demand.

To test the substitutability property in a comprehensive way, we extend the theoretical analysis of Ehrlich and Becker's model to cover corner solutions. Moreover, we have recourse to a two-part insurance tariff to compare the effects of a rise in the insurance unit price or the fixed cost on the demands for coverage. Finally, we deepen the analysis of the role of risk aversion on the demands for coverage.

Relying on an experimental measure of risk aversion, and controlling for the contractual parameters (unit insurance price and fixed cost), our experimental approach complements the empirical evidence of the substitutability issue (Carson et al. (2013), Kousky et al. (2014)) and makes it possible to emphasize the role played by risk aversion and insurance pricing on the demands for insurance and self-insurance. In our experimental setting, subjects are given the opportunity to cover a risk of loss by using either an insurance activity or a self-insurance activity, or both. Participants have to select their desired coverage within a range of 21 levels of insurance and 21 levels of self-insurance – including risk retention – which leads to 21*21 possible combinations of insurance and self-insurance (combinations exceeding their initial wealth were not allowed). Every subject has been confronted to the same 6 treatments, where only the insurance tariff differs and results in 21 different insurance levels. By contrast, the costs of self-insurance opportunities are kept constant across all treatments.

Therefore, our protocol provides us with the demands for insurance and self-insurance expressed for different unit prices and fixed cost levels. This makes it possible to test both the "unit-price-based substitutability" property exhibited by our extended-Ehrlich-and-Becker model and the related marginal returns equalization prediction. Moreover, for each type of hedging activity (insurance and self-insurance), we are also able to analyze in a more detailed way how the substitution operates at the 2-levels subjects' decision: to invest or not and then, how much to invest in the hedging activities. Finally, we also test a "fixed cost-crowding out effect" and compare the impact of an increase in the unit price of insurance with that of the fixed cost.

Similarly, we assess the risk aversion and coverage interplay to understand how and if the risk aversion coefficient modulates the way individuals use these two instruments. Indeed, our measure of risk aversion is no longer an indirect measure (for example, Carson et al. (2013) have estimated risk aversion by the deductible, owing that insurance coverage is decreasing with risk aversion) since we elicit the individual's risk aversion coefficient by adapting the procedure of Holt and Laury (2002) to the insurance context. Again, a two-level analysis of the risk aversion impact on each hedging tool decision (whether and how much to invest) can be carried out.

As predicted by the theory, our experimental results show that insurance and self-insurance are close unit-price substitutes: when the unit price of insurance rises, the demand for insurance decreases and the demand for self-insurance increases. However, individuals do not choose their levels of coverage (insurance and prevention) so as to equalize the marginal benefits of both instruments: they under-react to variations in insurance contractual parameters and exhibit a weaker price elasticity of insurance and self-insurance demands than expected. Instead, the global amount of coverage shows a strong stability across insurance tariffs. The comprehensiveness of the coverage increases with the risk-aversion intensity. Besides, our data do not support the fixed-cost crowding out effect. This highlights the asymmetrical impact of the contractual parameters on the demands for coverage. Implications for the public policies are discussed.

In Section II, we present, in an expected utility framework, the theoretical trade-off between insurance and self-insurance and the resulting propositions to be tested. In section III, we develop the two-steps procedure of our experimental design: the measure of risk aversion and the experimental trade-off between insurance and self-insurance. We report in section IV the experimental results concerning the properties of insurance and self-insurance demands analyzed in function of risk aversion and changes in insurance tariffs. Finally, in section V, we discuss the economic implications of our behavioral results and conclude the paper.

II. The substitutability between the demand for insurance and the demand for self-insurance:

We present the main theoretical results by modeling the joint decision to insure and self-insure. The decision maker is facing a two-part tariff on insurance side and a technology characterized by decreasing returns of scale on the self-insurance side. By our experiment, we emphasize some aspects usually omitted in the literature. Our model is intended to identify the effect of the fixed cost (FC), the unit price and risk aversion (RA) on each hedging demand. For this purpose, we distinguish between corner solutions and interior solutions. While the former allow understanding how each parameter specifically affects the willingness of people to use one or more instruments (the propensities PI and PSI), the latter focus on the demand of those who invest in both hedging schemes (the conditional demands CI and CSI). We stress the fact that, due to the marginal return equalization, self-insurance is generally independent of risk aversion intensity. We study both interior and corner solutions since, in our experiment, risk hedging investments are voluntarily decided, and some individuals may prefer risk retention. Also, the presence of a fixed cost may deter the individual from buying insurance and requires the use of a participation constraint.

1. The standard model

We consider the behavior of an individual who can combine two risk management tools: insurance (I) and self-insurance (SI). This individual is endowed with an initial wealth W_0 and is facing a probability q of losing a part of this wealth whose size $x(a)$ depends on a the SI expenditure. On the insurance side, we resort to a two-part insurance tariff: the individual receives an indemnity I in the case of an accident, 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. On the prevention side, the extent of the loss is a decreasing function of a the SI investment. As the SI technology has decreasing returns of scale we have: $x'(a) < 0$; $x''(a) > 0$.

Individual preferences are supposed to be characterized by a strictly concave utility function U(W). Thus, the decision maker maximizes the following expected utility:

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

Interior and corner solutions need to be distinguished since insurance and self-insurance are voluntarily combined by the decision-maker. So we explore the two dimensions of hedging decision: should we invest and how much to invest. At an aggregate or individual level, every demand for hedging activity (D = I or SI) derives from the multiplication of the propensity to invest in this activity (P = PI or PSI) by the amount of coverage bought by those who chose to invest (CD = CI or CSI) which can be expressed as:

$$D = P * CD$$

For one decision-maker, P is 1 or 0 while it is between 1 and 0 at a sample level.

The study of corner solutions allows us to focus on the decision to invest or not in each hedging mechanism, which provides information about the behavior of the propensities to get insured and self-insured (PI and PSI respectively). If the individual invests in both mechanisms, interior solutions characterize the determinants of the conditional demands for insurance and self-insurance (CI and CSI respectively).

A. Interior solutions:

In this case, an optimal choice for CI and CSI is described by the first order conditions (FOC)[2]:

$$\frac{\partial \mathrm{EU}}{\partial \mathrm{a}} = -(1-\mathrm{q})\mathrm{U}'(\mathrm{W}_1) - [1 + \mathrm{x}'(\mathrm{a})]\mathrm{qU}'(\mathrm{W}_2) = 0$$

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

These conditions are rewritten below to compare, for each coverage tool, its marginal cost (MC) to its marginal benefit (MB):

$$\frac{\partial \mathrm{EU}}{\partial \mathrm{a}} = -(1-\mathrm{q})\mathrm{U}'(\mathrm{W}_1) - \mathrm{qU}'(\mathrm{W}_2) - \mathrm{x}'(\mathrm{a})\mathrm{qU}'(\mathrm{W}_2) = 0$$

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

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

The ratio of these conditions leads to a fundamental result: a rational EU agent invests in SI in order to equalize marginal returns (MRs) of insurance and prevention:

$$\frac{1}{\mathrm{p}} = -\mathrm{x}'(\mathrm{a}) \quad (1)$$

As it is equal to the reverse of the MR of I, the unit price of I indirectly settles the CSI investment chosen by the individual. The decision maker sets her level of CSI at the point that equalizes the MRs, and complements it by buying some insurance coverage (CI) for the residual risk.

Therefore, the level of CSI is independent of the degree of risk aversion, while CI increases with risk aversion. The other results of comparative statics are also straightforward.

From equation (1), we easily infer that an increase in the unit price of I results in an increase in CSI (–x'(a) is decreasing with p, so "a" increases with p). In this case, it is trivial that, when "a" increases, the CI decreases (see the FOC).[3] Therefore, CI and CSI are substitutes.
A rise in C has no impact on the CSI demand since the equality of MRs, $\frac{1}{\mathrm{p}} = -\mathrm{x}'(\mathrm{a})$, results in the same amount for "a". On insurance side, it is helpful to rewrite the FOC for optimal insurance to figure out the nature of the effect:

$$\frac{\mathrm{p}(1-\mathrm{q})}{(1-\mathrm{p})\mathrm{q}} = \frac{\mathrm{U}'(\mathrm{W}_2)}{\mathrm{U}'(\mathrm{W}_1)} = \frac{\mathrm{U}'(\mathrm{W}_0 - \mathrm{pI} - \mathrm{C} - \mathrm{x}(\mathrm{a}) + \mathrm{I} - \mathrm{a})}{\mathrm{U}'(\mathrm{W}_0 - \mathrm{pI} - \mathrm{C} - \mathrm{a})}$$

By deriving the right-hand side with respect to C, we obtain: $\frac{\mathrm{U}'(\mathrm{W}_2)}{\mathrm{U}'(\mathrm{W}_1)}[\mathrm{A}(\mathrm{W}_2) - \mathrm{A}(\mathrm{W}_1)]$. Thus, following an increase in C, and excluding over-insurance ($\mathrm{W}_1 \geq \mathrm{W}_2$), the right-hand side ratio increases (resp. decreases) if the utility is DARA[4] (resp. IARA). As a consequence, to comply with optimality, the decision maker will have to compensate for that change in the ratio and will demand more (resp. less) insurance under DARA (resp. IARA) assumption.

B. Corner solutions:

The three types of corner solutions must be considered: insurance only, self-insurance only, none of them. The study of these solutions is necessary to characterize the determinants of the propensities to insurance and self-insurance (PI and PSI). Appendix B provides a detailed examination of these situations.

[3] This FOC (the derivative of EU with respect to "a") can be written as follows:
$\frac{\partial \mathrm{EU}}{\partial \mathrm{a}} = -(1-q)U'(W_0 - p\mathrm{I} - \mathrm{C} - \mathrm{a}) - [1 + x'(a)]qU'(W_0 - p\mathrm{I} - \mathrm{C} - \mathrm{a} - \mathrm{x}(\mathrm{a}) + \mathrm{I})$. Following an increase in "a", the 1st negative term increases (in absolute value) while the 2nd positive term decreases. So, as to avoid this condition to be negative, it is necessary to decrease I, which has exactly the opposite effect to an increase in "a".
[4] DARA: decreasing absolute risk aversion; IARA: increasing absolute risk aversion.

In two cases, the individual finds it profitable to base his risk coverage on a single hedging scheme I or SI:

(i) If the 1st monetary unit invested in SI is less profitable than if it would be with I, the corresponding MRs are ranked according to the following inequality: $-x'(0) \leq \frac{1}{p}$. As the MR of SI is decreasing while it is constant for I, it is then optimal to only use hedging opportunities offered by insurance. The occurrence of this situation is independent from risk aversion intensity and is not influenced by the presence of a fixed cost. As a consequence, when the individual only buys a positive amount of insurance, the PSI is increasing with p, while it is independent from the fixed cost and from risk aversion intensity. The demand for insurance (CI) follows the standard pattern.

(ii) On the contrary, if $-x'(\hat{a}) \geq \frac{1}{p}$, the unit price of insurance is too high and it is optimal to rely only on SI to cover the risk; the decision maker only resorts to SI and the 1st derivative characterizes her optimal choice and chose $\hat{a}$. When relying only on SI, we know that the CSI demand is increasing with risk aversion (Dionne and Eeckhoudt (1985)). If this situation arose, a less risk averse decision maker would demand a lower level of CSI; so $-x'(\hat{a})$ would tend to be greater than $\frac{1}{p}$. Therefore, the likelihood of this corner solution decreases with risk aversion.
Otherwise, it may also be preferable to rely only on SI if the fixed cost C is deterrent. This point is modeled with a participation constraint: $EU(I^*, a^*) \geq EU(0, \hat{a})$, where I^* and a^* stand for optimal choices in CI and CSI while $\hat{a}$ represents the optimal self-insurance choice without any use of insurance. The study of this constraint shows that it exists a threshold $\bar{C}$ that leaves the decision maker indifferent between the optimal bundle (I^*, a^*) and no insurance (0, $\hat{a}$). Using the implicit function theorem, it can be shown that this threshold is decreasing with the unit price *p*. And in accordance with the fact that the insurance premium is increasing with risk aversion (Pratt (1964)), we can also show that a more risk averse individual will be ready to bear a higher threshold $\bar{C}$ for the fixed cost, without leaving the insurance market.
Regarding propensity to insure, we infer from these results that PI is increasing with RA and decreasing with p and C.

(iii) The 3rd case of corner solution corresponds to "full risk retention": no insurance and no self-insurance. It occurs when the marginal returns of both hedging schemes are too small to attract the interest of the decision maker. This situation arises if the marginal return of SI is relatively small and if the unit insurance price (and/or the fixed cost) is sufficiently high. The likelihood of this case decreases with risk aversion intensity. Evidently, as previously seen, if the fixed cost is too high, the participation constraint is violated, and the individual does not resort to any hedging scheme if, simultaneously, SI opportunities are not attractive. Regarding propensities (PI or PSI), the study of this case underlines the positive effect of RA, while p and C have the same effects on PI (as in (i)) and no effect on PSI.

2. Theoretical predictions

For a risk-averse decision maker, the theoretical predictions about the behavior of CI and CSI mainly spring from equation (1) and the study of interior solutions, while the predictions for PI and PSI are derived from the study of corner solutions. Four sets of predictions will be tested. While prediction H1 is devoted to the examination of equation (1), the three following sets of predictions are considering the effects of the three parameters (risk aversion, unit price and fixed cost):

H1: Optimality of coverage demands

(H1) A rational EU risk-averter equalizes the MRs of conditional demands (CI and CSI):

$$\frac{1}{p} = -x'(a).$$

H2: Positive interplay between RA and coverage

(H2-a) The CSI investment is completely determined by the equality of MRs and is, therefore, independent of the intensity of risk aversion. On the other side, CI increases with risk aversion.

(H2-b) As the likelihood of corner solutions fall with risk aversion, PI and PSI do not decrease with RA.

On the whole, I increases with RA accounting for the raise of at least CI. On the contrary, SI is expected to be non-decreasing in RA.

H3: Unit-price-based substitution

We are thus facing with a substitution effect that operates at two levels: between the hedging instruments (whether to invest) and between the degrees of coverage (how much to invest).

(H3-a) The CI and CSI demands are substitutes: when the unit price of I increases, CSI increases while CI decreases.

(H3-b) An increase in the unit price of insurance (p), weakens PI and enhances PSI.

Therefore, the unit-price substitution effect operates at two levels: between hedging tools (whether or not to invest in I or/and SI in response to a change in p) and between investments magnitudes (in line with the predictions of Ehrlich and Becker (1972)).

H4: Fixed-cost crowding out effect

(H4-a) Following an increase in C, with p constant, the CI demand increases (resp. decreases) if the utility is DARA (resp. IARA) while the CSI demand remains the same. If the utility is CARA, the CI demand is independent of C.

(H4-b) The propensity to self-insure (PSI) is independent of the fixed cost (C) while PI diminishes with C. [5]

Overall, a change in C has no effect on the demand for SI while it decreases the demand for I if the utility is CARA or IARA; if the utility is DARA, the global effect is ambiguous.

III. Experimental design: Insurance and SI

Apart from the test on optimality condition, our experimental protocol has been designed to test our three following sets of predictions: the "unit-price-based substitution", the "fixed-cost crowding out effect" and "the positive interplay between risk coverage and RA".

The experiment took place in Montreal and involved 117 individuals. This sample consisted of students and workers, men and women. The average age was 30 with a high concentration of subjects between 20 and 30 years. The experiment involves two steps, the last including six repetitions. Sitting in front of a computer, the subjects had to decide whether and how much to hedge their risk of loss. They could use either insurance (I) or self-insurance (SI) opportunities, or both. Given our objectives, we also measured first subjects' prior risk aversion coefficient.

Step 1: Measuring risk aversion in an insurance context

In order to elicit risk aversion, we adapted the multiple price list method of Holt and Laury (2002) to the context of insurance. Subjects were first endowed with $10 and then, were facing losses as in Chakravarty and Roy (2009): for each of the 10 rows of Table 1 below, they had to choose their preferred option between A and B. Both options carried a risk of loss.

Table 1: Measurement of risk aversion

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

[5] In a very specific situation (when the individual buys only I in the first place), an increase in the fixed cost could deter insurance demand and, by reaction, could suddenly enhance the interest in self-insurance.

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 number of times option A – the least risky one – was preferred to option B results in an individual risk aversion indicator relevant for insurance issues. As suggested by Slovic (1987), people perceive risks differently according to the context. More specifically, several laboratory experiments (Schoemaker and Kunreuther 1979; Hershey and Schoemaker 1980; Kusev et al. 2009) documented the fact that subjects exhibit a higher risk aversion when the decision is explicitly framed as an insurance decision rather than a decontextualized risky decision. To this end, setting A and B options in the loss domain, with an initial endowment, provides a measure of risk aversion as close as possible to an insurance situations.

However, as our measure of risk aversion is implemented in the loss domain, one caveat needs to be scrutinized insofar. Our subjects were initially endowed with $10 for ethical reasons. Therefore, as mentioned by Thaler and Johnson (1990), they could exhibit a riskier behavior. According to this "house money" hypothetical bias, subjects would consider the endowment as manna from heaven and, therefore, would be likely to take more risk than with their own money. Etchart-Vincent and L'Haridon (2010) investigate the role of monetary incentives in the loss domain and compare several performance-based reward schemes. They argue that "the choice of a payment scheme may not be a very critical issue in the loss domain" and they find that a "losses-from-an-initial-endowment" procedure is not significantly affected by psychological biases; as a consequence, it can be used with a high degree of confidence.

Step 2: Investigating the trade-off between insurance and self-insurance

The second step involved 6 repetitions. In each repetition, the subjects were first endowed with a wealth of 1000 EMU (experimental monetary units) and were facing a 10% chance of losing all of it. To cope with this risk, subjects were given the opportunity to buy an insurance coverage and/or to invest in a SI activity. They could use both schemes, only one of them or none of them.

Providing that a subject decided to turn to the insurance device, then, in exchange for the payment of an insurance premium P at the beginning of the period, she would receive an indemnity I in the case of damage. The premium was an increasing function of the indemnity chosen level, in compliance with the following equation: $P = pI + C$, where P stands for the

insurance premium, p for the unit price of insurance, and I for the indemnity (ie the demand for insurance I).
Table 2 provides an example of the proposed premiums and their corresponding indemnities. For example, the premium payment P = 70 EMU at the beginning of the period entitles to a compensation I = 700 UME in the case of loss during the period. The last column of Table 2 also gives the marginal return of insurance, i.e. the additional compensation to which entitles an extra UME invested in I.

Table 2: Insurance premium grid

Premium = Total cost of insurance	**Indemnity: Demand for Insurance**	**Additional Indemnity**
P = 0.1 C = 0	Reimbursement in case of accident	from an additional UME of premium
0	0	-
5	50	10
10	100	10
15	150	10
20	200	10
25	250	10
30	300	10
35	350	10
40	400	10
45	450	10
50	500	10
55	550	10
60	600	10
65	650	10
70	700	10
75	750	10
80	800	10
85	850	10
90	900	10
95	950	10
100	1000	10

Simultaneously, as shown in Table 3, the subject had also the opportunity to self-insure: in return for an investment A in SI paid at the beginning of the period, she secured a part of her wealth in case of an accident. The 1st column of Table 3 gives the possible values for A; the second column gives the corresponding SI. For example, if she decided to secure an amount SI = 630 UME, the

subject had to invest the corresponding amount in SI, i.e. A = 60 EMU. Then, when facing a damage, he would lose 370 UME instead of 1000 UME.
The last column of Table 3 provides the marginal return of an additional investment in SI.

Table 3: Self-insurance investment

Investment in the SI activity A	Secured amount of wealth *SI*	Additional secured amount of wealth per additional UME of SI
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

Table 2 and 3 below were simultaneously displayed on the subject's computer screen. A device allowed the subjects to test as many combinations of P and A as desired, to better adjust their desired final wealth where W_1 stands for the no loss state and W_2 for the loss state:

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

Of course, if none of the hedging mechanisms was subscribed, the final wealth was respectively equal to $W_1 = 1000$ UME in the no loss state and to $W_2 = 0$ in the loss state. In all cases, the total amount of compensation paid in case of accident (I+SI) may not exceed the initial wealth (1,000 UME).

Once made, the subjects confirm their choice by clicking the button provided for this purpose.

At the end of the period and after the subjects had made their decision, a random draw determines whether an accident had occurred during the period. Then, the computer calculates their final wealth and displays it on their screen.

Subjects were faced with this same stage six times, corresponding to six different levels of the insurance contract parameters. Subjects were not told in advance that this stage would be repeated nor the number of repetitions. The six different insurance grids were obtained by crossing three levels of price (lower than actuarial ($p = 0.05$), actuarial ($p = 0.1$) and higher than actuarial ($p = 0.15$)) with two levels of fixed cost ($C = 0$ and $C = 50$). The premium grid reported in Table 2 has been computed in the particular case of an actuarial unit price $p = 0.1$ and a fixed cost $C = 0$. These grids were displayed randomly so as to control for a possible order effect.

Repetitions were independent: the initial wealth was reset at the beginning of each repetition. In addition, the subjects were made aware that wealth and/or losses from previous repetitions were not reported in the consecutive repetitions.

3. Monetary incentives

The incentives rewarded both steps of the experimentation. First, an endowment of $10 was intended to cover possible losses (about $ 5) from the step devoted to the measurement of risk aversion. A first draw involving a number between 1 and 10 identified a specific pair of lotteries. A second random draw determined the size of the individual loss, given the option chosen by the subjects for that pair. The value of the loss was not disclosed until the end of the experiment to avoid wealth effects.

Also, one of the 6 repetitions of the step dedicated to simultaneous hedging choices was also drawn at random. The final wealth obtained during this stage was then converted from UME into dollars.
On average, the total amount earned represents $15 on an hourly basis.

IV. Results

In the following paragraphs, we first review general results before addressing the question of the marginal returns equalization. For each hedging scheme and each component of the demand – propensity and conditional demand – we scrutinize the nature of the demands properties. For this purpose, we successively test the impact of each parameter (p, C, and RA) on the individual behavior of risk management and emphasize a remarkable empirical fact: the absolute stability of the aggregate hedging demand.

1. General results

Demands for coverage

The distributions of demand for I and SI reveal a strong dichotomous trade-off between hedging and not hedging. For all repetitions, almost 14% of the subjects never get insure, while 41% choose to invest in both I and SI whatever the insurance contract.

Table 4: Observed insurance and self-insurance average demands, by insurance contract

Unit Price	**Fixed cost**	***N***	**Demand for Insurance (Indemnity I)**	**Demand for Self-Insurance (SI)**	**Global Coverage (GC=I+SI)**
0.05	C=0	117	426.9	205.5	632.4
	C=50	117	351.71	232.8	584.51
	Combined	*234*	*389.32*	*219.21*	*608.53*
0.1	C=0	117	345.7	255.3	601
	C=50	117	300	298.5	598.5
	Combined	*234*	*322.86*	*276.88*	*599.75*
0.15	C=0	117	301.3	297.7	599
	C=50	117	273.1	295.1	568.2
	Combined	*234*	*287.18*	*296.41*	*583.6*
All prices	C=0	*351*	*358*	*252.8*	*610.8*
	C=50	*351*	*308.3*	*275.5*	*583.7*
	Combined	*702*	*333.1*	*264.2*	*597.3*

Table 4 presents, for each insurance contract, the average demands of I and SI along with the global coverage (GC). Across all insurance contracts, the average global coverage demand in case of an accident is 597 UME, which is broken down into I (333 UME) and SI (264 UME). On average, subjects spent 70 UME for coverage, 47 UME for I and 23 for SI. Table 4 indicates that the Global coverage is stable across contracts, leading to a final average wealth of respectively 527 UME and 930 UME depending on whether the individual faced an accident or not during the period.

Repetitions did not have a learning effect: neither the coverage nor the propensity to cover increase or diminish with the number of repetitions. Subjects have been confronted with a maximum of 3 accidents on 6 repetitions. However, 88% of subjects have had at most one accident. The behavior of insurance or self-insurance with respect to the decision to use one or the other of hedging instruments or both and the amount of coverage) have not been significantly different whether an accident had occurred during the prior repetition or not.[6]

RA

As it is prone to determine both coverage level and the likelihood of investing in hedging activities, RA coefficient addresses important issues in insurance choices. The robustness of this measure seems supported by the consistency of our subjects. 101 (86%) subjects have switched only once. Of the remaining participants, 5 have alternatively chosen option A and B which can be considered as a hedging strategy (following a diversification pattern), a few others (4) seem to have switched erroneously.[7] The others (7) have had quite strange choices but since they represent less than 6% we have chosen to keep them in the full sample. On the whole, except a few subjects whose risk-aversion coefficient, measured as the number of times the least risky lottery was chosen, takes extreme values, 85% of the participants show coefficient between 3 and 6.

2. Optimality of the demands for coverage: do marginal returns determine CI and CSI decisions?

In this section, we test whether MRs equalization determines the conditional demands for insurance and self-insurance of participants. The standard model of demand for insurance, including the opportunity to self-insure, asserts that for interior solutions, the optimum for individuals is to choose the level of both hedging activities that equalizes the MRs (prediction (H1)). However, when the unit price is less than actuarial and depending on technological returns, self-insurance activity may be not attractive (which is the case in our experiment), and the only optimal behavior is a corner solution where individuals choose to get only insured.

To what extent do those predictions are coherent with our data? For each insurance contract with at least an actuarial unit price, we test if the participants reach the optimal level of CSI that equalizes the MRs of both CI and CSI hedging activities. When $p = 0.1$, the MR of CI is equal to 10 (see Table 2), and two optimal values of CSI coexist at this marginal rate: 365 and 415 (see Table 3). We fixed CSI* = 365 to implement the test as a majority of CSI decisions are smaller than 365. Also, the rejection of CSI* = 365 implies the rejection of CSI = 415. When $p = 0.15$, the MR of CI is 6.66 and the corresponding optimal amount for CSI* is equal to 570. When the unit price is less than actuarial, we face a corner solution: the optimal self-insurance level is zero.[8]

In all cases, the theoretical levels depend only on unit price, not on the level of the fixed cost, so treatments dealing with the same unit prices but different fixed costs have been pooled.

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[6] The Mann-Whitney test on I (respectively SI), depending on the occurrence of an accident in the previous period provided a p-value= 0.9097 (respectively = 0.5206), meaning that neither the demand for insurance nor the demand for self-insurance is affected by the occurrence of an accident in the previous period.

[7] We refer to situations where choice A, for example, appears within long series of choices B (and inversely).

[8] When $p = 0.05$, the MR of CI is equal to 20 and all CSI opportunities are dominated with CSI* = SI* = 0.

Using the non-parametric Wilcoxon signed rank test, we compare those theoretical CSI levels to the experimentally observed levels. For each unit price, Table 5 provides the median of observed CSI (col. (1)), theoretical CSI level (col. (2) and the Wilcoxon sign rank test (col. (3)).

Table 5: Observed vs. theoretical self-insurance matching (prediction (H1-a))

Unit Price	(1) Observed Self-Insurance: CSI (N)	(2) Theoretical Self-Insurance: CSI*	(3) Wilcoxon test: z (p-value)
0.05	90 (234)[1]	0	11.06* (0.000)
0.1	272.5 (154)	365	-5.311* (0.000)
0.15	444.61 (156)	570	-11.19* (0.000)

* 1% significant

N = number of subjects who invest in both I and SI hedging activities. Note that N can exceed 117 since the 0 and 50 UME fixed costs treatments are pooled.

1: In this particular corner-solution case, N refers to the whole sample, whether the subjects invest in I and SI or not.

Table 5 shows that the MRs equalization prediction is rejected for our participants regardless of the unit price: when the unit price is, at least, actuarial, the observed demand for CSI is significantly lower than the theoretical one. On the contrary, when the unit price is below the actuarial price, the observed demand exceeds the theoretical one.[9]

Proposition 1: The demand for CSI exhibits a unit price inelasticity that makes our subjects depart from the optimal levels of CSI. Therefore, for our subjects, the marginal returns equalization strategy (H1) is rejected.

3. Testing the parameters-related predictions

In the previous section, for lack of adjustments to prices variations, we concluded to a departure of our subjects from an optimal behavior related to the marginal return strategy. In this section, we provide insight on the theoretical issues regarding I and SI behaviors by further investigating the sensitivity of demands for I and SI to the contractual parameters (unit price and fixed cost) and RA. We systematically disentangle the effects of the parameters on the two components of hedging demands, namely the propensity to cover and the conditional demand for coverage.

[9] This result can be partially explained by the specific form of the demand for SI. The first units of self-insurance may be attractive since the MR of SI (18 or 16 UME for the first units) is not far from the insurance MR (20 UME) when insurance is less than actuarial. So, we may expect a small positive investment (≤170).

In Figure 1 below, demands for I and SI are plotted according to unit price (x-axis) and fixed cost.

Figure 1: Demands for Insurance and self-insurance

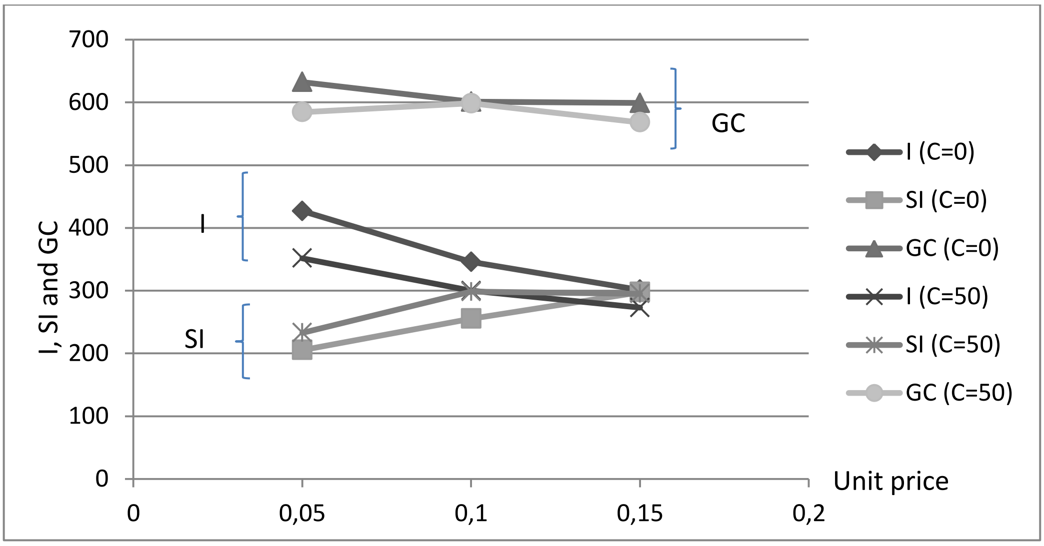


Figure 1 highlights strong behavioral patterns among participants. Demands for I and SI follow the predicted pattern of evolution with respect to price: when the price rises, the former decreases while the latter increases, making apparent their expected substitutability. These behavioral facts are compatible with both predictions (H3-a) and (H3-b)). Furthermore, the demand for I is slightly higher when the fixed cost is nil. The global coverage appears to be surprisingly stable and reveals how close substitutes the demands for I and SI are.

Table 6 (col. (2) and (3)) provides the Spearman's rank correlation coefficients, and their significance, between hedging activities (GC, I and SI) and each of the contractual parameters (p, C). The correlations with RA coefficient is reported in column (1). Correlation tests confirm our graphical intuitions and allow us to go further in the analysis.

Table 6: Spearman's rank correlation coefficients between parameters and demand for hedging

Hedging activity	Components	(1) RA Correlation coefficient (p-value)	(2) Price Correlation coefficient (p-value)	(3) Fixed cost Correlation coefficient (p-value)
I	PI	0.326** (0.000)	-0.062 (0.098)	-0.084* (0.026)
	CI	0.130** (0.005)	-0.111* (0.017)	-0.005 (0.908)

	I=PI*CI	0.324** (0.000)	-0.101** (0.008)	-0.073 (0.053)
SI	PSI	0.158** (0.000)	0.101** (0.007)	0.053 (0.161)
	CSI	-0.071 (0.136)	0.084 (0.079)	0.000 (0.991)
	SI=PSI*CSI	0.110** (0.003)	0.120** (0.001)	0.046 (0.224)
GC	GC=I+SI	0.275** (0.000)	-0.008 (0.821)	-0.012 (0.745)

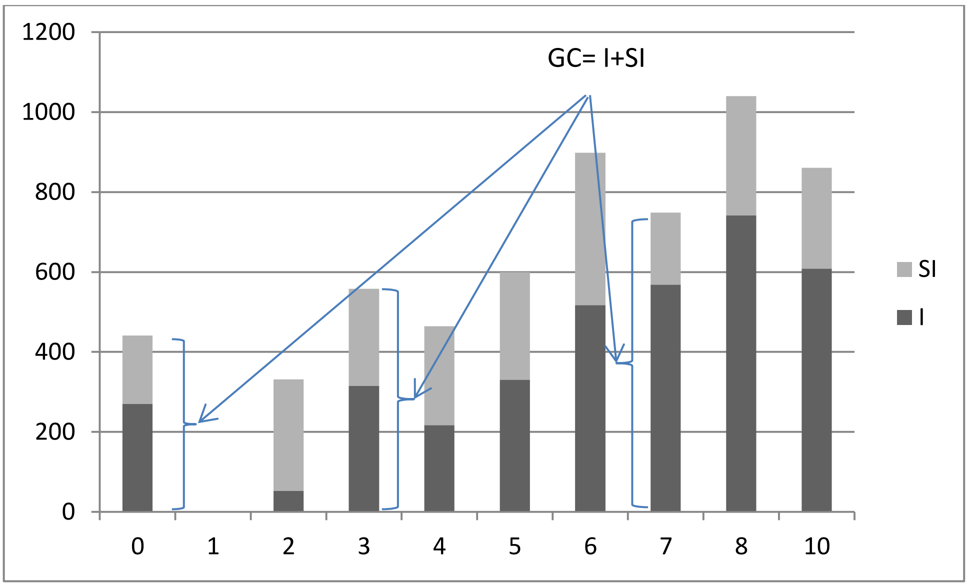
(N=702)
* 5% significant
**1% significant

A. Impact of risk aversion: The positive interplay between RA and global coverage

I, SI

Figure 2 below represents a vertical stacked bar graph showing demands for I and SI as well as GC, across risk aversion coefficient. Both Figure 2 and Table 6 (col. (1)) highlight some key results regarding the interplay between hedging components and risk aversion. In line with our theoretical expectations, they reveal a positive and significant relationship between RA and demand for I and little significant relationship between SI and RA: the more risk-averse the subjects are, the greater their demand for I, while the demand for SI seems not to account for RA.

Figure 2: Demands for Self-insurance and Insurance vs. risk aversion



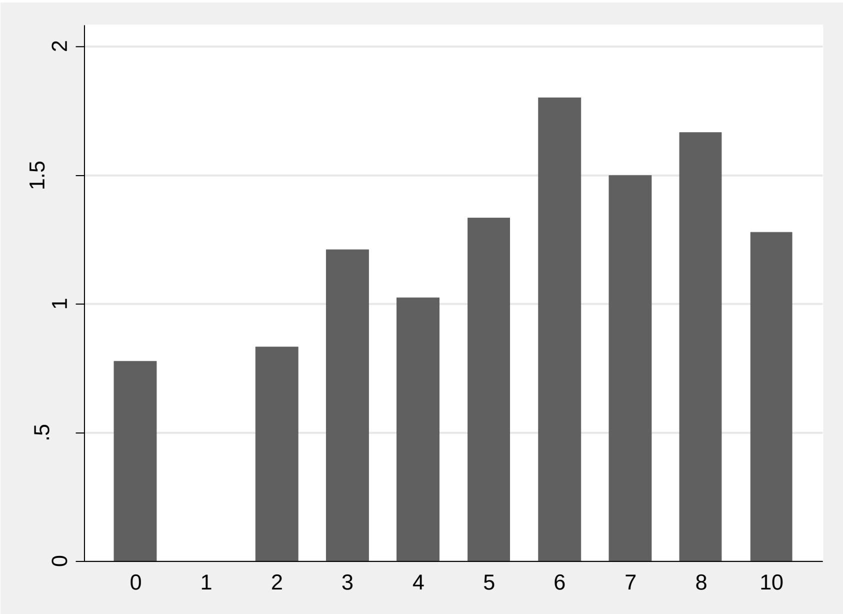
Proposition 2: Given both opportunities for activities I and SI, the observed behaviors fit with our theoretical predictions: Only the overall demand for I increases significantly with the RA coefficient which provides no rebuttal to predictions (H2-a) and (H2-b).

These elements can be explained by an increase in both the likelihood of hedging and the level of coverage as risk aversion coefficient rises.

PI, PSI: Relationship between RA and the number of hedging tools involved

The RA coefficient is theoretically expected to influence the likelihood of getting insured or self-insured (prediction (H2-b)). In Figure 4, the average number of hedging activities for all contracts is represented according to the RA coefficient. The Spearman correlation coefficient between RA and the number of chosen hedging activities is 0.27 and highly significant (p-value = 0.000)), so are the Spearman correlation coefficients between the likelihood of investing in a hedging activity (PI and PSI) and RA in Table 6 (col.(1)).

Figure 3: Average number of hedging activities vs. risk-aversion



Risk aversion parameters

In line with prediction (H2-b), RA exhibits a strong and significant positive influence on whether to invest or not in any hedging activity.

Proposition 3: The higher the RA coefficient, the higher the number of hedging activities involved in accordance with prediction (H2-b).

CI, CSI

Table 6 column (1) shows that only CI is increasing with risk aversion, which is in line with our theoretical expectation (predictions (H2-a).

B. The unit-price-based substitutability property

In the next sections, we examine how changes in the contractual parameters are transmitted to the two components of both the demand for insurance and self-insurance as policyholders react to the contractual environment changes by exiting/entering the market and/or adjusting the amounts of coverage.

The Spearman rank correlation tests reported in column (2) of Table 6 measure the impact of an increase in the unit price on demands for SI and I and their components. The 0 and 50 UME fixed costs treatments are pooled.[10]

The effects on I, SI

In compliance with the theoretical predictions, we observed that a rise in the unit price results in a significant decline of demand for I. A substitution effect is at play since demand for SI varies symmetrically.

Proposition 4: As stipulated by Ehrlich and Becker (1972), the theoretical substitutability property between demands for I and SI is observed in our data: a rise in the insurance price significantly reduces the demand for I and increases the demand for SI.

The effects on the components: PI, PSI, and CI, CSI

As the table 6 shows, and in accordance with the theoretical expectations ((H3-a) and (H3-b)), a higher unit price of I has a deterrent effect on the demand for I through both market exit (PI) and demand contraction of people who keep buying insurance (CI).

The offsetting effect is observed for the SI activity: A higher unit price of I makes the SI more attractive and results in a rise in both the likelihood of investing in that activity (PSI raises) and the conditional demand for SI (CSI).

Therefore, the substitution between I and SI seems to operate on the two levels of decisions: whether and how much to invest. A *quantity-based substitution* is emerging where a higher unit price causes a decrease in the amount of insurance required by those who choose to buy insurance (CDI) and correspondingly an increase in the demand for SI by those who still use it (CSI).

The second level of substitution, a *between-hedging-tools substitution* that affects the likelihoods of investing in SI and I activities must be underlined. Higher unit price results in a rise of the likelihood of investing in SI while the likelihood of investing in I decreases.

Proposition 5: A rise in the unit price of insurance provides effects that are compliant with the theoretical expectations (H3-a) and (H3-b). The substitutability property holds and is mediated by a two-level substitution: a substitution between hedging tools and between quantity bought.

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[10] Considering the fixed costs 0 and 50 separately do not modify for the essential the results.

C. The fixed-cost crowding out effect

We investigate the impact of increased fixed cost on both I and SI (predictions (H4-a) and (H4-b)). From the theoretical analysis, we expect changes in the fixed cost not to influence SI. On the other hand, assuming a DARA (resp. IARA) utility function, when the fixed cost rises, conditional demand for I is expected to increase (resp. decrease). While the propensity to insure (PI) is expected to decline with the fixed cost, the whole effect may be ambiguous.

The Spearman rank correlation tests (Table 6, Col. (3)) give, for each unit price of insurance, the impact of an increase in the fixed cost on coverage demands and their components.

I, SI

In compliance with theoretical predictions, the fixed cost increase appears not to have a significant effect on the demand for SI while it slightly decreases the demand for I.[11]

The components PI, PSI, and CI, CSI

Table 6 also highlights two key features when the fixed cost rises: first, a higher fixed cost has a significant negative influence on PI only while each component of SI (PSI, CSI) is left unchanged. The main effect of a fixed cost is, therefore, to crowd out subjects from the insurance market.

Proposition 6: **The effects of an increase in the fixed cost are in line with predictions (H4-a) and (H4-b). The fixed cost has no significant effect on self-insurance demand (PSI and CSI), neither on CDI, which supports a CARA utility function, but it exerts a crowding out of insureds from the insurance market.**

4. Beyond the theoretical model: an unexpectedly stable global coverage

The validation of the substitutability property requires us to go further and to assess and quantify the crowding out effect. The Spearman correlation tests given in the last row of Table 6 above, compare the variations of the global coverage when the unit price or the fixed cost rises. None of the differences are statistically significant: any decline in the demand for I appears to be strictly counterbalanced by an increase of the demand for SI. The demands for I and SI are then strongly substitutable and leave the global coverage unchanged across insurance contracts.

Proposition 7: Following a unit price increase, any decline in the demand for Insurance is strictly offset by a rise in the demand for Self-Insurance, of similar size.

Corollary: The amount of the global coverage appears not to depend on unit price or fixed cost.

[11] The fixed cost is low regarding the wealth involved.

RA

Even if the GC is remarkably stable across insurance contracts as the unit price rises, as discussed previously, it significantly increases with risk aversion (see Table 6, last column) mainly due to a rise of the demand for I.

Proposition 7: The only parameter that raises the global coverage is the risk aversion coefficient.

5. Discussion and conclusion

The originality of our experimental setting is threefold. First, we measure the demands for insurance and self-insurance involving 6 different insurance tariffs. Then, we implement an insurance-context-adapted Holt and Laury (2002)'s procedure to measure our subjects' risk aversion. Finally, we resort to a two-part insurance tariff – involving a unit insurance price and a fixed cost – coupled with a self-insurance technology, with decreasing returns.

We are therefore able to test, in a detailed way, both the unit-price-based and fixed-cost-crowding out effects on insurance and self-insurance and their components, and the marginal returns equalization prediction. We also investigate the role of risk aversion on the demands for coverage. Finally, our experimental setting makes it possible to compare the influence of each parameter (unit price, fixed cost, and risk aversion coefficient) on risk hedging.

We find experimental support for the unit-price-based substitutability property but because of a low price-elasticity, the subjects fail to equalize the marginal returns of hedging tools.

Moreover, we find that the unit-price-based substitutability property actually results from a combination of two effects that operate at each of the two levels of decisions (whether and how much to invest) and for each type of coverage (insurance and self-insurance). An increase in the unit insurance price results in the dual effect of the ousting from the insurance market of some individuals and the contraction in the conditional demand for insurance. The exact opposite effect is observed regarding the self-insurance activity: both propensity and conditional demand of self-insurance increase.

The unexpected result is that the effects on insurance and self-insurance compensate strictly and lead to a steady global coverage (insurance + self-insurance) across the treatments. The unit-price-based substitutability property of demands for insurance and self-insurance is complete: any decline in the demand for insurance involved by a rise in the unit price is strictly offset by an increase of the same magnitude in the demand for self-insurance.

However, if the amount of the global coverage appears not to depend on the unit price, it does increase along with risk aversion intensity. The "positive-interplay-between-risk-aversion-and-coverage" prediction finds, therefore, an experimental validation due mainly to a rise of both the likelihood and the conditional demand for insurance when risk aversion rises.

Finally, the fixed-cost crowding out effect seems supported by our data. Only the demand for insurance (exclusively through a contraction in the propensity of subjects to use insurance) is affected by an increase in the fixed-cost. Its only effect is to crowd some subjects out of the insurance market.

Public policy involvement

Regarding public policy, these behavioral traits – combining a strong stability of the total coverage with a strict substitution between hedging tools – provide striking insights. While bounded rationality seems to legitimate State intervention in the field of risk management, the strict substitution between insurance and self-insurance, the fixed-cost crowding out effect and the asymmetry of the behavioral responses to changes in the fixed-cost and the unit price, raise many fundamental difficulties. However, our experimental findings may also contribute to explain some puzzles such as the use of self-insurance clauses in insurance contracts.

The legitimacy of State intervention

From a normative point of view, our empirical findings highlight the existence of inefficient behavior with respect to standard theory. Individuals do not equalize the marginal returns of their hedging activities, which results in an under-use of self-insurance opportunities. By contrast, a benevolent planner could aim at equalizing marginal returns of hedging mechanisms so as to maximize social welfare. Our experimental design stresses this possibility as the marginal return of self-insurance is decreasing with the demand for self-insurance, and the marginal return of insurance is both constant (and equal to the unit price) and independent from the chosen level of insurance. Therefore, the self-insurance level that equalizes the marginal returns of the two hedging activities is completely determined by the insurance marginal return (i.e. the unit price). Besides, the level of the demand for insurance depends on the individual's risk aversion intensity: the insurance demand will be lower for weak risk-averters. Thus, given insurance tariffs, the benevolent planner only needs to set a compulsory level of self-insurance investment (equal to the insurance marginal return) to realize efficiency through the equality of marginal returns.

The issues of the substitutability property

Given the evidence of the substitution effect between insurance and self-insurance, we figure out that a policy intended to promote insurance through subsidized prices is doomed to failure: a decrease in insurance price increases the demand for insurance but expands the risk since it crowds out self-insurance. Such an adverse effect is particularly credible in a context where the global demand for coverage is very stable, regardless of insurance rates. In our experiment, individuals seem to trade-off between self-insurance and insurance under the constraint of the fixed global coverage they have in mind rather than by comparing marginal returns of insurance opportunities. Therefore, in terms of risk management, we cannot ascertain that a price subsidization will imply a rise in the net coverage of risks.

Is it possible to rely on insurance contractual tools – fixed-cost and unit price – to regulate risk management?

The impacts of the contractual tools – fixed-cost and unit price – are not equivalent, both theoretically and experimentally. On one side, an increase in the fixed cost will act exclusively on insurance demand by inducing people either to reduce their demand for insurance or to exit from the insurance market. On the other side, a change in the unit price of insurance will impact both insurance and self-insurance through a substitution effect involving either a change in their respective shares in the risk management process or a complete ouster of one hedging mechanism by the other.

Assuming that our experimental findings could be transposed to the real world, economic policy will have a different effect depending on whether it relates to the fixed cost or unit price. We could imagine using the fixed cost to reduce and control the insurance demand whereas the promotion of prevention (self-insurance) should pass through an action on the unit price of insurance.

From a macroeconomic point of view, the consequences of an exit of insurance market or a contraction in demand are not equivalent, even if both are harmful. The fixed cost is prone to generate drastic reactions and discontinuities while the unit price induces gradual adjustments.

In most cases (car insurance, liability insurance, health insurance…), insurance contracting is compulsory. So, unwanted effects of the fixed cost are excluded. Therefore, public policies rely almost exclusively on the unit price. For example, reforms that promote universal coverage, implement complementary mandatory health coverage, aim at providing coverage for everybody at a subsidized price. In this case, the fixed cost serves only the public accounts balance. However, the presence of cheap insurance opportunities is likely to crowd out self-insurance investments. It would follow a decline in mitigation efforts, inducing a risk increase, and an additional insurance coverage would be required. Finally, combined with price subsidies, an increase in the demand for insurance would cause an additional deficit. To get out of this vicious circle, our experimental results suggest subsidizing both insurance and self-insurance. This policy would alleviate the crowding out of self-insurance and would help to control public deficits.

A justification of self-insurance enforcements

Our behavioral insights provide a post hoc justification for both prevention enforcements and the presence of self-insurance clauses in insurance contracts (e.g. requirement for a burglar alarm or a security door in the case of household insurance). The latter point is of interest since, the prevalence, so far, in the real world, of mandatory self-insurance clauses in insurance contracts appears to be a pure puzzle from a theoretical perspective. According to standard theory, investment in self-insurance is firmly induced and determined by the unit price of insurance. So, there is no need for insurers to observe this prevention behavior since they can infer self-insurance choices made by policyholders through the equalization of marginal returns of insurance and self-insurance. As a consequence, the behavioral reluctance to adjust self-insurance hedging to insurance pricing overcomes this puzzle and justifies the insertion of such self-insurance clauses in insurance contracts.

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Appendix A: Second order conditions

From the decision problem,

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

We obtain the following first order conditions:

$$\frac{\partial \mathrm{EU}}{\partial \mathrm{a}} = -(1-q)\,U'(W_1) - [1 + x'(a)]q\,U'(W_2) = 0$$
$$\frac{\partial \mathrm{EU}}{\partial \mathrm{I}} = -\mathrm{p}(1-q)\,U'(W_1) + (1-p)q\,U'(W_2) = 0$$

The second order derivatives are checked below:

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

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

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

Appendix B: Corner Solutions

When hedging schemes are voluntary, three types of corner solutions may occur: insurance only, self-insurance only, none of them.

The 1st case – insurance only – happens when the first monetary unit invested in self-insurance is not profitable. To characterize this situation, we evaluate the 1st order derivative of EU with respect to "a", for a zero investment in self-insurance and for optimal insurance $\hat{I}$:

$$\left.\frac{\partial EU}{\partial a}\right|_{a=0} = -(1-q)U'\big(W_0 - \hat{P}\big) - q[1 + x'(0)]U'(W_0 - \hat{P} - x\big(0\big) + \hat{I}\big) \leq 0$$

If this expression is negative, it is optimal to neglect this hedging scheme. Combining this inequality with the 1st order condition for a strictly positive insurance demand, we obtain the following inequality:

$$-x'(0) \leq \frac{1}{p}$$

Therefore, as the marginal return of self-insurance is decreasing and the marginal return of insurance is constant, it is sufficient to compare their levels for the 1st unit of self-insurance to decide to engage or not in this hedging scheme.

The 2nd case – self-insurance only – appears whenever the fixed cost or/and the unit price are too high. To assess the effect a too high unit price may have, we need to calculate the 1st order derivative of EU with respect to I and evaluate it for I=0 and for $\hat{a}$ the optimal investment in SI:

$$\left.\frac{\partial EU}{\partial I}\right|_{I=0} = -p(1-q)U'(W_0 - \hat{a}) + (1-p)qU'(W_0 - \hat{a} - x(\hat{a})) \leq 0$$

Using simultaneously this inequality and the optimality condition for self-insurance, we get:

$$-x'(\hat{a}) \geq \frac{1}{p}$$

Then, the unit price of insurance is deterrent, and the decision maker finds it profitable only to invest in self-insurance, since the last desired unit of SI is more profitable than insurance.
However, even if the unit price is not that high, the decision maker may leave the insurance market. The presence of the fixed cost C introduces a discontinuity which needs a specific treatment through the following participation constraint: $EU(I^*, a^*) \geq EU(0, \hat{a})$, where I^* and a^* stand for optimal choices in I and SI while $\hat{a}$ represents the optimal self-insurance choice when insurance is not desired. By developing this constraint, we see that it always exists, ceteris paribus, a threshold $\bar{C}$ that leaves the decision maker indifferent between the optimal bundle (I^*, a^*) and no insurance (0, $\hat{a}$):

$$\begin{aligned}(1-q)U(W_0 - pI^* - \bar{C} - a^*) + qU(W_0 - pI^* - \bar{C} - a^* - x(a^*) + I^*) \\ = (1-q)U(W_0 - \hat{a}) + qU\big(W_0 - \hat{a} - x(\hat{a})\big)\end{aligned}$$

According to the implicit function theorem, it is straightforward that this threshold is decreasing with the unit price p. The threshold $\bar{C}$ is also increasing with risk aversion, a consequence of the fact that the insurance premium is increasing with risk aversion (Pratt (1964)). Thus, ceteris paribus, a more risk averse individual will be ready to bear a higher level for the fixed cost, without leaving the market.

The 3rd case – no insurance, no self-insurance – occurs if the marginal return of SI is relatively small and if the unit insurance price (and/or the fixed cost) is sufficiently high. By evaluating the FOC at a=0&I=0, we obtain the following conditions to be met:

$$\left.\frac{\partial EU}{\partial a}\right|_{\substack{a=0\\I=0}} = -(1-q)U'(W_0) - q[1+x'(0)]U'(W_0 - x(0)) \leq 0$$

$$\left.\frac{\partial EU}{\partial I}\right|_{\substack{a=0\\I=0}} = -p(1-q)U'(W_0) + (1-p)qU'(W_0 - x(0)) \leq 0$$

After rearrangements, full risk retention occurs if the following inequalities are simultaneously satisfied:

$$-x'(0) \leq \frac{(1-q)U'(W_0)}{pU'(W_0 - x(0))} + 1 \text{ and } \frac{1}{p} \leq \frac{(1-q)U'(W_0)}{pU'(W_0 - x(0))} + 1$$

Then, marginal returns of both hedging schemes are too small to attract the interest of the decision maker. We also may infer that these inequalities are more likely to be true if risk aversion is low. Indeed, the ratio on the right of the inequality is decreasing with the intensity of risk aversion. Therefore, all things being equal, the likelihood of full risk retention decreases with risk aversion.

In addition, as previously mentioned, if the participation constraint is violated, the individual does not resort to any insurance coverage, which arises if the fixed cost is sufficiently high.

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