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What if compulsory insurance triggered self-insurance? An experimental evidence.

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Abstract

Although it avoids the negative externalities associated with the damages caused by uninsured individuals, compulsory insurance raises the issue of insurance crowding out prevention. Interestingly, Pannequin and Corcos ((2020)) show that on a theoretical level, although *compulsory insurance* and *self-insurance* (prevention investments dedicated to loss reduction) are substitutes for risk averters, they *are complementary* for risk lovers. The present contribution aims to test, in the Lab, these surprising results using a model-based experimental design. Our experimental results support the theoretical predictions: compulsory insurance and self-insurance are complementary for risk lovers and substitutes for risk averters. This contribution fully supports public policies that aim to implement mandatory insurance. Far from deterring prevention activities and providing that its level is high enough, mandatory insurance increases prevention levels.

Keywords: compulsory insurance; self-insurance; experiment; risk-attitudes; substitutability; complementarity.

Introduction

The sharp increase in the risk of natural disasters raises questions about the insurance schemes able to manage such risks and, particularly prevention activities. While self-insurance can substantially reduce the size of the losses in case of natural disasters, insurance, especially when compulsory, can dampen the policyholders' investment in prevention activities (self-insurance and self-protection): For example, the existence of flood insurance can encourage building in flood-prone areas. Insurance scheme must therefore not alter policyholders' prevention efforts.[1] As a contribution to this debate, this paper proposes an experimental test of the effect of compulsory insurance on the self-insurance effort undertaken by the individual.
Compulsory insurance is found, to varying degrees, in the main insurance markets (health, automobile, civil liability, and housing). Compulsory insurance is generally justified by the desire to protect, with no exclusion, the population at risk but also to prevent the negative externalities that people who are not insured cause to those who are insured. While the economic and human stakes of such measures are well understood, one may wonder about their possible harmful effects on self-insurance. The risk of insurance crowding out self-insurance in situations where there is no insurance obligation has already been demonstrated theoretically (Ehrlich & Becker, 1972) and supported both empirically (Carson et al., 2013) and experimentally (Pannequin et al., 2020). Nevertheless, if Pannequin et al. (2020) confirm the substitutability between Insurance (I) and Self-Insurance (SI), their results suggest that it is weaker than expected. In the context of flood risk, Botzen et al. (2019), surveying more than 1000 homeowners in New York City, find that some loss reduction investments are complement to insurance. While these results are comforting regarding the risk of crowding out self-insurance when insurance rates are under-actuarial (particularly in health insurance), they also suggest that with a more-than-actuarial unit price of insurance, self-insurance investment might be lower than theory predicts.

In any case, these papers assume that insurance and prevention levels are voluntary. However, the growing number of compulsory insurances makes it necessary to study their effects on self-insurance for at least two reasons. First, risk-lovers (RLs) are not supposed to buy voluntary insurance, which explains why they are not part of research dealing with voluntary insurance decisions. However, by nature, an insurance obligation is binding on everyone, including RLs. Although it is possible, not without risk, to transpose to risk-averters (RAs) the results of substitutability between I and SI to the context of compulsory insurance, nothing can be said about the behavior of RLs. Therefore, studying specifically their behavior when insurance becomes compulsory cannot be avoided. This is the purpose of the theoretical paper by Pannequin and Corcos (Pannequin & Corcos, 2020), which studies the relationship between self-insurance and compulsory insurance by extending it to RLs. The authors show that, unexpectedly, in the presence of an insurance obligation, RLs *increase* their investment in self-insurance compared to the situation without compulsory insurance. The theoretical behavior of RAs is more expected; compulsory insurance encourages them to adjust their investment in SI to their situation on the insurance market: when facing insurance shortage,

[1] In France, the law n° 82-600 of July 13, 1982, has set up a national fund allowing compensation against natural disasters. However, due to the pooling of risks inherent in this national fund, insurance pricing has no direct connection with risk exposure, which raises questions about its incentive properties.

they are expected to increase their demand for prevention. If, on the other hand, compulsory insurance leads to insurance excess, they are expected to reduce their demand for insurance. However, the theoretical adjustment in SI does less than compensate for the excess or shortage of insurance.

This paper is a theory-driven laboratory experiment that tests the insights of Pannequin and Corcos' theoretical model. It investigates the nature of the relationship between I and SI - substitution or complementarity - in the presence of compulsory insurance. We use the methodology developed by Corcos et al. (2019) to elicit subjects' attitude toward risk. Our experimental results support the theoretical predictions of the model as we observe that while I and SI are *substitutable* for RAs, they are *complementary* for RLs. The following section details the experimental design. Section 2 briefly presents the theoretical results of the effect of compulsory insurance on the prevention behaviors of RAs and RLs. Section 3 presents the experimental results and Section 4 concludes the paper.

1) Experimental design

A. A two-step hedging decisions

The experimental design complements Pannequin et al.'s (2020). In this two-step experiment, subjects face, each round, a q=10% risk of losing their whole 1000 UME endowment. To cover for this risk, they can invest, at the beginning of the round, in a prevention activity (SI) whose cost *e* depends on the amount of coverage desired SI. Table 1 below provides the relationship between *e* and SI and remains unchanged throughout the experiment.

Table 1: Self-insurance investment

e^a	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
SI^b	0	90	170	240	305	365	415	460	500	535	570	600	630	655	680	700	715	725	730	730	730

a: Investment (cost) *e* in self-insurance
b: demand for self-insurance; (SI) : amount of wealth guaranteed by an investment in a prevention activity

In addition to self-insurance, the subjects can also use an insurance coverage which, depending on the step, is *compulsory* (Compulsory Insurance step CI), or *voluntary* (Volontary Insurance step VI).

Compulsory insurance step

In the compulsory step, insurance levels are set for the subjects: in exchange for a mandatory premium $\bar{P} = p\bar{I} + 50$ paid at the beginning of the round, the subject receives an indemnity $\bar{I}$ in case of loss. Participants are then only meant to choose their desired level of prevention. Once SI is chosen, a random draw of the accident occurrence is performed. Depending on whether a loss occurred during the round, subjects' earnings for the round are as follows, with $W_L \leq 1000$:

$$W_{\bar{L}} = 1000 - e - \bar{P}$$
$$W_L = 1000 - e - \bar{P} - 1000 + SI + Ic$$

Where $W_{\bar{L}}$ et W_L stand for the wealth in respectively the no-loss and the loss state. However, the latter cannot exceed the initial wealth: $W_L \leq 1000$.

This round is repeated 9 times corresponding to as many insurance premium $\bar{P}$: three levels of compulsory insurance *Ic* crossed with three unit-price *p* of insurance: actuarial, under and over-actuarial price. **Erreur ! Source du renvoi introuvable.** below provides the 9 insurance p remium.

Table 2: Insurance Premium $\bar{P}$

		p		
		5%	10%	15%
Ic	300	65	80	95
	500	75	100	125
	700	85	120	155

Volontary insurance step

In the voluntary insurance (VI) step, the subjects can voluntarily determine, in addition to their prevention investment, the level of insurance they need.[2] An example of an insurance rate is provided in Table 3 where p is actuarial (p=q=10%) and the fixed cost C=50 UME.

Table 3: Insurance premium P

(1) *P*	0	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
(2) *I*	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000

(1) P (Premium): Insurance cost when *p*=0,1 *C*=50
(2) I (Indemnity): reimbursement in case of damage.

In the VI step, the round is played a total of three times, corresponding to three different insurance prices: actuarial (p=10%), under (p=5%) and over actuarial (15%) unit insurance prices. The fixed cost (C=50 UME) remains unchanged. The related grids are provided in appendix A.

Again, once SI and I are chosen, a random draw of the loss occurrence is performed and subjects' earnings for the round are as follows, with $W_A \leq 1000$:

$$W_{\bar{L}} = 1000 - e - P$$
$$W_L = 1000 - e - P - 1000 + SI + I$$

B. Timing of the experiment

[2] Providing, as previously, that the wealth in case of accident does not exceed their initial wealth: $W_L \leq 1000$.

To avoid order effects, VI and CI steps are randomly balanced. Within each step, the rounds are randomized. Moreover, to avoid a gamblers' fallacy effect (Tversky & Kahneman, 1971), the rounds' outcome (loss vs no loss) is revealed to the subjects only at the end of the experiment.

C. **Incentives**

Subjects receive a showup fee of 10 Canadian dollars. In addition, at the end of the experiment, one of the 12 rounds of the CI and VI stages is drawn, played, and the round payoff paid to the subject. The round payoff depends on both whether an accident occurred during the period and insurance and prevention decisions made by the subject during that round.
The conversion rate for EMU to Canadian dollars is 1 EMU = 1 cent. Subjects are informed in advance of the compensation terms.

2) Theoretical predictions

We summarize in Table 4 and Table 5 below the theoretical results of Pannequin & Corcos's (2020) model on which the experiment is based. The theoretical results specifically developed for the purpose of this paper are provided in Appendix B. The model focuses on the prevention and insurance demands of individuals exposed to a risk q of losing their wealth. Two coverage schemes are studied: a scheme in which the level of insurance is mandatory for individuals (CI step). In the second, more classical scheme, individuals choose both the insurance and the prevention levels that maximize their utility (VI step).

A. **CI step**

The theoretical model studies the optimal prevention demands (self-insurance) of individuals facing mandatory insurance. The comparative statics analysis allows us to study the effect of an increase in the level of insurance obligation and of a variation in the unit price of insurance on prevention behavior. The originality of the model is that it also includes the analysis of RLS' behavior. The theoretical predictions are summarized in Table 4, col. 1 and 2 for RAs and RLs respectively.

Table 4: Theoretical predictions of the compulsory insurance step

		RA	RL
↗ Ic	*SIc*	↘	↗ or →
	GCc	↗	↗ or →
↗ p	*SIc*	↗ or →*	Indet.[b]
	GCc	↗ or →*	Indet.[b]

*↗ if DARA; → if CARA
b: indeterminate

B. **Comparaison CI and VI steps**

A comparative statics analysis also compares the levels of SI demand and global coverage for situations with voluntary and mandatory insurance. The theoretical expectations are summarized in Table 5. The details of their development are provided in Appendix B.

Table 5: Theoretical predictions of the SI adjustment to insurance shortage or excess

		(Ic-Iv)	
		< 0	> 0
RA	Valence (SIc-SIv)	> 0	< 0
	Magnitude	|SIc-SIv|<|Ic-Iv|	|SIc-SIv|<|Ic-Iv|
	Global coverage GC	↘	↗
RL	Valence (SIc-SIv)	n.a	≥ 0
	Magnitude	n.a	|SIc-SIv| indep|Ic-Iv|
	Global coverage GC	n.a	↗

dI=*Ic*-I; dSI=*SIc*-SI; dGC=*GCc*-GC
n.a : not applicable

3) Results

150 people participated in the experiment that took place in Montreal in 2021. The sample consisted of 86 women and 64 men with an average age of 24 years. The earnings were approximately 18 Canadian dollars for the 30 or 40 minutes of the experiment.

A. Risk attitude

Based on the methodology developed by Corcos et al.(2019), the insurance and prevention demands (I, SI) of the VI step are used to elicit the subjects' risk attitude (risk averters and risk lovers). Basically, subjects who do not buy insurance in any of the three rounds of the VI step are classified as risk-lovers (RL). The others are labelled risk-averters (RA). The revealed choices of I and SI are then used to identify, risk-averter individuals whose insurance and prevention choices are inconsistent.[3] For example, RAs who always buy insurance except when its price is less than actuarial are considered inconsistent; so are subjects who only self-insure when it is less advantageous (i.e. when the insurance price is less than actuarial).

Following this methodology, of the 150 subjects in our sample, 93 are classified RA, 37 as RL and 20 as inconsistent. Only RAs and RLs' behavior (71.5% and 28.5% of consistent subjects) are studied thereafter.

Table 6: Break down of Risk attitudes

Risk attitude	Freq	% of the whole sample	% of consistent subjects
Inconsistent	20	13.33	-
RA	93	62	71.5
RL	37	24.67	28.5

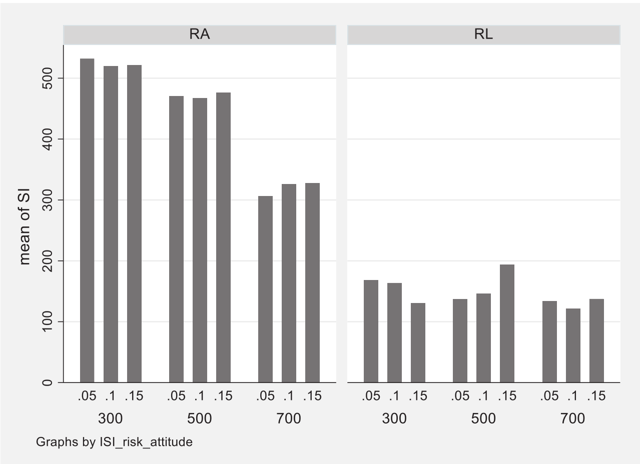
[3] For more details, see. Corcos et al. (2019).

B. **CI step: what are the effects on SIc of an increase in Ic?**

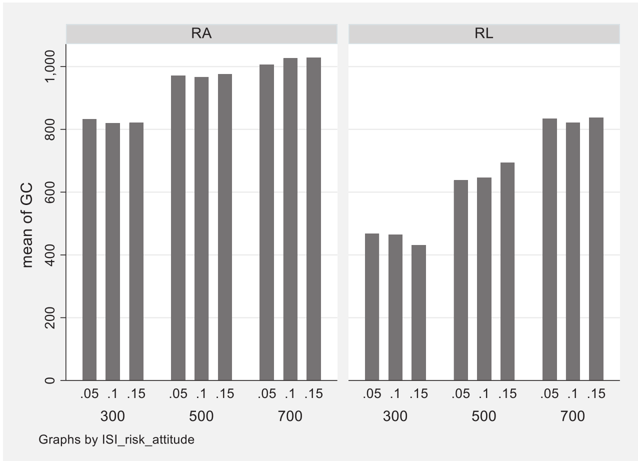
The CI step allows us to study how *p* (insurance price) and *Ic* (level of compulsory insurance) affect RAs' and RLs' self-insurance choices. The graphs below represent *SIc* (Graph 1) and *GCc* (Graph 2) when *p* and *Ic* vary. Their analysis highlights a few salient facts.

For RAs, the decrease of *SIc* as *Ic* increases (see the left side of Graph 1) suggests a substitution mechanism between *Ic* and *SIc*. On the contrary, for RLs, SIc does not seem to vary as *Ic* rises (see the right side of Graph 1). As a result, and because RAs' decrease in *SIc* less than offsets the increase in *Ic*, following an increase in Ic, the global coverage increases for both RAs and RLs (Graph 2). Moreover, regardless of risk attitude, an increase in the unit price of insurance *p* does not seem to have an impact on either *SIc* (Graph 1) or *GCc* (Graph 2).

Graph 1: Average demand for prevention



Graph 2: Global demand for coverage



The econometric estimates support these graphical insights. *SIc* and *GCc* are estimated as a function of the three independent variables of the experiment: the unit price of insurance p (p=0.05, 0.1, or 0.15), the level of compulsory insurance *Ic* (*Ic*=300, 500, or 700), and the risk attitude RA (RA=1 if individuals are RA, 0 if they are RL). The variables p and *Ic* crossed with risk attitude are also used to account for the influence of risk attitude mediated by the price or level of compulsory insurance. The models are provided by equations (1) and (2).

$$SIc_{ij} = F(a_0 + a_1 p_{ij} + a_2 Ic_{ij} + a_3 RA_{ij} + a_4 RA_{ij} \times p_{ij} + a_5 RA_{ij} \times Ic_{ij}) + \varepsilon_{ij} \text{ with } i = \{1, \dots, 120\}\,;\, j = \{1, \dots, 9\} \quad (1)$$

$$GCc_{ij} = F(b_0 + b_1 p_{ij} + b_2 Ic_{ij} + b_3 RA_{ij} + b_4 RA_{ij} \times p_{ij} + b_5 RA_{ij} \times Ic_{ij}) + \varepsilon_{ij} \text{ with } i = \{1, \dots, 120\}\,;\, j = \{1, \dots, 9\} \quad (2)$$

The index *j* denotes the 9 rounds of the VI step (3 unit prices x 3 levels of compulsory insurance) and *i* stands for the subject. *SIc* is estimated using a tobit left censored (0) and *GCc* using linear regression. The estimates, based on balanced panel data, are provided in Table 7 below. They make apparent the significant contrast between RAs' and RLs' coverage behavior ($a_3, a_5 > 0$ et $b_3, b_5 > 0$). Only RAs substitute the two hedging instruments (Table 7 col. (1)): *SIc* decreases significantly as *Ic* increases (a_2 is non-significant and a_5, $RA \times \bar{I}$'s coefficient is significant and negative). By contrast, RLs' self-insurance demand *SIc* does not vary with *Ic* (a_2 not significant).

Table 7: Estimates

	(1) $\widehat{SI}_c$	(2) $\widehat{GC}_c$
	Coeff (p-value)	Coeff (p-value)
p	190.44 (0.496)	76.12 (0.719)
Ic	-0.068 (0.328)	0.94 (0.000)*
RA	620.63 (0.000)*	518.83 (0.000)*
$RA \times p$	-130.99 (0.682)	-22.90 (0.927)
$RA \times Ic$	-0.452 (0.000)*	-0.452 (0.000)*
Constante	65.48 (0.217)	169.58 (0.000)*
Nb of obs	1170	1170
Nb of groups	130	130
Obs per group	9	9
Nb of left censored obs.	220	
Wald chi2(5)	315.92	675.95
Prob > chi2	0.000	(0.000)

* : 0.001 significant

As a result, *GCc* (Table 7 col. (2)) increases significantly with *Ic* regardless of risk attitude. Indeed, the coefficient of Ic, b_2, is significant and positive for RLs. Similarly, RAs' global coverage increases ($b_2 + b_5 > 0$ significant and positive) because the change in *SIc* (in absolute value) less than offsets that of *Ic* ($|a_2 + a_5| < 1$).[4] Nevertheless, risk attitude results in a significant difference in the global coverage (Table 7 col.(2)): the increase in *GCc* is significantly lower for RAs than for RLs (b_5, coefficient of $RA \times Ic$, significant and negative). Finally, the econometric analysis (Table 7) confirms the graphical intuition that regardless of risk attitude, the demand for coverage is not sensitive to the price of insurance ($a_1, a_4, b_1,$ et b_4 not significant).

Both the graphical observations and econometric estimates support the theoretical predictions provided in Table 4 and argue for CARA utility functions for RAs. The different findings can be summarized by the following propositions:

Observation 1: Supporting our theoretical predictions, data show that an increase in *Ic* affects only RAs' prevention behavior whose demand *SIc* decreases (although less than proportionally |d*SIc*|<|d*Ic*|). As a result, following an increase in *Ic*, GCc rises for both RAs and RLs.

[4] The hypothesis test H0: ($a_2 + a_5$) ≥-1 leads to RH0 (p-value =0.000)

Observation 2: As expected for a CARA utility function, regardless of risk attitude, an increase in the unit price of insurance has no significant effect on either SIc or GCc.

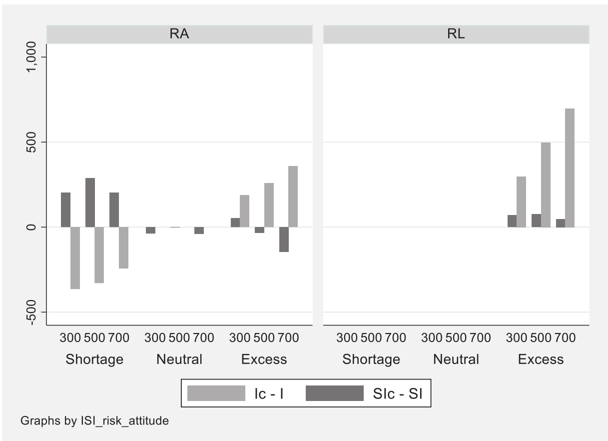
C. VI vs CI step

The comparison between CI and VI steps is meant to identify the situations of shortage (Ic-Iv<0), balance (Ic-Iv=0), or excess of insurance (Ic-Iv>0) induced by the level of compulsory insurance. The analysis of *SIc* makes it possible to understand for the role of self-insurance as an adjustment variable, depending on the situation in the insurance market (shortage, balance or excess in insurance). Our theoretical predictions (see A comparative statics analysis also compares the levels of SI demand and global coverage for situations with voluntary and mandatory insurance. The theoretical expectations are summarized in Table 5. The details of their development are provided in Appendix B.

Table 5) establish that if *Ic* and *SIc* are substitutable for RAs they are complementary for RLs.

In Graph 3 below, the light grey bars show the extent (dI=*Ic*-*Iv*) of the shortage or excess of insurance faced by subjects as a result of compulsory insurance. The dark grey bars represent the magnitude of the prevention adjustment (dSI=*SIc*-*SIv*) made by subjects in response. RAs are shown on the left and RLs on the right. By construction, the insurance obligation can only lead to RLs being over-insured.

Graph 3: RAs' and RLs' SI adjustment



The graph shows remarkable differences between RAs and RLs, as well as between the shortage and excess insurance situations. The non-parametric Wilcoxon tests on paired data provided in Table 8 validate the graphical intuitions and tend to support the predictions of the theoretical model. Columns (1) of Table 8 test the *valence* of the prevention adjustment dSI, according to the situation of shortage or excess faced by the subjects. Columns (2) test the *magnitude* of the adjustment (dSI+dI=0).

Table 8: Wilcoxon matched-pairs signed-rank test

RA	RL

	(1RA) Valence	(2RA) Magnitude	(1RL) Valence	(2RL) Magnitude
	H0 : dSI=0	H0 : dGC=dSI+dI=0[1]	H0 : dSI=0	H0 : dGC=dSI+dI=0[1]
	Z stat (p-value)	Z stat (p-value)	Z stat (p-value)	Z stat (p-value)
Shortage (*Ic*-*Iv*)<0	13.219 (0.000)*	-8.687 (0.000)*	n.a.[2]	n.a.[2]
Balance (*Ic*-*Iv*)=0	-0.708 (0.479)	-0.708 (0.482)*	n.a.[2]	n.a.[2]
Excess (*Ic*-*Iv*)>0	-6.695 (0.000)*	13.335 (0.000)*	5.977 (0.000)*	15.712 (0.000)

*: 0.001 significant
1: dI=*Ic*-I; dSI=*SIc*-SI<=>dSI+dI=dGC
1 : GC=*GCc*-GC
2: n.a. : not applicable

RAs behaviors

Valence adjustment

Column 1RA of Table 8 shows that RAs use *SIc* to adjust their situation (shortage or excess insurance). As in the CI step, *Ic* and *SIc* are substitutes: when the insurance obligation *Ic* leads to insurance rationing (*Ic*-*Iv*<0), subjects compensate by significantly increasing (z=13.219, p-value (0.000)) their investment in *SIc* (*SIc*>*SIv*). On the contrary, an excess of insurance results in a significant decrease (z=-6.695; p-value=0.000) in the demand for self-insurance compared to the VI step. For balanced situations (*Ic*=I), RAs do not significantly modify their investment in SI (p-value=0.479).

Magnitude of the adjustment

Wilcoxon paired-data tests of the equality of *Ic* and *SIc* for RAs (Table 8, column 2RA) show that, in the shortage and excess cases, although RAs adjust *SIc* to compensate for their situation on the insurance market, the adjustments are significantly smaller than those that would maintain the status quo of the VI situation (p-value <0.000 in the shortage and excess cases, Table 8, column 2RA).

This is borne out by the econometric model (3) for estimating RAs' Self-insurance adjustment. dSI is expressed as a function of the insurance market situation (using the dichotomous variables D_Shortage=1 if Shortage (*Ic*<*Iv*) and 0 otherwise and D_Excess=1 if (*Ic*>*Iv*) and 0 otherwise). These two variables are also crossed with the magnitude (dI=*Ic*-*Iv*) of shortage or excess to test the significance of the relationship between then magnitude and valence of the adjustments.

$$dSI_{ij} = a_0 + a_1\text{D\_Shortage}_{ij} + a_2\text{D\_Excess}_{ij} + a_3\text{D\_Shortage}_{ij} \times dI_{ij} + a_4\text{D\_Excess}_{ij} \times dI_{ij} + \varepsilon_{ij} \quad (3)$$

where $i = \{1, \dots, 93\}$; $j = \{1, \dots, 9\}$

As before, j denotes the 9 rounds of the VI step (3 unit-prices x 3 levels of compulsory insurance) and i stands for the subject. dSI is estimated using a balanced panel data linear regression whose results are given in Table 9, column (1).

Table 9: Estimates of dSI

$\widehat{dSI}$	(1) RA	(2) RL
	Coeff (p-value)	Coeff (p-value)
D_Shortage	-6.720 (0.839)	n.a.[1]
D_Excess	-12.921 (0.691)	
dI		-0.057 (0.364)
D_Shortage $\times$ dI	-0.722 (0.000)**	n.a.[1]
D_Excess $\times$ dI	-0237 (0.000)**	
Constant	-0.078 (0.998)	92.588 (0.023)*
Nb of obs	837	333
Nb of groups	93	37
Obs per group	9	9
Wald chi2(1)	463.69	0.82
Prob > chi2	(0.000)	(0.364)
R squared (overall)	0.390	0.0024

** : 0.001 significant
* : 0.05 significant
1 : n.a. : not applicable

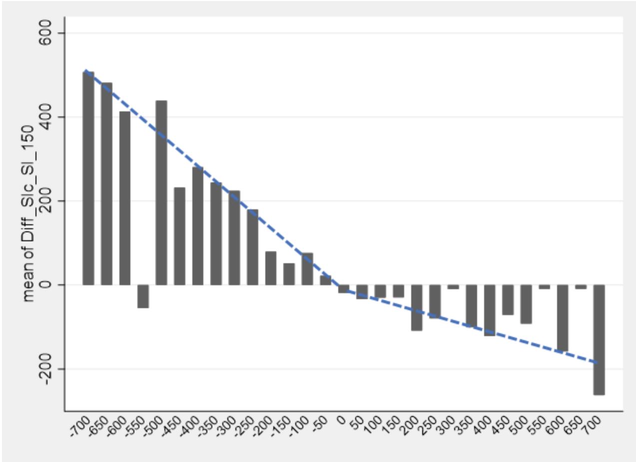
For RAs, only the coefficients of the variables $\text{D\_Shortage} \times |\text{dI}|$ and $\text{D\_Excess} \times |dI|$ are significant. Their negative signs confirm that dSI is negatively related to dI. Whether rationed or over-insured, individuals are less than compensating for the imbalance in the insurance market: $|a_3|$ and $|a_4| < 1$.[5] Moreover, the substitution rate between Ic and SIc is lower in the insurance excess situation than in the shortage situation $|a_4| < |a_3|$: rationed RAs increase SIc more than RAS in excess of insurance reduce their SI demand.[6] The Graph 4 below supports the conclusions of the econometric model: dI and dSI vary in opposite directions, with a slope (in absolute value), and an amplitude, that are higher in the shortage situation than in the excess situation.

The self-insurance adjustment has opposite consequences on RAs' global coverage (cf. Wilcoxon test Table 8, col. 2RA): the global coverage of individuals in the excess insurance situation is significantly higher in the CI step than in the VI step. On the contrary, the global coverage of rationed individuals is significantly lower in the CI situation. As expected, the insurance obligation does not significantly modify the coverage of balanced individuals.

[5] The hypothesis tests $H0$: $a_3 = -1$ and $H0$: $a_4 = -1$ lead to RH0 (p-value =0.000).

[6] In the same way, the hypothesis test $H0$: $a_3 = a_4$ leads to RH0 (p-value =0.000)

Graph 4: RAs: dSI and dI relationship



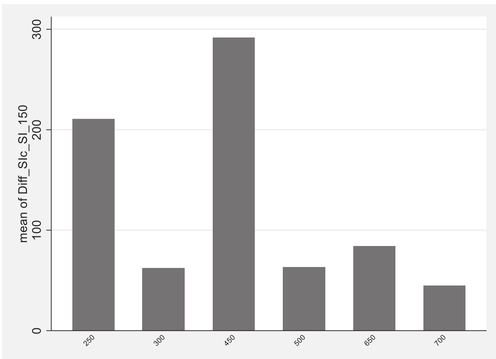
RLs' behaviors: valence and magnitude of the adjustment

By nature, mandatory insurance can only lead to RLs being over-insured.[7] In this situation, Wilcoxon tests show that instead of lowering their demand for self-insurance, RLs significantly *raise* it (cf. z>0 and significant in Table 8, col. 1RL). Thus, in accordance with theoretical predictions, excess insurance leads RLs to *increase* their demand for self-insurance compared to the VI step and, as a result, their global coverage (Table 8 col. 2RL).

Moreover, the adjustment of SI does not appear to follow a particular pattern, as illustrated in Graph 5 and supported by the estimation of the econometric model for the RLs (b_1 non-significant in Table 9 col. 2), whose equation (3) is given below:

$$dSI_{ij} = b_0 + b_1 dI_{ij} + \varepsilon_{ij} \text{ with } i = \{1, \dots, 37\}\,;\, j = \{1, \dots, 9\} \quad (3)$$

Graph 5: RLs: dSI and dI relationship



RAs and RLs react in different ways to mandatory insurance, regarding both the nature of the reaction and its magnitude. The previous graphs and statistical tests establish that while I and SI are substitutable for the RAs, they are complementary for the RLs. The results support the

[7] Recall that a necessary condition for being RL is to never buy insurance in the voluntary insurance step.

theoretical predictions (see A comparative statics analysis also compares the levels of SI demand and global coverage for situations with voluntary and mandatory insurance. The theoretical expectations are summarized in Table 5. The details of their development are provided in Appendix B.

Table 5) and are summarized in the following propositions.

Observation 1: RAs adjust their coverage by increasing (resp. decreasing) SI if the insurance obligation results in an insurance shortage (resp. excess). dSI and dI are of opposite signs. On the other hand, by its very nature, the insurance obligation leads to an excess of insurance for RLs. They react to this excess by *increasing* SI. For RAs, I and SI are *substitutable*, whereas they are *complementary* for RLs.

Observation 2: The magnitude of RAs' adjustment grows with the magnitude of the shortage or excess but less than proportionally (|dSI|<|dI|). The adjustment is significantly smaller under excess insurance than under shortage. On the contrary, the magnitude of RLs' adjustment does not depend on the magnitude of insurance excess.

Observation 3: When compulsory insurance brings individuals, whether RAs or RLs, into a situation of insurance excess, their global coverage increases. On the other hand, when it brings RAs into a shortage situation, their global coverage drops significantly below the global coverage of the VI situation.

4) Discussion and Conclusion

Our within-subject experiment has the significant advantage of measuring the demand for self-insurance when insurance is mandatory or voluntary. The experimental results show that, in the presence of compulsory insurance coverage, the nature of the risk attitude (risk aversion or risk loving) thoroughly guides the prevention behavior. Our graphs and statistical tests show that insurance and self-insurance are substitutable for RAs while complementary for RLs. However, for RAs, although SI varies to approach the voluntary risk coverage, the adjustments are insufficient to maintain the status quo of the unconstrained situation. This raises questions about the effect of moral hazard (crowding out of self-insurance).

A weakened moral hazard effect

Because of the substitution relationship between insurance and self-insurance, the risk of moral hazard is a problem naturally investigated by different authors. However, several recent works point out that the amplitude of this effect is somewhat limited (Botzen et al., 2019; Mol et al., 2020).

Our experimental observations point in the same direction: in the presence of compulsory insurance, a ratchet effect seems to determine the global coverage and, therefore, the demand for SI. Indeed, if the subjects are ready to increase their demand for SI to restore the level of global coverage, they do not reduce it as much as they should when faced with an excess of coverage over what they voluntarily chose.

Finally, the moral hazard effect, attenuated for the RAs, is even more so if we include the RLs since the complementarity observed for these individuals acts in the opposite direction of a crowding out of SI by I.

Lessons for Public Policies

The results of this experiment, and the questioning of the moral hazard effect, plead in favor of compulsory insurance schemes. Indeed, a mandatory insurance ensures coverage for the whole population and avoids the negative externalities resulting from the coverage denial of part of the population. Suppose the insurance coverage is sufficiently broad (inducing an excess of insurance with respect to the first-best optimum achieved in the unconstrained setting). In that case, we expect an increase in the overall coverage of the population (RAs and RLs) for two reasons: a weak I/SI substitution from RAs and an increase in SI from RLs. Thus, the entire population is covered against the risk, and the coverage is more comprehensive.

The presence of complementary insurance coverage does not fundamentally change our analysis. First, if the compulsory insurance overinsures a risk averter, she will not resort to any additional insurance coverage. According to our results, we should observe an increase in the global coverage (due to the weak substitution between I and SI). On the other hand, if our risk averter feels under-insured by the compulsory insurance, she can use the top-up insurance to achieve her first-order optimum of the voluntary setting. For RLs, the presence of top-up insurance has no effect and does not modify the positive results previously highlighted.

Finally, our experimental analysis suggests that the optimal insurance scheme should combine partial compulsory insurance coverage with top-up insurance. If the level of compulsory insurance is not excessive, RAs can achieve their optimum risk coverage by voluntarily investing in self-insurance and top-up insurance. For LRs, compulsory insurance mitigates the negative externality resulting from their insurance denial and encourages them to invest in self-insurance. In this context, a mandatory insurance scheme has no impact on the well-being of RAs. Moreover, it overcomes the negative externality linked to the presence of RLs while encouraging them to invest in prevention.

References

Botzen, W. J. W., Kunreuther, H., & Michel-Kerjan, E. (2019). Protecting against disaster risks: Why insurance and prevention may be complements. *Journal of Risk and Uncertainty*, *59*(2), 151–169. https://doi.org/10.1007/s11166-019-09312-6

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

Corcos, A., Pannequin, F., & Montmarquette, C. (2019). Holt and Laury measures and insurance decisions: A same risk attitude? *Revue Economique*, *70*(6), 1095–1114.

Ehrlich, I., & Becker, G. (1972). Market Insurance, Self-Protection, and Self-Insurance. *Journal of Political Economy*, *80*(4), 623–648.

Mol, J. M., Botzen, W. J. W., & Blasch, J. E. (2020). Risk reduction in compulsory disaster insurance: Experimental evidence on moral hazard and financial incentives. *Journal of Behavioral and Experimental Economics*, *84*, 101500. https://doi.org/10.1016/j.socec.2019.101500

Pannequin, F., & Corcos, A. (2020). Are compulsory insurance and self-insurance substitutes or complements? A matter of risk attitudes. *The Geneva Risk and Insurance Review*, *45*(1), 24–35. https://doi.org/10.1057/s10713-019-00043-x

Pannequin, F., Corcos, A., & Montmarquette, C. (2020). Are insurance and self-insurance substitutes? An experimental approach. *Journal of Economic Behavior & Organization*, *180*, 797–811. https://doi.org/10.1016/j.jebo.2019.05.018

Tversky, A., & Kahneman, D. (1971). Belief in the law of small numbers. *Psychological Bulletin*, *76*(2), 105–110. https://doi.org/10.1037/h0031322

Annexes

A. Insurance premium grids

Tableau 10 : Insurance premium tables

(1) *P*	0	52.5	55	57.5	60	62.5	65	67.5	70	72.5	75	77.5	80	82.5	85	87.5	90	92.5	95	97.5	100
(2) *I*	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000

(1) P (Premium): Insurance cost when *p*=0,05 *C*=50
(2) I (Indemnity): reimbursement in case of damage.

(1) *P*	0	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
(2) *I*	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000

(1) P (Premium): Insurance cost when *p*=0,15 *C*=50
(2) I (Indemnity): reimbursement in case of damage.

(1) *P*	0	57.5	65	72.5	80	87.5	95	102.5	110	117.5	125	132.5	140	147.5	155	162.5	170	177.5	185	192.5	200
(2) *I*	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000

(1) P (Premium): Insurance cost when *p*=0,15 *C*=50
(2) I (Indemnity): reimbursement in case of damage.

B. Theoretical predictions

We detail below all the theoretical predictions that drove the development of the experiment. First, we recall the basic predictions when the decision-maker voluntarily chooses insurance and self-insurance. Second, relying on Pannequin and Corcos (2020), we develop some new comparative statics results tested during the experimental compulsory insurance step.

The theoretical framing of the "voluntary insurance" step of the experiment

We model the decision-making of an individual facing a probability q to lose a monetary amount x_0. To cope with this potential sinister, the decision-maker (DM) can invest in self-insurance and insurance.
Assuming an interior solution, the following presentation of the model neglects the presence of the fixed cost C in the insurance pricing.[8] So, the insurance premium P is equal to $P = pI$, where p represents the unit insurance price, and I the indemnity. Moreover, the DM can complement the insurance coverage with an investment e in self-insurance: by investing a monetary amount e, the DM benefits from a loss reduction equal to $SI(e)$. Following Ehrlich and Becker (1972), the marginal return of self-insurance is decreasing: $SI'(e) > 0$ but $SI''(e) < 0$.
Therefore, the final wealth of a DM investing in both risk management tools is given below:

[8] Pannequin et al. (2020) emphasized the fact that the presence of a fixed cost may trigger the exit from the insurance market. But our experimental design does not rely on any change in the fixed cost (always equal to 50). Therefore, assuming an interior solution to focus on the impacts of p and I_c, we neglect C.

$$\begin{cases} w_{1v} = w_0 - pI - e, \text{in the } no - loss \text{ state} \\ w_{2v} = w_0 - pI - e - x_0 + SI(e) + I, \text{in the } loss \text{ state} \end{cases}$$

And assuming that the DM is an expected utility maximizer, we obtain the following expression to be maximized with respect to I and e :

$$EU = (1-q)u(w_0 - pI - e) + qu(w_0 - pI - e - x_0 + SI(e) + I)$$

Deriving this expression, we obtain the following first-order conditions (FOC):

$$\frac{\partial EU}{\partial I} = -p(1-q)u'(w_{1v}) + (1-p)qu'(w_{2v}) = 0$$

$$\frac{\partial EU}{\partial e} = -(1-q)u'(w_{1v}) + (SI'(e) - 1)qu'(w_{2v}) = 0$$

From these equations, we infer the standard condition defining the optimal investment in self-insurance e^*: $SI'(e^*) = \frac{1}{p}$ (1); while the optimal investment in insurance I^* is set by the following equation: $\frac{u'(w_{1v})}{u'(w_{2v})} = \frac{u'(w_0 - pI^* - e^*)}{u'(w_0 - pI^* - e^* - x_0 + SI(e^*) + I^*)} = \frac{(1-p)q}{p(1-q)}$ (2).

These well-known results provide the theoretical framing of our experiment's "voluntary insurance" step. A straightforward implication of the first equation, $SI'(e^*) = \frac{1}{p}$, is the substitution property between I^* and e^*. From equation (1), when p increases, then e^* increases.

The theoretical framing of the "compulsory insurance" step of the experiment

In the context of compulsory insurance, the subject has only one decision variable, denoted e_c. The self-insurance opportunities and the insurance pricing remain the same. The insurance indemnity I_c is set by the government, and the compulsory insurance premium is equal to $P_c = pI_c$. Therefore, the final wealth is equal to:

$$\begin{cases} w_{1c} = w_0 - pI_c - e_c, \text{in the } no - loss \text{ state} \\ w_{2c} = w_0 - pI_c - e_c - x_0 + SI(e_c) + I_c, \text{in the } loss \text{ state} \end{cases}$$

Accordingly, the individual maximizes the following expected utility:

$EU = (1-q)u(w_0 - pI_c - e_c) + qu(w_0 - pI_c - e_c - x_0 + SI(e_c) + I_c)$,

And the optimal choice of self-insurance is given by the following FOC:

$\frac{\partial EU}{\partial e_c} = -(1-q)u'(w_0 - pI_c - e_c) + (SI'(e_c) - 1)qu'(w_0 - pI_c - e_c - x_0 + SI(e_c) + I_c) = 0$ (3)

This FOC can be rewritten as:

$$\frac{(1-q)u'(w_0 - pI_c - e_c)}{qu'(w_0 - pI_c - e_c - x_0 + SI(e_c) + I_c)} + 1 = SI'(e_c)$$

<u>To assess the impact of compulsory insurance on self-insurance investment and global coverage (I+SI)</u>, we use the optimal solution (I^*, e^*) of the "voluntary insurance" step as a threshold. We distinguish between three cases depending on whether I_c is equal to, greater than, or less than I^*.

(i) If $I_c = I^*$, then $SI'(e_c) = \frac{(1-q)u'(w_0 - pI^* - e_c)}{qu'(w_0 - pI^* - e_c - x_0 + SI(e_c) + I^*)} + 1 = \frac{1}{p}$, and the DM is induced to invest $e_c = e^*$ in self-insurance. In this case, the compulsory insurance scheme replicates the first best optimum.

(ii) If $I_c > I^*$, the DM is over-insured. And as shown in Pannequin and Corcos (2020), the optimal level of e_c decreases with I_c.[9] It follows that $SI'(e_c) > SI'(e^*) = \frac{1}{p}$, and $e_c < e^*$. Then, using the FOC from both optimization problems, we obtain the following inequality:

$$SI'(e_c) = \frac{(1-q)u'(w_{1c})}{qu'(w_{2c})} + 1 > SI'(e^*) = \frac{(1-q)u'(w_{1v})}{qu'(w_{2v})} + 1$$

Therefore, simplifying and developing expressions of final wealth, we get:

$$\frac{u'(w_0 - pI_c - e_c)}{u'(w_0 - pI_c - e_c - x_0 + SI(e_c) + I_c)} > \frac{u'(w_0 - pI^* - e^*)}{u'(w_0 - pI^* - e^* - x_0 + SI(e^*) + I^*)}$$

Denoting $w_{1v} = w_0 - pI^* - e^*$, $w_{2v} = w_0 - pI^* - e^* - x_0 + SI(e^*) + I^*$, for the "voluntary insurance step", and $w_{1c} = w_0 - pI_c - e_c$, $w_{2c} = w_0 - pI_c - e_c - x_0 + SI(e_c) + I_c$, for the "compulsory insurance step", the previous inequality can be rewritten as follows:

$$\frac{u'(w_{1c})}{u'(w_{2c})} > \frac{u'(w_{1v})}{u'(w_{2v})}$$

- First, as a consequence of this inequality, we show that compulsory "over-insurance" ($I_c > I^*$) results in an increase in the global coverage expenditure: $pI_c + e_c > pI^* + e^*$. Indeed, assuming the reverse ($pI_c + e_c \leq pI^* + e^*$), we end up with a violation of the inequality.

  If $pI_c + e_c \leq pI^* + e^*$, it is straightforward that $SI(e_c) + I_c < SI(e^*) + I^*$. As we know that $SI'(e_c) > SI'(e^*) = \frac{1}{p}$, and $e_c < e^*$, we would obtain that $p(I_c - I^*) \leq (e^* - e_c)$. Due to the decreasing returns of the self-insurance technology and the fact that the decrease in *e* is higher than the increase in *pI*, the global coverage would diminish: the rise in insurance coverage would not compensate for the decrease in self-insurance coverage since for $e \in [e_c, c^*]$, $SI'(e_c) > \frac{1}{p}$. Then, with $pI_c + e_c \leq pI^* + e^*$ and $SI(e_c) + I_c < SI(e^*) + I^*$ we would have the following wealth inequalities: $w_{1c} > w_{1v}$ and $w_{2c} < w_{2v}$, which would reverse the expected inequality since the marginal utility is decreasing.
- Second, knowing that $pI_c + e_c > pI^* + e^*$, we prove that $SI(e_c) + I_c > SI(e^*) + I^*$.

  Assuming that $SI(e_c) + I_c = SI(e^*) + I^*$ implies that $w_{1c} < w_{1v}$ and $w_{2c} < w_{2v}$. Then, replacing $SI(e_c) + I_c$ by $SI(e^*) + I^*$, and assuming partial insurance it is easy to realize that the inequality is reversed:

$$\frac{u'(w_0 - pI_c - e_c)}{u'(w_0 - pI_c - e_c - x_0 + SI(e^*) + I^*)} < \frac{u'(w_0 - pI^* - e^*)}{u'(w_0 - pI^* - e^* - x_0 + SI(e^*) + I^*)}$$

  Indeed, under the standard DARA assumption, and by comparison with the right-hand side of the inequality, the denominator of the left-hand side increases

[9] Differentiating equation (3), we find that $\frac{de_c}{dI_c} < 0$.

relatively more than its numerator. The only way to restore the right inequality is to have:

$$SI(e_c) + I_c > SI(e^*) + I^*$$

***Proposition 1**: When the DM faces a situation of compulsory over-insurance, she reacts by decreasing her investment in self-insurance, but both her global coverage $(SI(e_c) + I_c)$ and global coverage expenditure $(pI_c + e_c)$ increase.*

(iii) If $I_c < I^*$, the DM is underinsured and, by symmetry, we obtain Proposition 2.

***Proposition 2**: When the DM faces a situation of compulsory underinsurance, she reacts by increasing her investment in self-insurance, but both her global coverage $(SI(e_c) + I_c)$ and global coverage expenditure $(pI_c + e_c)$ decrease.*

<u>To assess the impact of a change in the unit insurance price (p) on the self-insurance investment (SI) and the global coverage (I+SI)</u>, we differentiate the FOC (3) to calculate the impact on e_c of a change in p. We get, after simplification, the following expression:

$$\frac{de_c}{dp} = -\frac{I_c\left[(1-p)u''(w_{1c}) + (1 - SI'(e_c))qu''(w_{2c})\right]}{(1-p)u''(w_{1c}) + SI''(e_c)qu'(w_{2c}) + (1 - SI'(e_c))^2 qu''(w_{2c})}$$

As $SI'(e_c) > 0$ and $SI''(e_c) < 0$, the denominator is negative. We deduce that:

$$\mathrm{sgn}\left(\frac{de_c}{dp}\right) = sgn\left((1-p)u''(w_{1c}) + (1 - SI'(e_c))qu''(w_{2c})\right)$$

Replacing $(1 - SI'(e_c))$ by $-\frac{(1-q)u\prime(w_{1c})}{qu\prime(w_{2c})}$, we get:

$$\mathrm{sgn}\left(\frac{de_c}{dp}\right) = sgn\left[(1-q)u'(w_{1c})\left[\frac{u''(w_{1c})}{u'(w_{1c})} - \frac{u''(w_{2c})}{u'(w_{2c})}\right]\right]$$

Therefore,

$$\mathrm{sgn}\left(\frac{de_c}{dp}\right) = sgn[-A(w_{1c}) + A(w_{2c}]$$

And finally, assuming a partial global coverage, we obtain Proposition 3:

***Proposition 3**: When the DM faces an increase in the unit insurance price (p), all things being equal, she reacts according to the following pattern:*

$$\begin{cases} \frac{de_c}{dp} = 0 \text{ if her utility function is CARA} \\ \frac{de_c}{dp} > 0 \text{ } if \text{ her utility function is DARA} \end{cases}$$