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ORIGINAL PAPER

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

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Abstract

Although compulsory insurance mitigates the negative externalities caused by uninsured individuals, it raises the issue of insurance crowding out prevention. However, at the theoretical level, *compulsory insurance* and *self-insurance* (preventive investments dedicated to loss reduction) are know to be substitutes for risk averters but *complements* for risk lovers. This paper aims to empirically test these opposite predictions through a laboratory experiment using a model-based design. Our experimental results confirm the theoretical predictions: compulsory insurance and self-insurance are complements for risk lovers and substitutes for risk averters. This study strongly supports public policies advocating mandatory insurance implementation as they enhance risk lovers' self-insurance investments. Therefore, a risk management scheme combining voluntary top-up and compulsory partial insurance guarantees an optimal risk allocation for risk-averters and increases the investments in self-insurance for risk-lovers.

Keywords: Complementarity; Compulsory insurance; Experiment; Risk-attitudes; Self-insurance; Substitutability

JEL Codes: C91; D81; G22; I38

1. Introduction

The increasing incidence of natural disasters raises questions about the ability of coverage schemes (insurance and prevention) to manage these risks effectively. Mandatory insurance has become a common risk mitigation strategy used by public authorities in most insurance markets including health, automobile, liability, and housing. It aims to protect vulnerable people without exclusion and to avoid the negative externalities imposed on the insured by the uninsured. However, while the economic and social importance of such policies is well recognized, studies investigating the relationship between *voluntary* insurance and self-insurance raise concerns about the potential adverse effects of compulsory insurance on self-insurance. Indeed, both the theoretical literature (Ehrlich & Becker, 1972) and empirical evidence (Carson et al., 2013) show that the presence of *voluntary* insurance *undermines* self-insurance and self-protection investments. Pannequin et al. (2020) experimentally confirm the substitutability between voluntary insurance and self-insurance, albeit weaker than theoretically expected.

Compulsory insurance thus raises the question of its potential negative effects on self-insurance behavior. For risk averters, if the substitutability observed between voluntary insurance and self-insurance were to be extended to the context of compulsory insurance, compulsory insurance could lead to the crowding out of self-insurance by insurance. Concerns about compulsory insurance, however, also relate to the prevention behavior of risk-lovers whose presence in the population is well documented (Chakravarty & Roy, 2009; Cohen et al., 1987; Corcos et al., 2017; Kahneman & Tversky, 1979; Noussair et al., 2014). Theoretical predictions for risk-lovers under a voluntary insurance context can not hold when insurance is compulsory as they choose not to buy any insurance coverage when insurance is voluntary, but have no choice but to be insured when insurance is mandatory.

On these issues, the theoretical model of Pannequin and Corcos (2020) shows that, as in the case of voluntary insurance, risk-averters substitute compulsory insurance for self-insurance. In particular, they reduce their investment in self-insurance as the level of compulsory insurance increases. The theoretical model also shows that risk-averters adjust their self-insurance investment based on their position in the insurance market. If compulsory insurance results in an insurance shortfall compared to the voluntary insurance context, they increase their demand for self-insurance. Conversely, if compulsory insurance results in an insurance surplus, their demand for self-insurance decreases. By contrast, Pannequin and Corcos (2020) model shows that when insurance is *mandatory*, risk lovers *increase* their investment in self-insurance compared to the *voluntary* insurance context.

Therefore, studying the impact of compulsory insurance on individual prevention behaviors is an important issue given its prevalence on insurance markets. As a contribution to this debate, this paper proposes an experimental test of the effect of compulsory insurance on individuals' self-insurance efforts. We designed a theory-driven laboratory experiment to test Pannequin and Corcos (2020) theoretical model. The results support the model's predictions, showing that compulsory insurance and self-insurance are *substitutes* for risk-averters but *complements* for risk-lovers. Additionally, our data show that risk-averse individuals do not fully compensate for their excess or shortage in insurance coverage through self-insurance adjustments. We use the methodology of Corcos et al. (2019) to distinguish between risk-loving and risk-averse individuals.

The following section describes the experimental design in detail. Section 2 briefly presents the theoretical results on the effect of compulsory insurance on the prevention behavior of risk averters and risk lovers. Section 3 presents the experimental results, and section 4 concludes the paper.

2. Experimental design

2.1. A two-step hedging decision

The experimental design extends Pannequin et al.'s (2020) to compulsory insurance. In this two-step experiment, subjects face a q = 10% risk of losing their entire endowment of 1000 UME in each round. To cover this risk, they can invest at the beginning of the round in a prevention activity whose cost e depends on the desired self-insurance (SI) level. Figure 1 below shows the increasing and concave relationship between e and SI, which remains unchanged throughout the experiment.

To cover their losses and in addition to self-insurance, the subjects can also buy insurance, which, depending on the step, is *compulsory* (Compulsory Insurance step CI) or *voluntary* (Voluntary Insurance step VI).

2.1.1. Compulsory Insurance step

In the Compulsory Insurance step, the insurance levels are set for the subjects in exchange for a compulsory premium $\bar{P} = pI_c + 50$ paid at the beginning of the round, the subject receives an indemnity I_c in case of damage. Participants are asked to choose their desired level of self-insurance SI. A random draw is then performed to determine the occurrence of the accident. Depending on whether a loss occurred during the round, the subject's payoff for the round is as follows, with $W_L \leqslant 1000$:

$$W_{\bar{L}} = 1000 - e - \bar{P}$$

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

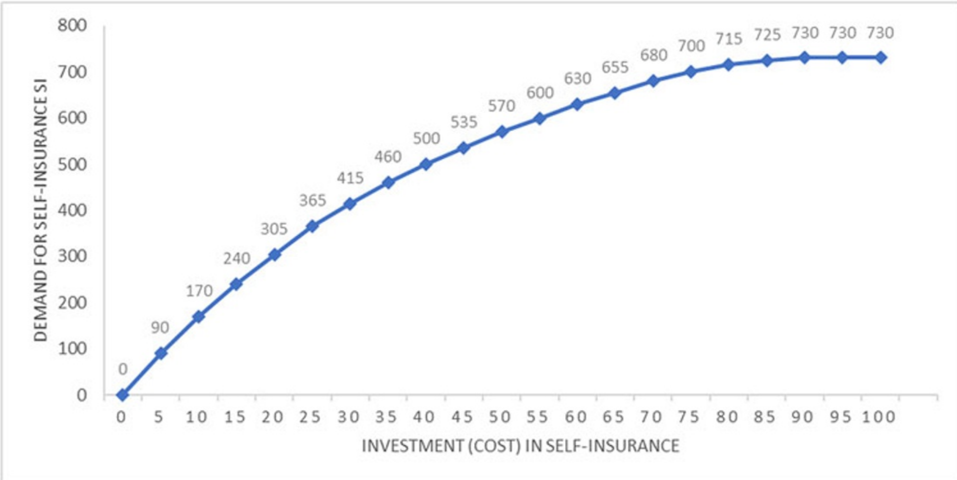

Fig. 1 Increasing and concave relationship between cost and investment in self-insurance

Table 1 Compulsory insurance premiums $\overline{P}$

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

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: $W_L \leqslant 1000$.

This round is repeated nine times, corresponding to as many insurance premiums $\bar{P}$: three levels of compulsory insurance *Ic* crossed with three unit-price *p* of insurance: actuarial, under- and over-actuarial price. Table 1 below shows the nine compulsory insurance premiums.

2.1.2. *Voluntary Insurance* step

In the Voluntary Insurance (VI) step, in addition to their prevention investment, the subjects can voluntarily determine the amount of insurance they need.[1] An example of an insurance rate is given in Fig. 2 where p is actuarial (p = q = 10%) and the fixed cost C = 50 UME.

In the Voluntary Insurance step, the round is played three times, corresponding to three different insurance prices: actuarial (p = 10%), below (p = 5%) and above (15%) the actuarial unit insurance price. The fixed cost (C = 50 UME) remains unchanged. The corresponding grids are shown in tables Table A1, A2 and A3. Again, once the levels of self-insurance and insurance are chosen, a random draw of the accident event is performed and the subjects' earnings for the round are as follows, with $W_A \leqslant 1000$:

$$W_{\bar{L}} = 1000 - e - P$$

$$W_L = 1000 - e - P - 1000 + SI + I$$

[1] Assuming, as before, that the wealth in the event of an accident does not exceed their initial wealth: $W_L \leqslant 1000$.

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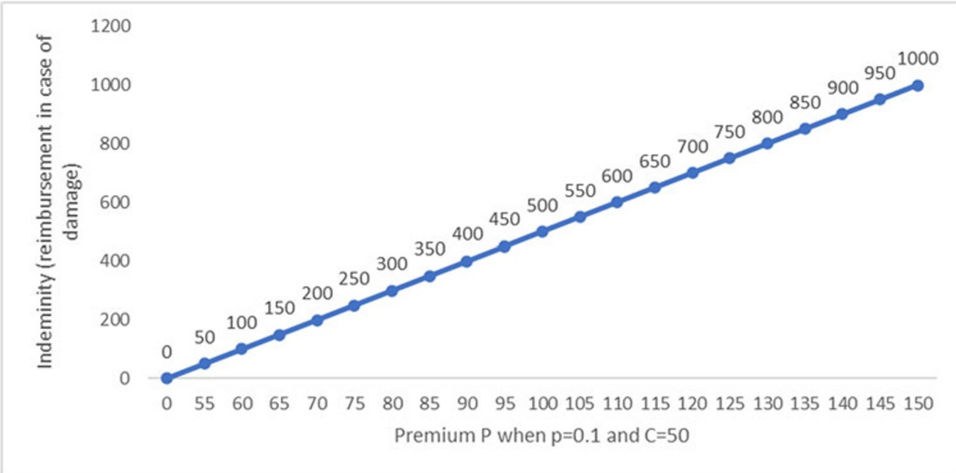

Fig. 2 Increasing linear relationship between P and I

2.2. *Timing of the experiment*

To avoid any order effect, Voluntary and Compulsory Insurance steps are randomly balanced. Within each step, the rounds are randomized. Furthermore, to prevent a gambler's fallacy effect (Tversky & Kahneman, 1971), the outcome of the rounds (loss versus no loss) is not revealed to the subjects until the end of the experiment.

2.3. *Incentives*

Subjects are given a show-up fee of $CAD 10. In addition, at the end of the experiment, one of the 12 rounds of the Compulsory Insurance and Voluntary Insurance steps is drawn, played, and the subject is provided with the round payoff that depends both on whether an accident occurred during the period and on the insurance and prevention decisions made by the subject during that round. The conversion rate for EMUs to Canadian dollars is 1 EMU = 1 cent. Subjects are informed of the payoff terms in advance.

3. Theoretical predictions

Tables 2 and 3 below summarize the theoretical results of the Pannequin and Corcos (2020) model underlying the experiment. Appendix B presents the theoretical results developed specifically for the purpose of this paper. The model focuses on the prevention and insurance demand of individuals exposed to a risk q of losing their wealth. Two coverage schemes are considered: One where insurance is mandatory for individuals (Compulsory Insurance step). The second allows individuals to choose both the insurance and prevention levels that maximize their utility (Voluntary Insurance step).

3.1. *Compulsory Insurance step*

The theoretical model investigates the optimal self-insurance demand (SIc) and the global coverage (GCc) of individuals faced with mandatory insurance. The effect of increasing the level of compulsory insurance and varying the unit price of insurance on prevention behavior is studied using comparative static analysis. In addition to analyzing risk averters' (RAs) behavior, the model also examines risk

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Table 2 Theoretical predictions of the Compulsory Insurance step

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

a ↗ if DARA (Decreasing Absolute Risk Aversion); → if CARA (Constant Absolute Risk Aversion).
b: indeterminate.

Table 3 Theoretical predictions of the self-insurance adjustment to shortage or excess in insurance

		(Ic-Iv)	
		Shortage < 0	Excess > 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	$\geqslant 0$
	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.

lovers' (RLs) behavior. The theoretical predictions are summarized in Table 2, columns 1 and 2, for risk averters and risk lovers, respectively.

3.2. Comparison between Compulsory and Voluntary Insurance steps

A comparative static analysis also compares the levels of self-insurance demand and global coverage for voluntary and compulsory insurance situations. The theoretical expectations are summarized in Table 3. A detailed development of the theoretical model results is presented in Appendix B.

4 Results

A total of 150 people participated in the experiment, which took place in Montreal in 2021. The sample consisted of 86 women and 64 men with an average age of 24. The earnings were about $CAD 18 for the 30 or 40 minutes of the experiment.

4.1. Risk attitude

Based on the methodology developed by Corcos et al. (2019), the insurance and prevention demands (I, SI) of the Voluntary Insurance (VI) step are used to elicit subjects' risk attitudes (risk-averters and risk-lovers). Basically, any subject who does not purchase insurance in any of the three rounds of the Voluntary Insurance step is classified as risk-lover (RL). The others are referred to as risk-averters (RAs). The revealed choices of insurance and self-insurance are then used to identify risk-averse individuals whose insurance and prevention choices are inconsistent.[2] For example, individuals who

[2]Our experiment is designed in such a way that no insurance contract offers an overall below-actuarial insurance rate. Indeed, a C = 50 UME fixed cost makes the premium P at least actuarial (even if the unit price of insurance p is less than

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Table 4 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

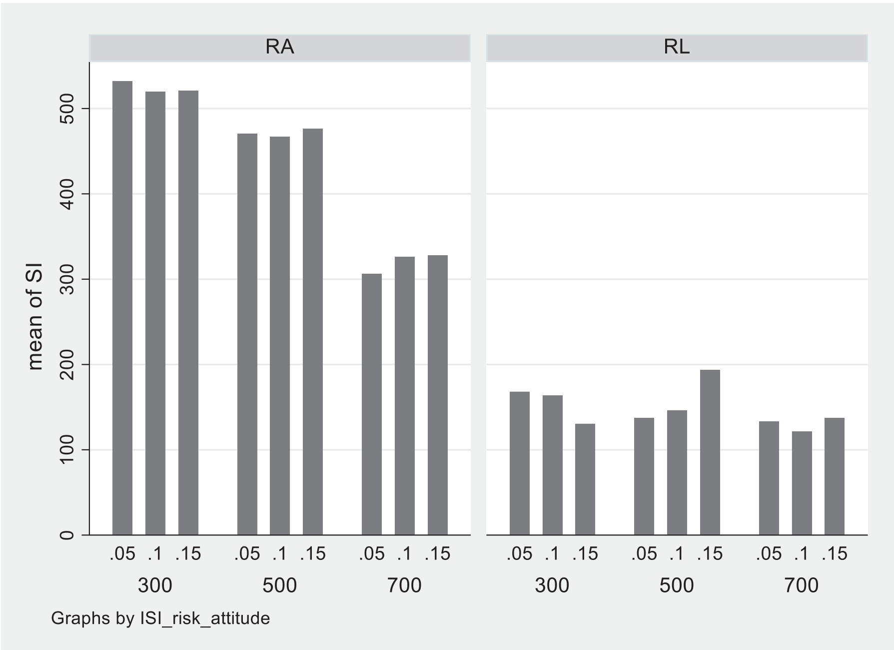

Fig. 3 Average demand for self-insurance

always purchase insurance except when the price is less than the actuarial price are considered inconsistent, as are individuals who self-insure only when it is less advantageous (i.e., when the insurance price is less than the actuarial price).

Following this methodology (see Table 4), of the 150 subjects in our sample, 93 are classified as risk averters, 37 as risk lovers, and 20 as inconsistent. Only the behavior of risk averters and risk lovers (71.5% and 28.5% of the consistent subjects, respectively) is then examined.

4.2. Compulsory Insurance step: what are the effects of an increase in compulsory insurance ic on self-insurance demand sic?

In the Compulsory Insurance (CI) step, we examine how p (insurance price) and Ic (Compulsory Insurance level) affect the self-insurance decisions SIc of the subjects. The figures below show SIc (Fig. 3) and GCc (Fig. 4) as p and Ic vary. Their analysis highlights some salient facts.

For risk averters, a substitution mechanism between insurance and self-insurance is suggested by the decrease in SIc as Ic increases (see the left side of Fig. 3). On the contrary, the demand for self-insurance of risk-lovers does not seem to vary with increasing mandatory levels of insurance (see

actuarial). Therefore, in the ISI classification method, individuals who do not buy insurance in any of the three rounds of this phase are classified as risk lovers. For more details, see. Corcos et al. (2019).

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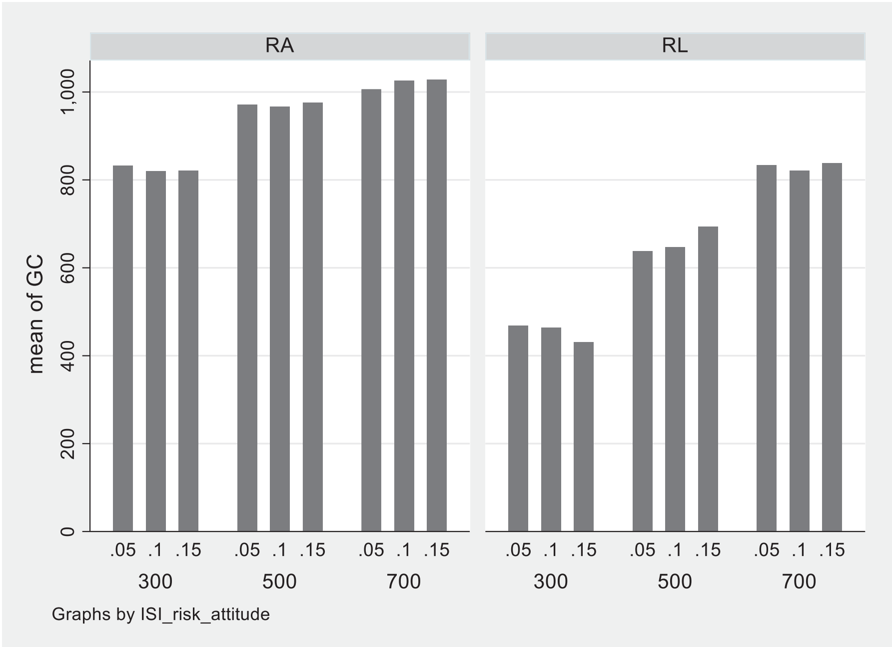

Fig. 4 Global demand for coverage

the right side of Fig. 3). As a result, for both risk attitudes, global coverage increases as the mandatory insurance level increases (Fig. 4). It means that for risk averters, the decrease in self-insurance demand does not offset the increase in compulsory insurance. Furthermore, increasing the unit price of insurance p does not seem to affect either the demand for self-insurance (Fig. 3) or the global coverage (Fig. 4), regardless of risk attitude.

The econometric estimates support these graphical results. Self-insurance demand *SIc* and global coverage *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 risk averters, 0 if they are risk lovers). 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 given by equations (1) and (2).

$$SIc_{ij} = F(a_0 + a_1 p_{ij} + a_2 Ic_{ij} + a_3 RA_{ij} + a_4 RA_{ij} \times p_{ij} + a_5 RA_{ij} \times Ic_{ij}) + \varepsilon_{ij} \tag{1}$$

with $i = \{1, \ldots, 120\}$; $j = \{1, \ldots, 9\}$

$$GCc_{ij} = F(b_0 + b_1 p_{ij} + b_2 Ic_{ij} + b_3 RA_{ij} + b_4 RA_{ij} \times p_{ij} + b_5 RA_{ij} \times Ic_{ij}) + \varepsilon_{ij} \tag{2}$$

with $i = \{1, \ldots, 120\}$; $j = \{1, \ldots, 9\}$

Index j denotes the 9 rounds of Voluntary Insurance step (3 unit prices x 3 compulsory insurance levels) and i denotes subject. *SIc* is estimated using a Tobit left censored (0), while *GCc* is estimated using linear regression. The estimates, based on balanced panel data, are presented in Table 5 below. They show the significant contrast between the hedging behavior of risk averters and risk lovers ($a_3, a_5 > 0$ et $b_3,\ b_5 > 0$). Only risk averters substitute the two hedging instruments (Table 5 column (1)): *SIc* decreases significantly as *Ic* increases (a_2 is not significant and a_5, the coefficient of $RA \times \bar{I}$

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Table 5 Estimates

	(1) $\widehat{SI}_c$ Coeff (p-value)	(2) $\widehat{GC}_c$ 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.

is significant and negative). In contrast, for risk lovers, their self-insurance demand *SIc* does not vary with the level of compulsory insurance *Ic* (a_2 not significant).

As a result, the global coverage *GCc* (Table 5, column (2)) increases significantly with the level of compulsory insurance *Ic*, regardless of the risk attitude. Indeed, the coefficient of *Ic*, b_2, is significant and positive for risk lovers. Similarly, the global coverage of risk averters increases ($b_2 + b_5 > 0$ significant and positive) because the change in self-insurance *SIc* (in absolute value) less than offsets that of compulsory insurance *Ic* ($|a_2 + a_5| < 1$).[3] Nevertheless, the risk attitude leads to a significant difference in the global coverage (Table 5, column(2)): its increase is significantly lower for risk averters than for risk lovers (b_5, coefficient of $RA \times Ic$, significant and negative). Eventually, the econometric analysis (Table 5) confirms the graphical intuition that the demand for coverage is not sensitive to the price of insurance, whatever the risk attitude (a_1, a_4, b_1, et b_4 not significant).

Both the graphical observations and the econometric estimates support the theoretical predictions presented in Table 2 and do not refute the CARA utility assumption for risk averters. The results can be summarized in the following propositions:

Observation 1: In support of our theoretical predictions, the data show that an increase in compulsory insurance *Ic* only affects the prevention behavior of risk averters whose prevention demand *SIc*

[3] The hypothesis test H0: $(a_2 + a_5) \geqslant$-1 leads to RH0 (p-value = 0.000).

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decreases (although less than proportionally $|dSIc| < |dIc|$). As a result, after an increase in *Ic*, the global coverage GCc increases for both risk averters and risk lovers.

Observation 2: Regardless of risk attitude, an increase in the unit price of insurance has no significant effect on either SIc or GCc.

4.3. *Voluntary Insurance vs Compulsory Insurance steps*

The comparison between Compulsory Insurance and Voluntary Insurance steps helps identify situations of insurance shortage (Ic-Iv < 0), balance (Ic-Iv $= 0$), or excess of insurance (Ic-Iv > 0) caused by the level of compulsory insurance. Analyzing the demand for self-insurance *SIc* explains how self-insurance serves as an adjusting variable depending on shortage, balance, or excess in the insurance market. Our theoretical predictions, as shown in Tables 2 and 3, indicate that, in a context of compulsory insurance, if insurance and self-insurance are substitutes for risk averters, they are complements for risk lovers.

Figure 5 below displays the extent (dI $=$ *Ic-Iv*) of the surplus or deficit of insurance faced by subjects due to compulsory insurance as indicated by the light grey bars. The dark grey bars indicate the magnitude of prevention adjustments (dSI $=$ *SIc-SIv*) made by subjects in response. The left side of Fig. 5 shows risk averters while the right displays risk lovers. It should be noted that the insurance obligation can only result in risk lovers being over-insured.

Figure 5 displays significant distinctions between risk averters and risk lovers, as well as between the situations of shortage and excess insurance. The non-parametric Wilcoxon tests on paired data presented in Table 6 validate the graphical intuitions and support the theoretical model's predictions. Columns (1) of Table 6 test the *valence* of the prevention adjustment dSI, based on whether the subjects were facing a shortage or excess situation. Columns (2) test the *magnitude* of the adjustment (dSI $+$ dI $= 0$).

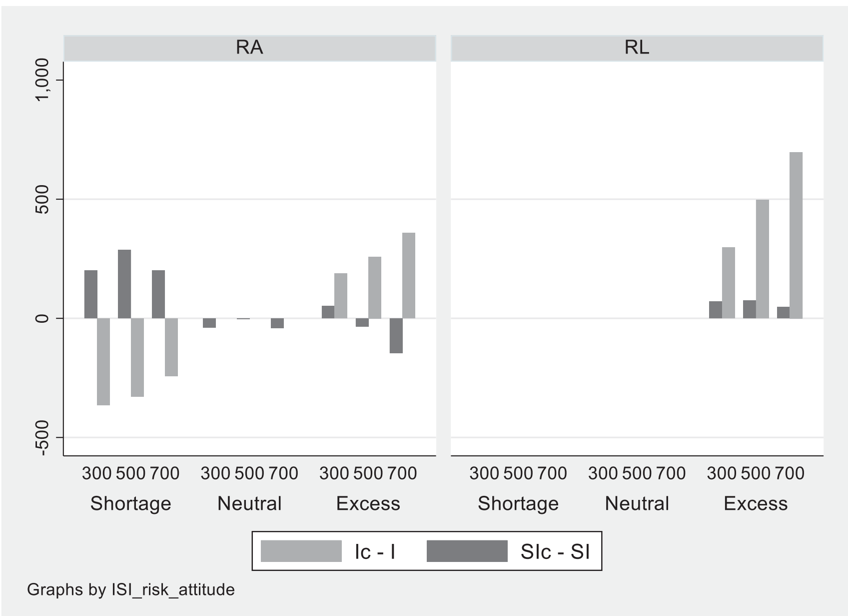

Fig. 5 Self-insurance adjustment

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Table 6 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.

4.3.1. Risk averters' behaviors: Valence and Magnitude of the adjustment

Valence adjustment

Column 1RA in Table 6 indicates that risk averters use self-insurance opportunities to adjust their insurance situation (shortage or excess) when insurance is mandatory. Self-insurance *SIc* and insurance *Ic* are substitutes, as seen in the Compulsory Insurance step. When the insurance obligation *Ic* leads to insurance rationing (*Ic*-*Iv* < 0), the subjects respond by significantly increasing their investment in self-insurance *SIc* (*SIc* > *SI*, with z = 13.219, p-value (0.000)). Conversely, if there is an excess of insurance, the demand for self-insurance decreases significantly (z = − 6.695; p-value = 0.000) when compared to the Voluntary Insurance step. For balanced situations (*Ic* = I), risk averters do not make significant modifications to their investment in SI (p-value = 0.479).

Magnitude of the adjustment

Results of Wilcoxon paired data tests on the equality of insurance and self-insurance levels (*Ic* and *SIc*) for risk averters (Table 6, column 2RA) indicate that, in shortage and surplus situations, risk averters make adjustments to their self-insurance demand SIc to accommodate their insurance market situation. However, these adjustments are significantly smaller than those required to maintain the Voluntary Insurance step's status quo (p-value < 0.000 as seen in Table 6, column 2RA).

This is supported by the econometric model (3) which estimates the self-insurance adjustment of risk averters. The change in self-insurance (dSI) is a function of the insurance market situation, determined by the dichotomous variables D_Shortage and D_Excess. D_Shortage equals 1 in cases of shortage where *Ic* < *Iv* and 0 otherwise, while D_Excess equals 1 in cases of excess where *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 the magnitude and the 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 previously stated, j refers to the nine rounds of the Voluntary Insurance step (3 unit prices x 3 levels of compulsory insurance) and i refers to the subject. dSI is estimated using a balanced panel data linear regression and the results are presented in Table 7, column (1).

Only the coefficients of the variables D_Shortage × |dI| andD_Excess × $|dI|$ are significant for risk averters. The negative signs of these coefficients confirm the negative relationship between self-insurance and insurance adjustements (dSI and dI). Regardless of being rationed or overinsured, individuals do not compensate for the imbalance in the insurance market as both $|a_3|$ and $|a_4|$ are

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Table 7 Estimates of dSI

$\widehat{dSI}$	(1) *RA* Coeff (p-value)	(2) *RL* 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 × *dI*	−0.722 (0.000)**	n.a.[1]
D_Excess × *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.

less than 1.[4] In the situation of insurance surplus, the substitution rate between Ic and SIc is lower compared to the insurance shortage situation: $|a_4| \langle |a_3|$. Rationed risk averters increase their demand for self-insurance SIc more than overinsured risk averters decrease it.[5] Fig. 6 below confirms the findings of the econometric model: dI and dSI change in opposite directions. The slope (absolute value) and amplitude of dSI are higher in the shortage situation than in the surplus situation.

The adjustment of self-insurance has opposite effects on the overall coverage of risk averters (cf. Wilcoxon test Table 6, column 2RA): individuals with excess insurance have significantly higher global coverage in the Compulsory Insurance step than in the Voluntary Insurance step. Conversely, the global coverage of rationed individuals is significantly lower in the Compulsory Insurance situation. As expected, the insurance obligation does not significantly modify the coverage of balanced individuals.

4.3.2. *Risk lovers' behaviors: Valence and magnitude of the adjustment*

Compulsory insurance naturally leads to overinsuring risk lovers.[6] Wilcoxon tests reveal that instead of decreasing, risk lovers actually *increase* their demand for self-insurance (cf. $z > 0$ and significant in Table 6, column 1RL). In line with theoretical predictions, excess insurance spurs risk lovers to *raise*

[4]The hypothesis tests $H0: a_3 = -1$ and $H0: a_4 = -1$ lead to RH0 (p-value = 0.000).
[5]Likewise, the hypothesis test $H0: a_3 = a_4$ leads to RH0 (p-value = 0.000).
[6]Recall that a necessary condition for being a risk lover is to never buy insurance in the voluntary insurance stage.

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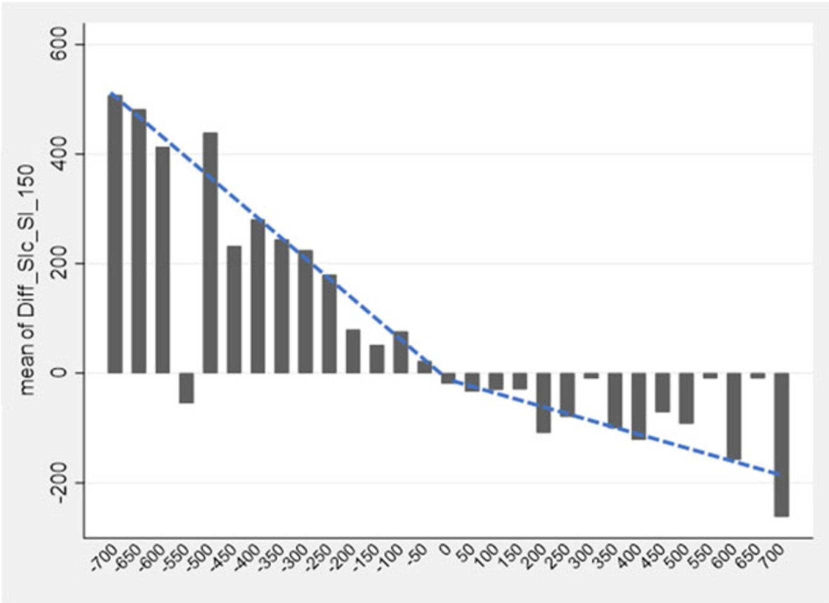

Fig. 6 Risk averters: dSI and dI relationship

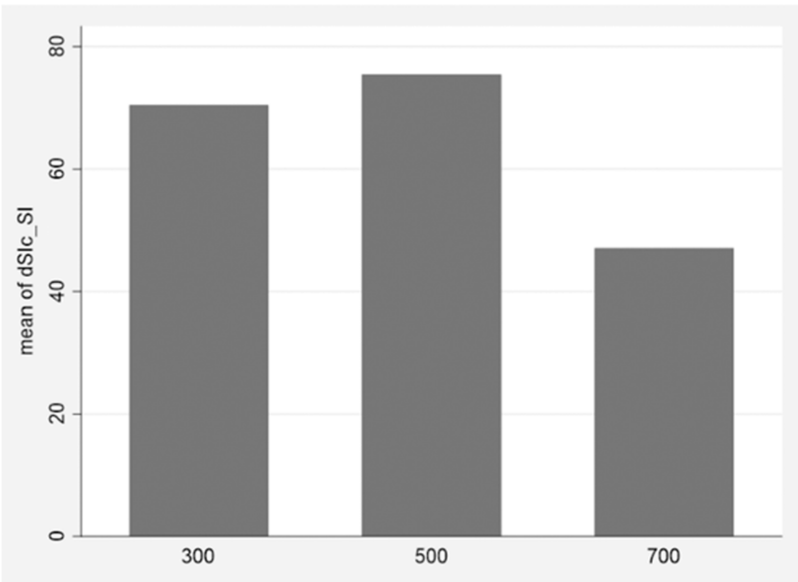

Fig. 7 Risk lovers: dSI and dI relationship

their demand for self-insurance relative to the Voluntary Insurance step and, as a consequence, their overall coverage (Table 6, column 2RL).

Furthermore, the adjustment of self-insurance (SI) lacks a clear pattern, as shown in Fig. 7 and supported by the econometric model estimation for the risk lovers (b_1 not significant in Table 7, column 2). Equation (3) pertaining to the model is provided below:

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$$dSI_{ij} = b_0 + b_1 dI_{ij} + \varepsilon_{ij} \text{ with } i = \{1, \ldots, 37\}\ ; j = \{1, \ldots, 9\} \tag{3}$$

Risk averters and risk lovers exhibit different responses to mandatory insurance, with variations in both the nature and extent of their reactions. The previous statistical tests and graphs indicate that insurance and self-insurance are substitutes for risk averters, but complements for risk lovers. These findings are consistent with our theoretical predictions (see Table 3) and can be summarized in the following propositions.

Observation 1: Risk averters adjust their coverage by increasing or decreasing insurance when there is a shortage or excess of insurance, respectively (dSI and dI have opposite signs). Conversely, the insurance obligation leads to an excess of insurance coverage for risk lovers. They respond to this excess by *increasing* their demand for self-insurance. For risk averters, insurance and self-insurance are *substitutes*, while for risk lovers they are *complements*.

Observation 2: Risk averters adjust the size of their coverage in order to address the issue of underinsurance or overinsurance. However, this adjustment is not made on a proportional basis ($|dSI| < |dI|$). Moreover, the adjustment for shortage is greater than that for excess insurance. On the other hand, risk lovers' adjustment size does not depend on the insurance excess.

Observation 3: Mandatory insurance increases the global coverage of individuals, whether risk averters or risk lovers, when it causes them to have excess insurance. On the other hand, if risk averters experience an insurance shortage, their overall coverage decreases substantially compared to the coverage in the Voluntary Insurance situation.

5. Discussion and conclusion

Our within-subjects experiment examines the demand for self-insurance when insurance is mandatory or voluntary. Experimental results suggest that individuals' risk attitudes significantly influence their prevention behavior. Our statistical tests and graphs reveal that insurance and self-insurance are substitutes for risk-averters and complements for risk-lovers under mandatory insurance. However, even though risk-averse individuals adjust their self-insurance to match the level of voluntary risk coverage, these adjustments do not provide enough protection to maintain the same level of coverage as in an unconstrained situation. This observation raises concerns about the possibility of crowding out self-insurance.

5.1. A weak crowding-out effect

Our data shows a relatively mild crowding-out effect for risk averters. When presented with either a deficit or surplus in insurance, these participants adjust their self-insurance demands. However, this response does not entirely offset the initial misadjustment, as illustrated by the behavior of overall coverage. Furthermore, a desirable aspect of the substitution behavior among risk averters is its asymmetry: When faced with excess insurance, they reduce their self-insurance investment less intensively compared to their increase in the presence of an insurance shortage. This behavioral trait serves as a natural brake on the crowding-out effect of prevention.

On the other hand, for risk lovers, the observed complementarity between insurance and self-insurance is at odds with the idea that insurance crowds out self-insurance.

5.2. Lessons for public policies

Our research supports the need for mandatory insurance as it ensures universal coverage while preventing the negative impacts that arise when segments of the population are left uninsured. Suppose

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the level of compulsory insurance is high enough to induce a level of insurance above the first-best optimum achieved in the unconstrained setting. In that case, we expect an increase in the overall coverage of the population (risk averters and risk lovers) under a twofold effect: a weak substitution between insurance and self-insurance for risk averters and an increase in self-insurance for risk lovers. Overall, mandatory insurance guarantees coverage for the entire population while providing more comprehensive coverage.

The presence of voluntary complementary insurance coverage would not drastically alter our analysis. If compulsory insurance overinsures risk-averse individuals, they are unlikely to buy supplementary insurance. We should observe an increase in global coverage (due to the weak substitution between insurance and self-insurance). On the other hand, if the mandatory insurance level falls short compared to the voluntary insurance regime, risk-averse individuals may opt for additional coverage through complementary insurance to achieve their optimal level of voluntary insurance. For risk lovers, complementary insurance has no impact and does not modify the abovementioned results.

Finally, our experimental analysis suggests that an optimal insurance scheme should combine partial compulsory insurance coverage with top-up insurance. Risk averters can achieve their optimal risk coverage by voluntarily investing in self-insurance and top-up insurance if mandatory insurance is not excessive. Compulsory insurance mitigates the negative externality of risk lovers' refusal to insure, and encourages them to invest in self-insurance. In this context, a mandatory insurance program does not affect the well-being of risk-averse individuals. However, it does address the negative externality caused by the presence of risk lovers and encourages them to focus on prevention.

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Annexes Insurance premium grids

Table A1 Insurance premium tables

(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.

Table A2

(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.

Table A3

(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.

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.[7] 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:

$$\left[\begin{array}{l} w_{1v} = w_0 - pI - e,\ \textit{in the no} - \textit{loss state} \\ w_{2v} = w_0 - pI - e - x_0 + SI\,(e) + I,\ \textit{in the loss state} \end{array}\right.$$

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^*: $SI'\left(e^*\right) = \frac{1}{p}$ (1); while the optimal investment in insurance I^* is set by the following equation: $\frac{u'(w_{1v})}{u'(w_{2v})} = \frac{u'\left(w_0 - pI^* - e^*\right)}{u'\left(w_0 - pI^* - e^* - x_0 + SI\left(e^*\right) + I^*\right)} = \frac{(1-p)q}{p(1-q)}$ (2).

[7] 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.

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These well-known results provide the theoretical framing of our experiment's 'voluntary insurance' step. A straightforward implication of the first equation, $SI'\left(e^*\right) = \frac{1}{p}$, 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:

$$\left[\begin{array}{l} w_{1c} = w_0 - pI_c - e_c, \ \textit{in the no} - \textit{loss state} \\ w_{2c} = w_0 - pI_c - e_c - x_0 + SI\left(e_c\right) + I_c, \ \textit{in the loss state} \end{array}\right.$$

Accordingly, the individual maximizes the following expected utility:

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

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

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

This FOC can be rewritten as:

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

To assess the impact of compulsory insurance on self-insurance investment and global coverage (I±SI), 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 $SI'\left(e_c\right) = \frac{(1-q)u'\left(w_0 - pI^* - e_c\right)}{qu'\left(w_0 - pI^* - e_c - x_0 + SI(e_c) + I^*\right)} + 1 = \frac{1}{p}$, 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 overinsured. And as shown in Pannequin and Corcos (2020), the optimal level of e_c decreases with I_c.[8] It follows that $SI'\left(e_c\right) > SI'\left(e^*\right) = \frac{1}{p}$, and $e_c < e^*$. Then, using the FOC from both optimization problems, we obtain the following inequality:

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

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

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

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

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

– 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 $\left(pI_c + e_c \leqslant pI^* + e^*\right)$, we end up with a violation of the inequality.

If $pI_c + e_c \leqslant pI^* + e^*$, it is straightforward that $SI\left(e_c\right) + I_c < SI\left(e^*\right) + I^*$. As we know that $SI'\left(e_c\right) > SI'\left(e^*\right) = \frac{1}{p}$, and $e_c < e^*$, we would obtain that $p\left(I_c - I^*\right) \leqslant \left(e^* - e_c\right)$. 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:

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

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The rise in insurance coverage would not compensate for the decrease in self-insurance coverage since for $e \in [e_c, e^*]$, $SI'(e_c) > \frac{1}{p}$. Then, with $pI_c + e_c \leqslant pI^* + e^*$ and $SI(e_c) + I_c < SI\left(e^*\right) + I^*$ 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 $SI(e_c) + I_c > SI\left(e^*\right) + I^*$. Assuming that $SI(e_c) + I_c = SI\left(e^*\right) + I^*$ implies that $w_{1c} < w_{1v}$ and $w_{2c} < w_{2v}$. Then, replacing $SI(e_c) + I_c$ by $SI\left(e^*\right) + I^*$, and assuming partial insurance it is easy to realize that the inequality is reversed:

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

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

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

Proposition 1: *When the DM faces a situation of compulsory overinsurance, 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.*

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), 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:

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

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

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

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

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:*

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

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