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Efficiency of sharing liability rules: An experimental case*

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Abstract

We experimentally investigate the relative performance of two liability sharing rules for managing environmental harms that are jointly caused by two firms which can make *ex ante* safety investments in order to reduce the magnitude of the harm. The investment levels are chosen non-cooperatively and assumed to be non-observable by the regulator. If one firm is unable to cover its part of the damages, third parties might not receive full compensation for their harm. Through an experiment, we analyze the investment choices under two widely used liability sharing rules and compare the decisions to theoretical predictions. In line with theory, we show that insolvency leads to under-investment. Moreover, we show that the relative performance of each rule depends on the firms' relative degree of solvency. Our results indicate that the legislator should make the default liability sharing rule dependent upon the degree of capitalization of firms.

Keywords: Environmental Regulation; Liability Sharing Rules; Multiple Tortfeasors; Firms' Insolvency

JEL Classification: K13 ; K32 ; Q53

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1 Introduction

We study the design of public policies which aim to prevent environmental harms jointly caused by several firms. Many industrial activities are known to impact the quality of air, soil, surface water and groundwater. For instance, on soil contamination, the US Environmental Protection Agency (EPA) established an inventory of hazardous waste sites which could be subject to clean up operations. More than 30,000 sites were inventoried and the clean up cost of soil contamination from industrial activities in the US amounts to almost $1000 billion.[1]

The issue of industrial pollution has been addressed since the 1970s, with the emergence of environmental regulations and regulatory agencies. Command-and-control, emission permits and taxes are the most widely used instruments, but the use of civil liability was also introduced for pollution control by CERCLA[2] in 1980 in the US. The European Union has progressively implemented civil liability for environmental harms since 2004.[3] Civil liability aims at reaching two goals: (i) it makes it possible to compensate *ex post* third parties and/or to finance the clean up costs of hazardous sites, and (ii) the threat of this payment provides incentives *ex ante* to make investments in processes or care measures that reduce the likelihood and/or the magnitude of harms.

As a consequence of the concentration of (industrial) production facilities in specific areas, many cases of local pollution arise through the activity of multiple firms. Among the most classical examples is the case of pollution by two firms located along a river. In order to carry out their activities, they need to dump into the river pollutants that cause unique harm. Because individual contributions are difficult to identify, the regulator is faced with several contributors for one harm.[4] In cases with multiple tortfeasors, civil liability has to deal with two important issues: (i) apportioning the harm between the firms so as to provide them with optimal incentives to invest in care; and (ii) dealing with the potential insolvency of some (or all) of them, as the magnitude of the harm caused to the environment can be so high that it may exceed the value of the firms' assets. Indeed, when the firms' level of assets is too low the harm can be only partly

[1] Data are available on the EPA website: https://www.epa.gov/superfund/superfund-data-and-reports. On the National Priority List, the reader can visit: https://www.epa.gov/superfund/superfund-national-priorities-list-npl

[2] Comprehensive Environmental Response, Compensation, and Liability Act.

[3] See Directive 2004/35/CE.

[4] See the cases of "non-distinct harms" documented by Ackerman (1973) and used by Kornhauser & Revesz (1989a).

compensated for, as firms benefit from limited liability (which limits their debts up to their financial capacities).

The consequences of insolvency in the presence of several firms crucially depend on the liability rule in force. Assume that because of non-observability of safety investments made by the firms, each of the two firms has to compensate for half the harm. Then, under a *Non Joint* liability rule (NJ), each firm has to pay for half the harm, up to its asset level. If one firm is unable to pay for its full share of the harm, then the harm is not entirely compensated. A crucial difference occurs under a *Joint and Several* liability rule (JS), under which the remaining damages from an insolvent injurer have to be paid by the solvent injurer(s), if any, up to its (their) financial capacity.[5] Thus, in the example with two firms, if one is unable to pay its half, then the other one has to pay for its own share plus for the uncompensated share of the other firm.

As it allows victims to obtain high levels of compensation while minimizing their cost of suing, JS liability was primarily introduced as the default rule of apportionment in the US. But this rule has been intensively criticized as it has been judged both unfair and potentially inefficient (see e.g. Kornhauser & Revesz, 1990, p.625). Indeed, first, by holding the solvent defendants liable for the remaining damages due by insolvent defendants, JS can lead to situations where solvent defendants pay for the entire harm while their contribution to the harm is small. Second, potential insolvency undermines the incentives to invest in care, and this can lead to suboptimal decisions: the most solvent firms may be encouraged to over-invest in order to reduce the overall harm, while less solvent ones may choose to under-invest for obvious reasons.

Mainly because of these two criticisms, a tort reform movement began in the USA in the 1980s to persuade states to suppress JS liability in favor of NJ liability (see Lee *et al.*, 1994, p.298). Several US states thus adopted NJ liability for non-economic harm (including bodily injuries and moral harm), but in the field of pollution control JS liability is still the default rule of apportionment. In the European Union, Directive 2004/35/CE leaves it up to Member States to decide which rule to apply (see article 22 of the directive). Most of them adopted JS liability, except Denmark, Finland and France which introduced NJ liability (OECD, 2012).

[5] According to CERCLA, "any one potentially responsible party may be held liable for the entire clean up of the site (when the harm caused by multiple parties cannot be separated)". Source: https://www.epa.gov/enforcement/superfund-liability

Our aim in this paper is to investigate experimentally which liability sharing rule is the most desirable for managing environmental harms caused by two tortfeasors, in terms of minimization of the social cost. This question is important from a public policy perspective because of the coexistence of these two rules, and the significant reliance on them in practice. Furthermore, it has received little attention from the literature. Many theoretical contributions analyze civil liability as a tool for regulating risky activities,[6] but few analyze it as a way to regulate pollution (Kornhauser & Revesz, 1989b, 1990; Endres & Bertram, 2006; Endres *et al.*, 2008).[7] In addition, few experiments have been performed on civil liability. Exceptions are Kornhauser & Schotter (1990) and Kornhauser & Schotter (1992), who test for the incentives provided by strict liability and negligence to reduce, respectively, a risk of unilateral accident and a risk of bilateral accident. Angelova et al. (2014) compare strict liability, negligence and no liability in the framework of a unilateral accident, and investigate the impact of insolvency; strikingly, they find no impact of insolvency. Finally, Wittman et al. (1997) test how fast different liability rules enable equilibrium to be achieved. However, all these studies only consider the case of a single tortfeasor, and to the best of our knowledge, our paper provides the first experimental study on the effectiveness of liability rules in the case of more than one tortfeasor.[8]

More precisely, as insolvency is known as a serious impediment to the effectiveness of liability rules, we analyze how and to what extent firms' willingness to invest in safety depends on their ability (and the other firm's ability) to financially compensate the harm. More specifically, we compare the performance of NJ and JS rules enforced in the framework of a strict-based liability system, against firms that can potentially cause harm to third parties. We consider a unilateral accident setting, i.e., third parties cannot carry out any action to prevent the harm. Our framework focuses on the case of environmental disasters, such as pollution, the extent of which can be reduced by investments in safety (e.g., filters, recycling production processes). By making such investments, firms jointly reduce the extent of the harm, which will occur with certainty.[9]

[6] Pioneering contributions are those of Calabresi (1970), Brown (1973), Shavell (1980).

[7] Note also that even though civil liability has been widely studied in a framework of risk regulation, some contributions can be transposed to a context of pollution control - see especially the "magnitude model" of Dari-Mattiacci & De Geest (2005).

[8] Multiple tortfeasors are taken into account by Dopuch et al. (1997), but they focus on the incentives to settle before a trial.

[9] In the economic literature on civil liability, investments or efforts are either assumed to reduce the probability of occurrence of an accident (Shavell, 1980, 1984, 1986), or its consequences (see notably

We assume that safety measures are observable neither by the other firm (simultaneous investment decisions) nor by the authorities, so that incentives to take such measures are given by the liability system. As the two liability sharing rules can only differ in cases where assets are asymmetric, we investigate the investment decisions for various asymmetric levels of assets between the firms.

Beyond an experimental comparison of the rules, our experimental design proposes to compare observed safety investments with theoretical ones. Our theoretical predictions are derived from the analysis of Kornhauser & Revesz (1990), who determine the investments made by firms in different scenarios, varying the initial asset level and the liability sharing rule.[10]

We first find that some individual characteristics, such as inequity aversion, impact investment choices. Our experiment then highlights that both liability sharing rules are inefficient: they both lead to under-deterrence from insolvent firms and over-deterrence from a solvent firm facing an insolvent one. Moreover, according to our results, a NJ rule leads to the highest social welfare in cases with at least one or two insolvent firm(s), whereas JS is preferable in cases where both are solvent (in contradiction with theory). Therefore, in industries where firms' assets are low, leading to a higher risk of insolvency, our results plead in favor of a NJ rule. From a public policy perspective, this implies that the legislation should depend on the type of industry. In particular, in industries where some degree of firm capitalization is required (as documented by Jacob (2020)), so that insolvency is less likely, then a JS rule could be enforced. Converse cases, where capitalization does not have a floor value, making insolvency more likely, should call for a NJ rule.

The remainder of the paper is structured as follows. The model is outlined in Section 2 and the experimental design is explained in Section 3. The results are displayed in Section 4, and Section 5 concludes and suggests further research.

Boyd & Ingberman (1994)). An exception is Dari-Mattiacci & De Geest (2005) who consider all cases (reduction of the probability and of the size of the harm). As we focus on pollution, the assumption according to which any investment from a firm reduces the extent, and not the probability, of the harm is the most appropriate.

[10] Our theoretical analysis is a special case of Kornhauser & Revesz (1989a) and Kornhauser & Revesz (1990) that we extend and numerically run, through suitable specifications, in order to provide numerical results to be challenged by experimentation. More precisely, consider Kornhauser & Revesz (1989a), who provide all mathematical proofs of the analysis developed in Kornhauser & Revesz (1990) (see in particular Kornhauser & Revesz (1989a) pp. 76-91). We only consider the cases of strict liability, with both actors being solvent, and then insolvent under fractional (non-joint) rule and under unitary (joint-and-several) rule. We focus on strict liability because of its increasing use to regulate the most dangerous harms to the environment (see CERCLA in the US, and Directive 2004/35/CE in Europe).

2 Theoretical analysis

In this section, we introduce a brief theoretical analysis, which is based on the contribution of Kornhauser & Revesz (1990). We first present the basic assumptions, and then provide the main results and intuitions. All proofs are available in the appendix.

2.1 Basic assumptions

We consider two firms X and Y, whose activity causes a global and joint harm that occurs with certainty. For any occurring harm, a strict liability rule applies: the firms always have to repair the harm, regardless of their past behavior and decisions. Given the non-observability by the regulator of investments, we assume that, as is usual in practice, a *per capita* rule applies: each firm has to pay for half the harm, conditional on a sufficient asset level.[11]

Each firm is endowed with assets, the value of which is denoted by W_i, $i = X, Y$. These assets can be confiscated for compensation. We assume that limited liability applies, so that the amount of damages that each firm has to pay cannot exceed the value of its assets W_i. Note here that in the rest of the paper, solvency and insolvency are defined *ex post*, which means that a firm is considered as solvent (resp. insolvent) if, given its investment and the other firm's investment *at equilibrium*, it can (resp. cannot) pay for its share of damages.

We suppose that each firm can make an investment in pollution abatement, $I_i \in {}^+$, to reduce the magnitude of the global harm $D(I_X, I_Y)$, with $i = X, Y$, $j = X, Y$, $i \neq j$. Each investment makes it possible to reduce the magnitude of harm (i.e., $\frac{\partial D(I_i,I_j)}{\partial I_i} < 0$, $\frac{\partial D(I_i,I_j)}{\partial I_j} < 0$, $\frac{\partial^2 D(I_i,I_j)}{\partial I_i^2} > 0$, $\frac{\partial^2 D(I_i,I_j)}{\partial I_j^2} > 0$), and both investments are imperfect substitutes (i.e., $\frac{\partial^2 D(I_i,I_j)}{\partial I_i \partial I_j} > 0$). Investment is costly in that it reduces the firms' net benefit from their activity, denoted by $B(I_i)$ (i.e., $\frac{\partial B(I_i)}{\partial I_i} < 0$, $\frac{\partial^2 B(I_i)}{\partial I_i^2} < 0$).[12]

As is customary in the literature, the social planner aims at maximizing the sum of all costs and benefits from activity:

$$\max_{I_X, I_Y} SW(I_X, I_Y) = B(I_X) + B(I_Y) + W_X + W_Y - D(I_X, I_Y) \tag{1}$$

[11]Strict liability applies in the US (CERCLA) and in the European Union (Directive 2004/35/CE) for the most severe harms. *Per capita* is the default sharing rule in case of harms where individual contributions cannot be identified (see Kornhauser & Revesz, 1989b).

[12]Note that the firms' benefit $B(I_i)$ cannot be confiscated to pay damages. Only assets W_i can be confiscated.

The first best levels of investments are I_X^{**} and I_Y^{**}, which simultaneously satisfy:

$$\frac{\partial SW(I_X, I_Y)}{\partial I_X} = 0 \Rightarrow -\frac{\partial D(I_X, I_Y^{**})}{\partial I_X} = -\frac{B(I_X)}{\partial I_X} \tag{2}$$

$$\frac{\partial SW(I_X, I_Y)}{\partial I_Y} = 0 \Rightarrow -\frac{\partial D(I_X^{**}, I_Y)}{\partial I_Y} = -\frac{B(I_Y)}{\partial I_Y} \tag{3}$$

Because of the firms' symmetry in their benefit functions, we obtain the same first-best levels of investments ($I_X^{**} = I_Y^{**}$, regardless of W_X and W_Y).

2.2 Theoretical predictions

Our analysis aims at comparing the incentives for investment in pollution abatement provided by two different sharing rules, *Non Joint* (NJ) and *Joint and Several* (JS) liability. We focus on cases where the firms do not have the same level of assets,[13] and from now on we set $W_X > W_Y$: X is the wealthier firm.

Non Joint liability. In case of a NJ liability rule, each tortfeasor is liable for its share of the harm only, i.e., the firm i only has to pay for $\frac{1}{2}D(I_i, I_j)$ (up to the limit of W_i), whatever firm j is able to pay for its share of liability or not. The expected profit under NJ for any firm i is therefore given by:

$$\max_{I_i} \Pi_i^{NJ}(I_i, I_j) = B(I_i) + W_i - Min\left\{W_i; \frac{1}{2}D(I_i, I_j)\right\} \tag{4}$$

Obviously, the *ex post* payment in damages depends on the firms' degree of solvency. The intuition is as follows.

Consider first the case where the two firms are "highly" solvent, in that they are always able to pay for their share of liability.[14] As there is a benefit in making an investment in abatement (in terms of decreasing the magnitude of harm - and so the magnitude of compensation), both firms make a positive investment. Moreover, because of symmetry (in benefit functions), these two investments are equal to each other: $I_i(\infty) = I_j(\infty)$, the symbol ∞ denoting the case of solvency, like in Kornhauser & Revesz (1990). Nevertheless, because each firm only pays for half the total harm (at the margin), we have: $I_i(\infty) < I_i^{**}$.

[13] Indeed, if they are symmetrically endowed, no transfer of liability is possible, so that NJ and JS rules cannot be distinguished *a priori* from each other.

[14] A sufficient condition is to have: $W_i > \frac{1}{2}D(0, 0)$.

Second, in the opposite case where the less wealthy firm has no assets at all (i.e., $W_Y = 0$), it derives no benefit from making an investment in abatement. We obtain $I_Y = 0$. This reasoning holds for some strictly positive values of W_Y until a threshold, say $\underline{W}$, above which firm Y makes the strictly positive investment $I_Y(\infty)$.

In the case where firm Y has no interest in making any investment (i.e., when $W_Y < \underline{W}$), the investment decision of firm X depends on its level of assets W_X. For low values of W_X[15], firm X has no incentive to make any investment in pollution control: the firm's profit is higher when it is insolvent (and choosing $I_X = 0$) than when it makes a sufficiently high investment in such a way as to be solvent (i.e., choosing I_X such that $D(I_X, 0) < W_X$). But if the firm's level of assets exceeds a threshold value, say $\bar{W}_{NJ}$, firm X has an interest in making a positive investment, say $I_X^b > 0$, and remaining solvent after paying for liability. This effort is higher than that which is made when both firms are solvent: $I_X^b > I_X(\infty)$. Indeed, because both investments are imperfect substitutes, the absence of investment by firm Y increases the marginal effectiveness of firm X's efforts on abatement: firm X thus "over-compensates" for the absence of investment from Y.[16]

Proposition 1. *Consider two firms X and Y, which are faced with a non joint liability and assume $W_X > W_Y$.*

- *If $W_Y < \underline{W}$, firm Y makes zero investment in care. Otherwise, if $W_Y > \underline{W}$, both firms make strictly positive investments $I_X(\infty)$ and $I_Y(\infty)$, but these levels of investment are lower than the first-best ones.*
- *In case of $W_Y < \underline{W}$ ($I_Y = 0$), then:*
  - *$W_X > \bar{W}_{NJ}$ leads firm X to make a strictly positive investment I_X^b. This effort is higher than the full-solvency level $I_X(\infty)$.*
  - *$W_X < \bar{W}_{NJ}$ leads firm X to make no investment.*

with $\underline{W} = B(0) - B(I_Y(\infty)) + \frac{1}{2}D(I_X(\infty), I_Y(\infty))$ *and* $\bar{W}_{NJ} = B(0) - B(I_X^b) + \frac{1}{2}D(I_X^b, 0)$

Proof: see Appendix A.1. ♦

[15] But still considering $W_X > W_Y$.

[16] However, we are unable to rank I_X^b relatively to I_X^{**}. Two opposite effects are at work. First, the absence of investment from Y tends to increase the level of investment of X (the effectiveness of which is raised). But X only pays for half the harm (at the margin), which reduces the incentives to invest (relatively the first-best ones).

Joint and Several liability. In case of a JS rule, when one of the two firms is insolvent after the harm has occurred, the remaining damages have to be paid by the most solvent injurer. As a consequence, in case of insolvency of Y, firm X's problem is now the following:

$$\max_{I_X} \Pi_X^{JS}(I_X,0) = B(I_X)+W_X-Min\left\{W_X;\frac{1}{2}D(I_X,0)+Max\left\{0;\frac{1}{2}D(I_X,0)-W_Y\right\}\right\} \tag{5}$$

Recall that when Y is insolvent, then $I_Y = 0$. $\frac{1}{2}D(I_X,0)$ is thus the *a priori* liability attributed to each firm. Moreover, when firm Y is insolvent, its remaining debt, $\frac{1}{2}D(I_X,0) - W_Y$, has to be paid by firm X. However, X also benefits from limited liability; it can therefore not pay more than W_X for compensation of damages.

Under JS, like in the NJ case, three different equilibria are possible, depending on the levels of wealth of each firm.

When both firms are sufficiently endowed with assets to have an interest in making positive investments, the problem is the same as the one described under a NJ rule. We therefore again obtain: $I_i(\infty) = I_j(\infty)$.

As with the NJ rule, there is a threshold under which the less solvent firm, Y , does not find it optimal to invest. It is possible to show that this threshold is the same as under the NJ rule, $\underline{W}$.

Finally, in case of insolvency of firm Y, firm X can choose whether or not invest in pollution abatement depending on its level of assets. In case of low values of W_X (below a threshold, denoted by $\bar{W}_{JS}$, but still having $W_X > W_Y$), firm X is insolvent *ex post* and makes no investment. But in cases where W_X exceeds the threshold level $\bar{W}_{JS}$, X has incentives to make an investment and remain solvent. However, in that case, the level of investment, say I_X^a, is even higher than that prevailing in a similar case[17] under a NJ rule: $I_X^a > I_X^b$. Indeed, under JS, the solvent firm has to pay for the remaining debt of the insolvent one: at the margin, the solvent firm thus internalizes the whole harm (while it internalizes only a share $\gamma = \frac{1}{2}$ under NJ). The marginal benefit of pollution abatement is thus higher under JS than under NJ, explaining $I_X^a > I_X^b$. We can also easily show that this level of investment is even higher than the first-best one:

[17] I.e., firm X is solvent and firm Y is insolvent.

$I_X^a > I_X^{**}$.[18]

These results are summarized in the following Proposition.

Proposition 2. *Consider two firms X and Y, which are faced with joint and several liability, and assume $W_X > W_Y$.*

- *If $W_Y < \underline{W}$, firm Y makes zero investment in care. Otherwise, if $W_Y > \underline{W}$, both firms make strictly positive investments $I_X(\infty)$ and $I_Y(\infty)$, but these levels of investment are lower than the first-best ones.*
- *In case of $W_Y < \underline{W}$ ($I_Y = 0$), then:*
  - *$W_X > \bar{W}_{JS}$ leads firm X to make a strictly positive investment, I_X^a. This effort is higher than the first-best level I_X^{**} and higher than I_X^b.*
  - *$W_X < \bar{W}_{JS}$ leads firm X to make zero investment.*

with $\underline{W} = B(0) - B(I_Y(\infty)) + \frac{1}{2}D(I_X(\infty), I_Y(\infty))$ *and* $\bar{W}_{JS} = B(0) - B(I_X^a) + [D(I_X^a, 0) - W_Y]$

Proof: see Appendix A.1. ♦

Note that without any specification, it is impossible to state whether $\bar{W}_{JS}$ is higher or lower than $\bar{W}_{NJ}$. In other words, it is impossible to say which liability rule is associated with the highest set of values of W leading firm X to be (in)solvent at equilibrium. Indeed, both threshold values of $\bar{W}_{NJ}$ and $\bar{W}_{JS}$ increase with the difference in benefits $B(.)$ between the insolvency and the solvency states (factor (i)), and with the payment in damages in the solvency state (factor (ii))[19]. However, while it is easy to check that the value of factor (i) is higher under JS than under NJ (because of $I_X^a > I_X^b$), it is impossible to conclude on the values of factor (ii): $I_X^a > I_X^b$ leads the firm to face a lower harm under JS than under NJ, but NJ ensures that the firm will only have to pay for half the harm.[20]

Finally, we make a comparative analysis of the different equilibria under each liability sharing rule . It is summarized in the following Proposition.

[18] Contrary to what prevailed in the NJ case, under JS only the effect of over-compensation of X (because of the absence of effort from Y, and the imperfect substitution of investments in the reduction of harm) works. As recalled above, at the margin X internalizes the full harm. Incentives are thus too great (relatively to the first-best ones).

[19] The higher these two factors, the more appealing the insolvency state. This is consistent with higher threshold values.

[20] While under JS, firm X pays for the entire harm (minus the value of Y's assets).

Proposition 3. *Consider two firms X and Y, which contribute to a common harm. X is wealthier than Y.*

(i) If X and Y are insolvent at equilibrium, NJ and JS sharing rules are equivalent: they both provide no incentive to invest in care ($I_X = I_Y = 0$), and they lead to the same levels of harm and social welfare.

(ii) If Y is insolvent at equilibrium (and chooses $I_Y = 0$) while X is solvent, then JS provides firm X with higher incentives to invest in care than NJ ($I_X^b < I_X^a$). The level of investment I_X^a, under a JS rule, is higher than the first-best one. Nevertheless, JS leads to higher social welfare than NJ.

(iii) If X and Y are both solvent at equilibrium, NJ and JS rules are equivalent: they provide the firms with the same investment incentives ($I_X(\infty) = I_Y(\infty)$) and lead to the same levels of harm and social welfare.

Proof: see Appendix A.1. ♦

About point (ii) of Proposition 3, we look at the case where firm X is solvent whatever the sharing rule that applies, i.e., when $W_X > \max\left\{\bar{W}_{JS}, \bar{W}_{NJ}\right\}$ (and firm Y is insolvent: $W_Y < \underline{W}$). In that case, the level of social welfare at equilibrium is higher under JS than under NJ: by leading firm X to internalize the entire (marginal) harm, JS ensures that the investment I^a of X is the socially best-response to $I_Y = 0$.
Finally, as underlined by Tables A.1 and A.2 in Appendix A.1, note that $\bar{W}_{JS} \neq \bar{W}_{NJ}$ implies that JS and NJ rules have different solvency regions. Considering $\bar{W}_{JS} > \bar{W}_{NJ}$, having $W_X \in [\bar{W}_{NJ}; \bar{W}_{JS}]$ leads the firm to be solvent under NJ liability, but insolvent under JS liability. As shown in Table A.1 in Appendix A.1, in such a case, NJ liability is socially preferred to JS liability. The reverse holds if $\bar{W}_{JS} < \bar{W}_{NJ}$ and $W_X \in [\bar{W}_{JS}; \bar{W}_{NJ}]$.

3 Experimental design

3.1 Parameters and predictions

In order to have predictions on the subjects' decisions, we specify functions which satisfy the theoretical assumptions of the model. We thus consider the following harm and benefit functions:

$$D(I_X, I_Y) = 500 \exp^{-0.1(I_X + I_Y)}$$

$$B(I_i) = 100 - 10\exp^{0.1I_i}, i = X, Y$$

Investments I_i range between 0 and 23.[21]

Departing from these functions, solvency thresholds as well as equilibrium and first-best levels of investments can be computed. They are displayed in Table 1.

Table 1: Numerical thresholds and equilibrium investments

	Both insolvent (JS or NJ)	Both solvent (JS or NJ)	Solvent/ insolvent JS	Solvent/ insolvent NJ
Relevant threshold for W_X	$\min\{\bar{W}_{NJ}, \bar{W}_{JS}\} = 90$	$\max\{\bar{W}_{NJ}, \bar{W}_{JS}\} = 111.42$	$\bar{W}_{JS} = 111.42$	$\bar{W}_{NJ} = 90$
Relevant threshold for W_Y	$\underline{W} = 48.48$	$\underline{W} = 48.48$	$\underline{W} = 48.48$	$\underline{W} = 48.48$
W_X	$< \min\{\bar{W}_{NJ}, \bar{W}_{JS}\} = 90$	$> \max\{\bar{W}_{NJ}, \bar{W}_{JS}\} = 111.42$	$> \bar{W}_{JS}$	$> \bar{W}_{NJ}$
W_Y	$< \underline{W}$	$> \underline{W}$	$< \underline{W}$	$< \underline{W}$
I_X^*	$I_X = 0$	$I_X^{FS} = 10.73$	$I_X^a = 19.56$	$I_X^b = 16.09$
I_Y^*	$I_Y = 0$	$I_Y^{FS} = 10.73$	$I_Y = 0$	$I_Y = 0$
First-best invest.	13.04	13.04	13.04	13.04

We set three pairs of wealth levels, so that players are either both solvent, or both insolvent, or one is solvent and the other is insolvent.[22] As we believe that not only solvency criteria but also subjects' endowments might be determinants of their decisions, we set asymmetric levels of wealth in all treatments.

Overall, we implement three different wealth scenarios under two (liability) sharing rules, which leads to six treatments labelled from A to F. This allows:

- to compare the incentives provided by the two sharing rules given each considered situation of solvency/insolvency
- to assess the impact of (in)solvency under a given liability rule

The theoretical values of investment, benefit, harm and welfare. These are shown in Table 2.[23]

We derive the following predictions from the model.

- **Prediction 1**: if one firm is solvent and the other one is insolvent (treatments A and B), then the insolvent firm makes zero investment under the two rules whereas

[21] In the experiment, the levels of investment are integers, in order to simplify the decision-making of subjects. Note that we provide the subjects with tables displaying all 24 possible decisions (and their consequences), from 0 to 23 included.

[22] Recall that according to the definition that is provided in the theoretical analysis, a firm is solvent if it is able to pay its share of liability at equilibrium.

[23] Instructions are available in the Appendix A.5. For the sake of length, we show the instructions for Treatments A and B only. Nevertheless, the instructions for treatments C and E are very close to those for treatment A since only endowments differ; equally, the instructions for treatments D and F are very close to those for treatment B.

Table 2: Treatments and predictions

Treatment	**A**	**B**	**C**	**D**	**E**	**F**
Liability rule	JS	NJ	JS	NJ	JS	NJ
W_X solvency/insolvency	120 **solvent**	120 **solvent**	120 **solvent**	120 **solvent**	80 **insolvent**	80 **insolvent**
W_Y solvency/insolvency	20 **insolvent**	20 **insolvent**	55 **solvent**	55 **solvent**	20 **insolvent**	20 **insolvent**
Equilibrium investment of X	19.56	16.09	10.73	10.73	0	0
Equilibrium investment of Y	0	0	10.73	10.73	0	0
Benefit of X at equilibrium	29.29	50	70.76	70.76	90	90
Benefit of Y at equilibrium	90	90	70.76	70.76	90	90
Theoretical harm	70.71	100	58.48	58.48	500	500
Theoretical social welfare	188.58	180	258.04	258.04	-220	-220

the solvent firm over-invests. Nevertheless, this over-investment is higher under JS rule (because of the transfer of liability to the solvent firm). The harm is lower and the social welfare higher under JS than under NJ.

- **Prediction 2**: if both firms are solvent (treatments C and D), they choose the same investment levels (10.73). The two rules are equivalent in terms of harm and social welfare.

- **Prediction 3**: if both firms are insolvent (treatments E and F), they choose a zero investment level. The two rules are equivalent in terms of harm and social welfare.

The previous predictions build on the assumption that players (firms) are risk-neutral. This relies on the fact that as the harm occurs with certainty, there is no risk in the model, so that considering risk-neutral players appears to be relevant. Nevertheless, in a broader and unrigorous sense, our model could leave room for strategic risk: indeed, participants might consider their partner's strategy as "risky" as they might not anticipate it correctly. Thus, to some degree, the players' behavior toward risk might impact their decisions in several ways. On the one hand, a higher risk-aversion could imply lower investment from players, since making no investment ensures a safe minimum payoff of 90 *for sure* ($B(e_i = 0) = 90$). If one player expects such a high harm that he could lose all his assets and become insolvent, a safe strategy would be to make no investment in order to keep his full endowment. We will refer to this effect as *Effect*

1. On the other hand, the absence of confidence in the partner's reaction leads to an absence of predictability about the damages to be paid. A risk-averse player may wish to make a high investment in order to reduce both the level of damages to pay and the impact of the partner's decision on these damages, thus reducing the variability in the potential final payoffs. We call this effect *Effect 2*. For these various reasons, our experimental protocol looks to elicit the participants' risk preferences, by relying on Holt & Laury (2002)'s method.[24]

Moreover, the theoretical model also neglects the participants' preferences for inequity. But, as mentioned previously, in order to distinguish between the two sharing rules, two partners (in any treatment) systematically have different initial endowments. From a theoretical viewpoint, this should not be relevant as only being above or below the relevant threshold influences the investments, with no consideration given to the distance to this threshold. But in the experiment we expect that this asymmetry in terms of endowments between players could lead them to adapt their choices. In particular, those that are more averse to inequity might try to reach more equity: thus, and especially in situations where both players are solvent (or insolvent) but asymmetrically, we expect players A (more endowed) to make higher investments than players B (least endowed), although theory predicts that their investment levels should be equal. Our experimental protocol also looks to elicit the participants' sensitivity to inequality, by relying on Blanco *et al.* (2011).

3.2 Experimental procedure

Our experiment was conducted at the Laboratory of Experimental Economics of Strasbourg (LEES), in France. The students were recruited from undergraduate and graduate courses in various fields (including law, economics, science and literature), through ORSEE (Greiner, 2015) and all sessions were computerized. Overall, 240 participants took part in the 12 sessions of this experiment (6 treatments, 2 sessions per treatment, 20 participants per session). Each group of 20 participants was divided into 2 groups of 10. Each participant was assigned a computer upon arrival, through a draw from a bag. No student could participate in more than one session (*between-subject design*) and the experimenters were the same for all the sessions. Instructions were read aloud by the

[24] The elicitation task is displayed in Subsection 3.2.

instructor (the same for all sessions) and questions were answered privately.

The experiment is divided into three tasks. Once assigned a computer, participants are successively given the instructions for tasks 1 and 2.[25]

Task 1 is expected to elicit the subjects' sensitivity to aversion to disadvantageous inequality. The game is a modified dictator game of Blanco *et al.* (2011) and relies mainly on Attanasi *et al.* (2019).[26] In this game, each subject is matched with another participant and has to make choices all the way through a list between two options: the left option gives 5 euros to player A and 0 to player B. The right option gives identical amounts to both players, from 0 at line 1 to 5 at line 11. The computer does not allow players to make inconsistent decisions: once one player switches to the right-hand option, he cannot switch to left. One option will be randomly selected for payment at the end of the experiment. Each subject makes his decision without knowing whether he will be randomly selected as player A or player B; if he is selected as player A, then his selected option will apply whereas if he is B, the other player's option will. The line number at which a subject switches to the right-hand option gives an estimate of his aversion to advantageous inequality: the higher the number of the switching-line, the less sensitive to aversion to advantageous inequality the subject.

Task 2 is a modified version of the task of Holt & Laury (2002) where a risky vs. a safe option is proposed for ten safe options increasing in stake (see e.g. Chakravarty & Roy, 2009; Attanasi *et al.*, 2018). In this game, each subject has to select options: the left option gives the subject 5 euros or 0 euro, each with a 1/2 probability. The right option gives him a safe payment, from 0 (line 1) to 5 euros (line 11). Again, one option will be randomly selected for payment at the end of the experiment. Thus, this task intends to elicit the subjects' attitude toward risk, with subjects switching from the left to the right option at lines 1-5 disclosing risk aversion, and those switching at lines 6-10 disclosing risk proneness (see Attanasi *et al.*, 2019).[27]

Task 3 is the main game. After reading the instructions for this task, subjects learn about their role: either they are X (most endowed) or Y (least endowed). At each period, they have only one decision to make, by choosing a number (standing for their investment

[25]Note that in order not to influence the subjects' decisions in Task 3, the task 1 and 2 lots were drawn after task 3 was completed.

[26]We also rely on Attanasi *et al.* (2019) for the scale of inequality aversion used in the regressions.

[27]Subjects switching at line 6 may be risk-neutral or risk-loving, but we assign them the risk-loving type without loss of generality.

level) which reduces their private benefit but also reduces the extent of the cost they will have to assume jointly. The experiment is decontextualized.[28] The decisions of the two partners are simultaneous, and revealed to each other once they both have indicated their choice. The instructions include four tables which represent:

- the individual *gain* of each player for all 24 possible choices (from 0 to 23)
- all the values of the joint *cost*, depending on the choice of *numbers* of each of the two players
- in order to simplify decision-making, a table displaying X's payoff for all values of his own number and Y's number
- and a table displaying Y's payoff for all values of his number and X's number

In order to ensure that this main task is understood, subjects have to answer a quiz comprising 10 questions. In the event of errors, the instructor clarifies each of them individually. Once the three tasks have been completed and the lots drawn, participants answer a post-experiment questionnaire, aimed at providing supplementary information (notably regarding their behavior during the experiment, their perception of their own altruism and of others' altruism.).[29]

In each treatment, the payoffs of Task 3 are denominated in experimental currency units (ECUs) at the conversion rate of 100 ECUs to 7 . Average earnings were 20.6 , and the experiment lasted between 60 and 75 minutes. The players are paid according to the sum of their earnings from Task 1, Task 2 and two randomly-picked periods in Task 3 (the main game) of the experiment.

4 Empirical results

In this section, we test our theoretical predictions with the data obtained from the experiment described above. In particular, we intend to analyze whether NJ and JS sharing rules lead to different investment levels for given wealth levels ($W_X^{JS} = W_X^{NJ}$ and $W_Y^{JS} = W_Y^{NJ}$), whether the observed investments are similar to those predicted by theory, and the impact of investments in terms of harm and social welfare.

[28]The harm is thus referred to as a *cost*, the investment is a *number* and the benefit is a *gain*.
[29]This questionnaire is available in the Appendix A.6.

4.1 Descriptive statistics

Table 3 presents the descriptive statistics on the investments over 20 periods, as well as for periods 1 and 20, for each treatment and for each role.

Table 3: Mean investments over all periods, for periods 1 and 20, per treatment and per role

Treatment	Role	Mean investment	SD	Min	Max	Mean Period 1	SD	Mean Period 20	SD
A	X	**15.94**	6.21	0	23	15.95	5.28	15.55	6.42
	Y	**3.08**	5.33	0	23	7.2	7.46	1.55	3.22
B	X	**15.45**	3.22	0	23	13.6	4.84	15.7	1.69
	Y	**0.90**	3.10	0	23	2.4	4.71	0	0
C	X	**13.08**	3.25	0	23	15.95	4.02	12.4	2.30
	Y	**8.96**	3.74	0	23	9.7	6.05	9.1	3.02
D	X	**12.55**	3.40	0	23	12.25	3.84	11.45	3.80
	Y	**7.76**	4.59	0	23	7.4	6.89	8.65	3.22
E	X	**2.07**	4.84	0	23	8.4	7.22	0.1	0.45
	Y	**0.62**	2.45	0	22	1.7	3.34	0	0
F	X	**3.41**	6.08	0	23	7.6	6.78	0.2	0.41
	Y	**1.44**	4.21	0	23	8.1	9.14	0.1	0.31
# Obs.		400	400	400	400	20	20	20	20

The mean investment choices of players X and Y over the 20 periods for all treatments are displayed in Fig. 1. We also indicate in the figure the theoretical predictions for each player's investment. Trends in Fig. 1 clearly indicate the impact of players' solvency on their investment choices: as the level of endowment of X diminishes (e.g., treatments A vs. treatment E), his/her investment choice also falls. The same can be observed regarding player Y: the investment level seems much higher in the case where the player is solvent (treatments C and D vs. other treatments).

Finally, summary statistics on individual characteristics of subjects are presented in Table 4, while the definition of variables is provided in Table A.3 of Appendix A.4.[30]

4.2 Results on treatment effects

We conducted a panel-data analysis of treatment effects on investment choices for both player types X and Y, in order to test for differences in mean investments between the different treatment levels and to quantify these differences. We used a random-effect (RE) model including individual-specific (random) effects to account for the possible correlation in a subject's decisions across periods. The RE model is estimated with treatment effects considered as fixed (i.e., proxied by dummy variables). In order to

[30]Some of the variables are indicated in the post-experimental questionnaire (see Appendix A.6).

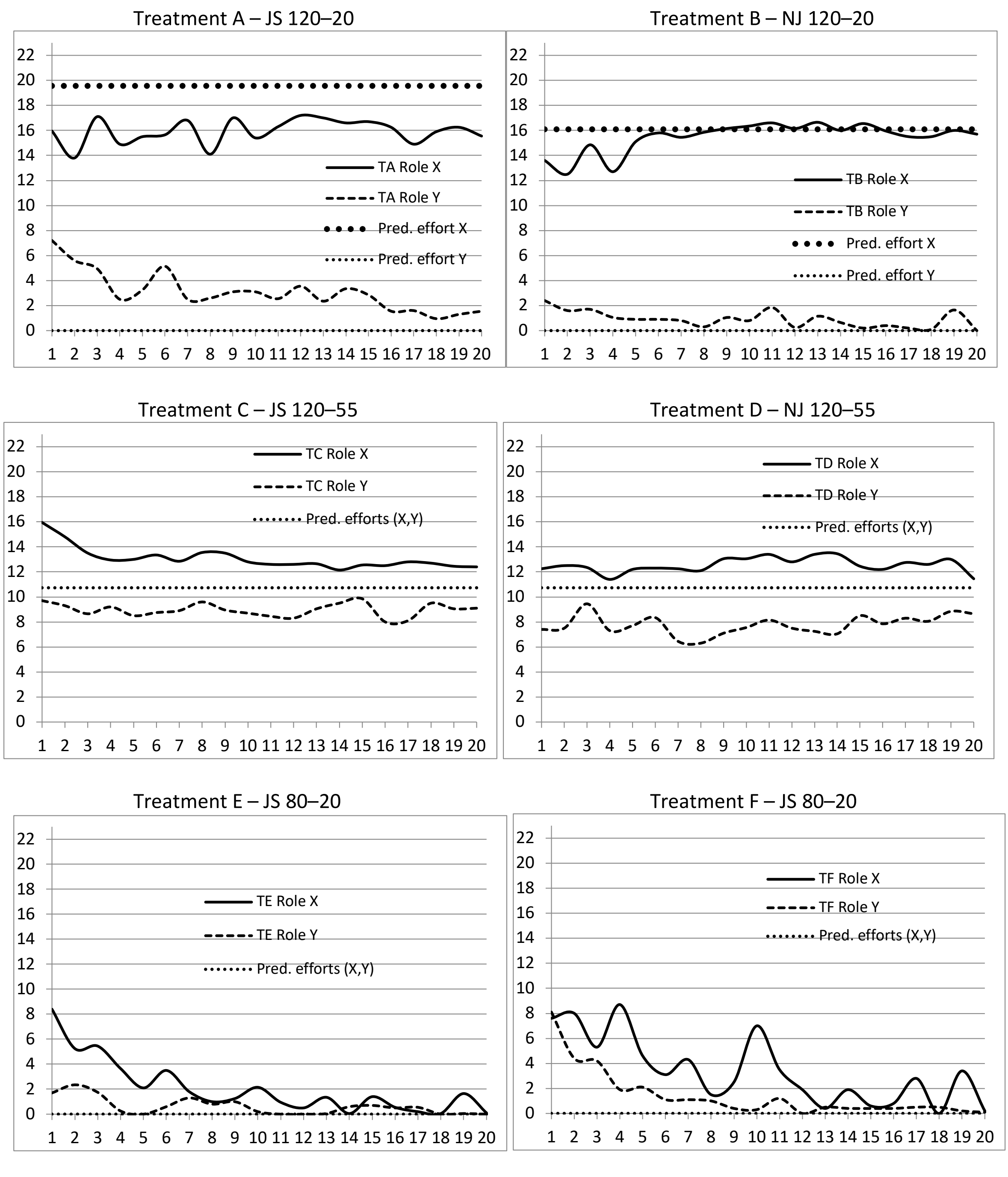

Figure 1: Mean investments by role, 20 periods - all treatments

Table 4: Descriptive statistics - Individual characteristics

Treatment		A		B		C		D		E		F	
Variable [Values]	Role	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Risk and inequity aversion, altruism													
DR	X	5.80	1.25	5.45	2.14	5.80	2.04	6	1.65	6.35	1.96	5.3	1.79
[1, 10]	Y	5.90	1.45	5.10	1.76	5.35	1.43	5.75	1.70	5.45	1.57	5	2.45
DE	X	6.30	2.05	6.55	2.23	5.60	2.34	5.55	2.64	5.05	2.38	5.2	2.27
[1, 10]	Y	6.20	1.60	5.70	2.41	5.85	2.15	6.65	2.52	6.05	3.08	5	2.61
Risk	X	5.40	1.86	5.30	1.74	5.30	2.08	5.8	1.51	6.30	1.52	4.8	1.40
[0, 10]	Y	5.70	2.15	4.90	2.35	5.20	1.72	6	1.55	5.35	1.96	4.60	2.54
Selfish12	X	0.70	0.46	0.45	0.5	0.50	0.50	0.60	0.49	0.55	0.50	0.70	0.46
[0; 1]	Y	0.50	0.50	0.70	0.46	0.70	0.46	0.50	0.50	0.35	0.48	0.60	0.49
Selfish21	X	6.60	1.28	6.40	2.09	6.05	2.14	6.15	1.96	7.15	1.77	6.50	2.01
[1, 10]	Y	6.10	2.30	6.30	1.9	6.05	1.63	6.90	2.15	5.60	2.64	5.80	1.94
Individuals characteristics													
Gender	X	0.50	0.50	0.50	0.50	0.55	0.50	0.30	0.46	0.65	0.48	0.60	0.49
[0; 1]	Y	0.60	0.50	0.55	0.50	0.45	0.50	0.40	0.49	0.45	0.50	0.10	0.30
Age	X	21.60	2.42	20.00	1.85	20.20	1.72	20.30	1.90	20.50	1.81	19.9	1.30
[18; 26]	Y	20.60	2.06	20.85	2.15	20.55	1.60	20.15	1.83	19.85	1.24	21.5	1.91
Current education level													
Master&Doc	X	0.40	0.49	0.20	0.40	0.25	0.43	0.30	0.46	0.35	0.48	0.30	0.46
[0; 1]	Y	0.10	0.30	0.30	0.46	0.30	0.46	0.30	0.46	0.10	0.30	0.30	0.46
University stream													
Sciences	X	0	0	0	0	0.10	0.30	0.10	0.30	0.10	0.30	0.10	0.30
[0; 1]	Y	0.10	0.30	0.05	0.22	0.05	0.22	0.20	0.40	0.05	0.22	0.10	0.30
Law&Literature	X	0.20	0.40	0.10	0.30	0.20	0.40	0	0	0.05	0.22	0.30	0.46
[0; 1]	Y	0.10	0.30	0.15	0.36	0.10	0.30	0.05	0.22	0.15	0.36	0.10	0.30
Economics	X	0.50	0.50	0.70	0.46	0.45	0.50	0.60	0.49	0.60	0.49	0.60	0.49
[0; 1]	Y	0.60	0.49	0.50	0.50	0.60	0.49	0.50	0.50	0.70	0.46	0.60	0.49

Notes. 400 observations per treatment for each player role.

perform all pairwise comparison tests, for each of the panel-data models, i.e., for the roles X and Y, we use five different specifications corresponding to five out of the six treatment effect references. Results are presented in Table 5.

Table 5: Tests for treatment effects on investment choices for each role

	Player X			**Player Y**		
Treatment comparison	Mean diff.	P-value		Mean diff.	P-value	
A - B	0.4950	0.536		0.1073	0.004	***
A - C	2.8600	0.000	***	-5.8800	0.000	***
A - D	3.3950	0.000	***	-4.6850	0.000	***
A - E	13.8750	0.000	***	2.4575	0.000	***
A - F	12.0425	0.000	***	1.6375	0.029	**
B - C	2.3650	0.003	***	-8.0600	0.000	***
B - D	2.9000	0.000	***	-6.8650	0.000	***
B - E	13.3800	0.000	***	0.2775	0.712	
B - F	12.0425	0.000	***	-0.5425	0.470	
C - D	0.5350	0.503		1.1950	0.112	
C - E	11.0150	0.000	***	8.3375	0.000	***
C - F	9.6775	0.000	***	7.5175	0.000	***
D - E	10.4800	0.000	***	7.1425	0.000	***
D - F	9.1425	0.000	***	6.3225	0.000	***
E - F	1.3375	0.094	*	0.8200	0.275	

Note. Treatments: A. JS 120-20, B. NJ 120-20, C. JS 120-55, D. NJ 120-55, E. JS 80-20, F. NJ 80-20.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

First of all, subjects' variation in choice between treatments depends on the players' role. We need a closer look at the differences between specific treatments to highlight the different effects of liability sharing rules and insolvency on the investment choices. Analyzing first treatments A and B (respectively JS 120-20 and NJ 120-20), the figures and tests indicate that these treatments imply significantly more investment from player X than all other treatments (see Tables 3 and 5). This means that when a solvent player faces an insolvent one, he always makes a higher investment to reduce harm than in all other cases, whatever the rule (NJ or JS).

Before investigating the behavior of subjects more deeply, let us recall that regarding treatments A and B, implementing respectively JS and NJ rules with **one subject solvent and the other one insolvent**, theory predicts that the behavior of X should be different between the two rules. X's investment should be much higher under a JS rule, whereas Y should make the same choice of zero investment whatever the rule (**prediction 1**). But the results of the tests indicate that the mean investment of subject X over the 20 periods is the same regardless of the rule: X makes an investment which is clearly higher than the first best level (13.04), so that X is over-deterred in both cases, but this over-deterrence is not higher under JS than under NJ. This is surprising since in the JS case, X has to bear the share of the damages that Y cannot take on himself. However, this might be explained by Y's behavior which is indeed different from what is predicted. Y chooses a significantly positive mean investment over the 20 periods in the two treatments (see Table 3). Moreover, according to Table 5 Y's investment is significantly higher in case of JS (TA) than in case of NJ (TB): the need for over-compensation for X is thus lessened under JS.

Considering now **the case where the two players are asymmetrically solvent** (Treatments C and D, resp. JS 120-55 and NJ 120-55), **prediction 2** is that the two players should behave the same way, both from one rule to the other and from one role to the other (10.73 for each player), which corresponds to full solvency equilibrium investments. The results indicate that this is the case between the rules: X's choice of investment is the same between the two treatments, as is the case for player Y. However, X chooses a relatively higher investment (13.08 and 12.55 respectively) than Y (8.96 and 7.76), in both treatments. This is very likely explained by *wealth effects*: X being the richer player, he takes it upon himself to make more investment, whereas Y chooses to make less investment. Such choices could be attributable to equity aversion: the choices of the players balance the initial difference in endowments, and that could explain why they try to move closer to a 50-50 situation in terms of final payoffs. We will investigate in Section 4.5 the effect of individual characteristics on these decisions, in particular whether altruism, risk or inequity aversion might play a role in the level of investments.

Finally, in **the case where the two players are (asymmetrically) insolvent** (treatments E and F, resp. JS 80-20 and NJ 80-20), they are both expected to choose zero investment (**prediction 3**). This allows them to keep their full benefit due to limited liability (recall that only their assets are confiscated). Surprisingly, in the two treatments, both players choose low but positive investments.[31] This choice is striking, since any positive investment from players is costly and is not sufficient (in these two treatments) to significantly reduce the level of harm. Consequently, the high level of harm implies that both players' assets are liquidated. This is precisely why theory predicts

[31] Note however that this is the case when considering mean investments. Period 20 investments are no longer significantly different from zero, except in treatment F for player X, but it is very close to zero. For the analysis, we will however consider the 20 periods.

that their investments should be zero. But this is not the case. Moreover, both players choose a higher investment under NJ (treatment F) than under JS (treatment E), but these differences are weakly or not significantly different from zero.

4.3 Observed versus predicted investments

In this section, we test the differences between the mean individual investments and the predicted equilibrium investment, for each role and for each treatment. To this end, we used a between estimator on the differences between observed individual values of investment and predicted (constant) values. Estimation results are presented in Table 6. They are all found to be significantly different from zero, which means that reported investments significantly differ from predicted ones on average.

Moreover, wishing to account for a potential learning effect, we also ran an OLS regression on the difference between the individual values at the last period of the game and the predicted values. We find that the difference is not significantly different from zero for several treatments (see bold figures in Table 6). It is particularly salient in treatments where one player is insolvent and should rationally choose zero investment: in all such cases except one (treatment F, role X), a convergence toward zero is observed. Treatment C (JS, both solvent) is the only one in which the difference remains significant for X and Y subjects. In other words, except for treatment C, there is evidence of a learning effect in most treatments.

Table 6: Tests of difference between experimental and theoretical investments

Treatment	Role	Mean diff.		T-stud	Period 20 diff.		T-stud
A	X	-3.6175	***	-3.95	-4.01	***	-2.79
	Y	3.0775	***	3.51	1.55	**	2.15
B	X	-0.6425	***	-2.77	**-0.39**		-1.03
	Y	0.8975	***	2.73	**0.00**		–
C	X	2.3525	***	5.60	1.67	***	3.24
	Y	-1.7725	***	-3.25	-1.63	**	-2.41
D	X	1.8175	***	3.41	**0.72**		0.85
	Y	-2.9675	***	-4.92	-2.08	***	-2.89
E	X	2.0675	***	4.80	**0.10**		1.00
	Y	0.6200	***	3.25	**0.00**		–
F	X	3.4050	***	5.55	0.20	**	2.18
	Y	1.4400	***	4.14	**0.10**		1.45

Note. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. In bold, non-significant differences between experimental and theoretical investments.

4.4 Relative performance of liability rules: harm and welfare

For public policy purposes, we are now interested in determining whether NJ and JS rules lead to different results in terms of harm and social welfare. Given our parameters, theory predicts that in case of similar situations in terms of solvency, the rules are equivalent. On the contrary, if only one firm is insolvent, the best rule is JS. We investigate whether the experiment leads to similar conclusions.[32]

Taking the couples' decisions at each period, we compute the observed level of harm and the social welfare for each of the couples at each period. Then we compute the mean of the harm and the mean of the welfare over the 20 periods in each treatment.[33]

Case 1: X solvent, Y insolvent (Treatments A and B)

The computed values comparing Treatments A and B are displayed in Table 7. According to **prediction 1**, when only one subject is solvent, he (player X) should theoretically be over-deterred, whereas the insolvent subject (player Y) should be under-deterred and make zero investment, whatever the liability sharing rule. However, this over-deterrence is stronger under JS, since the solvent player not only has to bear his part of the damages, but also Y's non-assumed part. Moreover, the level of harm is lower and the social welfare higher under JS.

Table 7: Theoretical / observed social welfare - Treatments A-B - 20 periods

Variables	**Treatment A**	**Treatment B**
W_X	120	120
W_Y	20	20
Equilibrium investment of X	19.56	16.09
Observed investment of X	15.94	15.45
Equilibrium investment of Y	0	0
Observed investment of Y	3.08	0.9
Equilibrium harm	70.71	100
Observed harm	104.22	108.02
Theoretical SW	188.58	180
Observed social welfare	162.24	171.32

From Table 7, we can see that whereas X's investment is not different between the

[32]Remember that solvency and insolvency cases are appreciated for equilibrium investments. Nevertheless, when considering one of the three cases, there can be situations where, given the couples of subjects' decisions, a subject who should be solvent (insolvent) according to the theoretical equilibrium is indeed insolvent (solvent) given the chosen investments. Nevertheless, for the sake of clarity, we separate the cases according to theoretical predictions.

[33]SW, which is defined by eq. (1), is computed as the sum of benefits $B(e_i) + B(e_j)$ and initial wealth levels $W_i + W_j$, minus harm $D(e_i, e_j)$ for each pair of decisions.

treatments, Y's is higher in Treatment A (JS). Although this implies different harms levels, the results show that the harms are indeed not significantly different between the two treatments. However, regarding social welfare, it is higher in treatment B (at the 1% level), which implies that NJ performs better than JS. This is explained by the fact that player Y's investment under JS reduces his benefit, and this reduction is less than compensated by the reduction in the level of damages to be paid by the players (with our choice of parameters).

Result 1. *When one player is solvent and one is insolvent (for asset levels of 120 and 20), solvent players are over-deterred and insolvent players under-deterred. The over-deterrence is similar under the two rules. The under-deterrence is lower than expected, and lower under JS than under NJ. Overall, in terms of social welfare, the NJ rule prevails.*

Case 2: X and Y solvent (Treatments C and D)

Turning now to the case where players are both solvent, the two players theoretically choose the same investment levels in the two treatments, which corresponds to full solvency equilibrium investments, implying that NJ and JS are equivalent in terms of levels of harm and welfare (**prediction 2**). The computed values comparing Treatments C and D are presented in Table 8.

Table 8: Experimental social welfare - Treatments C-D - 20 periods

Variables	**Treatment C**	**Treatment D**
W_X	120	120
W_Y	55	55
Equilibrium investment of X	10.73	10.73
Observed investment of X	13.08	12.55
Equilibrium investment of Y	10.73	10.73
Observed investment of Y	8.96	7.76
Equilibrium harm	58.48	58.48
Observed harm	61.75	77.92
Theoretical SW	258.03	258.03
Observed social welfare	247.87	235.85

Theoretically, when both players are solvent, X makes the same investment choices under the two rules, but Y makes more investment under a JS rule (treatment C). Consequently, whereas welfare should theoretically be the same, the data show that JS leads to the lowest level of harm and the highest social welfare. Differences with NJ are significant at the 1% level. This leads to result 2.

Result 2. *When both players are (asymmetrically) solvent, the more solvent player chooses a higher investment than the less solvent one, in contradiction with theory, but behaves the same way whatever the rule, whereas the less solvent one chooses higher investment under the JS rule. In terms of harm and welfare, JS liability performs better than NJ.*

Case 3: X and Y insolvent (Treatments E and F)

When both players are (asymmetrically) insolvent (endowments of 80 and 20), their investments should be zero whatever the rule. Because of the zero investment incentives due to their insolvency, the two rules are theoretically equivalent. From Table 9, we find that both players choose significantly positive investments and their investments are higher under a NJ rule (treatment F). Moreover, results indicate that the level of harm is much higher and social welfare lower in treatment E (JS rule) and this is highly significant (at the 1% level). Thus, in terms of social welfare, the impact of their positive investments on welfare more than compensates their own cost of their investment, making these investments desirable.

Table 9: Experimental social welfare - Treatments E-F - 20 periods

Variables	**Treatment E**	**Treatment F**
W_X	80	80
W_Y	20	20
Equilibrium investment of X	0	0
Observed investment of X	2.07	3.41
Equilibrium investment of Y	0	0
Observed investment of Y	0.62	1.44
Equilibrium harm	500	500
Observed harm	423.45	393.55
Theoretical SW	-220	-220
Observed social welfare	-149.4	-122.94

Result 3. *When both players are (asymmetrically) insolvent, they make a low but positive investment whatever the liability sharing rule. The more endowed player chooses a higher investment than the less endowed one and the less endowed one chooses more investment under the NJ rule than under the JS rule. Overall, our results suggest that NJ performs better since it leads to a lower level of harm and higher social welfare than JS.*

4.5 Controls for subjects' characteristics

In this section, we present econometric results on the effect of the characteristics of subjects on their decisions during the experiment. More specifically, the subjects' risk aversion and their pro-social behavior can interfere with the incentives provided by the liability system, and have an impact on their investment choices. So, in addition to risk aversion we test the effect of altruism and preferences related to equity on the investment choices.

We tested different measures of risk, altruism and inequity aversion. However, some measures are substitutable and we selected those which appear to be the most efficient in our model. These measures are risk aversion (DR) elicited by the Holt and Laury (2002) method, inequity aversion (DE) elicited by the Blanco et al. (2011) method, and altruism (Selfish1) which is the subject's stated perception of his/her own altruism (graded from 1 to 10).[34] Moreover, we think that these variables might have different effects according to the treatment. This is why we also include fixed treatment-specific effects and their interactions with the variables DR, DE and Selfish1. Finally, we also control for some other individual characteristics of subjects such as gender, age, diploma, and university stream. Note that all these individual variables vary between individuals but are constant between treatments and sessions, excepted cross-terms that make it possible to identify some differences between treatments.

Tables 10 and 11 present estimation results respectively for players X and Y. We proceed in several steps as we introduce different groups of variables successively into the RE model (i.e., with random individual-specific effects). First, we include the treatment dummies from B to E (Treatment A being considered as the reference) and the main measures described above (Column (1)). We then introduce cross-terms between treatment dummies and DR, DE and Selfish1 into Columns (2), (3) et (4) respectively. Finally, column (5) displays all variables including individuals' characteristics.

Globally, we find that inequity aversion (DE) is the individual variable that impacts investment choices the most, and that the effects are most visible for player X.[35] Looking at Column (1) in Table 10 with a model including the treatment dummies and the three

[34] See the different alternative measures of risk, inequity and altruism preferences in Section A.3 of Appendix A.4.

[35] We tried another classification of our measures of risk aversion, inequity and altruism, by splitting the current 10-Likert scale data into three categories, i.e., high, medium and low aversion. However, these new variables are not more efficient in our regressions.

Table 10: Estimation results of player X investment regression

Variables	(1) DecisXi	(2) DecisXi	(3) DecisXi	(4) DecisXi	(5) DecisXi
TB	-0.435	-5.412**	-5.901	-5.951	-5.202
	(0.809)	(2.486)	(4.019)	(3.986)	(3.959)
TC	-2.917***	-8.220***	-6.304	-6.097	-6.050
	(0.823)	(2.341)	(3.902)	(4.013)	(3.987)
TD	-3.479***	-10.55***	-10.07**	-9.587**	-8.669**
	(0.820)	(2.234)	(3.990)	(3.983)	(4.081)
TE	-14.03***	-18.98***	-20.13***	-19.13***	-18.23***
	(0.823)	(2.209)	(4.091)	(4.198)	(4.179)
TF	-12.56***	-18.42***	-18.07***	-20.10***	-18.51***
	(0.817)	(2.296)	(3.869)	(3.996)	(4.159)
DR	0.116	0.0300	0.0739	-0.0557	0.0240
	(0.132)	(0.132)	(0.453)	(0.459)	(0.470)
DE	-0.0770	-0.865***	-0.859***	-0.943***	-0.836***
	(0.104)	(0.271)	(0.276)	(0.280)	(0.280)
Selfish1	0.00223	0.0113	0.00218	0.336	0.163
	(0.102)	(0.100)	(0.106)	(0.264)	(0.273)
DE×TB		0.786**	0.772**	0.881**	0.737*
		(0.367)	(0.373)	(0.377)	(0.379)
DE×TC		0.846**	0.983***	1.063***	0.965**
		(0.365)	(0.380)	(0.382)	(0.378)
DE×TD		1.169***	1.183***	1.259***	1.173***
		(0.347)	(0.385)	(0.386)	(0.387)
DE×TE		0.793**	0.796**	0.932**	0.849**
		(0.356)	(0.362)	(0.369)	(0.365)
DE×TF		0.950**	0.954**	0.844**	0.790*
		(0.369)	(0.396)	(0.416)	(0.411)
DR×TB			0.108	0.335	0.270
			(0.522)	(0.547)	(0.544)
DR×TC			-0.459	-0.334	-0.329
			(0.543)	(0.547)	(0.544)
DR×TD			-0.0915	0.157	0.0135
			(0.624)	(0.636)	(0.658)
DR×TE			0.176	0.243	0.155
			(0.538)	(0.544)	(0.549)
DR×TF			-0.0641	0.316	0.0931
			(0.587)	(0.603)	(0.615)
Selfish1×TB				-0.546	-0.312
				(0.408)	(0.412)
Selfish1×TC				-0.382	-0.199
				(0.338)	(0.342)
Selfish1×TD				-0.596*	-0.395
				(0.357)	(0.363)
Selfish1×TE				-0.608	-0.475
				(0.396)	(0.394)
Selfish1×TF				0.0747	0.0925
				(0.369)	(0.386)
Master&Doc					0.708
					(0.548)
Law&Literature					1.424*
					(0.802)
Gender					-0.431
					(0.563)
Constant	15.74***	21.18***	20.92***	20.99***	20.13***
	(1.075)	(1.982)	(3.372)	(3.345)	(3.513)
Wald test	574.49	621.76	612.27	629.12	656.99
Pvalue	0.0000	0.0000	0.0000	0.0000	0.0000

Note. # obs. = 2400. # indiv. = 120. Standard errors in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 11: Estimation results of player Y investment regression

Variables	(1) DecisYi	(2) DecisYi	(3) DecisYi	(4) DecisYi	(5) DecisYi
TB	-2.266***	-4.130*	-4.553	-4.404	-4.469
	(0.765)	(2.509)	(3.065)	(3.313)	(3.409)
TC	5.826***	-0.540	0.460	1.582	1.009
	(0.760)	(2.594)	(3.336)	(3.440)	(3.541)
TD	4.715***	2.706	2.413	1.691	1.137
	(0.760)	(2.622)	(3.758)	(3.895)	(4.080)
TE	-2.487***	-5.406**	-5.408*	-5.221	-5.419
	(0.759)	(2.428)	(3.268)	(3.366)	(3.376)
TF	-1.796**	-3.090	-2.817	-3.434	-3.016
	(0.772)	(2.444)	(3.108)	(3.431)	(3.445)
DR	-0.0314	-0.0483	-0.0159	0.0821	-0.0735
	(0.126)	(0.130)	(0.454)	(0.489)	(0.517)
DE	-0.0998	-0.497	-0.515	-0.473	-0.371
	(0.0920)	(0.340)	(0.406)	(0.416)	(0.452)
Selfish1	-0.0218	-0.0298	-0.0280	-0.160	-0.159
	(0.0944)	(0.0950)	(0.100)	(0.250)	(0.251)
DE×TB		0.289	0.238	0.196	0.0188
		(0.398)	(0.483)	(0.493)	(0.527)
DE×TC		1.063***	1.132**	1.180**	1.104**
		(0.410)	(0.483)	(0.499)	(0.544)
DE×TD		0.328	0.357	0.221	0.150
		(0.399)	(0.462)	(0.482)	(0.516)
DE×TE		0.472	0.488	0.445	0.339
		(0.376)	(0.441)	(0.453)	(0.479)
DE×TF		0.160	0.173	0.149	0.101
		(0.400)	(0.457)	(0.467)	(0.485)
DR×TB			0.143	0.0492	0.239
			(0.583)	(0.612)	(0.622)
DR×TC			-0.261	-0.332	-0.177
			(0.603)	(0.633)	(0.649)
DR×TD			0.0205	0.00978	0.177
			(0.567)	(0.598)	(0.617)
DR×TE			-0.0162	-0.115	0.0875
			(0.568)	(0.599)	(0.632)
DR×TF			-0.0660	-0.114	-0.111
			(0.512)	(0.545)	(0.562)
Selfish1×TB				0.148	0.209
				(0.357)	(0.365)
Selfish1×TC				-0.214	-0.140
				(0.372)	(0.379)
Selfish1×TD				0.391	0.429
				(0.359)	(0.360)
Selfish1×TE				0.145	0.0912
				(0.338)	(0.339)
Selfish1×TF				0.255	0.270
				(0.339)	(0.343)
Master&Doc					-0.835
					(0.603)
Law&Literature					-0.855
					(0.908)
Gender					0.204
					(0.552)
Constant	3.981***	6.578***	6.490***	6.264**	6.586***
	(1.098)	(2.115)	(2.456)	(2.510)	(2.519)
Wald test	235.40	259.06	248.99	247.57	251.48
Pvalue	0.0000	0.0000	0.0000	0.0000	0.0000

Note. # obs. = 2400. # indiv. = 120. Standard errors in parentheses.
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

measures regarding behavior related to risk, inequity and altruism, estimation results show treatment effects (compared to Treatment A) on the investment decision of player X but no direct effect of behavorial variables.[36]

In Column (2), the model is augmented by cross-terms between treatments and the variable DE. As endowments between X and Y have been distributed asymmetrically in favor of players X for all treatments, we could expect higher inequity aversion to induce more investment from players X and less investments from players Y, all other things being equal. Results in Table 10 show highly significant effects of all variables accounting for DE. We can first note that there is a direct and negative impact of DE (with a value of -0.865) on the investment choice of player X. Remembering that a lower value of DE indicates a larger aversion to inequity, this result shows that if the subject is more averse to inequity then he/she significantly increases his/her investment. However, the significantly positive cross-terms lessen this effect. Sometimes, such as for Treatment D, the coefficient is even significantly larger (with a value of 1.169), indicating that in the case of NJ liability rule and both players solvent, the effect is reversed. Having a look at results from Table 11 on Y's investment, we find that DE has a non-significant effect on investment, except for Treatment C where players Y who are more averse to inequity invest significantly less than for Treatment A.

In column (3) of both Tables 10 and 11, we add cross-terms of the variable DR with the treatment variables. All coefficients associated with terms related to DR are found to be non significantly different from zero. Thus, we find no evidence that risk aversion could affect investment decisions in our experiment.

Column (4) shows a model with additional terms interacting treatments with the altruism variable (i.e., Selfish1). We find a significantly negative coefficient for player X when the variable is crossed with Treatment D. Given that a low value of this variable indicates an altruistic behavior, this result means that altruism induces players X to make more investment than in Treatment A. We do not find any affect of altruism on the investment decision for player Y.

Finally, Column (5) of Table 10 shows that the players X studying Law or literature invest more than other students. The education level is collinear with the age variable, and none of them has an effect on investment decisions. Moreover, we found no evidence

[36] A regression including only treatment effects would trivially amount to the same results as those found for Treatment A in Table 5.

of any gender effect.

5 Conclusion

In this paper, we compare the performance of two existing liability sharing rules enforced against firms that jointly cause harm to third parties. The firms invest in safety in order to reduce the extent of the harm and may lack assets to compensate victims after the harm has occurred. Under a Non Joint rule, each firm bears its own share of the damages up to the value of their assets; in case of insolvency of at least one firm, the victims are not compensated. Under a Joint and Several Rule, the portion of damages that cannot be borne by one firm is attributable to solvent firms, so that the victims may be fully compensated if the sum of firms' assets exceeds the amount of harm. We model the firms' simultaneous investments in safety and test the predictions of the theoretical model with a laboratory experiment. In line with theory, we highlight that the combination of insolvency and limited liability leads to under-deterrence whereas solvency in the presence of insolvent firms leads to over-deterrence. However, the under-deterrence is lower than predicted since insolvent firms choose positive investments in most cases, which may be partly explained by inequity aversion. We also highlight wealth effects in several treatments, which cannot be evidenced by theory: indeed, in four treatments, the most endowed player takes more care than the least endowed one, while theoretical investments between players are the same because the firms' situation in terms of being solvent (or insolvent) is the same.

We also compare the performance of liability sharing rules in terms of levels of harm and social welfare, and show that with at least one insolvent firm, the Non Joint rule performs better in the experiment. When all firms are solvent, a Joint and Several rule leads to lower harm and higher social welfare. Thus, in industries where no requirement in terms of firms' capitalization is required (and/or when firms are little endowed with assets, relatively to the magnitude of the potential harm), our results call for the enforcement of a Non Joint Rule. In activities where a high degree of firms' capitalization is required, then a Joint and Several Rule should be enforced. The legislator might thus make the default rule dependent upon the existence of capitalization requirements. Moreover, as high levels of capitalization are required in the most dangerous activities, the combination of such a requirement and of a JS rule ensures a highly improved compensation of third parties.

This work can be extended in several directions. Whereas our framework applies better to an environmental harm such as pollution, in that firms jointly reduce the extent of the harm, further research should be done on cases where their investments reduce the probability of occurrence of an environmental disaster. In such situations, it would be interesting to analyze the impact of their behavior toward risk on their incentives to take care. Another extension of this paper would be to consider another liability rule, which is a negligence rule, rather than strict liability: under a negligence rule, if firms make sufficiently high investments, thereby respecting a standard of due care, they are not held liable for harm and thus do not have to compensate for the harm. As the negligence rule is the one enforced in the European Union for most (low) environmental harms (and in the US for non-economic harms), it would be relevant to experimentally compare different combinations of liability rules, associating with each liability sharing rule (NJ and JS) either a negligence rule or a strict liability rule. This would provide a complete picture of existing situations.

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A Appendix

A.1 Proof of Propositions 1, 2, and 3

Proof of Proposition 1

Recall that under a NJ rule, the expected profit of a firm i, $i = X, Y$, is given by:

$$\max_{I_i} \Pi_i^{NJ}(I_i, I_j) = B(I_i) + W_i - Min\left\{W_i; \frac{1}{2}D(I_i, I_j)\right\}$$

So, in a case where the two firms, X and Y, are "highly" solvent, each firm i has to maximize:

$$\max_{I_i} \Pi_i^{NJ}(I_i, I_j) = B(I_i) + W_i - \frac{1}{2}D(I_i, I_j) \tag{A.1}$$

Investments at equilibrium, $I_X(\infty)$ and $I_Y(\infty)$, satisfy:

$$\begin{aligned} \frac{\partial \Pi_X^{NJ}(I_X, I_Y)}{\partial I_X} &= 0 \Rightarrow -\frac{\partial \frac{1}{2}D(I_X, I_Y(\infty))}{\partial I_X} = -\frac{B(I_X)}{\partial I_X} \\ \frac{\partial \Pi_Y^{NJ}(I_X, I_Y)}{\partial I_Y} &= 0 \Rightarrow -\frac{\partial \frac{1}{2}D(I_X(\infty), I_Y)}{\partial I_Y} = -\frac{B(I_Y)}{\partial I_Y} \end{aligned}$$

Because of symmetry we obtain $I_i(\infty) = I_j(\infty)$.

Consider now another case where $W_Y = 0$: in that case, firm Y cannot pay for liability (limited liability). It is obvious that it has no interest in making any investment: $I_Y = 0$. This is also true for some strictly positive values of W_Y, until a threshold-value, say $\underline{W}$, for which firm Y is indifferent between making a positive investment and making no investment. This threshold is defined by:

$$\begin{aligned} &B(0) = B(I_Y(\infty)) - \frac{1}{2}D(I_X(\infty), I_Y(\infty)) + W_Y \\ &\Rightarrow W_Y = B(0) - B(I_Y(\infty)) + \frac{1}{2}D(I_X(\infty), I_Y(\infty)) = \underline{W} \end{aligned} \tag{A.2}$$

with $B(0)$ being the firm's profit when it is insolvent (and makes no investment).

Consider now that: $W_Y < \underline{W}$. So we have: $I_Y = 0$. In this case, if firm X is able to remain solvent in the event of damage, it will pay its share of liability, $\frac{1}{2}D(I_X, 0)$. Its level of investment responds to:

$$\max_{I_X} \Pi_X^{NJ}(I_X, 0) = B(I_X) + W_X - \frac{1}{2}D(I_X, 0) \tag{A.3}$$

Note the equilibrium investment to be: $I_X^b > 0$.

If it is unable pay this amount, it will be liquidated (and pay only W_X). In that case, its payment does not depend on its investment I_X: at equilibrium, we have $I_X = 0$, and its profit falls to $B(0)$.

All in all, it is possible to determine a threshold in firm X's level of assets, say $\bar{W}_{NJ}$, under which it chooses to be insolvent (and making no investment), and above which it chooses to remain solvent after damage and making a positive effort I_X^b. This threshold is defined by:

$$\begin{aligned} & W_X + B(I_X^b) - \frac{1}{2}D(I_X^b, 0) > B(0) \\ & \Leftrightarrow W_X > B(0) - B(I_X^b) + \frac{1}{2}D(I_X^b, 0) = \bar{W}_{NJ} \end{aligned} \tag{A.4}$$

Note that I_X^b and I_X^{**} cannot be compared, but we can easily check that $I_X^b > I_X(\infty)$. Indeed, I_X^{**} is defined by equation (2). $I_X(\infty)$ is defined by the first derivative of (A.1), with respect to I_X, equalized to 0, i.e., $\frac{\partial B(I_X)}{\partial I_X} - \frac{1}{2}\frac{\partial D(I_X, I_Y)}{\partial I_X} = 0$. I_X^b is defined by the first derivative of (A.3), with respect to I_X, equalized to 0, i.e., $\frac{\partial B(I_X)}{\partial I_X} - \frac{1}{2}\frac{\partial D(I_X, 0)}{\partial I_X} = 0$. A comparison between these three FOC makes it possible to see that I_X^b and I_X^{**} cannot be compared because we cannot rank $\frac{1}{2}\frac{\partial D(I_X, 0)}{\partial I_X}$ and $\frac{\partial D(I_X, I_Y)}{\partial I_X}$ (with $I_Y > 0$). However, $-\frac{1}{2}\frac{\partial D(I_X, 0)}{\partial I_X} > -\frac{1}{2}\frac{\partial D(I_X, I_Y)}{\partial I_X}$ (with $I_Y > 0$) leads to $I_X^b > I_X(\infty)$.

Q.E.D

Proof of Proposition 2

Like in the case of a NJ rule, three different equilibria can be met, depending on the firms' level of assets.

First, when both firms are sufficiently endowed with assets, they can have an interest in making an investment and staying solvent in case of damage. This case is the same as the one encountered under a NJ rule, and we obtain: $I_i(\infty) = I_j(\infty)$.

Second, like in the case of a NJ rule, the least solvent firm Y can be so poorly endowed with assets that it has no interest in making any investment at all (i.e., $I_Y = 0$). It is easy to demonstrate that the threshold-level of assets under which firm Y has no interest in investing is the same as those which prevail under a NJ rule: $\underline{W}$ (see (A.2) above).

Consider now that: $W_Y < \underline{W}$. So we have $I_Y = 0$. In this case, if firm X is able to remain solvent in the case of damage, it will pay for its share of liability, $\frac{1}{2}D(I_X, 0)$, but it also has to pay for the remaining debt of firm Y: $\frac{1}{2}D(I_X, 0) - W_Y$. As a consequence, firm's X payment is: $D(I_X, 0) - W_Y$. Thus its investment responds to:

$$\max_{I_X} \Pi_X^{JS}(I_X, 0) = B(I_X) + W_X - [D(I_X, 0) - W_Y] \tag{A.5}$$

Note the equilibrium investment to be: $I_X^a > 0$.

In the case where firm X chooses to not be solvent after a damage occurring, it will be liquidated (and pay only W_X). In that case, its investment at equilibrium is: $I_X = 0$.

All in all, it is possible to determine a threshold in firm X's level of assets, say $\bar{W}_{JS}$, under which it chooses to be insolvent (and making no investment), and above which it chooses to remain solvent after damage and making a positive effort I_X^a. This threshold is defined by:

$$\begin{aligned} & W_X + B(I_X^a) - [D(I_X^a, 0) - W_Y] > B(0) \\ & \Leftrightarrow W_X > B(0) - B(I_X^a) + [D(I_X^a, 0) - W_Y] = \bar{W}_{JS} \end{aligned} \tag{A.6}$$

We can easily check that: $I_X^a > I_X^{**} > I_X(\infty)$ and $I_X^a > I_X^b$. Indeed, I_X^{**} is defined by equation (2). $I_X(\infty)$ is defined by: $\frac{\partial B(I_X)}{\partial I_X} - \frac{1}{2}\frac{\partial D(I_X, I_Y)}{\partial I_X} = 0$. I_X^b is defined by: $\frac{\partial B(I_X)}{\partial I_X} - \frac{1}{2}\frac{\partial D(I_X, 0)}{\partial I_X} = 0$. And I_X^a is defined by the first derivative of (A.5) with respect to I_X, equalized to 0, i.e., $\frac{\partial B(I_X)}{\partial I_X} - \frac{\partial D(I_X, 0)}{\partial I_X} = 0$. It is easy to see that $I_X^a > I_X^{**}$ because $-\frac{\partial D(I_X, 0)}{\partial I_X} > -\frac{\partial D(I_X, I_X)}{\partial I_X}$ (with $I_Y > 0$). Moreover, $-\frac{\partial D(I_X, 0)}{\partial I_X} > -\frac{1}{2}\frac{\partial D(I_X, 0)}{\partial I_X}$ leads to $I_X^a > I_X^b$. $I_X^{**} > I_X(\infty)$ was demonstrated before.
This implies that under a JS rule, a solvent firm which is faced with an insolvent firm is pushed to over-invest in care. Moreover, this investment level is higher than that under a NJ rule: because the solvent firm has to pay the remaining debt of the insolvent firm, its incentives to reduce the extent of the damage are even higher.

Q.E.D

Proof of Proposition 3

Point (ii)

This point is the result of a comparison of different outputs, depending on the apportionment rule, summarized in the following two tables.

Table A.1: Joint and several vs non-joint liability, when agent Y is insolvent and $\bar{W}_{NJ} < \bar{W}_{JS}$

—	Invest. of X		Damage		Compensation		Welfare
W_X	JS	NJ	JS	NJ	JS	NJ	JS vs NJ
$[0; \bar{W}_{NJ}]$	0	0	$D(0,0)$	$D(0,0)$	$W_X + W_Y$	$W_X + W_Y$	Equal
$[\bar{W}_{NJ}; \bar{W}_{JS}]$	0	e_X^b	$D(0,0)$	$D(I_X^b, 0)$	$W_X + W_Y$	$0.5D(I_X^b, 0) + W_Y$	$NJ > JS$
$> \bar{W}_{JS}$	I_X^a	I_X^b	$D(I_X^a, 0)$	$D(I_X^b, 0)$	$D(I_X^a, 0)$	$0.5D(I_X^b, 0) + W_Y$	$JS > NJ$

Table A.2: Joint and several vs non-joint liability, when agent Y is insolvent and $\bar{W}_{NJ} > \bar{W}_{JS}$

—	Invest. of X		Damage		Compensation		Welfare
W_X	JS	NJ	JS	NJ	JS	NJ	JS vs NJ
$[0; \bar{W}_{JS}]$	0	0	$D(0,0)$	$D(0,0)$	$W_X + W_Y$	$W_X + W_Y$	Equal
$[\bar{W}_{JS}; \bar{W}_{NJ}]$	I_X^a	0	$D(I_X^a, 0)$	$D(0,0)$	$D(I_X^a, 0)$	$W_X + W_Y$	$JS > NJ$
$> \bar{W}_{NJ}$	I_X^a	I_X^b	$D(I_X^a, 0)$	$D(I_X^b, 0)$	$D(I_X^a, 0)$	$0.5D(I_X^b, 0) + W_Y$	$JS > NJ$

Recall that $\bar{W}_{NJ}$ is defined by (A.4) and $\bar{W}_{JS}$ is defined by (A.6). The values of these threshold cannot a priori be ranked. So we consider two cases: $\bar{W}_{NJ} < \bar{W}_{JS}$ (Table A.1) and $\bar{W}_{NJ} > \bar{W}_{JS}$ (Table A.2).

We still consider firm Y to be insolvent (and thus making no investment). The two tables are exhaustive (i.e., they treat for all possible values of W_X) but, in this comment, we focus on the case where X is solvent while Y is not, regardless of the rule (i.e., $W_X > \bar{W}_{JS}$ for the case of Table A.1, $W_X > \bar{W}_{NJ}$ for the case of Table A.2; we therefore consider $W_X > \max\left[\bar{W}_{NJ}, \bar{W}_{JS}\right]$).

We can observe that the two tables show JS to be preferred to NJ in that case (JS provides a higher welfare than NJ). This is the case because under JS, (at the margin) agent X internalizes the whole damage so that I_X^a is the socially best response to $e_Y = 0$; while I_X^b is suboptimal because only a 0.5 share is internalized at the margin. Moreover, when X is sufficiently wealthy, JS ensures total compensation for the victim. Finally, because $\frac{\partial D(I_X, I_Y)}{\partial I_X} < 0$, we have: $D(I_X^a, 0) < D(I_X^b, 0)$: JS ensures a lower level of pollution than NJ. These three outputs (social welfare, level of damage, victims' compensation (or environmental reparation)) leads to JS to be preferred over NJ.

Q.E.D

A.2 Damage values depending on investment choices

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	500	452	409	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50
1	452	409	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45
2	409	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41
3	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37
4	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34
5	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30
6	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28
7	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25
8	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23
9	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20
10	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18
11	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17
12	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15
13	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14
14	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12
15	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11
16	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10
17	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9
18	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8
19	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7
20	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7
21	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7	6
22	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7	6	6
23	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7	6	6	5

A.3 Benefit of one agent depending on its investment level

Effort	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Benefit	**90**	**89**	**88**	**87**	**85**	**84**	**82**	**80**	**78**	**75**	**73**	**70**	**67**	**63**	**59**	**55**	**50**	**45**	**40**	**33**	**26**	**18**	**10**	**0**

A.4 Definition and descriptive statistics of individual characteristics

Note that the meaning of the variables is given either in the main text, or within the post-experiment questionnaire, available in Appendix A.6.

Table A.3: Definition of variables

Variable	Definition
I_i	Level of investment of player i in each period of Game 3
W_i	Endowment of player i
DR	(test) equals 1 (most risk-averse) and 10 (most risk-loving)
DE	(test) equals 1 (most inequity-averse) and 10 (most inequity-loving)
Risk	(stated) equals 1 (most risk-averse) and 10 (most risk-loving)
Selfish1	(stated) equals 1 (most altruist) to 10 (most selfish)
Selfish12	(stated) equals 1 if the subject thinks he/she played as an altruistic person, 0 otherwise
Selfish21	(stated) equals 1 (the others are most altruistic) to 10 (the others are most selfish)
Selfish22	(stated) equals 1 if the subject thinks his/her partners are altruistic, 0 otherwise
Age	the age of the subject
Gender	Equal 1 if the subject is male
Master&Doc	Equals 1 if the subject is at Master or Doctorate level
Sciences	Equals 1 if the subject studies Sciences
Law&Literature	Equals 1 if the subject studies Law or Literature
Economics	Equals 1 if the subject studies Economics

A.5 Instructions for the experiment

[Translated from French to English]

Welcome to our laboratory.

You are about to participate in an experiment in decision-making. If you follow the instructions carefully, your decisions will allow you to earn some money. All subjects have identical instructions and all decisions are anonymous. You will never be asked to enter your name on the computer. During the experiment, you are not allowed to communicate with each other. Do not hesitate to ask questions after reading the instructions and during the experiment, by raising your hand. One of us will come and answer you. Your payment during this experiment will depend on your own decision choices, on the decisions of others and on the results of a random draw. Your earnings will be paid to you in cash at the end of the experiment.

General framework

The experiment comprises three tasks.

The instruction for the first task will be directly handed out.

The instruction for the second task will be handed out after the first task.

The instruction for the third task will be handed out after the second task.

Each task will be paid out. Your payment is the sum of the payoffs of the three tasks. We will inform you about the payoffs of the three tasks at the end of the experiment.

A.5.1 Task 1

During this task, you will have to make several decisions: you will have to make choices between two options, the Left option and the Right option.

The alternative will determine the allocation of a certain amount between you (you will make your decisions as Player A) and another subject (Player B) present in this room. Your role (A or B) will be randomly chosen at the end of the experiment.

The alternatives are as follows:

- Alternative Left will pay 5 to player A and 0 to player B.
- Alternative Right will pay player A and player B an equal amount of X . Note that the amount X increases from one line to the next one.

Note: You are not allowed to make inconsistent decisions during this task. More precisely, if you prefer alternative ”Right” for a certain line, the computer requires you to choose the same alternative for the lines lower than X. Furthermore, the computer requires you to choose alternative ”Left” for the amount X equal to 0 and alternative ”Right” for the amount X equal to 5 .

Payoffs:

At the end of the experiment, the computer assigns you randomly as player A or B. If you are assigned as player A, the computer will randomly draw a line (X). Given the result of the random draw, your payoff depends on your decision choice. If you have chosen the alternative ”Right”, the payoffs of both

Figure A.1: **Information table**

Option Gauche : 5€ pour le joueur A et 0 pour le joueur B.	Gauche	Droite	Option Droite : X€ pour le joueur A et pour le joueur B.
(5€;0€)	◉	○	(0€;0€)
(5€;0€)	○	○	(0,5€;0,5€)
(5€;0€)	○	○	(1€;1€)
(5€;0€)	○	○	(1,5€;1,5€)
(5€;0€)	○	○	(2€;2€)
(5€;0€)	○	○	(2,5€;2,5€)
(5€;0€)	○	○	(3€;3€)
(5€;0€)	○	○	(3,5€;3,5€)
(5€;0€)	○	○	(4€;4€)
(5€;0€)	○	○	(4,5€;4,5€)
(5€;0€)	○	◉	(5€;5€)

players will be X . If you have chosen alternative "Left", player A's payoff will be 5 and player B's payoff will be 0 . If you are assigned as player B, your payoff will depend on player A's decision choice and the random draw of the line (X). If player A chose the alternative "Right", the payoffs of both players will be X. If player A chose alternative "Left", your payoff will be 0 .

The random draws are performed individually.

A.5.2 Task 2

In this second task, you will first indicate whether you prefer your winning color to be Yellow or Blue. This will matter at the end of the experiment, in determining your payoff for this task. Then you have to make several choices between two alternatives: "Left" and "Right".

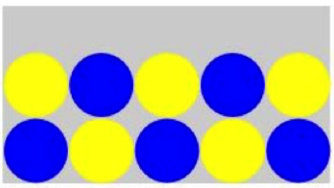
- Alternative Left will pay 5 with 1 chance out of 2 and 0 euro with 1 chance out of 2.
- Alternative Right will pay you a guaranteed amount of X . Note that the amount X increases from one line to the next one.

Figure A.2: **Information table**

Dans l'Option Gauche, l'urne contient exactement 5 boules jaunes et 5 boules bleues.

Rappel : Votre couleur gagnante est

Veuillez choisir entre l'Option Gauche dont l'issue est incertaine et l'Option Droite qui consiste à recevoir avec certitude X€.



Option Gauche : Jouer la loterie ci-dessous	Gauche	Droite	Option Droite : Recevoir avec certitude un montant X =
	◉	○	0€
	○	○	0,5€
	○	○	1€
	○	○	1,5€
	○	○	2€
	○	○	2,5€
	○	○	3€
	○	○	3,5€
Gain de 5€ si	○	○	4€
Gain de 0€ si	○	○	4,5€
	○	◉	5€

N.B.: You are not allowed to make inconsistent decisions during this task. More precisely, if you prefer alternative "Right" for a given line (amount X), the computer requires you to choose the same alternative for the lines which are under X. Furthermore, the computer requires you to choose alternative "Left" for the first line (you have to choose the lottery rather than a secure payoff of zero) and alternative "Right" for the last line (the secure amount equal to 5).

Payoffs:
At the end of the experiment, the computer will randomly determine a line X. If you chose alternative "Left", a ball will be drawn from the urn. If the color of the ball corresponds to your winning color, your payoff will be 5 , otherwise your payoff will be 0 euro. If you chose alternative "Right", your payoff will be equal to X. The draw is performed on an individual basis during this task.

A.5.3 Task 3

Task 3 of the experiment - Treatment A

During this third task, your payoffs are expressed in ECUS. Your real payoffs for this task will be converted at the rate of 100 ECUS = 7 .

This task comprises 20 independent periods. You will have to make a decision at each period. At the end of the 20 periods, one participant will be randomly designated to draw the two winning periods and will read them aloud to all participants. The payoffs that every participant will obtain during this task 3 will be calculated by adding up the gains of these two periods.

Description of the task

You are randomly assigned the role of player X or player Y at the beginning of this game and you keep this role during the 20 periods. You are 20 participants in total, divided into 2 groups of 10 participants; these two groups will never interact with each other. Within each group of 10, there are 5 participants X and 5 participants Y. At the beginning of each of the 20 periods, each participant X is paired with a participant Y for this period. You will never know the identity of your partner. Moreover, the partner you are paired with at each period is randomly determined before each new period.

A.5.4 Description of a period

Participant X starts each period with an endowment of **120 ECUS** and participant Y starts each period with an endowment of **20 ECUS**. During each period, you have to choose a number between 0 and 23, and your partner also has to choose a number between 0 and 23. Nevertheless, you both have to make these decisions simultanously, so that at the time you make your own private choice, you do not know your partner's choice and he does not know yours at the time he makes his decision. Your gain for this period is made up of three elements A, B and C: A is determined from the start, B is entirely determined by your choice, and C is determined both by your choice and the choice of your partner.

- A is your initial endowment of **120** if you are X and **20** if you are Y.

- B comes in addition to your initial endowment and depends only on the number that you choose. The values of B depending on the chosen number are shown in **Table 1**. The higher the number you choose, the lower B; the lower the chosen number, the higher B. For example, if you choose number 3, your B equals 87; if you choose number 22, your B equals 10.
- C is a cost, which is deducted from your endowment and depends both on your number choice and on the number chosen by your partner. The values of C depending on the choice of the two partners are displayed in **Table 2**. The higher the numbers chosen by your partner and you, the lower C; the lower the numbers, the higher C. For instance, if you choose number 3 and your partner chooses number 2, then C equals 303; if you choose number 20 and your partner chooses number 22, then C equals 7. C is borne by the two partners, within the limits of their initial endowment. There may be cases where each one bears half of C and cases where X bears a higher share of C than Y. Several scenarios are possible:

  51 If C is lower than or equal to 40 then each partner bears half of C.

  51 If C is between 40 and 140, then Y bears the cost within the limit of his endowment (i.e. 20) and X bears the remaining cost (so $C - 20$)

  51 If C is higher than 140, then each partner bears the cost within the limits of his endowment (X bears 120 and Y bears 20). In this case, part of C (the part beyond 140) is not borne by anybody.

The earnings of each participant are thus as follows:
payoff of a player = initial endowment A + B − borne part of C (part $\leq A$)

*Let us take two **arbitrary** examples. Note that these two examples are just used to illustrate but are absolutely not intended to guide your decisions; in particular, they are not intended to reflect the best possible situation, whether for one of the two partners, or for the two.* **Example 1**: X chooses 18 and Y chooses 10.

Earnings of Y:

- The endowment of Y is $A = 20$.
- The element B of Y is equal to 73 (*Table 1*).
- The total cost C is equal to 30 (*Table 2*). Y is able to bear half of C, that is, 15, since his initial endowment A of 20 is sufficient.
- Y obtains a total gain of $20 + 73 - 15 = 78$.

Earnings of X:

- The endowment of X is $A = 120$.
- The element B of X is equal to 40 (*Table 1*).
- The total cost C is equal to 30 (*Table 2*). X also bears half of C, that is, 15, since his initial endowment A of 120 is sufficient.
- X obtains a total gain of $120 + 40 - 15 = 145$.

Example 2: Y chooses 3 and X chooses 1.

Earnings of Y:

- The endowment of Y is $A = 20$.
- The element B of Y is equal to 87 (*Table 1*).
- The total cost C is equal to 335 (*Table 2*). Half of C is equal to 167,5. Y cannot bear half of this cost since his endowment A of 20 is not sufficient; he then bears the cost within the limits of his endowment A (that is, 20).
- Y obtains a total gain of $20 + 87 - 20 = 87$.

Earnings of X:

- The endowment of X is $A = 120$.
- The element B of X is equal to 89 (*Table 1*).
- The total cost C is equal to 335 (*Table 2*). Partner Y bears 20. The remaining cost to bear is then $335 - 20 = 315$. X cannot bear all this remaining cost since his endowment A of 120 is not sufficient. X then bears the remaining cost within the limits of his endowment A, that is, 120.
- X obtains a total gain of $120 + 89 - 120 = 89$.

N.B.: the values of B and C displayed in Tables 1 and 2 are rounded values. It is thus possible that your real earning moves at most 1 unit from your calculations.

In order to make your decision-making easier, we now give you:

- **Table 3**, which shows the net gains of X depending on his choice (indicated on the first column of the table) and on the choice of Y (indicated on the first row)
- **Table 4**, which shows the net gains of Y depending on his choice (indicated on the first column of the table) and on the choice of X (indicated on the first row)

These tables 3 and 4 thus identify all your possible gains depending on your choice and your partner's choice. Lets us consider **example 1** again, where X chooses 18 and Y chooses 10:

- Table 3 indicates that the net gain of X given his choice of 18 (cf 1st column) (and given that Y chose 10, cf 1st row) is equal to 144.
- Table 4 indicates that the net gain of Y given his choice of 10 (cf 1st column) (and given that X chose 18, 1st row) is equal to 78.

Let us now consider **example 2** again, where X chooses 1 and Y chooses 3:

- Table 3 indicates that the net gain of X given his choice of 1 (cf 1st column) (and given that Y chose 3, cf 1st row) is equal to 89.
- Table 4 indicates that the net gain of Y given his choice of 3 (cf 1st column) (and given that X chose 1, 1st row) is equal to 87.

Once the first period has ended, you are paired with another randomly assigned participant and you again have to choose a number between 0 and 23. The gains are calculated the same way in each period.

Before this task begins, we ask you to answer a few questions in order to test your understanding of the instructions. These questions will appear on your computer screen shortly.

Table 1

Table 1 : Determination of B

Your number choice	Value of B
0	90
1	89
2	88
3	87
4	85
5	84
6	82
7	80
8	78
9	75
10	73
11	70
12	67
13	63
14	59
15	55
16	50
17	45
18	40
19	33
20	26
21	18
22	10
23	0

Table 2

Table 2 : Determination of C

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
0	500	452	409	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50
1	452	409	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45
2	409	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41
3	370	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37
4	335	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34
5	303	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30
6	274	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28
7	248	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25
8	225	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23
9	203	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20
10	184	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18
11	166	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17
12	151	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15
13	136	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14
14	123	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12
15	112	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11
16	101	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10
17	91	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9
18	83	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8
19	75	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7
20	68	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7
21	61	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7	6
22	55	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7	6	6
23	50	45	41	37	34	30	28	25	23	20	18	17	15	14	12	11	10	9	8	7	7	6	6	5

Table 3

Table 3 : Nets gains of X depending on his choice (1st column) and on Y's choice (1st raw)

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
0	90	90	90	90	90	90	90	90	90	90	90	90	90	94	107	118	129	139	147	155	162	169	175	180
1	89	89	89	89	89	89	89	89	89	89	89	89	93	106	117	128	138	146	154	161	168	174	179	184
2	88	88	88	88	88	88	88	88	88	88	88	92	104	116	127	136	145	153	160	167	172	178	182	187
3	87	87	87	87	87	87	87	87	87	87	90	103	115	126	135	144	152	159	165	171	176	181	185	188
4	85	85	85	85	85	85	85	85	85	89	102	114	124	134	142	150	157	164	170	175	180	184	187	188
5	84	84	84	84	84	84	84	84	87	100	112	123	132	141	149	156	162	168	173	178	182	185	187	188
6	82	82	82	82	82	82	82	86	98	110	121	130	139	147	154	161	166	172	176	181	183	185	187	188
7	80	80	80	80	80	80	84	97	108	119	129	137	145	152	159	164	170	175	179	181	183	185	186	187
8	78	78	78	78	78	81	94	106	117	126	135	143	150	157	162	168	172	177	179	181	183	184	185	186
9	75	75	75	75	79	92	104	114	124	133	141	148	154	160	165	170	174	177	179	180	182	183	184	185
10	73	73	73	77	90	101	112	121	130	138	145	152	157	163	167	172	174	176	178	179	180	182	183	184
11	70	70	74	87	98	109	119	127	135	142	149	155	160	165	169	171	173	175	176	178	179	180	181	182
12	67	71	84	95	106	115	124	132	139	146	151	157	161	166	168	170	172	173	174	176	177	178	178	179
13	67	80	92	102	112	121	129	136	142	148	153	158	162	165	167	168	170	171	172	173	174	175	176	176
14	76	88	98	108	117	125	132	138	144	149	154	158	161	163	164	166	167	168	169	170	171	172	173	173
15	84	94	104	113	120	128	134	140	145	150	154	157	158	160	161	163	164	165	166	167	168	168	169	170
16	90	99	108	116	123	129	135	140	145	149	152	154	155	157	158	159	160	161	162	163	164	164	165	165
17	94	103	110	118	124	130	135	140	144	147	148	150	152	153	154	155	156	157	158	158	159	160	160	161
18	97	105	112	118	124	129	134	138	141	143	144	146	147	148	149	150	151	152	153	153	154	154	155	155
19	98	105	112	118	123	128	132	135	136	138	139	141	142	143	144	145	146	146	147	148	148	149	149	149
20	98	105	111	116	121	125	128	129	131	132	134	135	136	137	138	139	139	140	141	141	142	142	142	143
21	97	103	108	113	117	120	122	123	125	126	127	128	129	130	131	132	132	133	133	134	134	135	135	135
22	94	100	104	109	111	113	115	116	117	118	120	121	121	122	123	124	124	125	125	126	126	126	127	127
23	90	95	99	102	103	105	107	108	109	110	111	112	113	113	114	115	115	116	116	117	117	117	117	118

Table 4

Table 4 : Nets gains of Y depending on his choice (1st column) and on X's choice (1st raw)

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
0	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
1	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89
2	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
3	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	88
4	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	87	88
5	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	85	87	88
6	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	83	85	87	88
7	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	81	83	85	86	87
8	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	79	81	83	84	85	86
9	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	77	79	80	82	83	84	85
10	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	74	76	78	79	80	82	83	84
11	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	71	73	75	76	78	79	80	81	82
12	67	67	67	67	67	67	67	67	67	67	67	67	67	67	68	70	72	73	74	76	77	78	78	79
13	63	63	63	63	63	63	63	63	63	63	63	63	63	65	67	68	70	71	72	73	74	75	76	76
14	59	59	59	59	59	59	59	59	59	59	59	59	61	63	64	66	67	68	69	70	71	72	73	73
15	55	55	55	55	55	55	55	55	55	55	55	57	58	60	61	63	64	65	66	67	68	68	69	70
16	50	50	50	50	50	50	50	50	50	50	52	54	55	57	58	59	60	61	62	63	64	64	65	65
17	45	45	45	45	45	45	45	45	45	47	48	50	52	53	54	55	56	57	58	58	59	60	60	61
18	40	40	40	40	40	40	40	40	41	43	44	46	47	48	49	50	51	52	53	53	54	54	55	55
19	33	33	33	33	33	33	33	35	36	38	39	41	42	43	44	45	46	46	47	48	48	49	49	49
20	26	26	26	26	26	26	28	29	31	32	34	35	36	37	38	39	39	40	41	41	42	42	42	43
21	18	18	18	18	18	20	22	23	25	26	27	28	29	30	31	32	32	33	33	34	34	35	35	35
22	10	10	10	10	11	13	15	16	17	18	20	21	21	22	23	24	24	25	25	26	26	26	27	27
23	0	0	0	2	3	5	7	8	9	10	11	12	13	13	14	15	15	16	16	17	17	17	17	18

Task 3 of the experiment - Treatment B

[***Note for the reader: for ease of reading, we inform you that only the <u>underlined parts</u> are different between this treatment B and the previous treatment A.***]

During this third task, your payoffs are expressed in ECUS. Your real payoffs for this task will be converted at the rate of 100 ECUS = 7 .

This task comprises 20 independent periods. You will have to make a decision at each period. At the end of the 20 periods, one participant will be randomly designated to draw the two winning periods and will read them aloud to all participants. The payoffs that every participant will obtain during this task 3 will be calculated by adding up the gains of these two periods.

Description of the task

You are randomly assigned the role of player X or player Y at the beginning of this game and you keep this role during the 20 periods. You are 20 participants in total, divided into 2 groupes of 10 participants; these two groups will never interact with each other. Within each group of 10, there are 5 participants X and 5 participants Y. At the beginning of each of the 20 periods, each participant X is paired with a participant Y for this period. You will never know the identity of your partner. Moreover, the partner you are paired with at each period is randomly determined before every new period.

Description of a period

Participant X starts each period with an endowment of **120 ECUS** and participant Y starts each period with an endowment of **20 ECUS**. During each period, you have to choose a number between 0 and 23, and your partner also has to choose a number between 0 and 23. Nevertheless, you both have to make these decisions simultanously, so that at the time you make your own private choice, you do not know your partner's choice and he does not know yours at the time he makes his decision. Your gain for this period is made up of three elements A, B and C: A is determined from the start, B is entirely determined by your choice, and C is determined both by your choice and the choice of your partner.

- A is your initial endowment of **120** if you are X and **20** if you are Y.
- B comes into addition to your initial endowment and depends only on the number that you choose. The values of B depending of the chosen number are shown in **Table 1**. The higher the number you choose, the lower B; the lower the chosen number, the higher B. For example, if you choose number 3, your B equals 87; if you choose number 22, your B equals 10.
- C is a cost, which is deducted from your endowment and depends both on your number choice and on the number chosen by your partner. The values of C depending on the choice of the two partners are displayed in **Table 2**. The higher the numbers chosen by your partner and you, the lower C; the lower the numbers, the higher C. For instance, if you choose number 3 and your partner chooses number 2, then C equals 303; if you choose number 20 and your partner chooses number 22, then C equals 7. *Each partner of the pair must bear* ***half*** *of the cost, within the limits of his initial endowment. Thus X cannot bear more than 120 and Y cannot bear more than 20.*

Several scenarios are possible:

51 *If C is lower than or equal to 40 then each partner bears half of C.*

51 *If C is between 40 and 240, then Y cannot bear half of C, so that he bears within the limit of his endowment (that is, 20); X bears half the cost since his endowment is sufficient. In this case, some part of C is not borne by anybody.*

51 *If C is higher than 240, then each partner bears the cost within the limits of his endowment (X bears 120 and Y bears 20). In this case, some part of C is not borne by anybody.*

The earnings of each participant are thus as follows:

payoff of a player = initial endowment A + B − borne part of C (part $\leq A$)

Let us take two ***arbitrary*** *examples. Note that these two examples are just used to illustrate but are absolutely not intended to guide your decisions; in particular, they are not given to reflect the best possible situation, whether for one of the two partners, or for the two.*

Example 1: X chooses 18 and Y chooses 10.

Gain of Y:

- The endowment of Y is $A = 20$.
- The element B of Y is equal to 73 (*Table 1*).
- The total cost C is equal to 30 (*Table 2*). Y is able to bear half of C, that is 15, since his initial endowment A of 20 is sufficient.
- Y obtains a total gain of $20 + 73 - 15 = 78$.

Gain of X:

- The endowment of X is $A = 120$.
- The element B of X is equal to 40 (*Table 1*).
- The total cost C is equal to 30 (*Table 2*). X also bears the half of C, that is 15, since his initial endowment A of 120 is sufficient.
- X obtains a total gain of $120 + 40 - 15 = 145$.

Example 2*: X chooses 5 and Y chooses 10.*

Gain of Y:

- *The endowment of Y is* $A = 20$.
- *The element B of Y is equal to 73 (Table 1).*
- *The total cost C is equal to 112 (Table 2). The half of C is equal to 56. Y cannot bear this half since his endowment A of 20 is not sufficient; he then bears the cost within the limits of his endowment A (that is, 20).*
- *Y obtains a total earning of* $20 + 73 - 20 = 73$.

Gain of X:

- *The endowment of X is* $A = 120$.
- *The element B of X is equal to 84 (Table 1).*
- *The total cost C is equal to 112 (Table 2), half of C is then equal to 56. X can bear this half since his endowment A of 120 is sufficient. X then bears 56. The remaining part of C (112-20-56=36) is not borne by anybody.*
- *X obtains a total earning of* $120 + 84 - 56 = 148$.

N.B.: the values of B and C displayed in Tables 1 and 2 are rounded values. It is thus possible that your real earning moves at most 1 unit from your calculations.

In order to make your decision making easier, we now give you:

- **Table 3**, which shows the net gains of X depending on his choice (indicated on the first column of the table) and on the choice of Y (indicated on the first row)
- **Table 4**, which shows the net gains of Y depending on his choice (indicated on the first column of the table) and on the choice of X (indicated on the first row)

These tables 3 and 4 thus identify all your possible gains depending on your choice and your partner's choice. Lets us consider **example 1** again, where X chooses 18 and Y chooses 10:

- Table 3 indicates that the net gain of X given his choice of 18 (cf 1st column) (and given that Y chose 10, cf 1st row) is equal to 144.
- Table 4 indicates that the net gain of Y given his choice of 10 (cf 1st column) (and given that X chose 18, 1st row) is equal to 78.

Let us now consider ***example 2*** *again, where X chooses 5 and Y chooses 10:*

- *Table 3 indicates that the net gain of X given his choice of 5 (cf 1st column) (and given that Y chose 10, cf 1st row) is equal to 148.*
- *Table 4 indicates that the net gain of Y given his choice of 10 (cf 1st column) (and given that X chose 5, 1st row) is equal to 73.*

Once the first period is ended, you are paired with another participant randomly assigned and you have to choose again a number between 0 and 23. The gains are calculated the same way in each period.

Before this task begins, we ask you to answer a few questions in order to test your understanding of the instructions. These questions will appear on your computer screen shortly.

Note for the reader: we do not include tables 1 to 4 again. Tables 1 and 2 are identical to previously, and tables 3 and 4 are adapted to this treatment.

A.6 Post-experiment questionnaire

Note for the reader: the name of the variables presented in the results is indicated in bold inside the brackets.

We now ask you to answer a few questions about yourself. This will take a few minutes. All your answers are anonymous and will remain confidential. At the end of this questionnaire, your computer will calculate your total gains from tasks 1, 2 and 3. You will then be paid anonymously.

1. Indicate your gender ☐ male ☐ female
2. Are you the kind of person who is more likely to take risks or are you rather cautious? Indicate on a scale from 1 to 10 where you stand, 1 standing for a person who loves taking risks and 10 for a person who hates taking risks. [**Risk**]

   1 2 3 4 5 6 7 8 9 10
3. Would you say that, in everyday life, you try to help other people or you mainly care about yourself? Indicate on a scale from 1 to 10 where you stand, 1 standing for a person who loves helping others and 10 for a person who cares only about him/herself. [**Selfish1**]

   1 2 3 4 5 6 7 8 9 10
4. Through the 20 periods of the game (task 3 of the experiment), did you take into account your partner's payoff or did you take into account only your payoff? [**Selfish12**]

   ☐ Only your payoff [Selfish12=0] ☐ Your partner's payoff, too. [Selfish12=1]
5. Would you say that, in everyday life, people try to help other people or that they mainly care about their own interest? Indicate on a scale from 1 to 10 where you think others stand, 1 standing for a person who loves helping others and 10 for a person who cares only about him/herself. [**Selfish21**]

   1 2 3 4 5 6 7 8 9 10
6. Through the 20 periods of the game (task 3 of the experiment), do you think your successive partners took into account your payoff in their decisions or only their own one? [**Selfish22**]

   ☐ Their own payoff only [Selfish22=0] ☐ Your payoff, too. [Selfish22=1]