Comparison of liability sharing rules for environmental damage: An experiment with different levels of solvency*

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Abstract

Civil liability is the legal requirement to compensate victims when causing a damage. When two firms raise a common environmental damage, their liability depends on the applicable liability rule and on the solvency level of each firm. Under non-joint liability, each injurer is liable for some part of the damage up to its financial capacity. Under joint and several liability, if damages cannot be recovered from one injurer for insolvency grounds, they are borne by the other one to the extent that it is solvent. We theoretically and experimentally investigate the impact of these two liability rules in terms of incentives to care, varying for the degree of (in)solvency of each firm. We highlight that with at least one insolvent firm, non-joint liability leads to higher social welfare than joint and several liability, whereas the latter should be preferred in the presence of solvent firms only.

Keywords: Environmental damage; Liability Sharing; Multiple Tortfeasors; Abatement Efforts; Insolvency

JEL Classification: K13 ; K32 ; Q53

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1 Introduction

Many industrial activities are known to impact the quality of air, soil, surface and groundwater. Focusing on soil contamination, a brief look on available data highlights the importance of the problem. In the USA, the Environmental Protection Agency (EPA) in the frame of the CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act), has established an inventory of hazardous waste sites, which could be subject to cleanup operations. More than 30,000 sites are inventoried and, in October 2016, no less than 1337 of them are listed on a National Priority List reporting the sites with the most serious cleanup problems.[1] Given an average cleanup cost of $30 million per site Anderson (1998), soil contamination from industrial activities in the USA amounts to almost $1000 billion.

In order to provide economic agents with incentives to control their level of pollution (and so to limit damage, and the associated high remedial costs), public regulators have implemented market-based policy tools (e.g., pigovian taxation, tradable permits) and command-and-controls systems (e.g., pollution standards).[2] However, there is a market-based instrument that has received less attention, despite a progressive implementation since the 1980s: civil liability.

Civil liability, which is the legal requirement to compensate victims when causing a damage, aims at reaching two goals: providing justice *ex post* to the victims, and giving to the injurer incentives *ex ante* to control the damage. Indeed, the threat of having to pay *ex post* for damages provides *ex ante* incentives to make efforts to control the damage. In the frame of pollution control, civil liability has been enforced in the USA since 1980 with CERCLA, and it has been progressively implemented in the EU since the directive 2004/35/CE. If civil liability has been widely studied for regulating

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

[2] A vast literature has proven the superiority of market-based instruments over command-and-control ones in many contexts (Zerbe (1970); Magat (1978, 1979); Downing & White (1986); Milliman & Prince (1989)), and then has focused on establishing a ranking between market-based instruments, regarding their efficiency in regulating pollution and fostering "greener" production technologies (Fischer *et al.* (2003); David & Sinclair-Desgagné (2005); David & Sinclair-Desgagne (2010)).

risky activities,[3] its study for regulating pollution has received relatively few attention (Kornhauser & Revesz (1989b, 1990); Endres & Bertram (2006); Endres *et al.* (2008)).[4]

Yet, civil liability may have advantages for the public regulator, especially in terms of ease (and relatively low cost) of implementation. As highlighted by Kornhauser & Revesz (1990), when compared with pigovian taxation or tradable permits, civil liability is associated with relatively low enforcement costs since it applies *ex post*, in case of (sufficient) damage only. The ease of implementation is particularly salient in case of damage involving several polluters, what we study in this paper.

As a result of the concentration of industrial activities in specific areas, many cases of pollutions are the consequence of the activities of several firms. In such a case, civil liability has to deal with two important issues: (i) sharing the damage between the different tortfeasors, in a way to provide them with optimal incentives ; (ii) the potential insolvency of the polluters, because the damage on the environment can be highly costly to repair (in such a way they can exceed the firms' financial capacity).

Two main rules of apportionment exist: joint and several liability, and non-joint (only several) liability. Under non-joint liability, each injurer is held liable for some part of the damage, and has to pay this part up to his financial capacity; if one injurer is unable to pay for his whole part of liability, the remaining amount is borne by the victim (which is not fully compensated). In case of joint and several liability, the remaining damages of an insolvent injurer have to be paid by the other solvent injurer(s), up to his/their financial capacity. As a result, as long as the global solvency of all injurers exceeds the damage suffered by the victim, joint and several liability ensures the victim to be fully compensated. Which apportionment rule is the most appropriate is intensively debated, especially in the USA. Joint and several liability is the default rule of apportionment, notably because it minimizes the cost of suing for victims.[5] However, this rule can be perceived as unfair and inefficient.

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

[4]Note also that even if civil liability is widely studied in a frame 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).

[5]Under joint and several liability, if one injurer is able to pay for the whole damage, the victims can claim global damages to this sole injurer (instead of suing all tortfeasors).

First, holding wealthy defendants liable for the remaining part of damages due by less wealthy defendants may lead to situations where (wealthy) defendants, whose contribution to harm is small, are held liable for a large part of the judgment if the most important contributor is insolvent. Second, potential insolvency provides incentives to overproduce waste, which can trigger suboptimal decisions to other polluters: the most solvent ones can be pushed to overcontrol their level of emissions in order to reduce the global damage (for which they have to pay the larger part), while less solvent ones may choose to overproduce waste in a manner to become insolvent in case of damage.

Because of (but not only) these two criticisms, a movement of tort reform began in the USA in the 1980s, for persuading states to abolish joint and several liability (in favor of non-joint liability, see Lee *et al.* (1994), p. 298). Thus, several US states adopted non-joint liability for non-economic damage (including bodily injuries and moral damage) but in the field of pollution control joint and several liability is still the default rule of apportionment (CERCLA still applies this rule).In EU, the directive 2004/35/CE leaves the Member States to decide which rule they want to apply (see the article 22 of the directive). Most of them choose joint and several liability, except Denmark, Finland and France who choose non-joint liability (see OECD (2012)). But within each country, no lively debate took place about which rule to apply. In order to contribute to this debate, Kornhauser & Revesz (1990) developed an extensive theoretical comparative analysis of the efficiency of the different rules of apportionment, in a context where one or several tortfeasors can be insolvent. They conclude that no rule predominates over the other one, implying accordingly that this reform cannot be justified on efficiency grounds. Especially, under strict liability, both sharing rules are inefficient: non-joint liability provides too low incentives to abate pollution (because no injurer does internalize the full social impact of dumping), and joint and several liability provides the wealthier injurer with too strong incentives to control pollution (because he has to pay his part of the damage plus the remaining part of the insolvent one).

In this paper we aim to empirically test the efficiency properties of the two rules of apportionment of liability in a context where two polluters cause a common damage and face potential insolvency. The lack of data (and the absence of enforcement of non-joint liability in the context we consider) justify the use of experimentation in this paper.

To do this, we first introduce a simple theoretical model in order to provide predictions which can be easily testable through a laboratory experiment. This model is an adaptation (and simplification) of Kornhauser & Revesz (1990), while restricting our attention to the case where there are only two tortfeasors, facing a strict liability rule. Such a setting is relevant for representing situations of common local pollutions, and it allows focusing on the analysis of the incentives provided by the two rules of apportionment. Hence three testable theoretical propositions are provided. We especially compare the efforts (of pollution abatement) provided by the two polluters, the levels of social welfare, the level of global damage and the level of reparation.

To our knowledge, this is the first empirical study on the impact of the rules of apportionment on the injurers' behaviors. Indeed, few experimental studies have been made about civil liability. Kornhauser & Schotter (1990) and Kornhauser & Schotter (1992) 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) analyze the impact of insolvency in the case of a unilateral accident. Wittman et al. (1997) test how fast different liability rules enable to meet equilibrium. But all these studies only consider the case of a unique tortfeasor.[6]

We show that some theoretical results are experimentally validated. This is the case notably that a solvent tortfeasor tends to be over-deterred in taking care when facing an insolvent tortfeasor, as predicted by theory. But some of our results contradict the model, regarding notably the most efficient rule in termes of social welfare: when both agents are solvent, or both are insolvent, the model states that both rules are equivalent, which we do not verify experimentally. Finally, we highlight wealth effects which lead to different behaviors from asymetrically endowed players in cases where they theoretically behave the same way.

The remainder of the paper is structured as follows. The model is exposed in Section

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

2. We present the experimental design in Section 3. The results are displayed in Section 4, and Section 5 concludes.

2 Theoretical predictions

2.1 Setup of the model

Our model adapts and simplifies the theoretical analysis provided by Kornhauser & Revesz (1990) in order to provide clearcut and easily testable theoretical predictions. In this sense, we focus our attention on the most relevant setting for studying the regulation of common local pollutions: we consider two firms, endowed with different levels of solvency, facing a strict liability rule. We will compare incentives and welfare provided by two rules of apportionment: joint and several liability, and non-joint liability.

As in Kornhauser & Revesz (1990), we only consider two polluters. Focusing on strict liability allows simplifying the analysis while keeping it relevant for the regulation of pollutants. To sum up, our analysis focuses on the cases of *strict liability*, *different solvencies*, *unitary share rule* and *fractional share rule*.[7]

We consider two firms, indexed by i and j. Their activities raise a global and common damage, which occurs with certainty. Each firms makes an effort in abatement, respectively e_i and e_j, to reduce the amount of global damage $D(e_i, e_j)$, with $\frac{\partial D(e_i,e_j)}{\partial e_i} < 0$, $\frac{\partial D(e_i,e_j)}{\partial e_j} < 0$, $\frac{\partial^2 D(e_i,e_j)}{\partial e_i^2} > 0$, $\frac{\partial^2 D(e_i,e_j)}{\partial e_j^2} > 0$, $\frac{\partial^2 D(e_i,e_j)}{\partial e_i \partial e_j} > 0$.[8] Such an effort is costly, in that it reduces the agents' net benefit from activity, respectively $B_i(e_i)$ and $B_j(e_j)$, with $\frac{\partial B_i(e_i)}{\partial e_i} < 0$, $\frac{\partial B_j(e_j)}{\partial e_j} < 0$, $\frac{\partial^2 B_i(e_i)}{\partial e_i^2} < 0$, $\frac{\partial^2 B_j(e_j)}{\partial e_j^2} < 0$.

Each agent is endowed with equities, respectively W_i and W_j, which can be confiscated for compensation. Indeed, we suppose that all agents are subject to strict liability: they always have to compensate the victims, whatever their abatement effort. But they

[7] This framework has been developed by Kornhauser & Revesz (1990), pp 637-644 (and the associated companion Kornhauser & Revesz (1989a), pp 76-92.

[8] $\frac{\partial^2 D(e_i,e_j)}{\partial e_i \partial e_j} > 0$ means that the marginal damaging effect of one additional pollutant emitted by i increases with the amount of pollutants emitted by j. As highlighted by Ackerman (1973), in many cases a global pollution, the damage cannot be separate into several distinct harms (Kornhauser & Revesz (1989a), p. 853, talk about "non-distinct harms"). The detrimental effect of one pollutant depends on the amount of pollutants already dumped before.

also benefit from limited liability: the amount of damages they have to pay for cannot exceed their wealth, W_i (or W_j).

2.2 First-best solution

We first calculate the first-best solution, before to determine how the different rules of applying civil liability perform in regulating this pollution. Considering the viewpoint of a benevolent, omniscient and omnipotent dictator, the problem he has to solve is:

$$\max_{e_i,e_j} SW(e_i,e_j) = B_i(e_i) + B_j(e_j) - D(e_i,e_j) + W_i + W_j \tag{1}$$

The first-best solutions e_i^{**}, e_j^{**}, satisfy the following program:

$$\frac{\partial SW(e_i,e_j)}{\partial e_i} = 0 \Rightarrow -\frac{\partial D(e_i,e_j^{**})}{\partial e_i} = -\frac{B_i(e_i)}{\partial e_i} \tag{2}$$
$$\frac{\partial SW(e_i,e_j)}{\partial e_j} = 0 \Rightarrow -\frac{\partial D(e_i^{**},e_j)}{\partial e_j} = -\frac{B_j(e_j)}{\partial e_j} \tag{3}$$

Posing $B_i(.) = B_j(.)$, we have $e_i^{**} = e_j^{**}$.

Considering the case of the agent i, e_i^{**} is defined by the equalization of the marginal benefit from the effort in terms of reducing the global damage, $-\frac{\partial D(e_i,e_j^{**})}{\partial e_i}$, with its marginal cost in terms of reducing the net benefit from activity, $-\frac{B_i(e_i)}{\partial e_i}$, with e_j^{**} given. $\frac{\partial^2 D(e_i,e_j)}{\partial e_i^2} > 0$ and $\frac{\partial^2 B(e_i)}{\partial e_i^2} > 0$ ensures the problem to be a maximization.

2.3 Private equilibria with different levels of solvency

We now derive the equilibria under decentralized policies. In order to focus on cases where the two rules of apportionment distinguish from each other, we will consider cases where the two agents have not the same level of equities. We first determine the equilibria under joint and several liability (section 2.3.1) and then under non-joint liability (section 2.3.2), before proceeding to a comparative analysis (section 2.3.3).

2.3.1 Joint and several liability

Consider the agent i to be wealthier than the agent j: $W_i > W_j$. Let γ and $1-\gamma$ to be the shares of the global damage $D(e_i, e_j)$ which are attributable to agents i and j respectively. This means that *a priori* (i.e. without regard any consideration of solvency), agents i has to pay for a share γ of the global damage $D(e_i, e_j)$, and the agent j has to pay the complementary share $1-\gamma$ of this damage. However, the *a posteriori* payment for liability depends on the agents' degrees of solvency. Consider for illustration the extreme case where the agent j has no equity: $W_j = 0$. Because of the limited liability principle, the agent j cannot pay for liability. It is obvious that, in such a case, he has no interest in doing any abatement effort: $e_j^* = 0$.

Under joint and several liability, we know that the remaining damages (from an insolvent injurer) have to be paid by solvent injurers. As a consequence, in this case of insolvency of the agent j, the agent i's problem is:

$$\max_{e_i} \Pi_i^{JS}(e_i, e_j) = B_i(e_i) + W_i - Min\left\{D(e_i, e_j) - W_j; W_i\right\} \tag{4}$$

with the subscript JS meaning joint and several liability, and $e_j = 0$, W_j the payment for damages of the (insolvent) agent j (with here $W_j = 0$). Depending on whether the agent i is able to pay ($W_i > D(e_i, 0)$) or not able to pay ($W_i < D(e_i, 0)$) for liability, his profit is different. Thus, his effort will also be different. Of course, the agent will choose the situation which maximizes his private profit.

Now, we first determine the minimum level of solvency, $\underline{W}$, under which the agent j has no interest in doing any effort (whatever the agent i's behavior). Then we determine the agent i's reaction depending on the different situations he can face.

Lemma 1. *Consider an agent j, less wealthy than the agent i ($W_j < W_i$), who has to pay a priori for a share $(1-\gamma)$ of the global damage $D(e_i, e_j)$. He has an interest in doing no effort ($e_j^* = 0$) whatever the value of e_i if his amount of equities W_j satisfies:*

$$W_j < B_j(0) - B_j(e_j(\infty)) + (1-\gamma) D(e_i(\infty), e_j(\infty)) = \underline{W}$$

Proof. See the appendix ⧫

Consider the agent j to have a level of equity W_j such that $W_j < \underline{W}$, i.e. he is unable to pay for his share of liability and makes no effort in abatement. This case is similar (but more general) than the case where $W_j = 0$ discussed above[9]. In this case, the agent i can face two equilibria depending on whether he is able to pay, or not able to pay, for his share of liability plus the remaining share of the agent j, i.e. $D(e_i, 0) - W_j$.

Proposition 1. *Consider two agents i and j, with $W_j < \underline{W}$ and $W_i > W_j$. We pose $B_i(.) = B_j(.)$ and $\gamma = \frac{1}{2}$*

There exists a threshold value of equities, $\bar{W}$, for which:

(i) If $W_i > \bar{W}$, then the agent i makes a positive effort e_i^a in abatement. This effort is higher than the first-best level e_i^{**}. The resulting global damage is: $D(e_i^a, 0)$

(ii) If $W_i < \bar{W}$, then both agents make no effort at equilibrium. The resulting global damage is: $D(0, 0)$

with $\bar{W} = B_i(0) - B_i(e_i^a) + (D(e_i^a, 0) - W_j)$

Proof. See the appendix ⧫

Finally, for the sake of completeness, when both agents are sufficiently wealthy to have an interest in making a strictly positive effort in abatement, $B_i(.) = B_j(.)$ and $\gamma = \frac{1}{2}$ ensure that the two agents made the same effort: $e_i(\infty) = e_j(\infty)$ (see the Proof of Lemma 1 in Appendix). A comparison between (A.1), (A.2) and (2) allows seeing that: $e_i^a > e_i^{**} > e_i(\infty)$.

2.3.2 Non-joint liability

Now we turn to determinate the private equilibria under the alternative rule of apportionment, i.e., the non-joint liability. As mentioned in Introduction, joint and several

[9] We need to determine this more general case for the needs of the experiment (see section 4). Indeed, posing $W_j = 0$ could (in a trivial way) lead the subjects having the role of an agent j to choose making no effort. By determining a range of strictly positive values of W_j which lead to no effort at equilibrium, we can better test for the predictive power of the model, and determine whether decision-makers might be empirically subject to some endowment effect.

liability is often blamed to provide "too much" incentives for the most solvent parties, when the tortfeasors have different levels of solvency. We saw in the previous subsection that this fear is confirmed by the theoretical model (Proposition 1, point (i)). Now we turn to see what prevails under non-joint liability.

We still consider the agent i to be wealthier than the agent j: $W_i > W_j$. Under non-joint liability, each tortfeasor is only liable for his share of the judgment: in other words, a solvent agent has not to pay the remaining debts of an insolvent agent. So, even assuming $W_j < \underline{W}$ (so that $e_j^* = 0$), the agent i has only to pay for $\gamma D(e_i, 0)$ (up to the limit of W_i) in case of damage: the agent j's remaining debt, $(1-\gamma)D(e_i, 0) - W_j$, remains not compensated, borne by the victims.

However, as under joint and several liability, there are two possible equilibria for the agent i when assuming the agent j has never interest in making any effort (i.e. $e_j^* = 0$ because of $W_j < \underline{W}$). He can choose a strictly positive effort if his level of equity W_i is sufficiently high, or he can make no effort if W_i is too low[10]. The following Proposition summarizes these features.

Proposition 2. *Consider two agents, facing non-joint liability, with* $W_j < \underline{W}$ *and* $W_i > W_j$*. We pose* $B_i(.) = B_j(.)$ *and* $\gamma = \frac{1}{2}$

There exists a threshold value of equities, $\bar{\bar{W}}$*, for which:*

(i) If $W_i > \bar{\bar{W}}$*, then the agent i makes a strictly positive effort* $e_i^b > 0$ *in abatement. The resulting damage is* $D(e_i^b, 0)$

(ii) If $W_i < \bar{\bar{W}}$*, then both agents make no effort at equilibrium and the resulting global damage is:* $D(0, 0)$

with $\bar{\bar{W}} = B_i(0) - B_i(e_i^b) + \gamma D(e_i^b, 0)$

Proof. See the Appendix. ♦

Finally, as under joint and several liability, when both agents are sufficiently wealthy to have an interest in making a strictly positive effort in abatement, $B_i(.) = B_j(.)$ and $\gamma = \frac{1}{2}$ ensure that they made the same effort: $e_i(\infty) = e_j(\infty)$ (see the Proof of Lemma 1

[10] And as under joint and several liability, we find that for "intermediate" values of W_i, solvency is endogenous to the agent i's decision making.

in Appendix). e_i^b and e_i^{**} cannot be compared, but a look at (A.4) and (A.1) and having in mind that $\frac{\partial^2 D(e_i,e_j)}{\partial e_i \partial e_j} > 0$ allows seeing that: $e_i^b > e_i(\infty)$.

2.3.3 Comparing joint and several liability with non-joint liability

We now provide a comparative analysis of the different equilibria reached under each rule of apportionment.

Proposition 3. *Consider two polluters, i and j, which cause a common damage. The agent j is insolvent at equilibrium.*

(i) $e_i^b < e_i^a$: when i is solvent but j is insolvent at equilibrium, non-joint liability provides i with less incentives for abatement than joint and several liability.

(ii) When the two agents are insolvent at equilibrium, both rules are similar. However, when the agent i is solvent at equilibrium (i.e. $W_i > \max\left\{\bar{W}; \bar{\bar{W}}\right\}$), joint and several liability leads to a lower level of pollution, a higher level of compensation and a higher level of social welfare than non-joint liability. However, the net profit of agent i is lower under joint and several than under non-joint liability.

Proof. See the Appendix. ♦

For the sake of completeness, we can make the following remark.

Remark 1

$\bar{W} > \bar{\bar{W}}$*: a higher set of values of W_i leads to $e_i^* = 0$ under joint and several than under non-joint liability, iff:*

$$W_j < B_i(e_i^b) - B_i(e_i^a) + D(e_i^a, 0) - \gamma D(e_i^b, 0) \tag{5}$$

Proof. See the Appendix. ♦

When the condition (5) is satisfied, then joint and several liability leads "more often" to insolvency (and no effort) of the agent i than non-joint liability. In that case, non-joint liability can be socially preferred to joint and several liability for some "intermediate" values of W_i, for which the agent i is insolvent when facing joint and several liability but solvent when facing non-joint liability. Nevertheless, for the rest of the paper, we will focus our analysis on a comparison of the incentives provided by the two rules, for given agents' situation regarding their (in)solvency. So, in the following section, we empirically test for the three Propositions introduced above, via a lab experimentation.

3 Experimental design

3.1 Experimental procedure

Our experiment was conducted at the Laboratory of Experimental Economics of Strasbourg (LEES), in France.[11] The students were recruited from undergraduate and graduate courses from various fields (including notably law, economics, science, literature), though ORSEE. In total, 240 participants took part in the 12 sessions of this experiment (6 treatments, 2 sessions by treatment, 20 participants by session). Each group of 20 participants was divided into 2 groups of 10 participants. Each participant was assigned a computer upon arrival, by a draw in a bag (students picking numbers 1 to 5 and 11 to 15 are X and those picking numbers 6 to 10 and 16 to 20 are Y, but students are informed about their role once the instructions read). X is the most solvent type and Y the least solvent. No student could participate in more than one session and the experimenters were the same for all the sessions. All treatments are run on personal computers and the experiment is programmed with EconPlay software (Bounmy, 2015). Instructions are read aloud by the instructor and questions are answered privately.

The experiment is divided into three parts. Once assigned to a computer, participants are given the instructions of tasks 1 and 2. Task 1 is a modified dictator game according to Blanco *et al.* (2011), aiming at eliciting subjects fairness preferences.[12] This measure of inequity aversion allows to build an inequity-aversion index from 1 (inequity adverse) to 10 (inequity lover).[13] Task 2 is a Holt & Laury (2002) test which intends to elicit the

[11] http://paderborn.u-strasbg.fr/orsee-2.0.2/public/index.php

[12] We refer to Fehr & Schmidt (1999) model of inequity aversion which states that individuals do not only care about their own payoff but also about others' payoffs.

[13] We will refer to this variable in the results as DE.

subjects' attitude toward risk and allows to obtain a risk-aversion index from 1 (risk avderse) to 10 (risk loving).[14]

Once these first two parts completed, the students are given the instructions of Task 3 (the main game).[15] In order to ensure that this main task is understood, subjects have to answer a quiz comprising 10 questions. In case of errors, the instructor clarifies each of them in an individual way. The instructions of tasks 1 to 3 for the six treatments are available in the Appendix A.6. Finally, once the three tasks completed, participants respond to a post-experiment questionnaire, aiming at providing supplementary information (about their behavior during the experiment, about their perception of their own altruism, of others' altruism, etc.).[16]

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 last between 60 and 75 minutes. The players were paid according to the sum of their earnings of Task 1, Task 2 and of two randomly-picked periods earnings in Task 3 (the main game) of the experiment. Summary statistics on individual characteristics of subjects are presented in Tables A.3 and A.4 in Appendix A.4.

3.2 Parametrization and numerical solutions

Our experiment is designed to test several predictions of our model : we set three pairs of wealth levels, so that players are either both solvent, both insolvent or one is solvent and the other one is insolvent.[17] In any case, their levels of wealth are asymmetric in order to distinguish between the two liability rules, and these rules are both enforced in separate treatments for each level of wealth, so that their impact can be compared.[18] Overall, we build three different scenarios under two liability rules, which implies six

[14]This measure will be referred to as DR in the results. The expected impact of DR and DE are displayed at the end of this section.

[15]They play only one treatment and are not aware of the existence of other treatments.

[16]This questionnaire is available in Appendix A.7.

[17]Remind that solvency is defined theoretically as the situation of a firm who is able to fully pay its part of the damage.

[18]In the case where endowments are equal and if agents have to bear *a priori* half of the damage ($\gamma = 0.5$, as we suppose - see later), non-joint and joint and several rules are equivalent since there is no report of liability from the least solvent firm to the most solvent firm.

treatments. This allows testing for the impact of (in)solvency under the two liability rules and to compare the incentives they provide (depending on the degree of solvency):

- one firm is solvent, the other one is insolvent, under JS rule (treatment A) and NJ (treatment B)
- both firms are solvent, but asymmetrically under JS rule (treatment C) and NJ (treatment D)
- both firms are insolvent, but asymmetrically under JS rule (treatment E) and NJ (treatment F)

In order to be in line with the theoretical model, we use the following specifications, which satisfy the required assumptions over the functions:

The damage function is:

$$D(e_i, e_j) = 500 \exp^{-0.1(e_i+e_j)} \tag{6}$$

The benefit function for each agent i is:

$$B_i(e_i) = 100 - 10 \exp^{0.1 e_i}, \{i = X, Y\}, \{j = X, Y\}, i \neq j \tag{7}$$

Moreover, in order to simplify, we set $\gamma = 0.5$, which implies that each agent is a priori held liable for half the damage. With these specifications, the effort levels chosen by the subjects at each period are integers comprised between 0 and 23.[19] The damage is thus comprised between 5 and 500, and the benefit of each eagent is between 0 and 90. The damage and benefit values conditional on each effort level are displayed in Appendix A.2 and Appendix A.3 respectively.

These specifications allow to find numerical values for theoretical predictions. Table 1 displays the different thresholds above/under which agents are optimally, over- or under-deterred when making efforts.

[19]Note that contrary to the model which states a continuous effort, the effort is discrete here. This allows to give different tables exposing all possible scenarios in terms of damage, benefits and net payoff. This would not be possible with a continuous effort.

Table 1: Numerical thresholds and equilibrium efforts

	Both insolvent	Both solvent	Solvent/ insolvent JS	Solvent/ insolvent NJ
Relevant threshold for W_i	$\underline{W} = 48,48$	$\underline{W} = 48,48$	$\bar{W} = 111,42$	$\bar{\bar{W}} = 90$
Relevant threshold for W_j	$\underline{W} = 48,48$	$\underline{W} = 48,48$	$\underline{W} = 48,48$	$\underline{W} = 48,48$
W_X	$< \underline{W}$	$> \underline{W}$	$> \bar{W}$	$> \bar{\bar{W}}$
W_Y	$< \underline{W}$	$> \underline{W}$	$< \underline{W}$	$< \underline{W}$
e_i^*	$e_i = 0$	$e_i(\infty) = 10,73$	$e_i^a = 19,56$	$e_i^b = 16,09$
e_j^*	$e_j = 0$	$e_i(\infty) = 10,73$	$e_j = 0$	$e_j = 0$
First-best efforts	13.04	13.04	13.04	13.04

Departing from these thresholds, we build the six scenarios mentioned before, and we compute the theoretical values of efforts, benefit, damage and welfare. These are exposed in Table 2.[20]

Before looking at the experimental results, we can make some expectations relative to the impact of DR and DE variables on effort choices.

As regards risk-aversion (DR), two effects can be expected. First, a higher risk-aversion (lower DR) can lead to less efforts from players. Indeed, recall that making no effort allows ensuring a payoff of at least 90 *for sure* ($B_i(e_i = 0) = 90$). Thus, in the case one player expects a damage which would be so high that he would lose his total wealth W and become insolvent, a secure strategy can be to make no effort. We will refer to this effect as *Effect 1*, which may dominate for a player who anticipates few efforts from his partner (and so, a high damage to pay). But another effect can take place: the absence of certainty about the partner's reaction leads to an absence of certainty about the damage to be paid. A risk-averse player (low DR) may wish to make a high effort for both reducing the level of damage to pay, and also the impact of the partner's decision on it (recall that: $\frac{\partial^2 D(e_i,e_j)}{\partial e_i \partial e_j}$), thus reducing the variability in the possible final payoffs.

[20]We remind you that instructions are available in Appendix A.6. For the sake of the paper length, we display the instructions of Treatments A and B only. Nevertheless, the instructions of treatments C and E are very close of those of treatment A since only endowments differ; equally, the instructions of treatments D and F are very close to those of treatment B.

Table 2: Treatments and predictions

	Treatment A	**Treatment B**	**Treatment C**	**Treatment D**	**Treatment E**	**Treatment F**
Liability rule	JS	NJ	JS	NJ	JS	NJ
W_X	120	120	120	120	80	80
W_Y	20	20	55	55	20	20
Equilibrium effort of X	19.56	16.09	10.73	10.73	0	0
Equilibrium effort 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 damage	70.71	100	58.48	58.48	500	500
Theoretical social welfare	188.58	180	258.04	258.04	-220	-220

We call this effect as *Effect 2*. This last effect can especially arise for players having a sufficiently high level of wealth, and in situations where where the partner's decision is not a priori trival (*i.e.* when he also has a sufficient level of wealth).

The expected impact of inequity aversion (DE) might come from the inequality between the players' initial levels of wealth. Since there is a gap between both players' endowments, a higher inequity aversion (lower DE) from the most endowed player (X) should lead to a higher level of effort in order to compensate the initial inequality in endowments ; while a higher inequity aversion from the least endowed player (Y) should lead to less personal effort.

4 Results

In this section, we are interested in testing whether the six different treatments (from A to F) have different effects on the effort choice of subjects to reduce the damage. In particular, we intend to analyze whether NJ and JS rules lead to different effort levels for identical wealth levels, whether the observed efforts are similar to those predicted by theory, and the impact of these in terms of social welfare.

4.1 Descriptive statistics and general results

We first report in Table 3 descriptive statistics about the mean efforts of subjects over 20 periods, in each treatment and for each role.

Table 3: Individual experimental mean efforts over periods 1 to 20, by treatment

Treatment	Role	N	Mean effort	Std. Dev.	Min	Max
A	X	400	15.94	6.21	0	23
	Y	400	3.08	5.33	0	23
B	X	400	15.45	3.22	0	23
	Y	400	0.90	3.10	0	23
C	X	400	13.08	3.25	0	23
	Y	400	8.96	3.74	0	23
D	X	400	12.55	3.40	0	23
	Y	400	7.76	4.59	0	23
E	X	400	2.07	4.84	0	23
	Y	400	0.62	2.45	0	22
F	X	400	3.41	6.08	0	23
	Y	400	1.44	4.21	0	23

Moreover, in order to account for a possible learning effect during the 20 periods, we also compute mean efforts for the first and the last periods. These are reported in Table 4.

Table 4: Mean efforts for periods 1 and 20

Treatment	Role	N	Period 1 Mean effort	Std. Dev.	Period 20 Mean effort	Std. Dev.
A	X	20	15.95	5.28	15.55	6.42
	Y	20	7.2	7.46	1.55	3.22
B	X	20	13.6	4.84	15.7	1.69
	Y	20	2.4	4.71	0	0
C	X	20	15.95	4.02	12.4	2.30
	Y	20	9.7	6.05	9.1	3.02
D	X	20	12.25	3.84	11.45	3.80
	Y	20	7.4	6.89	8.65	3.22
E	X	20	8.4	7.22	0.1	0.45
	Y	20	1.7	3.34	0	0
F	X	20	7.6	6.78	0.2	0.41
	Y	20	8.1	9.14	0.1	0.31

In order to compare theoretical and experimental efforts, we run Student tests to analyze the significance of the differences. In Table 5, the "Mean difference" column gathers the differences between the mean experimental value of effort (over the 20 periods), and the theoretical one, for each role in each treatment. The difference between theoretical and observed efforts is also calculated for the first and the last period (columns "Period 1 Difference" and "Period 20 Difference" respectively): this allows questioning the presence of a learning effect.

Table 5: Tests of difference between experimental and theoretical efforts

Treatment	Role	Mean difference	T-stud	Period 1 Difference	T-stud	Period 20 Difference	T-stud
A	X	-3.6175***	-3.95	-3.6100**	-2.16	-4.0100**	-1.98
	Y	3.0775***	3.51	7.2000***	3.05	**1.5500**	1.52
B	X	-.6425***	-2.77	-2.4900**	-2.30	**-0.3900**	-1.03
	Y	.8975***	2.73	2.4000**	2.28	**0**	–
C	X	2.3525***	5.60	5.2200***	5.81	1.6700***	3.24
	Y	-1.7725***	-3.25	**-1.0300**	-0.76	-1.6300***	-2.41
D	X	1.8175***	3.41	1.5200*	1.77	**0.7200**	0.85
	Y	-2.9675***	-4.92	-3.3300**	-2.16	-2.0800***	-2.89
E	X	2.0675***	4.80	8.4000***	5.20	**0.1000**	1.00
	Y	.6200***	3.25	1.7000**	2.28	**0**	–
F	X	3.4050***	5.55	7.6000***	5.01	0.2000**	2.18
	Y	1.4400***	4.14	8.1000***	3.96	**0.1000**	1.45

Notes: In bold, non significant difference between experimental and theoretical efforts.
Standard errors have been adjusted for 20 clusters.

For all treatments, over all 20 periods (*i.e.* considering mean efforts), the difference between observed and predicted values are found all significantly different from zero: mean efforts significantly differ from equilibrium efforts.

Besides, as regards learning effect, we observe that, in several treatments, the difference between predicted and observed efforts is not significant for the last period (see bold figures in Table 5). 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 are evidences of learning effect in most treatments.

We then run a one-way analysis of variance considering a treatment factor with six levels, in order to test for differences in terms of mean efforts between the different treatments. The overall F tests for players X and Y return values significantly different from zero (680.72 and 331.66, respectively). These results indicate significant differences in mean efforts for the different treatments for both roles of players. To know more about the nature of the differences, we can use (pairwise) mean comparison methods. In Table 6, we report results on means of the treatment levels tested with Tukey's studentized range procedure. One advantage of this test is to control the type I experiment-wise error rate.

Table 6: Tukey's studentized range tests

	Player X				**Player Y**			
Treatment comparison	Difference between means	95% confidence interval			Difference between means	95% confidence interval		
A - B	0.4950	-0.4488	1.4388		2.1800	1.3697	2.9903	***
A - C	2.8600	1.9162	3.8038	***	-5.8800	-6.6903	-5.0697	***
A - D	3.3950	2.4512	4.3388	***	-4.6850	-5.4953	-3.8747	***
A - F	12.5375	11.5937	13.4813	***	1.6375	0.8272	2.4478	***
A - E	13.8750	12.9312	14.8188	***	2.4575	1.6472	3.2678	***
B - C	2.3650	1.4212	3.3088	***	-8.0600	-8.8703	-7.2497	***
B - D	2.9000	1.9562	3.8438	***	-6.8650	-7.6753	-6.0547	***
B - F	12.0425	11.0987	12.9863	***	-0.5425	-1.3528	0.2678	
B - E	13.3800	12.4362	14.3238	***	0.2775	-0.5328	1.0878	
C - D	0.5350	-0.4088	1.4788		1.1950	0.3847	2.0053	***
C - F	9.6775	8.7337	10.6213	***	7.5175	6.7072	8.3278	***
C - E	11.0150	10.0712	11.9588	***	8.3375	7.5272	9.1478	***
D - F	9.1425	8.1987	10.0863	***	6.3225	5.5122	7.1328	***
D - E	10.4800	9.5362	11.4238	***	7.1425	6.3322	7.9528	***
F - E	1.3375	0.3937	2.2813	***	0.8200	0.0097	1.6303	***

Notes: Significant differences at the 0.05 level are indicated by ***.

Individual characteristics.

We test the effect of individual characteristics of subjects and different measures concerning risk and pro-social behaviors, such as inequity aversion and altruism level.[21] In Table 7, we regress the players' effort on treatments and individual characteristics. While we find very few evidence of effect of individual characteristics on the levels of

[21]Some of the variables that are used are indicated following the successive questions of the post-experimental questionnaire. See Appendix A.7. In the regressions, we tested with different measures of risk-aversion and inequity aversion, and the variables which are exposed in the following tables are those which are the most significant.

effort (over all treatments), it is still possible that these variables affect efforts differently among the different treatments. This is why we run regressions with individual characteristics for each treatment separately. Results are reported in Tables 8 and 9, for players X and Y respectively.

Table 7: Estimation results of players' effort regressions (Reference: Treatment A)

Variable	(1) DecisX	(2) DecisX	(3) DecisX	(4) DecisY	(5) DecisY	(6) DecisY
B	-0.495	-0.435	-0.0440	-2.180**	-2.266**	-2.162**
	(0.927)	(0.918)	(0.986)	(0.917)	(0.921)	(0.904)
C	-2.860***	-2.917***	-2.739***	5.880***	5.826***	5.906***
	(0.988)	(0.954)	(0.999)	(1.011)	(1.035)	(1.046)
D	-3.395***	-3.479***	-3.030***	4.685***	4.715***	4.628***
	(1.039)	(0.984)	(1.044)	(1.042)	(1.030)	(1.005)
E	-13.87***	-14.03***	-13.61***	-2.457***	-2.487***	-2.404***
	(0.992)	(0.938)	(0.950)	(0.879)	(0.881)	(0.898)
F	-12.54***	-12.56***	-12.49***	-1.637*	-1.796*	-1.718*
	(1.081)	(1.040)	(1.009)	(0.924)	(0.939)	(0.884)
DR		0.116	0.159		-0.0314	-0.136
		(0.103)	(0.0974)		(0.101)	(0.109)
DE		-0.0770	-0.0641		-0.0998	-0.0806
		(0.108)	(0.107)		(0.0736)	(0.0731)
Selfish1		0.00223	-0.0473		-0.0218	-0.0277
		(0.0881)	(0.0934)		(0.0933)	(0.114)
MasterDoc			0.675			-0.359
			(0.710)			(0.510)
Sciences			-0.564			0.792
			(0.723)			(0.598)
DroitLet			1.671**			-1.347*
			(0.812)			(0.797)
Eco			-0.689			-0.0777
			(0.581)			(0.537)
Age			-0.0320			-0.0119
			(0.176)			(0.131)
Sexe			-0.464			0.139
			(0.453)			(0.470)
Constant	15.94***	15.74***	16.26***	3.077***	3.981***	4.805
	(0.898)	(1.085)	(4.164)	(0.859)	(1.300)	(3.147)
Observations	2,400	2,400	2,400	2,400	2,400	2,400
R-squared	0.587	0.588	0.601	0.409	0.412	0.420

Std. Err. adjusted for 20 clusters.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Testing differences of efforts depending on individual characteristics for each treatment raise different results than previously. We find that risk aversion, inequity aversion and altruism level can impact effort levels for some treatments, as it will be displayed in the next subsection.

Table 8: Estimation results of the player X effort regression

Treatment Variable	A	B	C	D	E	F
DR	0.739	0.224*	-0.620***	0.503	0.207	0.533**
	(1.337)	(0.107)	(0.204)	(0.419)	(0.140)	(0.201)
DE	-0.837	-0.0762	0.126	-0.0904	0.274	-0.504*
	(0.600)	(0.0928)	(0.175)	(0.228)	(0.159)	(0.274)
Selfish1	0.0376	-0.249**	-0.109	-0.0689	-0.413*	0.121
	(0.600)	(0.118)	(0.159)	(0.229)	(0.226)	(0.270)
MasterDoc	2.310**	0.00230	0.316	2.396	-1.137	
	(0.980)	(0.547)	(0.976)	(2.531)	(0.775)	
Sciences			1.067	-2.746**	-0.887	
			(1.224)	(1.270)	(1.100)	
DroitLet	0.915	-0.884	-1.138			
	(2.010)	(0.752)	(1.609)			
Eco	0.827	0.0306	0.0622	-3.032***	-2.499**	-2.382*
	(2.523)	(0.663)	(1.140)	(1.018)	(1.116)	(1.283)
Age	0.468	-0.199	-0.267	-1.092	-0.0600	0.783
	(0.554)	(0.161)	(0.339)	(0.698)	(0.382)	(0.454)
Sexe	0.916	0.164	-0.726	0.482	-0.915	1.897
	(5.478)	(0.450)	(0.822)	(0.714)	(0.758)	(1.411)
Constant	4.718	19.53***	22.31**	33.75**	4.609	-12.58
	(21.74)	(4.022)	(7.936)	(12.63)	(8.235)	(9.177)
Observations	400	400	400	400	400	400
R-squared	0.174	0.047	0.097	0.290	0.062	0.104

Std. Err. adjusted for 20 clusters.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1

4.2 Comparison of efforts under different liability rules

We are interested in determining whether NJ and JS rules lead to different effort choices. Given our parameters, theory predicts that efforts of solvent player X should be different between Treatment A (JS) and Treatment B (NJ), and efforts of insolvent player Y should be the same. Moreover, the efforts of both players should be the same when both players are solvent whatever the liability rule (Treatments C and D), and when players are both insolvent (Treatments E and F).

Table 9: Estimation results of the player Y effort regression

Treatment Variable	A	B	C	D	E	F
DR	-3.123	0.242*	-0.261	0.356	-0.130	-0.355***
	(2.030)	(0.135)	(0.184)	(0.290)	(0.0810)	(0.0487)
DE	3.982	-0.219	0.542***	-0.169	-0.0451	-0.674***
	(3.387)	(0.136)	(0.157)	(0.215)	(0.0621)	(0.0608)
Selfish1	0.314	-0.0416	-0.664**	0.406	0.0626	0.324***
	(0.945)	(0.224)	(0.237)	(0.394)	(0.0743)	(0.0548)
MasterDoc	0.368	0.838	-2.772***	-3.464*	-1.232	
	(3.896)	(0.928)	(0.960)	(1.880)	(0.729)	
Sciences			-1.577	3.536**	-1.381*	
			(1.406)	(1.394)	(0.750)	
DroitLet	-12.10*	1.726	-0.576			
	(6.124)	(1.233)	(1.828)			
Eco	1.106	0.0332	-2.583	0.776	-1.236**	-2.625***
	(1.606)	(0.737)	(1.514)	(1.606)	(0.588)	(0.558)
Age	-1.892	-0.0514	0.672**	0.453	0.0760	-0.806***
	(2.434)	(0.211)	(0.283)	(0.323)	(0.150)	(0.104)
Sexe	-2.772	0.778	-3.842***	0.0503	0.118	1.505***
	(4.973)	(0.746)	(0.719)	(1.830)	(0.407)	(0.244)
Constant	36.53	1.194	0.602	-4.049	0.808	24.03***
	(38.35)	(5.023)	(5.031)	(5.582)	(3.019)	(2.911)
Observations	400	400	400	400	400	400
R-squared	0.175	0.083	0.296	0.103	0.035	0.109

Std. Err. adjusted for 20 clusters.

Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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

When one player is solvent and the other one is insolvent, the solvent player (player X) should theoretically be over-deterred (though differently depending on the liability rule), whereas the insolvent one (player Y) should be under-deterred and make zero effort, whatever the liability rule. First note that treatments A and B imply significantly more effort from player X than all other treatments (see Tables 3 and 6).[22] This indicates that when a player is solvent (and the other one is not), he/she always makes the highest effort to reduce damage than all other configurations.

Now turning to the analysis of the performance of each rule in terms of incentives to care, the results indicate that under a JS rule (*treatment A*), player X is indeed over-deterred since he chooses an effort (15.94) higher than the first-best equilibrium (13.04), but the level of effort is lower than predicted (19.56), so that he is over-deterred but less than expected. The Student tests in Table 5 indicate that the difference with equilibrium is significant. Conversely, players Y choose a positive mean effort (3.08) though the equilibrium is zero and this difference is significant; it seems however that players Y learn by playing since the difference to zero is no more significant over the period 20. The fact that the effort level of players Y over the 20 periods is positive might have been due to inequity aversion, but data do not confirm this hypothesis since *DE* and *Selfish1* are not significant (see Table 9).[23] Overall, these choices of X and Y imply an observed damage which is significantly higher than expected (104.22 instead of 70.71). Regarding the social welfare, as reported in Table 10, the observed social welfare is significantly lower (at 10%) than predicted (162.244 instead of 188.58).[24]

Under a NJ rule (*Treatment B*), the mean efforts are different from the theoretical ones (at 5% significance) for both players, but converge to the equilibrium values at

[22]Note that these efforts are significantly higher than first-best values, which confirms over-deterrence.

[23]The definitions of the variable *Selfish1* and of other measures of risk/inequity aversion based on declarations are available in Appendix A.7.

[24]SW, which is defined by eq. (1), is computed as the sum of benefits $B_i(e_i) + B_j(e_j)$ and initial wealth levels $W_i + W_j$, minus damage $D(e_i, e_j)$ for each couple of decisions. The tests of difference between observed and theoretical social welfare are displayed in Appendix A.5. For all treatments, the differences between observed social welfare and equilibrium social welfare are found all significantly different from zero. This means that social welfares resulting from played efforts are significantly different from equilibrium social welfares. We can notice that the social welfare is lower than predicted from Treatment A to D, but higher for Treatments E and F.

period 20. Player X is over-deterred, as predicted, but not as much as predicted (15.45). In this treatment, regressions indicate that variable DR has a positive and significant impact on X's effort (see Table 8). This means that effort will increase with risk-loving, which might be explained by *Effect 1*: among solvent players, the ones who are more risk averse make less efforts to keep a sure (but low) payoff (anticipating that damage will be high because of low effort from Y players). What is surprising here is that this effect is not significant in Treatment A, in which players X can pay for the remaining debt from insolvent players Y. *Selfish1* has a significant negative impact on player X effort, which means that more altruism leads to more effort. This implies that when choosing his effort level, subject X might be positively influenced by the welfare of his partner, and choose to make a higher effort. Player Y makes a positive, though low, effort (0.90). Moreover, as for Player X, this effort increases with risk loving (see Table 9). These choices imply an observed damage slightly higher than expected (108.02) and an observed social welfare lower than the theoretical one (171.315 against 180), but these differences between observed and predicted values are not significantly different.

An interesting result is that whereas efforts by X are different in theory between the two liability rules (19.56 and 16.09) and efforts by Y are similar (equal to zero), our results indicate exactly the opposite: indeed, as reported in Table 6, experimental efforts chosen by X are not different between the rules whereas experimental efforts by Y are different.

Finally, in terms of comparison of the relative performance of liability rules, recall that theory predicts the damage to be higher and the social welfare to be lower under non-joint than under joint and several liability. The experimentation does not validate these results: it appears that the damage is not significantly different between treatments A and B, and the social welfare is higher under non-joint than under joint and several liability (at 10% level).

Result 1. *In the case where one player is solvent and the other one insolvent (endowments of 120 and 20), solvent players are over-deterred (though less than in theory) and*

Table 10: Experimental social welfare - Treatments A-B

	Treatment A	**Treatment B**
W_X	120	120
W_Y	20	20
Equilibrium effort of X	19.5601	16.0944
Observed effort of X	15.94	15.45
Equilibrium effort of Y	0	0
Observed effort of Y	3.08	0.9
Equilibrium damage	70.71	100
Observed damage	104.22	108.02
Theoretical SW	188.58	180
Observed social welfare	162.244	171.315

insolvent players under-deterred (though less than in theory). However, in contradiction with theory, solvent players chooses similar efforts whatever the liability rule, whereas insolvent players make higher efforts under JS than under NJ. Overall, the observed social welfare is higher under NJ than under JS, whereas the model predicts the opposite.

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

Turning now to the case where players are both solvent (but in an asymmetric way, *i.e.* endowments of 120 and 55), the two players theoretically choose the same effort levels in the two treatments (10.73 for each player in each treatment), which corresponds to the full solvency equilibrium efforts. The results show that players X choose an effort that is higher than the expected one whatever the liability rule (*treatments C and D*), and player Y chooses an effort that is lower than the expected one. Thus, in the experiment, the most endowed player (X) is more deterred and the least endowed player (Y) is less deterred than predicted. This is probably be due to *wealth effects.* Some inequity aversion or altruism/egoism of players might play a role in their choices, trying to move closer to a 50-50 situation in terms of final payoffs. This is partly confirmed, but only for player Y, by the data: in particular, in *treatment C*, a lower altruism of player Y (higher *Selfish1*) implies a lower effort (*Selfish1* significant at 5% level, see Table 9). Moreover, still for subjects Y, *DE* is highly significant: higher inequity aversion (lower *DE*) leads to lower efforts, which is what could be expected (see Section 3) since players Y are disadvantaged in terms of initial wealth, compared to players X. In *treatment C*, the regressions also show that higher risk-aversion leads to higher effort, which might come from *Effect 2*, *i.e.* making a higher effort to bring less variability in the final payoff when the decision of the partner (which is relatively wealthy) is not easy to anticipate.

The comparison of treatments C and D interestingly shows that, as predicted, the two liability rules lead X to choose similar levels of efforts (efforts of X under each sharing rule are not significantly different) but, as said above, these efforts are higher than expected by theory (Table 6). The efforts of Y are however different under the two liability rules: JS leads to higher efforts of Y than NJ. While theory predicts both damage and social welfare to be the same for both sharing rules, we find that JS provides both the lowest damage and the highest social welfare (differences with NJ are significant at 1% level, see Table 11).

Table 11: Experimental social welfare - Treatments C-D

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

Result 2. *When both players are (asymmetrically) solvent, the most solvent player chooses an effort level which is higher than predicted whereas the least solvent one chooses a lower effort than the expected one, which leads to highly different efforts between players X and Y. Moreover, whereas theory predicts that the two rules are equivalent in terms of incentives to care and in terms of level of welfare, the results indicate that JS liability performs better in terms of social welfare than NJ.*

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

Finally, when both players are (asymmetrically) insolvent (endowments of 80 and 20), they are both expected to choose zero effort. In both *treatments E and F*, both players choose significantly positive effort levels.[25], thus leading to observed damages that are significantly lower than those expected (see Table 12).

Nevertheless, as in the two previous treatments, it seems that wealth effects have an impact. Indeed, the most endowed player (X) makes a higher effort level than the least endowed one (Y), which might come from some inequity aversion or from altruism (Table 9). Indeed, for Player X, the data show that the more X is altruistic (lower *Selfish1*), the more efforts he makes (Treatment E). In Treatment F, X seems to be guided by his behavior toward risk (*Effect 1*: the more risk-averse (lower DR), the less efforts he chooses) and by some inequity aversion (the higher inequity-adverse he is (lower DE), the more efforts he makes, which is what we could expec).

Regarding Player Y, whereas his behavior is only explained by his studies' field in Treatment E, Treatment F shows that social preferences play a role in his choices: the efforts of Y are higher when he is more inequity-adverse (lower *DE*), less altruistic (lower *Selfish1*) and more risk-averse ; these last two effects being quite counter-intuitive.

In terms of comparison between the liability rules, both type of players choose higher efforts under a NJ rule (*treatment F*) than under a JS one (*treatment E*). Our results indicate that these levels of efforts (higher than the expected "zero effort") might come from the risk aversion and inequity aversion of players (significant in treatment F at 5% and 10% levels for player X and 1% for player Y). Consequently, the observed damage is lower and the social welfare higher under a NJ rule (at 1% level).

Result 3. *When both players are (asymmetrically) insolvent, they make a positive effort whatever the liability rule, whereas the model predicts they should make no effort, but the most endowed player chooses a higher effort than the least endowed one, which is partly due to wealth effects and inequity aversion. Moreover, in contradiction with theory which states that both rules are equivalent in this case, experimental results suggest that*

[25]Note however that this is the case when considering mean efforts. Period 20 efforts are not any more significantly different from zero in treatment E for both players, and in treatment F for player Y.

NJ performs better since it raises higher efforts, lower damages and higher social welfare than JS.

Table 12: Experimental social welfare - Treatments E-F

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

5 Conclusion

In this paper, we analyze the performance of two liability sharing rules (joint and several *versus* non-joint liability) in situations where agents may be insolvent. This is, to our knowledge, the first experiment implying the comparison of liability rules with several injurers.

Our analysis is based on the theoretical model introduced by Kornhauser & Revesz (1990), which make the following predictions: (i) when both injurers are insolvent they should make no effort; (ii) when one injurer is solvent and the other one is insolvent, the former should make too much effort (over-deterrence) while the latter should make no effort; and (iii) when both injurers are solvent, they should make the same efforts whatever the liability rule (when they *a priori* have to pay the same part of the damage). However, our experimental analysis shows that the theoretical predictions are not always verified "in the lab".

We test the incentives in making efforts to reduce a common damage, under the three scenarios regarding the injurers' degrees of solvency (as described above), and for each scenario we test two liability sharing rules: joint and several liability, and non-joint liability. Our main results are the following: (i) we show that insolvent players choose positive efforts while theory predicts no effort, this leading to a social welfare which is higher than expected. This is explained by a pro-social behavior (aversion to inequity) ; (ii) we highlight that solvent players in face of insolvent ones are indeed over-deterred, but not as much as expected and in this case. In that case, the two liability rules seem to provide incentives which are similar for the solvent player. And finally (iii) we highlight wealth effects in several treatments, which cannot be put in light by theory: indeed, in four treatments, the most endowed player takes more care than the least endowed one though theoretical efforts between players are the same.

Kornhauser & Revesz (1990)'s analysis aimed at enlightening an American debate about which is the most desirable sharing rule to enforce, especially in case of environmental damage. As argued by some opponents to the enforcement of joint and several liability, they show that this rule leads the most solvent injurer to make too much efforts, thus reducing its level of profit ; but in terms of social welfare this rule is not dominated by non-joint liability. Putting in the perspective of this debate, our experimental results provide mixed conclusions. In case of very different levels of solvency (one injurer is solvent, the other one is insolvent), the (over) deterrent effect of joint and several liability is not so high than expected: both liability sharing rules lead to similar equilibria, even if the profit of the most solvent injurer is lower under joint and several liability than under non-joint liability. However, when the levels of solvency are closer (both injurers are solvent), the experimentation shows that the most solvent injurer makes much more efforts than the least solvent one, while it should not be the case. However, this effect is relatively similar under both liability rules, and joint and several liability leads, surprisingly, the least solvent injurer to make higher efforts than non-joint liability, thus leading the most solvent injurers to be better-off in case of joint and several liability than in case of non-joint liability. Hence, our results cannot conclude about a lower desirability of joint and several liability, based on efficiency grounds.

Nevertheless, the relative levels of solvencies of the different injurers play a crucial role in the resulting equilibria: depending on whether one, both or no injurer is able to pay for her share of the damage is of paramount importance in the relative efficiency of both sharing rules. Hence, when both injurers are solvent (which is the case for the least dangerous activities), joint and several liability provides both the highest social welfare and the lowest damage. For other setups, i.e. when both injurers are not able to pay for the damage (which can be the case for the most hazardous damage, in the chemical industry for instance), or when one injurer is solvent and the other one is not, non-joint liability provides the highest social welfare (and similar or lower damage than joint and several liability). As a consequence, the public regulator should take into account sectorial specificities (and especially the relative levels of firms' solvencies) when choosing which regulation to enforce.

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A Appendix

A.1 Proofs

Proof of Lemma 1

First recall that the agent i has a higher level in equities than agent j: $W_i > W_j$. Because of the symmetry we posed by assumption ($B_i(.) = B_j(.)$ and $\gamma = \frac{1}{2}$), we deduce that if the agent j is sufficiently endowed with equities W_j to have an interest in making a strictly positive effort in abatement (i.e. $e_j^* > 0$), the agent i has also an interest in doing the same. Consider that such a situation holds. The agent j's private level of abatement responds to:

$$\max_{e_j} \Pi_j^{JS} = B_j(e_j) + W_j - \min\left\{(1-\gamma)D(e_i, e_j); W_j\right\}$$

with, in that case (of high level of W_j): $\min\left\{(1-\gamma)D(e_i, e_j); W_j\right\} = (1-\gamma)D(e_i, e_j)$. We obtain:

$$\frac{\partial \Pi_j^{JS}}{\partial e_j} = 0 \Rightarrow -(1-\gamma)\frac{\partial D(e_i, e_j)}{\partial e_j} = -\frac{\partial B_j(e_j)}{\partial e_j} \tag{A.1}$$

We denote $e_j(\infty)$ the agent j's private effort satisfying this condition.
When facing an agent j who is able to pay for his share of liability, the problem the agent i has to respond is:

$$\max_{e_i} \Pi_i^{JS} = B_i(e_i) + W_i - \gamma D(e_i, e_j)$$

We obtain $e_i(\infty)$ which satisfies:

$$\frac{\partial \Pi_i^{JS}}{\partial e_i} = 0 \Rightarrow \gamma\frac{\partial D(e_i, e_j)}{\partial e_i} = -\frac{\partial B_i(e_i)}{\partial e_i}$$

Knowing $B_i(.) = B_j(.)$ and $\gamma = \frac{1}{2}$, we obtain: $e_i(\infty) = e_j(\infty)$.
So, $(e_i(\infty); e_j(\infty))$ is the equilibrium when both agents are sufficiently wealthy, under joint and several liability.

As mentioned in the body of the paper, there is a second equilibrium for the agent j: to be insolvent, and making no effort in abatement ($e_j^* = 0$). Obviously, this equilibrium arrives when $W_j = 0$. But by continuity, there are strictly positive values of W_j for which the agent j also has an interest in doing no effort in abatement. Below, we determine the agent j's level of equity, $\underline{W}$, below which (resp. above which) the agent j has no interest (resp. has an interest) in doing a strictly positive effort in abatement.

The threshold in equities $\underline{W}$ above which the agent j has an interest in making a strictly positive effort $e_j^* = e_j(\infty)$ is defined by:

$$\underline{W} + B_j(e_j(\infty)) - (1-\gamma)D(e_i(\infty), e_j(\infty)) > B_j(0)$$
$$\Rightarrow \underline{W} > B_j(0) - B_j(e_j(\infty)) + (1-\gamma)D(e_i(\infty), e_j(\infty))$$

with $\gamma = \frac{1}{2}$.
And, for any W_j such that $W_j < \underline{W}$, the agent j has an interest in being insolvent and making no effort (to obtain a profit equals to $B_j(0)$).

♦

Proof of Proposition 1

Consider $W_j < \underline{W}$ and $W_i > W_j$. We know that, in that case, the agent j is not solvent enough to pay for his share of liability, and he makes no effort in abatement: $e_j^* = 0$.

Consider, for illustration, a case where the agent i has an infinite level of solvency (i.e. $W_i \to \infty$). In that case, he always would be able to pay for all the remaining damage (after the agent j's payment of W_j). Then his level of effort would satisfy:

$$\max_{e_i} \Pi_i^{JS}(e_i, e_j = 0) = B_i(e_i) + W_i - D(e_i, e_j = 0)$$
$$\Leftrightarrow -\frac{\partial \Pi_i^{JS}(e_i, 0)}{\partial e_i} = 0 \Rightarrow -\frac{\partial D(e_i, e_j = 0)}{\partial e_i} = -\frac{\partial B_i(e_i)}{\partial e_i} \quad (A.2)$$

We note e_i^a the level of effort that satisfies (A.2). Comparing (A.2) with (2), and knowing $\frac{\partial^2 D(e_i,e_j)}{\partial e_i \partial e_j} > 0$, we can deduce: $e_i^a > e_i^{**}$. It is a situation of overdeterrence, in the sense that the agent i makes "too much" abatement efforts, in order to counterbalance the absence of effort of agent j.

Consider now another extreme case. Even when making a strictly positive effort e_i^a, the agent i is unable to pay for the remaining damage, i.e. we have: $W_i < D(e_i^a, e_j = 0) - W_j$. In that case, the agent i is liquidated (i.e. he pays W_i for damages) and he makes no effort in abatement (i.e. $e_i^* = 0$) since he will face no additional cost when reducing his level of abatement below e_i^a (his payment in liability is capped to W_i). So we obtain: $e_i^* = 0$, $e_j^* = 0$, $\Pi_i^{JS} = B_i(0)$, and the global damage amounts to $D(0,0)$.

However, if the agent i's level of equity lies in the interval $[D(e_i^a, 0) - W_j; D(0,0) - W_j]$, his ability to pay for the remaining damage depends on his level of effort in abatement: his solvency is endogenous. Indeed, remember that a higher effort in abatement leads to a lower damage, and so to a lower payment in liability. So, for a range of values of equities, it is possible for the agent i to determine, via its effort in abatement, his ability (or inability) to pay for liability. So the agent has the choice between two situations: making an effort e_i^a and being able to pay for the remaining damage $D(e_i^a, 0) - W_j$, or making no effort and being liquidated (to pay W_i).
So, the agent i chooses to be able to repair the damage if:

$$W_i + B_i(e_i^a) - (D(e_i^a, 0) - W_j) > B_i(0)$$
$$\Leftrightarrow W_i > B_i(0) - B_i(e_i^a) + (D(e_i^a, 0) - W_j) = \bar{W} \quad \text{(A.3)}$$

♦

Proof of Proposition 2

Consider $W_j < \underline{W}$ and $W_i > W_j$. We know that, in that case, the agent j is not solvent enough to pay for his share of liability, and he makes no effort in abatement: $e_j^* = 0$.

Consider, for illustration, a case where the agent i has an infinite level of solvency (i.e. $W_i \to \infty$). In that case, he always would be able to pay for her share of liability, $\gamma D(e_i, 0)$. Then his level of effort would satisfy:

$$\max_{e_i} \Pi_i^{NJ}(e_i, e_j = 0) = B_i(e_i) + W_i - \gamma D(e_i, e_j = 0)$$
$$\Leftrightarrow -\frac{\partial \Pi_i^{NJ}(e_i, 0)}{\partial e_i} = 0 \Rightarrow -\gamma \frac{\partial D(e_i, e_j = 0)}{\partial e_i} = -\frac{\partial B_i(e_i)}{\partial e_i} \tag{A.4}$$

We note e_i^b the level of effort that satisfies (A.4). Comparing (A.4) with (2), we are unable to rank e_b^i relatively to e_i^{**}. Indeed, a look at the FOC (A.4) and (2) allows seing that: (i) because the agent i has only to pay a share γ of the damage, non-joint liability reduces the incentives for making efforts (relatively to the first-best effort) but, (ii) because the other agent makes no effort at all ($e_j^* = 0$) the agent i has incentives for making (too much) efforts to decrease his amount of debt (because of $\frac{\partial^2 D(e_i, e_j)}{\partial e_i \partial e_j} > 0$). In such a general frame, we are unable to distinguish which effect dominates the other one.

Consider now another extreme case. Even when making a strictly positive effort e_i^b, the agent i is unable to pay for his share of the damage, i.e. we have: $W_i < \gamma D(e_i^b, e_j = 0)$. In that case, the agent i is liquidated (i.e. he pays W_i for damages) and he makes no effort in abatement (i.e. $e_i^* = 0$) since he will face no additional cost when reducing his level of abatement below e_i^b (his payment in liability is capped to W_i). So we obtain: $e_i^* = 0$, $e_j^* = 0$, $\Pi_i^{NJ} = B_i(0)$, and the global damage amounts to $D(0, 0)$.

However, if the agent i's level of equity lies in the interval $[\gamma D(e_i^b, 0); \gamma D(0, 0)]$, his ability to pay for his share of the damage depends on his level of effort in abatement: his solvency is endogenous. Indeed, remember that a higher effort in abatement leads to a lower damage, and so to a lower payment in liability. So, for a range of values of equities, it is possible for the agent i to determine, via its effort in abatement, his ability (or inability) to pay for liability. So the agent has the choice between two situations: making an effort e_i^b and being able to pay for his share of liability $\gamma D(e_i^b, 0)$, or making no effort and being liquidated (to pay W_i).

So, the agent i chooses to be able to repair the damage if:

$$W_i + B_i(e_i^b) - \gamma D(e_i^b, 0) > B_i(0)$$

$$\Leftrightarrow W_i > B_i(0) - B_i(e_i^b) + \gamma D(e_i^b, 0) = \bar{\bar{W}} \tag{A.5}$$

♦

Proof of Proposition 3

Point (i): this point is immediate from the comparison between (A.2) and (A.4). In both cases, the agent j makes no effort. But the incentives for the agent i to make abatement efforts is higher under joint and several (JS) liability than under non-joint (NJ) liability since, at the margin, he has to pay for the global damage $D(e_i, 0)$ under JS while he only has to pay for a share γ of this global damage under NJ.

Point (ii): this point is the consequence of a comparison of different outputs, depending on the apportionment rule, summarized in the two following tables.

Table A.1: Joint and several vs non-joint liability, when agent j is insolvent and $\bar{W} > \bar{\bar{W}}$

—	Efforts of i		Damage		Compensation		Welfare
W_i	JS	NJ	JS	NJ	JS	NJ	JS vs NJ
$[0; \bar{\bar{W}}]$	0	0	$D(0,0)$	$D(0,0)$	$W_i + W_j$	$W_i + W_j$	Similar
$[\bar{\bar{W}}; \bar{W}]$	0	e_i^b	$D(0,0)$	$D(e_i^b, 0)$	$W_i + W_j$	$\gamma D(e_i^b, 0) + W_j$	$NJ > JS$
$> \bar{W}$	e_i^a	e_i^b	$D(e_i^a, 0)$	$D(e_i^b, 0)$	$D(e_i^a, 0)$	$\gamma D(e_i^b, 0) + W_j$	$JS > NJ$

Table A.2: Joint and several vs non-joint liability, when agent j is insolvent and $\bar{W} < \bar{\bar{W}}$

—	Efforts of i		Damage		Compensation		Welfare
W_i	JS	NJ	JS	NJ	JS	NJ	JS vs NJ
$[0; \bar{W}]$	0	0	$D(0,0)$	$D(0,0)$	$W_i + W_j$	$W_i + W_j$	Similar
$[\bar{W}; \bar{\bar{W}}]$	e_i^a	0	$D(e_i^a, 0)$	$D(0,0)$	$D(e_i^a, 0)$	$W_i + W_j$	$JS > NJ$
$> \bar{\bar{W}}$	e_i^a	e_i^b	$D(e_i^a, 0)$	$D(e_i^b, 0)$	$D(e_i^a, 0)$	$\gamma D(e_i^b, 0) + W_j$	$JS > NJ$

We still consider the agent j to be insolvent (and thus making no effort). We can easily check that, in that case, joint and several liability (JS) provides similar outputs than non-joint liability (NJ) when the agent i is also insolvent, while JS is preferred to NJ for sufficiently high levels of W_i (i.e. $W_i > \max\left\{\bar{W}; \bar{\bar{W}}\right\}$). To be more precise, JS is said to be preferred to NJ in the sense that it leads to a higher level of social welfare. This is the case because under JS, (at the margin) the agent i internalizes the whole damage so that e_i^a is the social best-response to $e_j = 0$; while e_i^b is suboptimal because only a share γ is internalized at the margin. Moreover, when i is sufficiently wealthy, JS ensures a total compensation to the victim. Finally, because $\frac{\partial D(e_i,e_j)}{\partial e_i} < 0$, we have: $D(e_i^a, 0) < D(e_i^b, 0)$: JS ensures a lower level of pollution than NJ. These three outputs (social welfare, level of damage, victims' compensation (or environmental reparation)) ensures JS to be socially prefered than NJ. Nevertheless, we can note that it is likely that JS leads to a lower net profit to the agent i than NJ: $e_i^a > e_i^b$ leads to $B_i(e_i^a) < B_i(e_i^b)$ and JS leads the agent i to pay for the global damage. But the global damage is lower under JS than under NJ ($D(e_i^a, 0) < D(e_i^b, 0)$). So, given the degree of generality of the model, we cannot theoretically conclude that JS provides the agent i with a lower net profit than NJ. But $\frac{\partial^2 D(e_i,e_j)}{\partial e_i \partial e_i} > 0$ and $\frac{\partial^2 B_i(e_i)}{\partial e_i \partial e_i} < 0$, i.e. the presence of a convex increasing cost function of e_i and the presence of decreasing returns of e_i (in terms of lowering the global damage) ensure a high likelihood for the agent i to obtain a lower net profit under JS than under NJ.

Finally, we can also remark that for "intermediate" values of W_i (i.e. $W_i \in [\bar{W}; \bar{\bar{W}}]$), the social desirability of one sharing rule over the other one depends on the value of $\bar{W}$ relatively to $\bar{\bar{W}}$. This crucially depends on the specification of the damage function $D(.,.)$: no general theoretical conclusion can be provided.

♦

Proof of Remark 1

We have to compare:

$$\bar{W} = B_i(0) - B_i(e_i^a) + [D(e_i^a, 0) - W_j]$$

with

$$\bar{\bar{W}} = B_i(0) - B_i(e_i^b) + \gamma D(e_i^b, 0)$$

We obtain $\bar{W} > \bar{\bar{W}}$ if: $W_j < B_i(e_i^b) - B_i(e_i^a) + D(e_i^a, 0) - \gamma D(e_i^b, 0)$ with $B_i(e_i^b) - B_i(e_i^a) > 0$ because $e_i^b < e_i^a$ and $B_i'(e_i) < 0$, but the sign of $D(e_i^a, 0) - \gamma D(e_i^b, 0)$ is *a priori* undetermined because $e_i^b < e_i^a$ and $D_i'(e_i, .) < 0$ lead to $D(e_i^a, 0) > D(e_i^b, 0)$ but we have $0 < \gamma < 1$.

But this comparison only holds for the case where $W_j < \underline{W}$. So, W_j has simultaneously to satisfy:

$$W_j < B_i(e_i^b) - B_i(e_i^a) + D(e_i^a, 0) - \gamma D(e_i^b, 0) \tag{A.6}$$

$$W_j < B_j(0) - B_j(e_j(\infty)) + (1 - \gamma) D(e_i(\infty), e_j(\infty)) \tag{A.7}$$

Note that if condition (A.7) is more stringent than (A.6), then $\bar{W} > \bar{\bar{W}}$ always hold since we suppose (A.7) to be satisfied by assumption. But the comparison of the right-hand-sides of (A.6) and (A.7) leads to an ambiguous result. So, we can only say that, knowing $W_j < \underline{W}$, $\bar{W}$ is higher than $\bar{\bar{W}}$ if (A.6) is satisfied.

♦

A.2 Damage value depending on effort 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 effort 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 Summary statistics of individual characteristics

Table A.3: Summary statistics - Player X

	A		B		C		D		E		F	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
DR	5.8	1.25	5.45	2.14	5.8	2.04	6	1.65	6.35	1.96	5.3	1.79
DE	6.3	2.05	6.55	2.23	5.60	2.34	5.55	2.64	5.05	2.38	5.2	2.27
Risk	5.4	1.86	5.3	1.74	5.3	2.08	5.8	1.51	6.3	1.52	4.8	1.4
Selfish12	0.70	0.46	0.45	0.5	0.5	0.5	0.6	0.49	0.55	0.5	0.70	0.46
Selfish21	6.60	1.28	6.4	2.09	6.05	2.14	6.15	1.96	7.15	1.77	6.5	2.01
MasterDoc	0.4	0.49	0.2	0.4	0.25	0.43	0.3	0.46	0.35	0.48	0.3	0.46
Sciences	0	0	0	0	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3
DroitLet	0.2	0.4	0.1	0.3	0.2	0.4	0	0	0.05	0.22	0.3	0.46
Eco	0.5	0.5	0.70	0.46	0.45	0.5	0.6	0.49	0.6	0.49	0.6	0.49
Age	21.6	2.42	20	1.85	20.2	1.72	20.3	1.9	20.5	1.81	19.9	1.3
Sexe	0.5	0.5	0.5	0.5	0.55	0.5	0.3	0.46	0.65	0.48	0.6	0.49
N	400		400		400		400		400		400	

Table A.4: Summary statistics - Player Y

	A		B		C		D		E		F	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
DR	5.9	1.45	5.10	1.76	5.35	1.43	5.75	1.7	5.45	1.57	5	2.45
DE	6.2	1.6	5.7	2.41	5.85	2.15	6.65	2.52	6.05	3.08	5	2.61
Risk	5.7	2.15	4.9	2.35	5.2	1.72	6	1.55	5.35	1.96	4.60	2.54
Selfish12	0.5	0.5	0.70	0.46	0.70	0.46	0.5	0.5	0.35	0.48	0.6	0.49
Selfish21	6.10	2.3	6.3	1.9	6.05	1.63	6.9	2.15	5.60	2.64	5.8	1.94
MasterDoc	0.1	0.3	0.3	0.46	0.3	0.46	0.3	0.46	0.1	0.3	0.3	0.46
Sciences	0.1	0.3	0.05	0.22	0.05	0.22	0.2	0.4	0.05	0.22	0.1	0.3
DroitLet	0.1	0.3	0.15	0.36	0.1	0.3	0.05	0.22	0.15	0.36	0.1	0.3
Eco	0.6	0.49	0.5	0.5	0.6	0.49	0.5	0.5	0.70	0.46	0.6	0.49
Age	20.6	2.06	20.85	2.15	20.55	1.6	20.15	1.83	19.85	1.24	21.5	1.91
Sexe	0.6	0.5	0.55	0.5	0.45	0.5	0.4	0.49	0.45	0.5	0.1	0.3
N	400		400		400		400		400		400	

A.5 Tests of difference between observed and theoretical social welfare

Table A.5: Tests of difference between observed and theoretical social welfare

Treatment	A	B	C	D	E	F
Mean observed SW	162.25	171.32	247.91	235.85	-149.4	-122.93
Theoretical SW	188.58	180	258.04	258.04	-220	-220
SW difference	-26.33***	-8.685***	-10.13***	-22.19***	70.60***	97.07***
	(4.334)	(2.732)	(1.062)	(2.248)	(6.150)	(6.991)

$N = 400$ for each treatment.
Standard errors in parentheses. Significance level: *** p<0.01

A.6 Instructions of the experiment

[Translated from French to English]

Welcome in our laboratory.

You are about to participate in an experiment in decision making. If you carefully follow the instructions, 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 the reading of 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 decision of others and on the results of 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 inform you about the payoffs of the three tasks at the end of the experiment.

A.6.1 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 wil make your decisins as a 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 equally amount of X €. Notice that the amount X increases from one line to the next one.

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€)

Note: You are not allowed to make inconsistent decisions during this task. More precisely, in case you prefer alternative "Right" for a certain line, the computer imposes you 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 to 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. In the case you have chosen the alternative "Right", the payoffs of both players will be X €. In case 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 €). In the case player A chose the alternative "Right", the payoffs of both players will be e X. If player A chose alternative "Left", your payoff will be 0 €.

The random draws are performed individually.

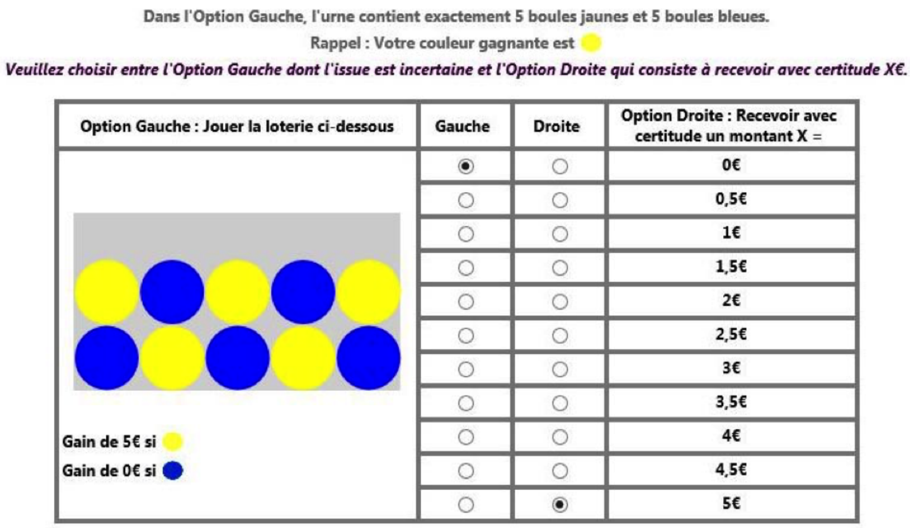
A.6.2 Task 2

In this second task, you will first indicate whether you prefer your winning color to be Yellow or Blue. This will matter in the end of the experiment, in order to determine 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 sure amount of X €. Notice 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, in case you prefer alternative "Right" for a given line (amount X €), the computer imposes you 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 determine randomly 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.6.3 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 participants will obtain during this task 3 will be calculated by adding 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.

A.6.4 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 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 exposed 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 can occur cases where each one bears the half of C and cases where X bears a higher part of C than Y. Several scenarios are possible:

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

  ✓ 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 $C - 20$)

  ✓ 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, some 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 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.

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 the 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 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: 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*). The half of C is equal to 167,5. Y cannot bear the half of this cost since his endowment A of 20 is not sufficient; he then bears 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 away of 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 raw)
- **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 raw)

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 raw) 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 raw) 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 raw) 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 raw) is equal to 87.

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 instructions. These questions will appear on your computer screen in a short time.

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 of the article: for ease of your reading, we let you know that only the parts in blue 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 participants will obtain during this task 3 will be calculated by adding 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 exposed 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:

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

✓ 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.

✓ 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 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 away of 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 raw)
- **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 raw)

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 raw) 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 raw) 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 raw) 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 raw) 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 instructions. These questions will appear on your computer screen in a short time.

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 : Net gains of X depending on his choice (1st column) and of 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	98	108	118	127	135	142	148	154	160	164	169	173	176	179	182	185
1	89	89	89	89	89	89	89	97	107	117	126	134	141	147	153	158	163	168	172	175	178	181	184	186
2	88	88	88	88	88	88	95	106	116	125	132	140	146	152	157	162	166	170	174	177	180	183	185	187
3	87	87	87	87	87	94	105	115	123	131	138	145	151	156	161	165	169	173	176	179	181	184	186	188
4	85	85	85	85	93	103	113	122	130	137	143	149	155	159	164	168	171	174	177	180	182	185	187	188
5	84	84	84	91	102	112	120	128	135	142	148	153	158	162	166	170	173	176	178	181	183	185	187	188
6	82	82	89	100	110	119	126	134	140	146	151	156	160	164	168	171	174	177	179	181	183	185	187	188
7	80	88	98	108	117	125	132	138	144	149	154	159	162	166	169	172	175	177	179	181	183	185	186	187
8	85	96	106	115	122	130	136	142	147	152	156	160	164	167	170	173	175	177	179	181	183	184	185	186
9	94	103	112	120	127	134	140	145	150	154	158	162	165	168	170	173	175	177	179	180	182	183	184	185
10	101	110	118	125	131	137	142	147	151	155	159	162	165	168	170	172	174	176	178	179	180	182	183	184
11	107	115	122	128	134	139	144	149	153	156	159	162	165	167	169	171	173	175	176	178	179	180	181	182
12	112	119	125	131	136	141	145	149	153	156	159	162	164	166	168	170	172	173	174	176	177	178	178	179
13	115	122	128	133	138	142	146	149	153	156	158	161	163	165	167	168	170	171	172	173	174	175	176	176
14	118	124	129	134	138	142	146	149	152	154	157	159	161	163	164	166	167	168	169	170	171	172	173	173
15	119	125	130	134	138	141	145	147	150	153	155	157	158	160	161	163	164	165	166	167	168	168	169	170
16	120	125	129	133	137	140	143	145	148	150	152	154	155	157	158	159	160	161	162	163	164	164	165	165
17	120	124	128	131	135	138	140	143	145	147	148	150	152	153	154	155	156	157	158	158	159	160	160	161
18	118	122	126	129	132	134	137	139	141	143	144	146	147	148	149	150	151	152	153	153	154	154	155	155
19	116	119	123	125	128	130	133	135	136	138	139	141	142	143	144	145	146	146	147	148	148	149	149	149
20	112	115	118	121	123	126	128	129	131	132	134	135	136	137	138	139	139	140	141	141	142	142	142	143
21	108	111	113	116	118	120	122	123	125	126	127	128	129	130	131	132	132	133	133	134	134	135	135	135
22	102	105	107	109	111	113	115	116	117	118	120	121	121	122	123	124	124	125	125	126	126	126	127	127
23	95	98	100	102	103	105	107	108	109	110	111	112	113	113	114	115	115	116	116	117	117	117	117	118

T5

Table 4

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

T5

A.7 Post-experiment questionnaire

Note for the reader of the article: you will find the name of the variables presented in the results 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 of tasks 1, 2 and 3. You will then be paid anonymously.

1. Indicate your gender ☐ a male ☐ a 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 0 to 10 where you find yourself, 0 standing for a person who loves taking risks and 10 for a person who hates taking risks. [*Risk*]

   0 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 0 to 10 where you find yourself, 0 standing for a person who loves helping others and 10 for a person who cares only about him/herself.[*Selfish1*]

   0 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 0 to 10 where you find others, 0 standing for a person who loves helping others and 10 for a person who cares only about him/herself. [*Selfish21*]

   0 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 you 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]