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## Keywords:

Mutual insurance pool, voluntary contribution mechanism, equal coverage, contribution-based coverage, heterogeneity of risk attitudes, experiment

## JEL codes:

I18, H21, H41, C72, C91

Working Paper

# Voluntary Contributions to a Mutual Insurance Pool[*]

Louis Lévy-Garboua [†]        Claude Montmarquette [‡]

Jonathan Vaksmann [§]        Marie-Claire Villeval[¶][‖]

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[†]Université Paris 1 - Panthéon Sorbonne, Paris School of Economics, Centre d'Économie de la Sorbonne, 106-112 Bd de l'Hôpital 75647 Paris Cedex 13, France; and CIRANO, Montreal, Canada. Louis.Levy-Garboua@univ-paris1.fr.

[‡]CIRANO and Université de Montréal, 2020 rue University, Montreal, (Quebec), Canada, H3A 2A5. Claude.Montmarquette@cirano.qc.ca.

[§]GAINS-TEPP, Université du Maine, Faculté de Droit et des Sciences Économiques Avenue O. Messiaen 72085 Le Mans Cedex 9; and Centre d'Économie de la Sorbonne, Université Paris 1 - Panthéon Sorbonne. jonathan.vaksmann@univ-lemans.fr

[¶]Corresponding author. villeval@gate.cnrs.fr. Phone: +33 4 72 86 60 79. Fax: +33 4 72 86 60 90.

[‖]Université de Lyon, F-69007-Lyon, France; CNRS-GATE Lyon St Etienne, 93, chemin des Mouilles F-69130-Ecully, France; LABEX CORTEX (ANR-11-LABX-0042) of Université de Lyon; IZA, Bonn, Germany. villeval@gate.cnrs.fr; University of Innsbruck.

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**Abstract**

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# 1    Introduction

In spite of the prevalence of assistance and universal insurance in a growing number of countries, the economic theory of insurance tends to ignore the fact that one's coverage against insurable risk will often not depend solely on one's own contributions. In this paper, we wish to examine cases in which individual coverage against risk is determined by the aggregate level of voluntary contributions in a group and a sharing rule. We designate this type of insurance scheme as "voluntary mutual aid". We envision mutual aid here as a unifying concept that can be useful for analyzing various institutions. Mutual-aid pools offer insurance to members of a specified group, typically sharing a common characteristic. The homogeneity of members facilitates the full coverage of independent random losses at fair price and enhances the solidarity among members and their willingness to contribute to the pool. To illustrate this point, Schwindt and Vining (1998) motivate their proposal for a mutual insurance pool for transplant organs by the incentive it provides to donate. Group members are free to join and contribute and they redistribute resources between themselves according to a sharing rule. All members are impartially treated and resources are divided between them according to needs or participation : those who need or participate most are helped most. Mutual-aid organizations have existed at least since the medieval craft guilds.[1] Important contemporary examples of voluntary mutual-aid pool are "climate clubs" of adherents to international climate policy agreements (Nordhaus, 2015) that offer some kind of mutual insurance against differential climate change damages and trade unions that provide unionized workers with protection against employment hazards. However, trade unions and climate clubs are perfect illustrations of the problem raised by the

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[1]Friendly Societies were found throughout Europe in the 18th and 19th centuries. During the Great Depression, the American "fraternity societies" and the English "workers clubs" provided their members with health insurance. (Almost) complete consumption insurance in small communities (Townsend, 1994) and in large societies (Mace, 1991, Cochrane, 1991, Schulhofer-Wohl, 2011) reveals an efficient implicit structure of mutual insurance in those groups. Anecdotally, we have been aware of the example of students contributing to a fund used to reimburse contraveners who have been fined for fare dodging in public transportation.

group's heterogeneity to voluntary mutual-aid pools. Workers who didn't unionize and countries who didn't sign the agreement may still benefit from the contributions of unionized workers or cooperative countries. Thus, a conflict arises between insurance motives and incentives, which needs to be resolved. For illustration, going back to the proposal of a mutual insurance pool for transplant organs, Howard (2007) remarks that the pool derives its efficiency by linking very explicitly the willingness to donate and the ability to benefit from transplantation and by punishing free riders: persons who refuse to donate but would gladly accept organs from others.

In contrast with formal mutual insurance schemes in which paying a premium is contractual, compulsory and excludable,[2] voluntary contributions and indemnities to a mutual-aid pool constitute an informal insurance scheme with no contract, no legal obligation, and no excludability of eligible members. In particular, non-excludability confers a public good or common resource dimension to the mutual aid. In the absence of transaction costs (loading), all risk-averse agents exposed to a random loss and maximizing their expected utility of wealth would purchase full insurance on a competitive insurance market (Mossin, 1968). Full coverage is also realizable in our case with informal mutual insurance if everyone contributes the fair premium that he would be willing to pay on a private insurance market. However, the cooperation of all members of a mutual-aid pool is problematic when the pool is heterogeneous. We demonstrate in this paper that the mere heterogeneity of risk attitudes is sufficient to hamper the cooperation of members of a mutual-aid group.

Drawing on the rich literature on voluntary contributions to public goods, [3] we ask whether mutual aid enhances fairness and the level of individual contributions to the

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[2]In Barigozzi et al. (2013), "mutualization" corresponds to participating policies in which policyholders jointly hold the residual claims on the common pool. Policyholders share the aggregate risk and, after an initial contribution, contribute whatever amount is needed yearly to meet the losses insured by the pool (on participating policies, see also Doherty and Dionne, 1993; Smith and Stutzer, 1990, 1995; Picard, 2009; on mutual risk-sharing agreements, see notably Bourles and Henriet, 2012). This is different in our games since full coverage is not guaranteed.

[3]See among many others, Andreoni, 1993, Fehr and Gachter, 2000, Isaac and Walker, 1988, Andreoni, Harbaugh and Vesterlund, 2003, Masclet et al., 2003 or Sefton, Shupp and Walker, 2007.

point of offsetting the selfish drive. To this end, we study, both theoretically and experimentally, two different types of mutual aid conditioning or not the reimbursement of individuals who incur a random monetary loss on their preliminary contribution to an insurance pool. *Equal coverage* guarantees an equal reimbursement to all individuals who incur a loss irrespective of their voluntary contribution to the insurance pool. In contrast, *contribution-based coverage* partly conditions the individuals' reimbursement on their own voluntary contributions. The second regime introduces an incentive to increase individual contributions. We compare the (ex ante) efficiency of these two types of mutual aid in enhancing the sense of responsibility of individual contributors to the pool as measured in terms of individual contributions. Equal and contribution-based coverage also reflects different conceptions of equity. Indeed, equal coverage guarantees equal reimbursement for a given loss whereas contribution-based coverage guarantees equal reimbursement for a given effort. While the first approach represents an egalitarian view of equity, the second one is close to the notion of "just deserts" of Frohlich, Oppenheimer and Kurki (2004) in which individuals' earnings are a proportion of their contributions to income. We compare the net transfers of income, unrelated with the occurrence of loss, among low and high contributors to the insurance pool in these two regimes.

Our equilibrium analysis exhibits contrasting predictions under the different conditions implemented. Two focal outcomes are natural in our context. The first one is the no-insurance outcome in which nobody contributes and therefore no insurance is created for the group.

The second, that we call the full-insurance outcome, is such that the sum of contributions is high enough to provide full coverage of all losses (including those who had not fully contributed). Whereas the equal coverage policy leads to a unique no-insurance equilibrium, the contribution-based policy leads to multiple equilibria according to which both no-insurance and full-insurance equilibria coexist. Our finitely

repeated laboratory experiment allows us to analyze whether behavior converges to the predicted Nash equilibria, and to identify which equilibrium is selected in the case of multiple equilibria.

In accordance with predictions, the experimental evidence shows that the equal coverage policy generates least contributions and greatest transfers from high contributors to low contributors. The contribution-based coverage policy provides stronger incentives to contribute, which we interpret as an enhanced sense of individual responsibility. It also reduces the amount of transfers unrelated with the occurrence of a loss from high contributors to low contributors. However, under the latter regime full coverage is only rarely attained, even though this is a potential equilibrium. The observed situation can best be described as a "dual interior equilibrium". This dual equilibrium is consistent with the co-existence of different prior norms in the population which correspond to notable equilibria derived in the theory. That particular outcome is generated by two stable clusters of high and low contributors. High contributors have an incentive to reduce their contribution below fair insurance whereas low contributors have an incentive to give a little to reap the external benefit of coverage thanks to the high contributors. This type of equilibrium can be explained with heterogeneous players' who exhibit different risk attitudes (risk averse versus risk tolerant).

The remainder of this paper is organized as follows. Section 2 presents the equilibrium analysis of our experimental games. Section 3 details the experimental design. Section 4 analyzes the results. Finally, Section 5 concludes and discusses the implications of these findings.

# 2 Games and Incentives

## 2.1 The Model

In our set-up, every individual decides which part of his income to contribute to a mutual fund, which has the purpose of covering losses for randomly hit individuals. A key feature of mutual insurance is that the level of coverage is not chosen individually but rather determined collectively. This is a crucial difference with private insurance. Therefore individuals are embedded in a strategic setting in which they choose their contribution to the mutual fund, which in turn defines the level of coverage that applies to each agent. Overinsurance is prohibited: if the sum of contributions exceeds total losses, all subjects who experience a loss are fully covered and the surplus is burned.

Let us now introduce some notations. The experiment involves groups of $n$ players choosing their contributions to a mutual fund in a risky context in which each player can be randomly hit by a loss. We denote the set of players in a group by $N = \{1, ..., n\}$. Initially, each player is endowed with the same level of income $y > 0$. Player $i$ chooses his contribution $x_i \in [0, y] \; \forall i \in N$, and might experience an ex post random loss. We denote by $\theta_i \in \{0, 1\}$ the state of nature for player $i$, where $\theta_i = 1$ if player $i$ is hit by the loss and $0$ otherwise. $M$ is the set of players hit by the loss, i.e. $M = \{i \in N : \theta_i = 1\}$. Each individual hit looses $d$. In our experiment, a fixed number of players $m = |M|$ are randomly hit within a group. This hypothesis makes the total amount of losses $\ell = d.m$ a sure value, thus shortening the gap between the situation of a small experimental group and what the law of large numbers would naturally achieve in a large group.[4] Player $i$'s payoff is denoted by $\pi_i(x_i, x_{-i}, \theta)$, where $x_{-i} = (x_1, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n) \in [0, y]^{n-1}$ stands for the individual contributions of the other group members and $\theta = (\theta_1, \ldots, \theta_n) \in \{0, 1\}^n$ summarizes the states of nature associated with the $n$ players. Denote $u_i$, player $i$'s twice-differentiable vNM-

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[4]An interesting extension of the analysis would consist of introducing uncertainty on the probability of being hit by a loss.

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utility function with $\partial u_i(\pi_i)/\partial \pi_i > 0$ and $\partial^2 u_i(\pi_i)/\partial(\pi_i)^2 \leq 0$.

Therefore, the latter maximizes his expected utility function given by:

$$U_i = \sum_{\hat{\theta}=0,1} p_i\left(\hat{\theta}\right) \sum_{M\backslash\{i\}\subset N\backslash\{i\}} \left(\prod_{j\in M\backslash\{i\}} p_j\right).u_i\left(\pi_i(x_i, x_{-i}, \theta)\right), \tag{1}$$

where $p_i\left(\hat{\theta}\right) = \text{Prob}\left(\theta_i = \hat{\theta}\right)$ and $p_i(1) = 1 - p_i(0) = p_i = p, \forall i \in N$.

We distinguish between two archetypal mutual insurance mechanisms, namely *equal coverage* and *contribution-based coverage*. The rest of this section is devoted to a thorough description and analysis of these games.

## 2.2 The Equal Coverage Mechanism

Under equal coverage, players $i$'s payoffs depend not only on the contribution profile but also on the state of nature $\theta_i$. Specifically, when he does not incur a loss (i.e. when $\theta_i = 0$) player $i$'s payoff is given by:

$$\pi_i(x_i, x_{-i}, \theta_i) = \pi_i^0 = y - x_i. \tag{2}$$

Otherwise, when player $i$ incurs a loss (i.e. when $\theta_i = 1$), his payoff is given by:

$$\pi_i(x_i, x_{-i}, \theta_i) = \pi_i^1 = y - x_i - d\left(1 - c(x_i, x_{-i})\right), \tag{3}$$

where $d(= \ell/m) > 0$ is the loss suffered in the bad state of nature. $c(x_i, x_{-i})$ is a uniform coverage rate which depends positively on the sum of contributions. In this game, we consider the following coverage rate $c(x_i, x_{-i}) = \min\left\{\frac{1}{\ell}\sum_{j=1}^n x_j, 1\right\}$. Under loss we have $c(x_i, x_{-i}) < 1$ and player $i$'s expected utility function is given by:

$$U_i = pu_i\left(y - x_i - d\left(1 - \frac{\sum_{j=1}^n x_j}{\ell}\right)\right) + (1-p)u_i(y - x_i). \tag{4}$$

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Differentiating Eq.(4) with respect to $x_i$ we get:

$$\frac{\partial U_i}{\partial x_i} = p\frac{\partial u_i(\pi_i^1)}{\partial \pi_i^1}\left(-1 + \frac{d}{\ell}\right) - (1-p)\frac{\partial u_i(\pi_i^0)}{\partial \pi_i^0} < 0. \tag{5}$$

As $d < \ell$, the first term into brackets in the RHS of Eq. (5) is clearly negative $\forall(x_i, x_{-i}) \in [0, y]^n$. Therefore, 0 contribution is a dominant strategy $\forall i \in N$ in the presence of a loss and $(0, \ldots, 0)$ is an equilibrium profile of the game with equal coverage. To check the uniqueness of the equilibrium, it remains to show that if player $i$ were in a position to balance the budget, he would rather choose a null contribution. Formally, this will be the case if, given a contribution profile for others $\tilde{x}_{-i}$ such that $0 < \ell - \sum_{j\neq i}\tilde{x}_j \leq y$, the following inequality holds:

$$U_i(0, \tilde{x}_{-i}) \geq U_i\left(\ell - \sum_{j\neq i}\tilde{x}_j, \tilde{x}_{-i}\right), \quad \forall i \in N, \quad \forall\tilde{x}_{-i} \in [0, y]^{n-1}, \quad 0 < \ell - \sum_{j\neq i}\tilde{x}_j \leq y. \tag{6}$$

Condition (6) can be rewritten:

$$pu_i\left(y - \frac{d}{\ell}\left(\ell - \sum_{j\neq i}\tilde{x}_j\right)\right) + (1-p)u_i(y) \geq u_i\left(y - \left(\ell - \sum_{j\neq i}\tilde{x}_j\right)\right). \tag{7}$$

As $d/\ell < 1$, it becomes clear that (7) always holds. Therefore, a balanced budget does not arise in equilibrium and $(0, \ldots, 0)$ is the only equilibrium of the game with equal coverage.

## 2.3   The Contribution-Based Coverage Mechanism

Under this mechanism, the individual $i$'s coverage rate, $c_i(x_i, x_{-i}, \theta)$, depends on his contribution to the pool relative to the contributions of other individuals incurring a loss. As in the previous game, his indemnity can never exceed his loss (i.e., $c_i(x_i, x_{-i}, \theta)$ lies between 0 and 1) and the sum of indemnities paid to the players incurring a loss

is always covered by the sum of contributions.

When the sum of contributions covers all the losses, each individual is fully insured and receives a sure payoff. When this sum does not cover all the losses, reimbursement is partial and the compensation of every player incurring a loss is proportional to his own contribution relative to that of the other players incurring a loss.[5] Therefore, under partial coverage, $c_i(x_i, x_{-i}, \theta)$ can be given by the following formula:

$$c_i(x_i, x_{-i}, \theta) = \begin{cases} \min\left\{ \frac{\sum_{j=1}^n x_j}{\ell} \frac{x_i}{\frac{1}{m}\sum_{j=1}^n x_j.\theta_j}, 1 \right\} & \text{if } \sum_{j=1}^n x_j.\theta_j \neq 0 \\ \min\left\{ \frac{\sum_{j=1}^n x_j}{\ell}, 1 \right\} & \text{otherwise.} \end{cases} \quad (8)$$

In what follows, we will simply denote $c_i = c_i(x_i, x_{-i}, \theta)$ for notational clarity.

In the game with contribution-based coverage, players' payoffs in each state of nature are analogous to those given by Eqs. (2) and (3). Thus, player $i$ solves the following program:

$$\max_{x_i} U_i = p\left[ \frac{1}{C_{n-1}^{m-1}} \sum_{M\setminus\{i\}\subset N\setminus\{i\}} u_i\left(y - x_i - d(1 - c_i)\right) \right] + (1-p)u_i(y - x_i). \quad (9)$$

When $c_i < 1$, i.e. when there is a loss, the FOC of (9) is:

$$MRS_i^{0,1} = \frac{p}{1-p} \frac{1}{C_{n-1}^{m-1}} \sum_{M\setminus\{i\}\subset N\setminus\{i\}} \left( -1 + d\frac{\partial c_i}{\partial x_i} \right), \quad (10)$$

where $MRS_i^{0,1} = \frac{\partial u_i(\pi_i^0)}{\partial \pi_i^0} / \frac{\partial u_i(\pi_i^1)}{\partial \pi_i^1}$.

We claim that $(x_1^*, \ldots, x_n^*) = (0, \ldots, 0)$ is an equilibrium of this game. To see this, note that $\partial c_i/\partial x_i \mid_{x_{-i}=(0,\ldots,0)} = m/\ell, \forall x_i > 0$. Consequently, the RHS of (10) equals 0 when $x_{-i} = (0, \ldots, 0)$ and $\partial U_i(x_i, x_{-i})/\partial x_i|_{x_{-i}=(0,\ldots,0)} < 0$. Therefore we indeed have $x_i^* = 0$.

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[5]If none of the players hit by a loss has contributed, each of them gets the same share of the mutual fund.

Of course, other outcomes might also arise in equilibrium. As an antidote against the relative complexity of the set-up with contribution-based coverage and to give explicit solutions involving strictly positive contributions, in what follows, we will restrict our attention to homogeneous preferences and illustrate our purpose in more detail by taking two examples with conventional specifications of individuals' utility fonction.[6] Henceforth, we then focus on symmetric Nash equilibria, since it is expected that homogeneous players behave the same way.

First of all, let us consider symmetric equilibria in which players give (strictly) positive contributions but do not reimburse the global losses, so that a loss remains. Rewriting Eq. (10) accordingly, it turns out that such symmetric equilibria, whatever the amounts contributed, can only be sustained in the very special case where when all individuals' preferences are such that $MRS^{0,1} = \frac{p}{1-p} \frac{(m-1)(n-m)}{m^2}$.[7]

A more interesting candidate symmetric outcome to examine is the one in which everyone contributes $x_0 = \ell/n$ and all the losses can be entirely reimbursed. We now investigate this issue using in turn a constant absolute risk aversion (CARA) and a constant relative risk aversion (CRRA) utility function.

The contribution profile $(\ell/n, \dots, \ell/n)$ will indeed be an equilibrium profile if player $i$ has no incentive to deviate to partial coverage choosing $x_i^D < \ell/n$, given the fact that all other players choose $\ell/n$. $x_i^D$ can then be derived from Eq. (10) given the symmetric contribution profile of others, $x_{-i}^S = (\ell/n, \dots, \ell/n)$.[8] To verify that a deviation from $\ell/n$ is not profitable, we must check that:

$$U_i \left( \frac{\ell}{n}, x_{-i}^S \right) \geq U_i \left( x_i^D, x_{-i}^S \right). \tag{11}$$

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[6]Note that we do not require that players actually have the same preferences. It is sufficient that they *believe* others' preferences are the same as their own preferences. Psychologically-founded patterns emphasize this tendency to project own preferences, even exaggeratedly, onto others (this is the so-called "false consensus effect").

[7]Or $MRS^{1,0} = 0.75$ with the parameter values detailed in Table 1.

[8]Under the conditions given in Table 1, numerical analysis shows that, with both utility fonctions considered in the section, (CARA and CRRA utility functions) $x_i^D$ lies between 9 and 10 for all relevant values of individuals' risk aversion.

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*Example 1*: CARA utility function.

Consider the following parametric form:

$$u(\pi) = -\exp\{-\sigma\pi\}, \tag{12}$$

where $\sigma > 0$ represents players' absolute risk aversion.

Using Eq. (12), Condition (11) can be rewritten:

$$p.\exp\left\{-\sigma\left(y - x_i^D - d.c_i\left(x_i^D, x_{-i}^S\right)\right)\right\} + (1-p).\exp\left\{-\sigma\left(y - x_i^D\right)\right\} \geq \exp\left\{-\sigma\left(y - \frac{\ell}{n}\right)\right\}, \tag{13}$$

A straightforward numerical analysis using the parameter values of our experiment (given in Table 1 below) shows that Condition (13) holds for any reasonable value of $\sigma$ ($\geq 0.003$), which allows us to conclude that given $x_{-i}^S$ there is no profitable deviation for player $i$. Therefore, in addition to the no-insurance equilibrium $(0, \ldots, 0)$, $(x_1, \ldots, x_n) = (\ell/n, \ldots, \ell/n)$ is another symmetric equilibrium of the game with contribution-based coverage in this example.

Table 1: Parameter Values Used in the Experiment.

| $n$ | $y$ | $d$ | $\ell$ | $p$ | $m$ |
|-----|-----|-----|--------|-----|-----|
| 12 | 100 | 100 | 400 | 1/3 | 4 |

*Example 2*: CRRA utility fonction.

Let us consider a CRRA utility function and assume that players' utility function is given by:

$$u(\pi) = \begin{cases} \frac{1}{1-\eta}\pi^{1-\eta} & \text{if } \eta \neq 1 \\ \ln\pi & \text{otherwise,} \end{cases} \tag{14}$$

where $\eta > 0$ represents players relative risk aversion.

Plugging (14) into Condition (11) yields:

$$
\begin{cases}
p\frac{1}{1-\eta}\left(y - x_i^D - d\left(1 - c(x_i^D, x_{-i}^S)\right)\right)^{1-\eta} + (1-p)\frac{1}{1-\eta}(y - x_i^D)^{1-\eta} \leq \frac{1}{1-\eta}\left(y - \frac{\ell}{n}\right)^{1-\eta} & \text{if } \eta \neq 1 \\
p\ln\left(y - x_i^D - d\left(1 - c(x_i^D, x_{-i}^S)\right)\right) + (1-p)\ln(y - x_i^D) \leq \ln\left(y - \frac{\ell}{n}\right) & \text{if } \eta = 1.
\end{cases}
$$
(15)

With the parameter values of our design, one can check numerically that Condition (15) holds for all relevant values of $\eta > 0$. Thus, there is no profitable deviation from $\ell/n$ and $(\ell/n, \ldots, \ell/n)$ is consequently a symmetric equilibrium of the game with contribution-based coverage under the CRRA utility specification.

Therefore, it is still true in this illustration that, like with a CARA specification of the utility function, both $(0, \ldots, 0)$ and $(\ell/n, \ldots, \ell/n)$ are equilibria of the game.

## 2.4 Discussion

The above analysis emphasizes the incentives brought by each mechanism. Unambiguously, in the equal coverage mechanism, equilibrium forces drive contributions to the no-insurance outcome in which nobody contributes to the mutual fund. In contrast, results are not clear-cut with contribution-based coverage since the no-insurance outcome is always an equilibrium but the symmetric full-insurance outcome is another potential equilibrium. Interestingly, the no-insurance equilibrium is sustainable even for people with arbitrarily large degrees of risk aversion while full insurance can be obtained for individuals with arbitrarily low (but strictly positive) degrees of risk aversion. We considered a simplified version of our set-up to tackle the technical complexity of the game with contribution-based coverage. Still, we believe that our conclusions are of a wider applicability due to the robustness of our findings to an extended class of preferences (namely CARA and CRRA specifications).

The intuition behind these results is the following. Under the equal coverage mech-

anism the marginal return to contribution remains moderate whatever the amounts contributed, which in turn kills any incentives to contribute strictly positive amounts. In contrast, under the contribution-based coverage mechanism, the marginal return to contribution depends on the size of the amount contributed relatively to the contributions of others. Therefore, two conflicting forces are at stake here. Players have clear incentives to contribute little and reap some benefits of the contributions of others; but they are limited by the fear of "punishment" in the form of low coverage if their own contribution falls too much below the contributions of others. Which of these two conflicting forces prevails will depend eventually on the penalty imposed on low contributors. Multiple equilibria can be achieved depending on the inequality among individual contributions.

Concerning (ex ante) efficiency, it could be also noticed that the marginal individual cost of player $i$'s contribution is $p\frac{\partial u_i}{\partial \pi_i^1} + (1-p)\frac{\partial u_i}{\partial \pi_i^0}$ and its marginal social benefit in terms of an increase in the coverage rates equals $p\frac{1}{C_{n-1}^{m-1}} \sum_{j=1}^{n} \sum_{M\backslash\{j\}\subset N\backslash\{j\}} d\frac{\partial c_j}{\partial x_i}\frac{\partial u_j}{\partial \pi_j^1}$ (which reduces to $p\sum_{j=1}^{n} \frac{d}{\ell}\frac{\partial u_j}{\partial \pi_j^1}$ under equal coverage). Obviously, comparisons are tricky between the marginal cost and the marginal benefit and would depend on the distribution of individuals' risk attitudes in the population. However, it is worth noting that, despite the large differences that existed between these games and contrary to the contrasting incentives emphasized in this section, it is possible to draw similar welfare implications across mechanisms. For example, consider the stylized case with homogeneous preferences.[9] In this case, symmetric allocations of contributions would be such that, under partial coverage, the marginal social benefit of a player's contribution always exceeds its marginal cost for both regimes. More precisely, in the equal coverage regime, this rewrites $\frac{p}{1-p}(-1 + n.d/\ell) \geq MRS^{0,1}$, or $MRS^{0,1} \leq 1$ with our parametrization. In the contribution-based coverage regime, this rewrites $\frac{p}{1-p}\left(-1 + n\frac{m+n(m-1)}{m^2}\right) \geq MRS^{0,1}$, or $MRS^{0,1} \leq 14.5$ with our parametrization. These inequalities unambiguously hold

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[9]This assumption is widely common in the literature on voluntary contribution mechanisms, which predicts a social optimum of full contribution for homogeneous groups in a riskless context.

under both regimes for any degree of risk aversion (since $MRS^{0,1} \leq 1$ with $\pi^0 \geq \pi^1$). Hence, in our set-up, creating a mutual fund that fully covers the loss is a relevant socially optimal target ex ante across all the regimes under consideration. Interestingly, this target is also the optimal policy under private fair insurance for risk averse individuals (see Mossin, 1968). Thus, the optimal mechanism under mutual insurance coincides with the optimal mechanism under fair private insurance. As a result, the ex ante efficiency of mutual insurance mechanisms can be judged by their ability to enhance voluntary contributions. Consequently, any outcome different from full insurance can be considered as (ex ante) sub-optimal and would reflect coordination failure.[10]

## 2.5 On Partial Insurance Outcomes

Beyond the existence of these two focal issues of no insurance and full insurance, one could wonder whether 'interior' equilibria exist such that the total losses are only partially covered by some individuals' contributions. The range of possible outcomes is obviously very large but to illustrate this class of outcomes, consider the subset of equilibria such that $r$ players contribute 0 while the $n - r$ remaining ones ($n - r > 0$) contribute at some level $\overline{x} > 0$. It turns out that such equilibria can be sustained, for any $\overline{x}$, with an intermediate number of zero contributors ($8 \leq r \leq 10$ with our parametrization).[11] Indeed, as described in Eq. (8), when zero contributors are too few, they suffer, in expectation, a high penalty because some players are likely to contribute a (strictly) positive number of tokens and get all the indemnities. Therefore, there is no incentive to contribute a null amount when the number of zero contributors is too small. On the other hand, when zero contributors are too numerous, it does not

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[10]Another way to assess the efficiency of insurance institutions is to look at realized payoffs, or ex post efficiency. As long as the sum of contributions does not exceed losses, the insurance mechanism maintains incomes constant in the aggregate under both regimes, no matter how large the partial coverage. Subjects then support, on average, one $n^{th}$ of the total amount of losses. Therefore, ex post efficiency is not a criterion that can be used to evaluate the optimality of either regime.

[11]We describe here the intuition for the existence of such a class of equilibria. A formal proof is available from the authors upon request.

pay for other players to contribute strictly positive amounts as the relative benefit for positive contribution (in terms of an increase in the coverage rate) is relatively modest if total contributions are low. As the number of contributors in these equilibria is not larger than 4, no surplus can be generated.

In the above analysis we derive symmetric equilibria, but note that it does *not* imply that we expect symmetric outcomes to be achieved in our experiment. Indeed, the coordination issue that affects our contribution-based coverage treatment is likely to induce asymmetric behaviors depending on the equilibrium outcome targeted by individuals. Asymmetry in players' behavior can also naturally be triggered by the heterogeneity of preferences. Specifically, subjects'risk attitudes are likely to differ. More precisely, it can be seen from Eq. (10) that when $MRS_i^{0,1} \leq \frac{p}{1-p}\frac{1}{C_{n-1}^{m-1}}\sum_{M\setminus\{i\}\subset N\setminus\{i\}}\left(-1+d\frac{\partial c_i}{\partial x_i}\right)$, it is optimal for player $i$ to contribute $x_i^* = \min\{y, \ell - \sum_{j\neq i} x_j\}$. This condition is automatically met when $MRS_i^{0,1}$ tends to 0 (as its RHS is non-negative). In other words, extremely risk averse subjects have incentives to unconditionally give as much as they can until global losses are recovered. It is straightforward to observe that the greater the $MRS$ (players' risk tolerance) the harder it is to validate the condition. Hence relatively low risk aversion naturally hinders players' incentives to contribute. In contrast, in the polar case where subjects are all risk neutral, the symmetric equilibrium $(\ell/n, \ldots, \ell/n)$ exhibited above where everyone is fully insured and get $y - \ell/n$ cannot be sustained. Indeed it can be shown that any deviation to a contribution strategy $x^D$, $0.0008 < x^D < \ell/n$, would lead to higher expected payoffs.[12]

Again in the contribution-based coverage treatment, the set of possible equilibria is potentially very large. The experimental data will give us clues for eliciting the most likely equilibria and see how players eventually reach a specific outcome.

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[12]More precisely, the expected payoff of a deviator, who chooses $x^D < \ell/n$ (any deviation to $x^D > \ell/n$ is obviously irrelevant since the surplus is burned), is $y - x^D - pd(1 - c(x^D))$, where $c(x^D) = \frac{m}{\ell}\frac{x^D\ell - x^D}{3\ell/n + x^D}$, which turns out to be greater than $y - \ell/n$ as soon as $x^D > 0.0008$.

# 3  Experimental Design

We now describe the protocol used in our experiment. We implemented the two mechanisms detailed in the previous section under a between-subject design.

Twelve participants form a group ($n = 12$). At the beginning of each period, each participant receives an endowed income of 100 tokens.[13] Everyone can contribute to a common pool that serves to compensate the participants who will incur a loss of their entire income. The individual contribution is a number of tokens chosen between 0 and 100. Four of the 12 group members are then randomly hit by the loss ($m = 4$) so that the total loss is 400 tokens ($\ell = 400$).

The equilibrium is to contribute nothing in the equal coverage treatment. In the contribution-based coverage treatment, both no-insurance and full-insurance equilibria exist, the achieved issue remaining eventually empirical.[14] Each session consists of 50 periods, allowing us to observe long run contribution dynamics.

Regarding procedures, we have conducted 6 experimental sessions per treatment, for a total of 12 sessions of 12 participants each. In order to capture the possible role of cultural differences regarding the feeling of individual responsibility, half of the sessions for each treatment were run in the BUL-CIRANO lab (Center for Interuniversity Research and Analysis on Organizations), Montreal (Canada), and half at GATE (Groupe d'Analyse et de Théorie Économique), Lyon (France), on the same dates. In total, the experiment summoned 144 French-speaking participants, mostly students. It was programmed with the REGATE software (Zeiliger, 2000).

Upon arrival in the laboratory, each participant randomly drew a ticket with a computer name out of a bag. After the instructions were distributed and read aloud,

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[13]At the beginning of the first period, to avoid the possibility of negative earnings, each participant was given an endowment of 110 tokens. This does not influence the theoretical predictions.

[14]We did not tell the subjects explicitly that full coverage required an individual average contribution of 33 or 34, to avoid introducing a focal point and an experimenter demand effect. We acknowledge, however, that contributing 33 or 34 may be less salient than contributing 0. Thus, this equilibrium may be less focal than the equilibrium with a null contribution.

the participants' questions were answered in private and a questionnaire was used to check that all instructions had been well understood.[15] The latter were written in neutral terms. The average duration of sessions was an hour and a half including the payment of participants that was done privately in a separate room. The conversion rate was 300 tokens = 1.55 Canadian Dollar = 1 Euro. The average earnings were 35 Canadian Dollars or 23 Euros.

# 4 Results

In this section, we analyze contributions to mutual aid which conditions outcomes and efficiency. We first compare contribution levels between treatments in the aggregate. Then, we examine the heterogeneity of strategies and individual determinants of contribution behavior.

## 4.1 Aggregate Contributions and Efficiency

Table 2 displays summary statistics on aggregate behavior at the session level, by showing the average contribution and the share of null contributions.

Table 2: Summary Statistics by Session and by Treatment

| Treatment | Session Number | Average Contribution | Percentage of Null Contribution |
|---|---|---|---|
| Equal Coverage | 1 | 9.25 | 46.50% |
| | 2 | 10.76 | 39.17% |
| | 3 | 14.35 | 39.33% |
| | 4 | 8.24 | 56.67% |
| | 5 | 5.90 | 57.67% |
| | 6 | 4.13 | 76.17% |
| | Sub-total | 8.77 | 53.00% |
| Contribution-Based Coverage | 1 | 14.71 | 29.50% |
| | 2 | 19.81 | 25.83% |
| | 3 | 19.75 | 16.17% |
| | 4 | 13.79 | 24.50% |
| | 5 | 13.23 | 43.00% |
| | 6 | 13.11 | 28.17% |
| | Sub-total | 15.74 | 28.00% |

Table 2 shows that voluntary contributions per group of 12 players in a session over all the 50 periods are not sufficient to cover aggregate losses. No surplus was found for

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[15]The instructions for the two treatments have been translated and are presented in Appendix.

both treatments. Hence, it is worth noticing that, although full coverage equilibrium is a distinct possibility under contribution-based coverage, players do not conform to this outcome in the data.[16]

As a crude approximation, the incentives brought by each treatment are reflected in the difference of average contributions across treatments. The frequency of equilibrium play corresponding to the null contribution is higher in the equal coverage treatment (53%). Subjects only contributed an average of 8.77 (S.D. = 16.55) in this treatment. Under contribution-based coverage, subjects contribute a larger amount of 15.74 (S.D. = 17.77) and null contributions only represent 28% of the observations. However, even if the latter treatment succeeds in overcoming players' tendency to contribute 0, it fails to fully cover the losses. Subjects consequently get partially insured. More precisely, the individuals who incur a loss on average contribute and recover only 26.3% of the loss under the equal coverage policy and 47.2% under the contribution-based policy. Beyond the coordination failure issue caused by the multiplicity of equilibria, this average outcome may mask, as we shall see later, a contrasted situation due to the heterogeneity of risk preferences, with risk-averse players asking for high coverage and risk-tolerant ones enjoying low coverage.

Figure 1 displays the evolution of average voluntary contributions over time for each treatment.

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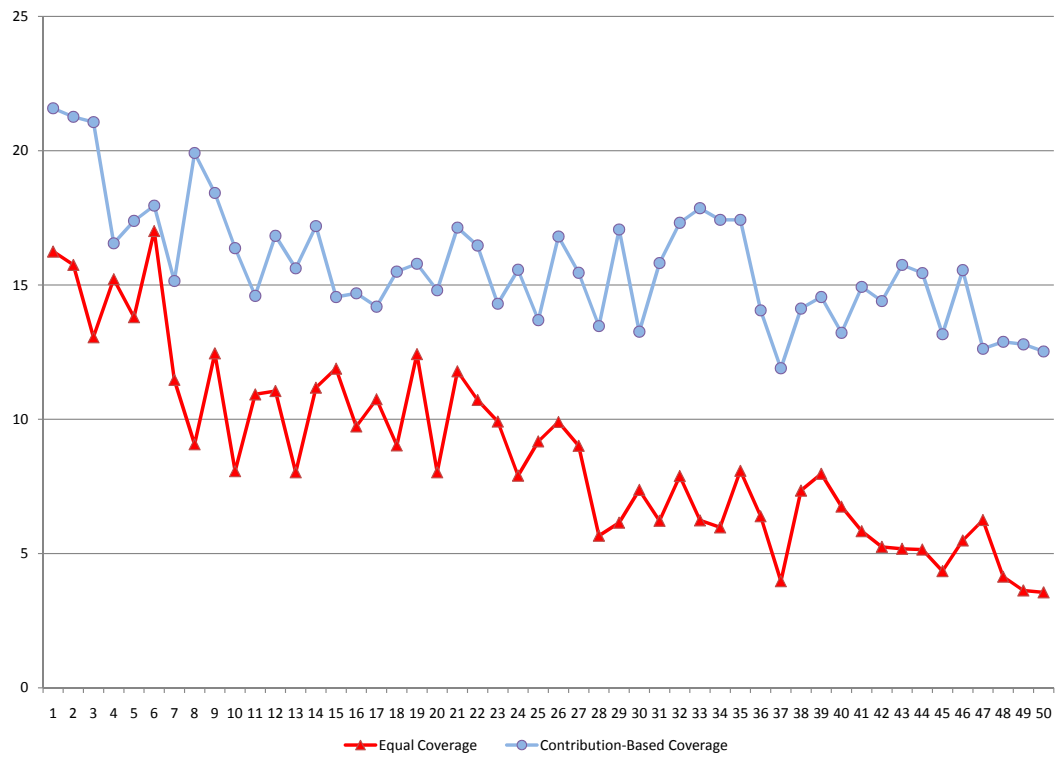[16]Only 4% of fair contributions have been found in the data.

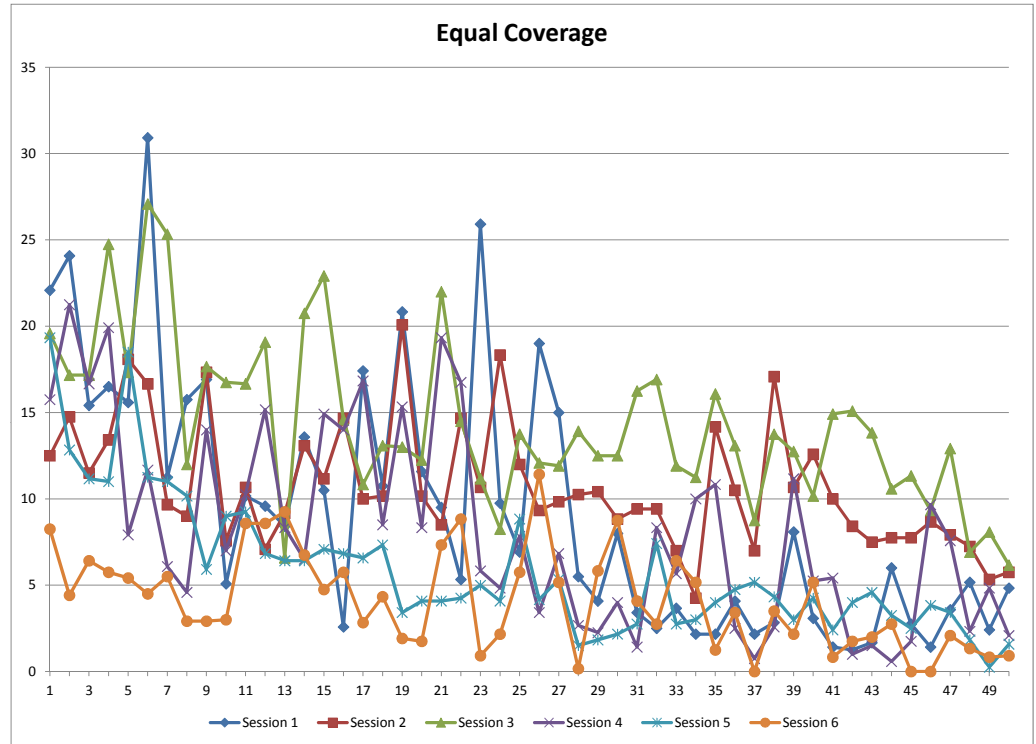Figure 1: Evolution of the Average Contributions Over Time by Treatment

Figure 2: Evolution of the Average Contributions Over Time by Group under Equal Coverage
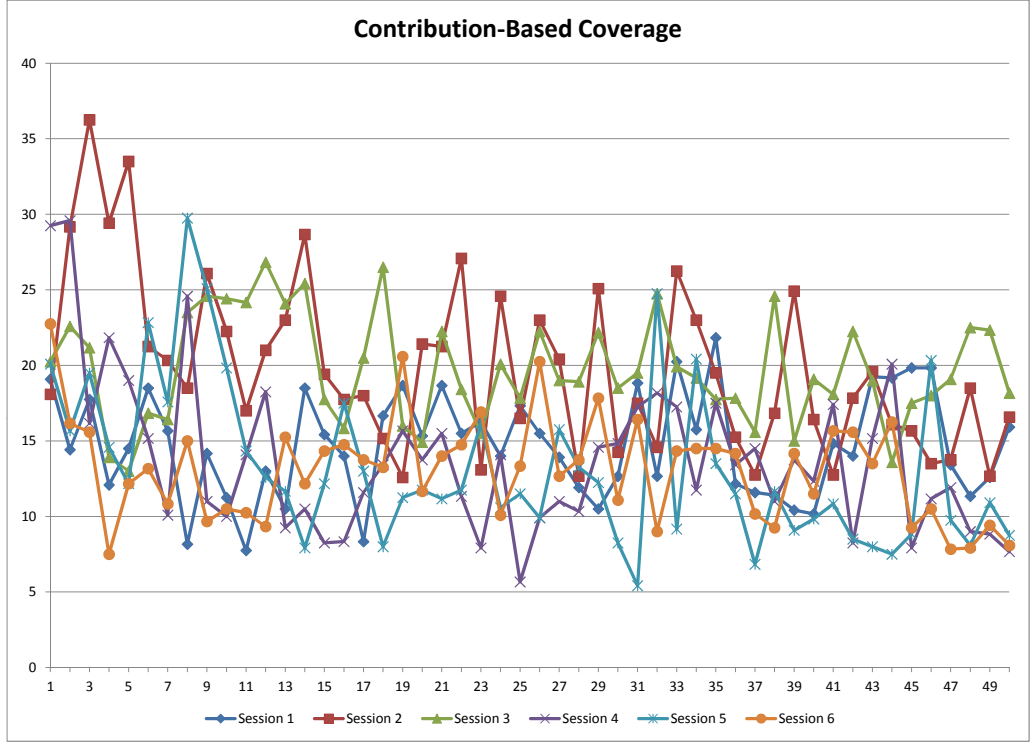
Figure 3: Evolution of the Average Contributions Over Time by Group under Contribution-Based Coverage

Figure 1 shows the sharp contrast in mean behavior between the two treatments. Differences can already be seen in the initial contributions and in the respective trends. In comparison with the contribution-based coverage treatment, under equal coverage mean contributions start at a lower level, decline more rapidly and converge to zero. Figures 2 and 3 disaggregate the description of average behavior at the group (i.e., session) level. They show a striking difference in average behavior in the first period across groups. While there is a wide dispersion of average contributions across groups in the equal coverage treatment, a remarkable concentration can be observed in the contribution-based coverage treatment. The latter suggests that the subjects do not

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immediately play the equilibrium and follow a common prior in the absence of information on the others' behavior. A common prior is common knowledge and may serve as a social norm (Lévy-Garboua, Meidinger and Rapoport, 2006). Assume for instance that the prior is that "all should equally contribute to get full coverage". The same norm initially applies to both treatments. However, it is much more strictly enforced with contribution-based coverage than with equal coverage which treats high and low contributors equally. Consequently, rational subjects do not deviate much from the prior norm of equal contribution and full coverage by fear of punishment (in terms of a relatively low coverage rate) when their final coverage is partially based on their own contribution relatively to the contributions of others. In contrast, the lack of punishment in the equal coverage treatment sets no bond on their private incentive to lower their contributions so that average deviations from the norm across groups critically vary then with the proportion of selfish players in each group. Behavior evolves differently across treatments as the individuals get gradually informed on others' behavior. The contribution-based coverage stabilizes the average contributions at a relatively high level in all groups, whereas equal coverage leads to a uniform decline of contributions towards zero.

In complement to these statistics, a simple regression of mean contributions on the inverse of time [17] helps us quantify the main differences of behavior across treatments. Table 3 analyzes this influence of time on individual contributions by estimating an Ordinary Least Squares model for each treatment.

Table 3: Evolution of the Average Contributions Over Time by Treatment

|  | Equal Coverage | | Contribution-Based Coverage | |
|---|---|---|---|---|
|  | Coeff. | t-stat. | Coeff. | t-stat. |
| 1/Period | $13.80^*$ | 5.70 | $9.29^*$ | 5.975 |
| Constant | $7.528^*$ | 17.25 | $14.89^*$ | 53.14 |
| Observations | 50 | | 50 | |
| $\overline{R}^2$ | 0.391 | | 0.415 | |

Note: $^*$ Statistically significant at the 1% level.

Table 3 confirms a difference between the two treatments in the initial average

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[17] A hyperbolic shape was preferred to declining linear curve because it forces contributions to be positive and allows identification of a stationary equilibrium.

contribution: 21.33 for the equal coverage treatment and 24.09 in the contribution based coverage treatment. The lower initial value under the equal coverage mechanism is consistent with the lack of an enforcement institution for the social norm of equal contribution in this treatment. Another significant difference among treatments lies in the higher asymptotic level of average contributions for the contribution-based coverage treatment: 14.89 versus 7.53.[18]

## 4.2    Determinants of Individual Contribution Behavior

To understand the determinants of individual contribution behavior, we proceed to an econometric analysis that is based on a two-step estimation procedure.[19] We first explain the decision to contribute, and next the choice of the amount contributed conditional on the decision to contribute. Indeed, we assume that these two decisions are separated in the subjects' decision process and that there may be a selection bias in the contribution decisions. The first decision is studied by means of a random-effects Probit model; and the conditional contribution is estimated with a Feasible Generalized Least Squares model corrected for the potential selection bias. This panel data analysis with random effects accounts for the fact that the same subject is observed fifty times.

Among the independent variables, we control for a time trend and demographic variables.[20] We also introduce a number of lagged exogenous variables and individual

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[18]These values and the difference between them may be biased upward by the limited duration of the game. However, the difference is so large that we can safely conclude that the contribution-based coverage treatment is much more efficient and yields higher contribution levels than the equal coverage treatment.

[19]A Tobit model of type 2 (generalized Tobit) would be ideal for a one-step estimation, but it is not user-friendly with panel data.

[20]Our experimental design also includes a simple test of risk aversion. More precisely, at the beginning of the session, the participants had a choice between getting a show-up fee of 5 Canadian Dollars (2 Euros) and participating at the end of the session in a lottery in which they had equal chances of winning either 11 Dollars (5 Euros) or 0. They tossed a coin at the end of the session to determine their extra earnings. The participants who exhibited a "certainty effect" by choosing the show-up fee were tentatively considered as being more risk averse. However, since Kahneman and Tversky (1979), there is an agreement among decision theorists that observing a "certainty effect" is no reliable evidence of risk aversion. Indeed, no clear pattern emerged concerning the impact of participants' lottery choices on their contribution behavior.

controls.[21]   Lagged variables are intended to capture the process of convergence to equilibrium and temporary deviations from the time trend. A positive effect of the sum of the other subjects' contributions in the previous period is intended to capture conditional cooperation (a subject contributes all the more as the others contributed more in the past, see Fischbacher, Gächter and Fehr, 2001). We also include a variable indicating whether the participant has incurred a loss in the previous period. Persistent bad luck is captured by the difference between the actual number of losses suffered by a participant during the elapsed periods and the expected number of losses given the objective probability of a loss. This variable captures the effect of an over-prevalence of bad luck on current contribution behavior. Last, we introduce in the second equations the Inverse of the Mill's Ratio (IMR) derived from the estimation of the first equations to control for a potential selection bias. These models are estimated separately for each of the two treatments since we assume that behavior is driven by different factors in various institutional environments.[22] Table 4 displays the results of these regressions.

Table 4 unambiguously attributes the decline in the mean contribution to an increasing propensity to not contribute in the equal coverage treatment, and to a diminishing amount of contributions in the contribution-based coverage treatment. These observations corroborate the very different nature of equilibria in these two treatments: a corner solution in the first case versus interior equilibria in the latter. The cultural dimension is also found to play a role since French subjects contribute less under both policies. Last, only few demographic variables intervene.

Short-run fluctuations around these trends are triggered by the occurrence and past frequency of losses. The occurrence of a loss diminishes the probability of a pos-

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[21]The individual controls include age, gender, student or worker status, education level, mathematical training, past participation in an experiment, and location of the session (Lyon, Montreal).

[22]Non-parametric Wilcoxon rank-sum tests were performed for assessing whether two samples of observations came from the same distribution. The null hypothesis is that the probability distributions of the two treatments considered are equal. The null is rejected in comparisons involving the percentage of zero contributions and gains. Therefore, the two treatments will be considered separately in the regression analyses.

Table 4: Probability and Determinants of the Positive Contributions by Treatment (Periods 2 to 50)

| Treatment | Equal Coverage | | | | Contribution-Based Coverage | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Random Effects Probit Model | | FGLS Panel | | Random Effects Probit Model | | FGLS Panel | |
| Variable | Coeff. | t-stat. | Coeff. | t-stat. | Coeff. | t-stat. | Coeff. | t-stat. |
| Period | $-0.022^*$ | $-10.806$ | $-0.095$ | $-0.767$ | $0.0017$ | $1.389$ | $-0.134^*$ | $-6.646$ |
| Others' contribution $t-1$ | $0.026$ | $0.556$ | $-0.827$ | $-1.572$ | $0.011$ | $0.318$ | $-0.108$ | $-0.328$ |
| Loss in $t-1$ | $-0.348^*$ | $-7.248$ | $4.191^{**}$ | $2.027$ | $-0.5099^*$ | $-10.336$ | $-3.243^*$ | $-3.235$ |
| Losses minus anticipated losses | $0.030$ | $1.499$ | $0.288$ | $0.920$ | $0.018^{**}$ | $2.001$ | $0.600^*$ | $3.211$ |
| Age | $-0.042^*$ | $-3.240$ | $0.879^{**}$ | $2.157$ | $-0.029^*$ | $-2.771$ | $-0.021$ | $-0.066$ |
| Gender (Males=1) | $-0.414^*$ | $-3.481$ | $7.344^{**}$ | $1.890$ | $-1.640^*$ | $-13.049$ | $-1.025$ | $-0.294$ |
| Experience | $-0.357$ | $-1.577$ | $-11.516^*$ | $-2.514$ | $0.305^*$ | $3.487$ | $-0.595^{**}$ | $-0.197$ |
| Student (Reference: worker and unemployed) | $0.129$ | $0.602$ | $-8.111$ | $-1.485$ | $-0.926$ | $-1.418$ | $-4.141$ | $-0.846$ |
| Graduate | $0.750^*$ | $6.218$ | $-7.001$ | $-1.198$ | $0.622^*$ | $3.178$ | $-9.078^*$ | $-2.444$ |
| Mathematical training | $-0.185$ | $-1.510$ | $2.645$ | $0.659$ | $-0.460^*$ | $-2.808$ | $2.515$ | $0.702$ |
| Montreal (Reference: Lyon) | $0.525^*$ | $4.076$ | $-8.416$ | $-1.560$ | $0.916^*$ | $7.464$ | $9.314^*$ | $2.783$ |
| Constant | $1.418^*$ | $3.564$ | $32.027^*$ | $3.158$ | $3.692^*$ | $4.856$ | $25.123^{**}$ | $2.342$ |
| $\rho$ | $0.625^*$ | $26.639$ | | | $0.621$ | $22.280$ | | |
| IMR | | | $-14.441^{**}$ | $-1.673$ | | | $3.186$ | $0.730$ |
| $R^2$ | | | 0.178 | | | | 0.078 | |
| Observations | 3528 | | 1655 | | 3528 | | 2537 | |
| Value of the likelihood | | | | | | | | |
| V: constrained | $-2438.68$ | | | | $-2094.92$ | | | |
| V: probit | $-2244.30$ | | | | $-1949.83$ | | | |
| V: probit panel | $-1493.57$ | | | | $-1411.18$ | | | |

Note: $^*$ Statistically significant at the 1% level; $^{**}$ Statistically significant at the 5% level.

itive contribution in the next period in both treatments, whereas an excess frequency of losses in the past convinces players to contribute more in the contribution-based treatment only.[23] None of these two effects of experienced losses on the decisions to contribute is consistent with expected utility maximization under risk. The lagged negative effect of a loss may reveal a gambler's fallacy (Tversky and Kahneman, 1974) or a "bomb crater" effect (Mittone, 2006), in which the unlucky individual underestimates the chances that his bad luck persists in the future. An alternative explanation is that participants try to regain the experienced loss by saving on contributions. The effect of an excess frequency of losses in the past evokes the "hot hand fallacy" (Gilovich, Tversky and Vallone, 1985). Individuals behave as if they think that, if they have been lucky or unlucky for some time, they will continue to be so in the future because it reflects their nature, and so they must take proper risk coverage. Such behavior runs counter the gambler's fallacy effect.

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[23]An excess frequency of loss has no positive effect on contributions in the equal coverage treatment because not contributing is then a dominant strategy.

In contrast with the literature on public goods games, Table 4 shows that conditional cooperation, captured by the influence of others' contributions in the previous period on one's own contribution level, does not affect behavior. Thus, in the presence of risk, players' strategies seem to be more dictated by Nature than by others' behavior or by reciprocity.

## 4.3 Heterogeneity of Strategies

Recent experimental literature has emphasized the heterogeneity of preferences and its impact on behavior in public goods games (see Burlando and Guala, 2005). To give a feeling of heterogeneity of individual behaviors, Figure 4 displays the dispersion of contributions over time. Notably, it shows a strong disparity across treatments. The median contribution drops in the equal coverage treatment, while it remains more stable in the contribution-based coverage treatment. Meanwhile, the gap between the first and last quartiles lessens with time.
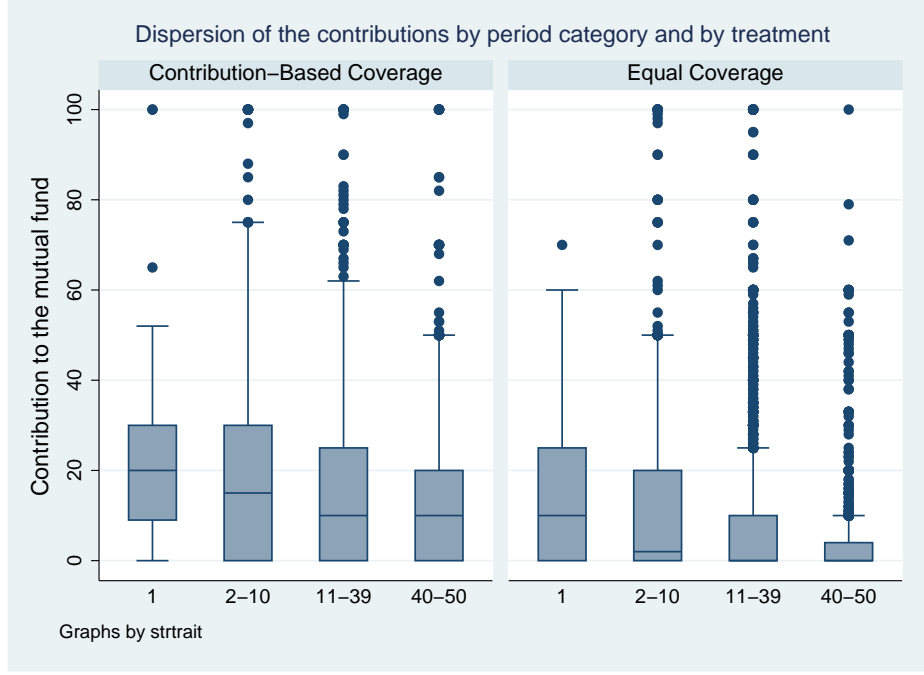
Note: The horizontal line within each bar represents the median; dots correspond to outliers.

Figure 4: Dispersion of the Contributions by Block of Periods and by Treatment

In order to track this heterogeneity properly, homogeneous groups of participants and strategies have been separated by a cluster analysis based on three discriminating variables: the frequency of positive contributions, the average and the standard deviation of contributions. The standard deviation of contributions identifies the variety of strategies. As shown below, two clusters for all treatments are enough to oppose very different strategies, and Table 5 characterizes these strategies for each treatment.[24]

In Table 5, cluster 1 describes the high contributors and cluster 2 the low con-

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[24]Insofar as we want to identify the most contrasting groups of behavior, we have used a difference criterion as an aggregation mean. The maximum link method (the distance between two groups is given by the distances of the furthest object of each group) and the Ward method (minimizing the intra-group variance) are best fitting. Since the Ward method tends to produce smaller groups, we have favored this method, that is, the minimization of the squared sum of the errors (the squared Euclidian distance $\sum_{k=1}^{p}(z_{ki} - z_{kj})^2$). Regarding the choice of the number of partitions, insofar we want to preserve the greatest differences between groups, we examine the decreasing curve of the distances between the merged partitions in each stage. This curve must diminish in a monotonic fashion as the near partitions are merged in each stage. If a net difference is observed in the course of iteration, it is not reasonable to group other partitions.

Table 5: Cluster Analysis of Strategies

| Treatment | Equal Coverage | | Contribution-Based Coverage | |
|---|---|---|---|---|
| Clusters | Cluster 1 (High Contributors) | Cluster 2 (Low Contributors) | Cluster 1 (High Contributors) | Cluster 2 (Low Contributors) |
| Frequency of non-null contributions | | | | |
| Average % | 37.051 | 7.939 | 44.622 | 21.815 |
| Standard deviation | 10.252 | 6.364 | 6.847 | 11.139 |
| Average of the contributions | | | | |
| Average number of tokens | 14.177 | 2.379 | 20.828 | 7.235 |
| Standard deviation | 11.504 | 2.475 | 10.046 | 4.954 |
| Average of the std. dev. of the contributions | | | | |
| Average | 13.843 | 5.558 | 13.609 | 9.769 |
| Standard deviation | 8.637 | 5.377 | 8.735 | 4.686 |
| Number of observations | 39 | 33 | 45 | 27 |

tributors. High contributors differ from low contributors, since the null hypothesis is often rejected in comparisons between treatments of the statistics presented in Table 5. High contributors give considerably more than low contributors but they adopt a more variable strategy, reflected by a larger standard deviation. The larger variability of contributions for high contributors may be caused, at least in part, by the common tendency to not contribute after being hit (gamblers' fallacy), as this would affect high contributors much more than low contributors. Between 55% and 62% of participants are classified as high contributors. Within each cluster of subjects, behaviors are rather comparable.

Aggregate earnings remain unchanged across regimes but the distribution of earnings between individuals depends on their respective contributions. More precisely, the sharing rule takes the form of a transfer from high contributors to low contributors. Average payoffs for the clusters of high contributors and low contributors are respectively 61.83 and 72.12 in the equal coverage treatment and 65.65 and 68.10 in the contribution-based coverage treatment. Therefore, the amount of transfer from high contributors to low contributors which is unrelated to the occurrence of a loss is diminished when coverage rates are determined on the basis of individual contributions. This reflects the fact that a higher level of contribution from low contributors under contribution-based coverage alleviates the burden of high contributors.

What determines the heterogeneity of contributions in the mutual-aid game? We saw previously that risk attitudes were a major source of difference in contribution

behavior. In an attempt to coordinate on a "normal" contribution, all risk averse play-ers would be attracted by the fair contribution whereas all risk tolerant players would be attracted by the null contribution. This conjecture is remarkably consistent with the observed mean contribution in the first round of the contribution-based coverage treatment. Indeed, if we assume that 28% of our subjects are non-risk averse (this is the mean frequency of null contributions in Table 2), the mean contribution in the first round (with no knowledge of others) would be given by: 0.28 (0)+0.72 (33.33)=24 which is to be compared with the observed mean contribution of 24.09! It is worth noticing that these two prior norms of fair contribution for risk averse players and no contribution for non-risk averse players coincide with the two extreme symmetric equi-libria $(\ell/n, ..., \ell/n)$ and (0,...,0) respectively. These equilibria would be reached in a one-shot game if all players were of one type or the other. The natural heterogeneity of risk attitudes makes this situation extremely unlikely. Instead, we observe two clusters illustrated by Table 5: a majority of risk averse high contributors and a minority of low contributors. Abstracting from short run deviations that may be caused by the occurrence of a loss, high contributors have an incentive to reduce their contribution -particularly so in the equal coverage treatment- and low contributors have an incentive to give a little to reap the external benefit of coverage thanks to the large contributions of the high contributors. This parallel behavior of the members of the two clusters may remain stable over time if the preoccupation with risk dominates reciprocity motives. It generates an asymmetric interior equilibrium with a mixture of high and low con-tributors in which the non-risk averse players impose a negative externality on the risk averse players who are forced to overcontribute for less than full insurance. Note that this particular type of asymmetric equilibrium seems consistent with the heterogene-ity of norms and risk attitudes but less consistent with other social preferences like inequity aversion. Indeed, in our context, if players prominently wanted to reduce the inequalities between payoffs, we would more likely observe symmetric outcomes with

similar amounts contributed.

# 5  Concluding Remarks

In this paper, we study games in which individuals choose to contribute voluntarily
to a mutual-aid pool. Mutual-aid groups provide informal mutual insurance to their
members who remain free to choose their contribution and receive a share of total con-
tributions if they incur a loss. They appear under various guises to offer insurance and
assistance to members of occupational groups, trade unions, communities of villagers
or countries, etc. In spite of its importance in social life and in public policies, mutual
aid has received little attention in the economic theory of insurance. We derived the
Nash equilibria of two mutual-aid games, defined respectively by equal coverage and by
contribution-based coverage of group members who experience a random loss. We limit
our study of mutual-aid groups to exogenous and fixed groups, leaving the endogenous
formation of such groups for further research.

If we assume that players are homogeneous and essentially risk averse, we can
conclude that contribution-based coverage takes us only half-way to efficiency since the
latter requires full insurance. In that respect, one could say that coordination failures
that arise from the existence of multiple equilibria have been only partially overcome by
the provided incentives. This is a conventional interpretation in game theory. However,
if we recognize the heterogeneity of risk attitudes, a very different interpretation arises
which interferes with the issue of coordination failures. This new interpretation was
suggested by the observation of a norm-induced behavior in the first round and the
emergence of a "dual interior equilibrium" with a majority of high contributors and a
significant minority of low contributors. Under the latter interpretation, players have
heterogeneous risk attitudes, with a majority of risk averse subjects and a significant
minority of risk tolerant players. These two groups share very different prior norms:

fair contribution and full insurance for the risk averse, but zero contribution and no insurance for the risk tolerant players. This type of preference heterogeneity is natural in a risky context and it seems to take the precedence over reciprocity and inequity aversion in our data, which demonstrates that voluntary contribution mechanisms in a risky context may yield very different outcomes than mechanisms with sure outcomes. It leads to a dual interior equilibrium in which the two groups interact, with the risk averse group less than fully contributing and the risk-tolerant group less than fully defecting.

Under homogeneous risk attitudes, the mean coverage rate equals 47.2% in the contribution-based treatment so that coordination failures are responsible for a social loss of 52.8% of the optimal (full) insurance. The picture is very different under heterogeneous risk attitudes. If we assume then that each of the two groups is homogeneous, the mean coverage rate equals 62.5% for the (risk averse) high contributors and 21.7% for the (risk tolerant) low contributors in the contribution-based coverage treatment. The presence of risk tolerant players deprives the high contributors of 37.5% of their optimal insurance, 21.7% of which is transferred to the former and 15.8% is a social loss. We can also compare across treatments the efficiency gains brought by imposing a coverage that is proportional to contributions rather than equal for all. Under homogeneous preferences, the mean coverage rate would be raised from 26.1% to 47.2% for everybody. However, under heterogeneous preferences, the mean coverage would be raised from 26.1% to 62.5% for (risk averse) high contributors whereas it would be cut down from 26.1% to 21.7% for (risk tolerant) low contributors.

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# Appendix: Instructions (translated from French)

## Treatment: Equal Coverage

You are participating to an experiment in which we ask you to make decisions. Each participant makes her (his) decisions individually in front of her (his) computer. **At the beginning of the experiment**, you are given an initial capital of 110 tokens. During the experiment, you can earn an additional amount of money. The final amount of earnings you will get depends on your decisions and on the other participants' decisions. At the end of the experiment, your earnings in tokens will be converted into Canadian $ according to the following conversion rate: 300 tokens = \$1.55. You will be paid individually in a separate room to preserve the confidentiality of your earnings. Each period, you will form a group with the other 11 participants. Communication between participants is forbidden and you are asked not to react loudly during the course of the experiment. The experiment has 50 periods. Each period is independent of the others. At the beginning of each period, you will receive 100 tokens. You can contribute to a common pool intended to cover the losses that will randomly strike 4 persons among the 12 group members. Each of the 4 afflicted members lose their 100 tokens. The common pool is equal to the sum of the contributions by each group member. Three situations can occur:

- The common pool is of 400 tokens. This allows all 4 afflicted members to regain their 100 lost tokens each.

- The common pool is greater than the sum of the lost tokens. In this case, the 4 afflicted members regain their 100 lost tokens and the surplus is not reported to the next period.

- The common pool is insufficient to allow the 4 afflicted members to regain their 100 lost tokens. In this case, each one of the 4 afflicted members receives 1/4 of

the common pool.

**Rules for each period**

You will be given 100 tokens. You choose, with the help of a cursor, the number of these tokens between 0 and 100 that you allocate to the common pool. This choice is validated as soon as you click on the OK button. The computer then gives you 5 pieces of information:

- You are or not one of the 4 persons who each loose their 100 tokens

- The total amount of the common pool

- If applicable, the total amount of the loss

- The number of tokens that are allocated to you if you are afflicted

- Your earnings in tokens for this period.

A new period, independent of the previous ones, is automatically shown. Each period, you receive a new allocation of 100 tokens. A new random draw determines the afflicted members. The conditions described above continue to apply.

**How we determine your earnings**

During a period, your earnings are calculated by the computer the following way: Your 100 tokens

- the tokens that you allocate to the common pool

- the tokens that you have lost if you are afflicted

+ the partial or total reimbursement of your lost tokens if you are afflicted.

At the end of the experimental session, your total earnings are calculated by the sum of your earnings for each of the 50 periods, plus the initial capital. It is this amount that will be converted in Canadian $.

**Additional information**

Before we begin the experimental session, we will ask you to answer a few comprehension questions on these instructions. As soon as you have all answered correctly all the questions, you will be asked to provide us some details on your age, gender, level and field of education, university or school currently frequented or your current work situation, and if you have participated to an experiment before. This information will remain anonymous. The experiment will then begin. After taking place in front of your computer, please raise your hand if you have questions on these instructions. We will come and answer your questions privately.

## Treatment: Contribution-Based Coverage

You are participating to an experiment in which we ask you to make decisions. Each participant makes her (his) decisions individually in front of her (his) computer.

At the beginning of the experiment, you are given an initial capital of 110 tokens. During the experiment, you can earn an additional amount of money. The final amount of earnings you will get depends on your decisions and on the other participants' decisions. At the end of the experiment, your earnings in tokens will be converted into Canadian \$ according to the following conversion rate: 300 tokens = \$1.55. You will be paid individually in a separate room to preserve the confidentiality of your earnings.

Each period, you will form a group with the other 11 participants. Communication between participants is forbidden and you are asked not to react loudly during the course of the experiment.

The experiment has 50 periods. Each period is independent of the others.

**At the beginning of each period**, you will receive 100 tokens. You can contribute to a common pool intended to cover the losses that will randomly strike 4 persons among the 12 group members. Each of the 4 afflicted members loose their 100 tokens.

The common pool is equal to the sum of the contributions by each group member. Three situations can occur:

- The common pool is of 400 tokens. This allows all 4 afflicted members to regain their 100 lost tokens each.

- The common pool is greater than the sum of the lost tokens. In this case, the 4 afflicted members regain their 100 lost tokens and the surplus is not reported to the next period.

- The common pool is insufficient to allow the 4 afflicted members to regain their 100 lost tokens. In this case, each one of the 4 afflicted members receives a reimbursement that depends on two elements: his contribution to the common pool with respect to the other afflicted members in the group and the total amount of the common pool. The common pool is thus redistributed to the 4 afflicted members proportionally to how much each has contributed with respect to the other afflicted members and within the limit of their initial loss.

**Rules for each period**

You will be given 100 tokens.

You choose, with the help of a cursor, the number of these tokens between 0 and 100 that you allocate to the common pool. This choice is validated as soon as you click on the OK button.

The computer then gives you 5 pieces of information:

- You are or not one of the 4 persons who each loose their 100 tokens

- The total amount of the common pool

- If applicable, the total amount of the loss

- The number of tokens that are allocated to you if you are afflicted

- Your earnings in tokens for this period.

A new period, independent of the previous ones, is automatically shown. Each period, you receive a new allocation of 100 tokens. A new random draw determines the afflicted members. The conditions described above continue to apply.

**How we determine your earnings**

During a period, your earnings are calculated by the computer the following way:

Your 100 tokens - the tokens that you allocate to the common pool - the tokens that you have lost if you are afflicted

and, if the common pool is <u>sufficient</u>

+ the reimbursement of your lost tokens if you are afflicted

or, if the common pool is <u>insufficient</u>

+ the reimbursement proportionally to how much each has contributed with respect to the other afflicted members and within the limit of your initial loss.

At the end of the experimental session, your total earnings are calculated by the sum of your earnings for each of the 50 periods, plus the initial capital. It is this amount that will be converted in Canadian $.

**Additional information**

Before we begin the experimental session, we will ask you to answer a few comprehension questions on these instructions. As soon as you have all answered correctly all the questions, you will be asked to provide us some details on your age, gender, level and field of education, university or school currently frequented or your current work situation, and if you have participated to an experiment before. This information will remain anonymous. The experiment will then begin.

After taking place in front of your computer, please raise your hand if you have questions on these instructions. We will come and answer your questions privately.