On the Adjudication of Conflicting Claims: An Experimental Study*

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Abstract

This paper reports an experimental study on three well known solutions for claims problems, that is, the constrained equal-awards, the proportional, and the constrained equal-losses rules. To do this, we first let subjects play three games designed such that the unique equilibrium allocation coincides with the recommendation of one of these three rules. Moreover, we also let subjects play an additional game, that has the property that all (and only) strategy profiles in which players coordinate on the same rule constitute a strict Nash equilibrium. While in the first three games subjects' play easily converges to the unique equilibrium rule, in the last game the proportional rule overwhelmingly prevails as a coordination device. We also administered a questionnaire to a different group of students, asking them to act as an impartial arbitrator to solve (among others) the same claims situations played in the lab. Also in this case, the proportional solution was selected by the vast majority of respondents.

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1 Introduction

When a firm goes bankrupt, how should its liquidation value be divided among its creditors? Previous question is an example of the so called *claims (or bankruptcy) problems (or situations),* which provide with a simple framework to study ways of distributing losses when agents' claims cannot be fully satisfied. Another example of a claims situation, and most likely the oldest one in the literature of rationing, is the division of an estate: a man dies and the debts he leaves behind are found to add up more than the worth of his estate. How should then the estate be divided? [see O'Neill (1982) or Rabinovitch (1973), among others, borrowing examples from the Babylonian Talmud]. Tax schemes can also be interpreted as claims problems: a certain amount of money should be collected out of individual gross incomes. What should be the net income of everyone in society? Or equivalently, what should be the contribution of each individual? [Young (1988, 1990)]. Rationing occurs when commodities have fixed prices, and also gives rise to claims problems. An example of that is medical triage, when the available resources are not enough to cover individual medical needs. What sort of needs should be rationed? [Winslow (1992)]. In the literature of arbitration [e.g., Elkouri (1952), Spielmans (1939)], rights arbitration refers to situations covered by pre-existing rules or customs. When a dispute has arisen because rules are unclear, the arbitrator makes a judgement about the meaning of the rules, and in this way she decides the parties' rights.

Claims problems are major practical issues and, as such, they have a long history, both from legal and economic viewpoints. In general, claimants belong to different types (e.g., senior creditors, junior creditors and shareholders, in the case of a bankrupt firm), and, accordingly, there is some sort of priority of claims. In some cases, bankruptcy regulations respect absolute priority (i.e., senior creditors are paid off first, then junior creditors, and finally shareholders), but, in other cases, a portion of value is reserved for shareholders (10%-20%) [Hart (1999)]. Then, awards are allocated among the claimants in the different groups, according to some method (e.g., proportional to the claims).

In the tax example, the most common method to allocate losses is not the proportional one. In general, progressive schemes are used instead, so that agents with larger incomes contribute relatively more. One of those schemes is the so called leveling tax [Young (1988)], that aims at equalizing after-tax income across the agents, without subsidies.

Similarly, consider the case of an irrigation community, facing a drought. Here, again, is not the proportional method the one generally used, but alternative schemes in which some sort of priority of the largest claimants prevail.

Previous examples indicate that not all claims problems are, in practice, solved in the same way, or, in other words, that different claims situations may ask for different views of distributive justice to be properly solved. Consequently, from practical cases, researches moved in the direction of looking for well-behaved methods, or *rules,* to solve families of claims problems, when agents belong to the same type, so that they only differ in their claims [see Moulin (2002) or Thomson (2003) for recent surveys of this literature]. The oldest formal principle of distributive justice follows Aristotle's maxim:

"*Equals should be treated equally, and unequals, unequally in proportion to relevant similarities and differences*".

Its direct application to claims situations gives rise to the best-known rule to solve claims problems: the *proportional rule,* which recommends awards to be proportional to claims. This is the rule normally used in many bankruptcy regulations. Its rational comes from the fact that -take, for example, the case of shareholders- proportionality amounts to award equally each share.

A different idea of equality underlies another well-known rule: the *constrained equal-awards rule.* It makes awards as equal as possible to all claimants, subject to the condition that no one receives more than her claim. A dual formulation of equality, focusing on the losses creditors incur, as opposed to what they receive, underlies the *constrained equal-losses rule.* It proposes losses as equal as possible for all claimants, subject to the condition that no one ends up with a negative award. This rule corresponds to the previously mentioned leveling tax in the case of tax schemes. Its rational, in this case, corresponds to the idea of looking for the most egalitarian after-tax income distribution. The constrained equal awards rule gives priority to agents with small claims. They are reimbursed relatively more than agents with larger claims. It seems a natural procedure to apply when agents claims are correlated with their incomes. On the contrary, the constrained equal-losses rule gives priority to agents with large claims. They start receiving money before agents with small claims, that are only reimbursed once the loss they experience equals the losses experienced by agents with larger claims. It is a natural procedure to be applied when claims are related to needs, as for example when we think of public support of health care expenses. These two ideas of equality also have a long history, and have been advocated by many authors, including Maimonides (12th Century) [Aumann and Maschler (1985)]

The behavior of the different rules comes from the properties those rules fulfill. The analysis and formulation of properties and the search for combination of properties characterizing a single rule is the object of an important branch of the claims literature: the so called *axiomatic approach.* The proportional, constrained equal-awards and constrained equal-losses rules satisfy many basic properties. Looking specially to those three solutions is by no means arbitrary. First because they are among the most common methods of solving practical problems. Second for their long tradition in history. And last but not least, because they are the only ones satisfying the four basic invariance axioms within the family of solutions that treat equally equal claims [Moulin (2000)].

Another approach to solve claims problems is that of *cooperative game theory,* in which claims problems are formulated either as TU coalitional games, or as bargaining problems, and rules are derived from solutions to coalitional games and from bargaining solutions, respectively. Instances of this approach are the papers of O'Neill (1982), Aumann and Maschler (1985), Curiel, Maschler and Tijs (1988) and Dagan and Volij (1993). The axiomatic, as well as the cooperative game-theoretic approach share a common view in the analysis of claims problems: they look at the fairness and cooperative aspects in order to support certain rules.

Finally, a limited number of papers applies *noncooperative* game-theory to deal with claims problems [Chun (1989), Dagan, Serrano and Volij (1997), Moreno-Ternero (2002) and Herrero (2003)]. These papers apply to claims problems the same methodology known as the *Nash program* for the theory of bargaining, that is, they construct specific procedures as noncooperative games which have the property that the unique equilibrium allocation corresponds to that dictated by a specific rule [Nash (1953), Binmore *et al.* (1992), Roemer (1996)]. In other words, this literature provides theoretical support to certain rules by constructing specific strategic situations for which these rules are self-enforcing.

There is another aspect which makes this noncooperative approach interesting for the analysis of claims situations. As it happens for bargaining theory, the theoretical debate is far from unanimous in identifying a *unique* optimal solution to claims problems. In consequence, there are many situations in which an arbitrator, or the outside authority in charge to design the procedure to solve a claims problem, may not have strict preferences, a priori, on which rule should be implemented for the problem at stake. Under these circumstances, the arbitrator may resort to a (noncooperative) procedure which may lead to alternative rules as the outcome of strategic interaction among the claimants.

The aim of this paper is to bring the theoretical debate on the selection among rules to solve claims problems into an experimental lab. Our main interest can be summarized as follows:

is there any particular rule which is salient in subjects' perception as the optimal solution of a claims situation?

To answer this question, two lines of research are open. One, very much in line with the axiomatic approach, is to provide subjects with hypothetical claims situations and ask them, taking the point of view of an outside observer, to choose a particular rule to solve it. The results of such a questionnaire potentially provide some experimental evidence to be compared with the axiomatic theoretical debate. Another possibility is to fully exploit the experimental methodology and provide subjects with *an active role* in the claims situation, that is, designing hypothetical situations in which they are *actual claimants* rather than simply *outside observers*. This alternative approach is clearly more in line with the noncooperative literature mentioned above. The results of such an experiment may provide with some experimental evidence of the way agents play when involved in real claims problems.

In this paper we follow both approaches, and the results we obtain are to be considered as complementaries. In both cases, we focus on a claims problem involving three agents, and ask subjects to choose among three different divisions of the liquidation value, corresponding, respectively, to the recommendations of the constrained equal awards, constrained equal losses and proportional rules.

We first selected 120 students (10 sessions involving 12 subjects each) to play a sequence of games in the lab. In particular, we asked subjects to play for money the (noncooperative) procedures of Chun (1989), Moreno-Ternero (2002) and Herrero (2003) when applied to *the same bankruptcy problem*. We focused on these three procedures because they share the same game-form (claimants are required, simultaneously, to propose a rule) and because they display very similar strategic properties (namely, there is always a player with a weakly dominant strategy by which she can force the outcome of the game in her favor). If subjects recognize the strategic incentives induced by each game, then choosing a particular procedure may be equivalent to choose a particular rule to solve the problem.

Then, we also considered an additional procedure (a simple "majority game") that has the property that all (and only) strategy profiles in which players coordinate on the same rule constitute a strict Nash equilibrium. This additional game has no selection incentives, but coordination incentives only. Thus, we used this game to investigate, in a more compelling way, which rule may emerge as the optimal solution of the strategic situation subjects are involved in.

In addition, we also wanted to check whether subjects' play in games with such strong strategic properties would be sensitive to *framing effects*. As we mentioned earlier, different rules are to be considered more appropriate depending on the problem at stake. Therefore, we explained each procedure to subjects with a different "story" (somehow consistent with the rule supported by the procedure) and compare the results with those in which the same procedures were played under a completely "unframed" scenario, where only monetary payoffs associated to strategy profiles were provided. We did so to see whether different frames may have induced subjects to behave differently.

We here briefly summarize the main findings of this experiment. While in the first three procedures subjects' play easily converges to the unique equilibrium rule even in the first rounds, in the majority procedure the proportional rule overwhelmingly prevails as a coordination device. As for the framing issue, we find that frames have some impact on subjects' behavior only in the majority game. As for the other procedures, strategic considerations appear so compelling to render framing effects negligible.

The alternative approach consisted in selecting a different group of 120 students, administering them a questionnaire in which they were asked to choose their preferred rule from the viewpoint of an arbitrator in charge to resolve, among others, the same claims situations played in the lab by the other group of subjects. Consistently with our experimental findings, the proportional solution prevailed as the modal choice for 90% of the respondents. Nonetheless, individuals also showed to be sensitive to the particular situation at hand.

Despite the extensive experimental literature on related issues such as bargaining [see Ochs and Roth (1989), and the literature cited therein], or arbitration [see Ashenfelter and Bloom (1984), or Ashenfelter *et al.* (1992), and the literature cited therein], this is, to the best of our knowledge, the first experiment on bankruptcy games. The closest reference to our work is the paper of Cuadras-Morató *et al.* (2001). They investigate, by way of questionnaires, the equity properties of different rules in the context of health care problems. In this respect, they find that, when asked to choose among six potential allocations (including the proportional and the constrained equal losses rule) using the perspective on an "impartial judge" in the context of health care problems, subjects display a slight preference for the constrained equal losses solution. A related paper is also Yaari and Bar-Hillel (1984), where different bargaining solutions are investigated also by means of questionnaires.

The remainder of the paper is organized as follows. In Section 2 we formally introduce claims problems, the three rules, and the noncooperative procedures object of the experiment. Section 3 is devoted to the experimental design. In Section 4 we report our experimental results. In section 5 we report on the results of the questionnaire. Conclusions, comments and further proposals are presented in Section 6. An Appendix contains the proofs of some theoretical results related to our study and the experimental and questionnaire instructions.

2 Claims problems, rules and procedures

Let $N = \{1, 2, \ldots, n\}$ be a set of agents with generic elements i and j. A *claims (or bankruptcy) problem* [O'Neill (1982)] is a pair (c, E), where $c \equiv \{c_i\} \in \Re^n_+$ and $C = \sum_{i \in N} c_i > E > 0$. In words, c_i is the claim of agent i over a certain amount (the *estate*) E. Let $\mathbb{B}$ denote the class of such problems. Without loss of generality, let $c_1 \geq c_2 \geq ... \geq c_n$.[1]

A *rule* is a mapping $r : \mathbb{B} \rightarrow \Re^n$ that associates with every problem (c, E) a unique allocation $r(c, E)$ such that:

(i) $0 \leq r(c, E) \leq c$.

(ii) $\sum_{i \in N} r_i(c, E) = E$.

(iii) For all $i, j \in N$, if $c_i \geq c_j$ then $r_i(c, E) \geq r_j(c, E)$ and $c_i - r_i(c, E) \geq c_j - r_j(c, E)$.

The allocation $r(c, E)$ is interpreted as a desirable way of dividing E among the agents in N. Requirement (i) is that each agent receives an award that is non-negative and bounded above by her claim. Requirement (ii) is that the entire amount must be allocated. Finally, requirement (iii) is that agents with higher claims receive higher awards and face higher losses.[2] We denote by $\mathcal{R}$ the set of all such rules.

Next, we introduce the three rules focus of our study. The *constrained equal-awards rule* makes awards as equal as possible, subject to no agent receiving more than her claim. The *proportional rule* distributes awards proportionally to claims. The *constrained equal-losses rule* makes losses as equal as possible, subject to the condition that no agent ends up with a negative award.

*The **constrained equal-awards** rule, cea, selects for all $(c, E) \in \mathbb{B}$, the vector $(\min\{c_i, \lambda\})_{i \in N}$, where $\lambda > 0$ is chosen so that $\sum_{i \in N} \min\{c_i, \lambda\} = E$.*

*The **proportional** rule,* **p**, *selects for all $(c, E) \in \mathbb{B}$, the vector λc, where λ is chosen so that $\sum_{i \in N} \lambda c_i = E$.*

*The **constrained equal-losses** rule,* **cel**, *selects for all $(c, E) \in \mathbb{B}$, the vector $(\max\{0, c_i - \lambda\})_{i \in N}$, where $\lambda > 0$ is chosen so that $\sum_{i \in N} \max\{0, c_i - \lambda\} = E$.*

Remark 1 *Note that for all $(c, E) \in \mathbb{B}$ and all $r \in \mathcal{R}$, $cel_1(c, E) \geq r_1(c, E)$ and $cea_n(c, E) \geq r_n(c, E)$. In other words, cel (cea) is the most preferred rule by the highest (lowest) claimant among all rules belonging to $\mathcal{R}$.*

As we mentioned in the introduction, these rules are salient in the theoretical debate on the way of solving claims problems. This may induce to select these rules over other alternatives. On the other hand, and as in the case of bargaining problems, the literature seems far from unanimous in proposing *a unique* rule to solve claims situations relying on axiomatic properties only. This opens the possibility of approaching claims problems by using alternative techniques.

[1] In the remainder of the paper, we shall refer to agent 1 (n), that is, the agent with the highest (lowest) claim, as the *highest (lowest) claimant.*

[2] While conditions (i) and (ii) are standard in the definition of a rule, requirement (iii) is considered in the claims literature as an independent axiom called *order preservation*, and any rule satisfying condition (iii) is said to belong to the set of *order preserving* rules. Since all the rules object of our experiment satisfy condition (iii), we shall abuse standard terminology by referring to order preserving rules as simply "rules".

2.1 Noncooperative solutions to claims problems

Let us now focus on some noncooperative *procedures* proposed to solve claims situations. All these procedures share the same game-form: agents simultaneously propose a rule belonging to the set $\mathcal{R}$, and the procedure selects a particular division of the amount accordingly. Moreover, all procedures share another common feature: if all agents agree in a particular allocation, then this allocation is selected as the solution to the problem.

In the *diminishing claims procedure*, if agents do not agree in a particular allocation, their claims are reduced by substituting them with the highest amount assigned to every agent by the chosen rules. Agents' rules are then applied to the resulting problem after adjusting claims. If they coincide in the allocation to the new problem, this is the solution the procedure provides. Otherwise, claims are reduced again. If the process does not terminate in a finite number of steps, the limit of the resulting claims vectors (if it exists) is chosen as solution to the problem. Otherwise, nobody gets anything.

Diminishing claims procedure (P_1) [Chun (1989)]. Let $(c, E) \in \mathbb{B}$ be given. Each player $i \in N$ chooses a *rule* $r^i \in \mathcal{R}$, with r^{-i} denoting the strategy profile selected by i's opponents. Let $r = \left\{r^i, r^{-i}\right\}$ be the profile of rules reported. The division proposed by the diminishing claims procedure, $dc[r, (c, E)]$ is obtained as follows:

Step 1. Let $c^1 = c$. For all $i \in N$, calculate $r^i(c^1, E)$. If $r^i(c^1, E) = r^j(c^1, E)$, for all $i, j \in N$, then $dc[r, (c, E)] = r^i(c^1, E)$. Otherwise, go to the next step.

Step 2. For all $i \in N$, let $c_i^2 = \max_{j \in N} r_i^j(c^1, E)$. For all $j \in N$, calculate $r^j(c^2, E)$. If $r^i(c^2, E) = r^j(c^2, E)$, for all $i, j \in N$, then $dc[r, (c, E)] = r^i(c^2, E)$. Otherwise, go to the next step.

Step k+1. For all $i \in N$, let $c_i^{k+1} = \max_{j \in N} r_i^j(c^k, E)$. For all $j \in N$, calculate $r^j(c^{k+1}, E)$. If $r^j(c^{k+1}, E) = r^i(c^{k+1}, E)$, for all $i, j \in N$, then $dc[r, (c, E)] = r^i(c^{k+1}, E)$. Otherwise, go to the next step.

If previous process does not terminate in a finite number of steps, then:

Limit case. Compute $\lim_{t \to \infty} c^t$. If it converges to an allocation x^* such that $\sum_{i \in N} x_i^* \leq E$, then $x^* = dc[r, (c, E)]$. Otherwise, $dc[r, (c, E)] = 0$.

In the *proportional concessions procedure,* if agents do not agree in the proposed allocation, they receive the proportional share of half the liquidation value. Agents' rules are then applied to divide the remainder after adjusting claims. If they coincide in the allocation to the new problem, then the solution the procedure provides is the allocation plus the concessions in the first stage. Otherwise, the process starts again. If it does not terminate in a finite number of steps, then the limit of the aggregation of concessions (if it exists) is chosen as solution to the problem. Otherwise, nobody gets anything.

Proportional concessions procedure (P_2) [Moreno-Ternero (2002)]**.** Let $(c, E) \in \mathbb{B}$ be given. Each player $i \in N$ chooses a *rule* $r^i \in \mathcal{R}$, with r^{-i} denoting the strategy profile selected by i's opponents. Let $r = \left\{r^i, r^{-i}\right\}$ be the profile of rules reported. The division proposed by the proportional concessions procedure, $pc[r, (c, E)]$, is obtained as follows:

Step 1. Let $c^1 = c$ and $E^1 = E$. For all $i \in N$, calculate $r^i(c^1, E^1)$. If $r^i(c^1, E^1) = r^j(c^1, E^1)$, for all $i, j \in N$, then $pc[r, (c, E)] = r^i(c^1, E^1)$. Otherwise, go to the next step.

Step 2. For all $i \in N$, let $m_i^1 = p_i(c^1, \frac{E^1}{2})$, $c^2 = c^1 - m^1$, where $m^1 = (m_i^1)_{i \in N}$, and $E^2 = E^1 - \sum m_i^1 = \frac{E}{2}$. For all $i \in N$, calculate $r^i(c^2, E^2)$. If $r^i(c^2, E^2) = r^j(c^2, E^2)$, for all $i, j \in N$, then $pc[r(c, E)] = m^1 + r^i(c^2, E^2)$. Otherwise, go to the next step.

Step k+1. For all $i \in N$, let $m_i^k = p_i(c^k, \frac{E^k}{2})$, $c^{k+1} = c^k - m^k$, and $E^{k+1} = E^k - \sum m_i^k = \frac{E}{2^k}$. For all $i \in N$, calculate $r^i(c^{k+1}, E^{k+1})$. If $r^i(c^{k+1}, E^{k+1}) = r^j(c^{k+1}, E^{k+1})$, for all $i, j \in N$, then $pc[r, (c, E)] = m^1 + \cdots + m^k + r^i(c^{k+1}, E^{k+1})$. Otherwise, go to the next step.

If previous process does not terminate in a finite number of steps, then:

Limit case. Compute $\lim_{k \to \infty}(m^1 + \cdots + m^k)$. If it converges to an allocation x^* such that $\sum_{i \in N} x_i^* \leq E$, then $x^* = pc[r, (c, E)]$. Otherwise, $pc[r, (c, E)] = 0$.

In the *unanimous concessions procedure,* if agents do not agree in the proposed allocation, they receive the minimum amount assigned by the chosen rules. Agents' rules are then applied to the residual problem after adjusting claims and the liquidation value. If they coincide in the allocation to the new problem, then the procedure provides the allocation plus the concessions in the first stage. Otherwise, the process starts again. If it does not terminate in a finite number of steps, then the limit of the aggregation of minimal concessions (if it exists) is chosen as solution to the problem. Otherwise, nobody gets anything.

Unanimous concessions procedure (P_3) [Herrero (2003)]. Let $(c, E) \in \mathbb{B}$ be given. Each player $i \in N$ chooses a *rule* $r^i \in \mathcal{R}$, with r^{-i} denoting the strategy profile selected by i's opponents. Let $r = \left\{r^i, r^{-i}\right\}$ be the profile of rules reported. The division proposed by the unanimous concessions procedure, $u[r, (c, E)]$ is obtained as follows:

Step 1. Let $c^1 = c$ and $E^1 = E$. For all $j \in N$, calculate $r^j(c^1, E^1)$. If $r^i(c^1, E^1) = r^j(c^1, E^1)$, for all $i, j \in N$, then $u[r, (c, E)] = r^i(c^1, E^1)$. Otherwise, go to the next step.

Step 2. For all $i \in N$, let $m_i^1 = \min_{j \in N} r_i^j(c^1, E^1)$, $E^2 = E^1 - \sum_{i \in N} m_i^1$, and $c^2 = c^1 - m^1$, where $m^1 = (m_i^1)_{i \in N}$. For all $i \in N$, calculate $r^i(c^2, E^2)$. If $r^i(c^2, E^2) = r^j(c^2, E^2)$, for all $i, j \in N$, then $u[r, (c, E)] = m^1 + r^i(c^2, E^2)$. Otherwise, go to the next step.

Step k+1. For all $i \in N$, let $m_i^k = \min_{j \in N} r_i^j(c^k, E^k)$, $E^{k+1} = E^k - \sum_{i \in N} m_i^k$, and $c^{k+1} = c^k - m^k$. For all $i \in N$, calculate $r^i(c^{k+1}, E^{k+1})$. If $r^i(c^{k+1}, E^{k+1}) = r^j(c^{k+1}, E^{k+1})$, for all $i, j \in N$, then $u[r, (c, E)] = m^1 + \cdots + m^k + r^i(c^{k+1}, E^{k+1})$. Otherwise, go to the next step.

If previous process does not terminate in a finite number of steps, then

Limit case. Compute $\lim_{k \to \infty}(m^1 + \cdots + m^k)$. If it converges to an allocation x^* such that $\sum_{i \in N} x_i^* \leq E$, then $x^* = u[r, (c, E)]$. Otherwise, $u[r, (c, E)] = 0$.

The strategic properties of these procedures have already been explored in the literature, as the following lemmas show.

Lemma 1 *If, for some $i \in N$, $r^i = cea$, then $dc[r,(c,E)] = cea(c,E)$. Furthermore, in game P_1, cea is a weakly dominant strategy for the lowest claimant. Finally, all Nash equilibria of P_1 are outcome equivalent to cea.*

Proof. See Chun (1989). ■

Lemma 2 *If, for some $i \in N$, $r^i = p$, then $pc[r,(c,E)] = p(c,E)$. Furthermore, in game P_2, if there exists an agent whose preferred allocation is p , then p is a weakly dominant strategy for her. Finally, all Nash equilibria of P_2 are outcome equivalent to p.*

Proof. See Moreno-Ternero (2002). ■

Lemma 3 *If, for some $i \in N$, $r^i = cel$, then $u[r,(c,E)] = cel(c,E)$. Furthermore, in game P_3, cel is a weakly dominant strategy for the highest claimant. Finally, all Nash equilibria of P_3 are outcome equivalent to cel.*

Proof. See Herrero (2003). ■

Previous lemmas indicate that the selected procedures do not seem to provide the agents with any freedom of choice, at least under very mild (first-order) rationality conditions. This is because, there is always some player (the identity of which depends on the procedure) who can force the outcome in her favor by selecting her weakly dominant strategy. This may render these procedures as inadequate, if we were genuinely interested in the rule selection problem, that is, in collecting experimental evidence on how subjects reach an agreement on claims problems in the lab. This is why we also consider an additional procedure which takes the form of a coordination game, which we call the *majority procedure*.

In the majority procedure, a claimant obtains the share of the liquidation value proposed by her chosen rule only if it has been selected by a simple majority of the agents (that is, all other rules have been chosen by a strictly smaller number of players). Otherwise, she is fined by $\varepsilon > 0$. More precisely:

Majority procedure (P_0). Let $(c,E) \in \mathbb{B}$ be given. Each player $i \in N$ chooses simultaneously a *rule* $r^i \in \mathcal{R}$, with r^{-i} denoting the strategy profile selected by i's opponents. The payoff function is as follows:

$$\pi_i\left(r^i, r^{-i}\right) = \begin{cases} r_i^i(c,E) \text{ if } r^i \text{ is the rule selected by a } \textit{simple} \text{ majority;} \\ -\varepsilon \text{ otherwise.} \end{cases}$$

The strategic properties of this procedure are contained in the following lemma, the (trivial) proof of which is here omitted.

Lemma 4 *The set of strict Nash equilibria of P_0 is $\{(r,r,...,r) : r \in \mathcal{R}\}$.*

3 Experimental design

In what follows, we describe in detail the main design features of our experimental study.

3.1 Subjects

Our study was conducted in ten experimental sessions in July, 2001 and May, 2003. A total of 120 students -mainly, undergraduate Economics students with no (or very limited) prior exposure to game theory- were recruited among the undergraduate population of the University of Alicante.

3.2 Frames

In the first six sessions the claims problem was framed in three different ways, depending on the procedure being employed. The idea was to provide a frame consistent with the (equilibrium) rule induced by the procedure.

All frames had in common that the claims problem was presented by the hypothetical situation of *a bank going bankrupt.*

- **Frame 1: Depositors** (P_1). Under this frame claimants are all *bank depositors*. In this case, common-sense (and usual practice) gives priority to smaller claims (i.e., smaller deposits), as it happens (in equilibrium) with procedure P_1.
- **Frame 2: Shareholders** (P_2). Under this frame claimants are all bank *shareholders*. This is the typical situation where, in case of bankruptcy, each shareholder usually obtains a share of the liquidation value proportional to the share of stocks in her possession, as it happens (in equilibrium) with procedure P_2.
- **Frame 3: Non-governmental organizations** (P_3). Our last frame is concerned with *non-governmental organizations sponsored by the bank*. In this case, we assumed that each claimant had signed a contract with the bank, previously to the bankruptcy situation, to receive a contribution according with its social relevance (the higher the social relevance, the higher the contribution). Under this framework, it would seem appropriate to give priority to higher claimants, as it happens (in equilibrium) with procedure P_3.
- **Frame 0: No frame**. We also run four unframed sessions. In this case, subjects were only provided with the payoff tables and played the four games without any story behind.

3.3 Treatments

The ten sessions were run in a computer lab.[3] In the first six sessions, subjects were assigned to a group of 3 individuals and played twenty rounds of a *framed* procedure, P_1, P_2 or P_3, followed by twenty rounds of P_0 presented under the same frame. In the last four sessions, subjects played twenty rounds of each of the four procedures, P_1, P_2, P_3 and P_0, without any framework. Table 1 reports the precise sequence of procedures played in the 10 sessions.

[3] The experiment was programmed and conducted with the software z-Tree (Fischbacher, 1999).

treat 1		treat 2		treat 3		treat 4		treat 5	
ses1	ses4	ses2	ses5	ses3	ses6	ses7	ses8	ses9	ses10
P1	P1	P2	P2	P3	P3	P1	P1	P3	P3
P0	P0	P0	P0	P0	P0	P2	P2	P2	P2
						P3	P3	P1	P1
						P0	P0	P0	P0
framed						unframed			

(1)

Table 1: Sequential structure of the experimental sessions

As Table 1 shows, all (un)framed treatments consisted in a sequence of (four) two procedures. In consequence, the framed sessions lasted for approximately 45', whereas the unframed ones lasted for approximately 70'. In all sessions, subjects played anonymously in groups of three players with randomly matched opponents. Subjects were informed that their *player position* (i.e., their individual claims in the problem) would remain the same throughout the session, while the composition of their group would change at every round.

Instructions were provided by a self-paced, interactive computer program that introduced and described the experiment. Subjects were also given a written copy of the instructions (identical to those appearing on the screen) and the payoff table associated to the procedure being played. All instructions were presented in Spanish language. The complete set of instructions translated into English can be found in the Appendix. At the end of each round, each player knew about the game outcome and the monetary payoff associated with it.

3.4 Group size

Our decision to focus on a claims problem with three players was dictated by several reasons. An interesting feature is that the procedures presented in Section 2 work not only with two-agents, but also with any arbitrary number of agents. This is not the case for bargaining procedures of a related nature, most significantly van Damme (1986), that only convergein the two-person case. Furthermore, the situation is different when more than two agents are involved than in the two-agent case. When only two agents are involved, given the estate, any amount that is not assigned to an agent is left to the other one. Nonetheless, when more than two agents are involved, which is left should be distributed between the remaining agents. Consequently, agents may care not only about the amount they receive, but also on the way the leftovers are distributed among the remaining agents. By choosing three agents, we moved away from the two-person case, but keeping the population size at a minimum. Finally, as we would like to test the three salient rules: proportional, constrained equal awards and constrained equal losses, by considering three agents we may built up the problem in such a way that each agent has a rule which proposes his preferred division of the estate. Thus, a priori, all division methods have equal chance of being chosen.

3.5 The claims problem

As we mentioned earlier, all four procedures were constructed upon *the same* claims problem (c^*, E^*), where $c^* = (49,\ 46,\ 5)$ (i.e., $\sum c_i = 100$) and $E^* = 20$.[4] The resulting allocations associated with each rule for this specific problem are the following:

$$cea(c^*, E^*) = (7.5, 7.5, 5),$$
$$p(c^*, E^*) = (9.8, 9.2, 1),$$
$$cel(c^*, E^*) = (11.5, 8.5, 0).$$

Since, in all sessions, subjects played more than one procedure in sequence, we decided to focus on a single claims problem to reduce the environment variability and to facilitate subjects' understanding of the strategic situation in which they were involved. The main motivation for the choice of the particular problem (c^*, E^*) was to provide each claimant with a strictly preferred allocation associated with one of the three rules. We already know, from Remark 1, that, for all rules belonging to $\mathcal{R}$, *cel* (*cea*) is the most preferred rule by the highest (lowest) claimant, independently of the particular problem at stake. However, it is not guaranteed that p were the most preferred rule by any (in particular, the middle) claimant, unless we imposed some conditions on the claims problem analogous to the ones above.[5]

There is another feature of the experimental design of the framed sessions that should be worth to mention at this stage. As can be noticed in the instructions, the three rules were presented to subjects without using their technical terminology (but simply referring to them as rules "A", "B" and "C"). However, the distributive properties of *cea* and *cel*, that is, the two rules whose simple definition might have been less transparent to subjects not acknowledged to claims problems, were explicitly mentioned in their description, stating that they were meant to "... *benefit the agent with the lowest (highest) claim*". In contrast, we omitted to mention that p was indeed the first-best option for player 2, the middle claimant (property we know peculiar to the specific parameterization of our problem (c^*, E^*)). The reason for this asymmetry in the description of the rules was twofold. On the one hand, we preferred to make sure that the distributive properties of *cea* and *cel* were common knowledge among subjects, in particular, with respect to the role they might have played in procedures P_1 and P_3. On the other hand, we wanted to see whether omitting this information in the case of p would have produced a significant change in the behavior of the middle claimant -in particular, with respect to her choice in P_2.

3.6 Game-forms and payoffs

As we mentioned earlier, all procedures share the same game-form. In each session, each player was assigned to a player position, corresponding to a particular claim in the claims problem (c^*, E^*), with c_i^* denoting player i's claim. In each round, each player was required to choose simultaneously a rule among *cea*, p and *cel*. Round payoffs were determined by the ruling procedure.

[4] All monetary payoffs are expressed in Spanish pesetas (1 euro=166 pesetas approximately).

[5] There were other reasons to prefer problems sufficiently "close" to (c^*, E^*) for our experiment, which we explain in more detail in the Appendix.

How to construct the (monetary) payoff functions for our experiment was one of the most delicate design choices. In a standard experimental session, subjects participate to a specific "role-game" protocol after which they receive a certain amount of money as a function of how they (and the other subjects in the pool) played the game. In other words, subjects participating in an economic experiment *win money*. On the contrary, in a real-life claims situation claimants *lose money*, in the sense they get back less than what they paid (or had the right to be repaid) sometime in the past. Distributing allocations as vectors of non-negative amounts of money (as they are presented in this paper and in all the literature on claims) would have simply reproduced in the lab a particular *bargaining* (as opposed to *claims*) game in which subjects bargain, under a certain protocol, over a particular division of the estate.

To some extent, the simple fact that subjects must leave the experimental lab with more money than what they had at the time they arrived may be considered incompatible with the possibility of running an experiment on claims. To (at least partially) ameliorate this dilemma, we constructed our monetary payoff functions so that, in each round, subjects *were losing the difference* (out of a predetermined endowment, known in advance) between their claim and the share of the estate's division assigned to them, given the ruling procedure and the group's strategy profile.

More precisely, rule allocations in the experiment were constructed as follows:

$$cea(c^*, E^*) - c^* = (7.5, 7.5, 5) - (49, 46, 5) = (-41.5, -38.5, 0).$$
$$p(c^*, E^*) - c^* = (9.8, 9.2, 1) - (49, 46, 5) = (-39.2, -36.8, -4).$$
$$cel(c^*, E^*) - c^* = (11.5, 8.5, 0) - (49, 46, 5) = (-37.5, -37.5, -5).$$

By the same token, the payoff matrix associated to procedure P_1, as shown in Table 2, only contains non-positive amounts.

(2)

Insert Table 2 about here.

Table 2 is exactly the same as that being used to explain subjects the game associated with procedure P_1. Player 1 (2) [3] selects the row (column) [matrix]. Each cell, corresponding to a strategy profile $r = (r^1, r^2, r^3)$ contains the payoffs for player 1 (first row) 2 (second row) and 3 (third row).

Payoffs were obtained as follows. By Lemma 1, if $r^i = cea$ for some $i \in \{1, 2, 3\}$, then the allocation is $cea(c^*, E^*) - c^* = (-41.5, -38.5, 0)$. If $r^i = r^j$ for all $i \neq j$ then the allocation is $r^i(c^*, E^*) - c^*$. The allocations of the remaining six profiles were obtained using a recursive algorithm based on the definition of P_1 that leads to $(10.7, 8.4, 0.9) - c^* = (-38.3, -37.6, -4.1)$.

As we know from Lemmas 1-3, every procedure provides a player (the identity of which depends on the procedure) with a weakly dominant strategy by which she can force her favorite outcome. In each game, we will refer to this player as the *pivotal* player of that game. For the diminishing claims procedure P_1, the pivotal player is player 3 (the lowest claimant), whose weakly dominant strategy corresponds to rule *cea*. However, given the reduced form used in the experiment (subjects could only choose among *cea*, *p* and *cel*), also player 1 has a weakly dominant strategy (*cel*), while player 2 has no weakly dominant strategies in this game.

Analogous considerations hold for the proportional concessions procedure P_2, whose payoff matrix is drawn in Table 3.

(3)

Insert Table 3 about here

Payoffs for this game were obtained as follows. By Lemma 2, if $r^i = p$ for some $i \in \{1, 2, 3\}$, then the allocation is $p(c^*, E^*) - c^* = (-39.2, -36.8, -4)$. If $r^i = r^j$ for all $i \neq j$ then the allocation is $r^i(c^*, E^*) - c^*$. The allocations of the remaining six profiles correspond to $(-39.2, -36.8, -4)$, that is, to the proportional allocation.

Here we notice that all players have a weakly dominant strategy at their disposal: p is weakly dominant for the pivotal player 2; *cea* is weakly dominant for player 3; *cel* is weakly dominant for player 1.

The payoff matrix of the unanimous concessions procedure (P_3) is reported in Table 4.

(4)

Insert Table 4 about here

Payoffs for this game were obtained as follows. By Lemma 3, if $r^i = cel$ for some $i \in \{1, 2, 3\}$, then the allocation is $cel(c^*, E^*) - c^* = (-37.5, -37.5, -5)$. If $r^i = r^j$ for all $i \neq j$, then the allocation is $r^i(c^*, E^*) - c^*$. The allocations of the remaining six profiles were obtained using a recursive algorithm, based on the definition of P_3 that leads to $(9.4, 9.4, 1.3) - c^* = (-39.6, -36.6, -3.7)$.

In this case, *cel* is weakly dominant for the pivotal player 1; *cea* is weakly dominant for player 3 while player 2 has no weakly dominant strategies.

To summarize, among the three procedures, *cea* (*cel*) always corresponds to a weakly dominant strategy for player 3 (1), while player 2 has a weakly dominant strategy (p) only in P_2.

As we can see from Tables 2-4, all situations where agents' rules do not coincide (and no agent selects the corresponding equilibrium rule) lead to a well-defined limit in the division of the liquidation value. In other words, the event of no convergence (associated with a 0 payoff for all players), contemplated in the definition of all three procedures, never occurs in our games. As it turns out, this is not a special feature of our specific parametrization of the bankruptcy problem (c^*, E^*) -or the constraint over the set of rules- but a general property of all procedures, as the following proposition shows.

Proposition 1 For all $(c, E) \in \mathbb{B}$ and for all *procedures,* P_1, P_2 *and* P_3 *with arbitrary strategy set* $\mathcal{R}^* \subseteq \mathcal{R}$, *the limit allocation* x^* *always exists.*

Proof. In the Appendix**.**

The last procedure object of this study, the majority procedure P_0, displays rather different strategic properties, as shown in Table 5.

(5)

Insert Table 5 about here

Since this procedure basically yields a coordination game, no player has a weakly dominant strategy. (Strict) Nash equilibria correspond to those profiles in which all players coordinate on the same rule.

Payoffs for this game were obtained as follows. If $r^i = r^j$ for all $i \neq j$ then the allocation is $r^i(c^*, E^*) - c^*$. If $r^i = r^j \neq r^k$, then agents i and j get $r^i_i(c^*, E^*) - c^*_i$ and $r^j_j(c^*, E^*) - c^*_j$ respectively whereas agent k gets $-1 - c^*_k$. Finally, if all agents propose different rules, the allocation is $(-1, -1, -1) - c^*$.

As we mentioned earlier, payoffs reported in Tables 2-4 were subtracted to subjects' endowments. In all sessions, before playing a procedure, all subjects received an initial endowment of 1000 pesetas from which all losses were subtracted along the 20 rounds. At the beginning of the following procedure, subjects would receive a new endowment of 1000 pesetas, and so on. In addition, subjects selected as players 1 and 2 received 500 pesetas as a show-up fee in the framed sessions, and 1000 pesetas in the unframed sessions. Subjects selected as players 3 did not receive an initial show-up fee, due to the fact that their losses were considerably lower than the others'. This asymmetry in the show-up fees, mainly intended to provide also players 1 and 2 with the appropriate financial gain, was communicated privately to each subject and we shall read the data under the assumption that it played no role in determining subjects' decisions. As for procedure P_0, the penalty ε was equal to 1 peseta. Average earnings per hour were around 1800 pesetas (11 euros) for players 1 and 2 and around 3600 pesetas (22 euros) for player 3.

4 Results

In analyzing the data, we first look at the six framed sessions (treatments 1 to 3 of Table 1). We then compare this evidence with that of the unframed sessions (treatments 4 and 5 of Table 1) to check for framing effects.

4.1 Framed Sessions

As for the six framed sessions, we first focus on allocations, then on subjects' behavior.

4.1.1 Allocations

Table 6 reports the relative frequencies of allocations in the six framed sessions of P_1, P_2 and P_3.

ALLOC. / PROC.	OBS.	*cea*	*p*	*cel*	Others
P_1	160	**.98**	0	0	.02
P_2	160	0	**1**	0	0
P_3	160	0	0	**.98**	.02

(6)

Table 6: Allocation distributions of P_1, P_2 and P_3 in the framed sessions.

Table 6 reports, for each procedure P_1, P_2 and P_3, the relative frequency of allocations which corresponds to each rule. The remaining category (labelled as "Others") pools all allocations which do not correspond to any particular rule. We begin by noting that *virtually all* matches yielded the allocation associated to the corresponding equilibrium rule. We also know, from Lemmas 1-3, that every Nash equilibrium is outcome equivalent to the corresponding rule of that procedure. However, there are also other strategy profiles which are not equilibria but yield the same allocation (take, for example, the case of P_1 if players 1 and 3 select rule p and player 2 selects *cea*). In this respect, our evidence shows that these strategy profiles occur only marginally. That is, if a particular rule dictates the game allocation, this is because the same rule is supported by a Nash equilibrium of the corresponding procedure.[6]

This striking evidence has to be compared with the allocation distributions of the framed versions of P_0, as shown in Table 7.

ALLOC. / FRAME	OBS.	*cea*	*p*	*cel*	Others
1	160	.01	**.82**	0	.17
2	160	0	**.69**	.01	.30
3	160	0	**.75**	.01	.24
TOTAL	480	0	**.75**	.01	.24

(7)

Table 7: Allocation distributions of P_0 in the framed sessions.

Remember that, in all framed sessions, P_0 was played after one of the other procedures, P_1, P_2 or P_3, under the corresponding frame. Table 7 shows the allocation distributions of P_0 depending on under which frame it was played.

We observe from Table 7 that the proportional rule is salient in describing the allocation distributions in all sessions, with an average frequency of 75% across all treatments. As Table 7 shows, if subjects succeeded in coordinating on an equilibrium allocation, they did it by way of the proportional rule (for each frame, coordination on *cea* or *cel* never exceeds 1% of the total observations). Moreover, we also observe a significantly higher frequency (compared to those of the framed sessions of P_1, P_2 and P_3) of non-equilibrium allocations -24% of the total observations- which do not correspond to any particular rule. As it turns out, these allocations mainly correspond to situations in which two out of three players select the proportional rule.[7]

The presence of such a significant proportion of non-equilibrium allocations in P_0 is mainly due to two different reasons. On the one hand, in P_0 a rule dictates the game allocation if and only if *all players* (as opposed to a *single one*) select it. On the other hand, learning effects are much stronger in P_0 than in any other procedure: the average frequency of proportional allocations raises from 75% to 90% if we consider only the last 10 rounds. We shall discuss learning effects more in detail in Section 4.2 below.

4.1.2 Behaviors

Table 8 shows, disaggregated for procedure and player position, the relative frequencies with which subjects used the three available rules in the six framed

[6] Also notice that, in procedures P_1-P_3, a Nash equilibrium occurs if a) the pivotal player selects the equilibrium rule ($p = 1/3$ if she plays random) and in case she does not (this would occur with probability 1-p = 2/3) if the other two players select the equilibrium rule (under random play, this would occur with probability 1/9). The expected probability of a Nash equilibrium under random play is therefore $1/3 + 2/3 * 1/9 \cong .4$. As Table 6 shows, the relative frequencies of equilibrium outcomes are significantly higher than this value to exclude the possibility that they come as results of random play on behalf of subjects.

[7] In particular, the frequency with which two out of three subjects selected the proportional rule under frame 1 (2) [3] was 13% (18%) [19%], with an average of 17% (that is, 71% over the total of non-equilibrium allocations).

sessions.

PLAYERS	P_1			P_2			P_3		
1	.08	.28	.64	.02	.22	.76	.02	.06	**.92**
2	.15	.66	.19	.07	**.76**	.17	.06	.45	.49
3	**.97**	.02	.01	.82	.14	.04	.54	.3	.16
RULES	*cea*	*p*	*cel*	*cea*	*p*	*cel*	*cea*	*p*	*cel*

(8)

Table 8: Aggregate behavior in the framed sessions of P_1, P_2 and P_3.

We can observe from Table 8 that pivotal players mainly used their weakly dominant strategies. More precisely, player 3 selects her weakly dominant strategy (*cea*) in P_1 97% of the times; in P_3 player 1 selects her weakly dominant strategy (*cel*) 92% of the times; in P_2 the relative frequency with which player 2 selects her weakly dominant strategy p is somehow lower (76%), but still significantly higher than any other available choice. This difference in behavior might have been caused by the fact that, as we mentioned before, unlike for *cea* and *cel*, it was not explicitly mentioned that p was the first-best option for player 2.

As far as non-pivotal players concerns, we also notice that, although not as frequently as pivotal players, weakly dominant strategies are selected always more than 50% of the times. Moreover, player 1 (3) selects her weakly dominant strategy in a non-pivotal position more frequently in P_2 than in P_1 (P_3). This may be due to the fact that P_2 is the procedure in which pivotal player 2 dictates her preferred allocation less often than in the other procedures and, in doing so, raises the incentive of using their weakly dominant strategy on behalf of non-pivotal players.[8]

Again, things change significantly when we look at the aggregate behavior in the framed sessions of P_0, as shown in Table 9.

PLAYERS	$FRAME$ 1			$FRAME$ 2			$FRAME$ 3		
1	.01	**.95**	.04	0	**.81**	.19	.02	**.88**	.10
2	.04	**.93**	.03	.02	**.86**	.12	.04	**.92**	.04
3	.12	**.88**	0	.07	**.87**	.06	.08	**.9**	.02
RULES	*cea*	*p*	*cel*	*cea*	*p*	*cel*	*cea*	*p*	*cel*

(9)

Table 9: Aggregate behavior in the framed sessions of P_0.

As Table 9 shows, independently on their player position, subjects selected the proportional rule at least 80% of the times, with an average frequency of use of 88.5%.

4.2 Framing effects

We now move to look at the experimental evidence of the four unframed sessions to check for framing effects. By analogy with Section 4.2, we first focus on allocations and then on subjects' behavior.

[8] More precisely, player 1 played *cel* 64% (resp. 76%) of the times in P_1 (resp. P_2) and player 3 played *cea* 54% (resp. 82%) of the times in P_3 (resp. P_2).

4.2.1 Allocations

The allocation distributions in the four unframed sessions are summarized in Table 10.

RULES / PROCEDURES	OBS.	*cea*	*p*	*cel*	Others
P_0	320	.01	.54	0	.45
P_1	320	.97	.01	0	.02
P_2	320	0	.99	.01	0
P_3	320	0	0	.98	.02

(10)

Table 10: Allocation distributions in the unframed sessions.

As for procedures, P_1, P_2 and P_3, Table 10 reports almost identical allocation distributions to those of the framed sessions, yielding the corresponding equilibrium allocation virtually in every match.[9]

When we look at P_0 (first row of Table 10), the proportional rule is again salient in describing the allocation distribution in all sessions. Moreover, as it happens in the framed sessions, if subjects coordinated on an equilibrium of P_0, they coordinated on the equilibrium supported by the proportional rule. However, the relative frequencies of the proportional allocations (54%, 76% if we consider the last 10 rounds) are significantly lower compared to those of the framed sessions (75% and 90% respectively). By the same token, the relative frequency of (non-equilibrium) allocations in P_0 is significantly higher than those of the framed sessions (45% against 24%).[10]

Table 11 confirms this evidence by testing for homogeneity in the allocation distributions of framed and unframed sessions of P_0 by means of standard chi-square statistics.[11]

[9] We run standard χ^2 statistics (see footnote 11 below) to test for any difference in the allocation distributions between framed and unframed sessions of P_1, P_2 and P_3. In all three cases, the null hypothesis (no difference in the allocation distribution) was never rejected at any reasonable significance level.

[10] As it happens in the framed sessions, these non-equilibrium outcomes mainly correspond to situations in which two out of three players select the proportional rule (27% of the total observations).

[11] Consider the case of sampling from p populations, $p \geq 2$, partitioned in $k \geq 2$ different categories. We wish to test the null hypothesis (H_0) that they all have the same distribution. Let $X_j \equiv \{X_{1j}, ..., X_{kj}\}$ be a sample from population $j = 1, ..., p$, where X_{kj} denotes the number of observations on X_j that belong to category $i = 1, ..., k$. Let $n_1, ..., n_p$ be the number of observations on $X_1, ..., X_p$, respectively. Finally, let

$$\widehat{p}_i = \frac{\sum_{j=1}^{p} X_{ij}}{\sum_{j=1}^{p} n_j}.$$

If $n_1, ..., n_p$ are large enough, and under H_0, then the random variable

$$\chi_0^2 = \sum_{j=1}^{p} \sum_{i=1}^{k} \left[\frac{(X_{ij} - n_j \cdot \widehat{p}_i)^2}{n_j \cdot \widehat{p}_i} \right],$$

is approximately a standard chi-square variable with $(p-1)(k-1)$ degrees of freedom (e.g., Rohatgi (1976)). We therefore reject H_0 at level α if the computed value of χ_0^2 is above $\chi^2_{(p-1)(k-1),\alpha}$, or what is equivalent, if the corresponding $p-$value is below α. Throughout the paper, we shall fix $\alpha = .05$, as the significance level.

	ALL ROUNDS		LAST 10	
H_0	χ_0^2	$p-$val	χ_0^2	$p-$val
$\mu^1 = \mu^2 = \mu^3$	7.33	.29	7.3	.29
$\mu^0 = \mu^1 = \mu^2 = \mu^3$	45.39	0	36.9	0
$\mu^0 = \mu^1$	31.54	0	23.12	0
$\mu^0 = \mu^2$	11.7	.01	15.16	0
$\mu^0 = \mu^3$	22.04	0	7.85	.04

(11)

Table 11: Testing for homogeneity of the allocation distributions of P_0

Remember that we have three different framed treatments for P_0, since P_0 was played within each frame, and two unframed treatments (depending on the sequence of procedures. As it turns out, there is no significant difference in the allocation distributions of P_0 between the two unframed treatments (treatments 4 and 5 of Table 1). In other words, our data do not show the presence of order effects in the unframed treatments. Therefore, all unframed observations of P_0 are aggregated under the "FRAME 0" category. For all $i = 0, ..., 3$, let μ^i be the allocation distribution of P_0 corresponding to frame i. The first column of Table 11 reports the null hypothesis object of test. The first row of Table 11 tests for homogeneity in the three allocation distributions corresponding to the three framed treatments of P_0: μ^1, μ^2 and μ^3. Here the null hypothesis is not rejected, whether we consider the entire dataset ("ALL ROUNDS") or we restrict our sample to the observations corresponding to rounds 11-20 ("LAST 10"). Also notice that the chi-square statistics are essentially the same (7.33 and 7.3 respectively). This implies that, despite the presence of learning effects, allocation distributions are always sufficiently close over time. Things change substantially when we also consider μ^0, that is, when we test for homogeneity in the set of framed and unframed distributions. As Table 11 shows, in this case, we always reject the null hypothesis of no difference in allocation distributions, both at the aggregate level (second row) and for each treatment pair independently (rows 3-5). This result does not depend on whether we consider the entire dataset or we restrict our sample to the last 10 rounds. In other words, unlike for the three procedures P_1, P_2 and P_3, for the majority procedure P_0 framing effects seem to play a role in determining the outcome distributions, enhancing coordination when the game is played in the context of an hypothetical claims situation.

4.2.2 Behaviors

Table 12 reports, disaggregated for player position and procedure, subjects' aggregate behavior in the four unframed sessions.

PLAYERS	P_1			P_2			P_3		
1	.05	.2	.75	.02	.07	.91	.01	.03	**.96**
2	.1	.63	.27	.06	**.86**	.08	.14	.13	.73
3	**.97**	.01	.02	.8	.11	.09	.72	.18	.1
RULES	*cea*	*p*	*cel*	*cea*	*p*	*cel*	*cea*	*p*	*cel*

(12)

Table 12: Aggregate behavior in the unframed sessions of P_1, P_2 and P_3

Here we notice that the pivotal players choose their weakly dominant strategies with a frequency even higher than in the framed sessions. More precisely, pivotal player 3 selects her weakly dominant strategy (*cea*) in P_1 97% (against 97%) of the times; in P_3 the pivotal player 1 selects her weakly dominant strategy (*cel*) 96% (against 92%) of the times; in P_2 the pivotal player 2 selects her weakly dominant strategy p 86% (against 76%) of the times. As far as the weakly dominant strategy used by non-pivotal players, we notice that it is selected always more than 72% of the times. This frequency is also higher than in the framed sessions.

We test the statistical significance of these differences (only as far as pivotal players are concerned) in Table 13.

H_0:	$\nu_1^F = \nu_1^U\ (P_3)$		$\nu_2^F = \nu_2^U\ (P_2)$		$\nu_3^F = \nu_3^U\ (P_1)$	
ROUNDS	χ_0^2	p-val	χ_0^2	p-val	χ_0^2	p-val
1-10	1.95	.38	5.09	.08	2.51	.29
11-20	3.07	.22	5.95	.06	0	1

(13)

Table 13: Testing for homogeneity in pivotal players' aggregate behavior

For all $j = 1, ..., 3$, let ν_j^F (resp. ν_j^U) denote pivotal player $j's$ aggregate behavior in the framed (resp. unframed) version of the corresponding procedure (reported under parenthesis in Table 13). Given this notation, $H_0 : \nu_j^F = \nu_j^U, j = 1, 2, 3$. As Table 13 shows, pivotal players' behavior seem not to be sensitive to framing effects in all procedures P_1, P_2 and P_3 (the null hypothesis is not rejected either if we consider the entire dataset ("ALL ROUNDS"), or if we restrict our sample to the observations of rounds 11-20 ("LAST 10"). This reinforces the evidence of Section 4.2.1: strategic considerations seem predominant in subjects' perception of procedures P_1, P_2 and P_3. The absence of a frame leads subjects even closer to equilibrium play, although this difference in behavior is never significant.

We now move to analyze the role of framing effects in the context of the majority procedure P_0. As we noticed earlier, framing effects may interact with learning effects in this case, since coordination increases significantly over time. This is in contrast with what we found in the case of procedures P_1, P_2 and P_3, where the corresponding equilibrium rule distribution emerges since the very beginning.

FRAMES		Frame 0			Frame 1			Frame 2			Frame 3		
Player	Rounds	*cea*	p	*cel*	*cea*	p	*cel*	*cea*	p	*cel*	*cea*	p	*cel*
1	1-20	.06	**.75**	.19	.01	**.95**	.04	0	**.82**	.18	.02	**.88**	.1
1	1-10	.13	**.6**	.27	.02	**.89**	.09	0	**.7**	.3	.05	**.79**	.16
1	11-20	0	**.9**	.1	0	**1**	0	0	**.93**	.07	0	**.96**	.04
2	1-20	.08	**.87**	.05	.04	**.93**	.03	.03	**.85**	.12	.03	**.92**	.05
2	1-10	.13	**.78**	.09	.07	**.9**	.03	.03	**.76**	.21	.06	**.85**	.09
2	11-20	.02	**.97**	.01	.01	**.96**	.03	.01	**.95**	.04	.01	**.99**	0
3	1-20	.25	**.69**	.06	.12	**.88**	0	.07	**.88**	.05	.08	**.9**	.02
3	1-10	.34	**.55**	.11	.24	**.76**	0	.14	**.8**	.06	.12	**.84**	.04
3	11-20	.16	**.82**	.02	0	**1**	0	.01	**.94**	.05	.04	**.96**	0

(14)

Table 14: Aggregate behavior in P_0

Each cell of Table 14 reports the relative frequency of use of each strategy, disaggregated for player position, under the four frames. We calculate these distributions over the entire dataset (rounds 1-20) but also considering the first (1-10) and the last (11-20) rounds respectively. If we consider only the first 10 rounds, subjects selected the proportional rule at least 55% of the times, with an average frequency of use of 77%. If we consider only the last 10 rounds, subjects selected the proportional rule at least 82% of the times, with an average frequency of use of 95%. These differences are always significant, for all frames and player positions. We also notice that player 2 "learns less" than her opponents. This is due to the fact that, while the proportional allocation corresponds to the second-best for players 1 and 2, it is the first best for player 2. Therefore, the learning pattern takes the form of players 1 and 3 gradually increasing their propensity to go for their second-best option. In this respect, our evidence is consistent with the main literature on coordination games (see, for example, Cooper and John (1988), Cooper and Ross (1985), Van Huyick *et al.* (1990a) or Van Huyick *et al.* (1990b)). The presence of strategic uncertainty, created by the multiplicity of equilibria, yields high variability in behavior in the first repetitions. This variability vanishes relatively quickly, once subjects are able to coordinate on some equilibrium (in this case, the one supported by the proportional rule). Also notice that in our game, unlike the literature cited above, equilibrium selection cannot be due to "efficiency" considerations, since all equilibria are equally Pareto efficient.

Most probably, other factors may have influenced the coordination pattern. First, as we noticed above, convergence on the proportional solution may have been facilitated by some sort of *median voter effect,* since the proportional rule is the only one in which no player receives less than her second-best option. If this were the only effect in play, we should not expect strong framing effects, since the same argument holds for both framed and unframed treatments.

As Table 15 shows, this conjecture is rejected by our data.

	PLAYERS	Player 1		Player 2		Player 3	
H_0	ROUNDS	χ^2_0	p-val	χ^2_0	p-val	χ^2_0	p-val
$\nu^0_j = \nu^1_j = \nu^2_j = \nu^3_j$	$1-20$	39.5	0	22.86	0	49.61	0
$\nu^0_j = \nu^1_j = \nu^2_j = \nu^3_j$	$11-20$	9.8	.13	3.23	.78	35.96	0
$\nu^0_j = \nu^1_j$	$1-20$	25.26	0	3.81	.15	23.08	0
$\nu^0_j = \nu^1_j$	$11-20$	8.52	.01	.22	.89	15.64	0
$\nu^0_j = \nu^2_j$	$1-20$	10.48	.01	11.65	0	20.55	0
$\nu^0_j = \nu^2_j$	$11-20$	.37	.83	.9	.64	12.68	0
$\nu^0_j = \nu^3_j$	$1-20$	9.54	.01	2.71	.26	24.67	0
$\nu^0_j = \nu^3_j$	$11-20$	2.71	.26	1.41	.49	8.74	.01

(15)

Table 15: Testing for framing effects in players' aggregate behavior in P_0

For all $j = 1, 2, 3$, and $i = 0, ..., 3$, let ν^i_j denote pivotal player $j's$ aggregate behavior under frame i (with $i = 0$ meaning "NO FRAME"). As Table 15 shows, framing effects are almost always significant when we consider the entire dataset. If we consider the last ten rounds only, we observe that are always significant for player 3 and sometimes for player 1. The situation is different as far as player 2 is concerned (but we already noticed that, whatever the reason, she plays p with frequencies that are comparable to those of P_2 since the very beginning). In any case, (as we know from Table 11) even if framing effects decrease over time if we look at them at the level of each player's behavior, the overall impact on outcome distributions remain substantial, even in the last rounds.

We conclude this section by briefly summarizing its main findings. Framing effects do not seem to play a significant role in the case of procedures P_1, P_2 and P_3, games whose such strong strategic properties seem to overcome any other consideration. A totally different scenario comes form the analysis of P_0. In this case, players need a coordination device to achieve efficiency and, when they coordinate, they do it by way of the proportional rule. Finally, frames seem to help coordination, even when we control for the learning effects typical of all repeated coordination situations.

5 Taking the viewpoint of outside observers: survey results

Our previous results with reference to procedure P_0 strongly suggest that the proportional rule shows a particular strength as a coordination device. Furthermore, we also observed that frames help to coordinate. Given that the different allocation rules are often justified, in the axiomatic literature, on the grounds of their fairness properties, we may then ask if, in our problem, a majority of subjects perceived the proportional allocation as *more just or socially appropriate* than the alternative proposals. In other words, we may ask whether the proportional rule may considered as a *social norm* to solve claims problems. If so, selecting the proportional rule as a coordination device may be interpreted as evidence of the power of social norms to enhance coordination and cooperation in the society [see, among others, Sugden (1986), Gauthier (1986), Skyrms (1996) and Binmore (1998)].

Along these lines, it may be worth exploring the potential of the proportional rule as social norm to solve claims problems. To do so, we need therefore to check subjects' perception of the adequacy of the proportional rule as the *right* way of solving claims problems under different frames even when *strategic considerations are totally absent.*

To this aim, we adopted the usual approach applied for resource allocation problems, that is, we asked subjects to answer a questionnaire adopting the perspective of an *outside observer*, rather than being involved in the problem as a *claimant.* This survey methodology is inspired by the seminal paper of Yaari and Bar-Hillel (1984) and is also present in Bar-Hillel and Yaari (1993) and Cuadras-Morató *et al.* (2001), among others.

More specifically, we distributed 120 questionnaires among undergraduate students of the University of Alicante (again, with no prior exposure to bankruptcy or related issues). These students were different from those who were recruited to run the experimental sessions in the lab. In the questionnaire, we proposed six different hypothetical situations in which a certain amount of money had to be allocated among three agents with conflicting claims. By analogy with our experimental design, all six situations referred to the same claims problem (c^{*}, E^{*}). Subjects were asked to select their preferred rule (among *cea*, *p* and *cel*) for each individual problem at stake. The first three situations corresponded to those presented as frames 1-3 in Section 3.2, the remaining three situations are described as follows.[12]

- **Frame 4: Estate division and debts**. Under this frame a man dies leaving an insufficient estate to cover three debts that he contracted. Then, E^* is interpreted as the estate and the vector of claims c^* as the debts contracted with each creditor.

- **Frame 5: Estate division and bequests**. Under this frame a man dies having promised to each of his sons an amount of money. The value of the bequest is not enough however to cover all his promises. Thus, his sons are the claimants now and their claims are the promises their father made to each of them.

- **Frame 6: Taxation**. The problem consists now of collecting a given amount of money (to be understood as a tax) out of a group of three agents, when the gross income of each agent is known. Then, E^* is interpreted as the amount to be collected and c^* as the vector of individual (gross) incomes.

Rules \ Frames	1	2	3	4	5	6
cea	0.06	0.06	0.14	0.15	0.37	0.11
p	0.89	0.69	0.46	0.76	0.61	0.56
cel	0.06	0.25	0.41	0.10	0.02	0.33

(16)

Table 16: Results of the questionnaire

Table 16 summarizes the rules' choices in the questionnaire's responses. Each column denotes the frequency of each of these three rules under the corresponding frame. For instance, in frame 4, 15% of respondents selected the constrained equal awards rule, 76% selected the proportional rule and only 10% of them selected the constrained equal losses rule.

We first observe choices vary depending on the frame. However, here again the proportional rule remains the solution which receives the highest support in all six cases, being the modal choice not only at the aggregate level (as Table 16 shows) but also for 90% of each individual respondent. Furthermore, 15% of them chose the proportional rule in all six cases, whereas no other rule was chosen for every case by any other subject.

If we restrict our attention to the (minoritarian) rules *cea* and *cel*, we observe that they were selected with a rather similar frequency, with a slight bias in favor of *cel* (15% and 19% respectively). More precisely, *cea* and *cel* received identical support under frame 1 (in which claimants are depositors), *cea* was preferred under frames 4 and 5 (the heritage situations), while *cel* was the most preferred rule in the remaining cases. In other words, subjects perceived *cea* more appropriate than *cel* in an estate division context, rather than in heritage or taxation situations, where the preference toward *cel* prevails. It is significant the support received by *cel* under Frames 3 and 6 (Non-governmental organizations and taxation), where 41% and 33% of the responses choose the

[12]See the Appendix for a complete description of the questionnaire.

constrained equal losses rule. The significant support of *cel* under Frame 3 agrees with that obtained by Cuadras-Morató *et al* (2001), in the health care context, where *cel* receives a slightly majoritarian support. This may be in consonance with the idea that *cel* is a solution perceived as fair when claims are related to needs. The support of *cel* under Frame 6 (taxation), also may respond to the idea of income related to needs: people with low income should contribute relatively less, and thus, taxation schemes should be progressive. The relatively large support of *cea* under Frame 5 (37%) may be due to an interpretation of bequests more in line with the Spanish tradition, in which a significant part of the estate is distributed equally among the children.

6 Conclusions

In this paper we made an empirical investigation on social perception of the adequacy of different well known rules to solve claims problems by way of two different and complementary perspectives.

As for our experimental results, we can unambiguously conclude that, when the rules of a procedure are specifically designed to induce a particular (equilibrium rule) behavior, subjects are perfectly able to recognize the underlying incentive structure and select the corresponding equilibrium allocation. In other words, for the three procedures $P_1 - P_3$ employed in the experiment, *the Nash program is completely succesful.*

This evidence is highlighted by the same comments made by subjects participating in the experiment:

- "*In P_3 everything was determined by my own choice.*"[13]

This is far more evident for pivotal players, those who could force the outcome in their favor by selecting their weakly dominant strategies. In this respect, our evidence confirms that compliance with equilibrium is high (in our case, practically full) in normal-form games that are solvable with one round of deletion of weakly dominated strategies [Costa-Gomes *et al.* (2001)].

By stark contrast, in the majority procedure P_0 coordination on the proportional solution overwhelmingly prevails. Furthermore, in this case, framing effects significantly enhance coordination. Simular conclusions can be drawn looking at our survey results. Here again, the proportional rule is the one receiving stronger support both at the aggregate and at the individual levels.

The relevance of this result is twofold. On the one hand, it provides strong support to a single solution to the claims problem, that is, it provides a clear-cut answer to our original question:

the proportional solution is salient in the view of subjects both involved in claims problems as well as for outside observers.

In this respect, it is again interesting to quote some of the explanations provided by subjects on their choice of the proportional rule in P_0:

[13] Debriefing section of Session 7 (unframed). Subject # 4 (player 1).

- *"First, I was trying the way to maximize my payoff, then I realized that this was not possible, since everybody was acting the same way and we were all losing money. So, we settled on an intermediate solution, which was not the best for me, but as not the worst either."*[14]
- "*I took the most equitable choice for the three of us.*" [15]

These two quotes suggest two complementary explanations on the coordinating power of the proportional rule. First, because the proportional rule tends, in general, to favor middle claimants and, therefore, to ease coordination when the choice of the rule is made by majority voting. Nonetheless, this *median voter effect* is probably not the only one acting as a coordination device. As the second quote suggests, the proportional rule may have been selected on social norm grounds if individuals perceived the proportional solution as the *right* solution to claims problems.[16]

Are there any interesting implications from our study to the analysis of real-life situations? So far, many rules in the literature have been defended on the grounds of their ability to capture different notions of fairness, and suggesting that, depending on the situation at stake, these different ideas would better agree with what people would consider as fair [Herrero and Villar (2001)]. Our results, nonetheless, indicate that a wide majority of subjects perceived the proportional solution as a fair way of solving claims problems, irrespective of the claim problem at stake and their own particular (strategic or non-strategic) situation. In this respect, one may wonder whether alternative rules to the proportional should be proposed as socially optimal to solve specific claims problems, or either, the proportional solution should be always considered instead. Further research is required prior to answer this question, but, at least, our results may well be of use in non neglecting a priori the use of the proportional solution to solve any sort of claims problems.

As mentioned in the introduction, this is, to the best of our knowledge, the first empirical study on claims problems mixing experimental evidence and outside observer's positions. Our conclusions clearly state that rational players systematically coordinate on a particular solution that, simultaneously, is the one perceived as the *fair* way of solving the problem. Even taking into account all the specific features of our study (take, for example, the choice of a single claims problem, of the focus on the three-player case) we feel that similar results would emerge under different conditions. In this respect, further research is certainly necessary to confirm the salient position of the proportional rule to solve claims problems derived from this study.

[14] Debriefing section of Session 1 (framed). Subject # 9 (player 3).

[15] Debriefing section of Session 1 (framed). Subject # 10 (player 3).

[16] An additional explanation most likely has to do with the properties the proportional solution enjoys, in particular, its immunity to strategic manipulations. In this respect, de Frutos (1999) has already shown that the proportional rule is the unique rule that meets this condition.

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7 Appendix

7.1 Proof of Proposition 1

In this Section we address the convergence of procedures P_1, P_2 and P_3 when applied to arbitrary rule sets. We show that, for all three procedures, if the process do not terminate in a finite number of stages, then the limit cases is always well defined.

7.1.1 Convergence of P_1

Let $(c, E) \in \mathbb{B}$ be a given problem. Let $r = \left\{r^j\right\}_{j \in N}$ be the profile of rules reported by the agents to solve the problem, where $r^j \in \mathcal{R}$ for all $j \in N$. For the sake of simplicity in the proof we assume that all rules reported are continuous with respect to claims.[17]

Fix $i \in N$ and consider the sequence $\{c_i^k\}_{k \in \mathbb{N}}$, recursively defined as follows:

$$\begin{array}{l} c_i^1 = c_i \\ c_i^{k+1} = \max_{j \in N}\{r_i^j(c^k, E)\}, \text{ for all } k \geq 2. \end{array}$$

Since $r^j \in \mathcal{R}$ for all $j \in N$, it is straightforward to show that $\{c_i^k\}_{k \in \mathbb{N}}$ is weakly decreasing and bounded below by 0. Thus, it is convergent. Let $x_i = \lim_{k \to \infty} c_i^k$ and $x = (x_i)_{i \in N}$. Then, taking limits in the definition of the sequence, we would have

$$x_i = \max_{j \in N}\{\lim_{k \to \infty} r_i^j(c^k, E)\}, \text{ for all } i \in N.$$

Since all rules reported by agents are continuous with respect to claims**,** then

$$x_i = \max_{j \in N}\{r_i^j(x, E)\}, \text{ for all } i \in N.$$

Note that, since $c_1 \geq c_2 \geq ... \geq c_n$, it is straightforward to show that $c_1^k \geq c_2^k \geq ... \geq c_n^k$ for all $k \in \mathbb{N}$, and therefore $x_1 \geq x_2 \geq ... \geq x_n$. Let $j_0 \in N$ be such that $x_1 = \max_{j \in N}\{r_i^j(x, E)\} = r_i^{j_0}(x, E)$. Then, since $r \in \mathcal{R}$,

$$0 = x_1 - r_i^{j_0}(x, E) \geq x_i - r_i^{j_0}(x, E) \geq 0, \text{ for all } i \in N.$$

In other words, $x = r^{j_0}(x, E)$, which implies $\sum x_i = E$. ■

7.1.2 Convergence of P_2

Let $(c, E) \in \mathbb{B}$ be a given problem. Let $r = \left\{r^j\right\}_{j \in N}$ be the profile of rules reported by the agents to solve the problem, where $r^j \in \mathcal{R}$ for all $j \in N$.

For all $i \in N$, consider the sequences $\{(c_i^k, E^k, m_i^k)\}_{k \in \mathbb{N}}$, recursively defined as follows:

$$(c_i^1, E^1, m_i^1) = (c_i, E, p_i(c^1, \frac{E^1}{2}))$$

$$(c_i^{k+1}, E^{k+1}, m_i^{k+1}) = (c_i^k - m_i^k, \frac{E}{2^k}, p_i(c^{k+1}, \frac{E^{k+1}}{2})), \text{ for all } k \geq 1$$

[17] This mild requirement is satisfied by all standard rules in the literature of bankruptcy. In particular, it is satisfied by the three rules that we consider in our experiment.

Now, given $i \in N$ and $K \in \mathbb{N}$ consider $\sum_{k=1}^{K} m_i^k = \sum_{k=1}^{K} p_i(c^k, \frac{E^k}{2})$. It is straightforward to show that

$$\sum_{k=1}^{K} p_i(c^k, \frac{E^k}{2}) = p_i(c, E) - p_i(c^{K+1}, \frac{E}{2^K}).$$

Thus, since p is continuous with respect to both arguments,

$$\sum_{k=1}^{\infty} m_i^k = p_i(c, E) - p_i(\lim_{K\to\infty} c^{K+1}, \lim_{K\to\infty} \frac{E}{2^K}) = p_i(c, E),$$

which proves the convergence. ■

7.1.3 Convergence of P_3

Let $(c, E) \in \mathbb{B}$ be a given problem. Let $r = \{r^j\}_{j\in N}$ be the profile of rules reported by the agents to solve the problem, where $r^j \in \mathcal{R}$ for all $j \in N$.

For all $i \in N$, consider the sequences $\{(c_i^k, E^k, m_i^k)\}_{k\in\mathbb{N}}$, recursively defined as follows:

$$(c_i^1, E^1, m_i^1) = (c_i, E, \min_{j\in N} r_i^j(c^1, E^1))$$

$$(c_i^{k+1}, E^{k+1}, m_i^{k+1}) = (c_i^k - m_i^k, E^k - \sum_{i\in N} m_i^k, \min_{j\in N} r_i^j(c^{k+1}, \frac{E^{k+1}}{2})), \text{ for all } k \geq 1$$

By definition, $m_1^1 = \min_{j\in N} r_1^j(c^1, E^1)$. Since $r^j \in \mathcal{R}$ for all $j \in N$, $r_1^j(c^1, E^1) \geq \frac{E}{n}$. Thus, $m_1^1 \geq \frac{E}{n}$ and therefore $\sum_{i\in N} m_i^1 \geq \frac{E}{n}$.

Now, it is straightforward to show that $c_1^2 \geq c_i^2$ for all $i \in N$. Then, since $r^j \in \mathcal{R}$ for all $j \in N$, then $r_n^j(c^2, E^2) \geq \frac{E^2}{n}$, which implies $\sum_{i\in N} m_i^2 \geq \frac{E^2}{n} = \frac{E}{n} - \frac{\sum_{i\in N} m_i^1}{n}$. By iterating this procedure we have the following:

$E^2 = E - \sum_{i\in N} m_i^1 \leq (1 - \frac{1}{n}) \cdot E$
$E^3 = E - \sum_{i\in N} m_i^2 \leq (1 - \frac{1}{n}) \cdot E^2 \leq (1 - \frac{1}{n})^2 \cdot E$
...
$E^{k+1} = E - \sum_{i\in N} m_i^k \leq (1 - \frac{1}{n}) \cdot E^k \leq ... \leq (1 - \frac{1}{n})^k \cdot E$

Thus, $\lim_{k\to\infty} E^k = 0$. Now, given $K \in \mathbb{N}$ we have

$$\sum_{i=1}^{n}\sum_{k=1}^{K} m_i^k = \sum_{k=1}^{K}\sum_{i=1}^{n} m_i^k = E - E^{K-1}.$$

Thus, $\sum_{i=1}^{n} \lim_{k\to\infty} \sum_{k=1}^{K} m_i^k = \lim_{k\to\infty} \sum_{i=1}^{n}\sum_{k=1}^{K} m_i^k = E$. ■

7.2 The claims problem

All four procedures played in all experimental sessions were constructed upon *the same* claims problem, where $c^* = (49, 46, 5)$ (i.e., $\sum c_i = 100$) and $E^* = 20$. The resulting allocations associated with each rule for this specific problem are the following:

$$\begin{aligned} cel(c^*, E^*) &= (11.5, 8.5, 0), \\ p(c^*, E^*) &= (9.8, 9.2, 1), \\ cea(c^*, E^*) &= (7.5, 7.5, 5). \end{aligned}$$

It is straightforward to show that, for every three-agent problem $(c, E) \in \mathbb{B}$ in which $c_1 \geq c_2 \geq c_3$, we have the following:

$$p_2(c, E) = c_2 \cdot \frac{E}{C},$$

$$cel_2(c, E) = \begin{cases} c_2 - \frac{C-E}{3} & \text{if } c_1 \leq E + 2c_3 - c_2 \\ \frac{c_2 - c_1 + E}{2} & \text{if } E + 2c_3 - c_2 < c_1 < E + c_2 \\ 0 & \text{if } c_1 \geq E + c_2 \end{cases},$$

and

$$cea_2(c, E) = \begin{cases} \frac{E}{3} & \text{if } \frac{E}{3} \leq c_3 \\ \frac{E-c_3}{2} & \text{if } E - 2c_2 < c_3 < \frac{E}{3} \\ c_2 & \text{if } c_3 \geq E - 2c_2 \end{cases}.$$

As we mentioned in the body of the paper, the main motivation for the choice of the particular problem (c^*, E^*) was to provide each claimant with a strictly preferred allocation associated with one of the three rules. This imposes a first restriction on the choice of the problem:

$$p_2(c^*, E^*) > \max\{cel_2(c^*, E^*),\ cea_2(c^*, E^*)\}.$$

We also wanted to avoid a solution in which the two claimants with lower claims receive nothing. This imposes our second restriction:

$$cel_2(c^*, E^*) > 0.$$

It is straightforward to show that both restrictions together imply either

$$(cel_2(c^*, E^*), cea_2(c^*, E^*)) = \left(\frac{c_2^* - c_1^* + E^*}{2}, \frac{E^* - c_3^*}{2}\right), \text{ or}$$

$$(cel_2(c^*, E^*), cea_2(c^*, E^*)) = \left(\frac{c_2^* - c_1^* + E^*}{2}, \frac{E^*}{3}\right).$$

We decided to choose the first one in order to avoid $cea_j = cea_i$ for all $i \neq j$. Altogether says that (c^*, E^*) must satisfy

$$\begin{aligned} E^* - 2c_2^* &< c_3^* < \frac{E^*}{3} \\ E^* + 2c_3^* - c_2^* &< c_1^* < E^* + c_2^* \\ (C^* - 2c_2^*) \cdot E^* &< c_3^* \cdot c^* \\ c_3^* \cdot E^* &< (C^* - E^*) \cdot (c_1^* - c_2^*) \end{aligned}$$

It is straightforward to show that the problem presented above satisfies all these inequalities.

7.3 The experimental instructions

In this section we present the experimental instructions. We only present here the instructions of Session 1 and Session 7. The remaining sessions go along the same lines, except for some differences that are introduced in footnotes.

7.3.1 Instructions of a Framed Session (Session 1)

SCREEN 1: WELCOME TO THE EXPERIMENT

This is an experiment to study how people interact in a bankrupt situation. We are only interested in what people do on average and keep no record at all of how our individual subjects behave. Please do not feel that any particular behavior is expected from you.

On the other hand, keep also in mind that your behavior will affect the sum of money you may win during the course of this experiment.

On the following pages you will find a series of instructions explaining how the experiment works and how to use the computer during the experiment.

HELP: When you are ready to continue, please click on the OK button

SCREEN 2: HOW YOU CAN MAKE MONEY

- You will be playing two sessions of 20 rounds each. In each round, for all sessions, you and other two persons in this room will be assigned to a GROUP. In each round, each person in the group will have to make a decision. Your decision (and the decision of the other two persons in your group) will determine how much money you (and the other) win for that round.
- At the beginning of each round, the computer will select at random the composition of your group.
- Remember that the composition of your group WILL CHANGE AT EVERY ROUND.
- To begin, you will receive 500 pesetas just for participating in this experiment.[18] Moreover, at the beginning of each session, an initial endowment of 1000 pesetas will be given to you.
- Note that the computer has assigned you a number of PLAYER (1, 2 or 3). This number appears at the right of your screen and will represent your type of player. There are three types of players: player 1, player 2 and player 3. Every group will be always composed by three players from different types. Remember that you will be the same type of player along the experiment.
- In each round, you will have to pay some of this money, depending on your action and those of the persons in your group. The sum of the amounts you pay in each round, will be subtracted to your initial endowment and will constitute your TOTAL payoff in this session. Remember that payoffs in this experiment are such that IN ALL CIRCUMSTANCES YOU WILL WIN MONEY.
- At the end of the experiment you will receive the TOTAL sum of money you obtained in each session, **plus the show-up fee of** 500 **pesetas.**[19]

[18] This sentence did not appear in the case of Player 3.

[19] In the case of Player 3: *At the end of the experiment you will receive the TOTAL sum of money you obtained in each session.*

When you are ready to continue, please click on the OK button.

SCREEN 3: THE FIRST GAME (I)

There is *a bank which goes bankrupt.* A judge must decide how its liquidation value should be allocated among the bank's creditors. In this experiment you (and all other persons participating to the experiment) are creditors who go to the court.

In this session, the bank's creditors are all *depositors*,[20] that is, people who have money saved in the bank. You have to come to an agreement with the other depositors in your group on how much of the liquidation value should be given to each of you. Clearly (since the bank has gone bankrupt) the sum of all claims, i.e., the sum of your deposits, is greater than the available liquidation value.

In each round, you need to guarantee as much as possible of your claim, which will determine your loss (the difference between your claim and the amount you receive) in each round. The sum of these losses will be subtracted to your initial endowment and will constitute your TOTAL payoff in this session.

Concerning the problem involving you and the other two persons in your group, your claims and the available liquidation value, are shown in the following table:

PLAYER	CLAIM
1	49
2	46
3	5

The liquidation value is 20.

As you can observe, there is no enough liquidation value to satisfy all claims.

Remember that the player number assigned to you (1, 2 or 3) appears on the computer screen and remains fixed throughout the experiment.

Among the different options on how the liquidation value of the bank should be distributed, the judge has decided that you can only choose among the following *rules:*

1. RULE A*,* that divides the liquidation value equally among the creditors under the condition that no one gets more than her claim. In other words, this rule benefits the agent with the lowest claim.
2. RULE B, that divides the liquidation value proportionally to claims.
3. RULE C, which makes losses as equal as possible, among creditors, subject to the condition that all agents receive something non-negative from the liquidation value. In other words, this rule benefits the agent with the highest claim.

Concerning the problem involving you and the other two persons in your group, the allocations corresponding to each rule are the following:

$$A \equiv (7.5, 7.5, 5)\,;\ B \equiv (9.8, 9.2, 1)\,;\ C \equiv (11.5, 8.5, 0)\,.$$

[20] This is the case of Frame 1. In the case of Frame 2 (3) it is said *shareholders* (*non-governmental organizations which are, at least, partially, supported by the bank*) instead of depositors.

For instance, rule B divides the liquidation value in three parts, assigning 9.8 to player 1, 9.2 to player 2 and 1 to player 3.

Screen 4: The First Game (II)

The structure of the game is as follows:

Your decision, and the decisions of the members of your group will determine the division of the liquidation value, as it is shown in the payoff matrices. Note that if you all agree on the same rule, then the division of the liquidation value is exactly the one you propose.

This is how to read the matrices. There are three tables with nine cells each: player 1 chooses the row, player 2 chooses the column and player 3 chooses the table. Each cell contains three numbers. The first number tells how much money player 1 loses if that cell is selected, the second number tells how much money player 2 loses and the third number tells how much money player 3 loses. For instance, consider the upper left cell. This cell is selected when every player chooses rule A. Therefore, the division of the liquidation value is the one that rule A proposes, i.e., $(7.5, 7.5, 5)$. As a consequence of this, and taking into account the above claims, player 1 loses $7.5 - 49 = -41.5$, which is the first number of that particular cell. Similarly, player 2 loses $7.5 - 46 = -38.5$, and player 3 loses $5 - 5 = 0$.

To summarize,

- You will be playing 20 times with changing components.
- At the beginning of each round, the computer selects your group at random;
- In each round, you and the other two persons in your group must choose one among the three available rules A, B and C. Your choice (and the choices of the other two persons in your group) will determine how much money will be subtracted to your initial endowment, as it is shown in the corresponding table in front of you.

To choose an action, you simply have to click on the corresponding letter. Once you have done that, please confirm your choice by clicking the OK button.

Screen 5: The Second Game.

Now, you are going to play 20 additional rounds of the following game. As before, in this session, the bank's creditors are all *depositors*,[21] that is, people who have money saved in the bank. You can observe from your computer screen that the claims of each player and the liquidation value do not change.

As before, you have to come to an agreement with the other depositors in your group on how much of the liquidation value should be given to each of you. Remember, as before, that 1000 pesetas were assigned to you at the beginning of the session.

[21] This is the case of Frame 1. In the case of Frame 2 (3) it is said *shareholders* (*non-governmental organizations which are, at least, partially, supported by the bank*) instead of depositors.

The instructions are the same as in the previous game with some slight modifications. In each round, as before, you have to choose among rules A, B and C. If you all agree on the same rule, in your group, then the division of the liquidation value is exactly the one you propose. If only two of you agree on a rule then, those who agree get the share proposed by that rule and the creditor who does not agree in the division, not only loses her whole claim, but also pays a fixed penalty of 1 peseta. Finally, if all of you disagree on the proposed shares, then all of you lose your claim and pay the fixed penalty of 1 peseta. The corresponding allocations to each possible situation are shown in the payoff matrices below.

The matrices are read exactly as before. For instance, consider the lower left cell. This cell is selected when players 2 and 3 choose A and player 1 chooses C. In this particular case, player 1 loses $-1-49=-50$, which is the upper number of that particular cell. Similarly, player 2 loses $7.5-46=-38.5$, and player 3 loses $5-5=0$.

To choose an action, you simply have to click on the corresponding letter. Once you have done that, please confirm your choice by clicking the OK button.

7.3.2 Instructions of an Unframed Session (Session 7)

SCREEN 1: WELCOME TO THE EXPERIMENT

This is an experiment to study how people interact. We are only interested in what people do on average and keep no record at all of how our individual subjects behave. Please do not feel that any particular behavior is expected from you.

On the other hand, keep also in mind that your behavior will affect the sum of money you may win during the course of this experiment.

On the following pages you will find a series of instructions explaining how the experiment works and how to use the computer during the experiment.

When you are ready to continue, please click on the OK button

SCREEN 2: HOW YOU CAN MAKE MONEY

- You will be playing four sessions of 20 rounds each. In each round, for all sessions, you and other two persons in this room will be assigned to a GROUP. In each round, each person in the group will have to make a decision. Your decision (and the decision of the other two persons in your group) will determine how much money you (and the other) win for that round.
- At the beginning of each round, the computer will select at random the composition of your group.
- Remember that the composition of your group WILL CHANGE AT EVERY ROUND.
- To begin, you will receive 1000 pesetas just for participating in this experiment.[22] Moreover, at the beginning of each session, an initial endowment of 1000 pesetas will be given to you.

[22] This sentence was not included in the case of Player 3.

- Note that the computer has assigned you a number of PLAYER (1, 2 or 3). This number appears at the right of your screen and will represent your type of player. There are three types of players: player 1, player 2 and player 3. Every group will be always composed by three players from different types. Remember that you will be the same type of player along the experiment.
- In each round, you will have to pay some of this money, depending on your action and those of the persons in your group. The sum of the amounts you pay in each round, will be subtracted to your initial endowment and will constitute your TOTAL payoff in this session. Remember that payoffs in this experiment are such that IN ALL CIRCUMSTANCES YOU WILL WIN MONEY.
- At the end of the experiment you will receive the TOTAL sum of money you obtained in each session, plus the show-up fee of 1000 pesetas.[23]

When you are ready to continue, please click on the OK button.

SCREEN 3: THE FIRST GAME.[24]

At the beginning of each round, the computer will select randomly the composition of your group.

In each round, you and the other two members of your group, must choose among three possible decisions: A, B and C.

Your decision, and the decisions of the members of your group will **determine how** much money you will lose from your initial endowment in this session, as it is shown in the payoff matrices.

This is how to read the matrices. There are three tables with nine cells each: player 1 chooses the row, player 2 chooses the column and player 3 chooses the table. Each cell contains three numbers. The first number tells how much money player 1 loses if that cell is selected, the second number tells how much money player 2 loses and the third number tells how much money player 3 loses.

For instance, consider the lower left cell. This cell is selected when player 1 chooses C and players 2 and 3 choose A. Therefore, player 1 loses -41.5, which is the first number of that particular cell. Similarly, player 2 loses -38.5, and player 3 loses 0.

To summarize,

- You will be playing 20 times with changing components.
- At the beginning of each round, the computer selects your group at random;
- Remember that your player number (1, 2 or 3) will keep constant throughout the experiment.

[23] In the case of Player 3: *At the end of the experiment you will receive the TOTAL sum of money you obtained in each session.*

[24] **This was the third game in Sessions 9 and 10.**

- In each round, you and the other two persons in your group must choose one among the three available rules A, B and C. Your choice (and the choices of the other two persons in your group) will determine how much money will be subtracted to your initial endowment, as it is shown in the corresponding table in front of you.

To choose an action, you simply have to click on the corresponding letter. Once you have done that, please confirm your choice by clicking the OK button.

Screen 4: The Second Game.
Now, you are going to play 20 additional rounds of the following game. The instructions are the same as in the previous game with some slight modifications. The only difference is in the payoff matrices.
For instance, consider the lower left cell. This cell is selected when players 2 and 3 choose A and player 1 chooses C. In this particular case, player 1 loses −39.2, which is the upper number of that particular cell. Similarly, player 2 loses −36.8, and player 3 loses −4.

HELP: To choose an action, you simply have to click on the corresponding letter. Once you have done that, please confirm your choice by clicking the OK button.

Screen 5: The Third Game.[25]
Now, you are going to play 20 additional rounds of the following game. The instructions are the same as in the previous game. The only difference is in the payoff matrices.
For instance, consider the lower left cell. This cell is selected when players 2 and 3 choose A and player 1 chooses C. In this particular case, player 1 loses −37.5, which is the upper number of that particular cell. Similarly, player 2 loses −37.5, and player 3 loses −5.

HELP: To choose an action, you simply have to click on the corresponding letter. Once you have done that, please confirm your choice by clicking the OK button.

Screen 6: The Fourth Game.
Finally, you are going to play 20 additional rounds of the following game. The instructions are the same as in the previous game. The only difference is in the payoff matrices.
For instance, consider the lower left cell. This cell is selected when players 2 and 3 choose A and player 1 chooses C. In this particular case, player 1 loses −50, which is the upper number of that particular cell. Similarly, player 2 loses −38.5, and player 3 loses 0.

HELP: To choose an action, you simply have to click on the corresponding letter. Once you have done that, please confirm your choice by clicking the OK button.

[25] **This was the first game in Sessions 9 and 10.**

7.4 The questionnaire

- *The first problem*

There is *a bank which goes bankrupt.* A judge must decide how its liquidation value should be allocated among the bank's creditors. In this first problem, the bank's creditors are all *depositors*, that is, people who have money saved in the bank. Clearly (since the bank has gone bankrupt) the sum of all claims, i.e., the sum of your deposits, is greater than the available liquidation value. More precisely, the claims and the available liquidation value, are shown in the following table:

CREDITOR	CLAIM
1	49
2	46
3	5

The liquidation value is 20.

Among the different options on how the liquidation value of the bank should be distributed, the judge can only choose among the following *rules:*

1. RULE A*,* that divides the liquidation value equally among the creditors under the condition that no one gets more than her claim. In other words, this rule benefits the agent with the lowest claim.
2. RULE B, that divides the liquidation value proportionally to claims.
3. RULE C, which makes losses as equal as possible, among creditors, subject to the condition that all agents receive something non-negative from the liquidation value. In other words, this rule benefits the agent with the highest claim.

Concerning this problem, the allocations corresponding to each rule are the following:

$$A \equiv (7.5, 7.5, 5)\,;\ B \equiv (9.8, 9.2, 1)\,;\ C \equiv (11.5, 8.5, 0)\,.$$

For instance, rule B divides the liquidation value in three parts, assigning 9.8 to creditor 1, 9.2 to creditor 2 and 1 to creditor 3.

What would be your choice if you were the judge?

- *The second problem*

In the second problem, claimants are all bank *shareholders* instead of depositors.

What would be your choice if you were the judge?

- *The third problem*

In the third problem, claimants are all *non-governmental organizations sponsored by the bank.* Each claimant had signed a contract with the bank, previously to the bankruptcy situation, to receive a contribution according with its social relevance (the higher the social relevance, the higher the contribution). Thus, for instance, *"Doctors without frontiers"* should receive the higher endowment, *"Save the children"* the second highest one, and *"Friends of Real Betis Balompié"* the lowest one. The judge must decide the amount that each one should obtain.

What would be your choice if you were the judge?

- *The fourth problem*

Assume now that a man dies leaving three debts. Let the liquidation value in the table above be the estate that he leaves and the claims be the debts contracted with each creditor.

What would be your choice if you were the judge?

- *The fifth problem*

In the fifth problem, a man dies having promised to each of his sons an amount of money. The value of the bequest is not enough, however, to cover all his promises. Thus, his sons are now the claimants and their claims are the promises the father made to each of them.

What would be your choice if you were the judge?

- *The sixth problem*

In this case, the situation is different. The problem consists now of collecting a given amount of money out of a group of three agents, when the gross income of each agent is known. You can interpret the amount to be collected as a tax. More precisely, individual incomes and the amount to be collected are the following:

AGENT	INCOME
1	49
2	46
3	5

The amount to be collected is 20.

We restrict our attention to three different tax schemes that are the following for this problem at stake:

$$A \equiv (7.5, 7.5, 5)\,;\; B \equiv (9.8, 9.2, 1)\,;\; C \equiv (11.5, 8.5, 0)\,.$$

Each one says the amount that each agent has to pay in order to collect the previous amount. For instance, rule B forces agent 1 to pay 9.8, agent 2 to pay 9.2 and agent 3 to pay 1.

What would be your choice if you were the person in charge of taking the decision?

7.4.1 Payoff tables

A

	A	B	C
A	-41.5 -38.5 0	-41.5 -38.5 0	-41.5 -38.5 0
B	-41.5 -38.5 0	-41.5 -38.5 0	-41.5 -38.5 0
C	-41.5 -38.5 0	-41.5 -38.5 0	-41.5 -38.5 0

B

	A	B	C
A	-41.5 -38.5 0	-41.5 -38.5 0	-41.5 -38.5 0
B	-41.5 -38.5 0	-39.2 -36.8 -4	-38.3 -37.6 -4.1
C	-41.5 -38.5 0	-38.3 -37.6 -4.1	-38.3 -37.6 -4.1

C

	A	B	C
A	-41.5 -38.5 0	-41.5 -38.5 0	-41 -38 0
B	-41.5 -38.5 0	-38.3 -37.6 -4.1	-38 -37 -4
C	-41.5 -38.5 0	-38.3 -37.6 -4.1	-37 -37 -5

Table 2: Procedure P_1

A

	A	B	C
A	-41.5 -38.5 0	-39.2 -36.8 -4	-39.2 -36.8 -4
B	-39.2 -36.8 -4	-39.2 -36.8 -4	-39.2 -36.8 -4
C	-39.2 -36.8 -4	-39.2 -36.8 -4	-39.2 -36.8 -4

B

	A	B	C
A	-39.2 -36.8 -4	-39.2 -36.8 -4	-39.2 -36.8 -4
B	-39.2 -36.8 -4	-39.2 -36.8 -4	-39.2 -36.8 -4
C	-39.2 -36.8 -4	-39.2 -36.8 -4	-39.2 -36.8 -4

C

	A	B	
A	-39.2 -36.8 -4	-39.2 -36.8 -4	-3 -3 $-$
B	-39.2 -36.8 -4	-39.2 -36.8 -4	-3 -3 $-$
C	-39.2 -36.8 -4	-39.2 -36.8 -4	-3 -3 $-$

Table 3: Procedure P_2

A

	A	B	C
A	−41.5 −38.5 0	−39.6 −36.6 −3.7	−37.5 −37.5 −5
B	−39.6 −36.6 −3.7	−39.6 −36.6 −3.7	−37.5 −37.5 −5
C	−37.5 −37.5 −5	−37.5 −37.5 −5	−37.5 −37.5 −5

B

	A	B	C
A	−39.6 −36.6 −3.7	−39.6 −36.6 −3.7	−37.5 −37.5 −5
B	−39.6 −36.6 −3.7	−39.2 −36.8 −4	−37.5 −37.5 −5
C	−37.5 −37.5 −5	−37.5 −37.5 −5	−37.5 −37.5 −5

C

	A	B	
A	−37.5 −37.5 −5	−37.5 −37.5 −5	−3 −3 −
B	−37.5 −37.5 −5	−37.5 −37.5 −5	−3 −3 −
C	−37.5 −37.5 −5	−37.5 −37.5 −5	−3 −3 −

Table 4: PROCEDURE P_3

A

	A	B	C
A	−41.5 −38.5 0	−41.5 −47 0	−41.5 −47 0
B	−50 −38.5 0	−39.2 −36.8 −6	−50 −47 −6
C	−50 −38.5 0	−50 −47 −6	−37.5 −37.5 −6

B

	A	B	C
A	−41.5 −38.5 −6	−50 −36.8 −4	−50 −47 −6
B	−39.2 −47 −4	−39.2 −36.8 −4	−39.2 −47 −4
C	−50 −47 −6	−50 −36.8 −4	−37.5 −37.5 −6

C

	A	B	C
A	−41.5 −38.5 −6	−50 −47 −6	−5 −3 −
B	−50 −47 −6	−39.2 −36.8 −6	−5 −3 −
C	−37.5 −47 −5	−37.5 −47 −5	−3 −3 −

Table 5: PROCEDURE P_0