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Abstract

This paper reports experimental evidence on a stylized labor market. The experiment is designed as a sequence of three treatments. In the last treatment, TR_3, four principals, who face four teams of two agents, compete by offering the agents a contract from a fixed menu. In this menu, each contract is the optimal solution of a (complete information) mechanism design problem where principals face agents' who have *social* (i.e. interdependent) distributional preferences a' la Fehr and Schmidt [19] with a specific parametrization. Each agent selects one of the available contracts offered by the principals (i.e. he "chooses to work" for a principal). Production is determined by the outcome of a simple effort game induced by the chosen contract. In the first two treatments, TR_1 and TR_2, we estimate individual social preference parameters and beliefs in the effort game, respectively.

We find that social preferences are significant determinants of the matching process between labor supply and demand in the market stage, as well as principals' and agents' contract and effort decisions. In addition, we also see that social preferences explain the matching process in the labor market, as agents display a higher propensity to choose to work for a principal with similar distributional preferences.

1 Introduction

Contract theory applied to personnel economics (both in its moral hazard and adverse selection/screening versions) predicts that there should be a substantial amount of inequality of pay within organizations. But the evidence on this is rather disappointing. For example, Baker *et al.* [3] comment that: "Evidence from research on compensation plans indicates that explicit financial rewards in the form of transitory performance-based bonuses seldom account for an important part of a workers compensation." Screening models also perform badly in this respect. Very few companies offer explicit or implicit menus of contracts from which the workers can choose, one of the more robust implications of this kind of models. The recent literature on fairness in game theory and experimental economics (see e.g. the surveys of Fehr-Schmidt [21] and Sobel [31]) has provided one way to explain these facts. Namely, workers have interdependent (inequality-averse) distributional preferences and dislike earning less than their peers. Thus, even a self-interested manager should take this into account when constructing her pay packages and may moderate the use of incentive pay and other forms of unequal payoffs.

This explanation is an important advance, but it is incomplete, as it cannot account, in its simplest form, for a couple of additional empirical observations. First, even if within-firm wage inequality is rarely observed, there is instead ample evidence of large *inter-firm wage differentials* (Card and di Nardo [13]). Second, the same experimental evidence that showed convincingly the existence of interdependent preferences, also showed clearly that individuals widely differ in the way in which their preferences depended on the outcomes of others. It turns out that the two phenomena can be related. Cabrales and Calvó-Armengol [12] show theoretically that if workers care about the pay of others and if they work in close locations, then workers of different abilities will sort into firms at different locations. By the same token, one would expect workers with different distributional concerns would also sort into different companies. One could, in fact, claim that this kind of sorting is a concrete way to capture the concept of "corporate culture" which, despite its importance in the management literature, has often eluded economic theory.[1]

[1]Kreps [24] has made the case that corporate culture serves the purpose of aligning expectations in organizations. See also Crémer [17] and Lazear [25] on other perspectives of corporate culture as shared expectations or information.

The aim of this paper is precisely to test experimentally the idea that workers have heterogeneous distributional preferences, that these matter for the contracts they are offered and choose, and for the way they sort into different firms. With this goal in mind, we design and perform an experiment on a stylized labor market in which there are 4 principals and 4 pairs ("teams") of agents. Principals compete by offering a *contract* from a given set. A contract specifies a pair of monetary rewards, one for each agent, if the team is successful in the assigned *project*. Technology is such that agents can increase the probability of success of the project by performing -independently and simultaneously- a costly action. This probability only depends on the number of agents who put effort, and not on their identity. This technology, which we borrow from Winter [33], is interesting for two reasons related with our motivating idea:

- First, *individual effort is not contractible* (in this sense, benefits are only conditional on the success of the project, and not on each individual effort decision). This mirrors a feature of many real-life situations, and also makes the inter-personal comparisons more focal for our experimental subjects.
- Second, in this environment, as Winter [33] shows, implementing the high effort level as a *unique* equilibrium of the game (this is what we call in the paper the *sini* solution) would require substantially *unequal* payoffs among ex-ante identical agents. On the other hand, implementing the high-effort level as *one of two* pure strategy equilibria (what we call the *wini* solution), does not require inequality. However, in this latter case, the high effort equilibrium is *not robust* to strategic uncertainty.[2]

For the above reasons, this is an ideal environment to see the trade-offs between robustness and fairness considerations: *fairness can be obtained only at the expense of robustness to strategic uncertainty.* Heterogeneity in preferences is a natural way to soften the impact of this dilemma. The less inequality averse agents are quite willing to bear significant inequality in order to avoid the cost of strategic uncertainty. Thus, if firms offer different kinds of contracts (some more unequal but more robust, some less unequal but more robust) workers can sort themselves into firms according

[2]Lopez-Pintado et al. [29] provide experimental evidence for Winter's [33] model.

to their preferences for inequality. Since differential contracts can match better individuals' preferences, the firms can take advantage of the increased welfare to become more attractive for workers (for any given wage bill).

The main finding our study is that *this sorting of principals and agents by their social preferences is indeed what happens in the lab:* agents' probability of selecting a given contract is higher, the lower the distance (in the parameter space) between their estimated preferences and those of the principals they end up working for. Moreover, we also see that, not only the agents, but also principals end up sorting themselves out into "corporate cultures" more in tune with their personalities (i.e. their estimated distributional preferences). Additionally, we observe that *equality is a less important consideration than robustness.* The egalitarian (but not robust) *wini* contract is rarely selected by both principals and agents.and, when it is selected, it often yields the low effort outcome.

To explain how this happens, we need to describe in some more detail the set of contracts from which the principal can choose. Given our setup, the theoretical problem is complex. Since "social preferences" are unlikely to be known, the principal would herself need to offer a menu of contracts to each team. This menu would give agents incentives to perform, respecting at the same time their (possibly heterogeneous) social preferences as much as possible. Such complication seems to us both counterfactual, and too hard to implement in the lab. Instead, we provide principals with a set of available contracts to choose from. *Each one of those contracts* would be optimal if it were common knowledge that the agents had preferences as in Fehr and Schmidt [19] (F&S hereafter) *with some particular parameter values.* We expect, and then corroborate in the data, that the presence of several competing principals acts as a kind of menu of contracts between which the agents sort themselves.

Before subjects face the experimental treatment we just described (TR_3), they had to play two introductory treatments in which we gradually get them accustomed to the experimental conditions of the full-fledged model while estimating, in sequence, individual social utility parameters and beliefs. Precisely:

1. In the first treatment (TR_1), subjects are randomly matched in pair and play a sequence of Dictator Games in which they have to choose among four options, each of which corresponds to a monetary payoff pair (one for them, one for their teammate). The choice set, *which*

changes at every round, corresponds to the (all-effort) equilibrium payoffs of the games they will face later in the following two treatments. We use TR_1 to estimate subjects distributional preference parameters within the realm of F&S'model.[3]

2. In the second treatment (TR_2), subjects are, once again, randomly matched in pair and, again, are asked to choose among four options (within the same choice set and sequencing as in TR_1). However, this time, the choice of an option induces a simple 2x2 game-form which they have then to play, at a subsequent stage. This corresponds to the effort game induced by Winter's [33] technology, given the ruling option (i.e. *contract).* We use this treatment to estimate subjects' beliefs in the effort game as a function of subjects' preferences (estimated in TR_1) and monetary payoffs in the game.

This three-stage experimental design (and the associated estimation strategy) is novel, and it is especially designed to solve the identification problem discussed by Manski [26], which is related to the impossibility to disentangle preference and beliefs parameters when the experiment produces only observations on game outcomes which, supposingly, are the results of the interaction between subjects' preferences and beliefs. As in TR_1 (our Dictator Game), beliefs do not play any role, we use data from TR_1 to estimate individual preference parameters, which we assume determine, together with the beliefs, choices made in TR_2. Under the assumption that preference parameters are constant across treatments, data from TR_2 convey useful information to estimate subjects' belief. This identification strategy exploits the possibility to create ad hoc treatments in the lab to solve the identification problems and, if compared to what recently proposed by Bellemare *et al.* [5], it differs because it does not rely upon hypothetical subjective probability questions to estimate beliefs.

In this respect, our experiment yields the following conclusions. First, subjects display a significant degree of heterogeneity in their decisions (which, in turn, translates into heterogeneity in their estimated distributional preferences and beliefs). This heterogeneity explains, to a large extent, agents' behavior in TR_3. That is, preferences and beliefs which best

[3] When doing this exercise we allow for a larger set of interdependent preferences than Fehr and Schmidt [19]. This will be clear when we describe the set of interdependent preferences below.

explain subjects' behavior in TR_1 and TR_2, typically also explain the contracts they choose among those offered by the different principals in TR_3, together with their subsequent effort decision. More precisely, around 80% of total observations in TR_3 are consistent with the estimated preferences and beliefs of the concerned agents.

The remainder of this paper is arranged as follows. In Section 2, we set up the theoretical model from which we derive the contract set. More precisely, we obtain the optimal *wini* and *sini* mechanisms in our environment for all possible combinations of F&S social preference parameters. In designing these contracts we solve a mechanism design problem that has interesting (and novel) features in itself. In particular, we depart from the existing literature (take, e.g. Itoh [23] or Rey [27]) in two realistic directions. First, we consider the moral hazard problem implicit in Winter's [33] technology (who, on the other hand, does not consider interdependent preferences). Second, we remove the assumption that agents hold identical interdependent preferences. In Section 3 we describe the experimental design and procedures, while in Section 4 we develop an econometric model in which principals and agents' distributional preferences and beliefs are estimated in treatments TR_1 and TR_2 respectively. This information is finally used in TR_3 to study the full-fledged market behavior. Final remarks and guidelines for future research are placed in Section 5, followed by an Appendix containing proofs and experimental instructions.

2 The model

The economic environment we reproduced in the lab has the following features. Within each round t,

1. At Stage 0, Nature moves first, fixing the choice set $C_t = \{b^k\}, k = 1, ..., 4,$, where $b^k = (b_1^k, b_2^k)$ defines *a contract*. By construction, $b_1^k \geq b_2^k$, $\forall k$ (i.e. 1 denotes the identity of the best paid agent, constant to all contracts in C_t). Then, 4 principals (indexed as Player 0) choose, simultaneously and independently, which contract they want to offer for that round.

2. At Stage 1, 8 agents are randomly paired in 4 *teams*, with player position (i.e. benefit ranking) determined randomly. Each agent has to choose her favorite contract within the set $C_t^0 \subseteq C_t$ of contracts

offered by the principals. Once contracts have been chosen by the agents, another random draw selects who is the *Dictator* in the choice of the contract, that is, the agent whose choice determines the ruling contract $b \in C_t^0$ for the pair.

3. At STAGE 2 production takes place and payoffs are distributed, according to a simple effort game-form $G(b)$ induced by the contract b selected by the Dictator. The rules of $G(b)$ are as follows. Each agent i has to decide, simultaneously and independently, whether to make a costly effort. We denote by $\delta_i \in \{0,1\}$ agent i 's effort decision, where $\delta_i = 1(0)$ if agent i does (not) put effort. Let also $\delta = (\delta_1, \delta_2) \in \{0,1\}^2$ denote the action combination taken by the agents. The cost of effort is c and is assumed to be constant across agents. Team activity results in either success or failure. Let $P(\delta)$ define production as the probability of success as a function of the number of agents in the team who have put effort:

$$P(\delta) = \begin{cases} 0 \text{ if } \delta_1 + \delta_2 = 0 \\ \gamma \text{ if } \delta_1 + \delta_2 = 1 \\ 1 \text{ if } \delta_1 + \delta_2 = 2. \end{cases} \tag{1}$$

with $\gamma \in (0, \frac{1}{2})$.[4]

If the project fails, then all (principal and agents) receive a payoff of zero. If the project succeeds, then agent i receives a *benefit*, $b_i > 0$. We shall further assume that both principal and agents are risk-neutral. Then, agent i's expected monetary profit is given by

$$\pi_i(\delta) = P(\delta)b_i - \delta_i c. \tag{2}$$

The expected monetary payoff for the principal is determined by the difference between expected revenues, for a given (randomly generated) value for the project $V \sim U[A, B]$, and expected costs:

$$\pi_0(\delta) = P(\delta)(V - b_1 - b_2).$$

[4]This corresponding to an "increasing return technology", according to Winter's [33] terminology.

2.1 Agents' (interdependent) preferences

We define the following preferences:

Definition 1 (F&S Preferences (FSP)) *According to FSP, agents' preferences are as follows:*

$$u_i(\delta) = \pi_i(\delta) - \alpha_i \max(\pi_j(\delta) - \pi_i(\delta), 0) - \beta_i \max(\pi_i(\delta) - \pi_j(\delta), 0). \quad (3)$$

In what follows, we shall focus on four parametrizations of (3), that we shall employ to analyze the experimental evidence.

Definition 2 (Egoistic Preferences (EP)) *According to EP,* $\alpha_i = \beta_i = 0$.

Definition 3 (Inequality Aversion Preferences (IAP)) *According to IAPs,*

$$0 \geq \alpha_i \geq \beta_i \quad (4)$$
$$0 \leq \beta_i < 1. \quad (5)$$

Following Bazerman *et al.* [4], F&S impose to the model conditions (i)-(ii) which can be rephrased as follows. By condition (i), α_i (i.e. the parameter that measures *envy),* cannot be lower than β_i (i.e. the parameter that measures *guilt*). On the other hand, by condition (ii), guilt is bounded above by 1.

The literature has also focused upon two alternative parametrizations of (3), namely "status seeking" (SSP, see Frank [?]) and "efficiency-seeking" (ESP, see Engelmann and Strobel [18]) preferences. By the former, an increase in the other player's monetary payoff is always disliked, independently of relative positions, by the latter, a reduction in her own payoff is acceptable only if it accompanied by an increase (at least of the same amount) in the other player's payoff.

Definition 4 (Status-Seeking Preferences (SSP)) *According to SSP,*

$$\alpha_i \in [0, 1), \quad (6)$$
$$\beta_i \in (-1, 0], \quad (7)$$
$$|\alpha_i| \geq |\beta_i|. \quad (8)$$

Definition 5 (Efficiency-Seeking Preferences (ESP)) *According to ESP,*

$$\alpha_i \in (-\frac{1}{2}, 0], \tag{9}$$

$$\beta_i \in [0, \frac{1}{2}), \tag{10}$$

$$|\beta_i| \geq |\alpha_i| . \tag{11}$$

Even though F&S only consider IAP preferences, we jointly call (with a slight abuse of notation) F&S Preferences to the four types of preferences described above (EP, IAP, SSP, ESP).

2.2 The mechanism design problem

We are now in the position to specify the mechanism design problem from which we derive the contracts which are available to the principal. Assume a principal who wishes to design a mechanism that induces all agents to exert effort in (some) equilibrium of the game induced by $G(b)$, which we denote by $\Gamma(b)$. A mechanism is an allocation of benefits in case of success, i.e., a vector b that satisfies this property at the minimal cost for the principal.

In this respect, two alternatives routes are possible. Following Winter [33], the principal may consider only mechanisms that *strongly* implement the desired solution, in following sense:

Definition 6 (Strong INI mechanisms) *We say that the mechanism b is strongly effort-inducing (sini) if all Nash Equilibria (NE) of $\Gamma(b)$ entail effort by all agents with minimal benefit distribution.*

If the principal is not particularly worried about the strategic uncertainty induced by the presence of multiple equilibria (precisely, by the existence on an equilibrium in which both agents do not make effort), he may opt for the following (cheaper) alternative, satisfying the following

Definition 7 (Weak INI mechanisms) *We say that the mechanism b is weakly effort-inducing (wini) if there exists at least a NE of $\Gamma(b)$ such that $\delta = (1, 1)$, with minimal benefit distribution.*

2.3 Solving Stage 2

Figure 1 describes the game-form $G(b)$ agents face, once a given benefit profile $b = (b_1, b_2)$ is determined.

	0	1
0	0 0	$\gamma b_2 - c$ γb_1
1	γb_2 $\gamma b_1 - c$	$b_2 - c$ $b_1 - c$

Figure 1. The game-form $G(b)$

By analogy with our experimental conditions (and without loss of generality), we assume $b_1 \geq b_2$. In Figure 2 we provide a graphic sketch of the solutions of the two mechanism design problems, *wini* and *sini,* under the assumptions that both agents share the same "preference type", either IAP, or SSP or ESP, although they may differ in their individual paramters (α_s, β_s), provided they belong to the corresponding preference set. The (rather tedious) details of the $2 \times 3 = 6$ proofs are reported in Appendix A.

Figure 2. Optimal contracts

The two big circles of Figure 2 correspond to the optimal contracts, *wini* and *sini,* when both players hold EPs, whereas the small circles correspond to the contracts actually used in the experiment. Notice that some points lie outside the feasible regions defining the optimal contract space for each preference type: this is because, in some periods, the optimal contracts were derived in the case of subjects' heterogenous preference types and, therefore, their characterization was not covered by any of our propositions, and was evaluated numerically (see Section *Treatments* below for further details).

As Figure 2 shows, *wini* and *sini* optimal contracts cover two disjoint regions of the $b_1 \times b_2$ contract space: *sini* contracts differ from *wini*, essentially, for the fact that player 1 is paid substantially more (while player 2 benefits are more similar across mechanisms). This is because, as we shall explain in Appendix A, in *sini,* player 1's benefit needs to be high enough to make the effort decision a weakly dominant strategy. We also notice that the "*sini* cloud" is somehow more dispersed.

3 Experimental design

In what follows, we describe the features of the experiment in detail.

3.1 Sessions

The experiment was conducted in 3 sessions in May, 2005. A total of 72 students (24 per session) were recruited among the student population of the Universidad de Alicante -mainly, undergraduate students from the Economics Department with no (or very little) prior exposure to game theory.

The 3 experimental sessions were computerized. Instructions were read aloud and we let subjects ask about any doubt they may have had.[5] In all sessions, subjects were divided into two *matching groups* of 12, with subjects from different matching groups never interacting with each other throughout the session.[6]

3.2 Treatments

In each session, subjects played three *treatments,* TR_1 to TR_3, of increasing complexity, for a total 72 rounds (24 rounds per treatment). This was done to gradually introduce subjects to the strategic complexity of the market environment and to estimate, in TR_1 and TR_2, subjects' preferences and beliefs, respectively.

In any given treatment, matching group and round, team composition was randomly determined. Within each treatment and for each round t, the choice set $C_t = \{b^k\}, k = 1, ...4$, where $b^k \equiv (b_1^k, b_2^k)$, was drawn at random, but not uniformly. Let us explain in more detail how this choice was determined.

- Each contract b^k in the set C_t is the optimal solution of one mechanism design problem, either *wini* or *sini*, for some given randomly generated preference profile $\left((\alpha_1^k, \beta_1^k), (\alpha_2^k, \beta_2^k)\right)$.

[5] The experiment was programmed and conducted with the software z-Tree (Fischbacher [22]). The complete set of instructions, translated into English, can be found in Appendix B.

[6] Given this design feature, we shall read the data under the assumprion that the history of each cohort (6 in total) corresponds to an independent observation of the corresponding mechanism.

- Depending on the round t, the choice set C_t could be composed of

  1. 4 *wini* contracts generated from 4 different preference profiles. These rounds are labeled as *wini* in Figure 2.
  2. 4 *sini* contracts generated from 4 different preference profiles These rounds are labeled as *sini* in Figure 2.
  3. 2 *wini* and 2 *sini* generated by two different preference profiles. These rounds are labeled as *mix* in Figure 2.

- We will group rounds into *time intervals*. A time interval is defined as a group of three consecutive rounds (starting at 1), and indexed by p so that round $\tau_p = \{3(p-1) < t \leq 3p\}$, is part of time interval $p = 1, ..., 8$. Within each time interval τ_p, subjects experienced each and every possible situation, 1. 2. or 3., and the sequence selected within each time interval was generated randomly. We did so to keep under control the time distance between two rounds characterized by the same situation.

- Player position (either player 1 or player 2) was also chosen randomly, for each team and round. This implies that, in the choice of contracts agents faced in each round, the player position (either the higher paid agent 1, or the lower paid agent 2) was common to all contracts.

- Finally, we also fixed in a deterministic fashion the sequence of preference "types" (IAP, SSP and ESP) used to derive the optimal contracts. The actual sequence of rounds, common to all matching groups and sessions, is reported in Figure 3. In the figure, the rounds when only IAP (respectively SSP, ESP) preferences are used for generating contracts are labeled as IAP (respectively SSP, ESP). Also the periods when two different types of preferences were used to generate contracts are denoted by MIX in Figure 3.

Fig. 3. Sequence of mechanisms

We now describe in detail the specific features of each treatment, TR_1, TR_2 and TR_3.

3.2.1 TR_1 : Dictator Game (24 rounds)

We use the classic protocol of the Dictator Game, to collect our subjects distributional preferences without any interference with any strategic consideration. The timing for each round and cohort is as follows:

1. At the beginning of the round, six pairs are formed at random. Within each pair, another (independent and uniformly distributed) random device determines player position.

2. Then, each agent, having been informed of her player position in the pair (common to all contracts), selects her favorite contract within C_t, the pool of 4 options available for that round.

3. Once choices are made, another independent draw fixes the identity of the *Dictator* (for that couple and round). Let $\hat{k}$ denote the ruling contract (for that couple and round) corresponding to the Dictator's choice.

4. Monetary consequences are as follows $\pi_i = b_i^{\hat{k}} - c$ (i.e. subjects receive the corresponding equilibrium payoffs of the induced effort game $G(b^{\hat{k}})$).

3.2.2 TR_2 : Effort Game (24 rounds)

Phases 1 to 3 are identical to those of TR_1. Instead of Phase 4, we have

4.1 Subjects play the effort game $G(b^{\hat{k}})$.

4.2 Monetary payoff are distributed according to the payoff matrix of Figure 1.

3.2.3 TR_3 : The Market (24 rounds)

This is the treatment described in the introduction. At the beginning of TR_3, within each matching group, 4 subjects are randomly chosen to play as principals throughout the treatment. Then, in each round t, these 4 principals have to select one contract C_t to offer to the 4 teams in their matching group. We denoted by $C_t^0 \subseteq C_t$ the set of contracts offered by at least one principal (this set may be a singleton, since contracts offered by the principals may all coincide, as it actually happened sometime during the experiment).Agents have then to choose within this subset C_t^0. Phases 2-4.2 are then identical to TR_2.

3.3 Payoffs

In treatment TR_2 and TR_3 subjects always received, as monetary reward, their expected payoff, given the strategy profile selected in the effort game $G(b)$. This was to make the experimental environment closer to the model's assumption of risk neutrality.

All monetary payoffs in the experiment were expressed in Spanish Pesetas (1 euro is approx. 166 ptas.).[7] As for their financial rewards, subjects received 1.000 ptas. just to show up. Monetary payoffs in the experiment (in ptas.) were calculated by fixing $c = 10$ $\gamma = \frac{1}{4}$,$A = 100$ and $B = 125$ (i.e. $V \sim U[100, 125]$). Average earnings were about 21 euros, for an approximately 90-minute experiment.

3.4 Three (testable) questions from the theory

We are now in the position to specify the main objectives of our experiment:

Q1. *Do the F&S preferences work?* That is, does the model provide a reliable framework to predict principals and agents' behavior? Evidence for this in Remarks 1 and 2.

Q2. *wini or sini?* Remember that optimal contracts had been calculated by using two different mechanism design strategies, which we denoted by *wini* and *sini*, with rather different distributional consequences. Two kinds of questions arise here.

[7] It is standard practice, for all experiments run in Alicante, to use Spanish ptas. as experimental currency. The reason for this design choice is twofold. First, it mitigates integer problems, compared with other currencies (USD or Euros, for example). On the other hand, although Spanish pesetas are no longer in use (substituted by the Euro in the year 2000), Spanish people still use Pesetas to express monetary values in their everyday life. In this respect, by using a "real" (as a opposed to an artificial) currency, we avoid the problem of framing the incentive structure of the experiment using a scale (e.g. "Experimental Currency") with no cognitive content.

Q2.1. Which contract type (*wini* or *sini*) induces more effort, and which one is chosen more often by principals and agents? Evidence for this in Remark 3.

Q2.2. *What is the role of strategic uncertainty?* That is, to which extent does the (non) existence of multiple equilibria in *wini* (*sini*) affect agents' behavior in the effort game. Evidence for this in Remark 4

Finally, our key question:

Q3. *Does separation emerge?* In other words, is the market able to sort (principals and) agents according to their distributional preferences? Evidence for this in Remark 5.

4 Results

In this Section, we shall first set up an econometric model by which we directly estimate

1. F&S individual preference parameters using data from TR_1
2. Agents' beliefs in the effort game using data from TR_2.

Once the experimental evidence is framed in the context of F&S's model, we will answer our testable questions.

4.1 TR_1: estimating (individual) social preferences

As we already noted, in our Dictator Game (TR_1), agents receive the (all effort) equilibrium payoff corresponding to the plan chosen by the dictator. In each round t, let L_{st} be a dummy variable which is equal to 1 if subject s is the lower paid agent- and zero otherwise. Assuming that each subject s is characterized by her own parameters α_s and β_s, her utility from choosing contract k at round t can be written as

$$u_{st}^k = (1 - L_{st}) \left[\pi_{1t}^k - \beta_s \left(\pi_{1t}^k - \pi_{2t}^k\right)\right] + L_{st} \left[\pi_{2t}^k - \alpha_s \left(\pi_{1t}^k - \pi_{2t}^k\right)\right] + \varepsilon_{st}^k$$

According to this notation, subject s chooses contract k at round t if

$$u_{st}^k = \max \left(u_{st}^1, \ldots, u_{st}^4\right)$$

(remember that 4 contracts are available each round). Under the assumption that the stochastic term ε_{st}^k is iid with an extreme value distribution, the probability that individual s chooses the contract k at round t is therefore

$$\begin{aligned} & \Pr\left(y_{stk}=1|\pi_1(.),\pi_2(.)\right) \\ = & \frac{\exp\left((1-L_{st})\left[\pi_{1t}^k-\beta_s\left(\pi_{1t}^k-\pi_{2t}^k\right)\right]+L_{st}\left[\pi_{2t}^k-\alpha_s\left(\pi_{1t}^k-\pi_{2t}^k\right)\right]\right)}{\sum_{k=1}^4\exp\left((1-L_{st})\left[\pi_{1t}^k-\beta_s\left(\pi_{1t}^k-\pi_{2t}^k\right)\right]+L_{st}\left[\pi_{2t}^k-\alpha_s\left(\pi_{1t}^k-\pi_{2t}^k\right)\right]\right)} \end{aligned} \tag{12}$$

Note that we allow for parameter heterogeneity across subjects. Thus, the iid assumption does not stem from neglected individual unobserved heterogeneity, and it is consistent with the random order of the four contracts in the choice set C_t. In Figure 4 we plot the estimated α_s and β_s of our subject pool.

Fig. 4. Estimating individual social preferences

Figure 4 plots the estimated social preferences for our subject pool. Figure 4 is composed of two different graphs:

1. *In Figure 4a) each subject corresponds to a point in the* (α, β) *space,* where we highlight the regions corresponding to the taxonomy presented in Section 2.1. As Figure 4 *a)* makes clear, our subjects display significant heterogeneity in their distributional preferences. Moreiver, in many cases, the constraints on absolute values (in particular, in the case of IAP) are violated. This is the reson why, in what follows, we shall refer to the corresponding quadrant in Figure 4a) to identify each distributional preference type. In this respect, the majority of subjects falls in the first quadrant (i.e. in the IAP case), followed by SSP and ESP. Finally 10% of our subject pool displays both α and β negative (a case not covered by the theoretical literature on these matters).

2. *Figure 4b) reports, together with each estimated* (α, β) *pair (as in Figure 4a), the corresponding 90% confidence intervals associated to each individual estimated parameter.* As Figure 4*b*) shows, we have now many subjects whose estimated distributional preferences fall, with nonnegligible probability, in more than one region. Moreover,

for some of them (about 20% of our subject pool), we cannot reject (at the 10% confidence level) the null hypothesis of egoistic preferences.

We have two alternatives ways to summarize our results on subjects' preference heterogeneity.

A. First, we can partition our subject pool, *assigning each subject to the quadrant (Q_1 to Q_4) in which their estimated parameters are most likely to fall.* At the same time, we group in an additional "EP" category those subjects s whose estimated α_s and β_s are jointly not significantly different from zero (at the 10% confidence level). Following this approach, Figure 5*a)* assigns each experimental subject (principals and agents) to the corresponding "distributional preference type".

   Fig. 5. Partitioning principals and agents into distributional "types"

   As for many subjects falling in quadrant Q_1 (i.e. the IAP region) in Figure 4, the estimated α and β are in fact not significantly different than zero, the biggest group in Figure 5*a)* is that of Q_4 (i.e ESP: 29.17% of the total), followed by Q_2 (SSP: 22.22%).

B. Alternatively, *we can compute the probability that a randomly drawn subject in the pool is characterized by a pair (α_s, β_s) belonging to one of the four quadrants.* This is the purpose of Figure 5b), in which these probabilities are calculated by averaging out the corresponding individual probabilities of the entire subject pool (disaggregated between principals and agents). Notice that, EPs do not appear in Figure 5b) since, by definition, egoistic preferences have zero mass in our preference space. As a consequence, in Figure 5b), IAP (Q_1) turns out to be the most represented group (36% of total probability mass), followed by ESP (Q_4) and SSP (Q_2), with almost the same representation (26% and 24% respectively).

Finally, we can compare these results with those we obtain by estimating distributional preferences of a "representative subject", i.e. by estimating the distributional preferences of our pool under the constraint that α_s and β_s are constant across s. In this case, estimated parameters of α and β would be .104 and .436 respectively (with standard deviations equal to 0.018 and 0.065).

The "representative agent" displays IAP distributional preferences in which guilt predominates over envy, a case not usually considered by the theoretical literature on social preferences.

4.2 TR_2: Estimating beliefs

In this Section, we look at agents' effort decisions in TR_2 as the result of a process of expected utility maximization. Assuming that distributional preferences are constant across treatments (i.e. that we can use each subject's (α_s, β_s) pair to parameterize her F&S utility function), the effort decision (partially) reveals each individual's subjective belief over the teammate's effort decision. We condition these beliefs on player position, monetary payoffs and estimated preferences, obtaining (by pseudo maximum likelihood) subjective beliefs as a polynomial functions of α and β.

With this aim in mind, we set up the maximization problem facing each player at the time of selecting her effort decision. For notational convenience, in what follows we drop the round index (t) . For each plan k, the utility function of the subject s in player position i is

$$u_{si}^k(\delta) = \pi_i^k(\delta) - \alpha_s \max\left(\pi_j^k(\delta) - \pi_i^k(\delta), 0\right) - \beta_s \max\left(\pi_i^k(\delta) - \pi_j^k(\delta), 0\right) + \varepsilon_{si}^k$$

where $\delta = (\delta_1, \delta_2)$, δ_i equals 1 if player i makes the effort, 0 otherwise. Given the plan k chosen by the dictator in the first round of TR_2

$$\delta_i^k = \mathbf{1}\left(u_{si}^k\left((1, \lambda_{is}^k)\right) > u_{si}^k\left((0, \lambda_{is}^k)\right)\right)$$

where λ_{is}^k is subject s expectation on her teammate effort choice in plan k. We parametrize λ_{is}^k as a logistic function of the subject characteristics (α_s, β_s), her player position and of the plan characteristics $\left(b_{1t}^k, b_{2t}^k\right)$

$$\lambda_{is}^k = \frac{\exp\left(\psi_{i1} b_i^k + \psi_{i2}(b_i^k - b_j^k) + \psi_{i3}\alpha_s + \psi_{i4}\beta_s\right)}{1 + \exp\left(\psi_{i1} b_i^k + \psi_{i2}(b_i^k - b_j^k) + \psi_{i3}\alpha_s + \psi_{i4}\beta_s\right)}$$

and assume that ε_{si}^k is such that

$$\begin{aligned} &\Pr\left(\delta_{is}^k = 1 | \alpha_s, \beta_s, i, \left(b_1^k, b_2^k\right)\right) \\ = &\frac{\exp\left(E_{\lambda_{is}^k}\left(u_{is}^k(1)\right)\right)}{\exp\left(E_{\lambda_{is}^k}\left(u_{is}^k(1)\right)\right) + \exp\left(E_{\lambda_{is}^k}\left(u_{is}^k(0)\right)\right)} \end{aligned} \tag{13}$$

We estimate the parameters of interest $\psi_i = (\psi_{i1}, \psi_{i2}, \psi_{i3}, \psi_{i4})$, $i = 1, 2$ by maximizing the pseudo-log-likelihood function. In fact, we do not observe (α_s, β_s), but we do have a consistent estimate of it $\left(\widehat{\alpha}_s, \widehat{\beta}_s\right)$ for all the subjects. Therefore the standard PML estimate of the covariance matrix $Var\left(\widehat{\psi}_i\right)$ is not consistent. To solve the problem we use TR_1 to obtain $N = 400$ bootstrap estimates of (α_s, β_s) for each of the 72 subjects and use them to obtain the boostrap distribution of $\widehat{\psi}_i$ at the second stage TR_2. Figure 6 reports the estimated values of $\widehat{\psi}_i$, their bootstrap standard error and the bias-corrected 95% confidence intervals.[8]

Player 1				
	Coeff.	**Std.err.**	**95% C.I.**	
ψ_1	.02499448	.00309576	.0214083	.0384497
ψ_2	-.0179758	00742303	-.0315004	-.0105376
$\psi_3\,(\alpha)$	.5542855	.25811632	.4046881	.9084173
$\psi_4\,(\beta)$	-1.1180877	.33475749	-1.987688	-1.021415

Player 2				
	Coeff.	**Std.err.**	**95% C.I.**	
ψ_1	.055668	.03092808	.0219957	.0867382
ψ_2	.1185161	.11056904	-.0228495	.3816541
$\psi_3\,(\alpha)$	.817708	2.8946111	-1.226787	5.478475
$\psi_4\,(\beta)$	-4.760476	2.4623682	-16.81285	-2.35411

Figure 6. Estimating subjective beliefs

Notice that, for both player positions estimated ψ_1 is positive and significant. That is, the higher is their own b_i the more the individuals expect their teammates to make effort. On the other hand estimated $\psi_4\,(\beta)$ are both negative: subjects with higher β are more pessimistic with respect to their teammates willingness to cooperate. When subjects play as Player 1, they worry about monetary payoff differences, and they expect their (unlucky) teammates to reduce their effort when the gap increase. Finally, more envious (higher α) Players 1 expect their teammates to cooperate.

[8] Due to convergency problem at the second stage of the bootstrap procedure, N=382 for the case of Player 2.

4.3 $Q1$. Does F&S work?

Before we check on how subjects' decisions in TR_3 are consistent with their estimated preferences and beliefs, let us remind that the model of Section 2 only provides a suitable framework to predict *agents*' decisions. This is because, as we already discussed, to fully describe principals' decision problem, one should consider *a)* competition among principals and *b)* incomplete information about agents' (and other competing principals) preferences.

On the other hand, once we provide agents with beliefs about their teammate's action in the effort game, we can fully characterize the agents' decision problem. As a consequence, we provide a unique prediction about the agents' modal choice.[9] In this respect, Figure 7 reports the relative frequencies with which agents acted so as to maximize their expected utility, subject to their estimated preference parameters (α_s, β_s) and their subjective beliefs evaluated by (12) and (13) respectively.

Fig. 7. Relative frequencies of agents' consistent decisions in TR_3

In Figure 7, the relative frequencies of consistent decisions are calculated as follows:

1. We begin by evaluating, for each round and subject, her optimal effort decision (conditional on her individual estimated parameters α_s and β_s, her current player position i, and estimated subjective beliefs), for all the contracts offered by the principals;

2. We then compare, in Figure 7*a)*, agents' actual decisions in TR_3 with their theoretical best-replies, highlighting in grey the relative frequency of effort decisions which correspond to the best-reply of the effort game selected by the Dictator;

3. The expected payoff of the optimal effort decision corresponds to the *value* associated to each available contract. In Figure 7*b)* we again compare actual and optimal contract choices, highlighting in grey the relative frequency of contract choices which maximize each subject's value.

[9] Remember that we work under the maintained assumption of a random utility framework. Thus, in principle, all actions are consistent with the model, albeit with different probabilities.

Remark 1 *Estimated preferences and beliefs explain about 80% of observed agents' choices.*

As Figure 7*a)* shows, for both player positions, the relative frequency of "optimal" effort decisions always exceeds 3/4 of total observations. As for non-optimal effort choices, player 1 is more likely not to put effort when it should do it otherwise, exactly the reverse than what happens with player 2. As for the contract choice, again, optimal decisions correspond, for both player positions, to more than 4/5 of total observations.

To summarize, in analyzing our TR_3 market dynamics, we find that *a)* subjects' distributional preferences provide a consistent framework to explain the (heterogeneous) composition of the contract supply, as well as *b)* contract demand and effort decisions.

As for principals' decisions, as we already know, a direct prediction is not available. The exercise here will then be to see how principals' estimated beliefs and preferences explain their contract decision, with respect to the two dimensions which are more natural for the problem at stake. That is, *a)* the total cost of the contract $(b_1 + b_2)$ and, *b)* its induced inequality $(b_1 - b_2)$.

As we know from Section 3, agents and principals were facing, in all treatments, the same sequence of choice sets along the 24 rounds, randomly selected following the balanced design of Figure 2. In this respect, we define, for each choice set C_t (i.e. for any round t), the following two variables:

$$\begin{aligned} \sigma &= \frac{\left(b_1^{\bar{k}} - b_2^{\bar{k}}\right) - \min_k \left(b_1^k - b_2^k\right)}{\max_k \left(b_1^k - b_2^k\right) - \min_k \left(b_1^k - b_2^k\right)}, k = 1, ..., 4; \\ \tau &= \frac{\left(b_1^{\bar{k}} + b_2^{\bar{k}}\right) - \min_k [b_1^k + b_2^k]}{\max_k [b_1^k + b_2^k] - \min_k [b_1^k + b_2^k]}, k = 1, ..., 4, \end{aligned} \tag{14}$$

where $\bar{k} \in \{1, 2, 3, 4\}$ denotes the contract selected by the principal in round t. By (14), we normalize players' benefits and costs, together with the induced inequality each contract implies, with respect to the choice set C_t. In other words, by choosing a contract for which $\tau = 1$, a principal goes for the option that, within the choice set available for that round, maximizes the total contract cost. By the same token, by selecting the contract by which $\sigma = 0$, (horizontal) inequality is minimized.

Figure 8 reports the estimates of four different (tobit) regressions, which share the same structure:

$$y_{st} = \vartheta_0 + \vartheta_1\alpha_s + \vartheta_2\beta_s + \vartheta_3 V_{st} + \vartheta_3 x_{st} + \vartheta_t + \varepsilon_s + v_{st}. \qquad (15)$$

The four regressions differ with respect to the dependent variable y_{st} under consideration. In regression I the dependent variable is τ_{st}, that is the variable we defined in (14) to measure the total contract cost relative to the available alternatives in C_t. In regression II, the dependent variable is instead $\theta_{st} = \frac{1+\sigma_{st}}{1+\tau_{st}}$, a proxy of the trade off principals face between the (horizontal) induced inequality and total contract costs. Equations Ia and IIa use, as dependent variables, $E(\tau_{st}\,|\mu)$ and $E(\frac{1+E(\sigma_{st})}{1+E(\tau_{st})}\,|\mu)$ respectively, that is the corresponding values of τ_{0st} and θ_{0st} conditional on the principals' beliefs (13). In the four regressions, the corresponding dependent variable y_{0st} is assumed to be a linear function of the subject's preference parameters (α_s, β_s) and the (randomly generated) value for the principal V_{st}. A set of round specific dummy variables x_{st} are used to control for the heterogeneity of the choice sets across rounds, as well as to control for matching group and for mechanism and preference profile for the choice set C_t, as derived from Figure 2. An individual time invariant (random) effect takes into account the unobserved individual heterogeneity. Assuming normality of the random components ε_s and v_{st} of equation (15) and strict exogeneity of the covariates, the parameters of interest can be estimated using a MLE for a double-censored tobit model for panel data. θ_0 is in fact bounded between 0 and 1 (regressions I and Ia) or 1/2 and 2 (regressions II and IIa). In Figure 8 we report the estimated values for ϑ_1 to ϑ_3.[10]

Fig. 8. Social preferences and contract choices (Principals)

Remark 2 *Beliefs and preferences parameters estimated in TR_1 and TR_2 account well for the Principals' observed choices.*

As Figure 8 shows, principals characterized by higher α_s and β_s (i.e. higher distributional concerns) tend to choose more expensive contracts, as the corresponding coefficients in regressions I and Ia are always positive

[10]The estimated coefficients for ϑ_0, ϑ_4 and ϑ_t are omitted in Figure 15, but available upon request.

and significant. The same conclusion holds both if we look at contracts face values (Regression I), or if we consider expected total costs, given our estimated system of subjective beliefs (Regression Ia). Analogous considerations hold when we consider the trade-off between induced inequality and total contract costs (Regressions II and IIa): the higher α_s and β_s, the lower relative inequality, as the corresponding coefficients are always negative (and significant, with the exception of β_s in equation IIa). In other words, our estimates suggest that principals' choices vary with the parameters of the F&S utility function: the more the principal is sensitive to envy and guilt, the more egalitarian (both with respect to "horizontal" as well as "vertical" inequality) is the contract offered to the workers. On the other hand, conditional on the characteristics of the choice set and on the preference parameters, the project value V_{st} does not seem to play a relevant role.

4.4 *Q2.* **wini or sini?**

We now move into the mechanism design issue, analyzing subjects' revealed preferences over the type of contract, *wini* or *sini*. As we just explained in Section 3, in 8 out of 24 rounds t, evenly distributed across the timeline, agents and principals had to choose between two optimal *wini* and two optimal *sini* contracts, built upon the same pair of preference parameters. Figure 9 uses the information drawn from this subsample of observations to discuss more in detail the choice of mechanism, tracing the relative frequency of subjects' choosing a *sini* contract in the 8 rounds in which both types of contracts were available.

Fig. 9. Choice between *wini* and *sini* in the "mix" rounds

Remark 3 *sini is the most frequent choice for all players and treatments.*

In Figure 9, relative frequencies of choices are disaggregated for player position and "preference type" as in fig. 5a). As Figure 9 shows, in all treatments, *sini* is, by far, the most popular choice, and this is particularly true for Player 1. As for principals, they also display a higher preference for *sini*, even though choice frequencies are much closer to those of the least advantaged Players 2.

We now move to analyze the agents' effort decisions in TR_2 and TR_3 . Figure 10 reports the relative frequency of effort choices disaggregated, once again, for player position and preference type.

Fig. 10. Relative frequencies of effort decisions

Not surprisingly, player 1 has a higher tendency to put effort, independently of her player type. This difference is much higher in *sini* (where her benefit in case of success is substantially higher): it is double the one in *wini* (38% vs. 19%). Difference in effort across player position is particularly strong in the case of Q_2 (SSP) subjects in TR_2 (while in TR_3 it converges to a value which is comparable to the other preference types). Apart from the case of SSP, effort frequencies of each preference group are basically constant across treatments.

We now look at the extent to which individual effort decisions affect aggregate outcomes (i.e. effort profiles). In Figure 11, we highlight in grey the strategy profiles which correspond to a Nash equilibrium of the corresponding mechanism.

Fig. 11. Outcome dynamics in the effort game

Remark 4 *Effort is much higher in sini that in wini.*

As Figure 11 shows, relative frequencies of the efficient (all-effort) equilibrium are about twice larger in *sini* than in *wini*. In *wini*, the inefficient (no-effort) equilibrium pools more than 1/3 of total observations (and it is, for both TR_2 and TR_3, played more frequently than the efficient equilibrium). Also notice that about 30% of total observations correspond to a (non-equilibrium) strategy profile in which only one agent puts effort. While this frequency stays basically constant over treatments and mechanisms, it is quite remarkable that the identity of the working agent crucially depends on the mechanism being played (either *wini* or *sini*): in *sini* the relative frequency of outcomes in which Agent 2 puts effort never exceeds 3% while, in *wini*, this frequency is five times bigger. This is probably due to the strategic uncertainty created by the existence of multiple equilibria in *wini* (strategic uncertainty which affects both agents).

To summarize, *sini* induces a relative frequency of equilibrium outcomes which is twice as much as in *wini*. In this respect, if we look at the mechanism design problem from the principal's viewpoint, our evidence yields a clear preference for the "*sini* program": despite its being more expensive (since the sum of benefits to be distributed is higher), the difference in average team effort is sufficient to compensate the difference in cost. In addition, in the "mixed" rounds of TR_3, principals offering *sini* contracts were selected by agents with a much higher frequency. As a consequence, average profits for a principal when offering a *sini* contract in the "mixed" rounds was substantially higher, three times as much as the corresponding profits when offering a *wini* contract (95.4 ptas. *vs.* 30.1).

4.5 $Q3$. Does separation emerge?

We finally look at the separation issue. To this aim, we measure the correlation between the (euclidean) distance -in the (α_s, β_s) space$-$ between agents' and principals estimated preferences (within the same matching group) and the the number of times agents accepted the contract offered by the principals. As it turns out, the correlation is negative (-.3967) and significant at any conceivable confidence level. Things do not change if we normalize distances in the [0,1] interval, 0 (1) being the smallest (largest) difference between any agent and any principal belonging to the same matching group. This normalization controls for the fact that the distance between the pools of agents and principals can substantially differ across matching groups. In this case, the estimated correlation coefficient is smaller (-.2694), but it still remains highly significant ($p = .0002$). If we further disaggregate the analysis, by normalizing the distance between each agent and the 4 principals of her matching group, the result, again, does not change in its essence: the estimated correlation coefficient is -.248, with $p = .0005$. This evidence justifies the following final

Remark 5 *Agents are more likely to choose a contract offered by a principal with more similar distributional preferences to her own.*

5 Conclusion

Our experimental results are encouraging for our research program for, at least, two reasons. First, because it provides evidence on the fact that distributional preferences may be at the core of how market sorts different attitudes towards distributional issues into different organizational cultures. The model is certainly ad-hoc in many respects (take, for example, our decision to give to only one agent the monopolistic power to decide the ruling contract for the entire team). Nevertheless, our experimental results are encouraging, on the ground that such a parsimonious model of individual decision making is capable of organizing consistently the evidence from such a complex experimental environment.

In this respect F&S's model seems to pass our "empirical examination". Given that principals face a more complex strategic environment, since they compete with other principals to attract agents, the stability of social preferences (and beliefs) across quite different environments is a positive piece of news for the research program in interdependent preferences. It is true that the literature has already discussed the ability of different models to explain quite diverse data sets (see e.g. Fehr and Schmidt [21]). But, to the best of our knowledge, this discussion has been done by showing that the same distribution of parameters that explains behavior in experiment A, also explains behavior in experiment B with a different subject pool. While this is suggestive, it does not go far enough. Since individuals in experiments A and B are different, it is possible that a subject that appeared to be highly fair-minded in experiment A, would have given the opposite appearance had she participated in experiment B. This kind of observation, by the way, would not necessarily mean that the subjects preferences shifted from one experiment to the other. It would also be consistent with having estimated a misspecified model for preferences. Our experiments provide a more definitive test, by following subjects' choices (with particular reference to principals' decisions), and showing their consistency with F&S' preferences, across rather different tasks.

We conclude by discussing three possible avenues for future research.

From a theoretical standpoint, it would be interesting to solve completely the mechanism design problem under incomplete information about the social preferences of the agent. The menus of contracts available to agents, possibly through the market via firms with different "corporate cultures" as in our experiment, could have a theoretically interesting structure.

From an empirical point of view, it would be interesting to observe the effect of having agents of different productivities, which are also private information. In this way we could see how finely and in which ways "corporate culture" partitions the agents. Also, notice that, in our setup, the numbers of principals and agents exactly balance one another. Thus, the effect of more intense competition on the side of either principals or agents is an empirically interesting extension.

Finally, we also would like to check the extent to which agents' decisions (and, consequently, the estimated distributional preferences which derive from these decisions) depend on whether the choice of the optimal contract is made *before* or *after* agents' are told about their player position in the game. If agents choose the contract before knowing their relative position within the team (i.e. "under the veil of ignorance"), their decisions may also reflect individuals' attitude to risk, as well as distributional considerations. This exercise would require to collect additional information about our experimental subjects on these two complementary dimensions, measuring how these dimensions interact in the solution of the decision problem facing them in the experiment.

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Appendix A

6 Solution of the mechanism design problem under the *wini* program

In the case of *wini*, the search of the optimal mechanism corresponds to the following linear program:

$$
\begin{aligned}
b^* \equiv (b_1^*, b_2^*) \in \arg \min_{\{b_1, b_2\}} [b_1 + b_2] \text{ sub} \qquad & (16) \\
u_1(1,1) \;\geq\; u_1(0,1) \qquad & (17) \\
u_2(1,1) \;\geq\; u_2(1,0) \qquad & (18) \\
b_1 \;\geq\; b_2 \geq 0 \qquad & (19)
\end{aligned}
$$

Assumption (19) is wlog. To solve the problem (16-19), we begin by partitioning the benefit space $B = \left\{(b_1, b_2) \in \Re_+^2, b_1 \geq b_2\right\}$ in two regions, which specify the payoff ranking of each strategy profiles in $G(b)$. This partition is relevant for our problem, since it determines whether in (1,0) - player 1 exerts effort and player 2 does not - whether it is player 1 or 2 the one who experiences envy (guilt):

$$
\begin{aligned}
R_1 &= \left\{b \in B : b_2 \leq b_1 - \frac{c}{\gamma}\right\}; \\
R_2 &= \left\{b \in B : b_1 - \frac{c}{\gamma} \leq b_2 \leq b_1\right\}.
\end{aligned}
$$

Let $g^1(b_1) = b_1$ $\left(g^2(b_1) = b_1 - \frac{c}{\gamma}\right)$ define the two linear constraints upon which our partition is built. The strategy proof is as follows. We shall solve the linear program (16-19) in the two regions independently (since, within each region, social utility parameters are constant for each agent and strategy profile), checking which of the two solutions minimizies the averall benefit sum $b_1 + b_2$, and determining the constraints on preferences which determine the identity of the best-paid player 1.

6.1 *Wini* under EPs

As for the solution of wini under EPs (i.e. with $\alpha_1 = \alpha_2 = \beta_1 = \beta_2 = 0$), the linear program (16-19) simplifies to the following:

$$\min b_1 + b_2$$

subject to:

$$\begin{aligned} b_1 - c &\geq \gamma b_1 \\ b_2 - c &\geq \gamma b_2 \\ b_i &\geq 0; \quad \text{with } i = 1, 2 \end{aligned}$$

In this case, the solution of the problem is problem is trivial:

$$b_1^* = b_2^* = \tfrac{c}{1-\gamma}.$$

6.2 *Wini* under IAPs

As for the solution of *wini* under IAPs, we need to add to the basic linear program (16-19) the IAPs constraints (4-5).

Proposition 1 (winiIAP) *The optimal wini mechanism under IAPs is as follows:*

$$b_1^* = \left(\begin{array}{c} \frac{c(-1+\alpha_2(-1+\beta_1)+2\beta_1+\gamma(-1+2\beta_1)(-1+\beta_2)-\beta_1\beta_2}{(-1+\gamma)(1+\alpha_2-\beta_1+\gamma(-1+\beta_1+\beta_2)}, \\ \frac{c(-1+\beta_1)(-1+\alpha_2-\beta_2+\gamma(-1+2\beta_2))}{(-1+\gamma)(1+\alpha_2-\beta_1+\gamma(-1+\beta_1+\beta_2)} \end{array} \right) \;\; \text{if } \beta_1 < \frac{1}{2}; \tag{20}$$

$$b_2^* = \left(\frac{c(1-\beta_1)}{1-\gamma}, \frac{c(1-\beta_1)}{1-\gamma} \right) \;\; \text{if } \beta_1 \geq \frac{1}{2}, \tag{21}$$

with $\beta_1 \leq \beta_2$.

To prove Proposition 1, some preliminary lemmas are required. Let $\hat{b}^k \equiv (\hat{b}_1^k, \hat{b}_2^k)$ define the solution of the linear program (16-19) in R_k.

Lemma 2

$$\hat{b}^1 = \left(\frac{c(1+\alpha_2)}{(1-\gamma)\gamma}, \frac{c(\gamma+\alpha_2)}{(1-\gamma)\gamma} \right) \tag{22}$$

.

Proof. In R_1, agent 1's monetary payoff, as determined by $G(b)$, is always higher (i.e. $\pi_1(\delta) \geq \pi_2(\delta)$, $\forall\delta$). This, in turn, implies that constraints (17-18) correspond to

$$b_1 \geq f_1^1(b_1) \equiv \frac{c(1-\beta_1)}{(1-\gamma)\beta_1} - \frac{1-\beta_1}{\beta_1} b_1; \tag{23}$$

$$b_2 \geq f_2^1(b_1) \equiv \frac{c}{1-\gamma} + \frac{\alpha_2}{1+\alpha_2} b_1. \tag{24}$$

Let x_i^k define the value of b_1 such that $f_i^k(b_1) = 0$. By the same token, let y_i^k denote the intercept of $f_i^k(b_1)$, i.e. $f_i^k(0)$. Finally, let τ_i^k denote the slope of $f_i^k(b_1)$. We then have $x_1^1 = \frac{c}{1-\gamma}$ and $x_2^1 = -\frac{c(1+\alpha_2)}{(1-\gamma)\alpha_2}$. Also notice that $0 \leq \tau_2^1 = \frac{\alpha_2}{1+\alpha_2} < 1$ and $y_2^1 = \frac{c}{1-\gamma} > 0$. This implies that $f_2^1(b_1)$ and $g^2(b_1)$ intersect in the first quadrant of the $b_1 \times b_2$ space. On the other hand, $f_1^1(b_1)$ is never binding in this case, since $\tau_1^1 = -\frac{1-\beta_1}{\beta_1} < 0$ and $x_1^1 = \frac{c}{1-\gamma} < \frac{c}{\gamma}$ since $\gamma < \frac{1}{2}$. This implies that $b_1 + b_2$ is minimized where $f_2^1(b_1)$ and $g^2(b_1)$ intersect, i.e. when $\hat{b}_1^1 = \frac{c(1+\alpha_2)}{(1-\gamma)\gamma}$ and $\hat{b}_2^1 = \frac{c(\gamma+\alpha_2)}{(1-\gamma)\gamma}$. ■

Lemma 3 *In R_2, the optimal wini contract under IAPs is (20) when $\beta_1 < \frac{1}{2}$, and (21) when $\beta_1 \geq \frac{1}{2}$, with $\beta_1 < \beta_2$.*

Proof. In the case of R_2, constraints (17-18) correspond to

$$b_1 \geq f_1^2(b_1) \equiv \frac{c(1-\beta_1)}{(1-\gamma)\beta_1} - \frac{1-\beta_1}{\beta_1} b_1; \tag{25}$$

$$b_2 \geq f_2^2(b_1) \equiv \frac{c(1-\beta_2)}{1+\alpha_2-\gamma(1-\beta_2)} + \frac{\alpha_2+\gamma\beta_2}{1+\alpha_2-\gamma(1-\beta_2)} b_1. \tag{26}$$

This implies that $f_1^1(b_1) = f_1^2(b_1)$ (i.e. the Nash equilibrium condition for player 1 remains unchanged in both R_1 and R_2), $\tau_1^2 = -\frac{1-\beta_1}{\beta_1} < 0$ (i.e. $|\tau_1^2| > 1$ if $\beta_1 < \frac{1}{2}$), and $0 \leq \tau_2^2 = \frac{\alpha_2+\gamma\beta_2}{1+\alpha_2-\gamma(1-\beta_2)} < 1$.

We first show that $\beta_1 \leq \beta_2$. Let $\check{\beta} = \min\{\beta_1, \beta_2\}$. If $\beta_1 > \beta_2$, then the optimal solution in R_2 would be $\hat{b}_i^1 = \hat{b}_i^2 = \frac{c(1-\check{\beta})}{1-\gamma}$ (i.e. $\hat{b}_i^1 + \hat{b}_i^2 = 2\frac{c(1-\check{\beta})}{1-\gamma}$). On the other hand, if $\beta_1 \leq \beta_2$, then $\hat{b}_i^1 + \hat{b}_i^2 \leq 2\frac{c(1-\check{\beta})}{1-\gamma}$. More precisely, if $\beta_1 < \frac{1}{2}$, the optimal solution is (20), that is, the intersection between $f_1^2(b_1)$ and $f_2^2(b_1)$; if $\beta_1 \geq \frac{1}{2}$, the solution is (21), that is, the intersection between $f_1^2(b_1)$ and $g^1(b_1)$. ■

We are in the position to prove Proposition 1.

Proof. [Proof of Proposition 1]. To prove the proposition, it is sufficient to show that $\hat{b}_i^1 > \hat{b}_i^2, i = 1, 2$. To see this, remember that $f_1^1(b_1) = f_1^2(b_1)$. Also remember that $f_1^k(b_1)$ is (not) binding for both $k = 1$ and $k = 2$. If x_i^{kl} solves $f_1^k(x) = g^l(x)$, then $x_2^{12} = x_2^{22} = \frac{c(1+\alpha_2)}{\gamma(1-\gamma)}$, which, in turn, implies

$$\begin{aligned}\hat{b}_1^1 &= \frac{c(1+\alpha_2)}{\gamma(1-\gamma)} > x_1^{21} = \frac{c(1-\beta_1)}{1-\gamma} \geq \hat{b}_1^2 \text{ and} \\ \hat{b}_2^1 &= \frac{c(\gamma+\alpha_2)}{\gamma(1-\gamma)} > x_1^{21} = \frac{c(1-\beta_1)}{1-\gamma} \geq \hat{b}_2^2.\end{aligned}$$

■

6.3 *Wini* with SSPs

As for the solution of *wini* under SSPs, we need to add to the basic linear program (16-19) the the SSPs constraints (6-8).

Proposition 4 (winiSSP) *The optimal wini mechanism under SSPs is (20), with* $\beta_1 \leq \beta_2$.

Proof. We begin by showing that, as in the case of IAPs, the optimal *wini* contract in R_1 is (22). This is because, also in this case, $f_1^1(b_1)$ is not binding, since $\tau_1^1 = -\frac{1-\beta_1}{\beta_1} > 1$ and $x_1^1 = \frac{c}{1-\gamma} < \frac{c}{\gamma}$.

On the other hand, the optimal *wini* contract in R_2 is (20), independently of the value of β_1. This is because, given -1$< \gamma_i < 0$, both τ_1^2 and τ_2^2 are positive. Since $\tau_1^2 = -\frac{1-\beta_1}{\beta_1}$; $|\tau_1^2| > 1$ (i.e., as before, $f_1^2(b_1)$ and $f_2^2(b_1)$ intersect in the first quadrant. Also notice that, given $\beta_i < 0, i = 1, 2$, $y_1^2 = \frac{c(-1+\beta_1)}{(1-\gamma)\beta_1} < 0$. Two are the relevant cases:

1. If $\beta_1 > \beta_2$, then $f_1^2(b_1)$ and $f_2^2(b_1)$ intersect outside R_2, and the optimal solution would be $b_1 = b_2 = \frac{c(1-\check{\beta})}{(1-\gamma)}$.

2. If $\beta_1 < \beta_2$, then the solution is (20) which averall cost is never greater than $\frac{2c1-\beta)}{(1-\gamma)}$.

We complete the proof by noticing, by analogy with the Proof of Proposition 1, that the optimal solution lies in R_2, rather than in R_1. ■

6.4 *Wini* with ESPs

In the case of *wini* with ESPs, we need to add to the basic linear program (16-19) the the ESPs constraints (9-11).

Proposition 5 (winiESP) *The optimal wini mechanism under ESPs is (20), with $\beta_1 \leq \beta_2$.*

Proof. We begin by showing that here the optimal *wini* contract in R_1 is (22) if $|\alpha_2| < \gamma$ and $\hat{b}^1 = \left\{\frac{c}{\gamma}, 0\right\}$ if $\beta_2 \geq \gamma$. This is because, like in the previous cases, $f_1^1(b_1)$ is never binding, since $x_1^1 = \frac{c}{1-\gamma} < \frac{c}{\gamma}$ and $\tau_1^1 = -\frac{1-\beta_1}{\beta_1} < 0$. On the other hand, given that $x_2^1 = -\frac{c(1+\alpha_2)}{\alpha_2(1-\gamma)}$ and $0 \leq \tau_2^1 \leq \frac{1}{2}$, $f_2^1(b_1)$ is binding if and only if $|\alpha_2| < \gamma$ (i.e. if $x_2^1 > \frac{c}{\gamma}$).

As for R_2, we begin to notice that $\tau_1^2 = -\frac{1-\beta_1}{\beta_1} \geq -1$ (since $|\beta_1| < \frac{1}{2}$) and that $0 \leq \tau_2^2 = \frac{\alpha_2+\gamma\beta_2}{1+\alpha_2\grave{a}\gamma(1-\beta_2)} < 1$. This implies, like before, that $f_1^2(b_1)$ and $f_2^2(b_1)$ intersect in the first quadrant. The rest of the proof is identical of that of Proposition 4. ■

7 Solution of the mechanism design problem under the *sini* program

In the case of *sini*, the search of the optimal mechanism corresponds to the *wini* linear program (16-19) with an additional constraint (implementation with a unique equilibrium):

$$u_1(1,0) \geq u_1(0,0). \tag{27}$$

The constraint (27) makes, on behalf of player 1, the choice of putting effort a weakly dominant strategy.

7.1 *Sini* under EPs

The solution of *sini* under EPs is as follows (see Winter [33]):

$$b_1^* = \frac{c}{\gamma},$$
$$b_2^* = \frac{c}{1-\gamma}.$$

7.2 *Sini* under IAPs

Proposition 6 *The optimal sini mechanism under IAPs is*

$$\begin{cases} b_1^* = \frac{c((1+\alpha_1)(1+\alpha_2)-\gamma(1-\beta_2))}{\gamma(1+\alpha_1+\alpha_2-\gamma(1+\alpha_1-\beta_2))}, \\ b_2^* = \frac{c(1+\alpha_1)(\gamma+\alpha_2)}{\gamma(1+\alpha_1+\alpha_2-\gamma(1+\alpha_1-\beta_2))}. \end{cases} \tag{28}$$

To prove Proposition 6, we follow the same strategy as before.

Lemma 7 $\hat{b}^1 = \left(\frac{c(1+\alpha_2)}{(1-\gamma)\gamma}, \frac{c(\gamma+\alpha_2)}{(1-\gamma)\gamma}\right)$.

Proof. In R_1, the constraints for agent 1 and 2 correspond to:

- $$b_1 \geq f_1^1(b_1) \equiv \frac{c(1-\beta_1)}{(1-\gamma)\beta_1} - \frac{1-\beta_1}{\beta_1}b_1, \tag{29}$$
$$b_1 \geq f_3^1(b_1) \equiv \frac{c(1-\beta_1)}{\gamma(1-\gamma)\beta_1} - \frac{1-\beta_1}{\beta_1}b_1, \tag{30}$$
$$b_2 \geq f_2^1(b_1) \equiv \frac{c}{1-\gamma} + \frac{\alpha_2}{1+\alpha_2}b_1, \tag{31}$$

  Let x_i^{kl} solves $f_1^k(x) = g^l(x)$. We first notice that (29) is not binding. This is becasue (29) defines a constraint which is parallel to (30), but with a smaller intercept ($y_1^1 < y_3^1$, since $\gamma < 1$). Also notice that, in this case, (30) is not binding either. This is becuase, $\tau_3^1 < 0$, $\tau_2^1 > 0$, and $x_3^{12}{=}\frac{c(1-\gamma\beta_1)}{\gamma(1-\gamma)} < x_2^{12}{=}\frac{c(1+\alpha_2)}{\gamma(1-\gamma)}$.

This implies that, in R_1, (b_1+b_2) is minimized (like in *wini*) where $f_2^1(b_1)$ and $g^2(b_1)$ intersect, i.e. when $\hat{b}_1^1 = \frac{c(1+\alpha_2)}{(1-\gamma)\gamma}$ and $\hat{b}_2^1 = \frac{c(\gamma+\alpha_2)}{(1-\gamma)\gamma}$. ■

Lemma 8 *The optimal sini contract in R_2 is (28).*

Proof. R_2, the relevant constraints are as follows:

$$b_1 \geq f_1^2(b_1) \equiv \frac{c(1-\beta_1)}{(1-\gamma)\beta_1} - \frac{1-\beta_1}{\beta_1}b_1 \tag{32}$$

$$b_1 \geq f_3^2(b_1) \equiv -\frac{c(1+\alpha_1)}{\gamma\alpha_1} + \frac{1+\alpha_1}{\alpha_1}b_1 \tag{33}$$

$$b_2 \geq f_2^2(b_1) \equiv \frac{c(1-\beta_2)}{1+\alpha_2-\gamma(1-\beta_2)} - \frac{\alpha_2+\gamma\beta_2}{1+\alpha_2-\gamma(1-\beta_2)}b_1. \tag{34}$$

Notice that, by analogy with R_1, condition (32) is not binding since $\tau_1^2 < 0$, $\tau_3^2 > 0$ and $x_1^1 = \frac{c}{1-\gamma} < x_3^3 = \frac{c}{\gamma}$. Also notice that $0 < x_2^{21} = \frac{c(1-\beta_2)}{1-\gamma} < x_3^{21} = \frac{c(1+\alpha_1)}{\gamma}$ and $x_2^{22} = \frac{c(1+\alpha_2)}{\alpha(1-\gamma)} > x_3^{22} = \frac{c}{\gamma}$. This, in turn, implies that, $f_3^2(b_1)$ and $f_2^2(b_1)$ always intersect in the interior of R_2, which implies the solution.[11] ■

We are in the position to prove Proposition 6.

Proof. To close the proposition, it is sufficient to show that $\hat{b}_i^1 \geq \hat{b}_i^2, i = 1, 2$. To see this, notice that $x_2^{12} = x_2^{22} = \frac{c(1+\alpha_2)}{\gamma(1-\gamma)}$ (i.e. $f_2^2(b_1)$ and $f_2^2(b_1)$ cross exactly at the intersection with $g^2(b_1)$). Since $\tau_2^2 = \frac{\alpha_2+\gamma\beta_2}{1+\alpha_2-\gamma(1-\beta_2)} > 0$ and $\hat{b}^2$ is interior to R_2, the result follows. ■

7.3 *Sini* under SSPs

Proposition 9 *The optimal sini mechanism under SSPs is (28).*

Proof. By analogy with the IAP case, in R_1, (29) is not binding. Also notice that $\tau_3^1 = -\frac{1-\beta_1}{\beta_1} > \tau_2^1 = \frac{\alpha_2}{1+\alpha_2} > 0$. Two are the relevant cases:

1. if $\alpha_2 \geq -\gamma\beta_1$,(i.e. if $x_3^{12} = \frac{c(1-\gamma\beta_1)}{\gamma(1-\gamma)} \leq x_2^{12} = \frac{c(1+\alpha_2)}{\gamma(1-\gamma)}$), then (33) is not binding, and the optimal solution is the intersection between $f_2^1(b_1)$ and $g_3(b_1)$, that is, $\hat{b}^1 = \left(\frac{c(1+\alpha_2)}{\gamma(1-\gamma)}, \frac{c(\gamma+\alpha_2)}{\gamma(1-\gamma)}\right)$;

[11] As it turns out, unlike the *wini* case, the search for the appropriate conditions on preferences to identify player 1 has no (algebraically manageable) closed-form solution, but it has to be evalutaed numerically (as we did in the calibration of our experimental conditions).

2. if $\alpha_2 < -\gamma\beta_1$, then the optimal solution is the intersection between $f_2^1(b_1)$ and $f_3^1(b_1)$, that is, .

$$\hat{b}^1 = \left(\frac{c(1+\alpha_2)(1-\beta_1(1+\gamma))}{\gamma(1-\gamma)(1+\alpha_2-\beta_1)}, \frac{c(\alpha_2+\gamma(1+\alpha_2))(1-\beta_1)}{\gamma(1-\gamma)(1+\alpha_2-\beta_1)}\right).$$

As for R_2, the optimal *sini* contract is, again, (28). This is becuase, by analogy with the IAP case, conditions (32) and $g^2(b_1)$ are not binding. Also notice that $x_2^{22} = \frac{c(1+\gamma_2)}{\gamma(1-\gamma)} > 0$ and $0 \leq \tau_2^2 = \frac{\alpha_2+\gamma\beta_2}{1+\alpha_2-\gamma(1-\beta_2)} < 1$. This, in turn, implies that, in R_2, (b_1+b_2) is minimized where $f_3^2(b_1)$ and $f_2^2(b_1)$ intersect, which implies the solution. ■

7.4 *Sini* under ESPs

Proposition 10 *The optimal sini mechanism under ESPs is (28).*

Proof. By analogy with the previous cases, in R_1, (29) is not binding. Also notice that, in this case, (32) is not binding either, since $\tau_2^1 < 0$ and $x_2^{12} = \frac{c(1+\alpha_2)}{\gamma(1-\gamma)} < \frac{c}{\gamma}$. Since, by (9-11), $\gamma_1 \leq \frac{1}{2}$, the unique solution in this case is $\hat{b}^1 = \left(\frac{c}{\gamma(1-\gamma)}, 0\right)$.

As for R_2, we first notice that, given that $|\beta_1| \leq \frac{1}{2}, \tau_3^2 > 1$. Since, by (9),$|\alpha_2| < \gamma$ (i.e. $x_2^2 > \frac{c}{\gamma}$, then the optimal solution is the intersection between $f_2^1(b_1)$ and $g_3(b_1)$, that is, (28). ■