Testing for Heterogeneity of Preferences in Randomized Experiments: A Satisfaction-Based Approach Applied to Multiplayer Prisoners' Dilemmas.

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Abstract

We use experimental data from the "vote with the wallet" multiplayer prisoner's dilemma to investigate with a finite mixture approach the effect of a responsible purchase on players' satisfaction. We find clear-cut evidence of heterogeneity of preferences with two groups of players that differ significantly in terms of effects of the responsible choice on satisfaction.

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I Introduction

Heterogeneity of preferences is a research frontier that may contribute to explain behavioral anomalies in experimental games. Erlei (2004) sketches a model with heterogeneous players and documents how his model has higher predictive accuracy than homogeneous preference models when applied to 43 different games. Rotemberg (2008) shows that heterogeneous agents help to explain anomalies observed in ultimatum and dictator games. However, these important contributions do not prove definitively the existence of heterogeneity since we cannot exclude in principle the emergence of models with homogeneous preferences that can explain better the same experimental results. Given the *lex parsimoniae* of the Occam's razor – a strong argument for simplicity in scientific models – the existence of heterogeneous preferences can be supported by demonstrating that heterogeneity actually exists in observed experimental behaviour.

Our contribution pursuits this goal and develops a methodological approach aimed at testing for heterogeneity in three steps: i) collecting information on satisfaction about the game and about other players' behaviour in randomised experiments; ii) testing with a mixture model for the presence of significantly different effects of experimental variables on players' satisfaction; iii) validating the identified groups with heterogeneous reactions by testing whether their observed behaviour in the game is actually different. This approach is very general and can be potentially replicated in all experiments.

From a methodological point of view our contribution provides three main innovations in the literature. First, we measure players' satisfaction about the experiment at each round. Second, we apply a finite mixture model (FMM) to satisfaction data to test for heterogeneity. Third, we deal with a game that is original and related to a phenomenon of growing relevance. Due to the widespread diffusion of corporate social responsibility by which corporations retail bundles of private and public goods (Besley and Ghatak, 2007), millions of consumers choose everyday between a conventional product and a product of equivalent quality which is advertised as containing higher environmental and/or social value. The second product generally costs more but its purchase contributes to a public good generating positive externalities on all other consumers. We model such choice as a multiplayer prisoner's dilemma. Even though we make explicit reference to the vote with the wallet problem our results remain valid for the broader class of hybrid provision-PD games where both the classical cooperation and defection strategies require an action (Arce and Sandler, 2005).

II The Model

Our theoretical benchmark is the Vote-with-the-Wallet game (Becchetti and Salustri, 2015). In its multiplayer version n players choose between a responsible good (good R) and a conventional good (good C). Good R has a higher price than good C but whenever a single player chooses it, a positive externality is generated on all other players. Good C is cheaper and produces no externalities. The game is represented by $\Gamma_{n,a_\theta,b,c} = \left(N, (A^i)_{i\in N}, (U^i)_{i\in N}\right)$ where $N = \{1, \ldots, n\}$ is the set of players, $A^i = \{R, C\}$ is the set of strategies $\forall i \in N$, and the utility of player i is

$$U^i(S^i, S^{-i}) = \begin{cases} \frac{k+1}{n}b + a_\theta - c & \text{if } S^i = R \\ \frac{k}{n}b & \text{if } S^i = C \end{cases}$$

with k being the number of buyers of good R in the sequence of other players' actions S^{-i} and $\theta \in \{L, H\}$ the subject's type.

The three parameters of the game are the positive externality ($b \geq 0$) accruing from the purchase of good R, weighted for the share of buyers of the same good; the social preference ($a_\theta \geq 0$) enjoyed by buyers of good R; and the price differential ($c \geq 0$) between good R and good C. The Nash equilibrium (NE) of $\Gamma_{n,a_\theta,b,c}$ is mutual conventional purchase (*i.e.*, all players choose C) if $a_\theta < c - \frac{1}{n}b$ for each type θ and mutual responsible purchase (*i.e.*, all players choose R) otherwise. If $c - b < a_\theta < c - \frac{1}{n}b$ we have a prisoner's dilemma since the (unique) NE (*i.e.*, mutual conventional purchase) is Pareto dominated by the mutual responsible purchase strategy that yields the highest payoff for both players.

In order to identify characteristics of players in the game we rely on a mixture model assuming that individuals are heterogeneous in terms of impact of their cooperative choice on satisfaction about the game (*GameSat*) and about other players' behaviour in the game (*OtherSat*).[1] More specifically, we assume the existence of players with low and high social preferences (a_L and a_H, respectively) and model *GameSat* as resulting from a mixture of two normal distributions, $N(\mu_L(\mathbf{x}), \sigma_L^2)$ and $N(\mu_H(\mathbf{x}), \sigma_H^2)$ for type-L and type-H individuals with individual covariates $\mathbf{x}$, respectively. We assume that the proportion of the type-L population is p_L and the proportion of the type-H population is $p_H = 1 - p_L$, and the density associated with a given value of satisfaction conditional on the individual

[1] *GameSat* is measured by asking to participants at the end of each period the question "On a scale from 0 to 10, please indicate your level of satisfaction about the experience of the game" and *OtherSat* by asking the question "On a scale from 0 to 10, please indicate your level of satisfaction about other players' behaviour in the game".

i being of type θ is

$$f(y_i \mid \theta, \mathbf{x}_i) = \frac{1}{\sigma_\theta}\phi\Big(\frac{y_i - \mu_\theta(\mathbf{x}_i)}{\sigma_\theta}\Big).$$

III The Experiment Design

Our experiment consists of 18 sessions, each of them composed by 20 periods. In each session a group of 10 participants chooses every period between good R, which costs 10 ECUs, and good C, which costs 5 ECUs (1 ECU = €0.5). For each buyer of good R, 3 ECUs are given to all participants as monetary equivalent of the positive externality arising from consumption of that good. Each participant receives an initial endowment of 20 ECUs in each period, and during the experiment she sequentially: i) declares how many participants she expects will buy good R; ii) chooses the good to buy; iii) is informed about the number of buyers of good R in that period; iv) declares her satisfaction about the game and the other participants' behaviour on a 0-10 scale for the same period. We implement three different versions of the game: in the *Baseline* version the experiment is performed as described above; in the *Framed* version good R is described as a product that has been awarded by the Italian Competition Authority with a 3–star legality ranking; in the *Conformity* version each player in sessions 7–9 (10–12) is informed about the average number of buyers of good R in sessions 13–15 (16–18) for the respective period. The Conformity version allows us to test for differences between conformity and conditional cooperation. In addition, each version is implemented for ten consecutive periods (either the first 10 or the last 10) with a *Redistribution* mechanism collecting 1 ECU from each buyer of good C and equally sharing what collected among buyers of good R. All details are provided in Appendix B.

IV Econometric analysis

Our specification is

$$\begin{aligned} GameSat_{i,T} &= \alpha + \beta GoodR_{i,T} + \gamma NRespBuyers_T \\ &\quad + \sum_j \delta_j D.Treatment_j + \sum_k \zeta_k SocioDem_{i,k} + \varepsilon_{i,T} \end{aligned}$$

where $GameSat_{i,T}$ is the average satisfaction about the game measured for each individual i over the 10 periods of treatment T. Our main regressor is $GoodR_{i,T}$, which represents the number of times the i-th individual buys good R over the 10 treatment periods. We also control for the average number of responsible buyers within treatment ($NRespBuyers_T$). $D.Treatment$ are dummies for the following treatment types: Baseline, Redistribution,

Frame, Frame and Redistribution, Conformity, Conformity and Redistribution. Socio-demographic characteristics such as age, sex, parental job and education, and yearly income are also included as controls.

We adopt an individual-averaged approach by considering the average of all our variables by individuals over each treatment. Even though this approach reduces our observations to 360, individual averages are more reliable and less subjects to bias or possible measurement errors.

In order to test for heterogeneity in the effect of the responsible purchase on satisfaction about the game between type-L and type-H individuals, we test the following homogeneity hypothesis

$$\begin{aligned} H_0 \quad &: \quad E[GameSat_{i,T} \,|\, i \in L] = E[GameSat_{i,T} \,|\, i \in H] \\ H_A \quad &: \quad E[GameSat_{i,T} \,|\, i \in L] \neq E[GameSat_{i,T} \,|\, i \in H], \end{aligned}$$

where $E[\,\cdot \,|\, i \in \theta]$ is the conditional expected value given i being of type θ, for $\theta \in \{L, H\}$.

Empirical findings

The distribution of satisfaction about the game does not seem to derive from a unique homogeneous player type (Figure 1). We therefore perform a Finite Mixture two-group regression (FMM) and find that AIC, sample-adjusted BIC and log-likelihood criteria reveal superior goodness of fit than in OLS one-group estimate (Tables 1). In the estimate the choice of the "responsible" product R affects negatively satisfaction about the game for the first group, while it is weakly positive but not significant in the second group. T-stat shows that homogeneity of coefficients across the two groups is rejected (Table 1).

In Figures 2(a)–2(b) we show that the two groups have separate satisfaction distributions with the second group being significantly less satisfied.

When we look at determinants of the responsible choice we find that second group respondents buy significantly more the responsible product (Table 2). The interpretation of our findings is that type-L respondents are non-standard homines economici with utility depending on monetary payoffs of the game and on a low level of social preferences (*i.e.*, a_L) explaining the (weakly significant) positive effect of responsible choice on satisfaction. The utility of a second group of players can be written as

$$U^i(S^i, S^{-i}) = \begin{cases} \frac{E_L(j)}{n}\beta + a_L - c & \text{if } S^i = R \\ \frac{E_L(j)}{n}\beta & \text{if } S^i = C \end{cases} \tag{1}$$

where j is the number of buyers of good R in S^{-i}, a_L is the social preferences component,

and $E_L(j)$ the expectation of type-L player on j.

We as well model first group respondents as "disappointed other-regarding individuals" that is, with higher social preferences (*i.e.*, $a_H > a_L$) and a disappointment effect proportional to the number of non cooperators conditional to the number of their responsible choices. They therefore choose significantly more to buy the responsible product but are at the same time disappointed by the behaviour of other players (Table 3).

In order to account for the paradox of type-H players we have two possible explanations. The first is that type-H players are other-regarding players with a pre-choice utility as in (1) and a post-choice utility

$$U^i(S^i, S^{-i}) = \begin{cases} \frac{E_H(j)}{n}\beta + \alpha_H - c - \phi(E_H(j) - j) & \text{if } S^i = R \\ \frac{E_H(j)}{n}\beta & \text{if } S^i = C \end{cases}$$

with social preferences a_H and a disappointment effect ϕ proportional to the error in their beliefs $E_H(j) - j$ (*ErrorBeliefs* in Table 1).[2]

The misalignment between pre- and post-choice utility occurs a sufficient number of times such that the number of cooperative choices of other regarding players is higher than that of homines economici (it does not need to occur for 10 periods but at least for a number of periods determining a difference in responsible choices between the two groups). The second is that type-H players are Kantian, that is, they comply to their inner duty of choosing the responsible product irrespective of the disappointment created.

V Conclusions

Our paper illustrates a novel methodology that can be potentially applied to all experimental papers in order to test directly for the presence of heterogeneity. The methodology consists in collecting information on satisfaction about the game, estimating with a mixture model the determinants of such satisfaction and validating groups in terms of significant behavioral differences in observed choices. By applying it to a multiplayer prisoner's dilemma we find that players belong to two distinct groups that differ in terms of utility generated by the cooperative choice.

[2]Error in beliefs is measured as expectation on the number of buyers of good R minus the true number of buyers of good R.

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VI Tables and Figures

Figure 1: Histogram of Satisfaction

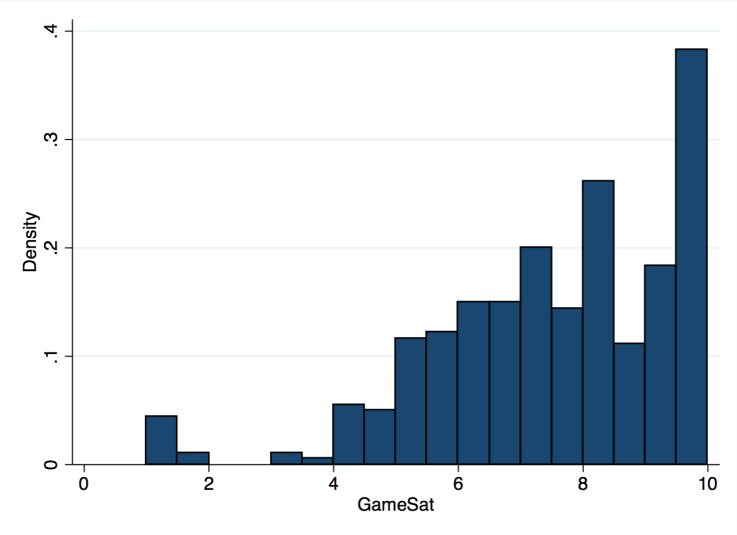
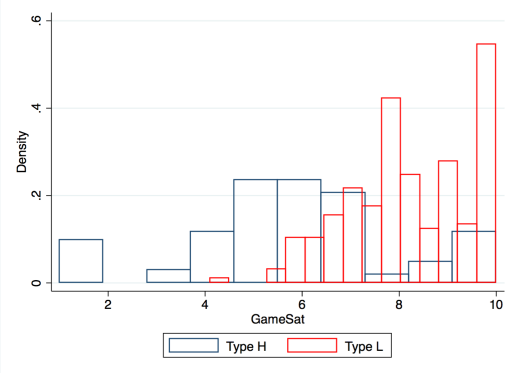
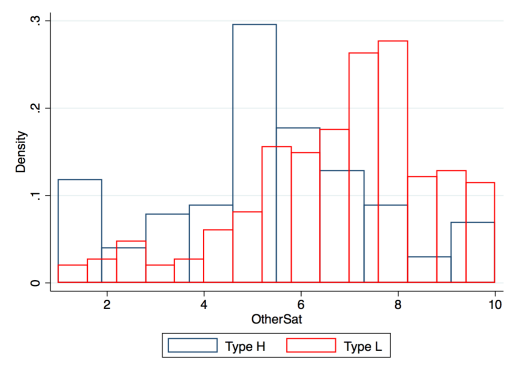


Figure 2: Histogram of Satisfaction by type



(a) GameSat



(b) OtherSat

TABLE 1
The impact of responsible purchase on satisfaction

Variables	OLS	FMM	
		Type H	Type L
Choice good R	-0.555	-2.128**	1.448*
	(0.519)	(0.894)	(0.797)
No. buyers good R	0.0572	0.274	-0.275
	(0.193)	(0.395)	(0.224)
Treatments	Yes	Yes	Yes
SocioDem	Yes	Yes	Yes
Constant	6.752***	7.406**	5.547***
	(1.614)	(3.045)	(2.134)
σ_θ		1.632	1.076
		(0.173)	(0.181)
p_θ		0.424	0.576
		(0.139)	(0.139)
Observations	360	360	360
R-squared	0.045		
Final class proportions (posterior probabilities)		0.424	0.576
Final class counts (posterior probabilities)		152.487	207.513
No. of subjects (most likely LC membership)		113	247
AIC	1538.833	1481.433	
Ss adjusted BIC	1552.39	1510.690	
Entropy		0.414	
# free parameters		41	
Log likelihood	-750.4163	-699.716	
$E[\text{GameSat}_L] - E[\text{GameSat}_H] \neq 0$		0.0004	
$E[\text{Beliefs}_L] - E[\text{Beliefs}_H] \neq 0$		0.0193	
$E[\text{ErrorBeliefs}_L] - E[\text{ErrorBeliefs}_H] \neq 0$		0.0004	

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

TABLE 2
The impact of type on responsible choice (OLS)

Variables	OLS Choice good R
Previous no. buyers good R	0.104***
	(0.0314)
Type L	-0.132***
	(0.0405)
Treatments	Yes
SocioDem	Yes
Constant	0.165
	(0.240)
Observations	360
R-squared	0.168

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 3
The effect of type on satisfaction about other players' behaviour

VARIABLES	OLS OtherSat
Choose good R	-1.616***
	(0.461)
No. buyers good R	-0.0665
	(0.167)
Type L	1.313***
	(0.281)
Treatments	Yes
SocioDem	Yes
Constant	8.230***
	(1.580)
Observations	360
R-squared	0.296

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1