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**Position Uncertainty in a Prisoner's Dilemma Game:
An Experiment**

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Position Uncertainty in a Prisoner's Dilemma Game: An Experiment

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April 23, 2025

Abstract

Gallice and Monzón (2019) present a natural environment that sustains full cooperation in one-shot social dilemmas among a finite number of self-interested agents. They demonstrate that in a sequential public goods game, where agents lack knowledge of their position in the sequence but can observe some predecessors' actions, full contribution emerges in equilibrium due to agents' incentive to induce potential successors to follow suit. Furthermore, they show that this principle extends to a number of social dilemmas, with the prominent example that of the prisoner's dilemma. In this study, we experimentally test the theoretical predictions of this model in a multi-player prisoner's dilemma environment, where subjects are not aware of their position in the sequence and receive only partial information on past cooperating actions. We test the predictions of the model, and through rigorous structural econometric analysis, we test the descriptive capacity of the model against alternative behavioural strategies, such as conditional cooperation, altruistic play and free-riding behaviour. We find that the majority resorts to free-riding behaviour, around 30% is classified as Gallice and Monzón (2019) types, followed by those with social preference considerations and the unconditional altruists.

Keywords: Position uncertainty · Conditional cooperation · Social dilemma · Social preferences · Experiment · Finite mixture models

JEL codes: C91 · D64 · H41

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The study has been pre-registered at the Open Science Framework (OSF) registries (<https://osf.io/fzm5t>).

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1 Introduction

An interesting question in the literature of environmental economics, which still remains (somewhat) unanswered, is how the nations, acting non-cooperatively, can deal with and achieve the goal of global emission abatement. Similar to public good provisions, in public bad situations such as abatement, the non-cooperative interaction among participants typically results in low levels of provision or abatement. The seminal paper by [Barrett \(1994\)](#) provides a simple abatement game (which acts as a prisoner's dilemma) where each country must decide whether to adopt eco-friendly policies (*cooperate*) or prioritize short-term economic interests (*defect*). Each country observes the choices of those preceding them (*sequential decision-making*), and these interactions capture the global environmental impact and economic consequences of climate-related policies. If all countries cooperate, there is a better chance of achieving global climate goals and minimizing environmental damage. However, if one or more countries defect by not taking sufficient action, it may undermine the collective effort and exacerbate global environmental problems. Similar difficulties also exist in situations involving management of shared environmental resources such as forests, fishery or water basin, where agents learn by observing the actions of others preceding them (observational learning), and may strategically anticipate the actions of future agents ([Banerjee 1992](#); [Celen and Kariv 2004](#)). This captures the essence of social dilemmas, where the optimal outcome requires coordinated efforts from all participants. It also explores how decision-making sequence and observations of others' behaviour influence individual choices in social dilemma contexts ([Suleiman et al., 1994](#)).

Cooperation in social dilemma situations is feasible, in the case of a repeated strategic interaction over an infinite horizon ([Friedman 1971](#); [Duffy and Ochs 2009](#); [Dal Bo et al. 2010](#); [Harstad et al. 2019](#)), or whenever the players' preferences are non-standard e.g. altruistic preferences ([Andreoni 1990](#); [Fehr and Gächter 2000](#); [Fehr and Gächter 2002](#)). In a recent study, [Gallice and Monzón \(2019\)](#) (G&M, henceforth) in the framework of a public good game, show

that it is possible to achieve full cooperation, even in the case where the interaction is one-shot, the number of players is finite, and the agents are self-interested. In this model, individuals have to make decisions sequentially, without knowing their position in the sequence (position uncertainty), but are aware of the decisions of some of their predecessors by observing a sample of past play. In the presence of position certainty, those placed in the early positions of the sequence would want to contribute, in an effort to induce some of the other group members to cooperate ([Rapoport and Erev, 1994](#)), while late players, would want to free-ride on the contributions of the early players. Nevertheless, if the agents are unaware of their position in the sequence, they would base their choice on the average payoff, from all potential positions, and would be inclined to contribute to induce potential successors to do the same. G&M show that full contribution can occur in equilibrium, where given appropriate values of the parameters of the game (i.e. return from contributions), there exists an equilibrium where all agents contribute. G&M extended these results to the case of a multi-player sequential prisoner's dilemma, showing that cooperation can be achieved when positional uncertainty is present.

In this study we design and conduct an economic experiment where we aim to test the theoretical predictions of the G&M model in a multi-player prisoner's dilemma environment, where subjects are not aware of their position in the sequence and receive only partial information on past cooperating actions. Our objective for this study is three-fold, as we aim to understand: (1) Whether agents cooperate or defect under positional uncertainty, given the observed actions of their two immediate predecessors; (2) How agents behave in case of positional awareness; (3) Are there any other behavioural attributes which are exhibited, like altruism and social preferences ([Charness and Rabin, 2002](#))(C&R, henceforth). To answer these questions, we vary the positional awareness of the subjects, and ask them to make conditional decisions in all potential information conditions about the predecessor(s) actions. Subjects in groups of 5 participate in a sequential prisoner's dilemma game where some members of the group face positional uncertainty. Using the *strategy method* elicitation method ([Selten, 1967](#))

we collect data from our participants varying the available information of past play. This allows us to test the predictions of the G&M model and to also explore the presence of other behavioural types such as those with social preferences (modelled assuming C&R preferences), free riders or unconditional altruists. Using finite mixture modelling, we are able to classify our experimental population to one of these types. We find that the majority of the subjects behave in a free-riding way, around 30% behave in line with the G&M predictions, 10% are subjects with altruistic tendencies and the remaining engage in either altruistic behaviour, or are types that cannot be clearly identified. We conclude that the assumption of full rationality is not sufficient to lead to full cooperation and argue how the alternative behavioural models of social preferences are able to contribute to the interpretations of the data.

Furthermore, we test the robustness of our design by introducing a within-subjects condition, where the choices of the subjects in the same game were elicited using the direct method. Our results extend the [Brandts and Charness \(2000\)](#) design to its sequential case, and confirm that there is no difference in the inference between the two elicitation methods.

The rest of the paper is organised as follows. In the next section, we discuss the related literature and the contribution of our study. In section 3 we present the main theoretical predictions of [Gallice and Monzón \(2019\)](#). Section 4 presents the experimental design and the procedures, while section 5 presents the descriptive statistics and results of the structural econometric analysis. We then conclude.

2 Related literature

Prior to the contribution of G&M, the timing of contributions in a public good and the total amount of funds raised had been the subject of significant theoretical investigation. [Varian \(1994\)](#) demonstrates that, under specific assumptions, a sequential contribution mechanism can lead to lower total contributions than a simultaneous one. This result stems from the

strategic structure of the model, in which a first mover may exploit a first-mover advantage to free-ride. In contrast, [Cartwright and Patel \(2010\)](#), using a sequential public goods game with exogenous ordering, show that agents positioned early in the sequence may be willing to contribute if they anticipate that others will imitate their behaviour. In the context of fundraising, [Romano and Yildirim \(2001\)](#) examine when a charity might prefer to implement a sequential-move mechanism for announcing contributions, while [Vesterlund \(2003\)](#) finds that revealing past contributions can help signal an organization's quality and simultaneously reduce the free-rider problem faced by the fundraiser. [Anwar et al. \(2025\)](#) extend G&M to a setting where groups contribute simultaneously but act sequentially based on partial observations of past contributions. They show that groups conditionally cooperate to influence subsequent ones, making each agent pivotal in sustaining contributions. In the context of self-enforcing climate agreements—typically lacking enforcement for defection ([Barrett 2003](#); [Nordhaus 2015](#))—their results suggest that group membership alone may sustain cooperation without formal enforcement.

In the framework of a prisoner's dilemma, previously, [Nishihara \(1997\)](#) analyse a n -person sequential prisoner's dilemma game with position uncertainty and shows how a planner can induce cooperation by immediately informing all agents when defection occurs. On the equilibrium path, agents cooperate for the same reason as they do in the G&M model, i.e. to encourage potential successors towards cooperation. Off the equilibrium path, agents in [Nishihara \(1997\)](#) are immediately informed if a predecessor defects before their move, and hence, no agent can convince his successors to cooperate. Instead, G&M focus on situations where observability is local and unconditional, and therefore an agent who observes defection may play a pivotal role in preventing further defection by choosing to cooperate.

Our study contributes to the literature of social preferences explaining decisions in sequential prisoner's dilemmas. Prisoner's dilemma have been thoroughly used in the literature to test the presence of conditional cooperation (see for example [Clark and Sefton 2001](#), [Blanco](#)

et al. 2011 for some early examples, and more recently in [Miettinen et al. 2020](#), [Baader et al. 2024](#), and [Kirchsteiger et al. 2024](#)). Table 1 summarizes some recent papers examining cooperation in sequential prisoner’s dilemma game. The various studies differ on a number of characteristics such as number of rounds, varying payoffs, provision of feedback, as well as on a number of more fundamental elements such as the way choices are elicited, either using the strategy (cold) or the direct (hot) method, whether beliefs are elicited, whether there is an estimation of a structural model and finally, whether there is a classification of subjects to types. The majority of the studies use two-player games (only two papers in this list including ours are using larger groups), do not elicit beliefs, and do not estimate a structural model. The closest studies to ours include [Vyrastekova and Funaki \(2018\)](#), [Baader et al. \(2024\)](#) and [Anwar and Georgalos \(2024\)](#) where our results extend and complement theirs.

[Vyrastekova and Funaki \(2018\)](#) design and conduct an economic experiment to test the theoretical predictions of [Nishihara \(1997\)](#). In a within-subjects experiment with 5-member groups, they study behaviour in two treatments, one with full and another without any information on the subjects’ position in the sequences and subjects receive information on whether someone before them defected or not. Their design differs to ours in a number of aspects. First, in order for the [Nishihara \(1997\)](#) cooperative equilibrium to hold, they need to focus on a special class of social dilemmas where the payoff function must be convex in cooperation and concave in defection. In our design, using an alternative information mechanism, we are able to study behaviour in a multi-player sequential prisoner’s dilemma , without the need to impose any constraints to the payoff function, extending their results to a more general case. Second, we elicit behaviour using both the direct and strategy method, and we also use structural estimations to classify subjects to various types. [Baader et al. \(2024\)](#) examine how the incentive to defect in a sequential prisoner’s dilemma affects conditional cooperation. Using 2-player games and eliciting behaviour from a large number of sequential prisoner’s dilemmas with varying payoffs, they structurally estimate a model of social preferences, highlighting the

role of positive weights on the opponent's payoff in conditional cooperation. In our study, we focus on a multi-person sequential prisoner's dilemmas and show how their results extend to the case of positional uncertainty. [Anwar and Georgalos \(2024\)](#) developed an experiment to test the predictions of G&M in the *public goods* game. They find that approximately 25% of the subjects behaved in line with the theoretical predictions, while the majority were classified as conditional cooperators. Some subjects exhibited altruistic tendencies, while only a small minority engaged in free-riding behaviour. Using the same information mechanism, we extend these results to the case of sequential prisoner's dilemmas, showing that while the proportion of G&M decision makers remains relatively constant, the majority of the players now adopt a free-riding approach.

From a methodological perspective, our study contributes to the literature comparing the strategy (cold) and direct (hot) elicitation methods (see, for example, [Brandts and Charness 2000](#), [Falk et al. 2005](#), [Reuben and Suetens 2012](#) in the context of sequential prisoner's dilemma games). Prior research has found that these two methods generally produce indistinguishable behaviour, suggesting that eliciting a subject's full strategy across all contingencies does not necessarily alter their choices during the experiment. Our results extend this finding to a more complex decision environment involving multiple information conditions and varying positions within the sequence across rounds. We find no significant differences in cooperation rates between the two elicitation methods, reinforcing the conclusions of [Brandts and Charness \(2011\)](#).

Finally, we also contribute to the finite mixture modelling literature. Most of the studies listed in [Table 1](#) that classify subject to different types, usually base this classification on deterministic choice and a relatively number of elicitation questions (usually two). This approach, despite its efficiency, does not allow the researcher to investigate further types, and also is susceptible to noise, as potential trembles of the decision maker will be wrongly classified as a certain behavioural type. On the other hand, finite mixture modelling allows for both the

identification of a number of discrete data generating processes, along with the estimation of error (stochasticity) in decision making. This econometric method has been extensively used in the literature of risky choice (see [Bruhin et al. 2010](#); [Conte et al. 2011](#) among others) and has been recently extended in the literature of social preferences (see for example [Bardsley and Moffatt 2007](#); [Iriberry and Rey-Biel 2013](#); [Conte and Moffatt 2014](#); [Bruhin et al. 2019](#))

Study	Size of group	Rounds	Method	Feedback	Beliefs	Treatments	Structural model	Types	Which types
Ahn et al. (2007)	2	4	strategy	no	no	3	no	yes	advantaged, disadvantaged, egoistic, conditional cooperator
Aksoy and Weesie (2014)	2	8*	both	no	no	1	yes	no	social value orientation model
Baader et al. (2024)	2	64*	strategy	no	yes	-	yes	yes	conditional cooperator, free-rider, unconditional cooperator, mismatcher
Bell et al. (2017)	2	2	direct	no	no	3	no	yes	positive and negative reciprocity, cooperation bias.
Blanco et al. (2011)	2	1	strategy	no	no	-	yes	no	-
Blanco et al. (2014)	2	1	strategy	no	yes	3	no	no	-
Brandts and Charness (2000)	2	1	both	no	no	2	no	no	-
Clark and Sefton (2001)	2	10	direct	yes	no	3	no	no	-
Dhaene and Bouckaert (2010)	2	1	direct	no	yes	-	yes	yes	whether a material and // or a reciprocity best response was given;
Eichenseer and Moser (2020)	2	1	strategy	no	no	-	no	yes	conditional cooperator; selfish; altruist; mismatcher
Guzmán et al. (2020)	2	60*	strategy	yes	no	-	yes	no	
Kirchsteiger et al. (2024)	2	30	both	yes	no	4	no	yes	conditional cooperator; selfish; altruist; mismatcher
Miettinen et al. (2020)	2	1	strategy	yes	yes	-	no	yes	homo economicus, inequity aversion, conditional welfare, reciprocity, altruism, homo moralis
Ridinger (2021)	2	20	direct	yes	no	4	no	no	-
Vyrastekova and Funaki (2018)	5	10	direct	yes	no	2	no	no	-
this study	5	10	both	yes	no	2	yes	yes	free rider, altruist, social preferences, G&M

Table 1: Comparison of related studies examining cooperation in sequential prisoner’s dilemma games. *Method* refers to the elicitation approach, either direct response, strategy method, or both. *Feedback* indicates whether subjects received feedback after each round. *Beliefs* indicates whether participants were asked to state their beliefs about others’ choices. *Structural* refers to whether a structural econometric model was estimated, and *Types* indicates whether subjects were classified into behavioural types. *Denotes studies in which each round involved a different set of payoffs.

3 Theoretical Framework

In this section we present the main features and predictions of the model – following the notation of [Gallice and Monzón \(2019\)](#) – and refer interested readers to the original study for further details. Consider a set $I = \{1, \dots, n\}$ of risk-neutral agents making choices in a sequential prisoner’s dilemma. They know the length n of the sequence, but are uncertain of their position in the sequence. Players are exogenously placed in the sequence that determines the order of play, and they can be at any position with equal chances. Thus, each player has symmetric beliefs about her position in the sequence. When the turn of player $i \in I$ arrives she can observe a *sample* of her predecessors’ action. She then choose one of two actions, $a_i \in \{C, D\}$, where $a_i = C$ indicates cooperation and $a_i = D$ indicates defection. Table 2 shows the payoffs for the agents from a one-shot interaction (i.e. when matched with only one person in the sequence).

		Player j	
		C	D
Player i	C	1,1	-l,1+g
	D	1+g,-l	0,0

Table 2: A Prisoner’s Dilemma Game

With $g > 0$ and $l > 0$, the game constitutes a prisoner’s dilemma. Agents sequentially choose whether to cooperate or defect. They receive information about the actions of their m immediate predecessors. After all players have chosen their actions, each agent is matched to all of her $n - 1$ opponents in a series of pairwise prisoner’s dilemma interactions. Agent i ’s total payoff is the sum of the payoffs from each pairwise interaction. The payoff of the agent in case she cooperates is given by:

$$u_i(C, G_{-i}) = G_{-i} - (n - 1 - G_{-i})l \quad (1)$$

with G_{-i} the number of players other than i who cooperated. In case she defects, the payoff is given by:

$$u_i(D, G_{-i}) = (1 + g)G_{-i} \quad (2)$$

We now introduce the notion of *sampling*. Before taking an action, each player observes how many of her $m \geq 2$ predecessors have contributed. Players in positions 1 through m will observe fewer than m actions, given that there are less than m players before them. For example, if $m = 2$, the first-position player sees an empty sample, the second-position player sees a sample consisting of just one past action, and the third-position player observes a full sample of two past actions. Each sample is represented by the pair

$$\xi = (\xi', \xi'')$$

where the first element indicates the number of agents sampled, and the second element records the number of agents who cooperated within that sample.¹ Importantly, a player cannot distinguish individual actions — only the overall sample size and the total number of cooperation. As a consequence, the first m agents can deduce their positional order based on the sample they observe. In this framework, players engage in an extensive form game with incomplete information, and G&M uses the solution concept of *sequential equilibrium* (Kreps and Wilson, 1982).

Let Ξ be the set of all samples that a player observes. Player i 's strategy is a function

$$\sigma_i(C \mid \xi) : \Xi \rightarrow [0, 1]$$

that specifies the probability of cooperating given the sample received. Let $\sigma = \{\sigma_i\}_{i \in I}$ denote a strategy profile and $\mu = \{\mu_i\}_{i \in I}$ a system of beliefs. For a pair (σ^*, μ^*) to be a *sequential*

¹For instance, $\xi = (2, 2)$ indicates that both of the previous 2 players cooperated; $\xi = (2, 0)$ indicates that neither of them cooperated; and $\xi = (2, 1)$ shows that only one of the two cooperated. Note that the first player in the sequence always receives the sample $\xi = (0, 0)$.

equilibrium, σ^* should be (sequentially) rational given μ^* , and μ^* should be consistent with σ^* . Let Ξ^C be the set of all samples without defection. Given this, Gallice and Monzón (2019, Lemma 5, p.2147) states that, assuming the following profile of play for all $i \in I$:

$$\sigma_i^*(C \mid \xi) = \begin{cases} 1, & \text{if } \xi \in \Xi^C \\ 0, & \text{otherwise} \end{cases}.$$

it follows that (σ^*, μ^*) is a sequential equilibrium provided that:

$$g \leq 1 - \frac{2m}{n + m - 1}. \quad (3)$$

In other words, a player will always cooperate when she observes a sample of size m with full cooperation, otherwise she will defect. Therefore, full cooperation emerges when agents play sequentially, are uncertain about their position, and observe the cooperating actions of some of their immediate m predecessors.

Proof. Consider first an agent who observes a sample with defection: $\xi \notin \Xi^C$. An agent who observes defection never believes she can prevent further defection and therefore, defects herself. Now consider an agent who observes a sample of full cooperation $\xi \in \Xi^C$. According to the equilibrium definition, this occurs at the equilibrium path, and the agent can therefore infer that all the previous agents in the sequence cooperated. By cooperating herself, she knows that all subsequent players will cooperate as well, and therefore, her expected payoff from cooperating will be equal to $n - 1$, and this payoff is independent of the agent's beliefs regarding her position in the sequence. On the other hand, the payoff from defecting depends on these beliefs. Consider an agent who observes a sample of m . This agent can therefore infer that she is not placed in the first m positions, and there are equal chances of her being in any of the

positions in $\{m + 1, \dots, n\}$. Let $Q(i)$ denote agent's position. The expected position is:

$$E_\mu[Q(i)|\xi] = \frac{1}{n-m} \sum_{t=m+1}^n t = \frac{n+m+1}{2},$$

which means that she can expect that $(n+m-1)/2$ agents have already cooperated. Observing full cooperation (and therefore, assuming that everyone beforehand has cooperated), the agent cooperates whenever:

$$E_{\mu^*}[u_i(\alpha_i, G_{-i})|\xi] \geq E_{\bar{\mu}}[u_i(\alpha_i, G_{-i})|\xi],$$

$$n-1 \geq \frac{1+g}{n-m} \sum_{t=m+1}^n (t-1) = \frac{n+m-1}{2}(1+g).$$

Therefore, the agent cooperates for values of g that satisfy:

$$g \leq \frac{n-m-1}{n+m-1}.$$

If the sample contains $\xi' < m$ total actions, the agent knows that she is in position $\xi' + 1$ with certainty. The number of agents who have cooperated so far is ξ' and the expected payoff from defecting is even lower (ξ'). The previous expression guarantees that agents in the first m positions cooperate. \square

For further generality, suppose that mutual cooperation yields the reward payoff R , defection against a cooperator yields the temptation payoff T , cooperation against a defector yields the sucker payoff S , and mutual defection yields the punishment payoff P , the game can be written as follows:

		Player j	
		C	D
Player i	C	R, R	S, T
	D	T, S	P, P

Table 3: General form

with the payoffs satisfying the conditions ²

$$T > R > P > S \quad (4)$$

and

$$2R > T + S. \quad (5)$$

In this general structure an agent cooperates for values of T that satisfy:

$$T \leq \frac{2(n-1)R - (n-m-1)P}{m+n-1} \quad (6)$$

Proof. Replacing for a generic payoff structure with R for cooperation and T for temptation respectively, the utility from cooperating is equal to $(n-1)R$, while the utility from defection is:

$$\frac{n+m-1}{2}T + \frac{n-m-1}{2}P$$

as the player expects that $(n+m-1)/2$ players have cooperated and the remaining will defect after they observe defection. Therefore, to observe full cooperation, we need:

$$(n-1)R \geq \frac{n+m-1}{2}T + \frac{n-m-1}{2}P$$

²Although $2R > T + S$ condition is primarily necessary in the repeated Prisoner's Dilemma—where it ensures that alternating between cooperation (C) and defection (D) is not a profitable strategy—we retain it here to facilitate comparison with the standard approach.

which holds whenever:

$$T \leq \frac{2(n-1)R - (n-m-1)P}{m+n-1}. \quad (7)$$

□

To keep it simple and relevant to our experiment, let us assume $n = 5$ players in the group, and a sample of $m = 2$. The model predicts: if players at positions 3, 4 and 5 in the sequence observe full cooperation, they will cooperate. If they observe at least one defection, the player believes that she cannot prevent further defections and, therefore, defects herself. Players in positions 1 and 2 (position certainty) have stronger incentives to cooperate.

Appendix A presents the analytical derivations of the G&M model's predictions across all positions and various information conditions, which we summarize in Table 4. For each position and corresponding information condition (m_c) — that is, cooperation by both previous players, cooperation by only one, or defection by both — Table 4 summarizes the expected utility (i.e., the expected payoffs) for each action. The table provides these utilities for a general group size (n) and sample size (m), as well as for the specific parameters used in our experiment ($n = 5, m = 2$). The last column reports the predicted choice of the decision maker, according to the G&M model, under the assumption that the constraints in the payoff matrix above hold.

Position	Info(m_c)	EU_C	EU_D	EU_C	EU_D	Decision
>2	2	$(n-1)R$	$(\frac{n+m-1}{2})T + (\frac{n-m-1}{2})P$	$4R$	$3T + P$	C
>2	1	$(\frac{n+m-1}{2} - 1)R + (\frac{n-m-1}{2} + 1)S$	$(\frac{n+m-1}{2} - 1)T + (\frac{n-m-1}{2} + 1)P$	$2R + 2S$	$2T + 2P$	D
>2	0	$(\frac{n+m-1}{2})S + (\frac{n-m-1}{2})S$	$(\frac{n+m-1}{2})P + (\frac{n-m-1}{2})P$	$4S$	$4P$	D
2	1	$(n-1)R$	$T + (n-2)P$	$4R$	$T + 3P$	C
2	0	$S + (n-2)S$	$P + (n-2)P$	$4S$	$4P$	D
1	-	$(n-1)R$	$(n-1)P$	$4R$	$4P$	C

Table 4: The Table summarises the Expected Utility (expected payoff) for each action at each position in the sequence along with the corresponding predicted choice. The third and fourth columns reports these values for any size of the group (n) and sample size (m), while the next two columns report the same information for the case of a group of size 5 ($n = 5$), where each player observes the choices of the two immediate predecessors ($m = 2$). The last column reports the predicted choice assuming Gallice and Monzón (2019) preferences.

This allows us to state our first two hypotheses that we aim to test:

Hypothesis 1. There will be full cooperation when there is position uncertainty, and the agents observe samples $m \geq 2$ of full cooperation.

and a complementary one

Hypothesis 2. cooperation will unravel when agents observe partial or no cooperation in samples of size $m \geq 2$.

4 Experimental Design

To test the predictions of the model presented in the previous section, we designed and conducted an incentivised economic experiment. The experiment took place at the Lancaster Experimental Economics Lab (LExEL) in February 2025, involving 85 subjects (48.2 females) across four sessions and were mainly undergraduate students from various disciplines.³. Re-

³The size of the sample is based on a power analysis, conducted with a significance level of 0.05 and aiming for 80% power, to detect a moderate effect size (Cohen's $w = 0.2$) in the specified McNemar's test for paired binary data. The analysis indicated a minimum sample of 64 subjects and was conducted using the *pwr.2p.test* function from the library *pwr* in R. For the power, we also used simulations for our structural model reported in section 5. In these simulation we assumed a sample of 50 subjects which was sufficient for our estimation routine to identify the behavioural parameters of our statistical model. We report details of the simulation in Appendix C.

cruitment took place via the ORSEE system ([Greiner, 2015](#)), and the experiment was computerised using a custom-developed software written in Python⁴. We excluded subjects who have participated in a prisoner’s dilemma experiment in the past, and all subjects participated only once.

Each session was divided into three parts. In Parts 1 and 3 participants play the game introduced earlier for 10 rounds each. We elicited behaviour using both the *strategy method* ([Selten, 1967](#)) in Part 1 and the *direct method* in Part 3. In Part 2, participants completed a real effort task. Scope of this part was to reduce cross-contamination between Parts 1 and 3. The order of the parts was the same for all participants. This fixed ordering was implemented to minimize potential anchoring effects, as our primary objective was to observe behaviour across all information conditions. Participants were informed that the experiment consisted of three parts, but the instructions for each part were provided only after the preceding part was completed.⁵

In our experimental implementation we use the following payoffs which satisfy all the conditions in (4), (5) and (6), at an exchange rate of £1 per 250 tokens⁶.

		Player j	
		C	D
Player i	C	500,500	50,600
	D	600,50	100,100

Table 5: Payoff Table

⁴[Python Software Foundation \(2023\)](#)

⁵The full set of instructions and screenshots from the experimental interface are provided in the Supplementary Material.

⁶The utilisation of both Experimental Currency Units (ECU) and the Random Payment Mechanism (RPM) has been a subject of ongoing debate in the literature. [Drichoutis et al. \(2015\)](#) show that there is no difference between using ECUs or cash in the lab; while at the same time, the use of ECUs leads to decisions closer to theoretical predictions. Conversely, empirical research comparing the different incentive mechanisms is inconclusive ([Azrieli et al., 2018](#)), while [Azrieli et al. \(2020\)](#) provide a theoretical justification that the RPM is incentive-compatible in almost all experiments.

In each session, participants formed groups of 5 and played for a total of 10 rounds in both parts. To replicate the one-shot play environment, we used a random matching protocol where in every round, participants were randomly matched into new groups. At the beginning of all the sessions, participants were given written instructions followed by a comprehension test. Participants were able to retake the questionnaire until they pass. The interface provided immediate feedback and explanation on the questions the subjects fail to respond to correctly. An experimenter was in the room to offer additional clarifications if there were further questions. Therefore, no exclusion criteria were applied. In every session, participants played the sequential prisoner's dilemma game, as described in the previous section. In every round, subjects were randomly positioned in the sequence (with equal chances of being allocated at each position) and were sequentially asked to choose either X (cooperation) or Y (defect). A participant would not learn about their position in the sequence unless they were at positions 1 or 2.

To rigorously test the predictions of the model, we need information on what subjects' choices are, in all potential samples they can observe. In particular, the model predicts that if a player observes full cooperation by the two previous players, she will cooperate herself, otherwise, if she observes at least one defection action, she will defect. In every round, participants were given different scenarios and were asked to choose either X (cooperate) or Y (defect) for each of these scenarios. The scenarios presented to the participant depended on their position. In particular, depending on their position, participants were given at least one of these scenarios:

- If the participant was at position 1 (i.e., there is no previous member), they would be asked to choose between X and Y.
- If the participant was at position 2, they would be asked to indicate what they would choose if the previous member chose X and what they would choose if the previous member chose Y.

- If the participant was at positions 3, 4, or 5, they would learn that their position is unknown. They would only be provided with information on the choices of the two immediate members before them. For instance, if the participant was at position 4, they would receive scenarios based on the choices of the members in positions 2 and 3, and so on. However, they would never find out the position of these members (and therefore in which position they themselves were). The participant would be asked to indicate what they would choose if the two previous members both chose X, both chose Y, and if one chose X and the other chose Y.

Once all subjects submitted their choices, the payoffs for a subject were calculated according to the four pairwise matches which were based on the actual realisation of play (i.e. based on what player 1 chose, the software would retrieve the contingent choice of player 2 and so on). At the end of every round, feedback was provided regarding the choices of the other members of the group, along with the corresponding payoffs. Subjects had access to an aggregate payoff table that informed them on their total payoffs that each of the available actions could generate, for all the potential choices of the other participants (e.g. if everyone defects, if only one person in the group defects and the other three cooperate, and so on) We implemented a random payment mechanism paying one randomly selected round from each part. The average payment was £15.9, including a show up fee of £3. The sessions lasted less than 45 minutes and payments were made via bank-transfer.

After Part 1 is completed participants were given instructions for Part 2. In Part 2 subjects were asked to complete a real effort task and in particular, they were asked to count the number of zeros in 5 randomly generated matrices (for a discussion on real effort tasks see [Charness et al. 2018](#)). This was a filler task to reduce potential cross-contamination between Part 1 and Part 3. After Part 2 was completed participants received instructions for Part 3. Part 3 was identical to Part 1, but now the choices were elicited using the *direct method*.

The main goal of our experiment is to test the theoretical predictions of G&M and using the

strategy method to elicit the full strategy of a player was crucial for our experiment, as it allows us to observe behaviour in all the potential information conditions (i.e., when both previous players cooperate, when only one cooperates, and when both defect). This means participants were asked to make contingent decisions for each possible information set depending on their randomly assigned position in the sequence.⁷ The secondary goal of our experiment is to examine whether the elicitation method influences participants' choices. Specifically, we aim to explore potential differences in decisions between those elicited using the strategy method and those using the direct method. [Brandts and Charness \(2000\)](#) were the first to test the direct-response method versus the strategy method in a 2-player sequential Prisoner's Dilemma⁸. With direct-response, a first mover made a choice that was observed by the responder, who then chose a response. With the strategy method, the responder had to make two contingent choices, one for each possible first-mover choice. We extend this framework to our multi-player sequential prisoner's dilemma. This leads us to our third hypothesis:

Hypothesis 3. There is no significant difference in behaviour between the *hot* elicitation environment (*direct*) and the *cold* environment (*strategy method*).

5 Results

5.1 Descriptive Statistics

Before estimating our structural model, we first present some summary information on choices and cooperation rates. We focus on the data from Part 1 where choices are elicited using the strategy method and therefore, we have data on the full strategy profile of our subjects. More

⁷The strategy method has been extensively used in the framework of prisoner's dilemma games (see [Aksoy and Weesie 2014](#); [Brandts and Charness 2000](#); [Kirchsteiger et al. 2024](#)) or public good games (see [Herrmann and Thöni 2009](#); [Fischbacher and Gächter 2010](#); [Teyssier 2012](#); [Martinsson et al. 2013](#); [Katuščák and Miklánek 2023](#)), while previous studies found no statistical differences in subjects' responses between the strategy and the direct response method (see [Brandts and Charness 2000](#); [Brandts and Charness 2011](#), or [Keser and Kliemt 2021](#) for a discussion).

⁸[Falk et al. \(2005\)](#) and [Reuben and Suetens \(2012\)](#) are comparing the two methods using a prisoner's dilemma game, but they do so in a different context. [Falk et al. \(2005\)](#) studied a prisoner's dilemma game with sanctioning opportunities, finding mixed results on the effect of the two methods, while [Reuben and Suetens \(2012\)](#) studied a repeated sequential prisoner's dilemma finding no significant difference.

specifically, we have data from three potential information conditions, namely, the decisions made by subjects when they observe a sample (the choice of the 2 immediate predecessors) of only defection (c_0), the decisions made by the subjects when they observe one cooperation and one defection action (c_1), and decisions made by subjects when they observe a sample of full cooperation (c_2).

Figures 1 and 2 present aggregate cooperation rates over time at the group and individual levels, respectively. Contributions remain relatively stable across all rounds, with no significant differences between the first and last five rounds, and no evidence of end-of-period effects. Furthermore, the overlap in the confidence intervals suggests that the dynamics of cooperative outcomes are not significantly affected by the information condition. Across all rounds, group-level cooperation is highest in condition c_0 (44%), followed by c_1 (38.8%) and c_2 (37.6%). Notably, cooperation in condition c_1 exceeds that in c_2 , running counter to the theoretical prediction that full cooperation observed in c_2 should encourage further cooperation.

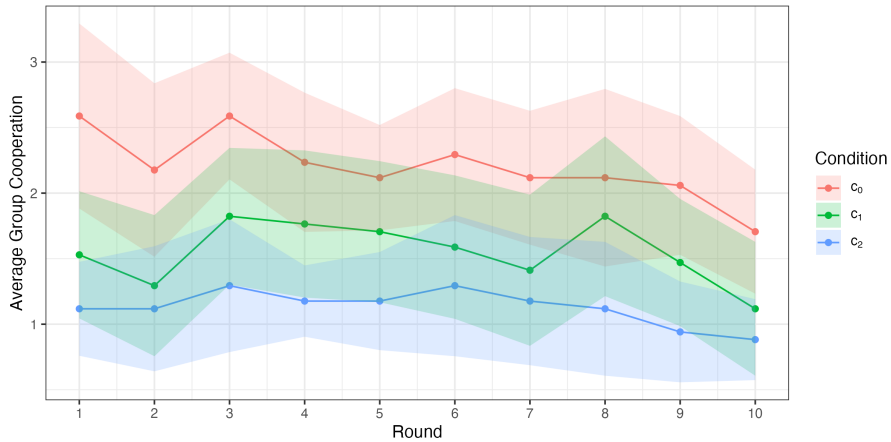


Figure 1: Group level cooperation across all conditions. The ribbon shows the 95% confidence interval.

Let \bar{c}_i denote the proportions of cooperation in conditions $i \in \{0, 1, 2\}$. The theoretical prediction is that $\bar{c}_2 > \bar{c}_1 > \bar{c}_0$, but we instead observe the opposite effect $\bar{c}_2 < \bar{c}_1 < \bar{c}_0$. One-sided exact binomial tests of $\bar{c}_2 > \bar{c}_0$ ($p = 0.9084$) and $\bar{c}_1 > \bar{c}_0$ ($p = 0.9352$) show no significant difference in the rate of cooperation between the two conditions⁹.

⁹A pairwise McNemar's test shows that there is no statistically significant difference between the choices under

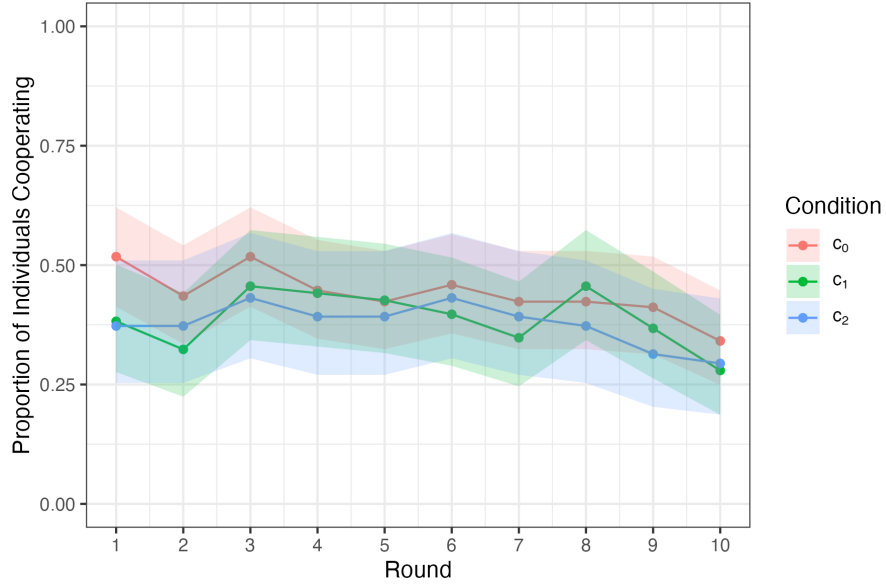


Figure 2: Individual level cooperation across all conditions. The ribbon shows the 95% confidence interval.

Figure 3 illustrates the rate of cooperation in Part 1. The left panel shows the decisions of all the subjects in all possible positions while the right panel shows the decisions of subjects positioned 3rd, 4th or 5th. where they face uncertainty. In both panels cooperation level is higher in condition c_0 compared to condition c_1 and c_2 . In the left panel, it appears that cooperation is decreasing in the condition. Nevertheless this difference is not statistically significant.

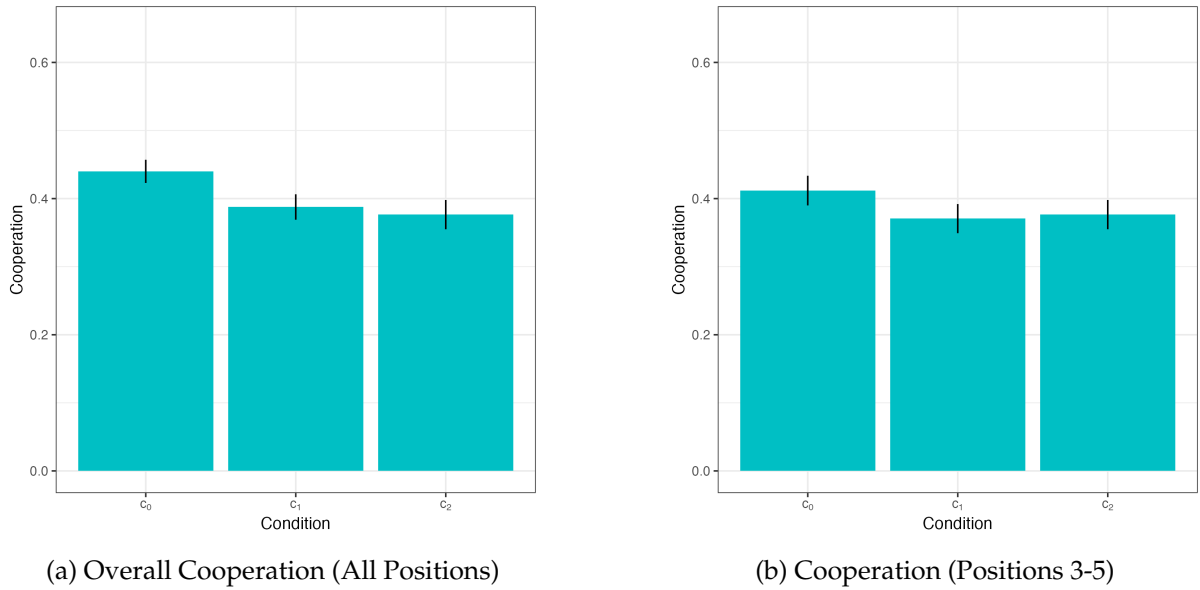


Figure 3: Comparison of Cooperation

the c_0 and c_1 conditions ($p = 0.1686$), and also c_2 and c_0 ($p = 0.234$).

At the individual level, the same pattern holds: cooperation in c_0 is consistently higher than in c_1 and c_2 , except for round 8, where the trend temporarily reverses. These findings do not support the hypothesis that cooperation would be highest in condition c_2 , relative to c_0 and c_1 . This leads us to our first result:

Finding 1. There is no significant difference in cooperation levels when subjects observe full cooperation, partial cooperation, or no cooperation in their sample. There is a significant level of cooperation even in the conditions where subjects observe defection in the sample.

These results provide no support for the hypothesis that position uncertainty promotes cooperation, nor for the notion that cooperation unravels when defection occurs. This result is in line with [Vyrastekova and Funaki \(2018\)](#) who find extensive free-riding and no difference between the no and full information treatments.

Table 6 reports the cooperation rates both in aggregate and disaggregated by position within the sequence. Interestingly, cooperation rates tend to decline as a subject's position in the sequence increases, suggesting that later players are less likely to contribute. The rate of cooperation of those placed at position 1 is 52.9% compared to 43.5% of those placed in the second position, and 41.2% of those we face position uncertainty, in no cooperation history condition. The difference between first and last places is highly significant ($p=0.0097$, McNemar's test). A similar pattern is observed in the other two conditions.

Position	c_0	c_1	c_2
1	0.529	-	-
2	0.435	0.441	-
>2	0.412	0.370	0.441
All	0.440	0.388	0.376

Table 6: Cooperation rates across all positions in the sequence.

Finding 2. The rate of cooperation is declining as a function of the position of the subject in the sequence.

This finding is closely related to the leading-by-example literature, based on the linear public goods game (see [Gächter et al. 2012](#); [Levati et al. 2007](#); [Potters et al. 2007](#); [Güth et al. 2007](#); [Figuieres et al. 2012](#); [Sutter and Rivas 2014](#); [Préget et al. 2016](#), in the context of public goods games, or [Moxnes and Van der Heijden 2003](#), in a public bad experiment). They all find robust evidence of first movers contributing more than later movers, and later movers' contributions to be positively correlated to the first movers' contributions, indicating reciprocal motives.

5.2 Structural model

While the results in the previous section do not provide support on the hypothesis that positional uncertainty would achieve full cooperation, there is a significant level of cooperation which appears to be independent of the information condition. In this section, we use structural econometrics to investigate why subjects contribute and under which conditions. More specifically we use structural modelling to distinguish between subjects who are best described by the G&M model and subjects whose preferences display alternative behavioural strategies (e.g. social preferences, conditional cooperation). Following the terminology adopted in the type-classification literature in public goods games (see for instance [Fischbacher et al. 2001](#); [Bardsley and Moffatt 2007](#); [Préget et al. 2016](#); [Thöni and Volk 2018](#); [Miettinen et al. 2020](#); [Katuščák and Miklánek 2023](#)) we define and explore the existence of the following types in our data: the *G&M* type, the *free-rider* type, the *altruist* type and the *conditional cooperator* type. The G&M type behaves as presented in section 3. The free-rider and altruist types represent two extremes: the former never cooperates, while the latter always cooperates, no matter their position in the sequence. An intermediate case is reflected in the conditional cooperator type, who always cooperates if she is in position 1 and also cooperates if she is at any other position and at least another player in the sequence has cooperated. This type has a conditional con-

cern for welfare which we model by assuming C&R preferences (see related papers [Miettinen et al. 2020](#); [Baader et al. 2024](#), [Bruhin et al. 2019](#)). Following C&R we assume that the utility of the players depends on both their own and others' earnings. In particular, letting π_A and π_B the monetary payoffs for players A and B respectively, the utility of Player B is given by the piecewise linear function:

$$U_B(\pi_A, \pi_B) \begin{cases} (1 - \rho)\pi_B + \rho\pi_A & \text{if } \pi_B > \pi_A \text{ (advantageous inequality)} \\ (1 - \sigma)\pi_B + \sigma\pi_A & \text{if } \pi_B < \pi_A \text{ (disadvantageous inequality).} \end{cases} \quad (8)$$

where σ and ρ parameters that capture various aspects of social preferences. This formulation says that the utility of Player B, is a weighted sum of her own monetary and the others player's payoff and may depend on whether the other player is getting a higher or lower payoff. Depending on the values of σ and ρ , subjects belong to different preference types. When both are zero, the model reduces to a purely selfish type and the predictions of the model coincide with those of G&M. When $\sigma < 0$ the subject is behindness averse, where she weights the other player's payoff negatively whenever her payoff is smaller than the other's. When $\rho > 0$, the subject is aheadness averse, that is she weights the payoff of the other player positively, whenever her payoff is larger than the other player. Consequently, a subject with $\sigma < 0 < \rho$ is both behindness and aheadness aversion, and furthermore, if $-\sigma < \rho$ then this subject is characterised as a difference averse type for whom disadvantageous inequality bears less weight than advantageous inequality. Similarly, in the case where $\sigma < 0 < \rho$ and $\sigma > \rho$, the subject is still difference averse but now disadvantageous inequality is more important than advantageous inequality. Preferences with both σ and ρ positive characterise an altruistic type, while negative values of the parameters indicate spiteful behaviour.

Our main objective is to model the behaviour of the *conditional cooperator* type, the one

who cooperates when she observes cooperation from at least one past predecessor, and defects otherwise. In Appendix B we provide the choice predictions of this model in the framework of our experiment, for three specifications.

5.3 Estimation method

To estimate the proportion of our experimental population that is best characterised by each type we adopt a finite mixture modelling approach (see McLachlan and Peel 2000, for an overview) which is based on the random utility framework (McFadden, 1981). Mixture models have been widely used to estimate models of risky choice (see, for example, Bruhin et al. 2010; Conte et al. 2011), and have more recently been applied in the social preferences literature to identify other-regarding types of behaviour (Bruhin et al., 2019)¹⁰.

A finite mixture model is flexible enough to identify the existence of distinct preference types, allowing for heterogeneity in decision making within the population. Mixture models assume that the population is made up by a finite number of \mathcal{K} distinct preference types, each characterised by its own set of parameters θ . Consider a subject $i \in \{1, 2, \dots, N\}$ who is best described by type k in the set of types $\mathcal{K} = \{gm, coop, alt, free\}$. Let π_k the population share of type k , with $\sum_{k=1}^K \pi_k = 1$. In round r the observed choice of individual i is a binary choice denoted by $y_i^r \in \{C, D\}$ for *cooperate* and *defect* respectively. There are in total four types, two of which are utility based (both G&M and C&R assume maximisation of expected utility), and two of which are heuristic-based (both the free-rider and altruist type always adopt the same

¹⁰An alternative methodology is the Strategy Frequency Estimation Method (SFEM) which was introduced by Dal Bó and Fréchette (2011) and Fudenberg et al. (2012) to estimate the distribution of behavioural types in experimental data. It assumes individuals follow one of a finite set of deterministic strategies and incorporates a fixed probability of implementation error (a tremble), independent of payoffs. SFEM has since been widely applied in the study of cooperation games, including Bigoni et al. (2015), Breitmoser (2015), Fréchette and Yuksel (2017), Dal Bó and Fréchette (2019) and Anwar and Georgalos (2024). A related approach is proposed by Bardsley and Moffatt (2007) in the context of continuous public goods games. In contrast, finite mixture models based on the random utility framework assume that individuals evaluate choices according to expected utility and that observed choices reflect stochastic utility differences across options. The likelihood of choosing a given option increases with the utility difference between the options. See McLachlan and Peel (2000) for a comprehensive overview of finite mixture models, and Dal Bó and Fréchette (2019, p. 3930) for a discussion of alternative strategy estimation methods and related identification issues.

strategy¹¹). To model stochasticity in decision making, we apply [McFadden \(1981\)](#) random utility model for discrete choices augmented with a tremble term, modelling both structured preferences and random errors. Specifically, we assume that choices are governed by a logit link function over deterministic utilities to capture stochasticity in preference evaluation. To account for additional behavioural noise such as inattention or response slips, we incorporate a tremble parameter ω ¹². The resulting probability of choosing an option is a convex combination between the model predicted choice and uniform random choice:

$$P(y_i^r = C; \theta_k, \beta, \omega) = (1 - \omega) \frac{\exp(\beta EU_c)}{\exp(\beta EU_c) + \exp(\beta EU_d)} + \frac{\omega}{2} \quad (9)$$

where EU_c and EU_d are the corresponding expected utilities of cooperation and defection as defined in section 3 and Appendix B, θ_k the vector of preference parameters of model, k , $\omega \in (0, 1/2)$ the tremble parameter, and β a parameter capturing the choice sensitivity with respect to the deterministic difference between the expected utility of the two options. When $\beta \rightarrow 0$ the model predicts random choice, and when $\beta \rightarrow \infty$ the probability of choosing the option with the highest expected utility converges to 1.

For the two types that assume heuristic decision making, we assume that the decision maker behaves according to the constant error model (see [Harless and Camerer 1994](#)), where with probability $1 - \omega$ she chooses the action that the heuristic prescribes, and with probability ω she chooses the opposite¹³. The likelihood for individual i is given by:

$$\mathcal{L} = \sum_{k=1}^K \pi_k \prod_{r=1}^R P(y_i^r | \theta_k, \beta, \omega) \quad (10)$$

where each individual's likelihood is a mixture of type-specific probabilities. The full sample

¹¹These preferences can also be modelled assuming [Charness and Rabin \(2002\)](#) preferences, when the parameters of the model are constrained in a particular range. Nevertheless, doing so would cause identification issues

¹²See [Moffatt and Peters \(2001\)](#) for a discussion on how omitting to account for a tremble can lead to biased coefficients, and [Conte et al. \(2011\)](#) for an implementation in a mixture model.

¹³For parsimony reasons and to reduce the total number of parameters in the statistical model, we assume that all types share the same parameters for β and ω . Relaxing this hypothesis does not alter the results qualitatively.

log-likelihood is therefore given by:

$$\log \mathcal{L} = \sum_{i=1}^N \log \left(\sum_{k=1}^K \pi_k \prod_{r=1}^R P(y_i^r | \theta_k, \beta, \omega) \right) \quad (11)$$

Objective is to find optimal values for β, ω, θ , and π that maximise the overall likelihood across all subjects I and set of types (strategies) \mathcal{K} . Therefore, there are seven parameters to estimate: two for the C&R model (ρ and σ), the precision and tremble parameters (β and ω), and the population shares for three types— π_{gm} (G&M), π_{coop} (conditional cooperator), and π_{free} (free-rider). The mixing probability π_{alt} for the altruist is simply the residual probability. We estimate the models using Maximum Likelihood Estimation techniques.¹⁴

All three specifications differ on the way the conditional cooperator decision maker is modelled. We explore three different definitions, one which assumes a modified version of the G&M model to account for social preferences, one that allows for the existence of a pure conditional cooperator, and one where we use the [Charness and Rabin \(2002\)](#) multi-player setting along with the notion of the *reciprocal fairness equilibrium*. We provide details on how each decision maker makes her optimal choices in Appendix B. Furthermore, in Appendix C we report the results of an extensive Monte Carlo simulation we performed to verify that our experimental design is appropriate to identify behavioural heterogeneity and that our econometric implementation is suitable to successfully estimate the parameters of our statistical model.

Table 7 reports the parameter estimates ($\hat{\theta}, \hat{\pi}_k, \hat{\beta}, \hat{\omega}$) of the mixture model under the three different specifications. Across all models, the pattern of type classification remains broadly consistent. Based on the values of the Akaike and Bayesian Information Criteria,¹⁵ the spec-

¹⁴For the estimation we use a general nonlinear augmented Lagrange multiplier optimisation routine that allows for random initialisation of the starting parameters as well as multiple restarts of the solver, to avoid local maxima. The estimation was conducted using the *R* programming language for statistical computing (The *R* Manuals, version 4.3.1. Available at: <http://www.r-project.org/>). The estimation codes are available in the replication repository.

¹⁵The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are model selection tools that balance model fit and complexity. In our mixture model, they help determine which specification best explains the data without overfitting, with lower values indicating a better trade-off between goodness of fit and parsimony. They are defined as:

$$\text{AIC} = -2 \cdot \log L + 2k, \quad \text{BIC} = -2 \cdot \log L + k \cdot \log(n)$$

ification that models the conditional cooperator as a modified version of the G&M framework—accounting for social preferences—provides the best fit to the data. As such, the remainder of the discussion focuses on the estimates from this model (first column on the table).

The majority of participants are classified as free-riders, comprising 48% of the sample. This finding aligns with [Baader et al. \(2024\)](#) who find the majority of their subjects behaving in a free-riding way, (49.3% on average varying between 42.6 and 57.0%) and [Kirchsteiger et al. \(2024\)](#), who report similar proportions of unconditional defectors (ranging from 38.6% to 54.1% across four treatments), as well as with [Vyrastekova and Funaki \(2018\)](#) and [Eichenseer and Moser \(2020\)](#), who also observe high, albeit non-majority, shares of such types. The G&M type accounts for 27.6% of the population, closely matching the 25% found in a public goods context by [Anwar and Georgalos \(2024\)](#). Furthermore, 10% of subjects are classified as conditional cooperators, and the remaining 14.5% either exhibit altruistic behaviour or could not be clearly classified into a specific type. With regards to the conditional cooperator type, our estimates suggest that subjects place substantial positive weight on others' outcomes when disadvantaged ($\sigma = 2.377$), consistent with reciprocal or fairness-motivated cooperation. Interestingly, the estimated value of $\rho = -1.2$, implies negative weighting of others' payoffs when ahead, which has been interpreted in the literature (e.g., [Bruhin et al., 2019](#)) as implausible or indicative of spiteful or competitiveness preferences. The values of the parameters for this model predict that this decision maker always cooperates unless she is at a position with uncertainty and observes full contribution. In that case the prediction is that this agent will defect. This pattern of behaviour could partially explain why there is a drop in cooperation in the full cooperation condition. Interestingly, this prediction runs counter to standard conditional cooperation logic and highlights how the structure of social preferences—particularly a negative weight on others' payoffs when ahead—can generate strategic defection even in highly cooperative environments. This result is very much in line with [Bruhin et al. \(2019\)](#) result, who

where $\log L$ is the log-likelihood of the model, k is the number of estimated parameters, and n is the number of observations.

find that their behindness averse type comprises roughly 10% of the population.

Finding 3. Based on the estimates of our structural model, the majority (48%) of our experimental population can be classified as free-riders, 27.6% as G&M decision makers, 10% as C&R, and the remaining 14.5% as altruists or individuals whose type could not be clearly identified.

Parameter	(1)	(2)	(3)
π_{gm}	0.276***	0.292***	0.330***
s.e.	(0.074)	(0.075)	(0.077)
π_{coop}	0.100**	0.088*	0.099
s.e.	(0.037)	(0.040)	(0.069)
π_{free}	0.480***	0.471***	0.457***
s.e.	(0.066)	(0.065)	(0.067)
π_{alt}	0.145	0.149	0.114
s.e.	(0.106)	(0.107)	(0.123)
σ	2.377*	4.734**	-
s.e.	(1.030)	(1.828)	-
ρ	-1.219*	-0.477	-
s.e.	(0.560)	(0.404)	-
γ	-	-	1.000
s.e.	-	-	(0.677)
δ	-	-	0.000
s.e.	-	-	(0.945)
β	0.623**	0.521**	0.282*
s.e.	(0.209)	(0.180)	(0.146)
ω	0.195***	0.191***	0.186***
s.e.	(0.017)	(0.016)	(0.017)
LL	-1186.544	-1191.416	-1210.32
AIC	2387.088	2396.832	2434.646
BIC	2426.433	2436.177	2473.991
Obs	2040	2040	2040

Table 7: The table reports the MLE estimates. All models include the same types, except for the specification of the conditional cooperator. Model 1 incorporates a modified version of G&M allowing for social preferences. Model 2 introduces social preferences motivation, while Model 3 includes a social welfare consideration. Standard errors are reported in parentheses. LL denotes the log-likelihood value, AIC the Akaike Information Criterion, and BIC the Bayesian Information Criterion. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.4 Strategy versus the direct-response method

Finally, we test whether the elicitation method had any impact on the cooperation rate. [Brandts and Charness \(2000\)](#) were the first to test the direct-response method versus the strategy method in a 2-player sequential Prisoner's Dilemma¹⁶. With direct-response, a first mover made a choice that was observed by the responder, who then chose a response. With the strategy method, the responder had to make two contingent choices, one for each possible first-mover choice. We now compare the results from Part 1 and Part 3 to examine the impact of the two elicitation methods — the strategy method (“cold”) and the direct method (“hot”). Part 3 was a repetition of Part 1, but choices were now elicited using the direct method. In each round, groups were re-matched, and players made decisions in a truly sequential manner. As a result, while the data from Part 1 include a full strategy profile for each player (i.e., choices for each possible history), in Part 3 subjects made only one decision per round, based on their position in the sequence and the actions of the two preceding players. To enable a direct comparison between the two methods, we convert the conditional choices from Part 1 into actual choices by matching the observed histories from Part 3. Aggregating over all decisions, the frequency of choosing action C in Part 1 was 43.2% (367/850), which is quite close to the 45.9% (390/850) observed in Part 3. This difference is not significant based on a McNemar's test ($p = 0.236$).

Figure 4 presents the level of cooperation/defection in Part and Part 3. We can see there's not much difference between them. Using McNemar's test we find that there is no significant difference between elicitation methods ($p = 0.2362$), therefore we fail to reject Hypothesis 3.

Finding 4. The elicitation method (whether decisions were made via the strategy method or direct method) does not significantly influence participants' decisions to cooperate or defect.

¹⁶[Falk et al. \(2005\)](#) and [Reuben and Suetens \(2012\)](#) are comparing the two methods using a prisoner's dilemma game, but they do so in a different context. [Falk et al. \(2005\)](#) studied a prisoner's dilemma game with sanctioning opportunities, finding mixed results on the effect of the two methods, while [Reuben and Suetens \(2012\)](#) studied a repeated sequential prisoner's dilemma finding no significant difference.

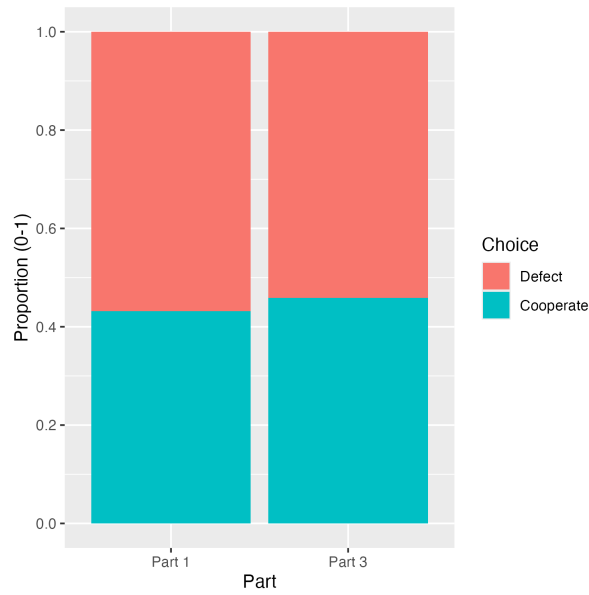


Figure 4: Hot vs Cold

6 Conclusion

Understanding the conditions under which cooperation emerges in social dilemmas is essential, as such behaviour characterises the functioning of societies where individual and collective interests often conflict. While a range of mechanisms—such as punishment, reputation, communication, and institutional design—have been proposed in the literature to sustain cooperation, empirical evidence on their effectiveness remains context-dependent and incomplete. In other cases, cooperation appears to rely heavily on the presence of social preferences, such as altruism or reciprocity, which motivate individuals to act beyond narrow self-interest.

In a recent study, [Gallice and Monzón \(2019\)](#) show that full cooperation can be achieved in the framework of social dilemmas (public goods game and prisoner’s dilemma), even when the interaction is one-shot, the number of players is finite, and individuals are purely self-interested. In their model, players make decisions sequentially without knowing their exact position in the sequence (i.e., under position uncertainty), but they do observe a sample of previous decisions made by others. The theoretical prediction is that players will cooperate when they observe full cooperation, otherwise they will defect.

In this study, we design and conduct an economic experiment to test the theoretical predictions of [Gallice and Monzón \(2019\)](#). In a within-subject experiment with two elicitation conditions: the strategy method (cold) and the direct method (hot), subjects in groups of 5, participate in a sequential prisoner’s dilemma game where they face positional uncertainty. Our findings indicate that the information structure does not significantly affect cooperation levels, consistent with [Vyrastekova and Funaki \(2018\)](#), who report similar results in a related game featuring a different information design. Nevertheless, we find a positive and significant level of cooperation in all information conditions, indicating the presence of alternative behavioural types. Using structural econometric analysis, we further classify subjects to those who are consistent with the predictions of the G&M model, those who behave in a conditionally co-operating manner, modelled according to the predictions of the [Charness and Rabin \(2002\)](#) model of social preferences, and to those who unconditionally cooperate (altruists) or unconditionally defect (free-riders). We find that the majority of the subjects resort to free-riding behaviour (48%), around 27% behave according to the predictions of G&M, 10% according to the predictions of [Charness and Rabin \(2002\)](#) while the remaining as best described as altruists. Finally, we find no difference in behaviour between the two elicitation methods, providing further support to the strategy elicitation method ([Selten, 1967](#)) as a valid instrument to elicit behaviour in an interactive environment.

Our results have implications both at a methodological and a policy making level. From a methodological point of view, the findings from the literature on the stability and transferability of cooperation types across games remain mixed, with recent work aiming to understand the conditions under which cooperative tendencies generalise. [Eichenseer and Moser \(2020\)](#) compare type classifications in a sequential Prisoner’s Dilemma and a one-shot public goods game, and find that conditional cooperators are consistently identified across games. However, they caution that sequential prisoner’s dilemmas are less reliable for identifying purely selfish types. Similarly, [Mullett et al. \(2019\)](#) demonstrate significant but imperfect cross-task

predictability between public good games and binary social dilemmas, concluding that prosociality behaves like a stable trait but is also context-dependent.

In the context of our study, this debate is directly relevant. In the sequential Prisoner's Dilemma, we find that a majority of subjects are best described as free riders, with approximately 27% aligning with Gallice and Monzon's strategic model which also entail a large amount of defection behaviour. In contrast, [Anwar and Georgalos \(2024\)](#), using the same information mechanism in a public goods game—albeit with a different subject pool—found that altruists and conditional cooperators make up over 65% of participants. These findings suggest that the nature of the strategic environment and institutional framing significantly affect the salience and detectability of social preference types, reinforcing conclusions by [Eichenseer and Moser \(2020\)](#) that some types (e.g., conditional cooperators) are more consistently expressed across games, while others are more context-sensitive.

Our results may also have a direct impact on the modelling of policy negotiations and the design of effective interventions. Consider, for example, the case of international environmental policy (e.g., climate policy). Recent literature has debated the appropriate game-theoretic framework for capturing such interactions. [DeCanio and Fremstad \(2013\)](#) provide a thorough analysis of how climate negotiations between two players can map onto different strategic environments depending on the underlying payoffs—such as the No-Conflict Game, Prisoner's Dilemma, Coordination Game, Chicken, Type Game, or Cycle. They conclude that under heightened perceptions of risk or long-term consequences, the structure of the interaction shifts away from a pure prisoner's dilemma dynamic and is better described as a coordination game—an argument further supported by [Mielke and Steudle \(2018\)](#). [Alessio and Manfredi \(2022\)](#) highlight the conditions under which this coordination may break down. Our results lend empirical support to the Climate Clubs proposal by [Nordhaus \(2015\)](#), who proposes the introduction of institutional mechanisms—such as selective incentives or trade sanctions—to shift the payoff structure and align incentives across heterogeneous actors. These clubs may be

especially effective in stabilising cooperation among self-interested (free-riding) types while simultaneously enabling reciprocity-driven or prosocial countries to coordinate on cooperative outcomes. Future work could explore how institutional designs can be tailored to populations with differing strategic dispositions, and how behavioural insights from laboratory settings can inform the dynamics of real-world climate negotiations.

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Appendix A Optimal choices in the Gallice and Monzón (2019) model

In this Appendix we present the optimal decisions according to the predictions of the Gallice and Monzón (2019) model for all potential positions and all information sets a player may find herself during the experiment. We first present the solution for any size of group n and then focus on the case of our experimental design where $n = 5$. In our experimental implementation we use the following payoffs which satisfy the following conditions: $T > R > P > S$ and $2R > T + S$.

		Player j	
		C	D
Player i	C	500,500	50,600
	D	600,50	100,100

Let $m = 2$ denote the sample size, and let m_c denote the number of cooperators observed in the sample (so $0 \leq m_c \leq m$). We consider three potential positions in the sequence : position 1 and 2, which entail decision making under certainty, and position >2 , which involves positional uncertainty.

Position >2 , $m_c = 2$. With a full sample of previous cooperating actions and position uncertainty, the player can infer that everyone before in the sequence has cooperated, and she also expects that playing C will motivate the next player in the sequence to also play C, while playing D will lead to defection from the next player. The corresponding payoffs are given by:

$$\begin{aligned}
 U_c &= (n-1)R = 4R \\
 U_d &= \left(\frac{n+m-1}{2}\right)T + \left(\frac{n-m-1}{2}\right)P \\
 &= 3T + P.
 \end{aligned}$$

where

$$\left(\frac{n + m - 1}{2} \right)$$

is the expected position in the sequence and

$$\left(\frac{n - m - 1}{2} \right)$$

is the number of the remaining participants in the sequence. Substituting for $m = 2$ and $n = 5$ we can show that the player always cooperates whenever $4R \geq 3T + P$.

Position>2, $m_c = 1$. When observing only one prior cooperative action, according to the G&M model, the player defects as she has no way to persuade the next player to cooperate. The expected payoffs are given by:

$$\begin{aligned} U_c &= \left(\frac{n + m - 1}{2} - 1 \right) R + \left(\frac{n - m - 1}{2} + 1 \right) S \\ &= 2R + 2S \\ U_d &= \left(\frac{n + m - 1}{2} - 1 \right) T + \left(\frac{n - m - 1}{2} + 1 \right) P \\ &= 2T + 2P. \end{aligned}$$

The player chooses the cooperating action whenever $R + S > T + P$ which given the structure of the payoffs in our experimental design, it can never happen.

Position>2, $m_c = 0$. A player observing a sample of zero cooperating actions can infer that no-one in the sequence before her has cooperated and also she has no way to incentivise

the subsequent player to do so.

$$\begin{aligned}
U_c &= \left(\frac{n+m-1}{2} \right) S + \left(\frac{n-m-1}{2} \right) S \\
&= 4S \\
U_d &= \left(\frac{n+m-1}{2} \right) P + \left(\frac{n-m-1}{2} \right) P \\
&= 4P
\end{aligned}$$

The player never cooperates since $P > S$ by design.

Position=2, $m_c = 1$ When the player is at position 2 and observes the cooperating action from the first player, she can then trigger cooperation or defection for all the subsequent players based on her choice. If she cooperates, then all the subsequent players are expected to cooperate. If she defects, all subsequent players will defect. The expected payoffs are given by:

$$\begin{aligned}
U_c &= (n-1)R = 4R \\
U_d &= T + (n-2)P = T + 3P
\end{aligned}$$

The player cooperates whenever $4R \geq T + 3P$

Position=2, $m_c = 0$ A player observing a sample of zero cooperating actions can infer that the first player did not cooperate and also she has no way to incentivise the subsequent player to do so.

$$\begin{aligned}
U_c &= S + (n-2)S = 4S \\
U_d &= P + (n-2)P = 4P
\end{aligned}$$

The player always defects since $P > S$ by design. cooperates when the condition below

holds:

Position=1 The first player in the sequence expects that if she cooperates (defects) everyone will cooperate (defect). The expected utility is given by:

$$U_c = (n - 1)R = 4R$$

$$U_d = (n - 1)P = 4P$$

which predicts that the player at the first position always contributes since $R > P$ by design. Table 4 summarises the expected utility or each decision at each position and the prediction of the G&M model.

Position	Info(m_c)	EU_C	EU_D	EU_C	EU_D	Decision
>2	2	$(n - 1)R$	$\left(\frac{n+m-1}{2}\right) T + \left(\frac{n-m-1}{2}\right) P$	$4R$	$3T + P$	C
>2	1	$\left(\frac{n+m-1}{2} - 1\right) R + \left(\frac{n-m-1}{2} + 1\right) S$	$\left(\frac{n+m-1}{2} - 1\right) T + \left(\frac{n-m-1}{2} + 1\right) P$	$2R + 2S$	$2T + 2P$	D
>2	0	$\left(\frac{n+m-1}{2}\right) S + \left(\frac{n-m-1}{2}\right) S$	$\left(\frac{n+m-1}{2}\right) P + \left(\frac{n-m-1}{2}\right) P$	$4S$	$4P$	D
2	1	$(n - 1)R$	$T + (n - 2)P$	$4R$	$T + 3P$	C
2	0	$S + (n - 2)S$	$P + (n - 2)P$	$4S$	$4P$	D
1	-	$(n - 1)R$	$(n - 1)P$	$4R$	$4P$	C

Table 8: The Table summarised the Expected Utility for each action at each position in the sequence along with the corresponding predicted choice.

Appendix B A model of social preferences

Following [Charness and Rabin \(2002\)](#) we assume that the utility of the players depends on both their own and others' earnings. In particular, letting π_A and π_B the monetary payoffs for players A and B respectively, the utility of Player B is given by the piecewise linear function:

$$U_B(\pi_A, \pi_B) \begin{cases} (1 - \rho)\pi_B + \rho\pi_A & \text{if } \pi_B > \pi_A \text{ (advantageous inequality)} \\ (1 - \sigma)\pi_B + \sigma\pi_A & \text{if } \pi_B < \pi_A \text{ (disadvantageous inequality)}. \end{cases} \quad (12)$$

with $\sigma < 0 < \rho < 1$ parameters that represent positive and negative reciprocal preferences. This formulation says that the utility of Player B, is a weighted sum of her own monetary and the others player's payoff and may depend on whether A is getting a higher or lower payoff. Our main objective is to model the behaviour of the *conditional cooperator* type, the one who cooperates when she observes cooperation from at least one past predecessor, and defects otherwise. We provide the optimal choice for two specifications of this model. First, we consider a modified G&M model, where the agent follows the same thought process as in G&M but has also social preferences. That is, this player cooperates when she observes a full cooperation sample and defects if the sample contains only defection. The player expects others to defect when they observe partial cooperation (only one player in the sample cooperated) but we derive the conditions under which this player will cooperate under partial cooperation. In the second specification, we explicitly model the behaviour of the conditional cooperator as one who always cooperates when there is a sample of partial cooperation and defects otherwise (and she also expects others to do so). In what follows, we consider the expected utility of the players in all the positions and all the potential information conditions on past cooperation. The beliefs of the player's position in the sequence are formed in a identical way as those in [Gallice and Monzón \(2019\)](#)

B.1 Social preferences in a modified G&M model

We present the optimal decision for a player at each position and each information set they may receive during the experiment. We denote by \tilde{X} the untransformed monetary reward.

Position>2, $m_c = 2$ With a full sample of previous cooperating actions and position uncertainty, the player knows that playing C will motivate the next player in the sequence to also play C, while playing D will lead to defection from the next player. The corresponding payoffs are given by:

$$\begin{aligned} U_c &= 4\tilde{R} = 4R \\ U_d &= 3\tilde{T} + \tilde{P} \\ &= 3((1 - \rho)T + \rho S) + P. \end{aligned}$$

The player cooperates whenever $U_c \geq U_d$ which holds for values of ρ that satisfy:

$$\rho \geq \frac{3T + P - 4R}{3(T - S)}$$

Position>2, $m_c = 1$ When observing only one prior cooperative action, two potential scenarios arise regarding the sample that the next player will observe. Let us focus on the cooperation decision of a player placed at position t in the sequence.

Case 1: If the observed cooperative action originates from the immediately preceding player at position $t - 1$, the cooperation of the player at t will generate a complete sample for the next player at position $t + 1$. This, in turn, prompts cooperation from the player at $t + 1$. The resulting expected utility from this sequence of actions would be $3\tilde{R} + \tilde{S}$.

Case 2: If the observed cooperative action comes instead from the player at position $t - 2$, then the cooperation of the player at t will result in a sample containing only one cooperative action for the player at $t + 1$. This would lead to defection by the player at

$t + 1$. The corresponding expected payoff would be $2\tilde{R} + 2\tilde{S}$. We assume that the player considers each of the cases equally likely and, therefore, attaches a weight of $1/2$ to each. Defection on the other hand, would trigger defection for all the subsequent players. The expected payoffs are given by:

$$\begin{aligned}
 U_c &= \frac{1}{2}(2\tilde{R} + 2\tilde{S}) + \frac{1}{2}(3\tilde{R} + \tilde{S}) \\
 &= \frac{5}{2}\tilde{R} + \frac{3}{2}\tilde{S} \\
 &= \frac{5}{2}R + \frac{3}{2}((1 - \sigma)S + \sigma T) \\
 U_d &= 2\tilde{T} + 2\tilde{P} \\
 &= 2((1 - \rho)T + \rho S) + 2P.
 \end{aligned}$$

The player chooses the cooperating action whenever:

$$\sigma \geq \frac{(2((1 - \rho)T + \rho S) + 2P - 5/2R - 3/2S)}{3/2(T - S)}$$

Position > 2, $m_c = 0$ A player observing a sample of zero cooperating actions can infer that no one in the sequence before her has cooperated and also she has no way to incentivise the subsequent player to do so.

$$\begin{aligned}
 U_c &= 4\tilde{S} = 4((1 - \sigma)S + \sigma T) \\
 U_d &= 4\tilde{P}
 \end{aligned}$$

The player cooperates when the condition below holds:

$$\sigma \geq \frac{P - S}{T - S}$$

Position=2, $m_c = 1$ When the player is at position 2 and observes the cooperating action from the first player, she can then trigger cooperation or defection for all the subsequent players based on her choice. That is:

$$U_c = 4\tilde{R}$$

$$U_d = \tilde{T} + 3\tilde{P} = (1 - \rho)T + \rho S + 3P$$

The player chooses C when:

$$\rho \geq \frac{T + 3P - 4R}{T - S}$$

Position=2, $m_c = 0$ As in the positional uncertainty case, a player observing a sample of zero cooperating actions can infer that no-one in the sequence before her has cooperated and also she has no way to incentivise the subsequent player to do so.

$$U_c = 4\tilde{S} = 4((1 - \sigma)S + \sigma T)$$

$$U_d = 4\tilde{P}$$

The player cooperates when the condition below holds:

$$\sigma \geq \frac{P - S}{T - S}$$

Position=1 The first player in the sequence expects that if she cooperates (defects) everyone will cooperate (defect). The expected utility is given by:

$$U_c = 4\tilde{R} = 4R$$

$$U_d = 4\tilde{P} = 4P$$

which predicts that the player at the first position always contributes.

B.2 Social preferences in a conditional cooperation model

This version of the model models the conditional cooperator player, who always cooperates when she observes a sample of partial cooperation (at least one of the previous players cooperated) and expects others to do so as well. The main difference is that there are circumstances where this type cooperates even after observing a full defection sample, aiming to motivate the subsequent players to do so.

Position > 2, $m_c = 2$ With a full sample of previous cooperating actions and position uncertainty, the player knows that playing C will motivate the next player in the sequence to also play C, while playing D will lead to defection from the next player. The corresponding payoffs are given by:

$$U_c = 4\tilde{R} = 4R$$

$$\begin{aligned} U_d &= 4\tilde{T} \\ &= 4((1 - \rho)T + \rho S). \end{aligned}$$

The player cooperates whenever $U_c \geq U_d$ which holds for values of ρ that satisfy:

$$\rho \geq \frac{T - R}{T - S}$$

Position > 2, $m_c = 1$ When observing only one prior cooperative action, two potential scenarios arise regarding the sample that the next player will observe. Since by definition a conditional cooperator player cooperates when she observes partial cooperation, the utility of cooperation is given by $\tilde{S} + 3\tilde{R}$ since only one player defected and the subsequent ones are expected to cooperate. Let us now focus on the defection decision of a player placed

at position t in the sequence that affects the sample that the subsequent players receive.

Case 1: If the observed defection action originates from the immediately preceding player at position $t - 1$, the defection of the player at t will not dissuade the player at position $t + 1$ to cooperate since they will observe a sample of partial cooperation. The resulting expected utility from this sequence of actions would be $3\tilde{T} + \tilde{P}$.

Case 2: If the observed defection action comes instead from the player at position $t - 2$, then defection of the player at t will result in a full defection sample for the player at $t + 1$ which would lead to defection by this player as well. The corresponding expected payoff would be $2\tilde{T} + 2\tilde{P}$. We assume that the player considers each of the cases equally likely and, therefore, attaches a weight of $1/2$ to each. The expected payoffs are given by:

$$\begin{aligned}
U_c &= \tilde{S} + 3\tilde{R} \\
&= (1 - \sigma)S + \sigma T + 3P \\
U_d &= \frac{1}{2}(2\tilde{T} + 2\tilde{P}) + \frac{1}{2}(3\tilde{T} + \tilde{P}) \\
&= \frac{5}{2}\tilde{T} + \frac{3}{2}\tilde{P} \\
&= \frac{5}{2}((1 - \rho)T + \rho S) + \frac{3}{2}P.
\end{aligned}$$

The player chooses the cooperating action whenever:

$$\sigma \geq \frac{5/2(T - \rho(T - S)) + 3P/2 - 3R - S}{T - S}$$

Position > 2, $m_c = 0$ A player observing a sample of zero cooperating actions can still cooperate if she expects that she can persuade the subsequent players to cooperate. The corre-

sponding expected payoffs in that case are:

$$\begin{aligned}
 U_c &= 3\tilde{S} + \tilde{R} \\
 &= 3((1 - \sigma)S + \sigma T) + R \\
 U_d &= 4\tilde{P} = 4P
 \end{aligned}$$

The player cooperates when the condition below holds:

$$\sigma \geq \frac{4P - R - 3S}{3(T - S)}$$

Position=2, $m_c = 1$ When the player is at position 2 and observes the cooperating action from the first player, she can then trigger cooperation or defection for all the subsequent players based on her choice. That is:

$$\begin{aligned}
 U_c &= 4\tilde{R} \\
 U_d &= 4\tilde{T} = 4((1 - \rho)T + \rho S)
 \end{aligned}$$

The player chooses C when:

$$\rho \geq \frac{T - R}{T - S}$$

Position=2, $m_c = 0$ At this position the player can affect future cooperation even if she observes defection by the first player. The expected payoffs are given by:

$$\begin{aligned}
 U_c &= \tilde{S} + 3\tilde{R} \\
 &= (1 - \sigma)S + \sigma T + 3R \\
 U_d &= 4\tilde{P} = 4P
 \end{aligned}$$

The player cooperates when the condition below holds:

$$\sigma \geq \frac{4P - 3R - S}{T - S}$$

Position=1 The first player in the sequence expects that if she cooperates (defects) everyone will cooperate (defect). The expected utility is given by:

$$U_c = 4\tilde{R} = 4R$$

$$U_d = 4\tilde{P} = 4P$$

which predicts that the player at the first position always contributes.

B.3 Reciprocal Fairness Equilibrium

Charness and Rabin (2002, Appendix 1) propose an alternative model in a multi-player setting where they allow decision makers to express preferences for more general social-welfare objectives, suggesting the concept of *reciprocal fairness equilibrium*. Let n individuals with material outcomes $\pi_1, \pi_2, \dots, \pi_n$. The utility function of any individual $i = 1, \dots, n$ is a weighted average of their own material payoff π_i and a “disinterested” social-welfare criterion given by:

$$W(\pi_1, \pi_2, \dots, \pi_n) = \delta \min[\pi_1, \pi_2, \dots, \pi_n] + (1 - \delta)(\pi_1 + \pi_2 + \dots + \pi_n) \quad (13)$$

with $\delta \in (0, 1)$ a parameter measuring the degree of concern for helping the worst-off person versus maximising the total social surplus. When $\delta = 1$ this corresponds to a “Rawlsian” criterion, where the objective is to maximise the utility of the least well-off in the society, while with $\delta = 0$ the objective is to maximise the total surplus. The utility function of any individual

$i = 1, \dots, n$ is then given by:

$$u_i(\pi_1, \pi_2, \dots, \pi_n) = (1 - \gamma)\pi_i + \gamma W \quad (14)$$

with $\gamma \in (0, 1)$. The parameter γ measures how much individual i cares about her own interest against the social welfare. When $\gamma = 0$ the model collapses to pure self-interest one (in which occasion the model predicts behaviour equivalent to G&M preferences). Following the same logic as above, Table 9 summarises the expected payoffs for each player in the sequence as seen from player i in all potential positions and for all potential information conditions (highlighted in the Table). For instance, consider the case when the position is unknown (position > 2) and the available information is that none of the previous two players in the sequence cooperated ($m_c = 0$). As shown in section 3, the decision maker expects to be at position 4, and given the zero cooperation sample, she may infer that none of the previous players in the sequence has cooperated. Therefore, her expected payoff by playing C is equal to $4S$ while for all the other players, their expected payoff is equal to $T + 3P$ consisting of one temptation payoff when they are matched with the player at position 4, and 3 punishment payoffs from the 3 mutual-defect matches. Using the information from each row, it is then straight-forward to calculate the corresponding utility for player i as a convex combination of her own material payoff and the social-welfare criterion. Monte Carlo simulations confirm that our design allows us to identify and successfully recover both γ and δ .

	choice	1	2	3	4	5
position=1	C	4R	4R	4R	4R	4R
	D	4P	4P	4P	4P	4P
position=2, $m_c = 0$	C	T+3P	4S	T+3P	T+3P	T+3P
	D	4P	4P	4P	4P	4P
position=2, $m_c = 1$	C	4R	4R	4R	4R	4R
	D	4S	T+3P	T+3P	T+3P	T+3P
position>2, $m_c = 0$	C	T+3P	T+3P	T+3P	4S	T+3P
	D	4P	4P	4P	4P	4P
position>2, $m_c = 1$	C	2R+2S	2R+2S	3T+P	2R+2S	3T+P
	D	R+3S	R+3S	2T+2P	2T+2P	2T+2P
position>2, $m_c = 2$	C	4R	4R	4R	4R	4R
	D	2R+2S	2R+2S	2R+2S	3T+P	3T+P

Table 9: The Table summarises the expected payoffs for each player in the sequence as seen from player i , in all potential positions and for all potential information conditions (highlighted in the Table). Combining the payoffs from each row, the utility of player i can be calculated as the convex combination of her material payoff π_i and the social-welfare criterion, defined as a convex combination between the minimum payoff in the sequence and the total surplus.

Appendix C Simulation

In this appendix, we use simulations to explore the robustness of the estimation method employed in this paper. Following [Dal Bó and Fréchet \(2019, Appendix E\)](#), we conduct an extensive Monte Carlo simulation to study the ability to identify the prevalence of different strategies in the data and, consequently, the existence of various types in the subject pool. We assess the methodology’s robustness, subject to our sample size, by successfully recovering the assumed parameters of our structural model.

We simulate data and assume conditions that resemble those to our lab implementation. We generate simulated data from 50 subjects. Each subject is allocated a type based on pre-determined proportions π_k with $k \in \{gm, alt, coop, free\}$ for the G&M, the altruist, the conditional cooperator, and the free-rider, respectively. In every round, subjects are matched in groups of 5 and are allocated to the sequence in a random order. Choices are simulated based on the planned experimental design. That is, each subject provides their conditional choice, dependent on their type and their position in the sequence (strategy method). The process is repeated for 10 rounds, where subjects are matched to a new 5-member group. We report the results of the simulation, based on the random utility method as presented in the manuscript.

In this simulation we assume four data generating processes: the G&M type, conditional cooperator type modelled assuming [Charness and Rabin \(2002\)](#) preferences, the free-rider and the altruist. There are 7 parameters to estimate, the mix probabilities for the G&M, the conditional altruists and free-rising subjects π_{gm} , π_{coop} , and π_{free} , respectively, the positive and negative reciprocal parameters for the conditional cooperator ρ and σ , the precision parameter β and the tremble parameter ω . We assume again three levels of noise (low, medium and high) and two levels for the reciprocal parameters with $\rho \in [0.100, 0.500]$ and $\sigma \in [-0.100, -0.400]$. The percentage of G&M subjects is set to 40%, C&R 30%, free-riders 20% and altruists 10%¹⁷.

¹⁷We explored numerous frequency combinations for the four types, and our findings consistently affirm that qualitative results remain unchanged, regardless of the assumed frequency combination.

We report the results assuming a medium level of noise with $\beta = 0.500$ and $\omega = 0.15$.¹⁸ The results of the Monte Carlo simulation, based on 100 iterations, are reported in Table 10. For all the parameters, the mean estimate is very close to the assumed value generating unbiased and precise estimates. The simulations reveal that the structural model can recover a wide range of parameters and discriminate between the different types with a remarkably high accuracy. Particularly, in our framework where discrimination between models depends on slight differences in choice patterns.

	π_{gm}	π_{coop}	π_{free}	σ	ρ	β	ω
True value	0.400	0.300	0.200	-0.100	0.500	0.500	0.150
Estimated value	0.397	0.304	0.200	-0.116	0.523	0.506	0.150
s.d.	0.025	0.022	0.009	0.063	0.119	0.070	0.017
True value	0.400	0.300	0.200	-0.400	0.100	0.500	0.150
Estimated value	0.398	0.304	0.199	-0.407	0.109	0.515	0.150
s.d.	0.073	0.071	0.010	0.166	0.082	0.084	0.018
True value	0.400	0.300	0.200	-0.400	0.500	0.500	0.150
Estimated value	0.396	0.306	0.199	-0.486	0.566	0.510	0.148
s.d.	0.036	0.034	0.010	0.280	0.218	0.069	0.017
True value	0.400	0.300	0.200	-0.100	0.100	0.500	0.150
Estimated value	0.392	0.309	0.200	-0.117	0.110	0.525	0.150
s.d.	0.091	0.090	0.009	0.085	0.059	0.107	0.018

Table 10: Mean estimates from the Monte Carlo simulation for the medium noise ($\beta = 0.500, \omega = 0.150$). π_{gm} is the mixing probability (proportion of subjects) characterised by [Gallice and Monzón \(2019\)](#) preferences. ρ and σ are the distributional preferences parameters of the [Charness and Rabin \(2002\)](#) model. s.d. is the standard deviation. The results are based on 100 iterations.

¹⁸The level of noise is selected in a way that the simulated data have a success rate between 77 and 80%.

Now we repeat this simulation by using the reciprocal fairness model of [Charness and Rabin \(2002\)](#) as the conditional altruist type, on top of the G&M, the free-rider and the altruist. Again, there are 7 parameters to estimate, the mix probabilities for the G&M, the conditional altruists and free-rising subjects π_{gm} , π_{coop} , and π_{free} , respectively, the reciprocal fairness weights γ and δ for the conditional cooperator, the precision parameter β and the tremble parameter ω . We assume again three levels of noise (low, medium and high) and two levels for the reciprocal parameters with $\gamma \in [0.300, 0.700]$ and $\delta \in [0.200, 0.600]$. The percentage of G&M subjects is set to 40%, C&R 30%, free-riders 20% and altruists 10%¹⁹. We report the results assuming a medium level of noise with $\beta = 0.500$ and $\omega = 0.15$. Table 11 summarises the results of the simulation confirming that the experimental design and the estimation method are suitable to identify behavioural strategies and to successfully recover the parameters our statistical model.

¹⁹We explored numerous frequency combinations for the four types, and our findings consistently affirm that qualitative results remain unchanged, regardless of the assumed frequency combination.

	π_{gm}	π_{calt}	π_{free}	γ	δ	β	ω
True value	0.400	0.300	0.200	0.300	0.600	0.500	0.150
Estimated value	0.390	0.310	0.200	0.309	0.584	0.510	0.150
s.d.	0.055	0.059	0.010	0.099	0.176	0.077	0.019
True value	0.400	0.300	0.200	0.700	0.600	0.500	0.150
Estimated value	0.406	0.296	0.202	0.704	0.571	0.510	0.151
s.d.	0.020	0.088	0.010	0.167	0.153	0.070	0.020
True value	0.400	0.300	0.200	0.700	0.200	0.500	0.150
Estimated value	0.406	0.316	0.202	0.733	0.183	0.505	0.151
s.d.	0.018	0.071	0.011	0.180	0.171	0.069	0.020
True value	0.400	0.300	0.200	0.300	0.200	0.500	0.150
Estimated value	0.405	0.303	0.201	0.310	0.198	0.511	0.151
s.d.	0.024	0.064	0.010	0.064	0.137	0.071	0.018

Table 11: Mean estimates from the Monte Carlo simulation for the medium noise ($\beta = 0.500, \omega = 0.150$). π_{gm} is the mixing probability (proportion of subjects) characterised by [Gallice and Monzón \(2019\)](#) preferences. γ and δ are the reciprocal fairness parameters of the [Charness and Rabin \(2002\)](#) model. s.d. is the standard deviation. The results are based on 100 iterations.