Chapter 5

Equilibrium Play and Best Response in Sequential Constant Sum Games

5.1 Introduction

In the previous chapter, we identified a class of non-trivial games for which Nash Equilibrium predictions work much better than in similar previous research.[1] This occurred even if the games were played in the laboratory for the first time by non-Economics trained subjects with no feedback. These games were two-player 3x3 constant sum normal form games with unique equilibria in pure strategies and with different number of rounds of iterated deletion of (strictly) dominated strategies necessary to reach the Nash equilibrium. We here study how well the subgame perfect equilibrium prediction works in sequential games which share the same payoff matrix as the normal form games of the previous chapter and that were played again by Non-Economics trained subjects for the first time without previous experience in the laboratory. We check if the subgame perfect equilibrium prediction works as well for these games as the Nash equilibrium prediction did in the simultaneous move games of the previous chapter.

There are several reasons why this question is interesting. Notice that in constant sum games the Nash equilibrium outcome of the normal form games and the subgame perfect equilibrium outcome of the sequential games coincide. This is because, thinking in terms of backwards induction for a game with two players, when the last mover in

[1] See, for example, McCabe et al. (1994), Mookherjee and Sopher (1994)), Stahl and Wilson (1995), Broseta et al. (2001), Brown and Rosenthal (1990), Rapapport and Boebel (1992) and Mookherjee and Sopher (1997)).

sequential games optimally chooses the action that maximizes his payoffs given the options left available, he minimizes the payoffs of the first mover and thus, a first mover optimally chooses the strategy that maximizes the minimum of his possible payoffs. This Maximin (or Minimax) strategy follows exactly the same logic as the Nash equilibrium strategy in normal form constant sum games. However, even if the theoretical outcome may coincide between the simultaneous and the sequential move games it is possible that when laboratory subjects actually play the sequential games the outcomes may differ.

A possible reason for differences in the outcomes of simultaneous and sequential games with the same payoff matrix may be that subjects may put greater weight on other regarding preferences in sequential games. This would seem particularly true for models of other regarding preferences that incorporate intentionality, as the sequentiality of the games makes clear that a second player's decision is contingent on the first player's choice and therefore, the way a second mover interprets the intentions of the strategy chosen by a first mover can clearly influence the outcome of the play. Anticipating this, a first mover may carefully select his own strategy in order to make, for example, the second mover interpret his intentions in a way that may induce him to reward supposedly kind behaviour by the first mover.

On the other hand, as we argued in the previous chapter, in constant sum games behaviour should not be affected by other regarding preferences that do not include concerns for intentionality, i.e., distributional preferences. The theoretical argument is that distributional preferences should not affect choices as long as subjects care more for their own payoffs than for those of other subjects.[2] This is because subjects who care about opponents' payoffs would have to give up the same units of payoffs that would go to their opponent in order to increase their opponents' payoffs. We showed previously that this theoretical argument, although compatible with other possible explanations, is not proven wrong by laboratory play in simultaneous constant form games. However, if we want to be more general and study for which types of games theory predictions are not affected by other regarding preferences, both with and without intentions, we precisely need to study games in which we suspect that intentions may play a role, and that is why we choose sequential constant sum games.

There is at least one type of constant sum games in which there is evidence that other regarding preferences may affect laboratory play: dictator games.[3] In them, a single subject has to allocate a fixed amount between him and another subject, with no strategic decision being taken by the receiver. When dictator games have been played in the laboratory strictly controlling for anonymity (both between subjects and

[2] Camerer et al. (1998) discuss this argument.

[3] See Hoffman, McCabe and Smith (1999) and Roth (1995).

with respect to the experimenter) there is a significant proportion of subjects who do not concord with the equilibrium prediction and allocate the minimum possible amount to the other player.[4] In our experiment, the situation faced by second movers is similar to the allocators' situation in dictator games. In fact, we could define second movers' strategic situation as "mini-dictator" games, since second movers do not have a continuous choice but they can only choose between three actions. There is a difference however between mini-dictator games and our games: when second movers in our games have to choose their action, they are limited by the action taken by first movers and therefore, intentionality and willingness to reward kind behaviour may affect their choices. In dictator games, there is no possible response to the allocator's strategy and thus, non equilibrium outcomes may be explained by distributional preferences by themselves, with no need of reciprocal or intentionally driven other regarding preferences. We are aware of two experiments with sequential constant sum games in which two players make decisions. In Falk and Kosfeld (2005) second movers decide an allocation of a constant quantity between then and a first mover, after observing whether the first mover decides to restrict or not the interval in which the second mover can decide. Thus, second movers face a dictator game situation once first movers have restricted them or not. They observe that when first movers restrict second movers, they allocate less to first movers. Thus, although the subgame perfect equilibrium prediction is not fulfilled, the "intentions"[5] signalled by whether first movers restrict or not makes a difference on second movers. Fey, McKelvey and Palfrey (1996) carried out sequential constant sum centipede games in which, at the first round, payoffs are divided evenly and, as the players pass, the division gets more and more lopsided. They observe that the subgame perfect equilibrium prediction in which the first mover takes in the first round works much better than in centipede games which are not constant sum. Therefore, we expect our results to be driven by the fact that games are constant sum and that both players can make decisions and thus, they may be signalling their intentions.

In terms of both subjects having an option to decide strategically, our games also resemble ultimatum games, in which also non subgame perfect equilibrium outcomes are frequently observed (Güth et al. (1982)). A key difference with our games is that in ultimatum games, the second mover has the clear option to punish the first mover by rejecting his allocation and leaving both players with no payoffs. In ultimatum games, such a threat would not be credible if second movers are only concerned for own payoff maximization, but it has been observed that not only a significant proportion of second movers exercise such threat, but that this threat is credible to first

[4] See Bolton and Zwick (1995) and Bolton, Katok and Zwick (1998).

[5] Referred as "trust" by the authors.

movers and they rarely allocate the minimum possible amount to second movers. The most frequent explanation for such behavior is that subjects have other regarding preferences that include intentionality. Ultimatum games are not constant sum because of the possibility of rejecting offers and leaving both players with no payoffs. In the games studied in this chapter, this possibility does not exist and in fact, the maximum "punishment" a second mover can inflict on a first mover is by choosing his own payoff maximizing strategy. However, although in constant sum games there is no possibility of punishment, second movers' intentionality driven other regarding preferences could manifest themselves in second movers rewarding kind behaviour by first movers and thus, giving up some units of payoffs in favour of first movers who have taken and action interpreted as kind by second movers. Notice that other explanations for second movers non payoff maximizing behaviour are possible and we try to discriminate between them using both the data and the results of an informal questionnaire.

There is a clear way in which subjects' choices in our games could show that subjects have other regarding preferences. As in the previous chapter, we designed a treatment in which one of the outcomes in all the games would be that payoffs were exactly equally split. In such treatment, first movers choosing strategies that may lead to the equal split outcome could be signalling to second movers their intention to split the payoffs evenly. Therefore, second movers who also choose to equally split the payoffs may be responding reciprocally to first movers' strategy. We compare whether the feasibility of exactly equally splitting the payoffs influenced subjects behaviour, by comparing choices in treatments that included the feasibility of equal splits in all ten games with choices in treatments in which such equal split was replaced by a less equal outcome, without affecting the subgame perfect equilibrium prediction. Although the feasibility of exactly equal splits have been shown to have an important effect in ultimatum games (Güth, Huck and Müller, (2001)), we find no such effects in our games.

The chapter studies how close subjects behaviour was to the subgame perfect equilibrium prediction and enquires whether subjects were able to reason in game theoretic arguments. It also includes a comparison of the results in this chapter with the previous chapter. We observe that the subgame perfect equilibrium prediction in sequential constant sum games works even better than the Nash equilibrium prediction in simultaneous constant sum games. This result indicates that even if the strategy space is more complex in sequential games, first movers seem better able to backward induct in our sequential games than to calculate Nash equilibria in the simultaneous ones. Additionally, second movers seem to be good at best responding once they observe first movers' choices.

The remainder of the chapter is organized as follows. Sections 5.2 presents the experimental design and procedures. Section 5.3 contains the results and the main descriptive statistics. Section 5.4 comments on the answers given by subjects on a voluntary questionnaire. Section 5.5 concludes. The Appendices contain the instructions and we also show the games.

5.2 Experimental Design and Procedures

5.2.1 Experimental Design

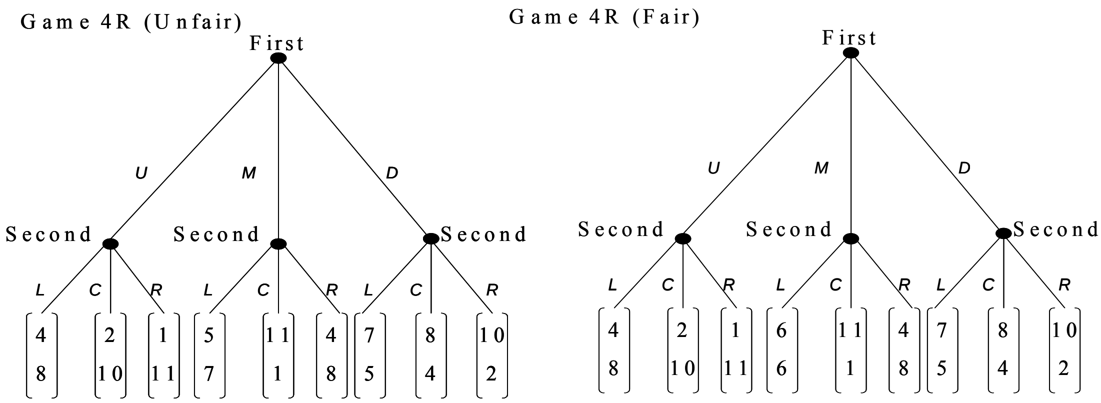
Subjects were presented with a series of ten 3x3 constant sum games with unique subgame perfect equilibria. The games had the same payoff matrix as the games in the previous chapter,[6] but the games were now played sequentially. First movers chose, for each of the ten games, one of three actions (labelled "UP", "MIDDLE" and "DOWN"). Then, second movers observed first movers' choice and picked one of their three actions available (labelled "LEFT", "CENTRE" and "RIGHT").

We constructed a 2x2 design according to two criteria. The first criterion was whether first movers' payoffs corresponded to the payoffs assigned to Column or to Row subjects in the previous experiment. By having a treatment in which first movers' payoffs corresponded to column subjects, but also another where first movers' payoffs corresponded to Row subjects, we can compare our results with the previous experiment with simultaneous play no matter the sequence of actions in this new experiment.

The second criterion, as in the previous experiment, was whether an equal split of payoffs was feasible in each of the games. As the games were constant sum, there was always the same amount of payoffs (£12) to be distributed among the two players. In the "Fair" treatments (F) an equal split of payoffs was feasible in one of the terminal nodes of each of the games subjects played. Payoffs were designed such that both subjects would get £6 if they both took the action leading to this node being reached. In the "Unfair" treatments (U), the payoffs in this terminal node were substituted by a more unequal split, such that one subject would get a payoff of £7 and the other a payoff of £5. For example, in Game 4R below, payoffs when first movers chose MIDDLE (M) and second movers chose LEFT (L) were £6 for both subjects in the Fair treatments, while they were £5 for first movers and £7 for second movers in the Unfair treatments. The location of this node and the changes in payoffs from the Fair to the Unfair treatments were designed such that in some games it was the first mover who got a better than equal split payoff in the Unfair treatments while in other games it was the second mover and such that subjects would get a higher payoff in this terminal node in some games (lower in other games) than when their

[6] The games can be found in Appendix B.

actions lead to the subgame perfect equilibrium, referred to simply as "Equilibrium" from here onwards. Notice that the terminal node in which the equal split was feasible never coincided with the terminal node that would have been chosen as a result of both subjects playing according to the subgame perfect equilibrium. Comparing the F and U treatments allows us to study whether the feasibility of an exact equal split influenced behaviour.



5.2.2 Experimental Procedures

The experiment was carried out with pen and paper in the ELSE laboratory in December 2004. Subjects were recruited by e-mail using the ELSE database, which consists of UCL undergraduate and graduate students. As we are interested in behaviour without previous experience by non-Economics trained subjects, we made sure all our subjects had not participated in previous game experiments and had not taken courses in Economics or Game Theory.

Our experiment consisted of four sessions with twenty subjects per session. In each session, ten of the subjects were randomly assigned first mover roles in all ten games, while the other ten subjects were assigned second mover roles. Neutral language was used by calling subjects "You" and their opponents "Participants in the other group".

Upon arrival, subjects were randomly assigned seats and were asked to read some preliminary instructions, which described a strategic decision situation and a 3x3 payoff matrix associated with it.[7] Therefore, although the games were played sequentially, the games were presented in similar tables as the ones in the previous experiment.[8]

[7] The strategic situations were called "Tables" in the instructions.

[8] See Appendix B for the actual presentation of the games.

This allow us to compare our results without recurring to "Presentation effects" explanations.[9] Then subjects were required to pass an Understanding Test where they had to demonstrate that they knew how to map players' actions in a game to outcomes, and outcomes to players' payoffs. Subjects were told that those who failed the test would act as "assistants" in the experiment. However, no subject failed the test in any treatment and so the over-recruited subjects were asked to assist the experimenter.[10]

Then, first movers chose their action in all ten games. After that, answer sheets were collected, reorganized and handed to second movers who could observe, for each game, the action taken by the first mover with whom they were matched in that game. Finally, second movers chose their actions in all ten games. All games were played with no feedback and the order in which each subject played the 10 games was randomized.

For each game subjects played, they were randomly and anonymously paired with a different participant from the other group. Subjects never learned who their matched participant in each game was.

Subjects were paid as follows. At the end of each session, a number from 1 to 10 was selected from a bingo urn. This number indicated for which of the 10 games all subjects would be paid.[11] Subjects were paid exactly the amount of pounds indicated in the lower left corner of the cell chosen as a result of their action and the action chosen by their matched participant in the particular game selected with the bingo urn.

Subjects were paid the sum of a £5 fixed fee, plus their earnings in the game selected. Average payments were £11 (around $17 at the time).[12] Each session lasted one hour and each subject was allocated twenty minutes to choose their action.

5.2.3 The Games

In all ten games, two subjects had to choose sequentially among three actions. First movers chose, for each of the ten games, one of three actions (labelled "UP", "MIDDLE" and "DOWN"). Then, second movers observed first movers' choice and chose one of their three actions (labelled "LEFT", "CENTRE" and "RIGHT"). Payoffs were represented by the same matrix as for the games in the previous chapter. Notice that

[9] Schotter, Weigelt and Wilson (1994), argue for same games played simultaneously or sequentially that what matters for differences in behaviour is not the actual presentation of the game but whether the instructions are explained in simultaneous or sequential form. Here, our games are different, but still we presented payoffs similarly.

[10] All subjects were informed of this.

[11] We paid subjects for one random game instead of for an aggregated measure of their answers in all 10 games to be able to maintain a one to one relationship between outcomes and payoffs.

[12] A British pound corresponded to 1.85 American dollars at the time of the experiment. Our design allowed us to provide reasonably high incentives while keeping one or two digit numbers to represent payoffs and avoiding conversion rates from experimental currency to monetary currency.

the subgame perfect equilibrium outcome for these games is the same as the Nash equilibrium outcome for the simultaneous games of the previous chapter.

We chose one-digit numbers to represent payoffs.[13] The sum of Row and Column players' payments in all cells of all games was 12.[14] The ten games were designed such that the equilibrium did not correspond to the same combination of actions by two players in more than two games.

5.3 Experimental Results

5.3.1 Descriptive Statistics

Table 1 below presents the main descriptive statistics for each game when grouping all treatments and subject roles. We report, for each of the ten games, the percentage of times the combination of first movers' and second movers' choices reached an Equilibrium outcome, as well as the percentage of first movers' actions taken according to Equilibrium and the percentage of second movers' actions that were best responses to their matched first mover's choice. Results are clear. On average, 91.5% of times, the Subgame Perfect Equilibrium was reached. First movers played Equilibrium 93.5% of the times, and second movers best responded to their matched first mover's choice in 94% of the times. Percentages were high and similar across all games.

Game	Equilibrium Played	1st Mover Equilibrium Actions	2nd Mover Best Responses
1R	90	92.5	97.5
1C	92.5	92.5	92.5
2R	85	92.5	87.5
2C	97.5	97.5	100
3R	90	95	92.5
3C	90	90	92.5
4R	92.5	92.5	92.5
4C	92.5	92.5	95
NR	90	92.5	92.5
NC	95	97.5	97.5
Average	**91.5**	**93.5**	**94**

Table 1: Descriptive statistics (percentages).

In the following sections we study these results with further detail.

[13] We did so because if subjects really chose their actions as a best response to their beliefs, calculating such best response in terms of expected payoffs may have been more difficult if numbers representing payoffs were large, and we did not want to discourage such type of behaviour.

[14] Numbers 10 and 11 were used in a few games to make it possible to discriminate models of behavior. Number 0 was not used to avoid behavior being possibly caused by aversion to getting no payoff.

5.3.2 Treatment Effects: Feasibility of Equal Splits

One of the main questions that motivated this follow-up experiment is whether intentionally driven other regarding preferences affected subjects' choices in sequential constant sum games, both when subjects played as first movers and when they played as second movers. As commented in the introduction to this chapter, our games are similar to ultimatum games, where the feasibility of equal splits has proved to affect how subjects play games (Güth et al. (2001)). In our games however, second movers do not have the option to reject proposals and thus leave both agents with no payoffs, but they have to choose between three possible allocations of payoffs between both subjects, all adding up to the same amount. In those circumstances, a choice of strategy leading to an equal split of payoffs may be an indication of concerns for the other subject's payoffs. For example, when second movers observe first movers' choices, they may want to reward an action taken by a first mover leading to an equal split with an action that gives both agents the same payoff, even if this is not optimal for payoff maximizing second movers. At the same time, first movers may anticipate this and choose actions leading to equal splits in the first place. If we observed this type of behaviour when equal splits are feasible but not when it is not, it would be an indication that subjects may have some concern for being "fair" or for how fair other subjects interpret that their own choices are. We thus study if the feasibility of equal splits affected how subjects played the games by comparing choices by first and second movers between treatments in which it was feasible to splits payoffs equally and treatments in which it was not.

Following the same procedures as in the previous experiment, we first use Fisher's Exact Probability Test (FEPT) for count data.[15] This test allows us to check if differences in observed proportions of actions chosen between a game containing equal splits ("Fair" treatment) and a game where equal splits are not feasible ("Unfair" treatment) might be expected by chance. The null hypothesis (two-tailed) is that there is no difference in the probability of playing each strategy generating the observed proportion of play of each strategy in each treatment.[16] As with all statistical tests in this thesis, we used the free software R (2003) to perform FEPTs.

We conduct FEPT separately for each game. We first compare subjects' aggregate actions for each player role (first or second movers) in each of the ten games between the Fair and Unfair treatments. Out of the 40 possible comparisons, we can never

[15] Developed by Fisher (1935), Irwin (1935) and Yates (1934).

[16] Although less common than the Chi-square test, Fisher's test requires less data in each category to be correctly calculated. Chi-square tests would require at least five subjects playing each action in each treatment which, given that most subjects chose the same actions, was not satisfied in our games. The main assumption required for both of these tests is independence between observations of the games in each treatment.

reject the null hypothesis of the underlying probability of each subject playing each of the three strategies available being equal at the 5% significance level.[17] [18] Notice in table 2 that the total number of actions taken not according with Equilibrium by first movers is very similar between the Fair and Unfair treatments and of these, the number of actions that coincided with the strategy leading to the equal split ("Fair Action") is also very similar between treatments. The same happens with the number of best responses for second movers. We finally performed Mann-Whitney tests under the null hypothesis that the median of the distribution of the number of games in which first movers chose the strategy containing the equal split was not different between the F and U treatments. We could never reject the null hypothesis at the 5% significance level.[19]

	First Movers			Second Movers		
	Non-Equilibrium Actions	**Fair Actions**	**Percentage**	**Non- Best Responses**	**Fair Actions**	**Percentage**
Fair Treatment	32	22	68.75%	31	7	22.58%
Unfair Treatment	29	20	68.96%	29	7	24.14%

Table 2: Percentages of Non-Equilibrium Actions and Fair Actions

Thus, we conclude the following:

Result 1: *Behaviour was not affected by the feasibility of equal splits.*

Small payoff differences between the equal and unequal split might explain Result 1. It would be worthwhile to study robustness to higher payoff differences. An alternative explanation is that the equal split was feasible (or not) in *all* the games subjects played. As subjects were only paid for one of the games, our experiment shares characteristics with experiments carried out under the strategy method, in which a weakening of the "equal split effect" has previously been observed (Güth et al. (2001)). In any case, and admitting these caveats, our results show that there are circumstances in which subjects do not change their behaviour whether equal splits are feasible or not when

[17] Although FEPT is specifically designed for small samples it is still not a very powerful test with only ten observations in each treatment. For example using this test, we cannot reject that distribution of answers (3,2,5) in one treatment is the same as the distribution (1,7,2) in another treatment at the 5% significance level. However, we can reject that it is the same as (1,8,1). The power of the test increases with the number of observations.

[18] Results of all FEPTs in this section are the same at the 10% signicance level.

[19] Same results were obtained for the null hypothesis that treatment effects did not affect the median of the distribution of the number of games in which first movers played the equilibrium strategy and also for the distribution of second movers' best responses to first movers' actions.

deciding how to share pies of given sizes, even if one of the subjects moved previous to the other.

Using these results, we will pool the data from "Fair" and "Unfair treatments to report the following statistics.

5.3.3 Actions

We here look at individual behaviour. We find that theory predictions translate well into individual behaviour. On average, first movers played according to Equilibrium in 8.5 of the 10 games, while second movers best responded to first movers' choices in 8.65 of the games. 97.5% of first movers played the Equilibrium action in 7 or more games, while 95% of second movers best responded in 8 or more games. Table 3 below shows the Cumulative Distribution Function (CDF) of the number of games for which at least first movers played according to Equilibrium predictions and the number of games for which at least second movers best responded.

Number of Games	1st Mover Equilibrium Actions	2nd Mover Best Responses
10	10	12.5
9	57.5	75
8	85	95
7	97.5	97.5
6	97.5	100
5	100	100
4	100	100
3	100	100
2	100	100
1	100	100
0	100	100

Table 3: Cummulative Distribution Function.

As we did in the previous chapter, we compared subjects' choices across games for both players' roles. We performed McNemar's tests comparing proportions of equilibrium play by first movers between each pair of games under the null hypothesis that the proportion of first movers who played equilibrium actions was the same between all pairs of games, both when grouping the F and U treatments and when not. We do not find statistically significant differences at the 5% significance level between any pair of games. The same occurs when we performed McNemar's tests under the null hypothesis that the proportion of second movers who played best responses to their first movers was not different between all pairs of games. Our results clearly differ from what we obtained in the previous chapter where the non dominance solvable games (NR and NC) showed much lower percentages on concordance to equilibrium predictions than the other games. Notice that in games NR and NC, when played in sequential form, best responding for the second mover is almost trivial as in most cases, once the first mover has chosen an equilibrium strategy, second movers would be playing the subgame perfect equilibrium no matter what they chose. This is due to the fact that in game NR once the first mover plays Equilibrium, payoffs for the second mover are exactly the same no matter what he chooses.[20]

We now compare the results of this experiment with the previous one to check if the Equilibrium prediction works better in the sequential games than in the simultaneous games. Given that in the sequential games we have first and second movers, we compare the actual percentage of times the equilibrium prediction was correct in each of the two experiments, which is the combination of both paired subjects choosing the Equilibrium action in each game. Table 4 reports the percentage of times the Equilibrium prediction was right by game, where we observe that the subgame perfect equilibrium prediction in the sequential games works better than the Nash equilibrium prediction in the simultaneous ones, for all games.[21] Chi-square tests for differences in proportions of equilibrium play between games with the same name confirm the null hypothesis that the proportions of play were different between the two experiments in all games with the same name at the 5% significance level. This result is important because, together with the results of the following section, it provides evidence that subjects may be better able to backward induct in our simple sequential games than to calculate Nash equilibria in the simultaneous ones. Although this result is partially caused by second movers observing first movers' choice and the high percentage of best responses, it seems that first movers are able to anticipate second movers' behaviour, even if the strategy space is more complicated in sequential games than in simultaneous ones.

Game	Sequential Play	Simultaneous Play
1R	90	57
1C	92.5	54
2R	85	66.5
2C	97.5	65.63
3R	90	67
3C	90	74.38
4R	92.5	76.57
4C	92.5	60.75
NR	90	48.56
NC	95	54.375
Average	**91.5**	**62.48**

Table 4: Percentage of Times the Equilibrium Prediction was Right.

[20] In game NC this only happens for one of the subject roles.

[21] Notice that the the data in the "Simultaneous Play" column, differs from data in Chapter 4, as here we compute the percentage of times the unique Nash equilibrium was reached, not the equilibrium actions.

Therefore, we conclude:

Result 2: *The Equilibrium prediction works well in constant sum games. When the games are played sequentially, the prediction is even more accurate.*

5.4 Questionnaire Answers

Given that experimental results were so close to equilibrium predictions, we wanted to check if the reasoning process subjects claimed they used to choose their actions was also close to the subgame perfect equilibrium reasoning process that Game Theory would predict. Notice that, contrary to the experiment in the previous chapter, in this experiment we did not elicit subjects' beliefs about opponents' choices. The reason was that to elicit beliefs would be more complicated in sequential games as first movers' beliefs would be conditional on their own choice. Thus, to reward the accuracy of stated beliefs conditional on first movers' choice, would require using a quadratic scoring rule in which nine probabilities had to be stated, which could be meaningless for subjects. Therefore, to investigate how subjects' reasoned when choosing their actions, we use the answers to a questionnaire distributed after the experiment in which there were no monetary incentives for truth-telling. Therefore, we cannot make a strong point of whether subjects really used the reasoning process they claimed when making their decisions, but only that at least they were able to reason in those terms in our simple games since they provided coherent explanations. Contrary to what happened in the questionnaire of the previous experiment, here subjects' answers were much less vague and it was easy to classify the. The evidence presented in this section may be useful in the ongoing debate on whether subjects are able to arrive at game theoretic arguments without previous teaching,[22] Let us remind the reader that subjects were not Economics students, nor had they previously taken any training in Game Theory.

We classified first movers' answers into four categories. "Equilibrium" corresponds to subgame perfect equilibrium reasoning. "Minimax" is self explanatory. "Fairness" corresponds to any argument in which distributional concerns were mentioned. Finally, "Other" corresponds to explanations that we were not able to classify. Second movers' answers were classified between "Best Responses", "Fairness", when they provided some argument for distributional concerns and "Not Answer" as two subjects did not fill in the voluntary questionnaire. Results are reported in Table 5.

[22] See Camerer (2003).

	1st Movers		2nd Movers
Equilibrium	65%	**Best Response**	87.5%
Minimax	22.5%		
Fairness	5%	**Fairness**	7.5%
Other	7.5%	**Not Answer**	5%

Table 5: Classification of Questionnaire Answers

For first movers, notice that even if both "Equilibrium" and "Minimax" would lead to the same choice and ultimately they both rely in expecting the second mover to choose their payoff maximizing strategy given the first mover's choice and then maximize against it, we distinguish between both kind of explanations. In total, 87.5% of first movers' explanations could be classified under one of these reasons. The criterion to separate both reasons was whether the subject's answer included a statement referring to the "maximum of the minima". For example, subject FCC2, a Medicine student in his third year, offered the following explanation:[23]

"I assumed that B participants would choose the column in which they would gain most money, so I chose the row where I would get the most if they chose their maximum strategy given my choice".

We classified this and similar statements as "Equilibrium". However subject FRR10, a Russian History student in her second year claimed:

"Compared the three rows. Looked for the lowest number in each row. Then chose which one of these was highest, which is the amount I would get paid".

We classified this statement as "Minimax". There were some cases in which the classification between the two was not so clear. For example subject FRR9, a second year Geography student, claimed:

"I know that the B participant will pick the column where they stand to make the most so I have to pick the row where the minimum I can get is higher than other rows".

This statement seems to contain both reasons, although following the criterium mentioned above we classified it as "Minimax".

In any case, what it is surprising is the small number of statements that made reference to distributional arguments. There were only two statements by first movers

[23] Subjects referred to first movers as "A participants" and to second movers as "B participants".

to distributional concerns, both of them in "Unfair" treatments, and thus, in cases where the equal split of payoffs was not feasible. These are the following:

"*Try to choose the most equal amount",* and

"Try against 'my better judgment' to be fair in my choice of row, so that a fair amount would also be allocated to B".

With respect to second movers, 87.5% of subjects claimed they chose best responses to the action taken by first movers. Here we show a couple of such answers:

"For each table, there were only three options. I chose the option that would give me most money", and,

"Based on A's selection, I made mine with the highest number reflected in the top right corner".

There were only three second movers who made reference to distributional concerns. Of these, we here reproduce the explanation given by subject FCR9, a Linguistics student in his fourth year, who seemed to hint on intentions driven reciprocity guiding his choices:

"*I tried to make a balance between the amount I could get and the money 'A' person could make. I rewarded as well and paid back 'A' 's decision".*

Therefore, we conclude that subjects' claims are in line with the results of the experiment and, in particular the percentage of subjects who claimed to have worried for the distribution of payoffs was low (only 6.25% of the total of subjects).

5.5 Discussion

We have confirmed that sequential constant sum games with unique subgame perfect equilibrium in which two consecutive players have three possible choices are a class of non-trivial games for which game-theoretical predictions work well, even if the games are played for the first time by subjects not trained in Economics and without previous experience in laboratory games. Comparing our results with normal form games which share the same payoff matrix we find that theory predictions work even better in the sequential games. This is most likely caused by the fact that in the sequential games second movers have the advantage of observing first movers' choices, and given that the games are constant sum, payoff maximizing for second movers is straightforward. Even if the strategy space is more complicated, and aided by the results of the informal questionnaire, we can conclude that subjects seem well able to backward induct in the sequential games while in the simultaneous games we only concluded that the Nash equilibrium prediction works well and that subjects behave strategically and believed opponents would play strategically, although the reasoning process they followed is unclear.

Contrary to our expectation, the feasibility or not of equal splits does not affect how first movers or second movers choose. This, together with the high percentages of subgame perfect equilibrium observed, provides some reassurance that in our experiment, subjects' behaviour was not affected by other regarding preferences, with or without intentions, as opposed to what has been observed in dictator and ultimatum games. Differences with respect to these games seem caused by first movers having the option to decide and by the non possibility of punishment.

Aided by the results from our informal questionnaire we conclude that it seems wrong to generally dismiss the Subgame Perfect Equilibrium outcome as a good predictor of behaviour in simple sequential games, as subjects' claims about how they reasoned were in line with standard game theoretic arguments. The results of the two experimental chapters of this dissertation suggest further research to help identify a broader class of games for which we can have some confidence that Game Theory is a good predictor of players' behaviour.

6 Instructions for Chapter 5

WELCOME TO OUR EXPERIMENT!

This is a serious scientific experiment and, as such, no talking, looking around or walking around will be permitted. If you have any questions or need any assistance, please raise your hand and an experimenter will come to you. If you talk, exclaim out loud, etc, YOU WILL BE ASKED TO LEAVE AND YOU WILL NOT BE PAID. Thank you.

This is an experiment on individual decision making. The ESRC Centre for Evolutionary Learning and Social Evolution (ELSE) has provided the funds for this experiment. You will be paid £5 (five pounds) for having arrived on time. Additionally, if you follow the instructions and pass an UNDERSTANDING TEST you will be allowed to continue in the experiment. Once in the experiment, depending on your decisions you may earn a considerable additional amount of money. This additional amount will be determined both by your decisions and by those of other participants in the experiment. Before making your decisions, you will be informed about how your earnings and the other participants' earnings depend on your and their decisions. All that you earn is yours to keep, and will be paid to you in private, in cash, after today's session.

We need 20 people for this session. Thus, if more than 20 people pass the UNDERSTANDING TEST, some of you will be asked not to participate in the experiment but to help the experimenter as "assistants". These assistants will check that everything is done as explained in the instructions. The assistants will be paid the average of the payments of the 20 participants in the experiment.

In this experiment, 10 participants will belong to group A (to whom we will refer as "A") and 10 participants will belong to group B (to whom we will refer as "B"). All participants have to take decisions from a table they will be presented. For each table, each participant in group A will be anonymously matched with one participant in group B.

Participants in group A will be presented with a TABLE. For this table, participants in group A will take a decision. Afterwards, participants in group B will be presented with the same table and, knowing what their matched participant in group A decided, they will make another decision. Together, the two decisions determine the number of POUNDS each of you earns, which may be different.

The table in the next page shows an illustrative example. IT IS ONLY AN ILLUSTRATION. The tables you will see during the experiment will be different from this one. AS YOU LOOK AT THIS TABLE, PLEASE CONTINUE READING THIS HANDOUT FOR INSTRUCTIONS ON HOW TO UNDERSTAND THE TABLE:

B

		LEFT	CENTRE	RIGHT
	UP	9 1	8 2	7 3
A	MIDDLE	6 4	5 5	4 6
	DOWN	3 7	2 8	1 9

In the actual experiment, A will be shown tables like this one (but with different numbers), and asked to choose one decision (“**UP**”, “**MIDDLE**” or “**DOWN**”). After A takes his/her decision, the participant from B with whom they are matched for each table will learnt what decision A took in that table and will be asked to choose his/her decisions (“**LEFT**”, “**CENTRE**” or “**RIGHT**”).

The combination of A’s decision and B’s decision determines the number of pounds they receive. These numbers are whole numbers ranging from 1 to 11.

The number of pounds A receives appears in the lower left corner of each cell of the table.

The number of pounds B receives appears in the upper right corner of each cell of the table.

To interpret the table, consider the results of the possible combinations of decisions.

-If A chooses **UP** and then B chooses **LEFT**, A earns 1 Pound and B earns 9 Pounds.
-If A chooses **UP** and then B chooses **CENTRE**, A earns 2 Pounds and B earns 8 Pounds.
-If A chooses **UP** and then B chooses **RIGHT**, A earns 3 Pounds and B earns 7 Pounds.
-If A chooses **MIDDLE** and then B chooses **LEFT**, A earns 4 Pounds and B earns 6 Pounds.
-If A chooses **MIDDLE** and then B chooses **CENTRE**, A earns 5 Pounds and B earns 5 Pounds.
-If A chooses **MIDDLE** and then B chooses **RIGHT**, A earns 6 Pounds and B earns 4 Pounds.
-If A chooses **DOWN** and then B chooses **LEFT**, A earns 7 Pounds and B earns 3 Pounds.
-If A chooses **DOWN** and then B chooses **CENTRE**, A earns 8 Pounds and B earns 2 Pounds.
-If A chooses **DOWN** and then B chooses **RIGHT**, A earns 9 Pounds and B earns 1 Pound.
Please be sure you understand this table. Raise your hand if you would like further explanation. Otherwise, please start with the Understanding Test in the next page. Please raise your hand once you have finished the Understanding Test.

UDERSTANDING TEST

You will now take a short UNDERSTANDING TEST. After you have finished the TEST, it will be graded and you will ONLY be allowed to continue in the experiment if you have answered ALL the QUESTIONS CORRECTLY. If one or more of your answers is not correct, we will ask you to be our assistant and to check that everything proceeds as explained in the instructions. Notice that even if all your answers are correct, you may be asked to be our assistant.
This test has 5 questions. After you have answered all 5 questions, please re-check your answers. Please raise your hand when you are finished so as we can grade this test.

		B		
		LEFT	CENTRE	RIGHT
	UP	6 2	3 7	4 5
A	MIDDLE	8 9	9 6	2 4
	DOWN	1 1	5 3	7 3

Using the table above, please answer the following questions.

<u>Questions:</u>

1. If A chooses **MIDDLE** and afterwards B choosess **RIGHT**, how many Pounds will A earn? __

2. If A chooses **UP** and afterwards B choosess **LEFT**, how many Pounds will B earn? _______

3. If A chooses **UP** and afterwards B choosess **RIGHT**, how many Pounds will A earn? _______

4. If A chooses **DOWN** and afterwards B choosess **CENTRE**, how many Pounds will A earn? __

5. If A chooses **DOWN** and afterwards B choosess **LEFT**, how many Pounds will B earn? ____

YOU HAVE JUST COMPLETED THE TEST.
Please re-check your answers and raise your hand when you are done.

INSTRUCTIONS

There are 20 participants in this experiment. We have randomly divided the 20 participants in two groups of 10 participants (“group A” and “group B”). Everyone has been recruited for this experiment using the same procedure and everyone has been assigned to one of the two groups randomly.

We are going to show you 10 different tables, similar to the one you have already seen.

For each of the 10 tables you receive a different answer sheet. In each answer sheet you will have to make a decision. Below we explain how to make your choices and how you will be paid for them.

First, participants of group A will circle their decision (UP, MIDDLE or DOWN) in each of the 10 tables.

After A have made all their choices, their answers sheets will be collected.

Then, participants in group B will receive 10 answer sheets, each one corresponding to a different table and coming from a different participant from group A.

Therefore, participants in group B will know what the participant from group A with whom they are matched in each table has chosen for each table.

After receiving the answer sheets, participants in group B will choose between “**LEFT**”, “**CENTRE**” and “**RIGHT**” in each of the 10 tables. These choices, together with the choice by the participant in group A, will select a cell in each of the 10 tables.

Notice that for each of the 10 tables, you will be anonymously and randomly matched with one of the 10 participants from the other group.

YOU HAVE BEEN MATCHED WITH A DIFFERENT PARTICIPANT IN EACH TABLE.

NO PARTICIPANT IN THIS EXPERIMENT WILL KNOW WHO THEY ARE MATCHED WITH FOR ANY PARTICULAR TABLE.

NO PARTICIPANT IN THIS EXPERIMENT WILL KNOW THE CHOICE MADE BY PARTICIPANTS WITH WHOM THEY ARE NOT MATCHED.

Example

In the table below A circles “DOWN” to indicate that DOWN is his choice. After observing A’s choice, B circles “RIGHT” to indicate that RIGHT is his choice:

		B		
		LEFT	CENTRE	RIGHT
	UP	5 2	4 8	3 4
A	MIDDLE	7 5	4 11	3 7
	DOWN	9 3	11 1	8 5

Caution: The numbers used in this example were selected arbitrarily. They are NOT intended to suggest how anyone might choose in any situation.

Below we explain how we will pay you according to your choices**.**

PAYMENTS

After the experiment is finished, we will randomly select ONE table from which all payments to all participants will be done. This table will be selected using a bingo urn with 10 numbered balls. The number on the ball selected determines for which of the 10 tables all participants are paid.

Participants from group A will be paid a number of pounds equal to the number that appears in the left down corner of the cell chosen by them and their matched participant from group B in the selected table.

Participants from group B will be paid the amount of pounds that appears in the upper right corner of the cell chosen by them and their matched participant from group A in the selected table.

YOU BELONG TO GROUP A (B)

You (Your matched participant in the table selected) will be paid the sum of two things:

- £5 for arriving on time.
- The amount of pounds indicated in the lower left corner in the chosen cell of the selected table.

Your matched participant in the table selected (You) from group B will be paid:
- £5 for arriving on time

- The amount of pounds that appears in the upper right corner in the chosen cell of the selected table.

FINAL INSTRUCTIONS

We will wait until all participants in group A have finished choosing in the 10 tables, to give the answer sheets to participants in group B. Please take some time to think and check your answers. We will allow each participant a maximum of 20 minutes to answer all questions. **Please, if you finish before time raise your hand and we will collect your answers.**
You are asked to remain in your seat quiet until the experiment is finished.

You have been given an identification number. **Please write this number at the top of each of your answer sheets (where it says "GROUP A (B) IDENTIFICATION NUMBER") and keep the number.** You will need this number to be paid.

While we calculate the payments you will be asked to fill in an anonymous questionnaire. After we have done the calculations, you will be asked to come with the questionnaire and your identification number to a room where you will be paid your earnings in cash and in private.

PLEASE WAIT UNTIL THE EXPERIMENTER TELLS YOU TO START

(Please raise your hand if there are any doubts with these instructions, and we will answer them privately)

7 The Games in Chapter 5

Below we show each of the ten games subjects played in “Unfair” treatments. Below each game we indicate the cell that was changed to create the “Fair” treatments. Additionally, we indicate the percentage of subjects who played each action, both for first movers (“First”) and second movers (“Second”).

Game 1R

	Left	Centre	Right	
Up	9 3	8 4	7 5	First: 0 Second: 0
Middle	7 5	5 7	5 7	First: 5 Second: 0
Down	3 9	3 9	4 Equilibrium 8	First: 95 Second: 100
	First: 10 Second: 10	First: 0 Second: 0	First: 90 Second: 90	

In the “Fair” treatments, the Middle-Left Payoff was changed by (6,6).

Game 1C

	Left	Centre	Right	
Up	2 10	10 2	11 1	First: 0 Second: 0
Middle	3 9	4 8	10 2	First: 10 Second: 0
Down	5 7	8 4	9 Equilibrium 3	First: 90 Second: 100
	First: 5 Second: 0	First: 0 Second: 10	First: 95 Second: 90	

In the “Fair” treatments, the Down-Left Payoff was changed by (6,6).

Game 2R

	Left	Centre	Right	
Up	**7** **5**	**7** **5**	**8** Equilibrium **4**	First: 100 Second: 95
Middle	**10** **2**	**1** **11**	**9** **3**	First: 0 Second: 5
Down	**11** **1**	**2** **10**	**9** **3**	First: 0 Second: 0
	First: 10 Second: 15	First: 5 Second: 0	First: 85 Second: 85	

In the “Fair” treatments, the Up-Left Payoff was changed by (6,6).

Game 2C

	Left	Centre	Right	
Up	**1** **11**	**8** **4**	**5** **7**	First: 5 Second: 0
Middle	**8** **4**	**8** **4**	**11** **1**	First: 0 Second: 0
Down	**5** **7**	**7** Equilibrium **5**	**5** **7**	First: 95 Bel: 100
	First: 0 Second: 0	First: 100 Second: 100	First: 0 Second: 0	

In the “Fair” treatments, the Down-Left Payoff was changed by (6,6).

Game 3R

	Left	Centre	Right	
Up	7 5	8 Equilibrium 4	7 5	First: 100 Second: 100
Middle	9 3	11 1	8 4	First: 0 Second: 0
Down	9 3	9 3	1 11	First: 0 Second: 0
	First: 5 Second: 10	First: 90 Second: 90	First: 5 Second: 0	

In the "Fair" treatments, the Up-Left Payoff was changed by (6,6).

Game 3C

	Left	Centre	Right	
Up	3 9	11 1	4 8	First: 0 Second: 0
Middle	2 10	2 10	3 Equilibrium 9	First: 85 Second: 100
Down	4 8	1 11	5 7	First: 15 Second: 0
	First: 0 Second: 0	First: 5 Second: 10	First: 95 Second: 90	

In the "Fair" treatments, the Down-Right Payoff was changed by (6,6).

Game 4R

	Left	Centre	Right	
Up	8 4	10 2	11 1	First: 0 Second: 0
Middle	7 5	1 11	8 4	First: 10 Second: 0
Down	5 Equilibrium 7	4 8	2 10	First: 90 Second: 100
	First: 100 Second: 95	First: 0 Second: 0	First: 0 Second: 5	

In the "Fair" treatments, the Middle-Left Payoff was changed by (6,6).

Game 4C

	Left	Centre	Right	
Up	5 Equilibrium 7	4 8	3 9	First: 90 Second: 100
Middle	7 5	1 11	3 9	First: 5 Second: 0
Down	9 3	11 1	2 10	First: 5 Second: 0
	First: 95 Second: 95	First: 0 Second: 0	First: 5 Second: 5	

In the "Fair" treatment, the Middle-Left Payoff was changed by (6,6).

Game NR

	Left	Centre	Right	
Up	**4** **8**	**7** **5**	**11** **1**	First: 0 Second: 10
Middle	**7** **5**	**7** Equilibrium **5**	**7** **5**	First: 100 Second: 35
Down	**10** **2**	**7** **5**	**5** **7**	First: 0 Second: 55
	First: 0 Second: 25	First: 85 Second: 55	First: 15 Second: 20	

In the "Fair" treatments, the Down-Right Payoff was changed by (6,6).

Game NC

	Left	Centre	Right	
Up	**11** **1**	**5** **7**	**9** **3**	First: 0 Second: 5
Middle	**8** **4**	**8** **4**	**8** Equilibrium **4**	First: 100 Second: 90
Down	**4** **8**	**10** **2**	**9** **3**	First: 0 Second: 5
	First: 5 Second: 20	First: 0 Second: 60	First: 95 Second: 20	

In the "Fair" treatments, the Up-Centre Payoff was changed by (6,6).

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