MONASH University
Business and Economics

DEPARTMENT OF ECONOMICS

ISSN 1441-5429

DISCUSSION PAPER 35/11

Bargaining with random arbitration: an experimental study

Nejat Anbarci and Nick Feltovich[*]

Abstract

We use a laboratory experiment to study bargaining in the presence of random arbitration. Two players make simultaneous demands; if compatible, each receives the amount demanded as in the standard Nash demand game. If bargainers' demands are incompatible, then rather than bargainers receiving their disagreement payoffs with certainty, they receive them only with exogenous probability 1−q. With probability q, there is random arbitration instead, with one bargainer randomly selected to receive his/her demand and the other bargainer receiving the remainder. The bargaining set is asymmetric, with one bargainer favoured over the other. We set disagreement payoffs to zero, and vary q over several values ranging from zero to one.

Our main experimental results support the directional predictions of standard game theory (though the success of its point predictions is mixed). In the spirit of typical results for conventional arbitration, we observe a strong chilling effect on bargaining for values of q near one, with extreme demands and low agreement rates in these treatments. For the most part, increases in q reinforce the built-in asymmetry of the game, further benefiting the favoured player at the expense of the unfavoured player. The effects we find are non-uniform in q: over some fairly large ranges, increases in q have minimal effect on bargaining outcomes, but for other values of q, a small additional increase in q leads to sharp changes in results.

Journal of Economic Literature classifications: C78, D74, C72.
Keywords: Nash demand game, random arbitration, chilling effect, equilibrium selection, experiment.

---

[*] Corresponding author. Financial support from Deakin University is gratefully acknowledged. Some of this research took place while Feltovich was at University of Aberdeen. We thank John Boyd III, Ehud Kalai and Herv´e Moulin for helpful suggestions and comments.
Nejat Anbarci School of Accounting, Economics and Finance Deakin University 70 Elgar Road Burwood VIC 3125, Australia. Email: nejat.anbarci@deakin.edu.au
Nick Feltovich Department of Economics Monash University Clayton VIC 3800, Australia
Email: nicholas.feltovich@monash.edu

1 Introduction

Many economic transactions involve a decentralised element, with the price (and perhaps other attributes) set by a single buyer and a single seller, each with some degree of market power. Well–known examples of at least partly decentralised markets include those for houses, new cars and used cars in most countries, as well as labour markets in many professions. In such a market, associated with any potential transaction is a relation–specific surplus for the parties involved: for example, if a painting is worth $50,000 to its current owner and $80,000 to a potential buyer, then a surplus of $30,000 is available to the two parties. The fundamental role of bargaining in determining how surpluses are divided (and indeed, whether they are even realised) in decentralised markets has long been recognised, with work in this area going back at least to the late nineteenth century (Edgeworth, 1881). However, until the 1950s, bilateral bargaining situations were deemed by economists to lack a clear predicted outcome.[1] The only quasi–prediction was that the division of the surplus would depend on the two parties' relative bargaining power.

Nash (1950) approached this indeterminacy problem by proposing a set of four axioms that the outcome of bargaining ought to follow, and proving that together, these axioms entail a unique solution to any bargaining situation that satisfies a few weak conditions, giving rise to the *Nash bargaining solution*.[2] Nash (1953) followed up this axiomatic approach by introducing a very simple non–cooperative game, now known as the *Nash Demand Game* (which we abbreviate as NDG). In the simplest version of the NDG, there is a fixed sum of money (a "cake") available to the two bargainers, each of whom simultaneously makes a single, irrevocable demand. If the demands are compatible (that is, their sum does not exceed the size of the cake), then there is "agreement", and each bargainer receives the amount he/she demanded. If not, then a predetermined "disagreement" outcome is imposed. By introducing the NDG, which was meant to capture the key aspects of real bargaining, Nash established a new research agenda, now called the "Nash program" (Binmore, 1998). This program uses non–cooperative game theory to provide a foundation for axiomatic (cooperative) bargaining solution concepts like the Nash solution.

The simplicity of the Nash Demand Game is a great virtue, but as a model of real bargaining it has two major disadvantages: one theoretical and one practical. Its theoretical disadvantage is that most versions of the NDG have a large number of Nash equilibria. In particular, every efficient, individually rational division of the surplus corresponds to a Nash equilibrium. (There are also inefficient Nash equilibria.) This multiplicity of equilibria – and resulting lack of predictive power – clearly limits the usefulness of the NDG for analysing real bargaining.

The practical shortcoming of the NDG concerns the case of incompatible demands. In this case, the disagreement outcome is imposed, resulting in a severe punishment to the bargainers, with no chance of avoiding it through renegotiation. The fact that failure to agree immediately leads to irrevocable disagreement (irrespective of how close to being compatible the two demands were) flies in the face of most people's intuitive understanding of how bargaining works. Despite this seeming deficiency, some researchers have defended the NDG as a model of real bargaining. Binmore (2007) points out that when bargainers can commit to demands, but neither has the ability to commit before the other, the NDG is the limiting case where both bargainers "rush to get a take–it–or–leave–it demand on the table first" (p. 496), resulting in simultaneous irrevocable demands. Moreover, Skyrms (1996) argues

[1] For example, as Roth (1979) points out, von Neumann and Morgenstern's (1944) bargaining solution coincides with the set of all efficient outcomes that both bargainers prefer to disagreement.

[2] Formally, a two–person bargaining problem is described by a pair (S, d) where $S \subset \mathbf{R}^2$ is the *set of feasible agreements* with a *disagreement point* $d = (d_1, d_2) \in S$ being the allocation that results if no agreement is reached. Nash's solution requires only that S is compact and convex, and that it contains some (x_1, x_2) with $x_1 > d_1$ and $x_2 > d_2$ (that is, gains from agreement are available); these conditions will be satisfied for the bargaining problems considered in this paper.

that in modelling the bargaining process, "[o]ne might imagine some initial haggling...but in the end each of us has a bottom line" (p. 4); focussing on these bottom lines results in the NDG. However, experimental evidence suggests that there are indeed systematic differences in behaviour between the NDG and less structured bargaining settings – both in the likelihood of reaching agreement and in how the resulting surplus is divided (Feltovich and Swierzbinski, 2011) – suggesting that some important features of real bargaining are lost by modelling it with the NDG.

Nash (1953) himself provided the first attempt to rectify these problems, with g a "smoothing" approach. Under smoothing, incompatible pairs of demands do not necessarily lead to zero payoffs; rather, the probability of a pair of demands being accepted decreases continuously from one (at the boundary of the original bargaining set) to zero based on a smoothing function.[3] Clearly, such a modification treats incompatible demands differently according to how close to being compatible they were. Less obviously, when an appropriate smoothing function is used, it results in the set of Nash equilibria shrinking to a unique equilibrium corresponding to the Nash bargaining solution. Although this smoothing attempt was the first to provide non–cooperative foundations for the Nash solution, it has typically not been deemed reasonable by game theorists since that time.[4]

A more recent attempt is that by Anbarci and Boyd (2011), whose "probabilistic simultaneous procedure" (p. 18) modified the NDG so that bargainers submitting incompatible demands do not necessarily receive their disagreement payoffs; instead, with probability $q \in [0, 1]$, a fair coin toss determines which of the two bargainers receives his/her demand (with the remainder going to the other bargainer). Only with probability $1 - q$ does disagreement actually lead to imposition of the disagreement outcome. Anbarci and Boyd's game can be thought of as combining the standard NDG with an element of arbitration. In the case of incompatible demands, with probability q the bargainers undergo final–offer arbitration, using the bargainers' final offers as their demands. Unlike many models of final–offer arbitration, the arbitrator does not have a preferred outcome with which to compare the demands to arrive at a decision, and simply chooses either of the demands with equal probability. We will refer to this class of games as "Nash demand games *with random arbitration*". The parameter q (the probability of random arbitration in the case of disagreement) admits several interpretations. In an abstract vein, it serves to relate standard Nash bargaining without arbitration (the case where $q = 0$) to standard final–offer arbitration without bargaining (where $q = 1$), and to highlight a connection between their theoretical implications. In a more concrete vein, one could consider imposition of the disagreement outcome with probability $1 - q$ as reflecting a possibility that subsequent external events make arbitration impossible.

Anbarci and Boyd (2011) were primarily concerned with the set of equilibria in which players agree (i.e., their demands are compatible, so the arbitration stage is not reached), and in particular how this set relates to the predictions of some of the well–known axiomatic bargaining solutions. However, their game, which we will often abbreviate as NDG(q), has an additional property that makes it interesting from a theoretical standpoint: as q increases, the set of Nash equilibria changes in a manner that is monotonic in a sense, but not uniform. The specifics of this will be discussed in some detail in Section 2, but intuitively, for some ranges of q, fairly large changes in q will have little or no effect on the set of equilibria, while for other ranges of q, the set of equilibria will be extremely sensitive to small changes in q.

The purpose of this paper is to put the theoretical implications of Anbarci and Boyd's (2011) game to the test,

[3] See Binmore et al. (1993) for an experiment using a "smoothed" bargaining set.

[4] For example, Luce and Raiffa (1957) write that "Nash offers an ingenious and mathematically sound argument for [resolving the indeterminacy problem], but we fail to see why it is relevant" (p. 141) and go on to call smoothing "completely artificial" (p. 142). Schelling (1960) was more sympathetic, but even so, stated that smoothing was "in no sense logically necessary" (p. 283) and that while it provided an way of selecting one of the multiplicity of equilibria, the same argument "equally supports any other procedure that produces a candidate for election among the infinitely many potential [solutions]" (p. 284).

with the use of a human–subjects experiment. To our knowledge, there has been no previous experimental study of this game, though of course both bargaining and arbitration have immense literatures.[5] Our study begins with an underlying bargaining environment that is biased, in that one bargainer has a favourable position relative to the other. Such asymmetry has two advantages from an experimental–design standpoint. First, it adds an element of genuine strategic uncertainty to the game, since in asymmetric bargaining settings, there is no single obvious focal outcome (in contrast to symmetric bargaining games, which are overwhelmingly likely to lead to equal splits). Second, it opens the possibility of examining whether varying q affects the extent to which the favoured player is able (or willing) to exploit this favourable position. Our experiment is designed to allow such an examination (among other things), utilising several values of q ranging from zero to one.

Our experimental results give positive, but not unequivocal, support to standard game theory. We find that the theory often performs poorly when faced with strong tests arising from equilibrium point predictions; these are often not seen in the experimental data. However, qualitative implications of the theory, based on the directions of effects on behaviour resulting from varying q, conform closely to what is seen in the experiment. In particular, compared to lower values, higher values of q are more often associated with a "chilling effect" on bargaining (as is often seen in models of conventional arbitration), with substantially lower agreement rates (e.g., less than 25% when $q = 1$, as compared to over 90% when $q = 0$) resulting from extreme demands. This effect tends to reinforce the inherent bias of the bargaining environment, increasing the payoffs of the favoured player at the expense of the unfavoured player (in effect giving players nearly diametrically opposed preferences over q). Specifically, the ratio between favoured– and unfavoured–player payoffs when q is low is close to that of the most equitable efficient division of the cake (the *lexicographic egalitarian* solution; see Chun, 1989), while when q is high, this ratio is comparable to that of the more uneven *Kalai–Smorodinsky* (1975) outcome. Finally, we find that consistent with the theory, increases in q have non–uniform effects. For a fairly large range of q, increases in q have minimal effect on bargaining behaviour and outcomes. From there, even a small additional increase in q can lead to sharp changes in results, while further increases have little effect beyond this.

2 Theoretical background

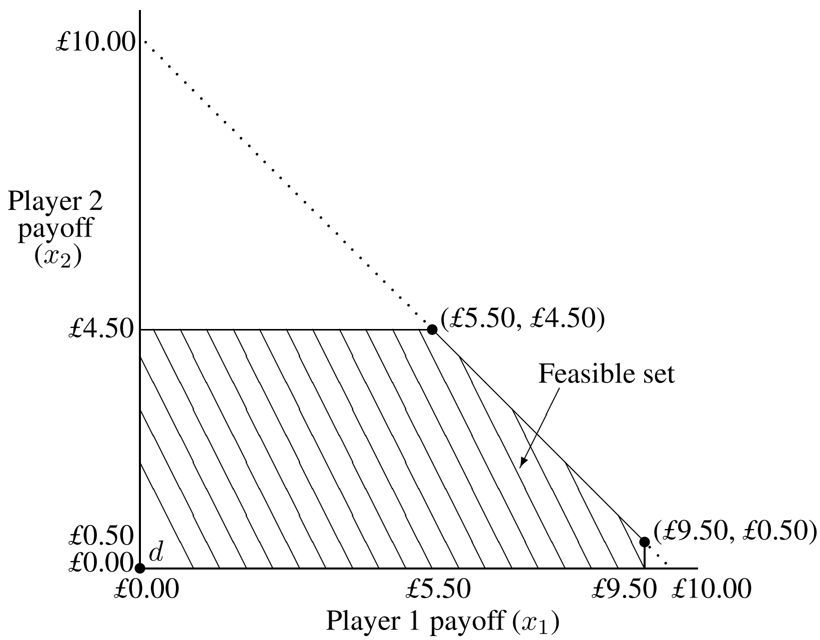
The game used in the experiment is an adaptation of the Nash Demand Game (Nash, 1953), which we abbreviate NDG. In the version we use, there is a fixed surplus ("cake") of £10 available to be divided by two bargainers. The bargainers make simultaneous demands; Player 1 (the favoured player) can choose any demand x_1 between zero and $\overline{x}_1$ = £9.50, while Player 2 (the unfavoured player) can choose any demand x_2 between zero and $\overline{x}_2$ = £4.50. If the demands are compatible (total £10 or less), there is "agreement", and each bargainer receives the amount demanded, with any remainder left "on the table". In this basic game, if the demands are incompatible ("disagreement"), both bargainers receive zero. In either case, the game ends with no opportunity for further negotiation. All rules of the game, including the limits placed on demands, are assumed to be common knowledge between the players.

Under the assumption that bargainers' payoffs are identical to their monetary payments, the bargaining problem can be depicted in Figure 1. As noted already, setting the players' maximum allowable demands to $\overline{x}_1 = 9.50$ and $\overline{x}_2 = 4.50$ makes the bargaining problem asymmetric, decreasing the likelihood that the players will agree on a single obvious focal point.[6] Indeed, the most common focal point in bargaining games, a 50–50 split of the surplus,

[5] Surveys of bargaining experiments can be found in Roth (1995) and Camerer (2003, pp. 151–198). Surveys of experiments involving bargaining with arbitration can be found in Kuhn (2009) and Charness and Kuhn (2010).

[6] A typical result in experiments involving symmetric bargaining games is that they tend to yield a high frequency of agreements on 50–50

Figure 1: The bargaining problem – feasible set and disagreement outcome d



is impossible in our game, and while other equal–payoff outcomes are possible (e.g., each player receives £4.50), they are neither equilibria nor efficient.

As is common in NDGs, this basic game has a large number of Nash equilibria. There are efficient pure–strategy equilibria in which Player 1 demands k and Player 2 demands $10 - k$, for $k \in [10 - \overline{x}_2, \overline{x}_1]$, as well as inefficient mixed–strategy equilibria. Ruling out any of these equilibria requires the use of additional assumptions; however, we note that both Harsanyi and Selten's (1988) risk dominance and their general equilibrium selection procedure select the most equitable of the efficient equilibria (5.5, 4.5).[7] This outcome is also implied by some of the well–known axiomatic bargaining solutions for the corresponding unstructured bargaining game, such as the Nash (1950) and lexicographic egalitarian (Chun, 1989) solutions (though not the Kalai–Smorodinsky (1975) solution, which selects an agreement with Player 1 getting £$6.78\frac{4}{7}$ of the £10).[8] Additionally, while Rawls's (1971) "difference principle" did not deal with bargaining specifically, arguments in this spirit would select (5.5, 4.5) as the fairest efficient division of the cake (as it maximises the payoff of the worse–off player). Given that so many cooperative and non–cooperative methods select the (5.5, 4.5) outcome, we might expect it to serve as an appealing focal point.

splits of the cake. Introducing any kind of asymmetry substantially lowers both agreement frequencies and equal splits, even when such play is still consistent with equilibrium, possibly due to players' self–serving views of fairness (Babcock et al., 1995, Roth and Murnighan, 1982). See Nydegger and Owen (1975) and Roth and Malouf (1979) for experimental comparisons of symmetric and asymmetric bargaining games.

[7]Risk dominance formalises the intuitive notion that when players have little information about the choices others will make, they will prefer strategies that are (in some sense) less risky. In the simplest case of a symmetric 2x2 game with strategic complementarities and two strict Nash equilibria (s, s) and (t, t), (s, s) is risk dominant if the threshold probability of the opponent choosing s at which s becomes a best response is lower than the corresponding threshold probability for t. Harsanyi and Selten's (1988) text extends this intuition for general non–cooperative games.

[8]The lexicographic egalitarian solution differs from the strict egalitarian solution in tolerating increases in inequity as long as they don't actually harm the worse–off player. For the bargaining set we use, the inefficient outcome (4.5, 4.5) is the strict egalitarian solution; weak Pareto improvements from here are possible, but benefit Player 1 only and are thus ruled out by a strict egalitarian. By contrast, a lexicographic egalitarian would allow any (weak or strong) Pareto improvements, and would thus select (5.5, 4.5) for our bargaining set.

2.1 The Nash demand game with random arbitration

From the basic NDG, we make one modification: in case of incompatible demands, the players might still do better than receiving their disagreement payoffs of zero. Specifically, with (common knowledge) probability $q \in [0, 1]$, one of the players is randomly selected – with either equally likely – to receive the amount he/she demanded, with the other player receiving the remainder of the cake. With probability $1 - q$, both players receive zero, as before. Thus, when $q = 0$, demands must be compatible in order for the players to get any positive payoffs, while as q increases, so increases the likelihood that players get significant payoffs without an agreement. We will use the notation NDG(q) to refer to a generic version of this game, so that NDG(0) is equivalent to the basic Nash demand game.

Obviously, our NDG(q) is much simpler than actual situations involving bargaining and arbitration. However, some real–world settings do have the flavour of this game, especially regarding the uncertainty of whether an arbitration phase will follow a disagreement. In many international political and commercial disputes, arbitration is neither automatic nor automatically ruled out. For example, two conflicting states may hope that the United Nations will provide arbitration if the conflict escalates out of control, but the UN may be reluctant to do so for various reasons; if there is uncertainty about whether the UN actually does arbitrate, the resulting situation is very much like our NDG(q) (where q is the probability that arbitration takes place). Likewise, in international commercial disputes, there can be conditions before authorised bodies would be able to provide arbitration.[9]

2.2 Theoretical predictions

As noted in the introduction, this modification to the game can be interpreted as (with probability q) tacking on a stage of final–offer arbitration, where the "final offers" are simply the players' demands, and the arbitrator chooses either demand with equal probability. It is worth pointing out that this arbitration rule differs in an important way from those in typical models of final–offer arbitration, where the likelihood of a player's offer being the one chosen is negatively related to its distance from some "ideal point" held by the arbitrator, thus punishing extreme demands to some extent. The arbitration rule in NDG(q) is not sensitive to the specific demands chosen by the players, and can thus be thought of as a stochastic version of conventional arbitration (conditional on arbitration occurring, in expected value terms it chooses an outcome midway between the bargainers' demands, as a simple model of conventional arbitration might). In particular, for q close to one, predicted behaviour is the typical "chilling effect" seen in models of conventional arbitration, where both players choose the maximum demand they are able to make.[10] As long as q is strictly less than one, this equilibrium is inefficient, and indeed, Pareto dominated by som non–equilibrium strategy profiles that lead to agreement.

Thus, when $q = 0$, NDG(q) has the usual problem of multiplicity of Nash equilibria, while when $q = 1$, the only equilibrium involves the chilling effect just described. However, for some $q \in (0, 1)$, the game's theoretical prediction can be precise as well as avoiding the most extreme demands, as the analysis below will show.

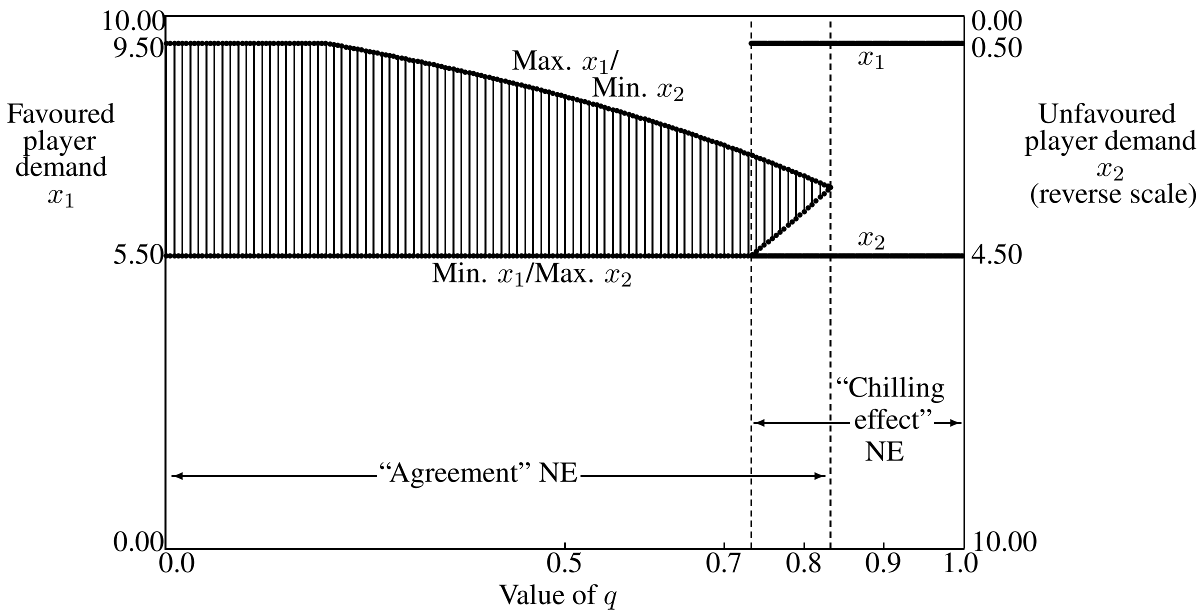
[9] Ryan (1999) provides such a real–life example in the context of international commercial disputes: "Chapter 2 of Title 9 of the United States Code contains the New York Convention and the enabling legislation by which it was ratified by the United States in 1970...The Convention contemplates a limited inquiry by courts when considering a motion to compel arbitration: 1. Is there an agreement in writing to arbitrate the dispute? 2. Does the agreement provide for arbitration in the territory of a Convention signatory? 3. Does the agreement to arbitrate arise out of a commercial legal relationship? 4. Is a party to the agreement not an American citizen or does the commercial relationship have some reasonable relation with one or more Foreign States?" The third and fourth of these criteria, relying on the interpretations of "commercial legal rationship" and "reasonable relation", may in some cases be ambiguous enough to permit real uncertainty regarding whether arbitration will be compelled; if so, the situation could be modelled using our NDG(q).

[10] The chilling effect that conventional arbitration, and to a lesser extent final–offer arbitration, can have on bargaining is well covered in the theoretical and empirical literature. See, for example, Feuille (1975).

Clearly, for any allowable demand x_{3-i} by the opponent ($i = 1, 2$), Player i's best response will be either the highest compatible demand $x_i = 10 - x_{3-i}$ or the maximum possible demand $x_i = \overline{x}_i$. Choosing $\overline{x}_i$ is best if either (a) x_{3-i} is low enough that agreement is reached even when $\overline{x}_i$ is chosen, or (b) q is high enough that the $\frac{q}{2}$ probability of being selected to get $\overline{x}_i$ is worth the risk of disagreement (noting that the player still gets $10 - x_{3-i}$ in the event that the arbitrator selects the opponent's demand). This leads to the possibility of two types of pure–strategy Nash equilibrium. The first type, which corresponds to the efficient equilibria of the standard NDG, has $x_1 + x_2 = 10$, and agreement occurs with probability one. The second type of equilibrium has both players choosing their maximum allowable demands: $(x_1, x_2) = (\overline{x}_1, \overline{x}_2)$, so expected payoffs are $\frac{q}{2}[10 + \overline{x}_1 - \overline{x}_2]$ and $\frac{q}{2}[10 - \overline{x}_1 + \overline{x}_2]$ respectively. We will sometimes refer to these two types of equilibrium as "agreement equilibria" and "chilling effect equilibria" respectively.

Which of these types of equilibria exists depends on q; as q increases, a choice of the maximum allowable demand becomes more profitable relative to lower demands that might lead to agreement; more precisely, a demand of $\overline{x}_i$ strictly dominates demands below $\frac{q}{2-q}\overline{x}_i$. So, as a function of q, the favoured player's minimum demand in an agreement equilibrium is $Max\left\{9.5\frac{q}{2-q},\ 5.5\right\}$, while her maximum demand in an agreement equilibrium is 9.5 for all q. Similarly, the unfavoured player's minimum demand in an agreement equilibrium is $Max\left\{4.5\frac{q}{2-q},\ 0.5\right\}$, while his maximum demand in an agreement equilibrium is 4.5 for all q. As a result, as q increases, the continuum of

Figure 2: Theoretical predictions – Nash equilibrium demands of favoured players (x_1) and unfavoured players (x_2), contingent upon q



agreement equilibria seen in the basic NDG shrinks, becoming a single point when $q = \frac{5}{6} \approx 0.833$, with the favoured player receiving $\frac{19}{28} \approx 0.679$ of the cake.[11] Beyond this value of q, only the "chilling effect" equilibrium exists; the favoured player demands 9.5 and the unfavoured player demands 4.5, implying expected payoffs of $7.5q$ and $2.5q$ respectively. Chilling effect equilibria also exist for some lower values of q: specifically, whenever $q \geq \frac{11}{15} \approx 0.733$. Except when $q = 1$, these chilling effect equilibria are inefficient, and indeed are payoff dominated by outcomes in which the players make compatible demands. For $q \in \left[\frac{11}{15}, \frac{5}{6}\right]$, these latter outcomes may be equilibria themselves,

[11]The unique Nash equilibrium outcome for this value of q coincides with the Kalai–Smorodinsky (1975) solution for the corresponding unstructured bargaining problem. As Anbarci and Boyd (2011) show, this is true for any bargaining set satisfying minimal properties.

but for higher q, they are necessarily non–equilibrium outcomes (in which case the game has some characteristics of the prisoners' dilemma).

Figure 2 shows the correspondence between the value of q and the set of Nash equilibria for NDG(q). As the figure shows, there is an element of monotonicity to the correspondence: for $q_1 < q_2$, the set of agreement equilibria of NDG(q_1) contains the corresponding set for NDG(q_2), and once we reach a value of q for which a chilling–effect equilibrium exists, it continues to exist for all higher q. However, the correspondence is not uniform. For $q \in [0, 0.2]$, the set of equilibria is exactly the same as it is for the basic Nash demand game, and for q from 0.2 all the way up to $\frac{11}{15}$, the set of agreement equilibria shrinks at a fairly constant rate, as relatively asymmetric agreements become worse for the unfavoured player than demanding his maximum; in particular, the risk–dominant equilibrium (5.50, 4.50) of the basic NDG continues to be an equilibrium of NDG(q) for this range of q. At $q = \frac{11}{15}$, there is a sudden change, as chilling–effect equilibria appear and, beyond this point, the outcome (5.50, 4.50) is no longer an equilibrium. For $q \in \left(\frac{11}{15}, \frac{5}{6}\right)$, the set of agreement equilibria shrinks quickly, as demanding the maximum becomes more attractive for the favoured player than the most equitable agreements, and for the unfavoured player, more attractive than the most inequitable agreements. At $q = \frac{5}{6}$, there is another sudden change, as agreement equilibria cease to exist beyond this point; only the chilling–effect equilibria are left.

2.3 Treatments and hypotheses

In the experiment, we use a total of six versions of NDG(q), with $q = 0$, 0.5, 0.7, 0.8, 0.9 and 1.0. Figure 2 shows that for the first three values of q, only agreement equilibria exist; for the last two, only a chilling effect equilibrium exists; and for $q = 0.8$, both kinds of equilibrium exist. Some equilibrium features of the NDG(q) with these particular values of q are summarised in Table 1. As noted already, in the cases of $q = 0$, 0.5, 0.7 and 0.8, a continuum of Nash

Table 1: Theoretical predictions for the versions of NDG(q) used in the experiment, to 2 decimal places

Value	Equilibrium	Equilibrium demands (£)		Equilibrium payoffs (£)		Agreement
of q		Favoured player	Unfavoured player	Favoured player	Unfavoured player	frequency
0	All	[5.50, 9.50]	[0.50, 4.50]	[5.50, 9.50]	[0.50, 4.50]	1
	Risk dom.	5.50	4.50	5.50	4.50	1
0.5	All	[5.50, 8.50]	[1.50, 4.50]	[5.50, 8.50]	[1.50, 4.50]	1
	Risk dom.	5.50	4.50	5.50	4.50	1
0.7	All	[5.50, 7.58]	[2.42, 4.50]	[5.50, 7.58]	[2.42, 4.50]	1
	Risk dom.	5.50	4.50	5.50	4.50	1
0.8	All	[6.33, 7.00] or 9.50	[3.00, 3.67] or 4.50	[6.33, 7.00] or 6.00	[3.00, 3.67] or 2.00	1 or 0
	Risk dom.	9.50	4.50	6.00	2.00	0
0.9	(Unique)	9.50	4.50	6.75	2.25	0
1.0	(Unique)	9.50	4.50	7.50	2.50	0

equilibria exist, making sharp predictions difficult without the use of additional assumptions. In order to overcome this difficulty, we also consider the implications arising from additionally imposing the selection criterion of *risk dominance* (Harsanyi and Selten, 1988); in all four of these versions of NDG(q), this leads to a unique prediction.

For $q = 0$, 0.5 and 0.7, risk dominance implies the most equitable efficient outcome, with agreement occurring with probability one, and with demands (and thus payoffs) of £5.50 and £4.50 by the favoured and unfavoured player respectively. For $q = 0.8$, although there are agreement equilibria, the risk dominant outcome is the chilling effect equilibrium, where both players choose their maximum demands and thus disagree with probability one; notably, this outcome is payoff dominated by all of the agreement equilibria.[12] NDG(0.9) and NDG(1.0) have only the chilling effect equilibrium, so the equilibrium prediction for these games is precise.

Comparison of these predictions, based on Nash equilibrium and in some cases risk dominance, for the various values of q in the experiment gives us the following hypotheses, which will structure our analysis of the experimental results.

Hypothesis 1 *(within p = 0, 0.5, 0.7) There are no systematic differences in favoured–player demands, unfavoured–player demands, favoured–player payoffs, unfavoured–player payoffs or agreement frequencies across the NDG(0), NDG(0.5) and NDG(0.7) games.*

Hypothesis 2 *(within p = 0.8, 0.9, 1.0) There are no systematic differences in favoured–player demands, unfavoured–player demands or agreement frequencies across the NDG(0.8), NDG(0.9) and NDG(1.0) games.*

Hypothesis 3 *(within p = 0.8, 0.9, 1.0) Within the NDG(0.8), NDG(0.9) and NDG(1.0) games, both favoured– and unfavoured–player payoffs increase as q increases.*

Hypothesis 4 *(between p = 0, 0.5, 0.7 and p = 0.8, 0.9, 1.0) There are no systematic differences in unfavoured–player demands between the NDG(0.8), NDG(0.9) and NDG(1.0) games and the NDG(0), NDG(0.5) and NDG(0.7) games.*

Hypothesis 5 *(between p = 0, 0.5, 0.7 and p = 0.8, 0.9, 1.0) Favoured–player demands and payoffs are higher, and unfavoured–player payoffs and agreement frequencies are lower, in the NDG(0.8), NDG(0.9) and NDG(1.0) games than in the NDG(0), NDG(0.5) and NDG(0.7) games.*

3 Experimental design and procedures

Our experimental design varies the game both within– and between–subjects. All subjects became familiarised with the experimental setting by playing ten rounds of the basic NDG (i.e., $q = 0$). Then, all subjects play an additional thirty rounds of NDG(q) with one of the strictly positive values of q (0.5, 0.7, 0.8, 0.9 or 1.0). The value of q in the second part of a given session was the same in all rounds and for all subjects in that session. Subjects also remained in the same role (favoured or unfavoured player) in all rounds, but they were randomly re–matched in each round to a subject in the opposite role.

The experimental sessions took place at the Scottish Experimental Economics Laboratory (SEEL) at the University of Aberdeen, between autumn 2010 and spring 2011. Subjects were primarily undergraduate students from

[12] In the case of NDG(0.8), risk dominance and Harsanyi and Selten's (1988) selection criterion have different implications. The risk dominant equilibrium is the chilling effect equilibrium, but this is payoff–dominated by all of the agreement equilibria. Since the Harsanyi–Selten criterion gives priority to payoff dominance over risk dominance, it will select any agreement equilibrium over the chilling effect equilibrium. Amongst the agreement equilibria, players' interests are perfectly opposed, so payoff dominance carries no implication once the chilling effect equilibrium is eliminated. Then, the $\left(6\frac{1}{3}, 3\frac{2}{3}\right)$ equilibrium – which risk–dominates all of the other agreement equilibria – is selected.

University of Aberdeen, and were recruited using the ORSEE system (Greiner, 2004) from a database of people expressing interest in participating in economics experiments. No one took part in this experiment more than once.

At the beginning of a session, subjects were seated in a single room and given written instructions for the first ten rounds.[13] These instructions stated that the experiment would be made up of two parts and that the second half would comprise thirty additional rounds, but additional details of the second half were not announced until after the first half had ended. The instructions were also read aloud to the subjects, in an attempt to make the rules of the game common knowledge. Then, the first round of play began. After the tenth round was completed, each subject was given a copy of the instructions for rounds 11–40. These instructions were also read aloud, after which time round 11 was played.

The experiment was run on networked personal computers, and was programmed using the z–Tree experiment software package (Fischbacher, 2007). Subjects were asked not to communicate with other subjects except via the computer program. No identifying information was given about opponents (in an attempt to minimise incentives for coordination across rounds, reputation, and other repeated game effects). Also, in order to minimise demand effects, we referred to a subject's opponent as "the other player" or "the player paired with you" which, while sometimes cumbersome–sounding, avoids the negative framing of "opponent" or the positive framing of "partner".

Each round of the experiment began with subjects being prompted to choose their demands (called "claims" in the experiment). Demands were restricted to be whole–number multiples of £0.01, between zero and the subject's maximum allowable demand (£4.50 or £9.50); both own and opponent maximum allowable demands were displayed on the computer screen at this time. After all subjects had entered their demands, the round ended and they received feedback. In rounds 1–10 (when subjects played the basic NDG), feedback comprised the subject's own demand, the opponent demand, whether agreement was reached, own payoff and opponent payoff. In rounds 11–40, feedback included all of these and in the case of disagreement, whether the subject, the opponent or neither was chosen to have his/her demand implemented. After viewing these results and clicking a button to continue, the next round began.

At the end of the fortieth round, the experimental session ended and subjects were paid, privately and individually. For each subject, one round from rounds 1–10 and three from rounds 11–40 were randomly chosen, and the subject was paid the sum of his/her earnings in those rounds, to the penny. Subjects' total earnings ranged from £4.50 to £34.00, and averaged approximately £17.85, for a session that typically lasted about 60 minutes.

4 Experimental results

A total of 264 subjects participated in the experiment (see Table 2), in 18 sessions. We will begin the discussion of experimental results with an analysis of the aggregate data. Our hypotheses concerning these aggregates will be tested with the use of conservative non–parametric statistical tests. The unit we will use for these tests is the "group". Subjects in one group interacted only with other subjects in the same group, so data from any group can be considered statistically independent of data from any other group. Each experimental session, depending on its size, comprised one or more groups; as Table 2 shows, the 18 experimental sessions comprised a total of 30 groups.

[13] Sample instructions and screenshots are shown in the Appendix. The remaining sets of instructions, as well as other experimental materials and the raw data from the experiment, are available from the corresponding author upon request.

Table 2: Treatment information

Value of q	Rounds	Groups	Subjects
0	1–10	30	264
0.5	11–40	6	64
0.7	11–40	6	50
0.8	11–40	6	48
0.9	11–40	6	56
1.0	11–40	6	46

4.1 Preliminaries

Some summary data are presented in Table 3. For each version of NDG(q), the table shows five statistics: the mean demands of both types of player (favoured and unfavoured), the mean payoffs of both types, and the frequency of agreement. Also shown are significance results from nonparametric tests of differences across individual cells

Table 3: Aggregate results – treatment means and significance test results

Value of q	0	0.5	0.7	0.8	0.9	1.0
Favoured player demand (£):	5.41^{a}	6.04^{b}	5.95^{b}	7.60^{cd}	6.88^{c}	8.06^{d}
Unfavoured player demand (£):	4.29^{a}	4.36^{b}	4.37^{bc}	4.37^{abc}	4.47^{c}	4.29^{abc}
Favoured player payoff (£):	4.76^{a}	5.10^{b}	5.19^{b}	5.80^{c}	5.78^{c}	6.88^{d}
Unfavoured player payoff (£):	3.85^{c}	3.77^{bc}	3.86^{bc}	3.05^{a}	3.62^{b}	3.02^{a}
Agreement frequency (%):	90.1^{d}	79.0^{c}	76.4^{c}	39.7^{ab}	52.3^{b}	24.2^{a}

Note: Within each statistic, entries with no superscripts in common are significantly different at the 5% level (group–level data, see text for additional details); superscripts earlier in the alphabet correspond to significantly lower values.

for each of these five variables, using group–level data, and with significance defined as a p–value of 0.05 or less.[14] These significance results are displayed as superscript letters to the table entries; for a given statistic, entries sharing a superscript are not significantly different, while entries with letters earlier in the alphabet correspond to significantly lower values (e.g., a statistic with a b superscript is significantly higher than one with an a superscript, but neither is significantly different from one with an ab superscript.)

Before revisiting our hypotheses, we remark on a few salient features of the aggregate data that are apparent from Table 3. First, the data show a fair amount of heterogeneity across treatments; this heterogeneity varies with the statistic of interest, but in some cases it is particularly striking. As an example, consider the sharp decrease

[14] For pairwise comparisons between NDG(0.5), NDG(0.7), NDG(0.8), NDG(0.9) and NDG(1.0), we use the robust rank–order test, since no group faces more than one of these games, making them independent samples. For comparisons between any of these games and NDG(0), we use the Wilcoxon signed–ranks test for matched samples, with data from a particular positive–q NDG group (e.g., NDG(0.9)) compared only to the subset of NDG(0) groups that subsequently played that particular version of NDG(q) – reducing any variability that might have been due to session effects. See Siegel and Castellan (1988) for descriptions of the nonparametric statistical tests used in this paper. Some critical values for the robust rank–order tests performed here and elsewhere are from Feltovich (2005).

in agreement frequencies as one moves from NDG(0) to NDG(1.0): from over 90% to less than one–quarter.[15] As a second example, note that as q increases, favoured–player payoffs rise substantially, while unfavoured–player payoffs fall. Consequently, the ratio of favoured– to unfavoured–player payoffs for low values of q (e.g., roughly 1.24 when $q = 0$) is comparable to $\frac{11}{9} \approx 1.22$, the common prediction of the Nash and lexicographic egalitarian bargaining solutions applied to the corresponding unstructured–bargaining setting, but for high values of q this ratio (e.g., approximately 2.28 when $q = 1$) is closer to $\frac{19}{9} \approx 2.11$, the ratio implied by the less equitable Kalai–Smorodinsky solution. Indeed, nonparametric Kruskall–Wallis tests (which differ from the robust rank–order test in that they detect differences across any number of independent samples, rather than between two samples) reject the null hypothesis of no difference across the positive–q treatments in favoured–player demands, favoured– and unfavoured–player payoffs and agreement frequencies ($\chi^2_4 \approx 20.25$, 14.66, 24.89 and 19.53 respectively; $p \approx 0.0055$ for unfavoured–player payoffs, $p < 0.001$ for the other three), though no significant differences are found in unfavoured–player demands ($\chi^2_4 \approx 5.50$, $p \approx 0.24$).

Second, separate from the success or failure of our hypotheses, all of which are of a qualitative nature (involving the direction of an effect, but not its size), the point predictions of Nash equilibrium (see Table 1) have, at best, equivocal success in characterising subject behaviour. In some cases, these point predictions fare well; for example, average unfavoured–player demands in all cells are close to the equilibrium point prediction of £4.50, and the ranges of predicted values for favoured–player demands and both favoured and unfavoured types' payoffs in NDG(0), NDG(0.5), NDG(0.7) and NDG(0.8) usually contain the corresponding observed value from the experiment. However, these three statistics in NDG(0.9) and NDG(1.0), and agreement frequencies in all cells except NDG(0.8), are far away from their corresponding point predictions.

In order to shed some light on the mixed success of equilibrium point predictions, Figure 3 displays the outcomes from each individual pair of bargainers in all cells, from all rounds after the first five using that value of q (i.e., from rounds 6–10 for NDG(0) and rounds 16–40 for the other games). Each outcome is completely characterised by the corresponding favoured– and unfavoured–player demands, shown on the horizontal and vertical axis respectively. For each pair of demands, the figure shows a circle with radius proportional to the number of times that pair of demands occurred in that cell.

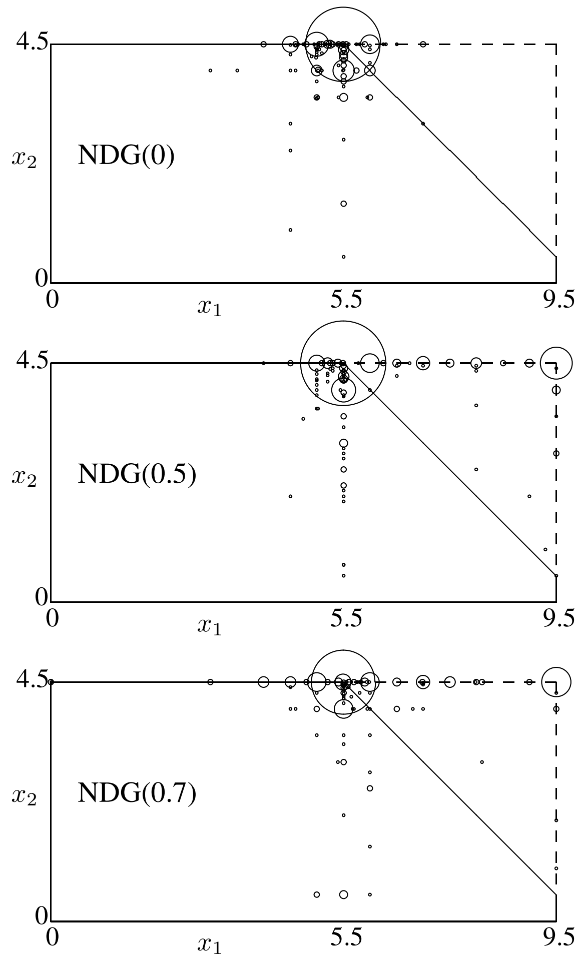
As the figure shows, there is typically substantial heterogeneity within cells as well as across them. Also, coordination on any division of the cake other than (5.5, 4.5) is extremely rare. In NDG(0), the agreement equilibrium (5.5, 4.5) is by far the most frequent outcome, while in the other cells, (5.5, 4.5) is one of two modes, along with the chilling–effect outcome (9.5, 4.5). This is true in NDG(0.5) and NDG(0.7), where there exist agreement equilibria but no chilling–effect equilibrium; in NDG(0.9) and NDG(1.0), where there is a chilling–effect equilibrium but no agreement equilibria; and in NDG(0.8), where both types of equilibrium exist, but (5.5, 4.5) is not an equilibrium. The substantial amount of non–equilibrium play in all cells except NDG(0) provides an explanation for the mixed success of theoretical point predictions to characterise play at the aggregate level, along with showing that this ability is also limited at the individual level.

4.2 Aggregate–level treatment effects

We next move to a comparison between the experimental data and the hypotheses from Section 2.3. The pairwise test results shown in Table 3 evidence general, but not complete, agreement with our hypotheses. Concerning

[15] Unsurprisingly, as agreements become less common, the chilling effect is observed more often. The frequency of (9.50, 4.50) outcomes tends to rise with q, from 0.1% of all outcomes when $q = 0$ and 8.2% and 8.8% for $q = 0.5$ and $q = 0.7$ (where there is no chilling–effect equilibrium) to 38.3% when $q = 0.8$, 22.7% when $q = 0.9$ and 60.2% when $q = 1$.

Figure 3: All pairs of favoured– and unfavoured–player demands (in £), rounds 6–10 for NDG(0) and rounds 16–40 for other games *(radius of circle is proportional to number of observations)*



Hypothesis 1, we see that although there are no significant differences at all between NDG(0.5) and NDG(0.7), there are significant differences between these two cells and NDG(0) for four of the five statistics we examine: favoured–player demands and payoffs are higher, and unfavoured–player demands and agreement frequencies are lower, in NDG(0.5) and NDG(0.7) than in NDG(0). The similarity between NDG(0.5) and NDG(0.7) is consistent with Hypothesis 1, though we should point out that here and elsewhere, failure to reject a null hypothesis of no difference is only weak evidence that there actually is no difference, and as always, we should be careful in drawing conclusions based on such results. By contrast, the observed differences between NDG(0.5) and NDG(0.7) on the one hand, and NDG(0) on the other hand, are at odds with Hypothesis 1.

Result 1 *We find no differences in behaviour between NDG(0.5) and NDG(0.7), but we find higher favoured–player demands and payoffs, and lower unfavoured–player demands and agreement frequencies, in NDG(0.5) and NDG(0.7) than in NDG(0).*

Concerning Hypothesis 2, Table 3 shows no significant pairwise differences in unfavoured–player demands across NDG(0.8), NDG(0.9) and NDG(1.0), and no significant differences in either favoured–player demands or agreement frequencies between NDG(0.8) and either NDG(0.9) or NDG(1.0), though there are significant differences in these two statistics between NDG(0.9) and NDG(1.0). Kruskall–Wallis tests for differences across all three of these cells are negative in the case of unfavoured–player demands ($\chi_2^2 \approx 2.25$, $p \approx 0.325$) and only weakly positive for the other two statistics ($\chi_2^2 \approx 5.30$, $p \approx 0.071$ for favoured–player demands; $\chi_2^2 \approx 5.80$, $p \approx 0.055$ for agreement frequencies).

Result 2 *We find no systematic differences in agreement frequencies or in either type's demand across the NDG(0.8), NDG(0.9) and NDG(1.0) games, though some pairwise differences do exist between NDG(0.9) and NDG(1.0).*

Concerning Hypothesis 3, Table 3 shows some signs of the expected relationship (increasing with q) in the case of favoured–player payoffs; while there is no significant difference between NDG(0.8) and NDG(0.9), they are significantly higher in NDG(1.0) than in either of the other two. A non–parametric Jonckheere test (similar to the Kruskall–Wallis test, but with a directional alternative hypothesis) finds that the increase in favoured–player payoffs with q is significant ($J = 88$, $p < 0.005$). On the other hand, another Jonckheere test fails to reject the null hypothesis that unfavoured–player payoffs do not increase with q ($J = 57$, $p > 0.1$). Examination of the pairwise tests in Table 3 suggests the reason: while there is no significant difference between NDG(0.8) and NDG(1.0), unfavoured–player payoffs are signficantly higher in NDG(0.9) than in either of the other two cells.

Result 3 *We find that favoured–player payoffs increase with q across the NDG(0.8), NDG(0.9) and NDG(1.0) games, but we do not find systematic differences in unfavoured–player payoffs across these games.*

Since Hypotheses 4 and 5 involve comparisons between NDG(0), NDG(0.5) and NDG(0.7) on one hand, and NDG(0.8), NDG(0.9) and NDG(1.0) on the other, we make these comparisons transparent by pooling data when appropriate. We cannot pool NDG(0) with any other cell, since the NDG(0) data are not independent of the data from any of the other cells. However, we can pool the NDG(0.5) and NDG(0.7) data, and also the NDG(0.8), NDG(0.9) and NDG(1.0) data. Table 4 shows the same statistics as Table 3, but with pooled data used where possible.[16] The table also shows the results of non–parametric tests of differences between the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells and either the NDG(0) cell or the pooled NDG(0.5) and NDG(0.7) cells.

Table 4: Aggregate results – means from NDG(0) treatment, pooled NDG(0.5) and NDG(0.7) treatments and pooled NDG(0.8), NDG(0.9) and NDG(1.0) treatments

	Value(s) of q			Significance of differences	
	0	0.5–0.7	0.8–1.0	0 vs. 0.8–1.0	0.5–0.7 vs. 0.8–1.0
Favoured player demand (£):	5.41	6.00	7.47	$p < 0.001$	$p < 0.001$
Unfavoured player demand (£):	4.29	4.37	4.38	$p > 0.1$	$p > 0.1$
Favoured player payoff (£):	4.76	5.14	6.12	$p < 0.001$	$p < 0.001$
Unfavoured player payoff (£):	3.85	3.81	3.26	$p \approx 0.0014$	$p < 0.001$
Agreement frequency (%):	90.1	77.8	39.6	$p < 0.001$	$p < 0.001$

Note: Significance assessed via non–parametric tests using group–level data and two–tailed rejection regions (see text for details).

[16] Obviously, pooling data from different cells can pose problems when the cells are heterogeneous. In this case, however, any such heterogeneity will increase the variation within–sample, making statistical tests less significant than they would otherwise have been. In other words, heterogeneity here simply makes our tests more conservative, so any significant result is at least as informative as it would have been without the heterogeneity.

Concerning Hypothesis 4, Table 4 shows that unfavoured–player demands in the NDG(0.8), NDG(0.9) and NDG(1.0) cells are not significantly different from those in the NDG(0), NDG(0.5) and NDG(0.7) cells. This reinforces the implication of the Kruskall–Wallis test discussed earlier, that found no significant difference in unfavoured–player demands across cells.

Result 4 *We find no differences in unfavoured–player demands between the NDG(0.8), NDG(0.9) and NDG(1.0) cells and the NDG(0), NDG(0.5) and NDG(0.7) cells.*

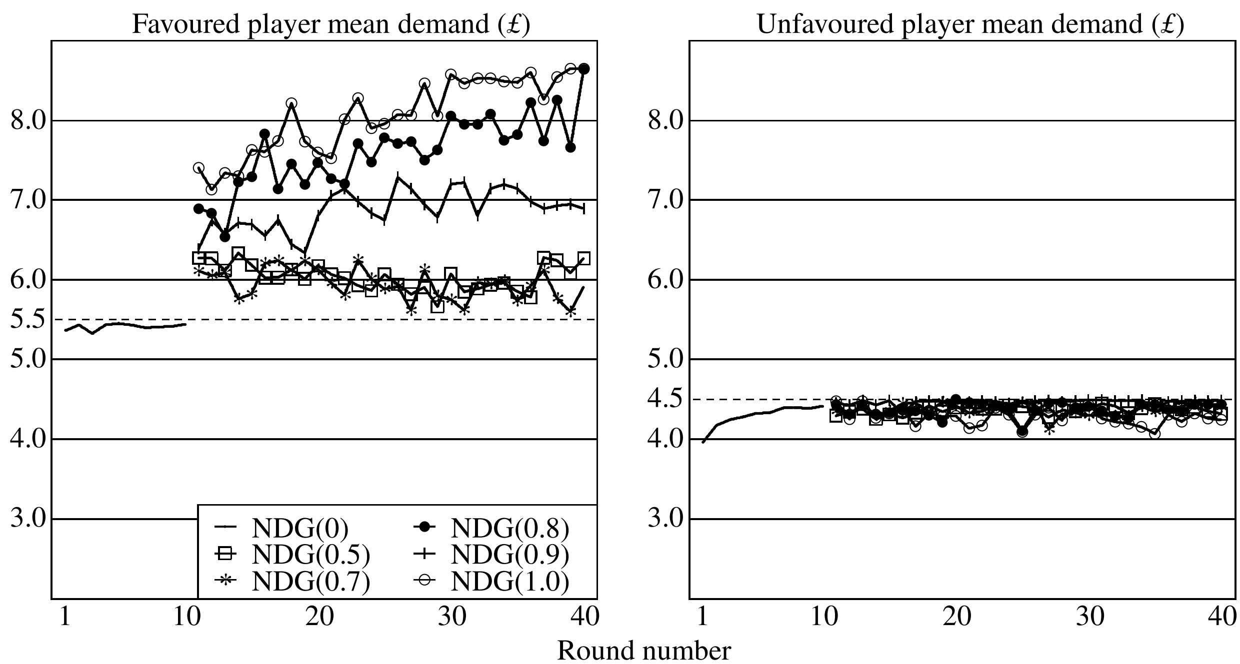
Concerning Hypothesis 5, Table 4 shows strong support. Wilcoxon signed–rank tests between the NDG(0) and the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells, and robust rank–order tests between the pooled NDG(0.5) and NDG(0.7) cells and the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells, yield significant differences in the predicted direction for favoured–player demands and payoffs, for unfavoured–player payoffs and for agreement frequencies ($p < 0.01$ in all cases). These differences were also apparent in Table 3, which showed a near–perfect separation in these statistics between the NDG(0), NDG(0.5) and NDG(0.7) cells and the NDG(0.8), NDG(0.9) and NDG(1.0) cells (the only exception being that while unfavoured–player payoffs are lower in NDG(0.9) than in NDG(0.5) and NDG(0.7), as predicted by Hypothesis 5, the difference is not significant).

Result 5 *Favoured–player demands and payoffs are higher, and unfavoured–player payoffs and agreement frequencies are lower, in the NDG(0.8), NDG(0.9) and NDG(1.0) games than in the NDG(0), NDG(0.5) and NDG(0.7) games.*

4.3 Evolution of play over time

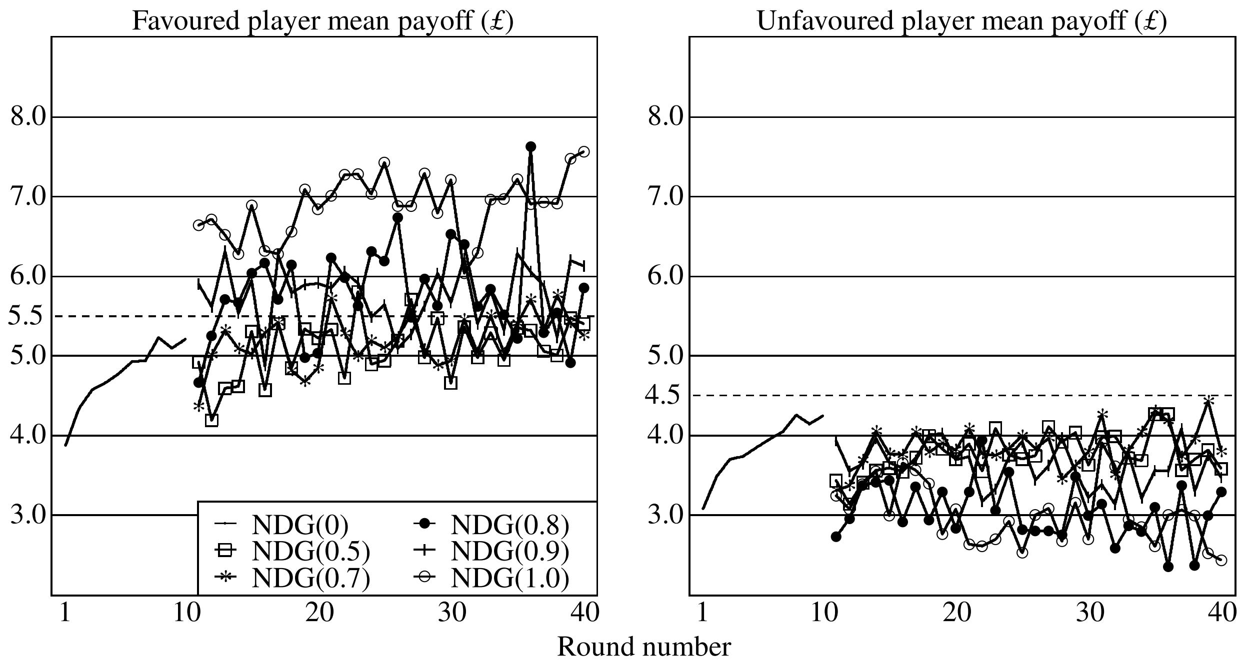
Some more information about subject behaviour comes from Figures 4, 5 and 6. Figure 4 shows the round–by–round time paths of favoured and unfavoured players' demands for each game, and Figures 5 and 6 do the same for favoured and unfavoured players' payoffs and agreement frequencies, respectively. The figures show that over the

Figure 4: Favoured and unfavoured player demands – time paths



first ten rounds (when all subjects play NDG(0)), behaviour converges approximately to the 55–45 split implied by risk dominance and other equilibrium selection criteria (and assumed in some of our hypotheses). Average favoured–player demands start and remain near £5.50, and average unfavoured–player demands, while beginning below £4.00, rise over time toward £4.50. Despite average favoured–player demands staying roughly constant and unfavoured–player demands rising, agreement frequencies also rise, due to decreases in the variance in both types' demands – also leading to increases in both types' average payoffs, toward (£5.50, £4.50).[17]

Figure 5: Favoured and unfavoured player payoffs – time paths



The left panel of Figure 4 shows that when a positive probability of arbitration is implemented (between rounds

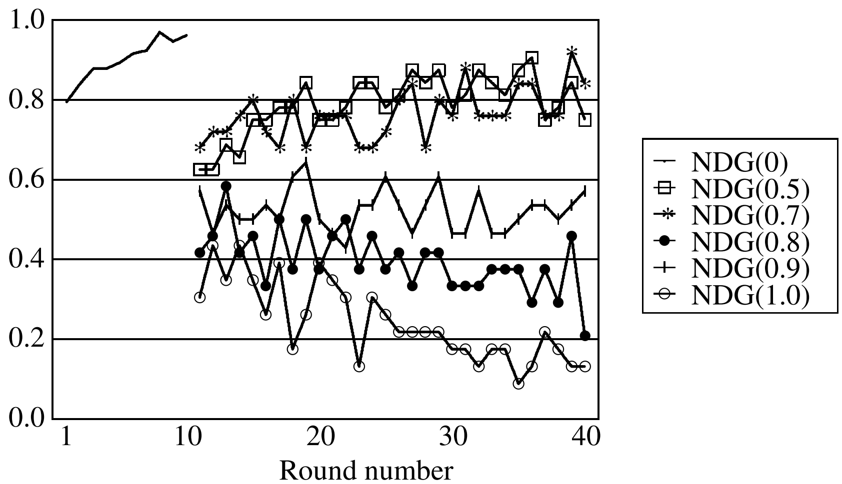
[17]The pronounced changes over time in the NDG(0) data also suggest that at least some of the significant differences seen in Table 3 between NDG(0) and the other games might be an artefact of early–round inexperience by subjects, rather than a true treatment effect. As some evidence of this, we repeat the Wilcoxon tests summarised in Table 3 and Table 4, using only rounds 6–10 of the NDG(0) data instead of rounds 1–10 so as to remove inexperienced–subject play. Based on these new tests, we find fewer differences between NDG(0) and either NDG(0.5) or NDG(0.7): unfavoured–player demands and favoured–player payoffs are not significantly different, nor are differences in unfavoured–player payoffs between NDG(0) and NDG(0.5). However, unfavoured–player payoffs in NDG(0.7) are significantly lower than in rounds 6–10 of NDG(0) (where differences from rounds 1–10 were insignificant), and we continue to find significant differences in favoured–player demands and agreement frequencies between rounds 6–10 of NDG(0) and either NDG(0.5) or NDG(0.7), as we did when rounds 1–10 were considered. Pooling NDG(0.5) and NDG)0.7) yields similar results: no significant differences ($p > 0.10$) from rounds 6–10 of NDG(0) in unfavoured–player demands or favoured–player payoffs, a marginally significant difference ($p \approx 0.055$) in unfavoured–player payoffs, and significant differences ($p < 0.001$) in favoured–player demands and agreement frequencies. Thus, we continue to find only equivocal support for Hypothesis 1 when we restrict consideration to rounds 6–10 of NDG(0); there are fewer, but still some, significant differences with NDG(0.5) and NDG(0.7).

On the other hand, using only the last five rounds of NDG(0) for comparisons with NDG(0.8), NDG(0.9) and NDG(1.0) does not materially alter Results 4 and 5. Differences in unfavoured–player demands are insignificant in two of the three cases ($p > 0.10$ between NDG(0) and either NDG(0.8) or NDG(0.9), $p \approx 0.031$ between NDG(0) and NDG(1.0)), while differences in favoured–player demands, both types' payoffs and agreement frequencies continue to be significant at the 5% level or better in all cases. Pooling the NDG(0.8), NDG(0.9) and NDG(1.0) cells yields similar results: marginally significant differences from rounds 6–10 of NDG(0) in unfavoured–player demands ($p \approx 0.076$), and significant differences in the other four statistics ($p < 0.001$). All of the differences between the NDG(0) cell and the NDG(0.8), NDG(0.9) and NDG(1.0) cells have the same signs irrespective of whether rounds 1–10 or rounds 6–10 are used.

10 and 11), mean favoured–player demands immediately rise by £0.70–1.95, depending on the treatment (an increase on the order of 25%, on average), as subjects in this role apparently attempt to take advantage of their perceived increase in bargaining power. In NDG(0.5) and NDG(0.7), this increase is followed by a slow decline, reflecting the continued existence of (5.5, 4.5) as an equilibrium, and suggesting its robustness as a focal point (as evidenced by the right panel of this figure, where unfavoured–player demands are, at least on average, nearly unaffected by introducing a positive q). By the last ten rounds, favoured–player demands in these two games fall back to between £5.50–6.00 – nearly where they were in NDG(0) – though there are signs of some sort of endgame effect in the last few rounds of NDG(0.5). By contrast, favoured–player demands in NDG(0.8), NDG(0.9) and NDG(1.0) continue rising over time (though more slowly in NDG(0.9) than in the other two cells), averaging more than £7 over the last twenty rounds, and in the case of NDG(1.0), more than £8. While these amounts are still far from the Nash equilibrium point prediction of £9.50, the movement away from the non–equilibrium (5.5, 4.5) outcome is clear.

Similar conclusions can be drawn from the time paths of agreement frequencies, shown in Figure 6. Here, we

Figure 6: Agreement frequency – time paths



see that from near–certain agreement in the last few rounds of NDG(0), there is a precipitous drop, to between 30% and 70% depending on q, when the possibility of arbitration is introduced. These drops reflect (as noted above) initial attempts by favoured players in each of these treatments to take advantage of their perceived improvement in bargaining position by raising demands, while unfavoured players do not notably decrease their own demands. As the sessions progress, the agreement frequencies further diverge across cells. In NDG(0.5) and NDG(0.7), favoured players are largely unsuccessful in their attempts to exploit their (seeming) improved bargaining power, and agreement frequencies slowly rebound as favoured players lower their demands back toward £5.50. This does not happen in the treatments with larger q. In NDG(0.9), agreement frequencies stay at roughly one–half; in NDG(0.8), they continue declining to approximately 30%; and in NDG(1.0) they fall even further, averaging below 20% over the last twenty rounds. As with favoured–player demands, while these levels are far from the equilibrium point prediction (zero agreement frequency), they are substantially below the corresponding frequencies in the NDG(0), NDG(0.5) and NDG(0.7) cells, consistent with the qualitative prediction of the theory.

4.4 Parametric statistics

We continue our examination of the experimental data with the use of parametric methods, in order to disentangle the effects of the various factors that could influence outcomes in our NDG(q) games. We consider three dependent variables: subject demands and subject payoffs (both as fractions of the cake) and agreement frequencies. For demands and payoffs, we estimate Tobit models on the individual–level data with zero as the left endpoint and the maximum allowable demand as the right endpoint; for agreement frequencies, we estimate probit models on the pair–level data. For each dependent variable, there are two sets of explanatory variables: a restricted set which does not allow for heterogeneity between the NDG(0.5) and NDG(0.7) cells or amongst the NDG(0.8), NDG(0.9) and NDG(1.0) cells, and an unrestricted set which does. (These correspond approximately to our use above of pooled data versus data from individual cells.) Thus, right–hand–side variables in the restricted set included an indicator for $q \in \{0.5, 0.7\}$ (which we name "$q57$") and one for $q \in \{0.8, 0.9, 1.0\}$ (called "$p8910$"), and for the equations with demands and payoffs (but not agreements) on the left–hand side, additional indicators for the favoured player and the products of the favoured–player indicator with either the $q57$ indicator or the $q8910$ indicator. By contrast, the unrestricted set had indicators $q5, ..., q10$ for each individual cell except for NDG(0) – and for the equations with demands and payoffs, the favoured–player indicator and its product with each of the individual–cell indicators – as explanatory variables. Finally, a constant term and a variable for the round number were in all six sets of right–hand–side variables.

All of the models were estimated using Stata (version 11.2), and incorporated individual–subject random effects. Table 5 presents the main results of these regressions: coefficient estimates and bootstrapped standard errors for each variable, and log likelihoods for each model. Reassuringly, we can see immediately that for each right–hand–side variable appearing in both models with a given left–hand–side variable, its coefficient estimate differs only slightly between the two models; this suggests our results are at least minimally robust.

Further results from these regressions are displayed in Table 6. The top and middle portions of the table show estimated values, standard errors and significance levels for certain linear combinations of variables. The bottom portion of the table shows p–values for additional hypothesis tests. The variable combinations and hypothesis tests were chosen for their relevance to the hypotheses that were listed in Section 2.3. For example, consider the models (1 and 2) with demand as the dependent variable. While the sign of the coefficient of $q57$ in Table 5 (i.e., β_{q57}) can be interpreted as the sign of the incremental effect of shifting from the NDG(0) cell to the pooled NDG(0.5) and NDG(0.7) cells on *unfavoured–player* demands, the combination $\beta_{q57} + \beta_{q57 \cdot favoured}$ (in Table 6) gives the sign of the effect of the same shift on *favoured–player* demands. Similarly, the combinations $\beta_{q8910} - \beta_{q57}$ and $(\beta_{q8910} + \beta_{q8910 \cdot favoured}) - (\beta_{q57} + \beta_{q57 \cdot favoured})$ give us the signs of the effects of shifting from the pooled NDG(0.5) and NDG(0.7) cells to the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells on unfavoured– and favoured–player demands respectively. The tests of $\beta_{q5} = \beta_{q7}$ and $\beta_{q8} = \beta_{q9} = \beta_{q10}$ examine whether unfavoured–player demands are different between the NDG(0.5) and NDG(0.7) cells and across the NDG(0.8), NDG(0.9) and NDG(1.0) cells respectively, and the tests of $\beta_{q5} + \beta_{q5 \cdot favoured} = \beta_{q7} + \beta_{q7 \cdot favoured}$ and $\beta_{q8} + \beta_{q8 \cdot favoured} = \beta_{q9} + \beta_{q9 \cdot favoured} = \beta_{q10} + \beta_{q10 \cdot favoured}$ do the same for favoured players.

The regression results in these two tables give ample evidence inconsistent with Hypothesis 1 (similar behaviour across NDG(0), NDG(0.5) and NDG(0.7)), but as before, all of the differences are between NDG(0) and the other two cells. The signs and significance levels of the $q57$ variable in Models 1 and 5 in Table 5 imply that unfavoured–player demands are higher, and agreement frequencies are lower, in NDG(0.5) and NDG(0.7) than in NDG(0) (though there is no significant difference in unfavoured–player payoffs). Moreover, the signs and significance levels for $\beta_{q57} + \beta_{q57 \cdot favoured}$ in Models 1 and 3 of Table 6 imply that favoured–player demands and payoffs are higher in NDG(0.5) and NDG(0.7) than in NDG(0). Finally, the insignificant p–values resulting from the tests of $\beta_{q5} = \beta_{q7}$ and $\beta_{q5} + \beta_{q5 \cdot favoured} = \beta_{q7} + \beta_{q7 \cdot favoured}$ in Table 6 suggest that there is little difference in any aspect of behaviour between NDG(0.5) and NDG(0.7) – though once again, we note the danger involved in making positive conclusions

Table 5: Regression results – coefficient estimates (bootstrapped std. errors in parentheses)

Dependent variable	Demand (as frac. of cake)		Payoff (as frac. of cake)		Agreement	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
constant	0.583^{***}	0.582^{***}	0.534^{***}	0.533^{***}	1.756^{***}	1.747^{***}
	(0.017)	(0.019)	(0.020)	(0.020)	(0.111)	(0.109)
round	0.0022^{***}	0.0022^{***}	0.0021^{***}	0.0021^{***}	0.002	0.001
	(0.0004)	(0.0005)	(0.0005)	(0.0004)	(0.004)	(0.005)
$q57$ ($q \in \{0.5, 0.7\}$)	0.078^{***}		0.016		-0.640^{***}	
	(0.020)		(0.016)		(0.170)	
$q8910$ ($q \in \{0.8, 0.9, 1.0\}$)	0.068^{**}		-0.122^{***}		-2.081^{***}	
	(0.024)		(0.022)		(0.173)	
$q5$ ($q = 0.5$)		0.085^{**}		0.015		-0.471^{*}
		(0.025)		(0.020)		(0.193)
$q7$ ($q = 0.7$)		0.065^{**}		0.012		-0.870^{***}
		(0.020)		(0.024)		(0.248)
$q8$ ($q = 0.8$)		0.122		-0.136^{***}		-1.869^{***}
		(0.047)		(0.035)		(0.284)
$q9$ ($q = 0.9$)		0.123^{**}		–0.047		-1.784^{***}
		(0.040)		(0.025)		(0.270)
$q10$ ($q = 1.0$)		0.007		-0.189^{***}		-2.603^{***}
		(0.054)		(0.028)		(0.287)
$favoured$ (indicator)	-0.054^{**}	-0.053^{**}	-0.081^{***}	-0.079^{**}		
	(0.328)	(0.018)	(0.023)	(0.023)		
$q57 \cdot favoured$	–0.035		0.007			
	(0.022)		(0.016)			
$q8910 \cdot favoured$	0.157^{***}		0.269^{***}			
	(0.028)		(0.029)			
$q5 \cdot favoured$		–0.051		0.003		
		(0.032)		(0.020)		
$q7 \cdot favoured$		–0.012		0.018		
		(0.032)		(0.025)		
$q8 \cdot favoured$		0.169^{*}		0.255^{***}		
		(0.067)		(0.042)		
$q9 \cdot favoured$		0.027		0.143^{***}		
		(0.055)		(0.029)		
$q10 \cdot favoured$		0.304^{***}		0.427^{***}		
		(0.074)		(0.036)		
N	10560	10560	10560	10560	5280	5280
$\|ln(L)\|$	967.83	1051.64	4310.26	4269.66	2115.91	2100.67

* (**,***): *Coefficient significantly different from zero at the 5% (1%, 0.1%) level.*

based on failure to reject null hypotheses.

Some of the results in Table 6 are relevant to Hypothesis 2 (similar behaviour across NDG(0.8), NDG(0.9) and NDG(1.0)). While the p–value for the test of $\beta_{q8} = \beta_{q9} = \beta_{q10}$ in Model 2 is (barely) insignificant, and the one in Model 6 is only weakly significant – suggesting only minor differences in unfavoured–player demands and agreement frequencies across NDG(0.8), NDG(0.9) and NDG(1.0)) – the strongly significant result of the test of $\beta_{q8} + \beta_{q8 \cdot favoured} = \beta_{q9} + \beta_{q9 \cdot favoured} = \beta_{q10} + \beta_{q10 \cdot favoured}$ in Model 2 implies significant differences in favoured–player demands across these treatments, in contrast to Hypothesis 2. On the other hand, the significant

Table 6: Additional regression results – compound effects and hypothesis tests based on models from Table 5

Variable combination/ Hypothesis	Demand (as frac. of cake)		Payoff (as frac. of cake)		Agreement	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta_{q57} + \beta_{q57 \cdot favoured}$	0.043^{***}		0.023^{**}			
	(0.013)		(0.008)			
$\beta_{q8910} + \beta_{q8910 \cdot favoured}$	0.225^{***}		0.147^{***}			
	(0.021)		(0.017)			
$\beta_{q8910} - \beta_{q57}$	–0.010		-0.139^{***}		-1.441^{***}	
	(0.032)		(0.022)		(0.192)	
$(\beta_{q8910} + \beta_{q8910 \cdot favoured}) -$	0.182^{***}		0.123^{***}			
$(\beta_{q57} + \beta_{q57 \cdot favoured})$	(0.025)		(0.016)			
$\beta_{q5} + \beta_{q5 \cdot favoured}$		0.034		0.019^{*}		
		(0.018)		(0.008)		
$\beta_{q7} + \beta_{q7 \cdot favoured}$		0.053^{*}		0.030^{*}		
		(0.023)		(0.013)		
$\beta_{q8} + \beta_{q8 \cdot favoured}$		0.233^{***}		0.119^{***}		
		(0.040)		(0.030)		
$\beta_{q9} + \beta_{q9 \cdot favoured}$		0.150^{***}		0.096^{***}		
		(0.035)		(0.016)		
$\beta_{q10} + \beta_{q10 \cdot favoured}$		0.311^{***}		0.238^{***}		
		(0.044)		(0.025)		
$\beta_{q5} = \beta_{q7}$		$p \approx 0.50$		$p \approx 0.89$		$p \approx 0.14$
$\beta_{q8} = \beta_{q9} = \beta_{q10}$		$p \approx 0.13$		$p < 0.001$		$p \approx 0.059$
$\beta_{q5} + \beta_{q5 \cdot favoured} = \beta_{q7} + \beta_{q7 \cdot favoured}$		$p \approx 0.45$		$p \approx 0.32$		
$\beta_{q8} + \beta_{q8 \cdot favoured} = \beta_{q9} + \beta_{q9 \cdot favoured}$						
$= \beta_{q10} + \beta_{q10 \cdot favoured}$		$p \approx 0.004$		$p < 0.001$		

Note: For variable combinations, point estimates and standard deviations are reported, along with significance levels (, **, ***: significantly different from zero at the 5%, 1%, 0.1% level) for test of difference from zero. For hypothesis tests, only p–values are reported.*

results for these tests in Model 4 means that favoured–player payoffs vary significantly across these treatments, consistent with Hypothesis 3.

There is mixed support for our Hypothesis 4. The fact that in Model 1, the estimate of $\beta_{q8910} - \beta_{q57}$ is not significantly different from zero suggests no difference in unfavoured–player demands between the pooled NDG(0.5) and NDG(0.7) cells and the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells. However, the significant positive coefficient estimate for $q8910$ in the same model, seen in Table 5, indicates significantly higher unfavoured–player demands in NDG(0.8), NDG(0.9) and NDG(1.0) than in NDG(0).

The support for Hypothesis 5 is even stronger here than in the aggregate data. The significant negative coefficient estimates for $q8910$ in Models 3 and 5 (Table 5) imply lower unfavoured–player payoffs and agreement frequencies in the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells than in NDG(0). Similarly, the negative and significant values for $\beta_{q8910} - \beta_{q57}$ in these models (Table 6) indicate that lower unfavoured–player payoffs and agreement frequencies are also lower in the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells than in the pooled NDG(0.5) and NDG(0.7) cells. Finally, the positive and significant estimates for $\beta_{q8910} + \beta_{q8910 \cdot favoured}$ and

$(\beta_{q8910} + \beta_{q8910 \cdot favoured}) - (\beta_{q57} + \beta_{q57 \cdot favoured})$ in Model 1 imply higher favoured–player demands in the pooled NDG(0.8), NDG(0.9) and NDG(1.0) cells than in (respectively) NDG(0) and the pooled NDG(0.5) and NDG(0.7) cells, while the analogous results for Model 3 imply the same about favoured–player payoffs.

5 Discussion

The Nash demand game (NDG) has long been used as a model of how two–party bargaining occurs. The game has two disadvantageous features, however. First, almost all variations of the game have a large number of Nash equilibria, lessening its value as a source of predictions. Second, only two outcomes are possible: immediate agreement or immediate disagreement, with no opportunity for renegotiation. Anbarci and Boyd (2011) proposed a modification of the standard NDG, under which incompatible demands – rather than leading to certain disagreement – only lead to disagreement with probability $1 - q$. With the remaining probability q, the bargainers go to arbitration, with one of them randomly chosen to receive his/her demand and the other receiving the remainder.

Our paper conducts an experimental examination of this "NDG with random arbitration". We begin with a bargaining setting in which one player is favoured relative to the other, and we vary the random arbitration parameter q. We show theoretically that as q increases, the set of "agreement equilibria" (Nash equilibria in which agreement is reached) weakly shrinks. Beyond a threshold value of q, there also exists a "chilling–effect" equilibrium with both players demanding their maximum amount (and thus not reaching agreement); beyond an even higher higher value of q, this is the only Nash equilibrium.

As is often the case, our experimental data provide (at best) mixed support for standard game–theoretic point predictions. However, we find fairly strong support for the theory's directional predictions, both with conservative non–parametric statistical tests and with standard regression techniques. Firstly, we find stark decreases in agreement frequencies as q increases, consistent with the rising prominence of the chilling–effect equilibrium in comparison with the set of agreement equilibria.

Secondly, we find that raising q tends to reinforce the asymmetry of the underlying bargaining setting, increasingly benefiting the favoured player at the expense of the unfavoured player. On average, we find that the ratio of favoured– to unfavoured–player payoffs increases with q, from being roughly comparable to the ratio implied by the lexicographic egalitarian outcome (the most equitable efficient outcome) at the lowest values of q to being about the same as that implied by the more unequal Kalai–Smorodinsky outcome at the highest values of q. This distributional aspect of random arbitration – and in particular, the possibility that bargainers may have almost diametrically opposed preferences over the size of q – may be an important topic for further research.

Finally, consistent with the theory, we find that increases in q yield non–uniform effects on observed bargaining outcomes. For fairly substantial ranges within the unit interval – from 0 to 0.7, and again from 0.8 to 1.0, changes to q are observed to have minimal effect on either the likelihood of agreement or the distribution of the surplus given that agreement is reached. But moving from $q = 0.7$ to $q = 0.8$ is associated with sharp changes in results, consistent with the implication of risk dominant Nash equilibrium.

References

Anbarci, N. and J.H. Boyd III (2011), “Nash demand game and the Kalai–Smorodinsky solution”, *Games and Economic Behavior* 71, pp. 14–22.

Babcock, L., G. Loewenstein, S. Issacharoff, and C. Camerer (1995), “Biased judgments of fairness in bargaining”, *American Economic Review* 85, pp. 1337–1343.

Binmore, K. (2007), *Playing for Real: a Text on Game Theory*, Oxford University Press, Oxford.

Binmore, K., J. Swierzbinski, S. Hsu and C. Proulx (1993), “Focal points and bargaining”, *International Journal of Game Theory* 22, pp. 381–409.

Camerer, C.F. (2003), *Behavioral Game Theory: Experiments in Strategic Interaction*, Princeton University Press, Princeton, NJ.

Charness, G. and Kuhn, M.A. (2011), “Lab labor: what can labor economists learn from the lab?” In *Handbook of Labor Economics, v. 4a*, O. Ashenfelter and D. Card, eds., North–Holland, Amsterdam, pp. 229–330.

Chun, Y. (1989), “Lexicographic egalitarian solution and uncertainty in the disagreement point”, *Zeitschrift für Operations Research* 33, pp. 259–266.

Edgeworth, F.Y. (1881), *Mathematical Psychics: An Essay on the Application of Mathematics to the Moral Sciences*, Kegan Paul, London.

Feltovich, N. (2005), “Critical values for the robust rank–order test”, *Communications in Statistics—Simulation and Computation* 34, pp. 525–547.

Feltovich, N. and J. Swierzbinski (2011), “The role of strategic uncertainty in games: an experimental study of cheap talk and unstructured bargaining in the Nash demand game”, *European Economic Review* 55, pp. 554–574.

Feuille, P. (1975), “Final offer arbitration and the chilling effect”, *Industrial Relations* 14, pp. 302–310.

Fischbacher, U. (2007), “z–Tree: Zurich toolbox for ready–made economic experiments”, *Experimental Economics* 10, pp. 171–178.

Greiner, B. (2004), “An online recruitment system for economic experiments”, in Kremer, K. and V. Macho eds., *Forschung und wissenschaftliches Rechnen*. GWDG Bericht 63. Göttingen: Gesellschaft für Wissenschaftliche Datenverarbeitung, pp. 79–93.

Harsayni, J.C. and R. Selten (1988), *A General Theory of Equilibrium Selection in Games*, MIT Press, Cambridge, MA.

Kalai, E. and M. Smorodinsky (1975), “Other solutions to Nash’s bargaining problem”, *Econometrica* 43, pp. 513–518.

Kuhn, M.A. (2009), “To settle or not to settle: a review of the literature on arbitration in the laboratory”, working paper, University of California, San Diego.

Luce, R.D. and H. Raiffa (1957), *Games and Decisions*, Wiley, New York.

Nash, J. (1950), “The bargaining problem”, *Econometrica* 18, pp. 155–162.

Nash, J. (1953), “Two–person cooperative games”, *Econometrica* 21, pp. 128–140.

Nydegger, R.V. and G. Owen (1975), “Two person bargaining: an experimental test of the Nash axioms,” *International Journal of Game theory* 3, pp. 239–249.

Raiffa, H. (1953), “Arbitration schemes for generalized two–person games”, in H.W. Kuhn and A.W. Tucker, eds., *Contributions to the Theory of Games. II: Annals of Mathematics Studies*, Princeton University Press, Princeton, NJ, pp. 361–387.

Rawls, J. (1971), *A Theory of Justice*, Harvard University Press, Cambridge, MA.

Roth, A.E. (1979), *Axiomatic Models of Bargaining*, Springer Verlag.

Roth, A.E. (1995), “Bargaining experiments”, in *Handbook of Experimental Economics*, J.H. Kagel and A.E. Roth, eds., Princeton University Press, Princeton, NJ, pp. 253–348.

Roth, A.E. and M.W.K. Malouf (1979), “Game–theoretic models and the role of information in bargaining,” *Psychological Review* 86, pp. 574–594.

Roth, A.E. and K.J. Murnighan (1982), “The role of information in bargaining: an experimental study,” *Econometrica* 50, pp. 1123–1142.

Ryan, R. (1999), “Enforcement of foreign arbitration agreements and awards in insurance coverage disputes”, *McCullough, Campbell & Lane LLP Publications*, http://www.mcandl.com/arbitration.html, accessed 26.10.2011.

Schelling, T.C. (1960), *The Strategy of Conflict*, Harvard University Press, Cambridge, MA.

Siegel, S. and N.J. Castellan, Jr. (1988), *Nonparametric Statistics for the Behavioral Sciences*, McGraw–Hill, New York.

Skyrms, B. (1996), *Evolution of the Social Contract*, Cambridge University Press, Cambridge.

von Neumann, J. and O. Morgenstern (1944), *Theory of Games and Economic Behavior*, Princeton University Press, Princeton.

A Sample instructions and screenshots

Below is the text of instructions from our cell with q = 0 in rounds 1-10 (given out before round 1) and q = 0.8 in rounds 11-40 (given out between rounds 10 and 11), followed by two sample screenshots (the decision screen and the end-of-round feedback screen). The other sets of instructions are the same except for where the value of q is mentioned; these are available from the corresponding author upon request.

Instructions: first part of experiment

You are about to participate in a decision making experiment. Please read these instructions carefully, as the money you earn may depend on how well you understand them. If you have a question at any time, please feel free to ask the experimenter. We ask that you not talk with the other participants during the experiment.

This experiment consists of ***two*** parts. These instructions are for the first part, which will be made up of ***10 rounds***. The second part will be made up of ***30 rounds***; you will receive instructions for the second part after this part has ended. Each round in this part consists of a simple computerised bargaining game. At the beginning of a round, ***you are randomly paired with another participant***, with whom you play the game. You will not be told the identity of the person you are paired with in any round, nor will they be told yours – even after the session ends.

The bargaining game is as follows. You and the person paired with you bargain over a ***£10.00*** prize. You and the other person make simultaneous claims for shares of this prize. The claims must be multiples of £0.01, and cannot be less than zero. ***The maximum allowable claim is different for the two people in a pair: for one, the maximum is £9.50, and for the other, it is £4.50.*** Your maximum allowable claim will be the same in all rounds.

Your profit in a round depends on the claims made by you and the person paired with you:
- If your claims add up to ***the amount of the prize or less***, your profit equals your claim, and the other person's profit equals his/her claim.
- If your claims add up to ***more than*** the amount of the prize, both you and the other person receive a profit of zero.

Sequence of Play: The sequence of play in a round is as follows.
(1) The computer randomly pairs up the participants. Your computer screen will display your maximum allowable claim and that of the other person.
(2) You choose a claim for your share of the £10.00 prize. The other person chooses a claim for his/her share of the prize. Your claim can be any multiple of 0.01, between zero and your maximum allowable claim (inclusive). Both of you choose your claim before being informed of the other's claim.
(3) The round ends. You receive the following information: your own claim, the claim made by the person paired with you, your own profit for the round, the profit of the person paired with you.

After this, you go on to the next round.

Payments: At the end of the experimental session, ***one round*** from this part will be chosen randomly for each participant. You will be paid the total of your profits in this round. In addition, there will be opportunities for payments in the second part of the session. Payments are made privately and in cash at the end of the session.

Instructions: second part of experiment

The procedure in this part of the experiment is similar to that in the first part. You will play a computerised bargaining game for ***30 additional rounds***. The participant paired with you will still be chosen randomly in every round, and the amount you bargain over and your maximum allowable claims will be the same as before.

The difference from the first part of the experiment is that ***you might not receive a zero profit if your claim and the other person's claim add up to more than £10.00***. Specifically, the computer randomly determines what happens in this case.
- There is now a ***40%*** (***8 out of 20***) chance that ***you receive the amount you claimed***, and the person paired with you receives the remainder (£10 minus the amount you claimed).
- There is now a ***40%*** (***8 out of 20***) chance that the person paired with you receives the amount he/she claimed, and ***you receive the remainder*** (£10 minus the amount he/she claimed).
- There is now a ***20%*** (***4 out of 20***) chance that ***both of you receive zero***.

As before, if your claims add up to the amount of the prize or less, you receive your claim, and the other person receives his/her claim.

Payments: At the end of the experimental session, ***three rounds*** from this part will be chosen randomly for each participant. You will be paid the total of your profits in those three rounds. Your earnings from this part of the experiment will be added to your earnings from the previous part.

Decision screen:

Round

2 of 2

Remaining time [sec]: 39

History of your past outcomes:

Round	Amount bargained over (£)	Your claim (£)	Other person's claim (£)	Agreement?	Claim implemented	Your profit (£)	Other person's profit (£)
1	10.00	9.50	4.50	No	Neither	0.00	0.00

This is the beginning of Round 2. You have been randomly matched to another person for this round. You and this person are bargaining over **£10.00**.

Your claim must be a multiple of 0.01, between zero and **£9.50** inclusive. The other person's claim must be a multiple of 0.01, between zero and **£4.50** inclusive.

If you reach an agreement (your claims total less than or equal to **£10.00**), you and the other person will each receive the amounts you claimed.

If you do not reach an agreement (your claims total more than £10.00), then there are three possibilities.

There is a **45%** chance that your claim is imposed. In that case, you will receive the amount you claimed, and the other person will receive the remainder (10.00 minus the amount you claimed).

There is a **45%** chance that the other person's claim is imposed. In that case, he/she will receive the amount he/she claimed, and you will receive the remainder (10.00 minus the amount the other person claimed).

There is a **10%** chance that bargaining breaks down. In that case, you will receive **£0.00** and the other person will receive **£0.00**.

Please choose your claim for this round. £

OK

Feedback screen:

Round

2 of 2

History of your past outcomes:

Round	Amount bargained over (£)	Your claim (£)	Other person's claim (£)	Agreement?	Claim implemented	Your profit (£)	Other person's profit (£)
1	10.00	9.50	4.50	No	Neither	0.00	0.00
2	10.00	9.50	4.50	No	Other person's	5.50	4.50

THIS ROUND'S RESULTS:

Your claim was **£9.50.**

The other person's claim was **£4.50.**

Your combined claims were **MORE THAN** the amount you were bargaining over.

The other person's claim was chosen to be implemented.

Your payoff is **£5.50**.

The other person's payoff is **£4.50**.

OK