Price Competition and Market Concentration: An Experimental Study*

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Abstract: The classical price competition model (named after Bertrand), prescribes that in equilibrium prices are equal to marginal costs. Moreover, prices do not depend on the number of competitors. Since this outcome is not in line with real-life observations, it is known as the "Bertrand Paradox." Many theoretical problems with the original model have been considered as an explanation of the paradox in the literature.

In this paper we experimentally investigate a model which is immune to the theoretical critique of the original model. We find, nevertheless, that the outcome does depend on the number of competitors: the Bertrand solution does not predict well when the number of competitors is two, but after some opportunities for learning are provided it tends to predict well when the number of competitors is three or four. A bounded rationality explanation of this is suggested.

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1. Introduction

The investigation of oligopolistic markets is central in economics. It is often assumed that firms in such markets compete in prices (see e.g. Tirole 1994, p.224). In the classical model of price competition (named after Bertrand 1883), the equilibrium entails that whenever at least two firms are in the market, price is set equal to marginal cost. In effect, each firm makes zero profits even in a duopoly situation. Since observations from real markets are not in line with this result, it is referred to as the "Bertrand Paradox."

In this paper we report experimental results of markets in which participants compete in prices. In particular, we consider the effect of changing the number of competitors on the outcome of the market. Before we describe the experimental set-up of the model reported in this paper, we note that with two firms the Bertrand model can be reduced to the following game. Each firm simultaneously chooses a real non-negative number (its price). The firm that bids the smallest number wins a dollar amount times this number and the other firms get a payoff of zero; ties are split. It is easy to verify that in the unique Nash equilibrium, both firms choose zero. It is also easy to see that if more than two firms interact, at least two of them will choose zero in any equilibrium. In this paper we study experimentally the following discretized version of the Bertrand game:

Each of N players simultaneously chooses an integer between 2 and 100.

The player who chooses the lowest number gets a dollar amount times the *number he bids and the rest of the players get 0. Ties are split among all players who submit the corresponding bid.*

N is a control variable in the experiment, which in different treatments take the respective values 2, 3, and 4. The unique Nash equilibrium in each treatment is a bid of 2 by all players, and each player gets a payoff of only $2/N$.[1]

This game retains the key elements of the original Bertrand game, and it has several attractive features that make it impregnable to some common critiques of the Bertrand model. In particular, economists have attempted to explain the Bertrand paradox along two different lines. First, it has been argued that certain assumptions that underlie the Bertrand model are not realistic. Edgeworth (1925), Hotelling (1929), Kreps and Scheinkman (1983), and Friedman (1977) respectively point out that the Bertrand paradox goes away if the assumption of constant return to scale is relaxed, if goods are not assumed to be homogeneous, if capacity constraints are introduced, or if firms are allowed to compete repeatedly. The firms may furthermore have incomplete information about cost functions or demand (as Bertrand models resemble first-price auctions, Vickrey 1961 is relevant), and, with reference to Cournot's (1838) model, one may also argue that firms compete in quantities rather then prices. The second line of attack is aimed at the game-theoretic foundations of the Bertrand reasoning. The assumption of Nash conjectures has been criticized (this type of objection has pre-Nash

[1] This is easily seen using the Bertrand reasoning. In the case of $N=2$, assume that one player bids 2. Then the other player choosing 2 yields a payoff of \$1, while choosing any other number leads to a payoff of \$0. To see that this equilibrium is unique, assume that one player chooses X, when $2<X\leq 100$. The best response for the other player is to choose $X-1$, since bidding less than $X-1$ results in a payoff smaller than $\$(X-1)$, and bidding X results in a payoff of $\$X/2$ which is smaller than $X-1$. However, if one player bids $X-1$, it is optimal for the other player to bid $X-2$, unless $X-1=2$. This proves that a bid of 2 by every player is the unique equilibrium. Using a similar argument it is possible to prove that bidding 2 by all players is the unique equilibrium for any $N>2$.

roots; see Bowley 1924), and the use of weakly dominated strategies in equilibrium is problematic.

The game we investigate is designed to give the Bertrand model its best shot at not being rejected by the data. If the Bertrand model would fail to perform well under such circumstances, there would be a good cause to reject it. The game can be derived from an economic model of price competition with constant returns, homogeneous goods, no capacity constraints, no repeated interaction, and no incomplete information about demand or costs. The unique Nash equilibrium is strict, and hence does not involve the use of weakly dominated strategies. A bid of 2 is furthermore the unique rationalizable strategy of the game, so the solution has a strong decision-theoretic foundation and Nash conjectures need not be assumed.

We wish to study the behavior of *experienced* participants, and so must let them play the game several times. Following the classic contribution by Fouraker and Siegel (1963), most other studies of experimental price competition cater for experience by letting a fixed group of participants interact repeatedly.[2] However, a drawback with this approach is that a confounding effect is introduced. Since *the same* firms interact repeatedly, opportunities for cooperation of the kind studied in the theory of repeated games (see Pearce (1992) for a general overview, and Friedman (1977) for the application to oligopoly) may be created. We wish to isolate the effects of experience from repeated game effects, and therefore let participants play the game several times *but not facing the same opposition in each round.*

In three out of the four experimental treatments described in this paper, twelve bidders participated. These treatments differed only in terms of how many bidders were matched in each round (two, three, or four). Markets operated for ten rounds. At the beginning of each round all twelve participants placed their bids. We then randomly matched N bidders together (N = 2, 3, or 4), resulting in 12/N different matchings per round. The actual matching and the entire bid vector were then posted on a blackboard. Note that it was relatively unlikely that two participants would run into each other in two consecutive rounds. The random-matching scheme is reminiscent of the institutions modeled in modern theories of evolution or learning (see Weibull (1995) or Fudenberg and Levine (1998)), and the set-up is intended to avoid repeated game effects and to retain the one-shot character of the Bertrand game while allowing for learning over time.

In all these treatments, behavior differed greatly from the theoretical outcome in the first round. In the N=2 treatment this was also the case in the last round. However, in the N=3 or N=4 treatments the winning bids converged towards the competitive outcome by the 10th round. Somewhat surprisingly, these results are roughly consistent with those reported by Fouraker and Siegel (1963, Chapter 10) for the case of repeated experimental price competition within a fixed group of participants. This suggests that experience has an important impact on price competition, while repeated game effects do not.

However, a possible objection to this conclusion could be that a pool of twelve players is just to small for all repeated game effects to vanish—strictly speaking, our design creates a repeated game with twelve ordinary players plus nature! In order to control for this, we include a fourth treatment in which N=2 but with random matching among 24 instead of twelve participants. It turns out that the results essentially do not change, so our aforementioned finding appears to be robust in that sense.

The theoretical literature on Bertrand competition does not offer an explanation of these observations. We suggest one that relies on bounded rationality. The idea is to

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[2] For overviews of this literature, see Plott (1982, 1989) and Holt (1995).

illustrate the disruptive effect of “noise” on the viability of the Bertrand outcome when there are sufficiently many firms. If with some “small” probability any firm in the market may bid differently from what the Bertrand model prescribes, then this itself is enough to explain why deviations from the Bertrand outcome depend on the number of firms.

2. Experimental procedure

We had two sessions for each of the four treatments, with 13 students in the cells corresponding to the first three treatments and with 25 students in the cell corresponding to the fourth treatment (128 participants all together).

In each session, after all students entered the experiment room, they received a standard-type introduction, and were told that they would be paid 7.5 Dutch guilders for showing up.[3] Then, they took an envelope at random from a box which, depending on the treatment, contained 13 or 25 envelopes. All but one of the envelopes contained numbers (S1,.., S12) or (S1,.., S24). These numbers were called “registration numbers.” One envelope was always labeled “Monitor”, and determined who was the person who assisted us and checked that we did not cheat.[4] Apart from the assistant, we asked the students not to show their registration number to the other students. Participants then received the instructions for the experiment (see Appendix 1), and ten coupons numbered 1, 2,..., 10. They were allowed to ask questions privately.

Each participant was then asked to write on the first coupon her registration number and her bid for round 1. The bids had to be between 2 and 100 “points,” with 100 points being worth 5 Dutch guilders. Participants were asked to fold the coupon,

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[3] At the time of the experiment, $1=1.7 Dutch guilders.
[4] This person was paid the average of all other subjects participating in that session.

and put it in a box carried by the assistant. We now refer to the three treatments where twelve students interacted as treatments 2, 3, and 4 (with groups of respectively two, three, and four students being matched in each round in treatment 2, 3, and 4). We refer to the fourth treatment where 24 students interacted as 2*. In treatments 2 and 2* (sessions 2a, 2b, 2a*, and 2b*), the assistant randomly took two coupons out of the box and gave them to the experimenter. The experimenter announced the registration number and the bid on each of the coupons. If one bid was larger than the other then the experimenter announced that the low bid won the same amount of points as she had bid, and the other bidder won 0 points. If the bids were equal the experimenter announced a tie, and said that each bidder won one half of the bid. The assistant wrote this on a blackboard so that all the subjects could see it for the rest of the experiment. Then the assistant took out another two coupons randomly, the experimenter announced their content, and the assistant wrote it on the blackboard. The same procedure was carried out for all coupons. Then the second round was conducted the same way. After round 10, payoffs were summed up and subjects were paid privately.

Treatments 3 (sessions 3a and 3b) and 4 (sessions 4a and 4b) were carried out the same way, except that the assistant matched three or four players, respectively, together every time instead of two.

3. Results

A. Sessions 2, 3, and 4

The raw data of the respective sessions are presented in Tables 1a-f, in which the average winning bids and the average bids are also presented. Correspondingly, the average winning bids and the average bids are plotted in Figures 1a-f. We start with describing the behavior in round 1, because at this stage no elements of learning or experience exist. From observation of the data it is clearly seen that the Bertrand outcome was not achieved in this round. The average bid (winning bid) was 33.5 (29.7) and 41.8 (23) in sessions 2a and 2b respectively, 26.4 (21.5) and 30.1 (16.5) in sessions 3a and 3b respectively, and 33.1 (24) and 30.8 (6.3) in sessions 4a and 4b. We also perform a statistical test of whether the bids in different sessions came from the same distribution. We consider each of the (15) possible pairs of sessions separately. We use the non-parametric Mann-Whitney *U* test based on ranks, and cannot, for any pair, reject (at a 5% significant level) the hypothesis that the observations came from the same distribution. In this sense, in round 1 the different rules in the different markets did not influence behavior.

When comparing the convergence of bids in later rounds, however, we observe great difference between treatments. In session 2a, we see a slow decrease of the average winning bid from 29.7 in round 1 to 16 in round 6. From round 6 to round 7, a jump in the average winning bid from 16 to 35.1 is observed. From this point on the averages are 25.8 in round 8, 33.8 in round 9, and finally 37.8 in round 10. It is clear that no convergence to bids of 2 is observed. In fact, the smallest bid in round 10 was 19. In session 2b, the average winning bid decreased constantly from 23 in round 1 to 16.2 in round 4. Then, however, the average winning bid started to rise, and in rounds 8, 9, and 10 the average winning bids were 38.2, 37.2, and 36 respectively. An interesting observation is that participant number S12 in this session used a constant bid of 2 throughout the experiment. Of course, this bid was “strange” given the fact that the next lowest bid in round 10 was 38. This bid was not enough to move the other bids to the neighborhood of 2. Furthermore, the bids in both sessions of treatment 2 were much alike in round 10; the average bids were 49.6 and 49.3 in sessions 2a and 2b respectively, and the average winning bids were 37.8 and 36 in the respective sessions.[5]

In session 3a we see a decrease in the average winning bid from 21.5 in round 1 to 5.3 in round 10. The largest decrease is observed moving from round 1 to round 2 (from 21.5 to 11). After round 2, although some fluctuation is observed, bids decrease steadily. The lowest bid in round 10 is 4, and 7 out of the 12 bids are between 4 and 7. In session 3b, the average winning bid decreased, monotonically, from 16.5 in round 1 to 3.2 in round 10. Unlike in session 3a, we do not observe a sharp decrease from round 1 to round 2, but rather a steady decrease between rounds. The lowest bid in round 10 was 2, with 10 out of the 12 participants bidding 5 or less. When comparing the two sessions of treatment 3 we see that, like in the case of treatment 2, the bids in both sessions were much a like in round 10; the average bids were 17.9 and 12.3 in sessions 3a and 3b respectively, and the average winning bids were 5.3 and 3.2 in the respective sessions.

In session 4a we see again a monotonic decrease in the average winning bid from 24 in round 1 to 2 in round 10. Like in session 3a, the largest decrease is observed moving from round 1 to round 2 (from 24 to 11.3). After round 2 bids decrease steadily. The striking result is that already in round 8 the average winning bid was 2, and it did not rise till the end of the session. The lowest bid in round 10 was 2, with 7 out of the 12 participants bidding 5 or less. In session 4b we observe a different trend in the first rounds. The matching in the first round were such that very low bids won (the average bids in round 1 were 33.1 and 30.8 in session 4a and 4b respectively, but the average winning bids were 24 and 6.3 in the respective sessions). When observing figure 1f we

[5] Unlike the case of first round behavior, it is not appropriate to use the Mann-Whitney test, because the assumption that all observations are independent is not justified.

see a hump in the average bid. In fact, the average bid in round 5 was 71.4 (which is the highest average bid in a single round in the entire experiment), with 6 out of the 12 participants bidding 100![6] A similar trend was observed in the average winning bid; it rose from 6.3 in round 1 to 28 in round 6. However, from that round on it seems as if participants "gave up", and the average winning bid decreased steadily to 2.4 in round 10, with 8 out of the 12 participants bidding between 2 and 6. Although the outcome in the intermediate markets was very different between sessions 4a and 4b, the results of round 10 show almost total convergence of the average winning bid in both sessions to the equilibrium. The average bids were 13.9 and 20.5 in sessions 4a and 4b respectively, and the average winning bids were 2 and 2.4 in the respective sessions.

It should be stressed that while there seem to be convergence towards the equilibrium for winning bids in treatments 3 and 4, the tendency of convergence over-all is less strong. In many cases certain losing bids were well above the equilibrium level. Another related observation is that while the average winning bids in treatments 3 and 4 were at its lowest point in round 10, the average bid actually went up a bit in round 10 in three out of four sessions. It is not clear how this end game effect can be explained. One speculation is that participants were frustrated as they realized that due to the low level of bidding they were not making much money in the experiment, and so decided to gamble a bit in the last round.

To summarize, the market outcomes in round 1 are similar across sessions. It is also the case that in all sessions the outcomes converge, and relatively little fluctuation

[6] It appears as if participant A10, who chose 100 also in the first three rounds, was attempting to "signal" a willingness to cooperate with the others. We note that related observations have been made in experimental oligopoly studies with repeated interaction among a fixed group of firms. See Fouraker and Siegel (1963, pp 185-88), Hoggatt, Friedman and Gill (1976), and Friedman and Hoggatt (1980). See Plott (1982, pp 1513-17) for a discussion. In future research we plan to investigate the role of price signals within a random matching set-up, by considering treatments where information about losing bids is not given.

is observed at the end of the experiment. However, while the round 10 outcomes in the two sessions of treatment 2 are far from equilibrium, the round 10 winning bids are relatively close to the equilibrium.

*B. Session 2**

The raw data of the respective sessions are presented in Tables 1g and 1h, in which the average winning bids and the average bids are also presented. Correspondingly, the average winning bids and the average bids are plotted in Figures 1g and 1h. We start with behavior in round 1 in which, like in the other treatments, it is clear that participants did not play the equilibrium. The hypothesis that the bids in sessions 2a* and 2b* come from the same distribution is not rejected. Comparing, however, the round 1 bids in treatment 2* with the corresponding bids in the other treatments we see significantly (at a 5% significant level) lower bids. The average bid (winning bid) was 20.8 (10.4) and 13.1 (7.4) in session 2a* and 2b* respectively.

We now consider the convergence of bids in later rounds, focusing on the comparison between treatment 2 and treatment 2*. Like in treatment 2, we again observe a decline in bids at the first stages—almost to equilibrium (e.g. the average winning bid in session 2b* in round 4 was 3.1). But, in treatment 2a*, as of round 4 (round 5 in 2b*) we see an increase in bids. Relatively to treatment 2, in 2* we see more fluctuations in the averages up to the last session. See, for example, the sharp reduction from round 8 to round 9 in treatment 2b*. The average bid (winning bid) in round 10 was 37.5 (20.5) in treatment 2a*, as compared with 44.1 (24.3) in 2b*. That is, it was somewhat smaller than in treatment 2.

Summing up, although the results in treatments 2 and 2* are quantitatively different, they are qualitatively similar. In particular, no convergence to equilibrium is observed. The question why the size of the group influences the results at all, and what would happen if more rounds of play were allowed, is, however, left for future research.

C. A comparison of total payoffs

Finally, we compare the profits of participants in the different treatments. The average profit per participant was 138, 43, 48, and 74 in treatments 2, 3, 4, and 2* respectively. It is interesting to note the difference in average profits between treatment 2 and 2*. It appears that the main cause for this difference is the different bids at the *initial* rounds of the experiment.

4. Discussion

In this paper we study how the number of competing firms influences the fierceness of competition in a Bertrand oligopoly game. The theoretical prediction is clear; all firms should submit the lowest possible bid irrespective of how many firms are matched. However, when we tested this model experimentally, we found that at the initial stage, competitors set prices higher than in the Nash equilibrium. In subsequent rounds the winning bids (but not all bids) typically converged rather rapidly towards the theoretical prediction when groups of three or four competitors were matched.[7] However, when only two competitors were matched prices remained much higher than the theoretical prediction.

It is striking that these results accord well with those reported by Fouraker and Siegel (1963), who let fixed sets of two or three participants interact repeatedly. Our

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[7] The predictability of the Bertrand model in these cases is all the more striking in that subjects ended up making so little money. While in the experiment some strategy profiles were amply rewarded, *in equilibrium* the payoffs were not very salient. Though this is a typical feature of a Bertrand game, it is from a methodology of experimental economics point of view an undesirable feature, which one might have suspected would undermine the attraction of the equilibrium outcome.

design differs crucially from theirs in that we have random matching of opponents between rounds, in order to isolate the effects of experience from the opportunities of cooperation that may occur in a repeated game. Nevertheless, in our case, as in Fouraker and Siegel's, duopolists exhibit more cooperative behavior than do triopolists.

Our findings suggest that learning is important, since behavior was not constant across time in all treatments. However, it is puzzling that the participants seem to come close to learning to play the equilibrium only when the number of competitors is sufficiently large. Our primary goal with this paper is not to solve this puzzle, but to document relevant experimental evidence. We conclude, however, by suggesting a reason why one might expect that the number of firms will have important bearing on the viability of the Bertrand equilibrium. We do not aim to provide a quantitatively exact model that fits the experimental data, but rather to hint at a phenomenon which may be qualitatively informative. Providing a quantitatively more accurate model may be a feasible research task, but it is beyond the scope of the present paper.

The profile where all firms bid 2 is the unique equilibrium of the Bertrand game we consider. A firm which unilaterally deviates from the equilibrium reduces its profit. However, in reality it seems highly unlikely that each firm is fully convinced that every other firm will behave in accordance with the equilibrium. Examples abound of irrational activity in economically important situations. Moreover, the consequences of irrationality may be large, even if the probability that individual decision makers are irrational is very small. Two relevant examples are Kreps, Milgrom, Roberts and Wilson's (1982) model of strategic interaction in the finitely-repeated prisoners' dilemma when rationality is not common knowledge, and "noise trading" in financial markets (see De Long, Shleifer, Summers and Waldmann, 1990). We now propose to illustrate how a little bit of irrationality can upset the viability of the Bertrand equilibrium if a high enough number of firms interact.

Suppose that in the context of our experimental game the firms believe that with a small probability $e > 0$ any given other firm is an irrational "noise bidder" who always simply submits a bid of 100. It is easy to verify that for a range of rather small values of e there cannot be an equilibrium where all firms that are not noise bidders bid 2, as long as not too many firms are being matched. Let N denote the number of firms being matched. Consider the decision problem faced by a non-noise bidding firm that believes with probability one that all other non-noise bidding firms will bid 2. It is clear that the firm should not submit a bid from the set {3,..., 98, 100}, since each bid in this set does strictly worse than a bid of 99. Let p_x be the probability that x firms out of the N-1 other ones bid 2. (Note that $p_0=e^{N-1}$ and that e^{N-1} is decreasing in N). One now sees that the firm should bid 99 if $\sum_{x\in\{0,\ldots,N-1\}} 2p_x / (x+1) < 99p_0$, and that the firm should bid 2 if the inequality is reversed. Given the assumptions, if N is large enough 2 is the optimal bid irrespective of the value of e. However, for a range of rather small values of e, a bid of 99 is optimal if N is not too large. As an example, note that with e=.05 and $N \geq 3$ a bid of 2 is optimal, but with e=.05 and N=2 a bid of 99 is optimal.[8]

To assume that all noise bidders bid 100 is clearly not realistic, but the main point of the argument goes through for a variety of other assumptions about the nature of noise bidding (e.g. that it is uniformly distributed between 2 and 100). The important insight from the example, which is supported by the experimental findings, is that the

[8] The purpose of the example is to show that a bid of 2 by all (non-noise bidding) firms is not an equilibrium with e=.05 and N=2. We do not suggest that a bid of 99 by all (non-noise bidding) firms is an equilibrium. Clearly it is not.

viability of the Bertrand outcome depends crucially on the number of firms being matched.

Tables 1a-h: The bids in the different sessions. * indicates a winning bid.

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	49	34	24*	22*	16*	15*	100*	100	60	20*
S2	15*	20*	25*	20	19	19	14*	9*	19*	19*
S3	39	39	30	35	40	19	100*	99	99	99
S4	40*	29*	28*	26	18*	16*	13*	80*	40	28*
S5	10*	20*	29	24*	19*	15*	14	100	79	79
S6	40*	30*	26	20*	21	15*	14*	19*	50*	60*
S7	23*	29	31*	24*	28	20*	14*	17*	40*	50
S8	46	32	24*	26	18*	100	20	35	88	66
S9	40	38	25*	25	20*	20	15	40	100	40*
S10	40*	40	35	19*	19*	18	40	39	35*	60*
S11	20	25*	20*	19*	17*	15*	12*	12*	20*	39
S12	40*	35*	30	23*	25	16	14*	18*	39*	35
Average bid	33.5	30.9	27.3	23.6	21.7	24.0	30.8	47.3	55.8	49.6
Average winning bid	29.7	26.5	25.3	22.0	18.1	16.0	35.1	25.8	33.8	37.8

Table 1a: Session 2a

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	66	50*	33*	66	44	85	98	96	50*	99
S2	30	24*	33*	22	30*	20	79	50*	54	40
S3	80	70	39	39	19	26	59*	69	67	46
S4	40*	50	40	20*	20*	80	79*	76	66	42
S5	85	85	85	20*	20	15*	20*	70	70	50
S6	22*	28*	18*	18*	28	20*	30*	49	48	39*
S7	98	40	84	85	99	99	99	99	99	99
S8	20*	30	28	20*	18*	80*	20	40*	40*	30*
S9	5	17*	20*	17*	17*	16*	13*	19*	35*	39*
S10	33*	29*	27*	26	17*	16	79*	49*	48*	38*
S11	21*	21	21	21	18*	16*	39	69*	48*	68*
S12	2*	2*	2*	2*	2*	2*	2*	2*	2*	2*
Average bid	41.8	37.2	35.8	29.7	27.7	39.6	51.4	57.3	52.3	49.3
Average winning bid	23.0	25.0	22.0	16.2	17.4	24.8	40.3	38.2	37.2	36.0

Table 1b: Session 2b

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	41	18	9*	13	8*	7*	6*	5*	4*	4*
S2	25	10*	10*	10	9*	8	5*	5*	5*	5*
S3	24*	17	17	12	10*	9*	10	8*	6*	50
S4	5*	19	15	87	9*	40	38	56	7	6
S5	29	18	15	14*	12	12	9	6*	6	24
S6	19*	24	27	14*	69	100	6*	12	78	36
S7	38	17	13	18	18	39	7	5	5	5
S8	38	18	12	11	11	7*	13	7	8	38
S9	25	2*	2*	5*	8*	7*	5*	5*	5*	5*
S10	25	34	20	15	13	15	10	53	53	6
S11	19*	17*	9*	8*	13	11	11	11	7	7*
S12	29	15*	13	9*	41	13*	100	100	38	29
Average bid	26.4	17.4	13.5	18.0	18.4	22.3	18.3	22.8	18.5	17.9
Average winning bid	21.5	11.0	7.5	10.0	8.8	8.6	5.5	5.8	5.0	5.3

Table 1c: Session 3a

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	12	12*	13*	12	11*	9*	8	7*	6	5
S2	40	17*	18	9*	11	7*	8*	9	5	2*
S3	40	8*	16	11	7*	14	9	7	5*	5
S4	40	15*	17	14*	13	10	10	7	5*	6
S5	12*	26	8*	2*	3*	2*	4*	2*	2*	2*
S6	29*	24	19	14	8	12	5*	11	2*	12
S7	48	37	11*	10*	9	9*	9	6*	5	5
S8	23*	19	11*	11	9	7*	7*	6*	5	3*
S9	20	20	25	90	90	50	10	10	5	5*
S10	50	18	15*	17	13*	13	13	7	6	4*
S11	45	39	35	100	43	100	99	2*	5	96
S12	2*	32	15	15	15	13	40	3	3*	3
Average bid	30.1	22.3	16.9	25.4	19.3	20.5	18.5	6.4	4.5	12.3
Average winning bid	16.5	13.0	11.6	8.8	8.5	6.8	6.0	4.6	3.4	3.2

Table 1d: Session 3b

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	55	25	15	16	10	10	5	5	5	2*
S2	10	20	10	10	5	2*	2*	2*	2*	2*
S3	48	29	15	14	9	5	4*	4	10	10
S4	47*	14	47	37	12	6	3*	6	4	4
S5	20*	26	16	9	8	5*	4*	4	2*	2*
S6	20	19	15	10	8	6	5	5	5	5
S7	48	8*	13	7*	4*	4*	2*	2*	2*	2*
S8	50	50	50	5*	5*	5	50	46	2*	100
S9	20	15	11*	10	7*	5	5	2*	2*	2*
S10	50	37	13	7*	20	15	13	10	8	8
S11	9*	10*	14*	15	10	7	3	3	2*	10
S12	20*	16*	8*	6*	6	3	3*	2*	16	19
Average bid	33.1	22.4	18.9	12.2	8.7	6.1	8.3	7.6	5.0	13.9
Average winning bid	24	11.3	11.0	6.3	5.3	3.7	3.0	2.0	2.0	2.0

Table 1e: Session 4a

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	34	34	34	34*	34	33	23	21	5*	2*
S2	15*	13	10	10	10*	28	12*	12	10	5
S3	10	10*	15	100	30*	99	25	8*	2*	2*
S4	2*	50	19	100	100	100	9*	9*	3*	2*
S5	2*	14	19*	100	100	100	100	34	10	100
S6	19	21	8*	13	98	74	42	9*	7	4*
S7	40	35	25	100	100	100	100	100	100	100
S8	49	10*	9	100	100	100	28*	24	3*	8
S9	35	10*	20	9	100	30*	97	15	5	2*
S10	100	100	100	10*	100	100	100	25	20	6
S11	48	20	9*	11	75	44*	35	20	16	10
S12	15	8*	10	8*	10*	10*	20	5*	5	5
Average bid	30.8	27.1	23.2	49.6	71.4	68.2	49.3	23.5	15.5	20.5
Average winning bid	6.3	9.5	12.0	17.3	16.7	28.0	16.3	7.8	3.3	2.4

Table 1f: Session 4b

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	39	44	26	36	24*	33*	45*	84	60	28*
S2	38	25	21*	5*	4*	15*	80	44*	22*	49
S3	2*	2*	9*	6*	4*	2*	100	69*	39	24
S4	15	16	17	9*	6*	13*	99	60*	29	9*
S5	28*	28*	16	16	16*	28	28*	95	33*	89
S6	18	12	10*	8	7	6	99	99	94	22
S7	10*	8*	8*	5*	4*	14	51	40	10*	80
S8	2*	19*	9*	5*	4*	10*	20*	18*	30	50
S9	19	9	17	15*	5*	7	11*	79	21*	5*
S10	49	49	40	36	67	49	45*	77*	42	41*
S11	21*	11	9*	18	6	22	7*	65	15*	70
S12	10*	9*	8*	7	6*	10	10*	80	13*	69
S13	49	10*	10*	8	10	100	100	98	25	80
S14	40	2*	10	6*	7	7*	7*	17*	17	17*
S15	2*	5*	7*	5*	6	4*	10*	10*	10*	10*
S16	10	2*	8*	7	4*	4*	4*	20*	14*	11*
S17	54	54	45	45	45	45*	45	45	45	45*
S18	11*	24	11	11	8	22	25	25*	25*	25*
S19	2*	2*	2*	2*	5*	5*	89	79	75	44*
S20	2*	2*	2*	2*	3*	2*	2*	7*	25	20
S21	19	4*	27*	3*	5*	10	10*	10*	10*	10*
S22	25	100	10	20	10	100	100	65	41*	35
S23	2*	2*	2*	2*	5*	4*	6	8	8*	8*
S24	33*	33	33	33	33	50	50	50*	49	49
Average bid	20.83	19.67	14.87	12.92	12.25	23.42	43.39	51.83	31.33	37.48
Average winning bid	10.42	7.31	9.43	5.42	6.79	12.00	14.00	33.92	18.50	20.46

Table 1g: Session 2a*

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
S1	19	24	4*	3*	2*	100	98	45*	55	55*
S2	38	25	21	2*	2*	22*	19	25*	25*	25*
S3	3*	8	4*	3*	50	50	49*	49*	30*	63
S4	6	6	5	5	20	20*	20*	15	13*	24
S5	6	5*	6	5	18*	14*	11*	39	39*	65
S6	5*	4	4*	3*	6	8	5*	5	5*	5*
S7	21	11	9	3	2*	5*	5*	4*	10*	35
S8	3*	5	4*	3*	2*	31	45	45	45	45
S9	5*	7*	3*	3*	12*	12*	12*	12*	58	12*
S10	61	53	51	65	59	82	82*	64	70	80
S11	8*	6*	5*	8*	17*	41	66	45	41	45
S12	5	4*	3	2*	7*	53*	98	97	85	94
S13	5*	5*	5	4	4*	50	78*	89	63	60
S14	14	5*	5*	4*	33	60	80	50*	60	60*
S15	3	4*	5*	2*	19	80*	79	79	3*	25*
S16	19*	3*	27	3*	15*	36*	90	100	100	97
S17	8*	5*	4*	4*	17	55	55*	55	50*	40
S18	9	8	5*	3*	18	19*	29*	19*	19	9*
S19	21*	19	5	2*	23	53	93	23*	23	23*
S20	2*	2*	2*	2*	16	45	60	45*	45*	34*
S21	5*	6*	4*	4	8	50	40	30*	20*	47*
S22	10*	10*	5*	5	20	20*	80	31*	20*	20*
S23	2*	2*	2*	2*	2*	2*	9*	9*	7*	99
S24	37	21	13	3*	3*	7*	7*	75	68	7*
Average bid	13.13	10.33	8.38	5.96	15.63	38.13	48.35	43.75	39.75	44.09
Average winning bid	7.38	4.92	4.00	3.06	7.17	24.17	30.17	28.50	22.25	24.27

Table 1h: Session 2b*

Figure 1a: Session 2a

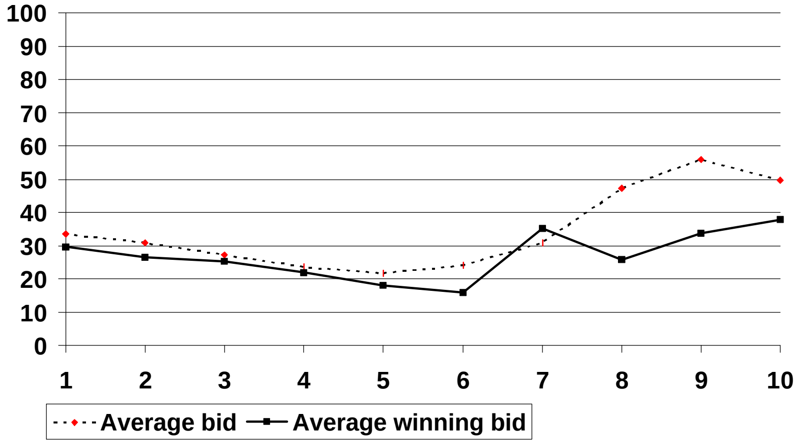


Figure 1b: Session b

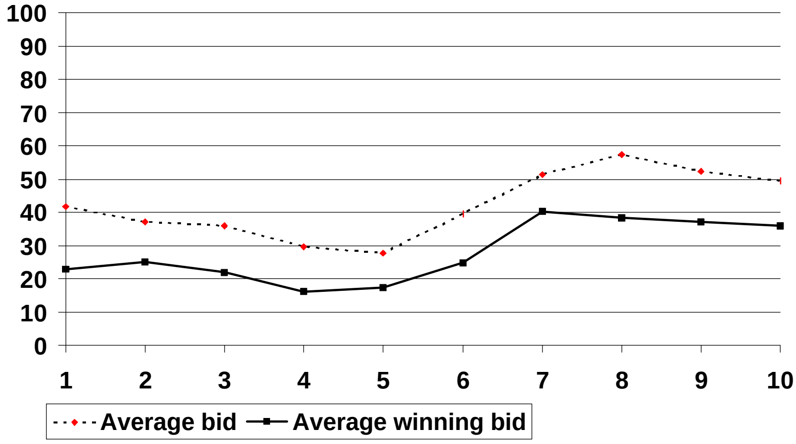


Figure 1c: Session 3a

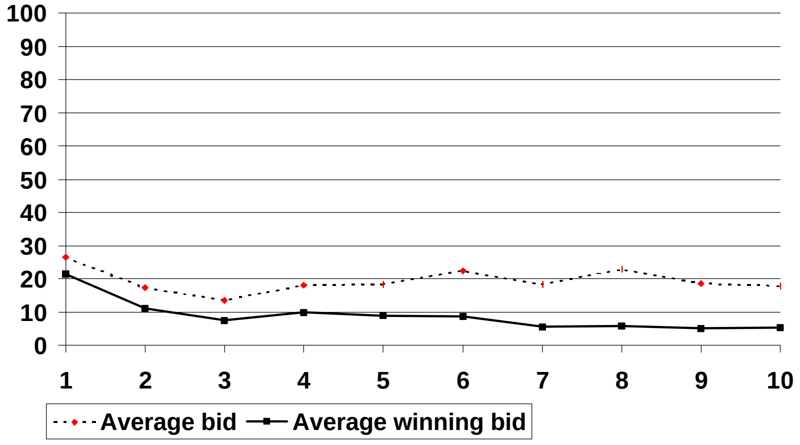


Figure 1d: Session 3b

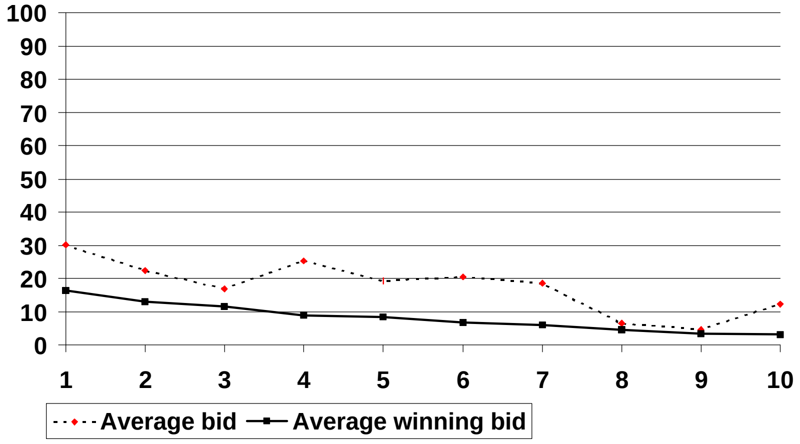


Figure 1e: Session 4a

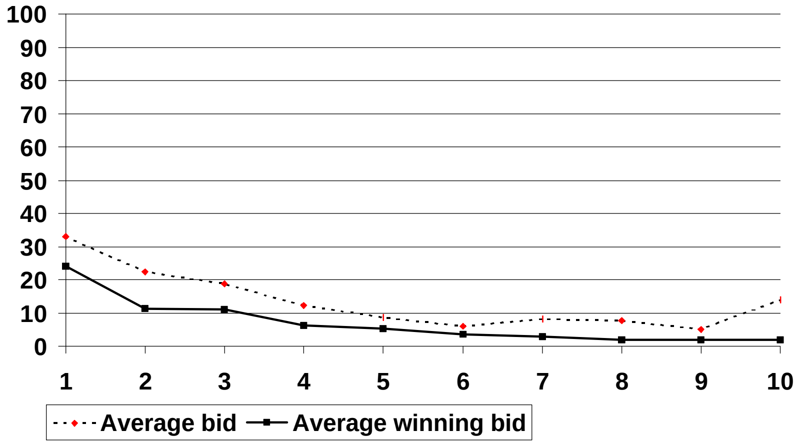


Figure 1f: Session 4b

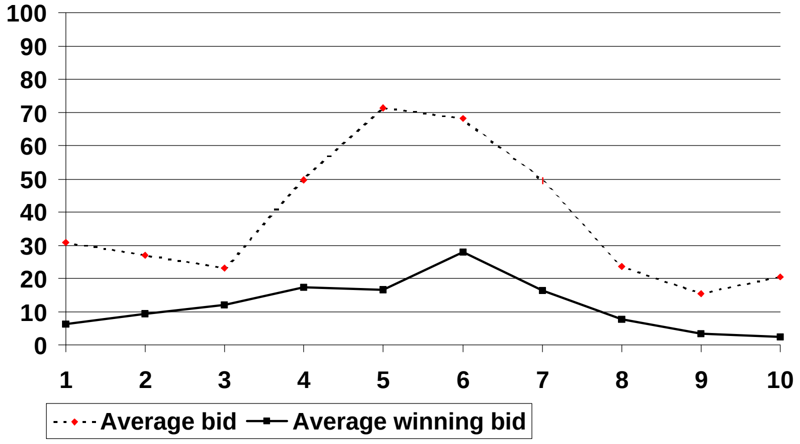


Figure 1g: Session 2a*

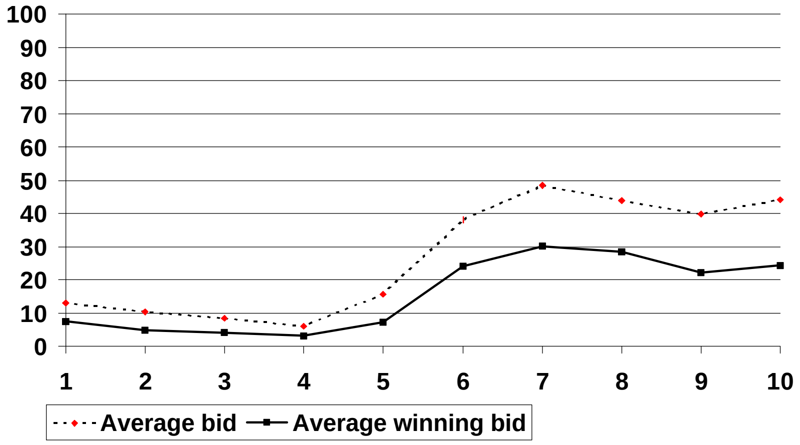
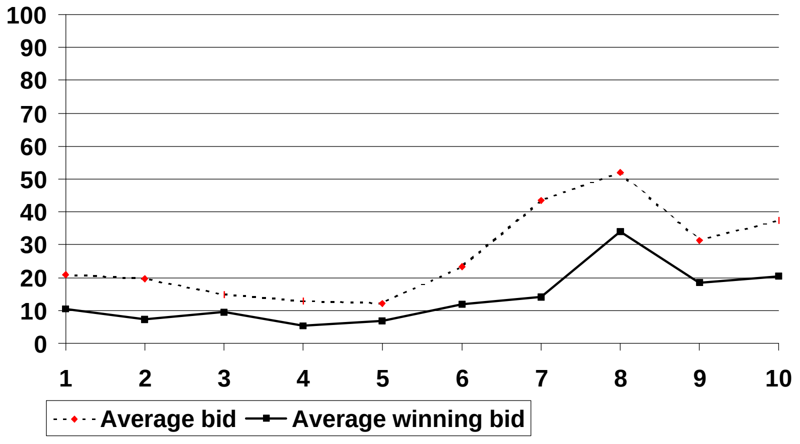


Figure 1h: Session 2b*



Appendix 1: Instructions for treatment 2

In the following game, which will be played for 10 rounds, we use "points" to reward you. At the end of the experiment we will pay you 5 cents for each point you won (e.g. 100 points equals 5 Dutch guilders). In each round your reward will depend on your choice, as well as the choice made by one other person in this room. However, in each round you will not know the identity of this person and you will not learn this subsequently.

At the beginning of round 1, you are asked to choose a number between 2 and 100, and then to write your choice on card number 1 (please note that the 10 cards you have are numbered 1,2,...,10). Write also your registration number on this card. Then we will collect all the cards of round 1 from the students in the room and put them in a box.

The monitor will then randomly take two cards out of the box. The numbers on the two cards will be compared. If one students chose a lower number than the other student, then the student that chose the lowest number will win points equal to the number he/she chose. The other student will get no points for this round. If the two cards have the same number, then each student gets points equal to half the number chosen. The monitor will then announce (on a blackboard) the registration number of each student in the pair that was matched, and indicate which of these students chose the lowest number and what his number was.

Then the monitor will take out of the box, without looking, another two cards, compare them, reward the students, and make an announcement, all as described above. This procedure will be repeated for all the cards in the box. That will end round 1, and then round 2 will begin. The same procedure will be used for all 10 rounds.

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