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Price Competition Between Teams*

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Abstract

This study uses an experimental approach to examine whether markets are sensitive to the internal incentive structure of the competitors. Toward this goal, we modeled the competitors in a price competition duopoly game as three-player teams. Each player simultaneously declares a bid (price) and the team whose total bid was lower won the competition and was paid accordingly. The losing team was paid nothing, and in case of a tie, each team was paid half its price. This duopoly game was studied under two conditions; a cooperative treatment in which the team's profit was divided equally amongst its members and a non-cooperative one in which each individual member was paid her own bid. Whereas the Nash equilibrium is for each player in either treatment to demand the minimal price possible, we predicted that convergence to the competitive price would be much faster in the cooperative treatment than in the non-cooperative one. The experimental results firmly confirmed this prediction.

Keywords: price competition, team games

JEL Classification: L11, C92

1. Introduction

In many economic models the agents (i.e., firms) operating in the market are treated as unitary players. The internal organization of these agents and, most importantly, the possibility of conflicting interests within agents, are dismissed as "inessential complexities". This simplifying assumption is reflected in experimental markets as well, where "firms" are commonly represented by individual subjects (Davis and Holt, 1993).[1]

In the present experiment we introduced competition within agents and study how this internal competition affects the outcome of the "market". To motivate this line of inquiry consider, for example, a recent competition between Boeing and Airbus over a large deal with El Al Airlines. To simplify, assume that the airline's decision was based solely on price. This market can be conceptualized as a simple duopoly treating the two competitors

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as unitary players. Alternatively, one can consider a more complex (and probably more realistic) market structure where the two competitors consist of alliances of firms, each developing and/or producing a different part of the airplane (e.g., engine, avionics, etc.)[2] Each firm in the alliance sets its price independently and the price of the final product is the sum of prices demanded by the individual firms. Conflict or competition within each alliance can stem from the fact that, while all the members in an alliance have a common interest in setting a competitive price and winning the competition, each individual member also has an interest in maximizing its own share in the group's profit.[3]

The market in our experiment was operationalized as a competition between two teams with three players in each team. Each player simultaneously submitted a bid (demanded a price), which had to be an integer between 2 and 25. The team whose total bids was lower won the competition and was paid its price.[4] The losing team was paid nothing. In case of a tie, each team was paid half of its total bids. This team game (Palfrey and Rosenthal, 1983; Rapoport and Bornstein, 1987; Bornstein, 1992) was played under two conditions that differed with regard to the way in which the team's profit was distributed among the three team members. In the non-cooperative treatment each individual player was paid her own bid if the team won, and half of her bid if the game was tied. In the cooperative treatment the team's profit for winning or tying the game was divided equally among its members. Thus, if the team won the competition, each member was paid one third of the total bids asked by her team. And if the game was tied, each player received one sixth of the team's total bids.

The unique strict Nash equilibrium of the above team game, *regardless* of how profits are divided within the teams, is for each team, and hence for each team member, to demand the minimal price (i.e., 2 points per player). Thus, if one assumes that the players are perfectly rational, one should expect them to exhibit the same equilibrium behavior in both treatments.[5]

However, if one considers the adaptive behavior of goal-oriented players who are not fully rational, and therefore, cannot be expected to play the equilibrium strategy right from the start, the difference between the two treatments becomes apparent. When behavior is away from equilibrium, that is, when prices are above the competitive minimum, the non-cooperative treatment provides each player with an opportunity, indeed a temptation, to free ride. Namely, if the other players in her team settle for a low price, player i can demand a higher price and still, possibly, win. In the cooperative treatment, on the other hand, where equal division of profits is imposed, the opportunity for free riding is eliminated.

To illustrate this point, assume that the members of team B make their decisions while knowing that the members of team A have already demanded a total of k points. The best response for team B in this case is to demand a total of $k - 1$ points. In the non-cooperative treatment each individual player prefers that her team-mates demand as little as possible, while she demands the rest. At the extreme, player i prefers that each of her team-mates demand the minimum of 2 points, while she asks for the remaining $k - 5$ points.[6] In the cooperative treatment, on the other hand, team members are indifferent as to how the total of $k - 1$ is reached, since any combination of individual prices, as long as they sum up to $k - 1$, results in a payoff of $(k - 1)/3$ for each member.[7]

When, as in the present experiment, the game is played recurrently for a large number of rounds, this difference in the internal incentive structure is bound to result in different behavior. Although we expect the participants in both treatments to reduce their bids as they gain more experience with the task, we predict that prices will decline much faster in the cooperative treatment than in the non-cooperative treatment. The rationale behind this prediction is rather intuitive. In both treatments a high demand by player i is likely to result in her team losing the competition and i receiving a payoff of zero. However, if i's team ends up winning the competition, her payoff is much higher in the non-cooperative treatment, where she is paid her asked price in full, than in the cooperative treatment, where she must share it with her team-mates. Since high demands are punished more consistently in the cooperative treatment, subjects are predicted to move faster towards the competitive stage-game equilibrium in this treatment than in the non-cooperative treatment.

2. Experimental procedure

2.1. Subjects and design

The participants were 120 undergraduate students (86 females and 34 males) at the Hebrew University of Jerusalem with no previous experience with the task. Subjects were recruited by campus advertisements offering monetary rewards for participating in a decision task. Subjects participated in the experiment in cohorts of 12; five cohorts took part in the non-cooperative treatment and five in the cooperative treatment.

2.2. Procedure

Upon arrival each participant received NIS 10 for showing up and was seated in separate cubicle facing a personal computer. The subjects were given written instructions concerning the rules and payoffs of the game (see Appendix) and were asked to follow these instructions while the experimenter read them aloud. Then subjects were given a quiz to test their understanding. Their answers were checked by the experiments and, when necessary, explanations were repeated. Subjects were also told that to ensure the confidentiality of their decisions they would receive their payment in sealed envelopes and leave the laboratory one at a time with no opportunity to meet the other participants.

Subjects played 100 rounds of the game. The number of rounds to be played was made known in advance. At the beginning of each round the 12 subjects were randomly divided into three-person teams and each team was matched randomly with another team. This random-matching protocol was carefully explained to the participants. In each round each subject had to enter a demand of between 2 and 25 points. Following the completion of the round, the subject received feedback concerning (a) the total number of points demanded by the three members of her group in that round; (b) the total number of points demanded by the three members of the other group with which her group was matched; (c) the number of points she earned in this round; and (d) her cumulative earnings (in points).

Following the last round, the participants were debriefed on the rationale and purpose of the study. The points were cashed in at a rate of NIS 1 per 10 points (1 New Israel Shekel was equal to about \$0.30 at the time the experiment took place) and the participants were dismissed individually.

Table 1. Mean bid, mean winning bid, and mean profit for each 12-person cohort summed across all 100 rounds.

Cohort no.	Treatment	Mean bid	Mean winning bid	Mean payoff (NIS)
1	no-co	10.71	9.18	45.9
2	no-co	8.54	7.77	38.8
3	no-co	8.86	7.42	37.0
4	no-co	8.13	7.50	37.4
5	no-co	7.15	6.25	31.1
6	coop	4.29	3.34	16.6
7	coop	6.72	5.13	25.7
8	coop	5.23	4.16	20.6
9	coop	5.98	4.95	24.8
10	coop	4.92	4.19	20.9

3. Results

3.1. Overall means

First, we look at price demands averaged across the 100 periods and 5 cohorts in each treatment. The mean demand per period in the non-cooperative treatment was 8.68 points, as compared with 5.43 points in the cooperative treatment. To test this difference for statistical significance we calculated the mean demand per period for each 12-person cohort separately and analyzed the 10 means using a Wilcoxon non-parametric rank test. As can be seen in Table 1, the means are perfectly ordered in the sense that all five means in the non-cooperative treatment are larger than the five means in the cooperative treatment. The statistical test is, of course, significant ($z = 2.51$, $p < .012$). The same rank-ordering, and consequently the same statistical result, hold for the mean winning price and the mean profit, which also appear in Table 1. On average, subjects in the non-cooperative treatment earned almost twice as much than those in the cooperative treatment (NIS 38.04 and 21.72, respectively).

Additionally, we computed the correlation between individual demands and individual profit in both treatments. In the cooperative treatment this correlation was significantly negative (Pearson $r = -.258$, $p < .05$), whereas in the non-cooperative treatment the correlation was essentially zero ($r = .078$). This finding directly supports our assertion that high individual demands are more reliably associated with lower payoffs in the cooperative treatment than in the non-cooperative treatment.

3.2. Convergence

The mean price per round in each treatment appears in figure 1(a). As can be seen in this figure, subjects' initial bids in the two treatments were almost identical. The mean number of points demanded in the very first round was 11.8 and 12.27 in the non-cooperative and cooperative treatments, respectively. These means are not statistically different ($t_{(118)} = .441$, ns).

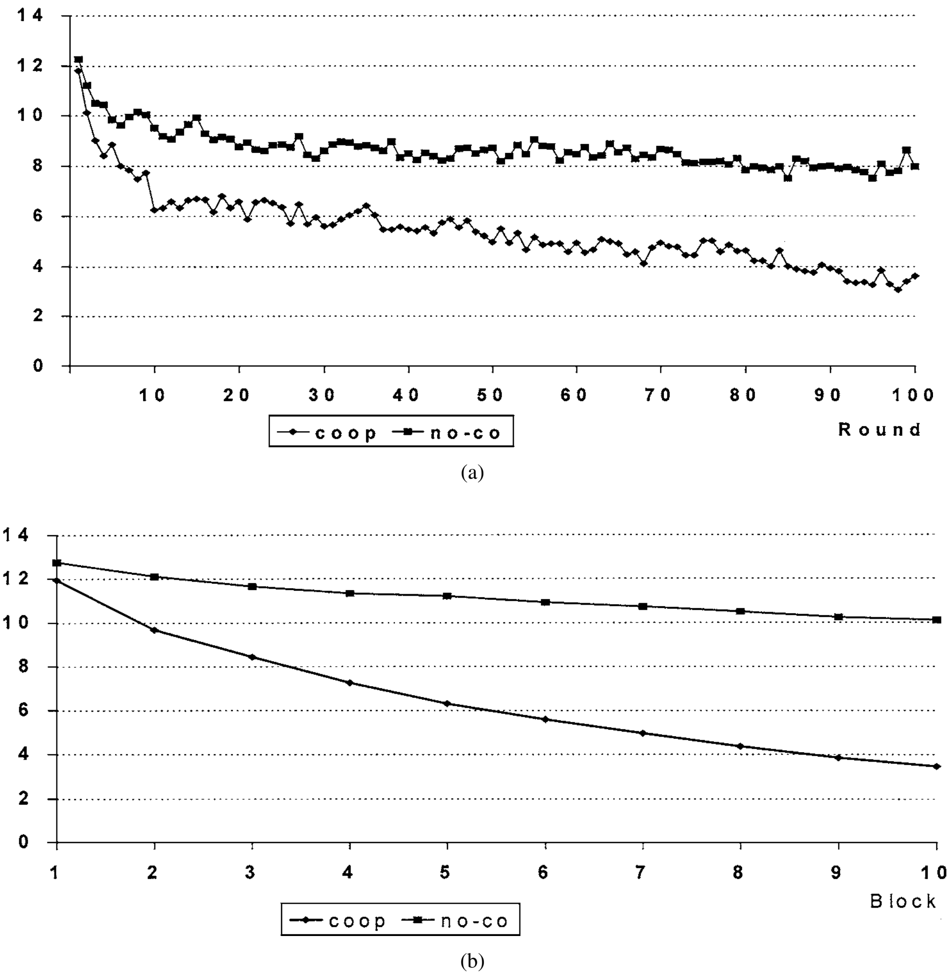

Figure 1. (a) Mean bid per round: Experimental results. (b) Mean bid per (10-round) block: Simulated results.

However, before long, subjects in the cooperative treatment began reducing their bids as compared with those in the non-cooperative treatment. The mean price in the first 10-round block was already almost 2 points lower in the cooperative treatment than in the non-cooperative treatment ($M = 8.55$ and $M = 10.36$, respectively). This difference is statistically significant by a Wilcoxon rank-test ($z = 1.67$, $p < .05$, one-tail), again using the 12-person cohort as the unit of analysis. The difference in first-block winning prices between the two treatments ($M = 9.08$ and $M = 7.09$ in the non-cooperative and cooperative treatments, respectively) is also significant ($z = 2.09$, $p < .05$).

The difference between the two treatments became much more pronounced as the game progressed. In the last 10 rounds (10th block) the average price in the non-cooperative treatment was 7.92 points—more than twice the 3.42 points demanded on average in the

Table 2. Mean bid and mean winning bid per 12-person cohort in the last 10-round block.

Cohort no.	Treatment	Mean bid	Mean winning bid
1	no-co	11.88	10.07
2	no-co	7.79	7.05
3	no-co	8.96	7.62
4	no-co	4.63	4.31
5	no-co	6.34	5.60
6	coop	3.01	2.41
7	coop	3.34	2.43
8	coop	3.23	2.59
9	coop	3.99	3.23
10	coop	3.55	3.14

cooperative treatment. This difference is significant by a Wilcoxon test using the 12-person cohort as the unit of analysis ($z = 2.51$, $p < 0.2$). The same statistical result holds for the mean winning bids (Table 2). The mean winning bid in this final stage was 6.93 in the non-cooperative treatment as compared with a mean of 2.76 in the cooperative treatment, which is quite close the competitive equilibrium (i.e., 2). In fact, examining the mean price per round separately for each 12-person cohort indicates that this general pattern of results is characteristic of the individual cohorts as well. In the non-cooperative treatment, prices typically decline very slowly, and occasionally even rise, whereas in the cooperative treatment prices decline much faster to approximate the competitive price.[8]

3.3. Learning

To examine the learning process in more detail, we employed the reinforcement learning model as formulated by Roth and Erev (1995) and Erev and Roth (1998). The basic principle underlying this model is the "Law of Effect" (Thorndike, 1898) which states that choices that have led to good outcomes in the past are more likely to be repeated in the future.[9] We derived the predictions of the learning model by having virtual subjects play each other in a simulation of the experimental environment.[10] Figure 1 (b) presents the mean bid in 200 simulated groups, each playing 100 rounds of the game under either the non-cooperative or cooperative treatments. As can be seen in the figure, the predictions of the learning model are clearly in line with our experimental findings. In both treatments the simulated players, like the actual ones, learned to decrease their demands over time, however, they learned to do so much faster in the cooperative treatment than in the non-cooperative treatment.

4. Discussion

The field of industrial organization studies the relationship between trading institutions and market performance. Issues central to this research are competition, collusion, and efficiency in price-setting (Bertrand) and quantity-setting (Cournot) environments. Particular theoretical and empirical attention has been given to the effects of market concentration on competition. The number of competitors and their respective "market power" have a direct influence on the market's outcomes, and it is typically assumed (e.g., as reflected in antitrust policies) that more competition results in lower prices.

The present paper explored the relation between competition and performance from a different angle. Rather than increasing the number of agents competing in the market, we introduced competition *within* each agent, and studied the effect of this internal competition on the market's performance. The classic model of price competition (named after Bertrand, 1883) is mute to this manipulation. The model predicts that prices (even) in a duopolistic market will be equal to the marginal cost, and each duopolist, whether a unitary actor or a coalition of actors, will demand zero profit in equilibrium (e.g., Tirole, 1994).

Nevertheless, we predicted that convergence to the competitive price will be much faster in the cooperative treatment where the teams are free of internal conflict (and, in that sense, can be regarded unitary players) than in the non-cooperative treatment where free riding within the teams is possible.[11] Our experimental results strongly confirm this prediction. Unlike competition between agents which leads to lower prices, competition within agents seems to keep prices higher. This result may have interesting real-life implications. In today's global markets firms often find it advantageous to compete by forging alliances. Although alliances can be beneficial in providing the firm with an access to greater resources, they also carry a risk. In particular, when engaged in an alliance a firm faces the risk that partners may free ride on its efforts, an action that could undermine its chances of succeeding in a competitive market (Amaldos et al., 2000). Future research will study "mixed" markets consisting of both cooperative and non-cooperative teams in order to examine this possibility more closely.

Appendix

Instructions

You are about to participate in a decision-making experiment. During the experiment you will be asked to make a large number of decisions, and so will the other participants. Your own decisions, as well as the decisions of the others, will determine your monetary payoff according to rules that will be explained shortly.

You will be paid in cash at the end of the experiment exactly according to the rules. Please keep quiet throughout the entire experiment and do not communicate in any way with the other participants.

The experiment is computerized. You will make all your decisions by entering the information in the specified locations on the screen. Twelve people participate in this experiment, which includes 100 decision rounds. At the beginning of each round, the 12 participants will be divided randomly into four groups of three persons each, and each group will be paired with another group. The pairing will be done randomly by the computer. You have no way of knowing who belongs to your group and who belongs to the other group.

In each new round, the computer will again divide the participants at random into four groups and each group will be paired at random with another group. At the beginning of a round each of you can demand any number of points between 2 and 25. After all the participants have entered their demands, the computer will sum up the number of points demanded by the three members of your group and will compare it with the total number of points demanded by the three members of the other group.

1. If the total demand made by your group is *lower* than that made by the other group, each member of your group will receive the number of points he or she demanded.
2. If the total demand made by your group is *higher* than that made by the other group, each member of your group will receive nothing (0 points).
3. If the total demand made by your group is *equal* to that made by the other group, each member of both groups will receive half the number of points he or she demanded.

At the end of each round you will receive information concerning (a) the total number of points demanded by your group; (b) the total number of points demanded by the other group; (c) the number of points you earned on that round; and (d) your cumulative earnings up to this point. Then we will move to the next round. Remember that for this new round you will be randomly divided into groups. At the end of the experiment the computer will count the total number of points you have earned and we will pay you in cash at a rate of 10 points = NIS 1.

The instructions for the cooperative treatment were identical except for the following changes in the payoff rules:

1. If the total demand made by your group is *lower* than that made by the other group, each member of your group will receive one third (1/3) of the group's total demand. In other words, the total number of points demanded by the group will be divided equally among the three group members.
2. If the total demand made by your group is *higher* than that made by the other group, each member of your group will receive nothing (0 points).
3. If the total demand made by your group is *equal* to that made by the other group, each member of both groups will receive one sixth (1/6) of the group's total demand. In other words, the total number of points demanded by the group will be divided by two and then divided equally among the three group members.

Following the reading of the instructions, the participants answered a quiz containing three examples. Each example listed the number of points demanded by each of the six players and the participants were asked to fill in the earning for each player. The experimenter went over the examples and explained the payoff rules until they were fully understood. The examples used in the two treatments were, of course, identical.

Notes

1. An important exception is the principal-agent theory, which studies different aspects of conflicting forces within firms (see Tirole, 1994). The study of the firm, however, is not done in a strategic context of competition against other firms.

2. E.g., Amaldos et al. (2000).
3. Alternatively, one can conceive of each alliance as consisting of different segments (e.g., management, workers, and stock-holders) within the same firm.
4. For an experimental study of this game using unitary players, see Dufwenberg and Gneezy (2000).
5. There are also non-strict Nash equilibria in which the bid of a member of a loosing team does not affect the outcome.
6. The internal game in thus a 3-person game of chicken with a strategic provision point (Bornstein et al., 1997).
7. The internal game is thus a pure coordination problem.
8. The only exception seems to be cohort no. 4 in the non-cooperative treatment where demands decreased substantially over time. But even in this particular cohort, prices remained relatively high (higher than those in any of the cohorts in the cooperative treatment) and never quite reached the competitive price.
9. However, it should be emphasized that the Erev and Roth (1998) model was chosen for its parsimony. Other learning models, such as the experience-weighted attraction model of Camerer and Ho (1999) and belief-learning models (e.g., Fudenberg and Levine, 1998) would have probably captured the same phenomenon.
10. In applying the model, we assumed that Player i considers $K = 24$ pure strategies (i.e., choosing an integer between 2 and 25). At time $t = 1$, Player i's initial propensity to play each of these strategies is evenly distributed. Her propensity to select a particular strategy, say strategy k, at time $t = 1$ is denoted by $q_{ik}(1)$. If Player i plays strategy k at time t and receives a payoff of x, then the propensity to play k is updated by setting $q_{ik}(t+1) = q_{ik}(t) + x$, while for all other pure strategies j, $q_{ij}(t+1) = q_{ij}(t)$. The probability $p_{ik}(t)$ that Player i will play strategy k at time t is $p_{ik}(t) = q_{ik}(t)/\sum q_{ij}(t)$ is the ratio of the propensity to play the kth strategy divided by the sum of the propensities to play each of the 24 strategies. We assumed that at $t = 1$ all players have the same initial propensity. In setting this initial propensity we considered two factors: the ratio $q_{ik}(1)/q_{ij}(1)$ of the propensities to play strategy k and not k, at time $t = 1$; and the sum of the initial propensities over the 24 strategies, $S(1) = q_{ik}(1) + q_{ij}(1)$. Following Roth and Erev, we set $S(1) = 10$.
11. Since our primary interest was in studying adaptive behavior in the single-shot (i.e., stage) game, we imposed conditions of play that prevent the use of repeated-game strategies. The game was played for a prespecified number of periods to ensure that the recurrent game has the same unique equilibrium as the stage-game. Decisions were made simultaneously in each period with no communication among players. And most importantly, assignment of subjects to teams, as well as the matching between teams, were randomized for each period. These procedures hinder any effective form of reciprocation among players, rendering tacit collusion impossible or at least very unlikely. However, it is also of interest to examine the repeated game where the groups' composition remains constant throughout the interaction.

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