Cheap, dirty (and effective) in-class experiments

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This paper describes a series of five in-class experiments run in a third-year industrial organisation course. A description is given of how these experiments can be run informally in a classroom without computers, while still maintaining a reasonable level of control. Each experiment involves an anonymous five-round ‘round-robin’ tournament. Thus, students play a total of $5 \times 5 = 25$ games, and are unaware of who they are playing in any particular game. The five games are: Bertrand price competition, Cournot quantity competition, an ultimatum vs. a dictator game, sealed-bid auctions, and a limit quantity model.

THE VALUE OF THE EXPERIMENTS

It is well known that students learn more effectively in an active learning environment such as gaming (Gremmen & Potters 1997). Experiments allow students to explore models from the inside: the students are put in the shoes of a decision maker. Students are often amazed to see how close the equilibrium prediction is to the observed choices of experienced players, even when playing an unfamiliar game. However, many of the interesting results are those instances where theory fails to explain the behaviour of real players. This is when students really start to think more deeply about the assumptions made in a model, and whether it is the strength of a particular assumption that is resulting in the difference.

DESCRIPTION OF THE EXPERIMENTS (GIVEN TO THE STUDENTS)

Bertrand price competition

Imagine you are a duopolist facing a market demand of $Q = A - p$. Suppose that you are player $i$, and you choose your price, $p_i$. If your price is lower than your competitor’s, then you capture the entire market, and make sales of $q_i = A - p_i$. If your competitor (call him player $j$) sets his price $p_j$ lower than yours, then he captures the entire market and you make sales of $q_i = 0$. In the event that you both set exactly the same price, then you split the market equally and make sales of $q_i = (A - p_i)/2$. Your profit is $(p_i - C)q_i$. In words, you can produce any level of output at a constant marginal cost of $C$, and fixed costs are zero. Parameters $A$ and $C$ take on values that can be found at the top of your record of play. Note that both you and your competitor face the same demand curve $Q = A - p$, and have the same marginal cost $C$.

Cournot quantity competition

Imagine you are a duopolist facing a market demand of $Q = A - p$. Suppose that you are player $i$ and you choose your quantity $q_i$. Suppose the other player is player $j$, who chooses some quantity $q_j$. Aggregate production is $Q = q_i + q_j$, and price adjusts to clear the market: $p = A - Q$. Your profit function is $(p - C)q_i$. In words, you can produce any level of output at a constant marginal cost of $C$, and fixed costs are zero. Parameters $A$ and $C$ take
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on values that can be found at the top of your record of play. Note that both you and your competitor face the same demand curve $Q = A - p$, and have the same marginal cost $C$.

**Bargaining**

Here we look at two types of bargaining games: an ultimatum game, and a dictator game.

- Ultimatum game. There are two players: player 1 and player 2. Player 1 and player 2 bargain over $V$. Player 1 moves first by offering player 2 some non-negative share of the $SV$. Player 2 then chooses whether or not to accept player 1’s offer. If player 2 accepts, then player 2 receives the offer, whereas player 1 receives $V$ minus the offer. If player 2 refuses player 1’s offer, then both players get zero.

- Dictator game. There are two players: player 1 and player 2. Player 1 and player 2 ‘bargain’ over $V$. Player 1 moves first by offering player 2 some non-negative share of the $SV$. Player 2 must accept player 1’s offer. Player 2 receives the offer, whereas player 1 receives $V$ minus the offer.

In each group, there are six teams represented by the letters $a$ through $f$ respectively. For each round of the game, the team with the letter closest to the start of the alphabet will be player 1, whereas the other team will be player 2.

(As an aside, this game results in highly asymmetric payoffs. For instance, player $a$ in the dictator group could potentially earn 50 lab dollars. However, students choose their seats without knowing which team they will be, and do not begrudge the lottery associated with the determination of identity.)

**Auctions**

Here we compare two types of auction: a sealed-bid first-price auction, and a sealed-bid second-price auction. In each auction, there are two teams that are bidding for the good. Each team has a private valuation of the object, $V$, which is drawn from a uniform distribution over the interval $[0, 10]$.

- A sealed-bid first-price auction. In this type of auction, both teams make simultaneous private (sealed) bids ($B_i, B_j$) on the object. The team with the highest bid wins the auction, and pays the highest (i.e. their own) bid. Suppose Player $i$ makes the highest bid. Then the payoff to player $i$ is $V_i - B_i$, and player $j$ gets zero.

- A sealed-bid second-price auction. In this type of auction, both teams make simultaneous private (sealed) bids ($B_i, B_j$) on the object. The team with the highest bid wins the auction, and pays the second-highest bid for the object. Suppose that player $j$ makes the highest bid. Then player $j$’s payoff is $V_j - B_i$, where $B_i$ is the second-highest bid. The payoff to player $i$ is zero.

**Limit quantity**

Here we investigate the influence that asymmetric information has on the behaviour of an incumbent facing a threat of entry. Two groups will play a game where the incumbent’s marginal cost is private knowledge, and two groups will play a game where the incumbent’s marginal cost is public knowledge.
1. Incumbent’s marginal cost is private knowledge.
   a. At the beginning of the game, nature determines whether the incumbent is a high or
      low cost firm. The result of nature’s move is only revealed to the incumbent.
   b. Next, the incumbent chooses quantity as a monopolist, given its realisation of cost.
   c. Next, the entrant must decide whether or not to enter, based on the observed incumbent
      quantity in the first period. If the entrant enters, it must pay an entry fee of $F$ dollars.
   d. The incumbent observes whether or not entry has occurred.
   e. If the entrant enters, it discovers what the incumbent’s marginal cost is.
   f. If entry occurred, both the incumbent and the entrant simultaneously choose quantities.
   g. If the entrant stays out, then the incumbent chooses quantity as a monopolist.

2. Incumbent’s marginal cost is public knowledge.
   a. At the beginning of the game, nature determines whether the incumbent is a high or
      low cost firm. Both the incumbent and the potential entrant are told the result.
   b. Next, the incumbent chooses quantity as a monopolist, given its realisation of cost.
   c. Next, the entrant must decide whether or not to enter, based on the observed incumbent
      quantity in the first period, and the incumbent’s marginal cost. If the entrant enters, it
      must pay an entry fee of $F$ dollars.
   d. The incumbent observes whether or not entry has occurred.
   e. If entry occurred, both the incumbent and the entrant simultaneously choose quantities.
   f. If the entrant stays out, then the incumbent chooses quantity as a monopolist.

The incumbent’s marginal cost is either high ($C_i^h = 3$) or low ($C_i^l = 0$), with probability
one half each. The entrant’s marginal cost is always low ($C_e^l = 0$). The inverse demand
curve is $p = 9 - Q$, where $Q = q_i + q_e$. The fixed cost of entry is $12$, which is
completely sunk once it is incurred. Note that the incumbent does not pay the entry cost,
as they are already in the market. Thus, the incumbent’s profit is the sum of the first and
second period profits, whereas the entrant’s profits are equal to their second-period
gross profit, minus the entry cost.

In each group, there are six teams represented by the letters $a$ through $f$ respectively. For
each round of the game, the team with the letter closest to the start of the alphabet will
be the incumbent, whereas the other team will represent the entrant.

(Again, payoffs will be highly asymmetric due to an endowment effect. For instance,
the payoff associated with being a low-cost incumbent far exceeds the payoff associated
with being an entrant when the incumbent is low cost. The students do not begrudge this
asymmetry, as it is a result of a lottery.)

THE EXPERIMENT SETUP (GIVEN TO THE STUDENTS)

When you come into the classroom, find a sheet of paper on one of the desks, and sit down
in one of the two chairs located behind the piece of paper. Do not move any of the chairs.
Do not turn over the sheet of paper. Do not leave your chair once you are seated. Failure to
abide by these rules will result in your earnings being withheld. I will keep a tally of your
earnings, and at the end of the term your earnings will be transformed into petrol vouchers.
There are $400$ dollars worth of petrol vouchers to be allocated. If the class as a whole
earns exactly $400$ dollars, then one experimental dollar is worth one petrol dollar.
Once seated, you will notice that most likely there is a person in the chair next to you. This person is your team-mate, with whom you will choose your team strategy. Alternatively, if the chair next to you is empty, you do not have a team-mate. In this case, you choose your team strategy on your own. Note that your personal earnings do not depend on the number of players in your team. You do not share the team earnings with the members of the team. For example, if your team earns $4.20, you will receive $4.20 regardless of whether or not you have a team-mate.

We are going to play a total of five different games over the next five tutorial meetings. In each tutorial meeting, we will play a particular game five times. Note that the desks in the room have been arranged into four long rows, each row having six sheets of paper, each sheet being associated with a different team comprised of either one or two players. You will be engaged in an anonymous round-robin tournament with the other five teams in your row. You will play each team in your row once, but you will be unaware of the order in which you play them. Teams will be identified by a letter of the alphabet from a through f. To maintain confidentiality, do not tell anyone your team letter.

Who you are playing will remain anonymous, but after you and your competitor have chosen an action, your competitor’s choice will be revealed to you. This information will give you the opportunity to learn how other teams in your group are playing. You then repeat this procedure four more times with the remaining teams in your group, for a total of five repetitions of the experiment. Given the round-robin nature of the experiment, you only face a given competitor once. Thus in each round you begin with a clean slate (your new opponent team does not know how you have played in the past), but with a little more knowledge of how other teams in your group have been playing the game. The order in which you play the other teams is determined by the matrix below (Table 1).

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For example, if you are player d, you will play player b in the second round. For each round of the experiment, you will fill in two forms. The first is your record of play, which includes your choice and your competitor’s choice. The second form you will fill out is a ‘disclosure’ slip, which will be collected by me, and then anonymously delivered to your competitor.

It is very important that you fill in both forms completely and accurately.
THE ROOM SETUP

Figure 1 shows the room setup for the experiments. The tables in the room are arranged into four groups of six tables. Each of the tables in a group represents a team within a given treatment. Each of the four groups represents a treatment. At the front there is a computer for (real-time) data entry, and a screen to present the results immediately following the experiments. Data is entered into a spreadsheet that is set up to draw graphics and perform statistical tests.

The students fill in two types of forms when playing the game. PDF versions of these forms are available at http://www.vuw.ac.nz/staff/richard_martin/experiment_stuff. The first is their record of play, onto which they record their name, their choice in each of the five rounds, and their competitor’s choices. These forms are collected at the end of the game and used to calculate payoffs. The other form is a disclosure sheet, which is cut into strips, onto which the players write what team letter they are, which team they are playing this round, and their choice. In a simultaneous-move one-shot game (such as experiments 1, 2 and 4) the instructor would take the following actions for a given round:

1. Collect all of the disclosure slips for a given group of six players. (It is important that all the disclosure slips are collected before they are delivered, in order to maintain confidentiality. If you delivered directly, students would be able to tell who they had played and, more importantly, would be able to deduce (imperfectly) who they were about to play. In the first couple of experiments, it is very important to ensure that players are filling out their disclosure slips correctly when they are collected. Otherwise, it is difficult to quickly unravel who has made an error.)
2. Deliver the disclosure slips to the appropriate teams. (For example, in round one player a would be delivered player f’s disclosure slip, and vice versa. All deliveries are determined by the round-robin schedule. Make sure that students record both their choice and the choice of their competitor on their record of play.)
3. Collect the disclosure slips again, and enter the data into a spreadsheet. Again, this is available at http://www.vuw.ac.nz/staff/richard_martin/experiment_stuff.
4. Repeat for a total of five rounds.
5. Discuss the results with the students immediately following the experiment.
6. Verify the outcomes, and calculate the payoffs.

Typically these experiments can be run easily by an instructor and a single TA within an hour, but one-and-a-half hours allows for a complete discussion of the results immediately following play, when it is most fresh in the students’ minds. As a caution, the instructor should be aware that the first and last experiments take the most time. The first experiment takes a long time because students are not familiar with the structure of the games. The last experiment requires a lot of time because it is a sequential game. We have found that for the first couple of experiments (Bertrand, Cournot) it is helpful if the students have some familiarity with the theory before playing. In the first couple of experiments, it is challenging enough for the students simply to contend with being involved in an experiment. For the final three experiments (bargaining, auctions, and limit quantity), the students play the games before being taught the theory. These experiments allow the students to see the predictive value of equilibrium, even when players are unaware of the equilibrium.

RESULTS

All of the following results were obtained from a third-year industrial organisation course at Victoria University of Wellington during the second semester of 2004.

Figure 2: Bertrand results
There are two interesting results in the Bertrand game. The first is that shifting the demand curve has an influence on price choices, even though the Bertrand prediction is that price should be equal to marginal cost. The second is that shifting the demand curve outwards results in lower price choices. Perhaps what is going on is that players have some minimum worthwhile payoff, and when the choke price is higher, this minimum payoff is associated with a lower price. However, observed prices converge to marginal cost in all four treatments. These results can be contrasted to those of Ortmann (2003) and Beckman (2003). In Ortmann, the action space is discrete, and the number of players is typically in the range of 24–60. In a single round of play, the overwhelming outcome is that the market always unravels down to either a price of zero or one. In Beckman, students form groups of two and play ten rounds against the same opponent. The strategy space is discrete, and the payoff matrix is provided to the students. The (somewhat) surprising result is that prices rapidly drop to the static-game Nash equilibrium. In such a game, with a constant non-anonymous pairing of players, one might expect to see reputation-based behaviour, as predicted by Kreps et al. (1982).

In the Cournot game we again see that, with experience, the average quantities converge toward the Nash equilibrium quantities. An interesting difference between Bertrand and Cournot is that the price path converges to the Nash equilibrium from above in the case of Bertrand, whereas it converges from below in the case of Cournot. In words, even though the Bertrand Nash equilibrium is ‘more competitive’, initially there is a higher degree of cooperation when compared to Cournot. Note that the Nash equilibrium quantities for both \( A = 9, C = 3 \) and \( A = 7, C = 1 \) are \( q_i = q_j = 2 \). These results can be contrasted to those of Beckman (2003) and Meister (1999). In Beckman, students form groups of two and play ten rounds against the same opponent. The strategy space is discrete, and the payoff matrix is provided to the students. Student behaviour varies remarkably across pairings. Students are split fairly evenly between playing dominated strategies, the Cournot strategies, and the joint maximising strategies. Again, one might expect to see a greater degree of cooperation early on in the game, based on a reputation effect (Kreps et al. 1982). In Meister, students play a Cournot stage game in a group of
five for an uncertain number of repetitions. Capacity constraints are placed on the players, although these constraints are non-binding in the Nash equilibrium. Overall, Meister finds a similar pattern of choice: students play aggressively in the initial rounds, and then quantities drop over time.

In the ultimatum vs. dictator games, we see a couple of interesting features. For one, it appears that in the ultimatum game, proposers are motivated mostly by a fear of rejection, rather than some sense of fairness. To see this, note that the offers in the dictator game peaked at approximately five percent of the surplus. It turns out that the proposers in the ultimatum game were correct to fear rejection. Indeed, offers less than 35 percent were always rejected. The startling result is that there is very little in the way of learning. Proposers seemed to have known right from the beginning that low offers would be rejected. Only five of thirty offers were rejected. The absence of learning seems to indicate that powerful social norms exist, and these obviously influence the outcome of the experiment. Part of the discussion following this experiment concerns how the ultimatum game is very similar to a monopolist setting price. The monopolist makes a ‘take it or leave it’ offer to consumers: ‘if you wish to purchase my good, you must pay this non-negotiable price’. Consumers respond by either purchasing the good or not. The implications of fairness for the behaviour of a monopolist are explored by Kahneman et al. (1986).

In the sealed-bid auctions, the striking outcome is that the ratio between the bids in a two-person sealed-bid auction is consistently above one-half, which is the predicted ratio. To see this, note that the equilibrium strategy in a second-price auction is to bid your valuation. Your bid has no influence on how much you pay (either zero if you lose, or the second-highest bid if you win), but it does influence whether you win or not. Obviously, you would wish to win the auction in all circumstances where the second-highest bid is lower than your valuation. Thus, you should bid your valuation. Now consider a first-price auction, where if you win the auction, you pay your bid. In a first-price auction, bidding one’s valuation ensures a payoff of zero. Thus, bidders in a first-
price auction generally bid less than their valuation, trading off a reduction in the probability of winning the auction against the size of the prize (valuation minus their bid). In a two-player game where the bidders are risk-neutral and their values are drawn from a uniform distribution, the equilibrium prediction is that each bidder should bid one-half of their valuation. Thus, if the auctions differ only by their design (first vs. second price), then the ratio of the bids should be one-half. However, revenue equivalence cannot be rejected using a matched pairs sign test ($p = 0.18$).

The last experiment is the most complex in that it is a two-stage game, and a game of imperfect information. As predicted by theory, low-cost incumbent firms attempt to signal this by producing a large quantity in the first period as a monopolist. However, high-cost incumbents also produce more than the static maximising quantity, perhaps betting on the limited rationality of the potential entrant. Of course, the payoffs are determined in such a way that only a low-cost incumbent would be willing to produce the ‘limit quantity’, and that is what makes the limit quantity a credible signal of low cost. For the case of hidden costs, we investigate whether first-period quantities influence entry. A non-parametric Mann-Whitney $U$ test is unable to reject the null hypothesis that first-period quantity has no influence on the entry decision. For a graphical depiction of the relationship, see the histogram in Figure 6 below.

These results can be compared to those of Capra et al. (2000) and Cooper et al. (1997). Capra et al. focus on predation rather than deterrence, and costs are common knowledge. In their setup, incumbents signal that they are tough by setting a low price and supplying a large quantity. In their design, predation is not very costly and the monopoly profits far exceed duopoly profits. The result is behaviour that is predatory in nature. Cooper et al. argue that in signalling games, refinements (such as a single round of elimination of dominated strategies) that predict the Riley outcome (the efficient pure-strategy separating equilibrium) do not in fact have much predictive value. If players either fail to recognise the dominated strategies (bounded rationality), or believe that others might fail to recognise the dominated strategies (strategic uncertainty), then
the Riley outcome looks quite risky for a low-cost incumbent. Note that in our signalling game, the Riley outcome involves a quantity of three for a high-cost incumbent, and a quantity of 5.83 for a low-cost incumbent. In nine out of fifteen games where the incumbent had a hidden cost of zero, the quantities chosen by the incumbent were lower than 5.83. It appears that the students (both the incumbents and the potential entrants) did not understand the nature of credible signals.

Figure 6: Limit quantity results

![Graph showing limit quantity results]

![Bar chart showing frequency of first period quantities]

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CONCLUSION

These experiments present an excellent way for students to explore the models in question. Students have repeatedly commented that they did not really understand the model until they were put in the position of being the decision maker. However, Gremmen and Potters (1997) suggest that subjective student feedback does not present a clear indication of the efficacy of gaming as a learning technique. Nevertheless, the students do appear to be engaging with the material to a greater extent than what they would in a lecture situation. In addition, making decisions as a team (of two) leads to heated discussions within a team as to the appropriate strategy. I have never encountered this phenomenon in the absence of experiments. One of the key features of the models described is that the strategy space is real, as opposed to discrete. The students are given the payoff functions, and have to calculate payoffs given the strategies chosen. This type of calculation really seems to improve students’ comprehension of the models. Students are told that the experimental results are examinable, to ensure that they are held accountable for what they have learned. One last benefit has to do with the preparation of the spreadsheet in advance. This allows for a graphical description of the results, and statistical testing immediately following the end of play, when the students’ interest is at a peak. Much of our discussion usually focuses on why we think the results vary from what standard game theory predicts.

REFERENCES


