The Professor's Dilemma: Teaching Game Theory in Principles of Agricultural Economics
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Abstract:

Typically, students in undergraduate agricultural programs are required to take an introduction or principles class in Agricultural Economics. These courses usually include a section on oligopoly markets, which may lead to a lecture on game theory. This presents a problem as game theory can be a very difficult topic. Herein, I present an easy and fun method that can be used to present static and repeated games in a classroom setting and describe the results of using an experimental Prisoner's Dilemma game as a teaching tool. Any instructor can replicate this in any classroom as a computer is not required.

Introduction:

Many Agricultural Economics or Agribusiness programs offer an introductory, or principles of agricultural economics class. Typically such a class will be required for all students in the major and often this class is required for all majors in the school or college of agriculture. The textbooks used for these courses frequently include a section on oligopoly pricing (see Seitz, Nelson et al. 2002). Thus, professors may find themselves teaching an advanced topic, game theory, to neophytes in our field and students from other majors within the school of agriculture. This presents several interesting dilemmas. How does one prepare students in the major for advanced upper-division classes while maintaining the interest of students not in the major? How does one address a topic that, *potentially*, could require a great deal of technical and mathematical skills in a non-technical manner that keeps students interested?

This dilemma is not limited to introductory classes; many marketing textbooks (see Norwood and Lusk 2007) also cover the topic. These dilemmas are not unique to game theory. However, the topic provides an excellent opportunity to develop an active learning exercise as an alternative to the traditional sage-on-the-stage lecture. In this paper I present an easy and fun method that can be used to demonstrate both a static and a repeated prisoner's dilemma in a classroom setting. It is important to remember that this is not an economic experiment; rather it is a teaching tool. The goal is not to test any particular hypothesis. The goal of the experiment is to actively engage students by providing an alternative to a traditional lecture and the goal of this paper is to determine if the method 1) increases student understanding of oligopoly pricing and game theory, 2) increases classroom participation.

Background:

The Prisoner's Dilemma (PD) is often used as a pedagogical tool. In the classic PD two criminals, who are accomplices in a crime, are detained by the police. When placed in separate rooms they are each given the chance to "rat out" their accomplice in order to get a reduced sentence. The payoffs are structured so that "rat out" is a dominate strategy. A dominate strategy is a best response, no matter what strategy your competitor chooses. The Nash Equilibrium finds both criminals choosing "rat out" and both spend more time in jail then they would if they both were chose the cooperative strategy, keep quiet.

In experimental settings, and many real-world examples, it is common to find players that choose the cooperative strategy, even though it is not an optimal solution. It turns out that cooperating is a Nash Equilibrium in a repeated game. In an infinite version of the repeated game the expected outcome is to cooperate until the competitor deviates from cooperation, called the trigger strategy, then cease cooperation until the end of time (Gibbons 1992).

Methods:

Three trials were used to test the effectiveness of both a lecture on game theory and the interactive game. The trials require three semesters (e.g. Fall, Spring, and Fall) to conduct. In the first trial no interactive game is used to teach game theory. Questions on game theory and oligopoly pricing are included on an exam and are used to assess the student's understanding of the topics. In the second trial a lecture on game theory and oligopoly pricing is *followed* by an interactive in-class PD framed as an oligopoly pricing game. Students are randomly paired and then simultaneously declare either a high price or a low price. Students are then shuffled and the static PD game is repeated. After several iterations the process is repeated for a dynamic version of PD. The results are recorded to determine if and when students converge to the Nash Equilibrium. Questions on game theory and oligopoly pricing are included on an exam and are used to assess the student's understanding of lectures on the topic. In addition a member of the faculty is invited to serve as an observer. In the third trial a lecture on game theory and oligopoly pricing is *preceded* by an interactive in-class prisoner's dilemma. Otherwise, the second and third trials are identical.

To conduct the trials students are given a handout (See Appendix 1) containing instructions, a hypothetical duopoly market, and a tally sheet so that students can recorded results. The handout also contains information on the three elements of a game

1. The Players, a pair of farm supply firms

2. The rules, simultaneous declaration of the two strategies (high price or low price)
3. The payoffs, profits

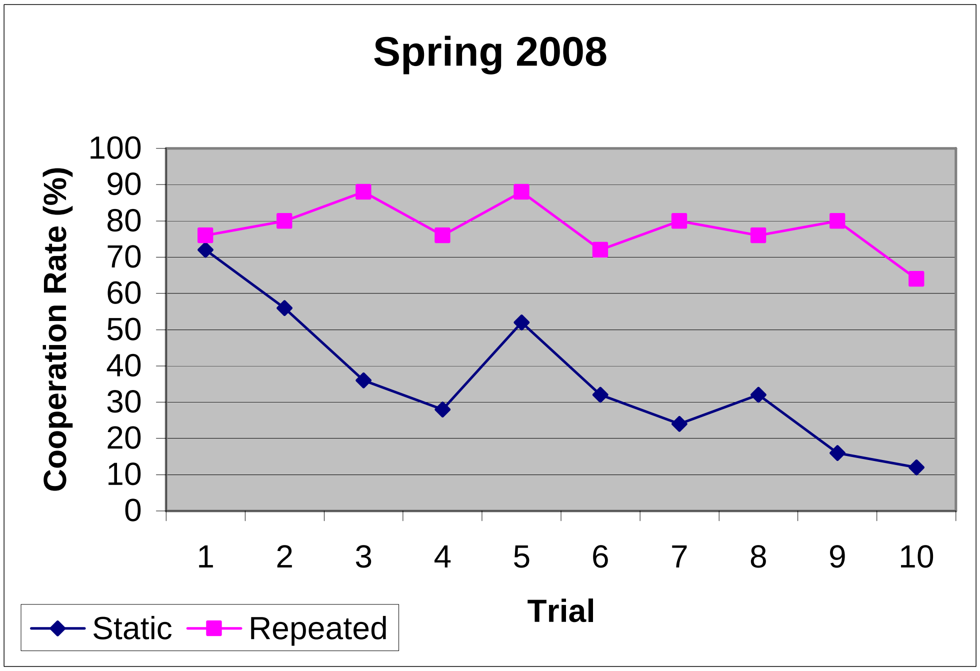
Students are also given a set of index cards, one with an H and one with an L to represent the high price strategy and the low price strategy respectively. Students are asked to stand up, move around the room and select a competitor. Competitors then stand back-to-back, select a strategy and simultaneously turn around to reveal their strategy. Students record the results, and in the static version of the game find another competitor for the next round. In the repeated version of the game students stay with the same competitor until the end of the round, then they find a new competitor for the next set.

During the first three sets communication between and among competitors is permitted. However, the pace of the experiment is fast enough to minimize strategic communication. During the final set students are rewarded with extra credit, or bonus points, if they can sustain a cooperative outcome. During the final set talking is prohibited. By this point it is expected that some students will have learned how to maintain a cooperative outcome however it will be difficult to maintain that outcome unless the competitors can establish a non-verbal signal.

Experimental Results:

Results were tracked for the first round during the spring and fall semesters of 2008 (figure 1 and 2). In the spring the experiment was conducted after a lecture on game theory where students were shown how to determine the Nash Equilibrium. In spite of prior knowledge regarding how to identify an optimal strategy 72% of the students cooperated in the first round of the static trial. By the end of the static trial 12% of the students still persisted in cooperating. But, in general, through the process of repeating the game students were able to learn how to identify the optimal strategy. Then students participated in three rounds of a dynamic version of the game, the final round is presented for spring of 2008 is shown in figure 1. Note that only 78% of the students cooperated in the first round of the dynamic trial even though they should have been able to ascertain that the optimal choice was to cooperate.

Figure 1: Cooperation Rate, Spring 2008



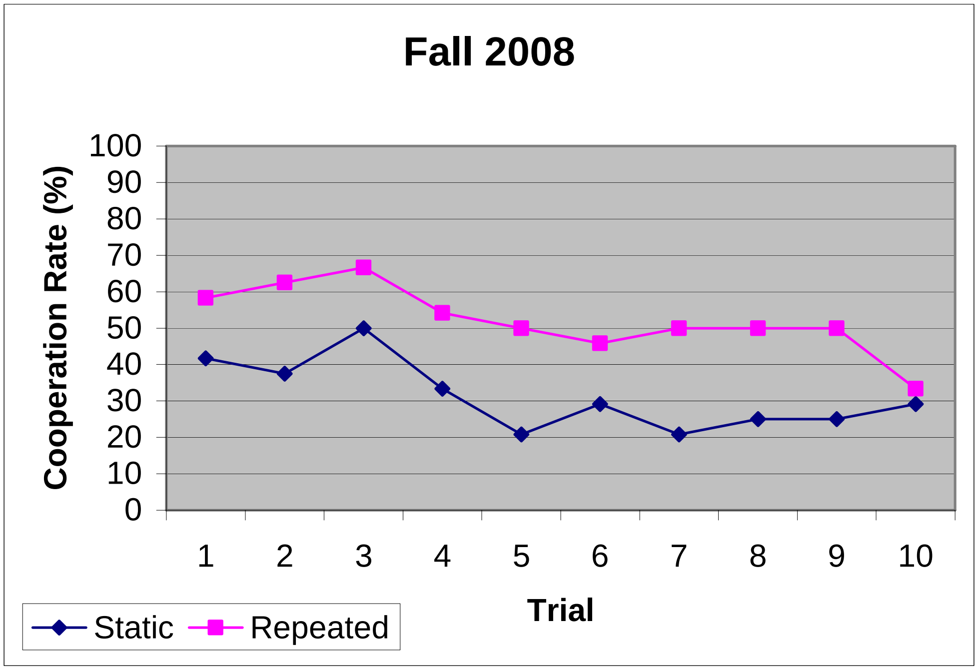
It may seem that the lecture on game theory was not effective, but remember that strategic thinking is a high-level skill that may be difficult for undergraduates to master. In addition, in experimental prisoner's dilemma games it is well-known that players do not always chose the optimal strategy. Cooper, DeJong et al. (1996) test some of the theories that are believed to lead to this result, reputation and altruism, in both one-shot and repeated games, and conclude that these theories do not fully explain the observed cooperation in their experimental games. Brosig (2002) studies the problem from a different angle, communication and signaling. She finds that "the motivation for cooperation, at least in anonymity, is closely related to the capability to signal and to recognize a willingness to cooperate" (p. 286). In addition "after communication, subjects are less inclined to exploit their partner's anticipated cooperation" (P. 286). It is important to note that in my experiment cooperation rates where always higher in the repeated game, which is consistent with economic theory.

In the fall of 2008 (figure 2) the experiment was conducted prior to a game theory lecture. We can see that in the static version of the game the cooperation rate in the first round was 41%. Again, this is not surprising as we know that people may seek to cooperate even when it is not optimal. What is surprising is that in the fall semester, prior to a game theory lecture, the cooperation rate is lower than it was in the spring semester, after a game theory lecture. The lecture may have created a cooperation bias. Using Brosig's language, the lecture may have signaled students to cooperate in order to maximize joint payoffs even though the optimal choice in a static PD is to not cooperate.

Compare the outcomes in the last two rounds of the static trials. In the spring of 2008 the cooperation rates for rounds 9 and 10 dropped below 20%. In the fall the cooperation rates never dropped below 20%, and actually increased in rounds 9 and 10. After some time to apply what they learned in class most of the spring students figured out that the non-cooperative strategy was the best choice, while the fall students began to move away from the dominate strategy.

As expected, cooperation rates for the fall 2008 dynamic game where higher than the cooperation rates for the fall 2008 static game. Cooperation rates in the fall 2008 dynamic game where lower than cooperation rates in the spring 2008 static game, lending credence to the notion that a game theory lecture creates cooperation bias. We see that in the final round of the dynamic game that cooperation rates hit their lowest points. This is consistent with the expected end-game behavior in a repeated PD, cooperation rates should decline through time, reaching there lowest point in the final time period.

Figure 2: Cooperation rate, Fall 2008



Educational Results

It is important to remember that this is not an economic experiment; rather it is a teaching tool. The goal is not to test any particular hypothesis about the PD. The goal is to actively engage students by providing an alternative to a traditional lecture and then determine if performing a PD in class can help students understand concepts related to game theory.

Education results can be found in table 1. Multiple choice and multiple-select questions were embedded in the final exam for the fall 2007, spring 2008 and fall 2008

Table 1: Educational Results

	% of Test Takers		% of Enrollment	
	FA 07	FA 08	FA 07	FA 08
Game Theory Definition	91.67	62.07	60.00	73.33
Game Theory Applications	85.42	41.38	40.00	68.33
Dominate Strategy Definition	87.50	79.31	70.00	76.67
Identify Cooperative Outcome	91.67	89.66	70.00	76.67
Identify Nash Equilibrium	95.83	79.31	76.67	76.67

semesters. The fall exams were administered using Desire to Learn, which is an online course administration system similar to WebCt, while the spring exam was a traditional paper exam. Unfortunately, the spring exam questions were not the same as the fall exam questions, so these exam results are omitted. Regrettably, due to the small sample sizes hypothesis testing is neither useful nor informative. This, of course, can be remedied with more data.

Both of the fall semesters had an enrollment of 30, however only 24 students took the final exam in 2007 while 29 students took the final exam in 2008. Results may be plagued by self-selection bias. In fall 2008 I provided extra credit assignments that were not available in fall 2007, such as extra credit for performing well in this experiment. In effect, giving lower performing students in fall 2008 an incentive to stick with the class that was not present in fall 2007. Likewise, test takers in 2007 may have needed a higher score on the final to obtain a desired grade, and thus may have studied harder. Therefore; I include results as both a percent of test takers and a percent of enrollment.

In fall 2007 91.67% of the test takers could successfully identify the definition of game theory, while only 60% of the enrolled students could. In fall 2008 62.07% of the test takers could successfully do the same, compared to and 73.33% of the enrolled students. When asked to identify potential game theory applications fall 2007 test takes outperformed fall 2008 test takers (85.42% vs. 41.38%), but when comparing enrolment fall 2008 students performed better (40% vs. 68.33%). When asked to identify a definition of a dominate strategy the pattern was the same. As a percentage of test takers fall 2007 students performed better, while as a percentage of enrollment fall 2008 students performed better. When presented with an extensive form game, in terms of test takers, both sets of students performed nearly the same. But in terms of enrollment the fall 2008 class performed better. With regards to the Nash Equilibrium fall 2007 test takers were more successful, but in terms of enrollment there was no difference between the two groups. In both years 23 students were able to correctly identify the Nash Equilibrium, but in the fall of 2008 29 students took the exam while 24 students took the exam in the fall of 2007. In other words, the number of students who mastered the task was the same. But, on a percentage basis it looks like fall of 2008 students perform better. In an ideal setting I would provide a statistical test to compare the difference in proportions and could thus conclude that students learned more when this method is used. However, the sample sizes are small and more data needs to be collected.

It is important for agricultural economists to develop innovative teaching tools, both from the standpoint of improving our own teaching skills and from the standpoint of relating to the students. Therefore, in addition to these student learning outcomes, a peer was asked to observe the classroom during the experiment. During the trial the classroom atmosphere was significantly different from the stereotypical lecture hall environment. The classroom observer noted that students were actively engaged in the learning process, and laughed frequently. In addition the observer noted that the exercise brought out a competitive streak in the students. The observer commented that this competitiveness is a significant incentive to learn and called the method innovative. Students were clearly having fun, and the observer deemed the experiment successful.

Summary:

I present a simple method to supplement lectures on game theory in an undergraduate classroom. Any instructor can replicate this in any classroom as a computer is not required. It is important to note that this is not an economic experiment, and I am not testing any hypothesis about the PD. Rather, I am using an economic experiment in class in order to improve student learning objectives. Toward that end, results indicate that students that first attend a lecture on game theory are better able to converge to the optimal choice in a static game and better able to sustain cooperation in a dynamic game while a lecture on game theory may induce cooperation bias in both static and dynamic games. When assessing educational outcomes it appears that test takers performed better when the experiment was not used. But, there may have been selection bias issues.

Observers noted that students seemed more interested in the subject matter when the experiment was used. However, due to small sample sizes and the potential for uncontrolled bias it is not possible to declare this teaching method a success. More replications are needed. Toward that end I invite my peers to join me in a large scale trial. Materials used in this experiment are provided in the appendix and the reader is invited to modify materials for their own use.

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Appendix

You run a small company that sells anhydrous ammonia to local farmers. You have one competitor in your local market. Because you only have one competitor the two of you will split the market (and the profits) if you both charge the same price. If, however, one of you charges a lower price all of the local farmers will purchase anhydrous ammonia from the supplier with the lowest price. For the sake of simplicity you and your competitor will only choose one of two possible prices, a high price and a low price.

- If you and your competitor *both* choose the high price you both will make $100,000 in profits.
- If you and your competitor *both* choose the low price then both firms will earn $75,000 in profit.
- If you and your competitor choose different prices then:
  - The player that charges the low price will capture the entire market and earn $125,000.
  - The player that chooses the high price will earn $0.

This game can be summarized in the following table:

	Player 2	
Player 1	High Price	Low Price
High Price	($100k,$100k)	($0,$125k)
Low Price	($125k,$0)	($75k,$75k)

The game will be played in three sets, four if we have time. Each set will consist of ten rounds. In set one you will choose a different opponent for each round, in sets two through four you will play against the same opponent for the entire set, but a different opponent for each set.

Set 1

Round	My Move	My Competitor's Move	My Profit
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Set 1 Total Profit: ____________________________

Set 2

Round	My Move	My Competitor's Move	My Profit
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Set 2 Total Profit: ______________________________

Set 3

Round	My Move	My Competitor's Move	My Profit
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Set 3 Total Profit: ________________________

Set 4

Round	My Move	My Competitor's Move	My Profit
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Set 4 Total Profit: _________________________