Bertrand Price Undercutting: A Brief Classroom Demonstration

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Abstract: The author presents a brief classroom demonstration illustrating Bertrand price undercutting. The demonstration is appropriate for micro principles and intermediate- and upper-level undergraduate classes, as well as graduate classes in micro, industrial organization, and game theory.

Key words: Bertrand competitors, classroom experiments, collusion, price undercutting
JEL codes: A1, A2, C7, D4

Bertrand price undercutting is arguably the key concept in analyzing the strategic interaction of price-setting oligopolists as well as in models of screening (e.g., Jehle and Reny 2001). This classroom demonstration translates a lesson about price undercutting into a demonstration that takes as little as 10 minutes and is likely to be remembered by students because of the significant amounts of money each of them could have earned. So far, not one student has earned a significant amount.

I first present design and implementation of the classroom demonstration (the experiment). Then I discuss the game theoretic solution of the experiment and my experiences with it. I conclude by discussing related literatures.

THE CLASSROOM DEMONSTRATION

Design and Implementation

After a standard lecture on Cournot and Bertrand duopolists and oligopolists (e.g., drawing on Stiglitz 1997; Schotter 2000; or Binmore 1992), I introduce an experiment on Bertrand price undercutting with the following instructions that I read aloud and project on a screen[1]:

> Each of you is one of (the number of students in class) sellers in a market in which an unspecified homogenous good is traded. If you all charge a price of 100 Czech Koruns, buyers (the number of students in class) will distribute themselves evenly and each of you will earn 100 Czech Koruns. Of course, because each of you happens to be a Bertrand competitor, you are allowed to offer a lower price (nonnegative integers only). Marginal costs are zero, and fixed costs are zero.

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Buyers are assumed to be price conscious and will go for the slightest of differences. The Bertrand competitor with the lowest price will therefore capture all of the market and will get (the number of students in class) x (difference between her or his price and the marginal cost). Bertrand competitors with identical bids share the spoils (buyers).

Questions?
If there are no further questions, submit your price now. Please initial your record sheet, fold it, and submit it.

Let n be the number of students in the class, T the number of students tied for the lowest submitted price, and p_{min} the lowest price. Then the profit function of participant i in this discrete version of the Bertrand price undercutting game is

$\Pi_i = p_i n$	if	$p_i < p_j$	$\forall\ i \neq j.$
$(p_i n)/T$	if	$p_i = p_j = p_{min}$	for some $j \neq i.$
0	if	$p_i > p_{min}.$	

For more than two players, two equilibria are obvious, requiring all students to choose 1 or all to choose 0.[2] The profit function invites the standard Bertrand price undercutting (unraveling). Prices of 0 and 100 are dominated by a price of 99, which in turn is dominated by a price of 98, and so forth.[3]

Multiple variations suggest themselves. First, the stakes can be varied arbitrarily.[4] Second, students are likely to argue that they would have done better had they been allowed to coordinate their strategy. The instructor may want to afford them that opportunity and allow students to appeal to the common interest, either before a repeat round or before the first round.[5] Third, the instructor may want to introduce a marginal cost of 10, thus setting the price range at 10–100.

This classroom demonstration is easy to implement. It requires only pieces of paper (record sheets) on which students can write their prices. After the classroom experiment has been conducted, I read aloud the submitted prices, pay off the winner(s), and then let the class discuss what happened. I often hear the suggestion during such discussions that everything would have ended differently had they been allowed to communicate beforehand.

Experiences

I conducted this experiment in a preparatory class of about 60 prospective graduate students at the Center for Economic Research and Graduate Education of Charles University in Prague in the summer of 2000.[6] At the time, 100 Czech Koruns corresponded to about $3 U.S. but was significantly more in terms of real purchasing power (especially for our students, who come almost exclusively from Central or East European transition countries); the total would have easily and generously financed the students' upcoming beer party. In any case, with 60 students, it was clearly a high-stake gamble under any circumstance. Indeed, one student incredulously asked me whether I was serious about this classroom experiment. Not to worry: The lowest price (set by two people) was 1, and one other person set a price at 2, driving home the issue of Bertrand price undercutting and the difficulty of collusion.[7]

I also used the experiment in the third course of our micro core sequence. Of the 24 students attending class that day (the majority of whom had participated in the first experiment the previous summer), 2 offered a price of 0; 13 offered a price of 1; 1 each prices of 3, 4, and 10; and 6 students offered 100. Most recently, I conducted this experiment in a master's level micro course at the University of Ljubljana, Slovenia. Bids of the 58 students attending the lecture were dispersed over the admissible range (nonnegative integers from 0 to 200), with a third clustering at 0 and 1 and less than 10 percent clustering between 195 and 200 tolars (roughly one dollar).[8]

In general, I have observed the following trends for this classroom demonstration and for a related one (discussed in the following section): First, the higher the stakes, the more likely unraveling becomes.[9] Second, allowing students to discuss the welfare maximizing solution will have a negligible effect on the outcome, but an instructor ought to make sure that prices are written down privately, for otherwise peer pressure might be effective. (Recall note 5.) Third, repetition of the experimental session leads to even stronger unraveling (if unraveling happened in the first round).

RELATED LITERATURE

This classroom demonstration is related to four literatures. First, the literature of classroom experiments on social dilemmas (Delemeester and Brauer 2000). Specifically, the prisoner's dilemma has been used as a paradigm for price competition (Holt and Capra 2000, 232). Although it is useful to show students that a simple game like the one-shot prisoner's dilemma captures the essence of various strategic situations, idiosyncratic aspects of price undercutting such as the iterative nature of the unraveling process (i.e., the iterated elimination of dominated strategies discussed above) are not captured. The current classroom experiment drives this point home effectively.

Second, this classroom experiment is related and would be a natural introduction to the rapidly increasing literature on guessing games and depths of reasoning, a topic which, in my view, is highly appropriate for intermediate- and upper-level undergraduate as well as graduate micro, industrial organization, and game theory classes. In the guessing game, participants are invited to submit a number between (and including) 0 and 100. (Several variants of this experiment exist, such as nonnegative integers only or nonnegative rational numbers.) The winning number is the submission closest to the average of all submitted numbers multiplied by a number p.

If p is taken from the open unit interval (e.g., ½), then it is trivial to see that the unique Nash equilibrium is 0. One of the intriguing aspects of the guessing game is the opportunity that it allows to make inferences about the levels of depths of reasoning. Take for example the case of $p = ½$. If everyone were to randomly draw their number from the interval [0,100], then the average would likely be around 50. The resultant number multiplied by $p \in (0,1)$ would have a good chance at being the winning number for a person who would anticipate correctly that everyone else will draw randomly (i.e., has "zero-order belief"). It is very likely, however, that most people engage in that kind of reasoning. Therefore the person who correctly anticipates other people's first-order beliefs (i.e., people's best response to what they believe is everyone else's zero-order belief) should best respond by multiplying 50 by p^2. And so on. Note that the exponent of p reflects the levels of iterative reasoning in which participants engage. Nagel (1995; see also her other articles) showed that participants typically employ one or two and, very occasionally, three such reasoning steps. This result has been shown to be robust across numerous subject pools.

Nagel (1995) spawned a most interesting literature on boundedly rational reasoning and the heterogeneity of agents. Although this material strikes me as inappropriate for principles and intermediate classes, it should be introduced in upper-level undergraduate and graduate courses. Because several nice summaries of the literature are available (Nagel 1995, 1999; Nagel et al. 1999), the present brief summary shall suffice.

A third related piece of literature, Dufwenberg and Gneezy (2000), explores the sensitivity of Bertrand price undercutting to the number of competitors. They found that the Bertrand solution does not predict well when the number of competitors is two but predicts well (after participants have been given opportunities to learn) when the number of participants is three or four.[10] This material addresses, among other issues, experimental design and implementation (Hertwig and Ortmann 2001); it, also, may be too advanced for principles and intermediate classes. That said, it makes for great material in upper-level undergraduate and graduate game theory and/or experimental economics courses. Because Dufwenberg and Gneezy (2000) is eminently readable, I will not elaborate here.

Finally, the present classroom demonstration is isomorphic to the following variant of collusion and common resource experiments (experiment 5 in Ortmann and Colander 1995):

> I have here [number of students times number of quarters] dollars. You are to bid for these dollars privately by submitting to me a bid on a piece of paper. Whoever has the highest bid will get [. . .] dollars minus his or her bid. If several of you submit an identical bid, those students will share the difference between the . . . dollars and the value of their (identical) bids.

Note that a bidder in this scenario, like a price setter in the Bertrand price-undercutting game or a participant in the guessing game, has to figure out the most likely bid (price, number) of all other participants to determine the winning bid. Having gone through the requisite reasoning, a participant will understand that others might reason similarly, setting in motion the same unraveling process triggered in the Bertrand or guessing-game scenarios.

CONCLUSION

It is well known that, although an increased emphasis on interactive teaching has materialized over the past five years, much of what happens in the economics classroom still fits the "chalk and talk" paradigm (Becker and Watts 2001). This unfortunate state of affairs has not been affected much by mounting evidence that classroom experiments can enhance the learning experience significantly (Gremmen and Potters 1997). In this article, I offered a brief classroom demonstration that I have found effective in my teaching of Bertrand price undercutting.

NOTES

1. A referee suggested that the instructions were too suggestive and proposed an alternative formulation which, slightly modified, I have since repeatedly used:

   > You are one of [the number of students in class] potential sellers who has to state a price between 0 and 100 Czech Koruns (nonnegative integers only) to sell a homogenous good to [the number of students in the class] potential buyers. The seller with the lowest price will capture the entire market and will receive [difference of his price and marginal costs] × [number of students in class] Czech Koruns. If there are ties for the lowest price, then the buyers are split among those who tie. Those with a higher price will receive nothing. Marginal costs are zero, and fixed costs are zero.

   This formulation, which does not use the terms "Bertrand price undercutting" and "Bertrand competitor," should also be used if an instructor prefers to do the experiment before lecturing on Cournot and Bertrand competition.
2. There are also a number of not so obvious Nash equilibria if $p_{min} = 0$ for T players such that $2 < T < n$ whereas others set $p > 0$. Note that for $n = 2$, this discrete version of the Bertrand game introduces three Nash equilibria at (0,0), (1,1), and (2,2), all with 0 or negligible profits. Of these equilibria, only (1,1) is strict and hence may be viewed as "best." Because the present classroom demonstration is not likely to be conducted in classes this small, I will not discuss the equilibrium selection problem in detail. See Dufwenberg et al. (2001) for such a discussion.
3. This unraveling is, of course, conditioned on the extreme price sensitivity induced by the postulated homogeneity of the good. The story for differentiated goods is different (see Binmore 1992, 335).
4. *Stake*s here means the money the instructor puts at stake. In the instruction, for example, one could have used 50 Koruns or 200 Koruns instead, that is, the price range can be contracted or expanded according to the instructor's risk attitude and budget constraint. It is likely that the attention of students is related positively to the amount of money that is at stake (Hertwig and Ortmann 2001); it certainly is in my experience. For that reason alone, I always use significant monetary payoffs in this classroom demonstration and in related ones of the social dilemma variety. I never use credit points in classroom demonstrations; the payoff of a student being a function of others' action choices could mean that I am asking for trouble from a student who does not like her or his grade. In addition, Brown-Kruse and Thompson (2001) provide intriguing evidence that the choice of a reward medium may make a difference in some settings. If, nonetheless, an instructor prefers credit points, they may be used in the obvious manner; just say points instead of Koruns and determine beforehand the conversion factor for credit points.
5. To make sure students write down their prices privately, the instructor may add the following instruction: "You have . . . minutes to discuss your optimal group strategy. (Hint: What happens if you all set a price of 100?) Do not write down your bid until you are asked to do so. Physical and other threats are unacceptable means of enforcement in this experiment."
6. Students may object that such a large number of participants (Bertrand oligopolists) rarely exist in the real world. In response, you may want to mention NASDAQ traders and bid-ask spreads before and after decimalization. You may also want to refer students to Selten (1973), whose theoretical work has since found convincing support in experimental research (e.g., Friedman 1996).
7. I allowed students in this instance to discuss briefly what the optimal strategy would be for the class as a whole. I then let students write down their prices privately. About 85 percent of them did write down a price of 100.
8. In both experiments described in this paragraph, I used the reformulation of the instructions proposed by an anonymous referee (see note 1). However, I did not allow students to communicate.
9. Gneezy and Rustichini (2000) have suggested that this relationship may not hold for very small payments.

10. Dufwenberg, Gneezy, Goeree, and Nagel (2001) found evidence that, for the case of two sellers and the price range [10, 100], the behavior unravels to the equilibrium, in contrast to the results reported in Dufwenberg and Gneezy (2000) where the price floor was 0.

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