An In-class Pricing Game

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ABSTRACT

An in-class price competition is discussed and analyzed. Students are distributed into five firms that choose their prices in a framework in which they know the demand and cost conditions facing them and their rivals. Students learn about trying to maximize profit in an oligopolistic environment with differentiated products. The game, and subsequent discussion and analysis can be used for reference when covering standard theoretical principles of price competition. Furthermore, the instructor can use insights from the game to help illustrate pricing practices seen in real industry.

I. INTRODUCTION

Many Microeconomics and Industrial Organization students learn about price competition models such as the classic Bertrand duopoly model, the Hotelling linear city model, and other models of price competition in the course work. For examples in Industrial Organization, see Pepall, Richards and Norman (2008). However, students can gain deeper understanding and ability to apply the models if they experience price competition and analyze their experience in a simulated market setting. The game in this paper was developed to help students achieve this. After students have experience with this game, the instructor can readily compare course concepts to aspects of the game that students have played. When students play this game and analyze it, they tend to have a better understanding of pricing principles in general. For a game somewhat related to this, see Eckalbar (2002). However, Eckalbar only has two firms, and players choose prices based on a payoff matrix. For a quantity competition game similar to the one in this paper, see Meister (1999).

II. SETUP AND INSTRUCTIONS

Students are to read the following set of instructions for the game.

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OLIGOPOLY PRICING GAME (INSTRUCTIONS)

You and your teammates are going to run a firm in an oligopolistic industry with five firms. In your industry, you produce a product differentiated from those of your competitors. Your decision is what price to charge for your product during each time period. The price you charge, the prices your competitors charge, and the demand curve facing your firm determines how much output you sell. Thus, your profit will depend not only on your own price, but also on the price levels chosen by your rivals.

You have the same production technology as your rivals (i.e., the same constant Marginal Cost and the same level of Total Fixed Cost). This information will be common knowledge among all firms in the industry. You will not know the price levels chosen by your competitors in a given round until you see all the results from that round. However, you will be able to see your competitors' pricing histories as the game progresses. Assuming you are firm *i*, you have the following things to consider.

Your price:	p_i
Rivals' price levels:	$p_j \qquad i \neq j$
Demand facing firm *i*:	$q_i = \max\{230 - 8p_i + \sum_{j \neq i} p_j \ , 0\}$
Constant MC:	$c = \$20$
Total Variable Cost for *i* :	$TVC = c\,q_i = 20q_i$
Total Fixed Cost for all *i* :	$TFC = \$300$
Profit for firm *i* :	$p_i = TR_i - TVC_i - TFC_i$
	$= P_i q_i - 20q_i - 300 = (p_i - 20)q_i - 300$

Additional Comments

Using the information above, one should note that if all five firms charge a price of $22, all firms would have negative profit. Also, if all firms charge a price of $56, all firms would have a negative profit.

I will divide each team's profit by a pre-determined number, and that is how many extra credit points each of your team members will earn! Extra credit will be added after the grade scale is determined. You will not be told when the game ends.

If a firm (or firms) price such that quantity demanded is zero, I will impute price(s) to the firm(s) selling 0 such that the imputed price would cause the firm's (or firms') quantity (or quantities) demanded to be exactly 0. Thus, if Z is the set of firms pricing such that they sell 0, I will impute price(s) to the firm(s) of

$$\bar{p} = \frac{230 + \sum_{j \neq i} p_j}{8 - (z - 1)},$$

where *z* is the number of firms in Z.

END OF INSTRUCTIONS

The instructor should inform the students that the "max" operator on the demand function, $q_i = \max\{230 - 8p_i + \sum_{j \neq i} p_j, 0\}$, is there in case some firm charges such a high price relative to the others that $q_i = 230 - 8p_i + \sum_{j \neq i} p_j < 0$. In this case, the quantity will be truncated to be zero.

In past trials, firms have typically been comprised of three to seven students each, depending on the size of the class. Students in Principles of Microeconomics, Industrial Organization, and Managerial Economics have participated in this game. It is a good idea to give students ample time to work through examples on their own before they play. Thus, it is advisable to have students confer in part of one class period and then actually play the game in the next class period. Outside of perhaps spending more time on examples, no modifications of the game are necessary for Principles' students (as long as they have covered things like marginal revenue, marginal cost, monopoly, and profit calculations).

III. PRE-GAME ANALYSIS

A. NUMERICAL EXAMPLE

The Instructor may decide to give students a numerical example to help them get accustomed to working the details of the game. If all firms were to choose a price of \$50, then firm *i* would sell

$$q_i = \max\{230 - 8p_i + \sum_{j \neq i} p_j, 0\}$$

$$= \max\{230 - 8p_i + \sum_{j \neq i} (50), 0\}$$

$= \max\{230 - 8(50) + 200, 0\}$, because $\sum_{j \neq i} (50) = 200$, due to there being four other firms;

$$= \max\{30, 0\} = 30.$$

Then, we can substitute this into firm *i*'s profit equation to obtain:

$$p_i = (p_i - 20)q_i - 300$$

$$= (50 - 20)(30) - 300$$

$$= 900 - 300 = 600.$$

B. RESIDUAL DEMAND DISCUSSION

To conduct more pre-game analysis, the instructor may wish to introduce the students to the concept of the residual demand function. This is the demand facing firm *i* once all other firms' prices (or predicted prices) are taken into account. In this game, we obtain firm *i*'s residual demand function the following way. First, invert the positive part of firm *i*'s demand function, $q_i = 230 - 8p_i + \sum_{j \neq i} p_j$, and obtain

$$p_i = \frac{230 + \sum_{j \neq i} p_j}{8} - \frac{1}{8} q_i .$$

The instructor can graph this noting that the intercept term is the first term on the right-hand-side of the equation above. Then note that as other firms increase their prices, $\sum_{j \neq i} p_j$ increases. Therefore, the residual demand facing firm *i* increases. This is analogous to a case in which Coke sees an increase in its demand when Pepsi increases its price, ceteris paribus.

Next, note that for linear demand, marginal revenue has the same intercept, but is twice as steeply sloped. Thus,

$$MR_i = \frac{230 + \sum_{j \neq i} p_j}{8} - \frac{1}{4} q_i .$$

It may be useful to remind students that in a one-period framework, profit for firm *i* is maximized at the quantity for which MR = MC, and then the optimal price would be read off of the demand curve. The instructor may go into more detailed examples if desired.

IV. RESULTS FROM A "TYPICAL" GAME

Next, results from a "typical" game are given. The word "typical" is used loosely, here, but most games have ended with prices near the range they would be in a one-period, simultaneous choice Nash equilibrium (which by the way would be all firms charging $32.50 – more on this later). Students are also instructed that admissible prices must be multiples of $0.25. This seems to make adjustments in the game move at a faster pace than if they can change prices by a penny. The Spreadsheet in Table 1 below lists the round of the game in the leftmost column, entitled "Rnd#1." The second column, "p(i)," gives the five firms' prices for each round. Note below that in round 1, firm 1 charged a price of $24, firm 2 charged a price of $25, firm 3 charged a price of $40, and firms 4 and 5 charged a price of $30. The third column, q(i), tells the quantity each firm sold under these prices. The entry uses the demand equation. For firm 1 in this case, $q_i = \max\{230 - 8p_i + \sum_{j \neq i} p_j, 0\} = \max\{230 - 8\,(24) + (25+40+30+30), 0\} =$ 163. The fourth column, prof(i), gives each firm's profit and uses the profit equation given in the instructions. Note that in the first round, firm 1 had a markup of $4 over its constant marginal cost of $20, and sold 163 units. This gives total markup of $652, but then the fixed cost of $300 must be subtracted, to arrive at the profit of $352. The fifth column, avg proft(i), simply keeps track of a given firm's average profit per round as the game progresses. The sixth column, e.c., gives the current status of a firm's extra credit (which is a firm's average profit divided by 300 – the instructor can choose different numbers, of course.). Please note that the level of extra credit can fluctuate like a thermometer during the game. Students should be made aware of this so that they do not think extra credit on the spreadsheet readout is cumulative. Also, a spreadsheet is used by the instructor and projected onto a screen so that students can view what is happening during the game. Students will not know what prices their rivals are choosing in a given round, but they will see the prices chosen when all are entered for that round. Therefore, students will see the pricing histories of their rivals as the game progresses.

Table 1: Spreadsheet of a Past In-class Game

Rnd #1	p(i)	q(i)	prof(i)	avg prof(i)	e.c.
1	24	163	352	352	1.173333333
	25	154	470	470	1.566666667
	40	19	80	80	0.266666667
	30	109	790	790	2.633333333
	30	109	790	790	2.633333333
AvgP,1	**29.8**				
2	28	122.5	680	516	1.72
	27.5	127	652.5	561.25	1.870833333
	28	122.5	680	380	1.266666667
	32.5	82	725	757.5	2.525
	28.5	118	703	746.5	2.488333333
AvgP,2	**28.9**				
3	31.99	99.78	896.3622	642.7874	2.142624667
	33.7	84.39	856.143	659.5476667	2.198492222
	27.75	137.94	769.035	509.6783333	1.698927778
	33.5	86.19	863.565	792.855	2.64285
	30.75	110.94	892.605	795.2016667	2.650672222
AvgP,3	**31.538**				
4	32.5	98.75	934.375	715.6843	2.385614333
	32.75	96.5	930.375	727.2545	2.424181667
	30.75	114.5	930.875	614.9775	2.049925
	33.5	89.75	911.625	822.5475	2.741825
	31.75	105.5	939.625	831.3075	2.771025
AvgP,4	**32.25**				

Note from Table 1 that in the first round of the game, the average price was $29.80. The low price was firm 1 at $24 and the high price was firm 3 at $40. Firm 1 sold the most, but had a meager $4 markup. It had the second-lowest profit. Firm 3 had a $20 markup, but only sold 19 units and only had profit of $80. Both of these firms could do after-the-fact analysis and see that they could have done better. Firm 1 could have increased its profit by increasing its price by a dollar (for example). If it had charged $25, its markup would have been $5, it would have sold 8 fewer units (recall the own-price coefficient on a firm's demand curve is "8"), which would have been 155. Thus, firm 1's profit would have been $p_i = (p_i - 20)q_i - 300 =$ \$5*155 – \$300 = \$475, which is noticeably higher than \$352 it earned in round 1. In fact, if firm 1 were to set $MR = MC$ as discussed in a previous section, it could have solved for its optimal quantity, then plugged that back into its residual demand curve to get its optimal price. Of course, this is all after-the-fact analysis, but it can give a firm an idea of where things stood in the previous round, and may help the firm figure out what it wants to do in the next round. Firm 3 could do similar calculations to determine it could have made more profit by charging a price lower than the \$40 price it chose in round 1.

Note in round 2 that the low price firms (firms 1 and 2, charging \$24 and \$24, respectively) decided to increase their prices (to \$28 and \$27.50, respectively). Note also, that the highest-priced firm (firm 3) decided to lower its price from \$40 to \$28. The two middle-priced firms (4 and 5) kept their prices about the same. The more extreme priced firms (1, 2, and 3) saw their profits increase, but the middle-priced firms saw their profits decrease somewhat primarily because the average price came down from \$29.80 to \$28.90. After this, it appears that firms may have been figuring out what was best given the other firms' choices, and that other firms were thinking this way to. It seems to be this way because the price drifted toward what would be the one-period, simultaneous-choice Nash equilibrium of this game (i.e., all firms pricing at \$32.50). In the last round of this game, the average price was \$32.25, without much variation. This average happens to be equal to the one-period, simultaneous-choice Nash equilibrium of this game.

Although repeated games with unknown numbers of rounds may have multiple equilibria, this game has usually ended up relatively close to the one-period, simultaneous-choice Nash equilibrium. Perhaps this is due to the fact that the students attach a higher probability to the rounds that are close to the end of the class period, and effectively treat it like the last round. Regardless, this does give the instructor opportunity to discuss the concept of Nash equilibrium in the context of this game.

V. POST-GAME ANALYSIS

As mentioned in the previous section, the instructor can illustrate that all firms charging \$32.50 is a one-period, simultaneous-choice Nash equilibrium of this game. One could do this mathematically, but immediately following the game, it may be more instructive to illustrate it on computer via overhead projection. The instructor can type in all five prices at 32.50, and students will see that each firm sells 100 units and earns profit of \$950. Then the instructor can change one firm's price (unilaterally) to \$32.25 and see that profit for that firm falls below \$950. Similarly, the instructor can change that firm's price to \$32.75 and see that profit for that firm falls below \$950 as well. Thus, if the other firms are charging \$32.50, the best the remaining firm can do is to charge \$32.50 as well. This will hold for the other firms as well by the symmetry of the setup. (The instructor can discuss how things might be different if one firm, for instance, had a lower constant marginal cost than the other firms.) This can be used as a springboard for discussion about where prices come from in oligopolistic markets. Other aspects of the game could be discussed here as well.

VI. COOPERATION

An interesting experiment would be to allow one round of cooperation by allowing students to talk across teams and make agreements if they like. At some point, it is useful to tell them they can talk no longer across teams, and subsequently make their decisions and hand in their prices independently. If an agreement is made to charge higher prices than have prevailed during the non-cooperative game, many teams will tend to undercut the agreement at least to some degree (at least they often have in past trials). Then it would be a good idea to discuss what is going on in this case.

After this experiment, the instructor may tell the students that if all choose a price of $38.75, the sum of the five firms' profits (joint profit) will be $1106.25. The quantity that each firm will sell in this case is 75. Then, we can use the residual demand and its associated marginal revenue to explain the incentive the individual firm has to undercut the agreed-upon, higher price. Start by looking at the one-period, simultaneous-choice Nash equilibrium of all firms charging a price of $32.50, and each firm selling 100 units and earning profit of $950. Now suppose all five firms agree to charge a price of $38.75. As stated before, this will cause each firm to sell 75 and earn profit of $1106.25. From firm *i*'s point of view, however, the increase in the price of the other firms' prices (from $32.50 to $38.75) will increase its residual demand (and its associated marginal revenue). Thus, firm *i* has individual incentive to sell more than it did in the one-period, simultaneous-choice Nash equilibrium (which was 100 units). However, we said that firm *i* would only sell 75 if it increases its price to $38.75 along with the other four firms. Therefore, if firm *i* were to undercut the agreed-upon price of $38.75, it could sell more than 75 (and in fact more than 100 if it were to cut its price enough). The instructor could discuss the idea of the "Best Response" function here. Unfortunately for all of the firms, they have this same individual incentive to undercut the agreed-upon price of $38.75. Therefore, it should not be surprising that players often price at a lower level than they agreed to in market experiments like this one. The instructor might find it valuable to discuss cases of such pricing agreements and their stability. (If the instructor decides to run the non-cooperative part of the game for extra credit, it may be better not to do the cooperative part for extra credit because of the individual incentive to cheat on the collusive agreement.)

VII. CONCLUSION

I have found this game to be very useful in helping students understand a variety of principles for pricing. As an instructor progresses through the course and introduces topics such as best-response functions, Nash equilibrium, residual demand functions, joint profit maximization, and undercutting collusive pricing agreements, (s)he can refer to elements of this game and students' experience with it to help students gain a deeper understanding for the application of the analytical models they are learning. Furthermore, students can gain more facility in analyzing real markets by comparing aspects thereof to what they have learned from this game and beyond.

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