AN IN-CLASS EXPERIMENT WITH AUGUSTIN COURNOT

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Introduction

Cournot theory of duopoly explains a model of oligopoly very suitable for economic experiments [7]). It occurs when just two firms share a large portion of the industry. Because there are only two firms, each one when decides about its actions has to take into account the other firms' reactions. Since firms may strategically interact in different way and be unpredictable, there is not a single model of duopoly [3], [5], [6]. This paper focuses on the Cournot model of duopoly.

Students in microeconomics are used to approach the topic of the oligopolistic market structures in a strictly theoretical, old fashion, yet effective manner. Since this year, at the University Matej Bel, it was decided to give to the students the possibility to study the oligopoly theory in a learning-by-doing style. A possible way for doing this is to run an in-class experiment after discussing with students the textbooks' parts on oligopoly and game theory [4]. At the end of the experiment, students reported that they have really learned what it is like to strategically interact in an industry in which firms have some influence on the market variables but not absolute control. They have also reported that it is an exciting challenge to elaborate strategies in order to gain the highest profits.

The main finding of the experiment is that at the beginning of the game students were producing more than the quantity that should have been theoretically produced in equilibrium. They were producing too much thinking to do so was the optimal choice. Then, output levels came close to the equilibrium quantity as the game advanced. Noteworthy, in the last rounds, students were able to coordinate on collusive outcome. Then, at the end of the game, in the very last round, known in advance by students, the temptation to cheat on the other group yielded a Pareto inefficient outcome. Due to the high level of output and the resulting low market price, the total industry profit was lower than in the case of both Cournot and collusive outcome.

The paper is structured as follows: Section 2 describes the rules of the in-class experiment. Section 3 reports on the theoretical equilibrium of the one-shot game. Section 4 shows the results of the experiment. Section 5 concludes.

1. Description of the Experiment

In order to run the experiment, students in the class are divided into two groups of firms (A and B) belonging to the same duopolistic industry. The game lasts 10 rounds and students know in advance how many rounds the game will last. Even though, this is not a good approximation of the reality because normally firms do not know ex-ante when the market for their products will dry up [4], it allows the experimenter to focus on the possibility to have weird behavior due to the fact that the game is in its last round. For every round, each group has to decide its profit maximizing output level. When decisions are taken, the market price is unknown because it depends on the total output produced in the industry. The game played between the two groups is a simultaneous-move quantity-setting á la Cournot, where each group when deciding has to make assumption about the rival's decision.

One worksheet was distributed (see annex 1) to each group of students (firm) in the duopolistic industry. The inverse market demand in the form of price as a function of total quantity and the cost function are known in advance by the students. In the cost function there are not fixed costs. The production technology is the same for all firms and so the marginal cost. Students have information about the capacity constraint. But, they do not know in advance the market price. The common market price, at which it is possible to sell all the units produced in any round, is determined by the total industry production. Therefore, it depends not only on the decision of a single group, but also on the decision of the other group. So, what makes the game interesting is to let students interact in each group when deciding its strategy so that they have to make assumptions about its rival's strategy and, since the game is repeated, they should learn from past events. For every round, each group reports its quantity, the other group's quantity, the common market price of the good, its profit and the other group's profit. Note that, students are not explicitly forbidden to tacitly collude although exchange of information between them is not allowed.

To stimulate students to maximize profit, each student earns extra credit depending on the whole group's average profit yielded over the game. Students belonging to the same group receive the same number of extra credit points. For this experiment, the duopolistic industry is endowed with 10 extra credit points to be divided between the two firms (groups of students) proportionally to the share of the average profit yielded over the game. The higher the average profit earned by a group, the more extra credit points are earned by each member of the group. Consequently, students would have an incentive to maximize their group's profit because the more extra credit points they earn, the more easily they will pass the exam of microeconomics. Note that the final course grade is fundamentally based on a written test (100 credit points), and then the extra credit points (up to 10) from the in-class experiment are added.

2. Note on the Nash Equilibrium of the One-Shot Cournot Games

The Nash equilibrium of the one-shot Cournot game assumes that firms set quantities simultaneously and in order to maximize profit each firm has to make assumption about the other firm's output choice [2]. Let q_1 and q_2 denote the quantities produced by firms 1 and 2. Let $P(q_1+q_2)= = a-b(Q)$ a generic linear inverse market demand function or, in other words, the market price prevailing in the industry when the total quantity is $Q=(q_1+q_2)$. Yet, let assume a constant marginal cost equals c, the same for both firms. In order to solve for the Nash equilibrium of this game, we have bear in mind that for this model of duopoly, the profit maximization problem facing both duopolistic firms is symmetric since the production technology is the same for both firms and so the marginal cost. Given that, each duopolistic firm's profit (π) can be written as a function of the rival's quantity as:

$$\pi_1=(q_1,\ q_2)=q_1\,[P(q_1+q_2)-c] \qquad (1)$$

$$\pi_2=(q_1,\ q_2)=q_2\,[P(q_1+q_2)-c] \qquad (2)$$

The symmetric maximization problem facing each firm can be stated as:

$$\max_{q_1} \pi_1(q_1,\ q_2)=\max_{q_1} q_1\,[a-bq_1-bq_2-c] \qquad (3)$$

$$\max_{q_2} \pi_2(q_1,\ q_2)=\max_{q_2} q_2\,[a-bq_1-bq_2-c] \qquad (4)$$

Then, the first-order condition for solving it implies that the first (partial) derivative with respect to q_1 in (3) and q_2 in (4) must be equal to zero:

$$\frac{\partial \pi_1}{\partial q_1} = a-2bq_1-bq_2-c=0 \qquad (5)$$

$$\frac{\partial \pi_2}{\partial q_1} = a-bq_1-2bq_2-c=0 \qquad (6)$$

which yield the two duopolistic firms' (symmetric) reaction functions:

$$q_1=f(q_2) \qquad (7)$$

$$q_2=f(q_1) \qquad (8)$$

So called since they computes each firm's best reaction to any given output choice by the rival [1] solving the system (9)

$$\begin{cases} q_1=\dfrac{a-bq_2-c}{2b} \\ q_2=\dfrac{a-bq_1-c}{2b} \end{cases} \qquad (9)$$

yields

$$q_1=\frac{a-c}{3b}\quad q_2 \qquad (10)$$

the Nash equilibrium of the Cournot duopoly game.

In the in-class experiment, the Nash equilibrium of the one-shot Cournot game predicts that each player produces 4 units of output. This is an equilibrium because each player maximizes its own profit given its rival's output choice and no group has an incentive to deviate from its predicted choice [1], [2], [3]. This simultaneous-move equilibrium yields a common market price of 9 and a total industry output of 8 units. The profit earned by each group is equal to 32 and the total industry profit is 64.

If the theoretical Nash equilibrium is realized in every round of the whole game, each group and group's member as well will earn 5 extra-credit points and increase his/her final course grade by 5 percent (100 points are available from the written test).

If the agreement about the quantity produced is realized between the two groups the total output will correspond to the collusive profit maximization output level. To secure maximum of joint profit the total output will be fixed at the point where the marginal revenue and marginal cost curves intersect each other. In the case of experiment the joint-profit maximization output level is 6 units (3 units produced by each firm). Although collusion was not allowed, two groups could tacitly collude by watching each other's performance.

3. Outcome of the Experiment

This experiment, which was run during one of the classes of microeconomics, lasted ten rounds.

In the first round, the industry total quantity produced is too much and, being the common price determined by the sum of quantities, the profits are zero.

In the second round, the group A notably reduced the quantity (from 8 to 2 units) while the group B kept production to the same level as the previous round (6 units). Due to the increased common price (9), the group B, which kept constant the output, earned a higher profit cheating on the group that reduced the output.

In the third round, the consequence of such a free-rider behavior on the part of group B can be figured out. The group A, which reduced the output in the previous round, now sharply increases its output as a sign of punishment against the rival group (from 2 to 6 units). Due to the very high industry total production (12 units) the resulting market price is too low (1) and no profits are earned by either group.

In the fourth round, the profit maximizing equilibrium quantity is produced by each group (4 units). The common market price is equal to 9 and each group earns a profit equal to 32.

In the fifth round, while the group A kept constant the output level (4 units), the group B chose to reduce its output and produce the joint-profit maximization output level (from 4 to 3 units), which corresponds to the collusive profit maximization output level.

In the sixth round, a failed attempt to collude can be detected since the group A, which was producing its Cournot equilibrium quantity (4 units) in the previous round, is now choosing to maximize the industry joint-profit and produce 3 units of output. Simultaneously, the group B, which already was producing the collusive profit maximization output level (3 units) in the previous round, is now choosing to produce its Cournot equilibrium quantity (4 units).

In the seventh round, both groups implemented the same strategy as the previous round keeping production to the same level.

In the eight and ninth rounds, is interesting to note that the two groups of students were able to coordinate on the collusive output level below the Cournot duopoly theoretical prediction. Holt [3] argues that the reason has to be found in the fixed nature of the matching, whereby if matching were random the players of the experiment couldn't coordinate. Even though generally accepted, the previous argumentation doesn't take into account the existence of an incentive to cheat on the rival through an output expansion. Indeed, the collusive profit maximization output level even though yields the highest profit as possible for both firms is not a Nash equilibrium, since each group is tempted to produce more. This can appear clearer observing the behavior of group B in the very last round.

In the tenth and last round, known in advance by the students, one group of students (group B) cheated on the rival one, increasing the output produced (from 3 to 6). The resulting raise in total industry output (9 units) decreased the market price and, as a result, the group A that kept constant the output level saw its profit shrank. At the very end of the game, neither Cournot nor collusive outcome was reached but the temptation to free ride and cheat on the rival group prevailed.

Concluding Remarks

The following class, students were asked to write an anonymous report about their experience. They emphasized:

It was an original, interesting and helpful way for a better understanding of the oligopolistic market structure to link the theory with a more practical example. It was stimulating and challenging for students to seek to develop strategies for attempting to maximize their profit and extra credit points. Playing the game helped students to have a more concrete idea of what in reality appears to be the maximization-profit problem facing a duopolist. The possibility of gaining some extra credit points, proportionally to the average profit earned by each group over the game, has been detected as a good motivation for more carefully take into consideration the potential rival's reaction. It also stimulated both a competitive atmosphere between groups and a cooperative spirit within the same group.

As suggestion for further research, this duopoly game could be extended to show the impact of different industry-size on the equilibrium level of output and market price (i.e. triopoly). Undoubtedly, what we expect is that the three-firm industry's equilibrium will be at a higher output level and a lower market price than that of the two-firm industry. Another possible extension of this game could entail running the experiment before the theoretical lecture has taken place so that students next should try to discover the theoretical foundations by themselves. In educational terms such an approach is also known as "discovery learning" or "inductive learning".

Annex 1

In-class experiment worksheet and outcome of the experiment

Description of the simultaneous-move quantity-setting duopoly game á la Cournot

Your choice is about your own quantity to produce each round. Remember, that the market price depends on the total industry output. Thus, your profit will depend not only on your output, but also on your rival's output. The game will last 10 rounds. You have information on the inverse market demand, the total cost and the marginal cost functions. Note that there are not fixed costs. Also you have a capacity constraint of 10 units of output to be produced. Then, for every round, each group has to reports its quantity, the other group's quantity, the common market price of the good, its profit and the other group's profit.

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Industry: group:

Members' name:

Cost function: TC = q MC = 1

Capacity constraint: 10

Determination of Price as a Function of Total Quantity

Q = $q_1 + q_2$	1	2	3	4	5	6	7	8	9	10	11	12	13 +
Price	23	21	19	17	15	13	11	9	7	5	3	1	0

Round	Group A quantity	Group B quantity	Market price	Group A profit	Group B profit
1	8	6	0	0	0
2	2	6	9	16	48
3	6	6	1	0	0
4	4	4	9	32	32
5	4	3	11	40	30
6	3	4	11	30	40
7	3	4	11	30	40
8	3	3	13	36	36
9	3	3	13	36	36
10	3	6	7	18	39

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ABSTRACT

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This paper illustrates the results of an experiment where students were made to play quantity--setting game based on the Cournot theory of duopoly. The aim of the in-class experiment was to provide student with a more active way of oligopoly strategy learning. At the same time the experiment served teachers to earn some experiences from learning-by-doing method of teaching. Based on this experiment teachers suppose to introduce similar activities to the study of different decision-making models of firms.

Strictly theoretical approach to the study of the oligopolistic market structure was replaced with a learning-by-doing method. Although only a short theoretical lecture preceded quantity-setting game (essential assumptions of Cournot duopoly model were explained), students were able to develop their own strategies from the very beginning of the experiment. Each group of students has understood that their decision about quantity produced was not independent but determined by the decision of the other group. Hence, they had to make assumptions about its rival's strategy and learn from each additional round of the game. At the end of the experiment students were asked to describe anonymously their opinion about new learning method. They found experiment interesting, stimulating and challenging. They have reported that they have really understood that free rider behavior might harm efficient outcome in market structures where firms can influence the main market variables but not absolutely control them. This experiment shows further possible extension of duopoly in-class game and it also justifies new approach to the study of different market structures.

Key Words: *Experimental Economics, Microeconomics, Game Theory.*

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