

PROJECT DESCRIPTION

A Multiperiod Cournot Duopoly with an unknown Demand Function: An Experimental Design

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1. INTRODUCTION

The purpose of the project is to design some market experiments to test the effect of an ‘unknown demand’ on the firms behaviour in a Multiperiod Cournot Duopoly. We assume the complete ‘unknowledge’ of the demand function, and we project different experiments to understand how this unknowledge should affect the quantity choices of the two firms and, consequently, the profits obtained during the time. Allowing for repetition, learning processes about the structure of the market demand and the rival strategies will become crucial to capture the role of a radical uncertain environment and should reduce demand unknowledge effects.

In Section 2 we explain the experimental design composed by five cases: in the first treatment we consider the case in which a monopolist has to choose, in each period, a quantity to maximize his profits without knowing his demand function; in the second treatment we design a Cournot market experiment in which each firm produces a homogeneous good and chooses, in every period, simultaneously and independently, a quantity to maximize his profits without knowing neither the demand function, nor the quantity chosen by his rival in the previous period, nor the profits obtained by him; in the third treatment we allow firms to know the quantity chosen by his rival; in the fourth treatment, we assume the knowledge of the profits obtained by his rival, and, in the fifth treatment we assume firms know both the quantity and the profits of the rival. In Section 3, we will briefly account for some theoretical predictions. In Appendix 1, we attach the relative instructions.

2. EXPERIMENTAL DESIGN

We are interested in five market experiments where the common feature is the complete unknowledge of the demand function. For the first treatment (Monopoly treatment) we plan to recruit 25 undergraduate students from various sections of the Principles of Economics class. For the remaining Duopoly treatments we will test 25 duopoly-experiments, i.e. 50 undergraduate students (of Economics class) for each treatment. We use different samples of subjects to avoid any possible knowledge about the experiment they are involved. Each session will last approximately 1.5 hours and subjects will earn the mean of the payoffs obtained during

the session (subjects know it). Every experiment will involve 50 rounds and subjects know how many rounds they are going to play. In order to make sure subjects understand the instructions, we will allow them to play 3 additional practise rounds involving a different demand function, which is, at the same time, different from the demand function we will utilize during each experiment. This last to avoid any possible influence with the real experiment (subjects know the first 3 rounds are not part of the real experiment). All experiments will be computerized and programmed. Subjects will be randomly allocated to computer terminals in the lab and cannot communicate each other. Each subject will be assigned a computer terminal and a sheet to record all the information they need during the experiment. At the beginning of each treatment subjects will read the instructions (see Appendix 1) on a paper.

Monopoly Treatment.

In the following treatment we assume each subject represent a Monopolist who faces the following profit function

$$\mathbf{p}_t = q_t p_t$$

where

$$p_t = D(q_t) = 10 - 2q_t$$

and zero production costs¹.

In each period t , the monopolist has to choose a quantity to solve the following maximization problem:

$$\underset{q_t}{\text{Max}} \mathbf{p}_t$$

with

$$\mathbf{p}_t = 10q_t - 2q_t^2$$

The monopolist doesn't know the demand function and has to choose, in each period, a quantity from a grid between 0 and 8 ($q \in [0, 8]$). The Monopolist obtain zero profit playing

$$q = 0 \text{ and } q = 5$$

and negative profits for $q \in (5, 8]$. We allow for negative profits to avoid a possible understanding of the demand functional form. Even if a linear demand function is practical for the experimenter, it can be easily discovered by every smart student. Moreover, as the first choice, people could have a tendency to choose the mean value of the grid, discovering immediately the

¹ We impose zero production costs to focalize the attention on the role of the unknown demand function.

argmax of the function, if we allow for a grid between 0 and 5. In our case the argmax of the profit function is, in fact,

$$q^* = 2.5$$

During the experiment, monopolist knows the demand function is constant over time but doesn't know:

- the demand function $D(q_t)$; and
- if all the quantities in the grid assure him a positive profit;

When monopolist chooses the quantity, he has to write the quantity chosen on the computer he is in front of. After few seconds, on the screen it will appear the corresponding profit. He can record the quantity chosen and the corresponding profit on a sheet received at the beginning of the experiment. He can make any computation he need. After 2 minutes, each subject has to play the following round.

Duopoly Treatment I, II, III, IV.

In these treatments each subject represent a duoplist who produce and sell an homogeneous product. The profit function for generic firm i is given by

$$p_{it} = q_{it} p = q_{it} D(q_{it}, q_{jt}).$$

As in the monopoly case, we assume zero production costs and a demand function

$$p_t = D(q_t) = 10 - q_{it} - q_{jt}$$

We choose this demand function since, in the case of perfect cooperation, it correspondes exactly with the monopolist demand function:

$$q_{it} = q_{jt} = q_t \Rightarrow D(q_t) = 10 - q_t - q_t = 10 - 2q_t$$

This could be useful to better understand how the strategic interaction between firms, modifies the results in term of learning path and strategies chosen.

In every duopoly treatment, subjects have to choose in each period t , simultaneously and independently, a quantity from a grid between 0 and 8 ($q \in [0,8]$). Even if firms could make negative profits using a grid of $[0,5]$, we will continue to utilize the usual grid to make treatments comparable with the monopolist case. For every treatment, each duopolist plays with the same rival all along the game. Subjects know it but they don't know exactly who his rival is. When each firm choose the quantity, he knows profit he will obtain depends, somehow, on the rival's quantity chosen too.

During experiments, each firm knows the demand function is constant over time and the same for his rival too, but doesn't know:

- the demand function $D(q_{ii}, q_{ji})$; and
- if all the quantities in the grid assure it a positive profit;

When firms choose the quantities, they have to write the quantities chosen on the computers they are in front of. After few seconds, on the screen they will appear the informations corresponding to the treatment subjects are involved. In *Duopoly Treatment I*, subjects will only know the profit corresponding to the strategy choosen. In *Duopoly Treatment II*, subjects will know both his profit and the quantity chosen by his rival. In *Duopoly Treatment III*, subjects will know both his profit and the profit obtained by his rival. In *Duopoly Treatment IV*, subjects will know his profit, the quantity chosen by his rival and his corresponding profit.

After each round, each firm can record informations he has on a sheet received at the beginning of the experiment. He can make any computation he need. After 2 minutes, each subject has to play the following round.

During each experiment, both firms know they have exactly the same information of the rival.

3. THEORETICAL PREDICTIONS

In every treatmnet, the most important thing we will look for is which learning process firm will adopt, how many rounds subjects need to understand the game (if they do) and if a stationary solution is obtainable, even if it doesn't correspond to the theoretical prediction of the game itself. The *Monopoly case* is quite simple. Subjects will find easily and in few rounds the profit maximization solution

$$q^* = 2.5$$

In the *Duopoly treatments*, the environment is more complex and strategic interaction should affect the learning process of the firms. Each firm knows its profits depend crucially on the rival choice.

While in the first treatment, learning process depend on the choices of the firm itself and are not directly affected by the knowledge of the rival choices and results, this is not true in the remaining duopoly treatments, where the knowledge of the quantities chosen by its rival and/or the profits obtained by it, could affect the firm's behaviour during the game.

In the monopoly case and in the first three duopoly treatments, we should observe a *trial and error learning process* that converges to the maximization solution in the monopoly case and to a range between the Nash prediction and the cooperation solution of the game, for the first three

Duopoly cases. As we have said before, the specific learning path in the Nash-Cooperation range will depend on the specific duopoly treatment adopted.

In the remaining Duopoly treatment (duopoly treatment IV) we should probably observe an *imitating learning process* ('*imitate the best*'), where the firm who earns a higher profit is imitated by the other duopolist. At each round, rival observes his last profit and rival profit too; if rival profit are greater, in the next round, firm will choose approximately the same quantity chosen by his rival. Thus the process results' depend crucially on the direction quantity choices assume during the game.

From a theoretical point of view the Nash Solution of the game is:

$$(q_1^*, q_2^*) = \left(\frac{10}{3}, \frac{10}{3} \right)$$

while the cooperative solution corresponds to the monopoly solution

$$(q_1^*, q_2^*) = \left(\frac{10}{4}, \frac{10}{4} \right).$$

APPENDIX 1

GENERAL INSTRUCTIONS

Welcome to our experiment. You are asked to read carefully the instructions. You are involved in an experiment in which you can earn real money. For each session You will earn the mean of the payoffs obtained during the experiment. You will be payed after the experiment. Don't talk with your neighbors. If you don't respect this rule you will not get paid. If you have a question please raise your arm. We guarantee anonymity with respect to other participants and we do not record any information connecting your name with your performance. Before each experiment you can practise yourself with the computer and with the experiment you are going to play in 3 trial rounds. The experiment is divided into 50 rounds. The real experiment starts with round 1.

MONOPOLY TREATMENT: INSTRUCTIONS

You represent a Monopolistic firm which produces and sells a certain product. Your aim is to maximize your profits

$$p = qp$$

where p is the market price and q is the quantity you have to choose in each round. The price is a function of the quantity you choose (is your demand function):

$$p = D(q)$$

In each round your task is to decide how much to produce of your good in order to maximize your profits (remember: the profits you obtain represent real money). You can choose your quantity from a finite grid between 0 and 8: $q \in [0, 8]$.

Be careful: you don't know the demand function $p = D(q)$ and you don't know if all the quantities in the grid assure you a positive profit. The demand function is the same in each period (market conditions don't change over time).

For each round, write the quantity chosen on your computer; after few seconds, on the screen it will appear the profit you have obtained. At each round you have a maximum of 2 minutes to decide the quantity to sell on the market. You can record the quantity chosen in each round and the corresponding profit on the sheet we have given to you. Good Luck!

DUOPOLY TREATMENT I: INSTRUCTIONS

You represent a firm (firm i) that produce and sell a product in a given market. Besides you there is an other firm (firm j) in the market which produces and sells the same product. Your aim is to maximize your profits:

$$p_i = q_i p$$

where p is the market price and q_i is the quantity you have to choose in each round. The price is a function of the quantity you choose (q_i) and the quantity chosen by your rival (q_j) (i.e., p is yours demand function):

$$p = D(q_i, q_j)$$

In each round your task (and the task of your rival too) is to decide how much to produce of your good in order to maximize your profits (remember: the profits you obtain represent real money). You can choose your quantity from a finite grid between 0 and 8: $q_i \in [0, 8]$. The demand function is the same for all periods and the same for each firm.

Be careful, you don't know:

- the demand function $p = D(q_i, q_j)$;
- if all the quantities in the grid assure you a positive profit;
- the quantities chosen by your rival and its profit at the end of each round.

At each round, the quantities chosen by you and your rival will influence the market price and hence the profit you can earn.

For each round, write the quantity chosen on your computer; after few seconds, on the screen it will appear the profit you have obtained. At each round you have a maximum of 2 minutes to

decide the quantity to sell on the market. You can record the quantity chosen in each round and the corresponding profit on the sheet we have given to you. Your rival has the same information of you.

At each round you will play always with the same rival; but remember: you don't know who is it.

Good Luck!

DUOPOLY TREATMENT II: INSTRUCTIONS

You represent a firm (firm i) that produce and sell a product in a given market. Besides you there is an other firm (firm j) in the market which produces and sells the same product. Your aim is to maximize your profits:

$$P_i = q_i p$$

where p is the market price and q_i is the quantity you have to choose in each round. The price is a function of the quantity you choose (q_i) and the quantity chosen by your rival (q_j) (i.e., p is yours demand function):

$$p = D(q_i, q_j)$$

In each round your task (and the task of your rival too) is to decide how much to produce of your good in order to maximize your profits (remember: the profits you obtain represent real money). You can choose your quantity from a finite grid between 0 and 8: $q_i \in [0,8]$. The demand function is the same for all periods and the same for each firm.

Be careful, you don't know:

- the demand function $p = D(q_i, q_j)$;
- if all the quantities in the grid assure you a positive profit;
- the profits obtained by your rival at the end of each round.

But you know:

- the quantities chosen by your rival at the end of each round.

At each round, the quantities chosen by you and your rival will influence the market price and hence the profit you can earn.

For each round, write the quantity chosen on your computer; after few seconds, on the screen it will appear the profit you have obtained and the quantity chosen by your rival. At each round you have a maximum of 2 minutes to decide the quantity to sell on the market. You can record the quantities and your profits on the sheet we have given to you. Your rival has the same information of you.

At each round you will play always with the same rival; but remember: you don't know who is it.

Good Luck!

DUOPOLY TREATMENT III: INSTRUCTIONS

You represent a firm (firm i) that produce and sell a product in a given market. Besides you there is an other firm (firm j) in the market which produces and sells the same product. Your aim is to maximize your profits:

$$P_i = q_i p$$

where p is the market price and q_i is the quantity you have to choose in each round. The price is a function of the quantity you choose (q_i) and the quantity chosen by your rival (q_j) (i.e., p is yours demand function):

$$p = D(q_i, q_j)$$

In each round your task (and the task of your rival too) is to decide how much to produce of your good in order to maximize your profits (remember: the profits you obtain represent real money). You can choose your quantity from a finite grid between 0 and 8: $q_i \in [0,8]$. The demand function is the same for all periods and the same for each firm.

Be careful, you don't know:

- the demand function $p = D(q_i, q_j)$;
- if all the quantities in the grid assure you a positive profit;
- the quantities chosen by your rival at the end of each round;

But you know:

- the profits obtained by your rival at the end of each round.

At each round, the quantities chosen by you and your rival will influence the market price and hence the profit you can earn.

For each round, write the quantity chosen on your computer; after few seconds, on the screen it will appear the profit you have obtained and the profits earned by your rival. At each round you have a maximum of 2 minutes to decide the quantity to sell on the market. You can record the quantities and your profits on the sheet we have given to you. Your rival has the same information of you.

At each round you will play always with the same rival; but remember: you don't know who is it.

Good Luck!

DUOPOLY TREATMENT IV: INSTRUCTIONS

You represent a firm (firm i) that produce and sell a product in a given market. Besides you there is an other firm (firm j) in the market which produces and sells the same product. Your aim is to maximize your profits:

$$p_i = q_i p$$

where p is the market price and q_i is the quantity you have to choose in each round. The price is a function of the quantity you choose (q_i) and the quantity chosen by your rival (q_j) (i.e., p is yours demand function):

$$p = D(q_i, q_j)$$

In each round your task (and the task of your rival too) is to decide how much to produce of your good in order to maximize your profits (remember: the profits you obtain represent real money). You can choose your quantity from a finite grid between 0 and 8: $q_i \in [0,8]$. The demand function is the same for all periods and the same for each firm.

Be careful, you don't know:

- the demand function $p = D(q_i, q_j)$; and
- if all the quantities in the grid assure you a positive profit;

But you know:

- the quantities chosen by your rival at the end of each round; and
- the profits obtained by your rival at the end of each round.

At each round, the quantities chosen by you and your rival will influence the market price and hence the profit you can earn.

For each round, write the quantity chosen on your computer; after few seconds, on the screen they will appear the profit you have obtained, the quantity chosen by your rival and its corresponding profit. At each round you have a maximum of 2 minutes to decide the quantity to sell on the market. You can record the quantities and the profits on the sheet we have given to you. Your rival has the same information of you.

At each round you will play always with the same rival; but remember: you don't know who is it.

Good Luck!