Oyunlarda Öğrenme: İki Deney

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Özet

İktisat bilimine deneysel yaklaşımlar son 40 yılda popülerliğini artırmış ve ampirik analizde önemli araçlardan biri haline gelmiştir. Davranışları matematiksel temellerde modellenen ajanların daima rasyonel davrandığı düşünülürken bu modellerin test edilmesi ve bireylerin farklı durumlarda aldığı kararların incelenebilmesi sağlanmıştır. Bu makalede, iki farklı ortamda yapılan deney ile bu durumu örneklendireceğiz. Braess paradoksu, günlük hayatta her bir bireyin karşılaştığı yol seçimi sorununu konu edinirken, Cournot oligipol modeli ise miktar rekabeti durumunda verilen üretim kararı üzerinden karar alma davranışını incelemektedir. Bu çalışma, rasyonel karar alma kabiliyetini farklı alanlarda eğitim alan öğrenciler üzerinden Braess paradoksu ve Cournot modeli dahilinde deneysel olarak incelemektedir.

Anahtar Kelimeler: *rasyonalite; bencil seçim; sosyal optimum; deneysel iktisat; ağ tıkanıklıkları; rekabet; cournot oligopol modeli; braess paradoksu; öğrenme etkisi*

Learning in Games: Two Experiments

Abstract

Experimental methods are even more popular in the last 40 years and became one of the fundamental instruments of empirical economic researches. Experimental economics provides a way to test the mathematical models created to explain the behaviours of economic agents and to observe those behaviours under different circumstances. In this paper, we will conduct two experiments to illustrate. The first experiment is on the Braess paradox suggesting that adding an additional route to a road topology may increase the amount spent in traffic when the drivers selfishly choose their route and the second is a Cournot oligopoly environment; quantity competition suggesting that competing firms will produce less than competitive quantity and more than collusive amount. This paper, explores the ability of rational decision making experimentally, in the scope of Braess Paradox and Cournot Oligopoly Model with two groups of participators for both experiments from different educational backgrounds.

Keywords: *rationality; selfish behaviour; social optimum; experimental economics; congestions; competition; cournot; braess paradox; learning effect*

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1. Introduction

Traditional economic research methods generally use mathematical analysis to understand individual behaviours and market mechanisms. Experimental economics is one of the must stunning methodological revolutions in the history of social sciences enabling researchers to test the results of these mathematical models in real life. Not so long, just few decades ago experimental methods were thought to be impractical and ineffective. But now, it is one of the most popular and exciting methods of economic researches. It is kind of a gate for economics to the laboratory.

It is quite hard to pin the exactly the first experiment in history, but it can be said that the first relevant and significant examples were in the early 1930's where a series of experiments have been made by psychologists and economists. Although it is possible to identify experiments even in 18th century (Daniel-Nicholas Bernoulli, St. Petersburg experiments) those in the 1930's were the roots of the contemporary experimental researches. Unquestionably, experimental economics owes a lot to the work of John von Neumann and Oskar Morgenstern *Theory of Games and Economic Behavior* (1944). After that work, especially in the 40's and 50's, experimental methods took place in the researches. In those times, game theoretic models to real problems known as "gaming" became more and more popular and spread from Princeton to elsewhere. As gaming was increasing its popularity, it greatened experimental implementations. And from those times, experimental economics literature is growing exponentially.

Vernon L. Smith provided an important piece of the experimental puzzle. Since 1956, Smith had been experimenting and conducted counter-experiments of Chamberlin's market model (design used by Chamberlin in 40's and 50's in the classroom implemented with students). After those times, works on judgment and decision making of Tversky-Kahneman and Lichtenstein-Dawes-Slovic (group of psychologists from Oregon) contributed great progress on the field. In 1970's, works of these groups were a challenge to the idea that humans are rational agents. Smith-Plott works in the late 70's and early 80's were important because they have been showing the importance of the monetary incentives to control subject's preferences (induced value theory) and the use of language in the experiments.

After this brief history, we could say that works on experimental economics gave birth to "*behavioural economics*". Now, experimental economics is a method of investigation for behavioural economics. The behavioural approach provides an opportunity to test the *homoeconomicus* and define the economic agents in more realistic ways. As exploring that, experiments give us a chance to create "*institutions*" by the definition of Douglas North, and observe the decision making process of individuals and markets under that *rules of the game.*

Humans are usually defined as the only creature changing their environment instead of adapting to it, but still we are facing an environment changing a lot every day. Are we really capable of choosing the very best alternatives every time? We tackle this question experimentally in this paper and investigate it first by creating a cooperation environment in a non-cooperative network model, *Braess Paradox*, then with a competitive environment *Cournot Oligopoly Model*. In this study, we aim to investigate Braess Paradox and Cournot Oligopoly model with the 2 groups of subjects from different educational backgrounds. For both experiment, one of the groups consisted of students of economics department who have taken game theory and were familiar with the concept of problem solving and the second group was taken from students of sociology department for the Braess Paradox experiment and students of engineering departments for the Cournot experiment. The purpose was to explore the impact of a more analytical and a more verbal education on problem solving skills for the first experiment and the impact of knowledge of game theory in case of economics students or optimization techniques in case of engineering students in selecting an action in a strategic environment for the second experiment. Both experiments were designed using the software Ztree (Zurich Toolbox for Readymade Experiments).

First, we will introduce the Braess Paradox and the experiment. In the first stage of the experiment, we introduce the normal topology of the route; subjects will be asked to choose one of the roads. In the second stage, the participants will be asked to choose their route in a classical Braess paradox topography. After making participants learn about Braess paradox, in the third stage, we will be testing if selfish driving can be avoided by adding a central traffic navigation mechanism to system. In the fourth stage, we will be testing the trust of participants to such a system. And finally in the fifth stage, we will be testing if participants will be adapted to changes in road topology. The topology used in this stage will actually not be paradoxical. The results of the experiment will be discussed.

Second, we will present Cournot Oligopoly Model and the experiment. In the experiment, participants are asked to determine their output level in a symmetric 10 firm-Cournot oligopoly in which every firm is given its *cost function* and production capacity. Subjects are asked to choose production level given their capacity and their costs. Subjects receive additional feedbacks including market share and the difference of the highest profit and their profit at the end of each round. The results will be discussed.

2. Braess Paradox Experiment

Braess paradox is analysed by D. Braess in 1968. The theory suggests that adding an additional route to a road topology may increase the amount spent in traffic when the drivers selfishly choose their route. Users of such networks choose their routes simultaneously and individually in an attempt to minimize their travel cost.

There are different types of topologies that the very same paradox may be observed, in this paper we will examine the simple version including two symmetric roads. The Braess Paradox seems to have a very basic format yet it is really hard to define the roads causing such problem in real life. Some basic problems (not everybody is starting from one point and try to reach the same point, or normal road topology is not constructed like linear straight lines, it is normally more likely a cobweb in which everybody goes different directions) exist. Also the amount of cars has a critical effect in the logical assumption of the paradox, and there are more than enough studies observing the change of drivers' reactions facing this change.

We can divide the characteristics of such a network system in two. The first is the user optimizing behaviour, in which drivers choose their optimal routes individually. The second is the centrally controlled traffic, in which drivers are navigated and controlled. The Braess paradox is constituted on the first one where travellers are referred as selfish decision makers. The main reason why this paradox occurs is that the drivers decide selfishly. In this paper we will assume that there are no changes in the amount of cars in the traffic and we will investigate if drivers are willing to use the route which seems as the best choice for them or they will take the advice of a central navigation system which will make them go on the road that does not seem to be the best choice for them but thinking deeper for that matter it will be the choice that they could use to achieve their best response when everybody "acts by the rules".

2.1. A Short Explanatıon Of Braess Paradox

N being the number of cars in the traffic (10 for this experiment), the time spent on the road from "START" to A and from B to "FINISH" depends only on the amount of cars passing through from that road. Normal distribution will be %50 - %50. So we can see that at first;

$N=N_1=N_2=5$

So we can say that in equilibrium the time spent on traffic for the route A will be equal to:

$5 + 12 = 17$ *minutes*

And the very same result for the route B.

Now we will see the effect of adding a new route to the topology between A and B. By the design of the Braess paradox itself, we will assume that the time spent on this road is equal to 0 or negligible.

Figure 1: Braess' Paradox Normal Topology

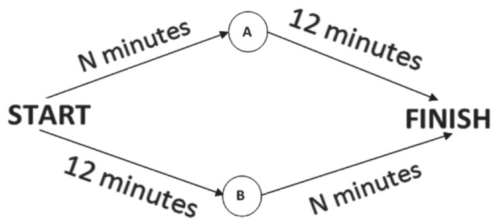
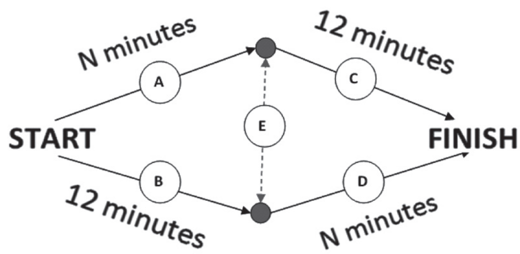


Figure 2: Braess' Paradox Paradoxical Topology



Since the extra road is cost free, we can consider that all drivers will actually make decisions in two symmetric periods. Now still assuming all drivers are rational, in the point of departure "START ", drivers have to choose between A and B. Even if all drivers choose the road A time spent on the road will still be lower from the road B.

N_{max}<12

Therefore all rational drivers will pass through from the road A at first then by using the extra road E they will finalize their journey using the road D. So we can say that in equilibrium the time spent on traffic for all drivers will be equal to:

10 + 10 = 20 minutes

Even though all individuals choose the best-case scenario for all periods, we can see that adding an extra road rises time spent on traffic for all drivers in this road design. Therefore we can see that individually made decisions to achieve the best outcome may not give the expected. Since it is the case in real life, if a similar topology occurs the same results would be seen in traffic. Previous works on Braess paradox are few: Nagurney (2010) results with the common selfish route choosing. Works similar to ours are Roughgarden (2002, 2005, 2006). They generally investigate the harm of selfish route selection and aim to find a solution to avoid it. Xu, Sun and Wang (2014) exhibit the inefficiency that selfish choices cause.

In this paper, two characteristics were combined with a computer-based experiment and it is made interesting by adding information asymmetry. In the first stage, to introduce the normal topology of the route, non-paradox version of the route will be shown to subjects and they will be asked to choose one of the roads. In the second stage, the participants will be asked to choose their route in a classical Braess paradox topography. After making participants learn about Braess paradox, in the third stage, we will test if selfish driving can be avoided by adding a central traffic navigation mechanism to system. In the fourth stage, the trust for such a system will be analysed. And finally in the fifth stage, we will be testing if participants will be adapted to changes in road topology. The topology used in this stage will actually not be paradoxical.

The experiment is made with two different groups. Main difference within these groups is that they are from different educational backgrounds. First the experiment is done with the students of sociology department. Their education is mostly verbal. They are not aware of the concept and nature of these kinds of game settings. Second students of economics department have participated to the experiment. These students have followed courses such as calculus, optimisation, and game theory. With this differentiation of participants we are able to see the difference in the results of the experiment, especially the effects of the way of thinking in context of analytical approach.

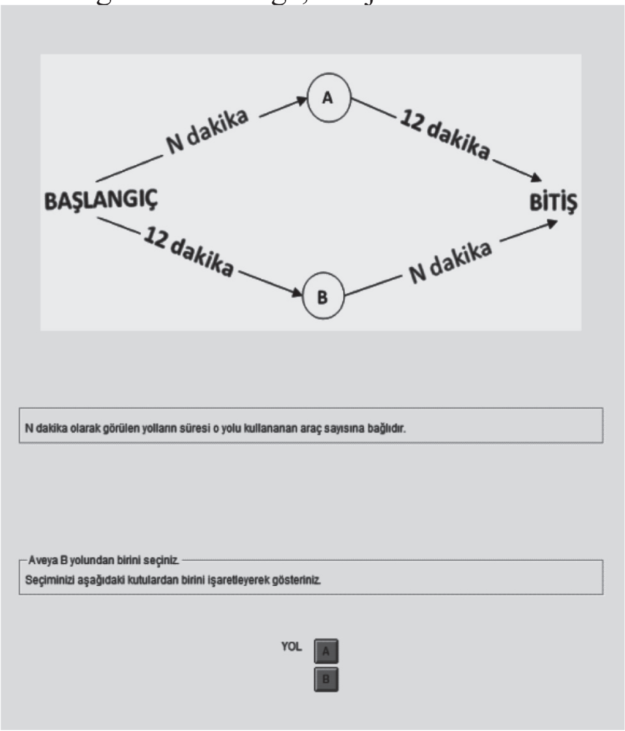
The main hypothesis consists on this differentiation of the way of thinking. For these kinds of game settings, analytical approach is considered to be a significant determinant for the individual's success. The time required to understand the process, ability to take necessary actions and a more profound understanding of both individually and socially optimal equilibrium concept are all major topics to be able to determine a correct strategy. We test the hypothesis about the importance of the analytical approach in computer based network experiment and report evidence that strongly supports it.

2.2. Experimental Design

The subjects (number of 10) were informed that they were going to play a simple route choice simulation game in traffic. The experiment took place in Galatasaray University and has been conducted in two sessions with different group of subjects. The Braess Paradox experiment consists of 5 stages each was repeated 10 times except *Stage 4*.

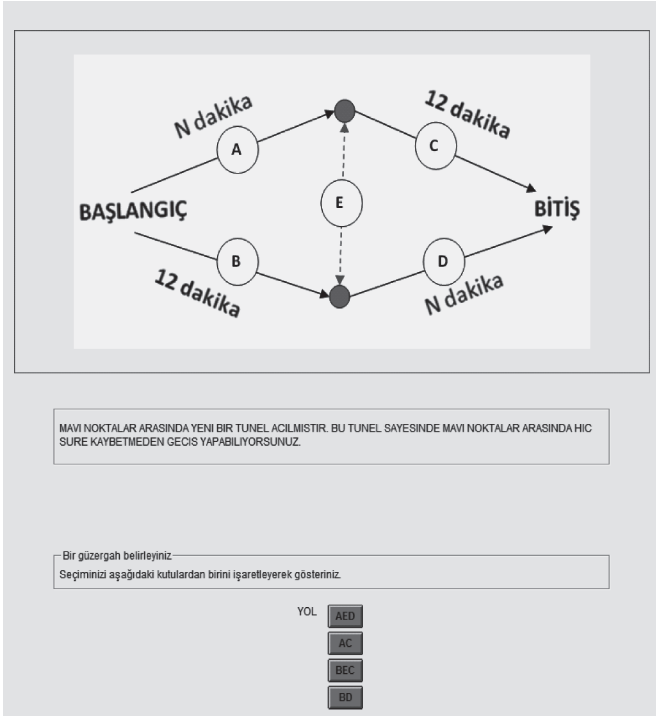
In the 1st stage, to introduce the normal topology of the route, non-paradoxical version of the route is shown to subjects and they are asked to choose one of the roads. They are expected to be distributed %50 - %50. Since the participants are few, to be able to make them learn how the experiment works, we conduct this stage 10 times. Thus, subjects would be able to see that the choice of others affects their outcome. The screen of the participants looked like Figure 3. And they were asked to choose the route they prefer. Their outcome was a function of traffic in the route they chose. So as the number of subject on a route increases, the payoff of the subjects on that route decreases. At the end of the stage, participants were shown a screen to make them learn what their payoff is and what the difference is between the subject with the best outcome and the amount of time spent on the traffic.

Figure 3: 1st Stage, Subjects' Interface



At the bottom of the screen subjects were able to see their results from earlier stages. By that we aimed to give them an insight how their results changed and therefore we tried to help them understand the process.

Figure 4: 2nd Stage, Subjects' Interface

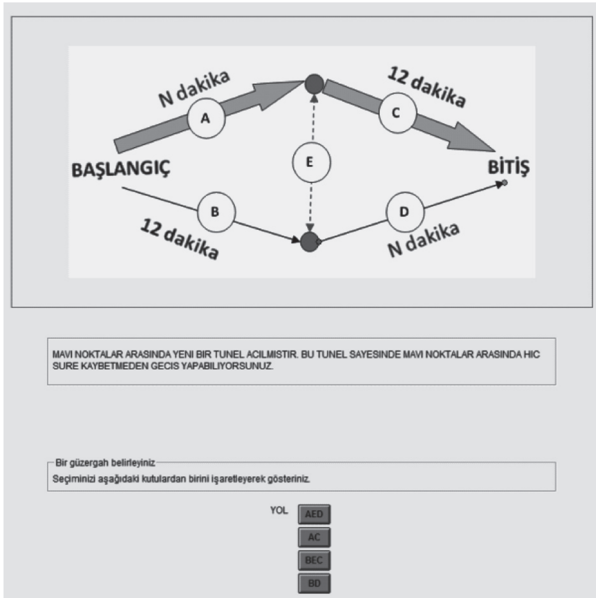


In the 2nd stage, subjects were asked to choose their route with an extra road (Figure 4). In this stage, we aimed to examine if the Braess' paradox occurs when the subjects choose their road individually. The cost or the time spent on the added road is equal to 0. Since the paradoxical choice is the only selfish rational choice, we are actually testing the rationality and how participants react and learn in this situation. To make it easier for subjects to understand how their actions work out, their earlier payoffs were also shown in an additional box. With this stage, a simple Braess Paradox experiment was conducted.

After the second stage, the subjects were expected to understand that no matter what they do, they would not be able to reach their original payoff and adding a route could easily augment their time spent on traffic and decrease their payoff. In the 3rd stage, subjects were informed that *a central traffic navigation mechanism* was added to the system. By this we expect to reach not individual but public optimal choice. After informing them that they do not have to choose the road suggested, they can still make their own choices and system could only achieve its purpose if only all individuals follow the instructions, we start the experiment. In this stage, subjects were paired in to 2 groups and shown different screens (A-C was the suggested route to Group 1 and B-D for Group 2, Figure 5).

In the 4th stage we examined if the participants had confidence on the central navigation system by making an error in the central navigation system. We suggested the same road to all participants and in case they trust the system, all their payoffs decrease. So, in other words, we forced them to make irrational individual choices by using central navigation mechanism. We repeated this 5 times.

Figure 5: 3rd Stage, Group 1 Subjects' Interface

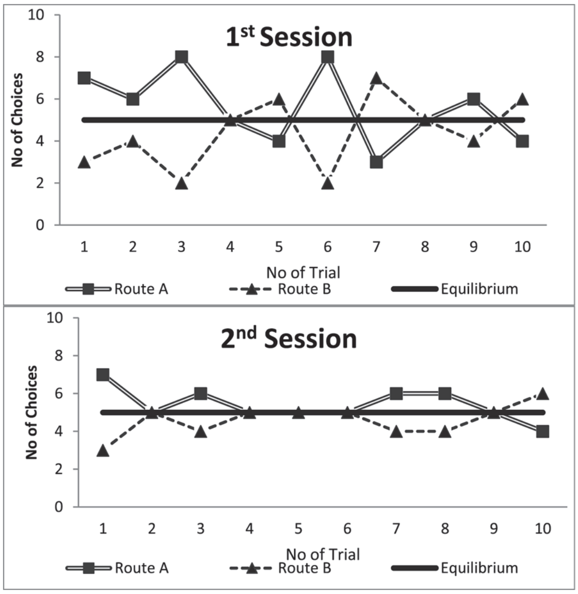


In the last stage we conducted the very same experiment we have done at the 3rd stage. We would be able to measure the difference in their behaviour before and after the error stage. We were again able to see their adaptation level and also we were going to be able to see if people tend to punish the system by comparing the results we got at the 3rd stage.

2.3. Results

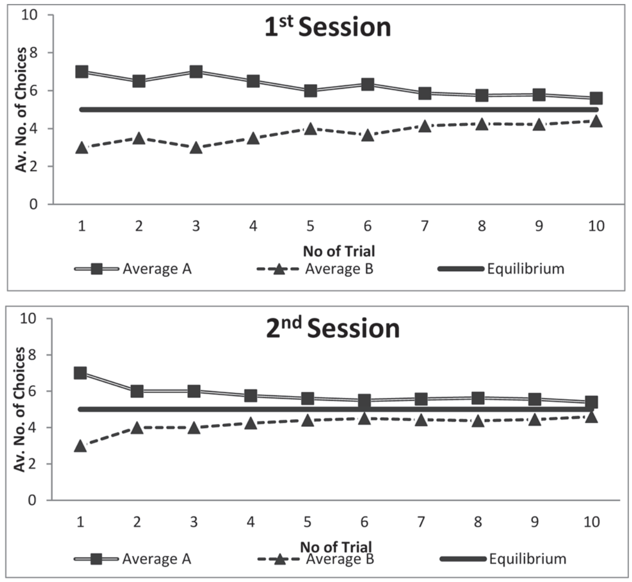
1st Stage: In the 1st session, the experiment was conducted with sociology students and in 2nd session to economics students. This session was repeated 10 times. In graph 1, we see frequencies of choices for each trial. As we have mentioned, an expected distribution is 50% - 50% since there are only two symmetric choices. This distribution rate is also the pareto optimal equilibrium where all participants maximize their outcome. As it can be seen, in the first session participants have made choices closer to the equilibrium after the fourth trial for the first time and the second group has managed to reach at the equilibrium directly in the second trial and their choices stayed closer to the equilibrium after that. Also we can see that both sessions start with a 7 to 3 distribution, but in the second session, even not in the equilibrium, distribution rate is never more than 6 to 4.

Graph 1: Frequency of Route Choices At 1st Stage (Sociology on top-Economics at the bottom)



This graph shows how much a route is selected each round. For example, at the first round, Route A is selected by 7 participants and Route B is selected by 3.

Graph 2: Average Of Choices At 1st Stage



This graph illustrates how much on average a route is selected. The numbers are obtained by the cumulative sum of participants choosing the route by the number of rounds. For example, in the first round 7 participants have chosen Route A and at the second round 6 participants have chosen Route A. The first point on the graph is 7/1 and the second is (7+6)/2=6.5.

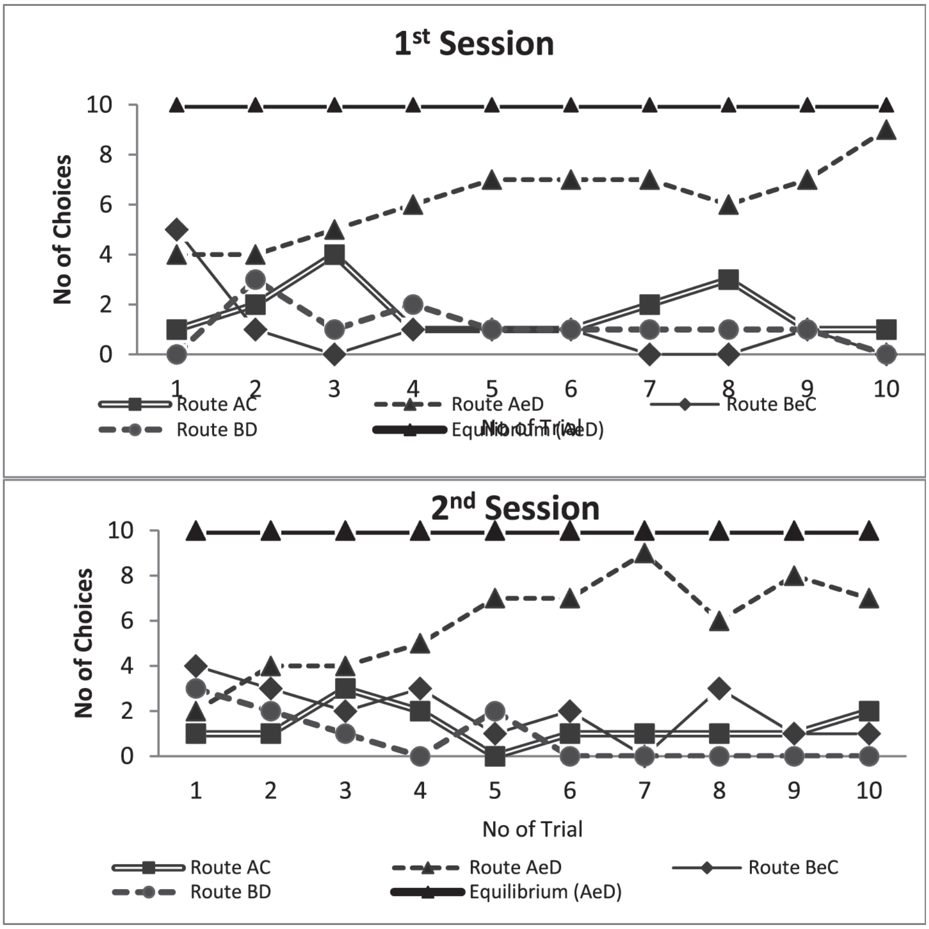
In graph 2, we are able to see that the average of number of choices is getting more and more closer to the equilibrium. Thus we understand that the choices are made rationally and the participants understood the nature of the experiment. Comparing the results of the two sessions, we see that in the second session, the average gets closer to the equilibrium faster and final average is also better in the second session. We can conclude that economics students satisfy more the rationality requirements.

What is interesting here is that for individual payoff maximization, participants have to create a common sense in order to be able to locate themselves as close as possible to the equilibrium. With a closer look to the participants' individual choices, we can see that in each sessions there are two participants who are strictly loyal to their first decisions and excluding one of the subjects who seemed to be trying to infect others' payoff, in stage two, people generally try to find an optimal choice for a balanced route choice equilibrium. Since the equilibrium is the best strategy to reach socially optimal response we can say that the students of economics are aware of the concept and trying to achieve to socially optimal choice.

In the first session, we saw that they have not managed to create a common sense and there are only two players who are trying to maximize their payoff by changing their route choice. Others seemed to embrace their utility level. We can link this situation with lack of experience for this kind of game settling directly related to absence of game theory education. Thus for the first stage, we managed to introduce the nature of the game and we may continue with the second stage of the experiment.

2nd Stage: This stage gives us a more profound look at the rationality of the participants and their capability of adaptation to changes. The equilibrium concept is a little bit different in this kind of route topology. Since the accumulation of the personal best responses decreases everybody's payoff, we examined which equilibrium is preferred by the majority of the subjects. What we expected here is that all participants would use the new added road in order to achieve individual best response.

Graph 3: Frequency of Route Choices At 2nd Stage



Graph 3 contains information for both economics and sociology departments. We see the frequency of each route selections for every trial. At the top of both graphics, we have the equilibrium line at 10 because the equilibrium of this stage is the AeD (all participants' selfish payoff maximization).

In the first session, we see that participants aim to get the best payoff. Sociology department is more willing to use the new added road and therefore, average frequency of the choice of the route AeD for the first session, is greater than those of the second session. From this point of view, sociology department may be seen to be more adaptable to new changes and more rational but when we look at the evolution of individual choices, we see that it is not the case.

Participants from the economics department tend to try to achieve their original outcome from the first stage. Without any given exterior instruction, they are spread to different roads. Since this case is different from the first stage, there are more possible route choices, they fail to be separated perfectly and gravitate to seek for personal best responses.

In the first stage we see that the participants adapt themselves in a more competitive manner but slower than the second stage. In general, after finding out that their outcome is the best alternative in the first stage, 12 different route choices have been made, but in the second stage, this number is 21. This major differentiation makes us think that the reason behind this is to reach a higher personal payoff even it was the highest payoff among the participants. This process is faster for the economics students. In the second stage participants have reached to their peak at 7th trial and it took 10 trials for sociology students to reach their peak. After reaching an optimal plateau, economics students looked for a better solution in order to achieve a higher payoff with a more cooperative manner. So the sum of total outcome in the first stage is 628 and 641 in the second. We can therefore expect more coordination from the economics department to navigation system.

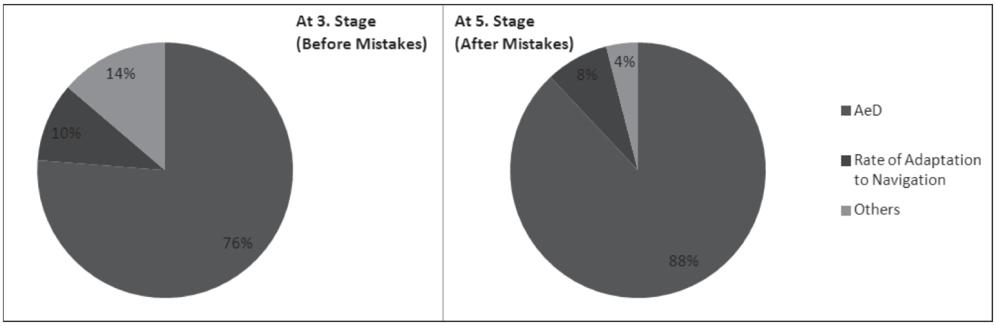
3rd Stage: In this stage we have introduced the participants with a navigation system and by separating the participants in two groups, we are directing them to not to choose the extra road thus we are offering them a chance to reach their original payoff in the first stage. This stage is also conducted in two sessions and participants are divided 5 to 5 for each session and were shown different interfaces for navigation suggestion. So far we have seen that the students of economics department tend to be more cooperative and more capable of creating a common sense. The results we get from this stage confirm our previous findings. The results of this stage are illustrated in Graph 4 and 5 by the first pie chart in each graph. The second pie chart is for the stage 5; these figures show the variation between 3rd stage and 5th stage. When we look at the pie chart for the 3rd stage, the adaptation to navigation system is much stronger in case of the economics students. The black part of pies implies that the adaptation to navigation is 27% for economics students and 10% for sociology students. Also we are able to see that the most commonly used route is AeD, which is the selfish best response. Since economics students are familiar with the optimal choice concept, instead of seeking to be the very best subject, they are willing to be more cooperative for the maximization of their payoff.

4th Stage: So far we conducted a Braess Paradox experiment and examined the trust level and willingness to cooperation of the participants. At this stage, we are purposely communicating a wrong signal from the navigation system to be able to see if the participants are going to notice that their payoff is decreasing and penalize the system because of this mistake. This stage is a transition stage to compare the results of before and after the system's mistake. At this stage all participants are shown the very same signal, which is the AC route. Since their time spent on the traffic is directly linked to the number of subjects who are passing through the same road, more participants follow the navigation less their outcome will be. In the first session, the constant increase in the AeD choice continues. But in the second session people are still distant to make selfish best choices.

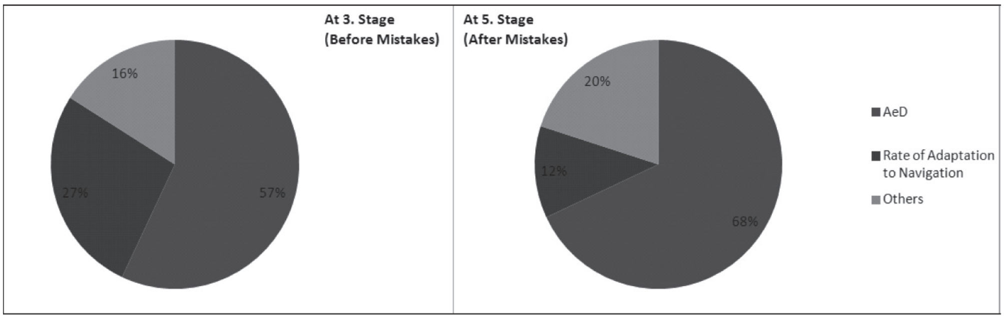
Since the road topology and the possible choices have not changed we can consider this stage different than the earlier stages, as a follow up of the previous stage. Comparing the average route choices, we see that in the second session, even if a small bit, there is a tendency to augmentation of the AeD choice. Thus we expect that the trust to the central navigation mechanism will be lost.

5th Stage: At this stage we explored if the participants were really willing to penalize the system and if the recovery of this lost trust would be possible. To see the exact differentiation, we designed this stage exactly the same way with the 3rd stage. Thus by comparing the results in the context of adaptation to central navigation system we are able to see the evolution of participants' choices.

Graph 4: Comparison of Results From Sociology Department With 3. Stage



Graph 5: Comparison of Results From Economics Department With 3. Stage



Results from 3rd stage are on left and 5th stage on right. (Sociology Graph 4, Economics Graph 5) The red part of the pie implies the selfish route choice (AeD) and the black one shows the route suggested by central navigation, the grey one, the other options. Before central mechanism's mistake (3rd stage) selfish route choice was %76 for sociology students and after the mistake, it increased to %88, those percentages are 57 and 68 for economics students.

In graph 4 we see the comparison of sociology department's at 3rd and 5th stages in the context of adaptation to navigation. And the same for economics in graph 5. The red part represents rate of selfish best choice and the black part represents rate of adaptation to navigation system. Comparing results from 3rd and 5th stages, we see that for both groups, the rate of adaptation to navigation is constantly decreasing. For sociology department, it decreases from 10% to 8% and for economics department this decline is from 27% to 12%. Thus we see that after the mistake of navigation system %80 of sociology students still continue to trust the system and this ratio for economics department is 44%. Therefore the response of economics department to system's error is a lot stronger. Students with analytical thinking are more capable of adapting to new changes.

3. Cournot Experiment

Cournot oligopoly model is one of the most widely used models in applied industrial organization. The classical quantity-setting Cournot oligopoly describes a situation between competing firms that strategically decide how much to produce. Players choose their quantities of production simultaneously by using their best response against other players' outputs. Theoretically, in Cournot oligopoly, agents decide with complete rationality and act strategically, seeking to maximize their profit and moreover the theory claims that all market participants have full knowledge of all relevant market factors, each producer has a complete knowledge of the market demand function and all rivals' production decisions. However it is unrealistic to think that the agents move rationally. Furthermore, in real life, there does not exist perfect information for all agents.

There has been a growing literature studying models of endogenous timing in oligopoly. Many experimental studies of Cournot model have essentially confirmed that the Nash equilibrium is a reasonably good prediction of the eventual behaviour of subjects under conditions of incomplete information and constant marginal cost.

Experimental economics provide a great method to make market simulations, which are one of the most appropriate instruments to test behaviours under different circumstances and getting more popular in the market researches especially in the last 40 years. In previous works, experimenters often give the demand function to the subjects by using variety of methods. Linear demand functions are the most common way but by giving profit tables, profit calculators and best response options experimenters indirectly show participators the demand function. According to Requate and Waichman (2011), these different methods led to different results.

Huck et al.(2002) test experimentally the predictions of Hamilton and Slutsky's action commitment game. In the experiment they use the linear inverse demand function and a linear cost of production. Their game modifies the standard duopoly model by allowing for two production periods before the market clears. Firms can choose their quantities in one of the two periods, t = 1, 2. They ran the experiment with a large payoff matrix where subjects could pick an integer quantity from 3 to 15 units. 70 subjects, students from various fields, mainly from economics, business administration, and law participated in this experiment. 10 players played in each session and there were three sessions, each consisting of 30 rounds. Their results show us Cournot equilibrium is common.

Raab and Schipper (2009) analyses a symmetric 3 firm Cournot oligopoly in which every firm faces the linear inverse demand function and consider two different systems of distributing the firm's profits among its members; profits distributed equally per head in treatment SH, profits distributed proportionally according to each member's costly effort in treatment SP and there is a control treatment named treatment C. Because of they found that 40 rounds sufficient for learning, they chose 40 rounds to play. In total 168 subjects participated in this experiment (the majority is economics students and there are also law, history, communication students). About 19 per cent of the students announced that they had previously discussed game theory in a course. At the end of the experiment, they found that market quantities are distributed closely around the Cournot Nash equilibrium. In this study, we conduct a similar experimental game. The aim is investigating if subjects play the Cournot Equilibrium and how fast they would converge to this equilibrium if they end up playing it. We have chosen two groups of students from different fields: economics and engineering.

Cox and Walker (1998) have tried to experiment the learning effect in their study. In this study, 20 participants played the role of a firm in a Cournot duopoly. Subjects divided in two groups in terms of their cost of production: 10 type A and 10 type B subjects. So there exist 10 duopoly markets. Each market contains one type of A subject and one type of B subject and subjects are randomly matched into new pairings in each period. There were 30 market periods. This study shows that most subjects choose Nash equilibrium quantities after only a few periods, and deviations from Nash equilibrium were small. 70-90 per cent of the players with constant marginal cost functions played their part of the Nash equilibrium in the last 10 periods.

Besides Bosch-Domenech and Vriend (2008) can be referred to for classical Cournot games, David (1999, 2011) exhibit the behavioural concepts of Cournot and compare it with Bertrand, Fonseca et al. (2005, 2006) are interesting versions of Cournot game with endogenous timing, Huck et al. (1999, 2000, 2001) are great works for understanding Cournot experiments, Rassenti et al. (2000) is one of the fundamental works of the literature, Santos- Pinto (2008) investigates endogenous timing in the model and Weichman et al. (2014) investigates the impact of communication in Cournot.

3.1. Experimental Design

Our model of market competition is a symmetric 10 firm-Cournot oligopoly in which every firm faces their cost function and their production capacity to determine its output. Only the experimenter knows the exact demand function, subjects have only the cost function. Every subject determines his output with respect to his cost. Subjects receive additional feedbacks like market share at the end of each round. Huck et al. (1999, 2000) documented that competition becomes more intense when subjects can also observe others' actions and profits. Hence, to provide a competitive environment, we give the difference between subjects' own profit and the highest profit of the round at the end of each round. There will be 2 groups with different backgrounds; economics students and engineering students. Economics students already have taken and passed a game theory course in consequence of their academic field, and engineering students are unfamiliar with game theoretic concepts and tools. We will compare these groups' behaviours considering their knowledge and different problem solving skills.

Subjects choose their outputs in an interval because we suppose that firms have capacity constraints. After each stage subjects, get their market share and their profit to have an insight of their position in the market and their profitability. If subjects get negative profits in 5 successive rounds they would not be able to continue, as there are credit constraints. We do not allow any communication between subjects.

First stage (Information):

In this stage cost function is given to players with a descriptive box that says: "***Your cost function is c=(q×45) + 100. So you have 45TL cost per unit produced. Whatever your level of production, you will have 100TL fixed cost.***" Capacity of production that players must choose is given as [0, 30]: "***Your output level should be in this interval: [0, 30]***" As we are investigating the likelihood of collusion the capacity has been restricted.

Second stage (Decision):

Players will make a decision with given information. After each decision, players will have their results from previous games and will be invited to review their decision again. These results include: "***Your market share % …***" and "***Your profit is …***" When all decide, the price and aggregate output are calculated, players have their market share and the distance of their profit from maximum profit. We've added a histogram chart at the bottom of the screen, so players will be able to see the results of their previous decisions.

Second stage will be repeated about 25 rounds.[1]

The demand function of this experiment is:

$$p = 610 - (2 \times Q)$$

The cost function of each firm is:

$$c = (q \times 45) + 100$$

Each firm i Є {1, 10} try to maximize their profit by deciding the firm's production level.

$$\max_{q_i} \pi_i = p(Q) \times q_i - (q_i \times 45) - 100$$

$$\max_{q_i} \pi_i = (610 - 2Q) \times q1 - (q \times 45) - 100$$

$$\frac{\partial \pi}{\partial qi} = 610 - 2Q_{-i} - 4q_i - 45 = 0$$

The best response of the firm i is:

$$q_i = \frac{565}{4} - \frac{Q_{-i}}{2}$$

We consider a symmetric Cournot equilibrium $q_i = q_j = q^c$, $(i \neq j)$, then:

$$q^c = 25{,}682$$

$$p^c = 96{,}36$$

$$\pi^c = 1219{,}028$$

We know that sometimes they may collude in their decision to produce and make a cartel increasing their profits. The cartel will maximize the profit of all firms;

$$\max_{q_i} \pi_T = \sum_{i=1}^{10} \pi_i(q_i)$$

$$\frac{d\pi}{dq} = 610 - 2Q - 2Q - 45 = 0$$

The aggregate cartel quantity is:

$$Q^{cartel} = \frac{565}{4}$$

$$q^{cartel} = \frac{565}{40} = 14{,}125$$

$$p^{cartel} = 610 - 565/2 = 327{,}5$$

$$\pi^{cartel} = (610 - 565/2 - 45) * 565/40 - 100 = 3890{,}313$$

We see that the collusive behaviour increase the profit level for all firms. However if they decide individually they will have lower level of profits.

1 For further explanation of Cournot Oligopoly Model ; Oz Shy "Industrial organization: Theory and applications" (1996)

3.2. Results

When we investigate this experiment's results, we can observe that the economics students mostly started the experiment with an output level close to collusive output (15) and they have continuously increased their production level throughout the experiment. Because of this increase, price level decreased and profit averages decreased simultaneously, we can see this in Table 1. Table 1 contains the average production decisions of subjects for the first 5 rounds, last 5 rounds and for all game. When we compare the averages for the first 5 and last 5 rounds, subjects increased their production during the experiment. By giving the difference between maximum profit and the subject's profit, we aimed to create a more competitive market. After the examination of the results, we can see that they played competitively despite the decrease in price and profit level, they increased their output and the results converged to the Cournot output level.

According to the volatility of decisions, we can say that they used trial and error method to determine their strategy. Few of them did not react and they only produced the same output level (the maximum level of their capacity, 30). These subjects' behaviours were interesting, we can think that this result is due to their choice of signal in their decision making; they acted according to the difference between the maximum profit of the round and their profit instead of their own profit. As they first started by producing 30, the gap between their profit level and the maximum profit level decreased as others were producing more and this in turn caused that these people did not have any initiative to change their production.

By looking the overall average of economics students, we can see that results are converging to the Cournot equilibrium. After the 10th round, price level was close to Cournot price level. Also, output decisions and surely profits converged to Cournot levels (Graph 6). As it can be seen; after 10th period most of the subjects increased their output level and remained steady after they were close to the Cournot output level, mostly they didn't diverge after the first hit to the Cournot level.

Table 1: Average output decisions and profits of Economics students

	Output			**Profit**
Economics Students	**Average (for 25 periods)**	**Average for first 5 periods**	**Average for last 5 periods**	**Average (25 periods)**
Subject 1	24,76	22,6	27,83	1772,36
Subject 2	21,8	17,8	16,16	1613,96
Subject 3	25,2	15,8	29,33	1703,6
Subject 4	23,36	18,6	29,33	1601,6
Subject 5	23,48	20,4	22,83	1736,92
Subject 6	21,84	22	25,16	1580,24
Subject 7	25,2	16,8	30	1662
Subject 8	26,8	21,8	29	1914,48
Subject 9	20,52	17,8	23,66	1447
Subject 10	29,08	26,8	29,66	2171,08

In the case of engineering students, results show that players haven't preferred same strategies. Most of the subjects have started the experiment with an output level very close to collusive output level. Except few subjects whom we think did not understand the game, players have continuously increased their production level just like the economics students. Table 2 gives the average output levels in the first and last 5 periods and for the whole experiment. Like economics students, they used trial and error method to determine their strategy. For engineering students, price and profits converged to Cournot equilibrium (Graph 7).

Table 2: Average output decisions and profits for engineering students

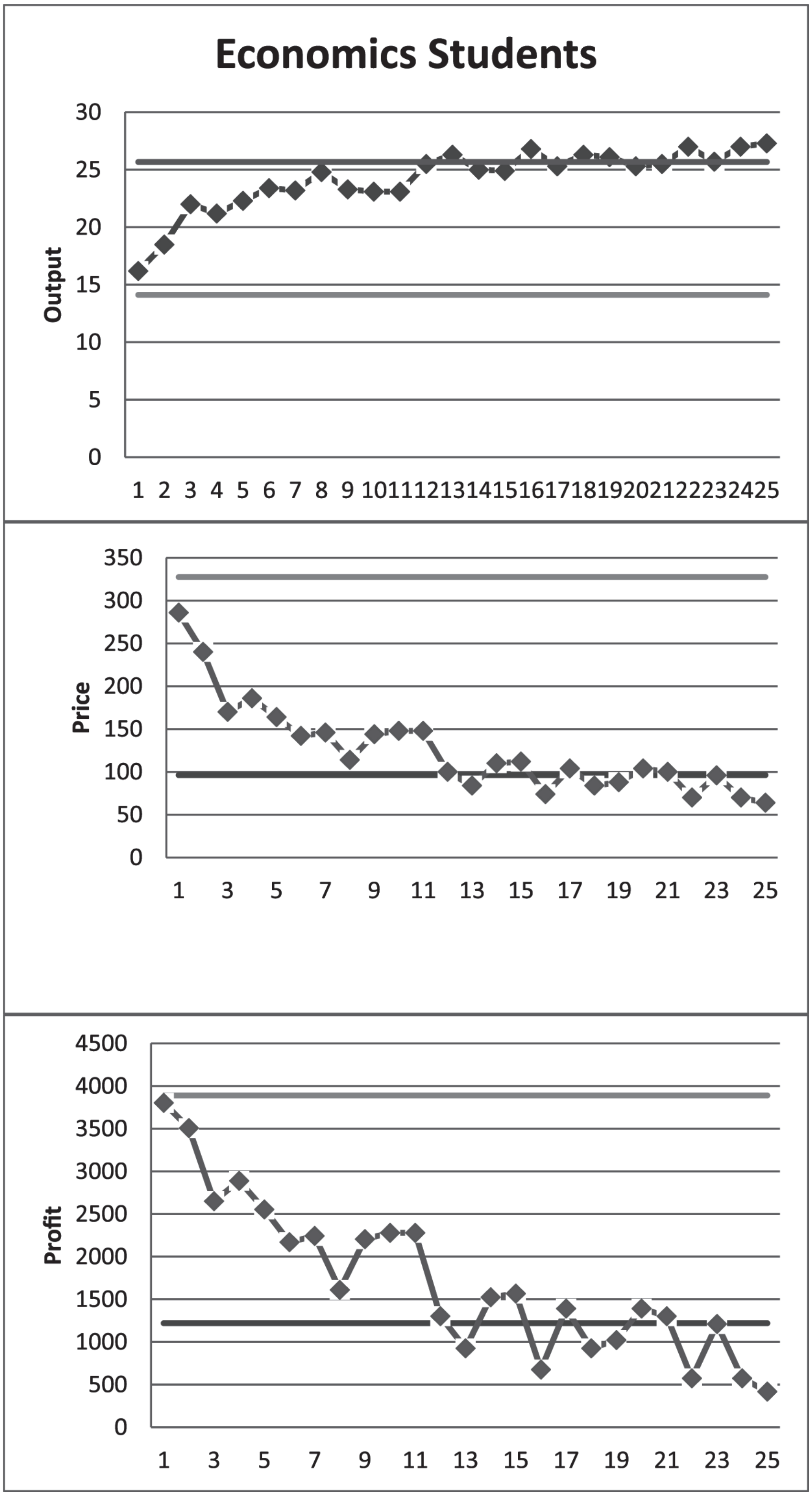
	Output			Profit
Engineering Students	**Average (for 25 periods)**	**Average for first 5 periods**	**Average for last 5 periods**	**Average (25 periods)**
Subject1	20	14	23,67	1908,08
Subject2	13,56	12	14,67	1354,36
Subject3	23,76	13	29,83	2286,72
Subject4	13,04	11	13,00	1303,44
Subject 5	26	19,6	30,00	2581,76
Subject 6	23,8	19,4	27,00	2446,2
Subject 7	26,76	23,2	29,33	2791,32
Subject 8	25,48	19,2	28,17	2557,8
Subject 9	27,08	22,8	29,33	2801,08
Subject 10	26,16	19,4	30,00	2594

When we compare these two different groups, we can say that economists have reached Cournot levels more quickly than engineers. By looking Graph 6 and Graph 7 it can be noticed the increase in the output is sharper for students of economics. So we can deduce, economics students are more competitive. This result may be due to their game theory knowledge they learned about the strategic interaction and Cournot competition. Learning effect is stronger on economics students.

By looking at the average output and profit levels of these two groups, we can claim that engineering students and economics students choose different methods when deciding. We think that engineering students mostly decided according to their profits, but economics students decided according to the difference between maximum profit and subject's profit. So, economics students seem more competitive than engineering students.

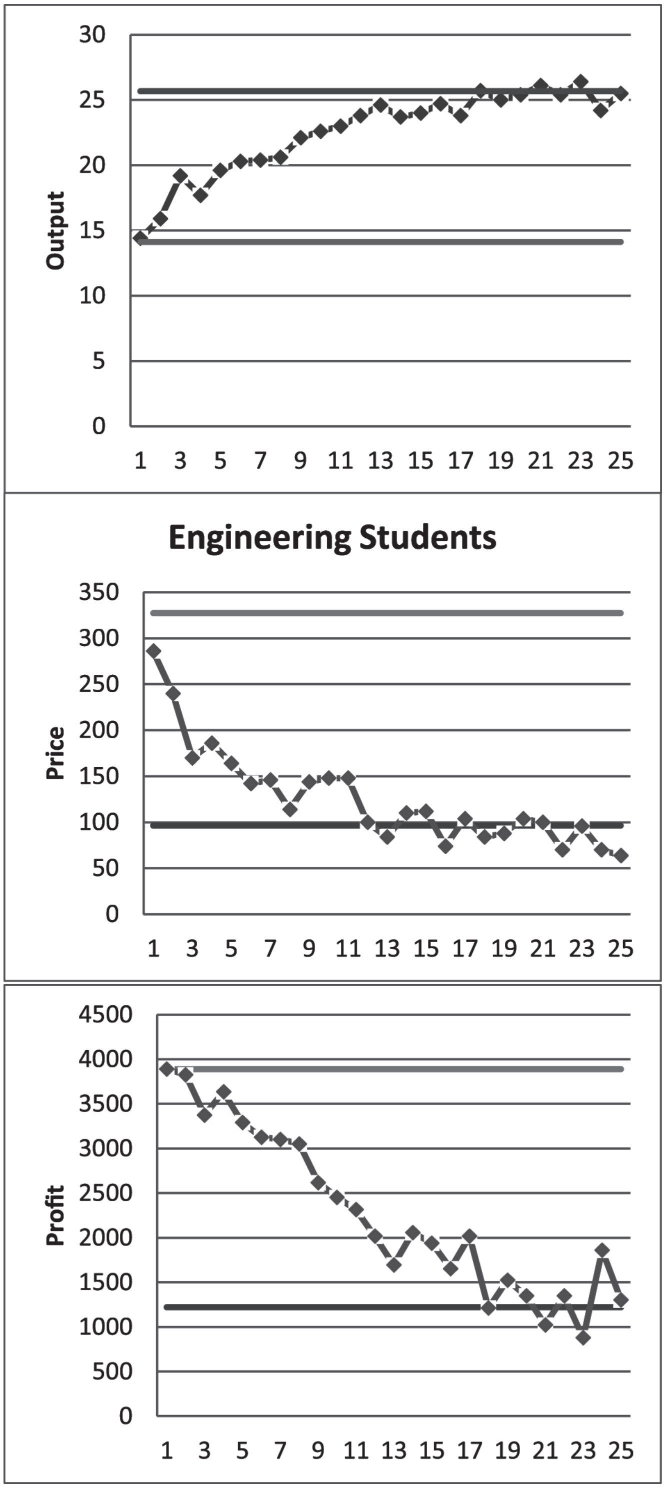
It is obvious that most subjects - no matter what is their understanding of the problem and game theory knowledge - discovered the game process and they had a competitive attitude; they followed the path to Cournot level. Considering the amount of occurrence of Cournot price and equilibrium, we can say that the Cournot model represents a real life competitive quantity competition environment. Eventually, we made this experiment without giving any demand function to subjects; therefore we can claim Cournot theory is suitable for real situations.

Graph 6: Average Output, Profit and Price for Economics Students



The dark horizontal line shows the Cournot level and the light horizontal line shows the collusive level. We can see that the average decisions converge to the Cournot equilibrium.

Graph 7: Average Output, Profit and Price for Engineering Students



The dark horizontal line shows the Cournot level and the light horizontal line shows the collusive level. We can see that the average decisions converge to the Cournot equilibrium.

4. Discussion

The rational agent described and frequently used by the economic theory is really capable to make the right decisions under all circumstances and is the education has an impact on that? In this paper that we were searching answers to those questions by conducting 2 experiments: Braess Paradox and Cournot Competition. We asked subjects to decide which road to choose in the first experiment, for this type of choice encountered in every day life, we have chosen two groups to see the impact of the education of mathematics and analytical thinking. The second experiment is the choice mostly faced by the financial planning departments and the production planning departments in production facilities and companies. We have chosen the groups of economics and engineering students for this experiment because later they will face these types of decisions when they will work in such departments as they usually do. We wanted to see the difference of an economist and an engineer. The first experiment is aimed to test the trust of the subjects to an authority figure even when this figure will make mistakes.

As the results of the first experiment reveal, economics students reached the social optimum earlier than sociology students and they tend more to penalise the system. Also, in that experiment, economics students were more adaptive to changes. They were easily changing their decisions and reach the social optimum points. We think that comes with the educational background. Problem solving skills vary with the educational background.

In the second experiment, we asked subject to decide their output level when they were given the cost function, an interval for production level and after each round their market share, the gap between their profit and the maximum profit of the period. When we analyze results, we see that although two groups started at collusive outputs, economics students reached the Cournot equilibrium earlier. And the decision of engineering students depended on their own profit but economics students mostly decided using the gap with the maximum profit. We think that economics students were more competitive.

Our experiments revealed similar results to previous works. Subjects generally acted selfishly in Braess experiment and their decisions converged to Cournot equilibrium in Cournot experiment. There is a major difference and contribution in Braess model which is the trust mechanism. We aimed to test participants' trust to an authority by giving them a suggested route from central navigation mechanism, and then we wanted to observe their reactions when there is the central navigation system makes an error. 3rd and 5th stages differed from literature in that manner. And the results show that economists were more adaptive to changes. Also when there is a mistake, the participants from both groups lost their trust to the navigation and choose the selfish route. In the Cournot experiment, we aimed our simulation to be more realistic. Subjects were not given the demand function but we gave them a cost function and a production capacity to decide their output. They were shown their own profit and the difference between maximum profit and their profit. The setting was similar to previous Cournot settings and in that sense our results confirmed the previous findings with the addition of a comparison of different analytical perspectives.

For the both experiments, as we expected before, economics students' decisions were more competitive and adaptive. We think that problem solving skills were improved with the courses of economics and especially game theory.

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