Bilateral Monopoly with the Elements of Price Leadership: Experimental Study

Keywords

game theory, experimental economics, bilateral monopoly

1. Introduction

For a very long time economics was considered a branch of science which, because of the complexity of phenomena it analyses and a significant level of uncertainty of conditions in which business entities function, cannot develop experimental methods. The one, who used an experiment as a tool to verify the economic theory for the first time, was L.L. Thurstone. In 1931 he published an article describing an experiment verifying the hypothesis of the shape of the indifference curve (Thurstone, 1931). The research done by E.H. Chamberlin concerning market behavior of the seller and the buyer had the pioneer importance for the classroom experiment method (Chamberlin, 1948). An outstanding form of acknowledgement of the importance of experimental economics was awarding the Nobel Prize to two leading scientists in this field Vernon L Smith and Daniel Kahneman in 2002.

2. The didactical importance of classroom experiment

The first contact with the economic model, particularly when it refers to the consumer behavior, can seem inadequate. A person, who has never before had a contact with the language of economic models, confronts in a natural way their own idea of decision making concerning spending income with an abstract picture of a phenomenon based on marginal approach. Only
appropriate intellectual effort, combined with a considerable training of the imagination can let you find the reflection of your own behavior in the model of consumer optimum. The same situation happens when an entrepreneur learns about the model of a company which maximizes profits.

In natural sciences the experimental method was a link which verified the relations between the reflection of the phenomena existing in nature and the theories which describe these phenomena. This method consisted in doing an activity in order to make an observation. This activity is supposed to either commence the observed phenomenon or to influence it. (Ajdukiewicz, 1965).

For many years economics was regarded a science in which experimental methods are useless. Only in the XX century, especially when the game theory was acknowledged as a separate branch of science, new opportunities of using experimental methods in economics appeared. According to the authors dealing with it, the crucial importance for its development was brought by the fundamental work published by von Neumann and Morgenstern “Theory of Games and Economic Behavior” (Roth, 1993).

Game theory can record a specific situation of conflict of interests or cooperation in its special language and that is why it has created a tool which enables the transformation of a chosen economic theory into rules of the game being the object of the experiment. The game, in the sense of game theory, must meet the following criteria:

- You can appoint at least two players. Any separate subject aware of its own interest, trying to maximize its payoff, can be a player.
- Every player has a limited number of strategies to choose from.
- Each combination of strategies of all the players brings the definite result of the game. The result of the game is a set of every player’s payoff corresponding to the strategy chosen by them (Straffin, 2001).

There is no doubt that the basic subject of economic theories is a rationally behaving producer or consumer who, in his choices, is trying to reach maximum profits. Strategy equivalents in economic theories are chosen levels of variables which are decided by the
subjects. Finally, the profits reached by the subjects depend on their
decisions and their interactions as well.
The presented analogies let us formulate the thesis that a strategic
game creates an environment in which business entities can experimentally test their behavior.

“Game theory creates a new system of testing rational
economic theories” (Shubik, 1995). The economic theory basing on
an abstract model, brings conclusions about the equilibrium or
character of the function which describes the examined phenomenon.
Game theory creates a tool which can be used in economic
experiments and therefore can verify conclusions from a theoretical
model. What is more, carrying out an experiment can reveal relations
which cannot be marked off by a highly abstract theoretical model. A
good example to support this thesis is the research by Fouraker,
Siegel and Harnett (Fouraker, Siegel, 1963). They did experiments
using the model of Bowley bilateral monopoly (Bowley, 1928).
These experiments showed that the balance within the frames of the
examined market structure can deviate from the indication of a
theoretical model depending on the information which sellers and
buyers possess.

While one is writing about experimental economy one
cannot only describe the one-sided influence of game theory on its
origin and development. Many observations made in experiments set
the course for research in game theory. Dresher and Flood’s
experimental research into the Prisoner’s Dilemma (Flood, 1952,
1958) made it possible to search for alternative solutions for the
Nash equilibrium. The recurrent character and the outcome of this
research, far from the theoretical expectations, brought about
attempts for the theoretical synthesis of the iterated Prisoner’s
Dilemma, which were undertaken among others by Shubik
(Shubik, 1970), who defined a condition under which it does not pay
off for a player to play confrontationally. Another example of the
influence of experimental economics on game theory was research
by Allais, who identified the paradox which rules individual choices
under the conditions of uncertainty (Allais, 1953). The discovery of
this paradox led to search for the utility concept alternative to von
Neumann and Morgenstern’s theory of expected utility.

It is necessary to add that many outstanding representatives
of game theory dealt with experimental economics. These are Nash
Selten, Schelling and Shubik. The first two used the method of classroom experiment to verify hypotheses, which later they submitted to mathematical formalization. This practice is an exemplification of the didactical importance of experimental economics. Of course, the main area of using experiments in teaching economics is microeconomics, the science which studies the behavior of subjects, which relates to individual choices of how to use resources.

Experience proves that testing an economic model by playing a strategic game based on it, makes it easy to further comprehend its concept. An abstract character of the theoretical construction can be for some students a barrier which is somehow “tamed” by active participation in the experiment. However, one has to bear in mind that the experiment should be carried out in the conditions reflecting the assumptions of the theoretical model. In particular, it refers to the scope of information and the possibility of communication among participants. The situation goes bad when the outcome of the experiment is different from the theoretical expectation as a result of collateral factors whose influence was not isolated.

3. Bowley bilateral monopoly

Bowley bilateral monopoly (Bowley, 1928) is a situation where two companies make deals. One of them is a supplier (a wholesaler) the other is a buyer (a retailer). The relation between these two companies has a feature of mutual exclusiveness. The supplier, who is a price leader in the analysed pair, as the first sets the price. In this way, they bid the price so as to maximize their profit at the expected order.

If the wholesaler is a price leader, then any price they choose will be an average cost and marginal cost for the retailer, and the product of the price and quantity will be a total cost. If the demand of the retailer for the goods can be described as:

\[
\frac{R}{Q} = A - BQ
\]  

(1)

where:

R – retailer’s profit,
Q – quantity,
A, B – equation parameters (positive real numbers),

The retailer’s profit can be described by a formula:
\[ Z_{C_D} = R - PQ = AQ - BQ^2 - PQ \]  
(2)

where:
P – price set by the supplier.
It will be maximized if and only if
\[ Q = \frac{A - P}{2B} . \]  
(3)

Supply of the supplier-wholesaler is described by the equation:
\[ \frac{C}{Q} = A' + B'Q \]  
(4)

where:
C – total cost of the seller
A’, B’ – parameters of the equation (positive real numbers).

The supplier’s profit can be described by a formula:
\[ Z_{C_H} = PQ - C = PQ - A'Q - B'Q^2 \]  
(5)

After substitution of the equation (3), which determines responses of the buyer the profit of the supplier will be maximized when they set the price at the level:
\[ P = A - \frac{2B(A - A')}{2B^2 + 4B} , \]  
(6)

For which the buyer will respond with the order:
\[ Q = \frac{A - A'}{2B^2 + 4B} . \]  
(7)

Such a pair, joining the price which maximizes the seller’s profit with the quantity ordered in the response by the buyer will be called Bowley point later in the article. The wholesaler, knowing that the retailer will respond with the quantity maximizing profit, chooses the price for which the optimum response will bring the seller the highest profit.

Bowley point can be opposed, within the same model, to joint profit maximization point. It can be reached when the marginal profit of the buyer equals the marginal cost of the supplier:
\[
\frac{dR}{dQ} = \frac{dC}{dQ} 
\tag{8}
\]
\[A - 2BQ = A' + 2B'Q \tag{9}\]

what is true if:
\[Q_m = \frac{A - A'}{2B' + 2B}. \tag{10}\]

The comparison of the equations (7) and (10) shows that at Bowley point companies make deals with a smaller quantity than at the point of joint profit maximization point. At the same time the price in the first case is higher than in the other. When putting it into the language of game theory we can treat Bowley point as an equilibrium in the game begun by the wholesaler, and the point of joint profit maximization as a corporate solution. In the first situation, the supplier reaches a significantly higher profit than the buyer but the joint profit is lower than in the case of the corporate solution, in which it reaches its maximum and is submitted to an equal distribution.

The linear model, depicting Bowley bilateral monopoly, can be described by a strategic game matrix. Strategies of the supplier (wholesaler) in this game are the prices which they may propose and the strategies of the buyer (retailer) are quantities the same as the quantities ordered in transactions. In the analyzed game players payoffs are profits they can achieve choosing definite pairs of strategies. This is a game whose sum is not equal with zero. In such games equilibrium is a pair of strategies which are the best responses to each other.

In the payoff matrix of the supplier, profits increase together with the increase of the price regardless of what quantity the buyer will respond with. The supplier will achieve the highest profits for the highest price taken into consideration. This price will be a dominating strategy in case of the supplier, which means it will bring the highest profits regardless of what strategy will be chosen by the other player. The buyer’s response to a dominating strategy will supplement the pair of strategies constituting the Nash equilibrium in this game. Of course, this is true under condition that the players choose strategies simultaneously, not knowing about their decisions and the game is played without repetitions.
One has to remember, however, about the recurrence of transactions and about the possibility of zero quantity choice, which should be treated as a strategic movement compelling the opponent to lower the price. Both the Nash equilibrium and Bowley point are not optimum solutions in the Pareto sense. If the supplier did not choose the highest possible price and the buyer did not respond with the quantity maximizing profit they could find themselves at the point of equal division of the total joint profit, which meets Pareto optimum criterion.

4. Results of pioneer experimental research into bilateral monopoly

The fact that Bowley point does not meet Pareto optimum criterion was an argument to expect a different equilibrium in an analysed model. The point of equal distribution of the total joint profit is an alternative. W. Fellner supported such a solution, arguing that even if the price leadership is sustained, bilateral monopoly will tend to equilibrium at Pareto optimum point of the equal distribution of total joint profit (Fellner, 1947). Siegel and Fouraker also supported a version of equilibrium stating that it refers only to the situation in which both parties have equal potential (Fouraker, Siegel, 1963).

The repeatability of the transaction is an important factor which influences equilibrium. If the transaction is made once with a full knowledge of the wholesaler about the retailer’s profit matrix, the equilibrium should be at Bowley point. The equilibrium in the model corresponds to the equilibrium in the sense of game theory.

Luce and Raiffa showed that repeatability of the game constitutes conditions for the silent agreement to tend to an optimum solution in Pareto sense where the total joint profit will undergo equal distribution. Even if the players cannot communicate with each other before the game, they still can exchange information in the form of their choices of strategies in the previous rounds (Luce, Raiffa, 1964).

In the experiment by Fouraker, Harnett and Siegel (Fouraker, Siegel, Harnett, 1962) two hypotheses concerning the equilibrium in the model were assumed. Firstly, when the game is sequential and with full information (both players know their own
and their opponent’s profits) the equilibrium should be at Pareto optimum point. Secondly, when the game is repeated with incomplete information (the players know only their own profit matrices) it will be more difficult for the players to move to the corporate solution at the point of equal distribution of total joint profit. One can rather expect equilibrium at Bowley point.

The experiment of Fouraker, Harnett and Siegel (Fouraker, Siegel, Harnett, 1962) consisted in carrying out a certain amount of negotiating rounds, in which the wholesaler proposes a price and the retailer respond with a quantity. Its participants were 42 students of economics at Pennsylvania State University. These students were divided into 21 pairs of “wholesaler-retailer”. To unable a different communication than this of stating prices and placing orders, wholesalers and retailers were closed in separate rooms. The wholesalers and retailers could not communicate in their groups either. Out of 21 pairs, 9 played under condition of incomplete information (they knew only their own payoff matrix) and 12 knew both, their own and their opponent’s matrix. After they had been informed about the rules of the game, they played three mock rounds in order to get accustomed with the rules and the applications of payoff matrices. Then, 20 proper rounds were conducted. Each proposal of the wholesaler was every time preceded by the information of the quantity in response to the previous proposal. Before the 20th round, the participants were informed that it was going to be the last one. The results of the last round were considered the most representative. After the experiment had been finished the joint profits were established for each retailer and wholesaler. These joint profits decided about the payoff for the whole negotiating experiment. In its original version the profits were paid in dollars.

The above described experiment was supplemented by the comparison study by Siegel and Harnett. It was conducted on the group of sales department employees of General Electric (Siegel, Harnett, 1964). The only differences were that there were fewer negotiating rounds (managers faster achieved equilibrium) and higher profits than in the case of students. Test experiments showed that managers needed far fewer transactions to reach a stable solution. The results of the 10th transaction for managers and the 20th transaction for students were accepted as the representative ones.
The results confirmed the initial hypothesis. With the full information the price goes down from the level near to Bowley point (P=9) to stabilize at the level of the equal distribution of total joint profit (P=4). With incomplete information, the price and the quantity almost from the beginning stabilize around Bowley point (P=9, Q=10). For the students who participated in the experiment with full information, the average price in the condition of stable solution was 5, which means that it is much closer to the point of equal distribution of total joint profit than to Bowley point. The same situation was with the average quantity (Q=13.92). The group of students with incomplete information reached a stable solution, in which P = 8.78 and Q = 10.22. These values are significantly closer to Bowley point than to the point of equal distribution of total joint profit. In fact, the averages almost exactly reconstructed Bowley point.

Siegel and Harnett did not point out significant differences in stable solutions achieved by students and managers with full information. However, under the condition of incomplete information, the average price of managers in the stable solution was significantly higher than the price fixed by students (P = 10) and the quantity was significantly lower (Q = 7.13). Although average price was here approaching to the hypothetical one from Bowley point (P=9) the quantity was definitely lower than the expected one (Q=10). Despite expectations, the 9th turn of negotiations did not lead here to a stable solution. Quantities were very dispersed between 2 and 11. The authors rectified the appointment of the point of stable solution to the 11th turn, in which the average price decreased a little to 9.13 with a simultaneous significant growth of an average quantity to the level indicated by Bowley point (Q = 9.88). The indication that the 11th turn is representative for the stable solution for managers playing with incomplete information can be backed up by a tiny dispersion of proposed prices (between 8 and 10) and placed orders (between 9 and 11).
5. Classroom experiment – bilateral monopoly (case study)

The conditions of the experiment were designed so as to generate the situation of bilateral monopoly compliant with the essence of Bowley model. The revenue function of an average retailer and the cost of an average wholesaler are linear:

\[
\frac{R}{Q} = 16 - \frac{1}{2} Q \tag{11}
\]
\[
\frac{C}{Q} = -8 + \frac{1}{2} Q \tag{12}
\]

These functions were used to define the revenue function for a retailer and wholesaler, which will measure payoff for both players:

\[
ZC_D = 16Q - \frac{1}{2} Q^2 - PQ \tag{13}
\]
\[
ZC_H = PQ + 8Q - \frac{1}{2} Q^2 \tag{14}
\]

Payoff matrices for a retailer and wholesaler were built by substituting in these functions the prices from the interval 1 to 10 and the quantities from the interval 0 to 14. In order to get significant differences between the values of potential profits these functions were transformed according to the formula:

\[
ZC_t = \left( \frac{ZC}{2} + 2 \right) 100 \tag{15}
\]

It is important for the game that the quantity equals zero and then the profits of retailers and wholesalers equal zero. The response of the zero quantity is a form of pressure on the wholesaler to lower the price. The quantity close to zero and much smaller than the ones which would maximize the retailer’s profit at a given price, play a similar role.

The following points are characteristic for the matrices (Tables 1 and 2):

- all the transactions at \(P=4\), where both players achieve the same profits,
all the transactions at $Q_m = 12$, where both players achieve maximal joint profit $Z_{CD} + Z_{CH} = 7600,$
Table 1. Retailer's profits depending on wholesaler's price and quantity

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Source: author’s own study
Table 2. **Wholesaler’s profits depending on his price offer and retailer’s orders**

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<td>3 775</td>
<td>4 425</td>
<td>5 075</td>
<td>5 725</td>
<td>6 375</td>
<td>7 025</td>
<td>7 675</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>1 600</td>
<td>2 300</td>
<td>3 000</td>
<td>3 700</td>
<td>4 400</td>
<td>5 100</td>
<td>5 800</td>
<td>6 500</td>
<td>7 200</td>
<td>7 900</td>
</tr>
</tbody>
</table>

*Source: author’s own study*
equal distribution of maximized joint profit at $P=4$ and $Q=12$; at the quantity $Q_m=12$ there is a maximization of joint profit ($ZC_D + ZC_H = 7600$), and if it is accompanied by the price at 4, it is equally divided between the retailer and the wholesaler ($ZC_D=ZC_H=3800$); this point meets the Pareto optimum criterion,

- Bowley point at $P=8$ and $Q=8$; the wholesaler’s profit is higher than the retailer’s profit (5000 and 2620 respectively).

The form of payoff matrices shows different strategies of the buyer. Firstly, they can respond to every price with a quantity $r$ maximizing their profit (the retailer’s optimum responses were marked by a box). Both Bowley point and the equal distribution of total joint profit are examples of such pair of strategies. The choice of an order maximizing the retailer’s profit is characteristic of a passive attitude, accepting price decisions of the seller. Another type of behavior is using a threat of a much lower order than optimum in response to unsatisfactory high price. This strategy is a confrontational one and its aim is to make the wholesaler lower the price.

To do the experiment one must divide a group of students into pairs of “wholesaler-retailer”. This division has to be made in such a way so that the participants could not identify their partners. Wholesaler and retailers should be closed in separate rooms. No communication is allowed except price proposals, acceptance and rejections exchanged with the help of forms which should be prepared in advance. The experiment can be carried out with limited information, when every player knows exclusively their own profit matrix or with full information. Then the profits reached by the other player are noted down in the communication form. Each negotiating round consists in writing down a price offer in the communication form of the wholesaler which is given to the retailer to respond with the quantity. The next price offer is every time preceded by the information about the quantity in response to the previous offer. It is important not to suggest any solutions or strategies to the participants while presenting the principles of the experiment.

After the participants have been instructed they should play three mock rounds in order to get used to the rules and the application of payoff matrices. Then 20 proper rounds should be
played. Before the 20th round, the participants should be informed that this round is the last one. The outcomes of the last round can be considered as the representative ones for the equilibrium. It can happen that the equilibrium is reached earlier. Everything depends on the stability and dispersion of prices and the quantity. After the experiment has been finished, joint profit for each retailer and wholesaler are set. This joint profit decides about the payoff for the whole negotiating experiment. In its original version the joint profit was paid in dollars. In a classroom experiment, to make students motivated, one can devise a method to exchange the joint profits into points needed to get a credit.

The presentation of the payoffs and the course of the experiment is an integral part of using the experiment for didactic purposes. It must be accompanied by a presentation of Bowley model, on which the game is based. Its perception is significantly easier after students have taken part in the strategic game, which deals with making decisions under the condition of bilateral monopoly.

6. Comprehension check

1. What was the origin of experimental economics?
2. What are the connections between game theory and experimental economics?
3. What is bilateral monopoly and what kind of equilibrium can be expected in this market?
4. What is the nature of Bowley point and the point of equal division of total joint profit with regard to game theory?

7. Recommended readings


References:


