Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

PROCEEDINGS

ODESA, ONUT 2022

Ministry of Education and Science of Ukraine

Black Sea Universities Network

Odesa National University of Technology

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Proceedings

Odesa, ONUT 2022

UDC 001.8(063)

Black Sea Science 2022: Proceedings of the International Competition of Student Scientific Works / Odesa National University of Technology; B. Iegorov, M. Mardar (editors-in-chief) [*et al.*]. – Odesa: ONUT, 2022. – 749 p.

Proceedings of International Competition of Student Scientific Works «Black Sea Science 2022» contain the works of winners of the competition.

The author of the work is responsible for the accuracy of the information.

Odesa National University of Technology, 2022.

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INTRODUCTION

International Competition of Student Scientific Works "Black Sea Science" has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

2. ECONOMICS AND ADMINISTRATION

RESEARCH OF THE MODEL OF RELATIONS BY METHODS OF GAME THEORY

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Abstract. *We considered a two-player signal game: the sender and the receiver. This game was solved for the mixed strategy Nash equilibrium. It gives us game theoretic predictions. We found the optimal strategy of both participants for the optimal solution of the conflict model.*

Keywords: *The Market for «Apples», game theory, economics.*

INTRODUCTION

To date, any questions related to the economy are important for follow – up. In the minds of the complicated situation in the world economy, it is important to understand the basic principles and laws that govern the economy.

The current world cannot be seen without markets, and the markets, in their own right, cannot be imagined without competition. However, markets and, obviously, competition are not the same. When solving economic problems, it is often necessary to analyze situations in which the interests of two or more competing parties collide, which are followed by different numbers – which is especially characteristic in the minds of the market economy.

We will say that the situation is a conflict one, that it is the subject of the conflict, the sides are stubborn, for some reason, the subject of the conflict could have been designated as the subject of the conflict, it could be possible to reach its goal.

LITERATURE ANALYSIS

So what is a game? The game is a system of rules that determines the possible actions of participants, their number, the rules of distribution of winnings, which depend on the behavior of each participant, as well as the outcome of the game as the winnings of each player. To solve the game means to give recommendations to the players on the optimal choice of strategy and to indicate the winnings of the player who corresponds to the chosen strategy of behavior.

The subject of the study is the model of the conflict situation of the economic market between buyer and seller. The object of the study is the strategy of both participants to optimally resolve the conflict model. Solution methods are game theory methods.

Let us turn to a brief historical overview of the emergence and development of game theory. Already in the XVIII century, some formalized the strategic approach in the behavior of market participants, including the work of J. Bertrand and A. Cournot. Later, E. Lasker, E. Cermelo, E. Borel offered the world the idea of a mathematical approach to conflict resolution. But the lack of relevant methodology for taking any steps by market participants in the XX century gave impetus to the creation of game theory. In their research, John von Neumann and Oscar Morgenstern concluded that the specific behavior of a market participant is influenced not only by his personal intentions and condition, but also by similar indicators of his competitors.

In their work “Game Theory and Economic Behavior” Neumann and Morgenstern formulated the concept of “game” as the activity of two or more people, which has the conditions of the so – called. "Win". It is important to note that participants in such a “game” can use certain “resources” and interact with each other. Therefore, make any decisions based on the behavior of other participants. The authors mathematically describe the means of finding optimal strategies – those that lead to gain [1].

To further study conflict situations, we turn to theoretical materials.

The nature of player relationships affects the ability to form coalitions. Non-coalition games are games in which players are unable to form coalitions.

By the nature of winnings, games are classified as zero – sum games and non – zero – sum games. In the first case, it is a game in which the total capital of all players does not change, but is redistributed between players depending on the results of the game, ie the sum of players winnings is zero. Otherwise, the game will be with a non – zero amount. An example of a game with a non – zero amount can be trade relations between countries. As a result of applying their strategies, all countries can benefit [1].

Bimatrix game is a non-coalition game in which each player has a finite number of strategies. Let the first player have m, $i = 1,...,m$. The second player has n strategies, $j = 1,...,n$ .The winnings of the first and second players are determined by the matrices, respectively: $\begin{pmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ a_{i1} & & a_{ij} & & a_{in} \\ a_{m1} & \dots & a_{mj} & \dots & a_{mn} \end{pmatrix}$ $\begin{pmatrix} b_{11} & \dots & b_{1j} & \dots & b_{1n} \\ b_{i1} & & b_{ij} & & b_{in} \\ b_{m1} & \dots & b_{mj} & \dots & b_{mn} \end{pmatrix}$.

In the context of the study of the coalition-free game, it is important to mention the concept of “equilibrium” as defined by John Nash. Equilibrium according to John Nash is characterized by the fact that deviating from the balance of one player can not increase his winnings, and thus the rational strategy of each player should be to achieve balance.

Nash equilibrium is a set of strategies (i^*, j^*), that for any player, deviating from their strategy can only worsen their situation:

$$\begin{cases} a_{ij^*} \le a_{i^*j^*} \\ b_{i^*j} \le b_{i^*j^*} \end{cases}, \text{ to all} (i, j).$$

So, to solve a bimatric game means to find all the balance situations and winnings of the players that correspond to them.

The number of moves of the game is divided into: single-step and multi – step. In the first case, the game ends after one move by each player. Multi – step games, in turn, are divided into: positional – games in which there may be several players, each of which can make moves. Winnings are determined depending on the results of the game. If the moves in the game lead to the choice of certain positions, and it is possible to return to the previous position, the game is stochastic. For the game Γ_1 we have:

$$\begin{pmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ a_{i1} & & \Gamma_1 & & a_{in} \\ a_{m1} & \dots & a_{mj} & \dots & a_{mn} \end{pmatrix} \quad \begin{pmatrix} b_{11} & \dots & b_{1j} & \dots & b_{1n} \\ b_{i1} & & \Gamma_1 & & b_{in} \\ b_{m1} & \dots & b_{mj} & \dots & b_{mn} \end{pmatrix}$$

In this situation (i, j), there is a draw of the game Γ_1 in which the number of strategies for players is finite, but may be different. In turn, a new game Γ_1 can be drawn in the game: $\begin{pmatrix} a_{11} & \dots & a_{1l} & \dots & a_{1n} \\ a_{k1} & & \Gamma_2 & & a_{kn} \\ a_{m1} & \dots & a_{ml} & \dots & a_{mn} \end{pmatrix} \begin{pmatrix} b_{11} & \dots & b_{1l} & \dots & b_{1n} \\ b_{k1} & & \Gamma_2 & & b_{kn} \\ b_{m1} & \dots & b_{ml} & \dots & b_{mn} \end{pmatrix}$.

Depending on the state of information, there are games with complete and incomplete information. If at each stage each player knows which choices were made by the players before, such a game is called with full information. Otherwise, the game with incomplete information. An example of a game with complete information is a game of checkers [1].

By repeating the bimatrix game repeatedly, players will choose their pure strategies with a certain frequency. Therefore, we can move on to a new production - bimatric game in mixed strategies (Bayesian game). We will consider a complete set of probabilities $x = (x_1, \dots, x_m)$ the first player's application of his pure strategies to the mixed strategy of the first player, and the full set of probabilities $y = (y_1, \dots, y_n)$ the second player's use of his pure strategies – the mixed strategy of the second player.

There are other types of games, other principles of game classification are also possible.

Nash equilibrium (or decision of the game) is a set of strategies (i^*, j^*) and player gains, which for any player deviating from their strategy can only worsen their situation $\begin{cases} a_{ij^*} \le a_{i^*j^*} \\ b_{i^*j} \le b_{i^*j^*} \end{cases}$, to all (i, j).

By repeating the bimatrix game repeatedly, players will choose their pure strategies with a certain frequency. So you can move on to a new setting of the game, the solution of which will provide a full set of probabilities and $\begin{matrix} x^* = (x_1, \dots, x_n) \\ y^* = (y_1, \dots, y_n) \end{matrix}$. This new production is a matrix game in mixed strategies or a Bayesian game. Incomplete game or Bayesian game in game theory is characterized by incomplete information about opponents, but players have some confidence in the distribution of probability. The Bayesian game can be turned into a game with complete but imperfect information, assuming the assumption of a general a priori distribution. Unlike incomplete information, imperfect information includes knowledge of opponents strategies and winnings, but the game history (previous actions of opponents) is not available to all participants. Bayesian equilibrium is a generalization of Nash equilibrium in mixed strategies in the case of Bayesian games. The winning function is a mathematical expectation of winning [2].

A pair of numbers $\left(x^*, y^*\right)$ forms Nash equilibrium in a mixed expansion of the coalition – free matrix game $\begin{cases} \sum_{i,j} a_{ij} x_i y_i^* \le \sum_{i,j} a_{ij} x_i^* y_j^* \\ \sum_{i,j} b_{ij} x_i^* y_i \le \sum_{i,j} b_{ij} x_i^* y_j^* \end{cases}$, when $x = \left(x_1, ..., x_n\right)$ – mixed strategy of the first player, $y = \left(y_1, ..., y_n\right)$ – mixed strategy of the second player [2].

The paper will also use a decision tree – a mathematical model consisting of arcs, decision nodes, event nodes and end nodes (outputs), which defines the decision – making process so that it reflects every possible decision that precedes, subsequent events or other decisions and the consequences of each final decision [3].

OBJECT, SUBJECT, AND METHODS OF RESEARCH

It is known from game theory that it is impossible to find the "perfect" solution for all players, but to use the optimal solution is a very real task. This aspect is especially relevant for the economy. Consider a market model with incomplete and asymmetric information on the example of the game "buyer – seller".

Assume that the seller sells only two types of used computers: good (let's call them plates), which are worth $330(\$)$, the cost of this product is $200(\$)$, and bad (let's call them apples), which are worth $220(\$)$ the cost of this product is $150(\$)$. This is not an auction where only one product is selected, and the gain depends on the mathematical expectation of the price of the product. In this case, there are several products - bad and good gadgets. Therefore, it is worth mentioning the strategies of the game. The number of good and bad computers is the same. The buyer has no additional information about the condition of the goods, so the probability that he will choose a plate or an apple is $\frac{1}{2}$. The buyer can offer an average price for the product: $\frac{330+220}{2} = 275(\$)$. If the selected product is a plate, the seller will refuse the transaction, because then his profit will be $200 - 275 = -75(\$)$. But it doesn't make sense for the buyer to offer an average price for an "apple", as he can buy this computer for a lower price: $275 > 220(\$)$. That's why he always has to offer $220(\$)$. In such a coincidence, the seller for one stage of the sale can earn: $\frac{1}{2}(220-150) + \frac{1}{2}(0) = 35(\$)$. Expected income is: $\frac{1}{2}(220-150) + \frac{1}{2}(330-200) = 100(\$)$, with full awareness of buyers and the same demand for both types of gadgets.

This situation has the following consequences: the seller will be forced to reduce the share or stop selling quality computers altogether. Customers who need a quality computer are forced to move to another market.

Now consider the signal game "The market for Apples". This theory was based on the article by Nobel laureate George Ackerloff "The market for Lemon"[4].

Suppose a reseller of used computers again has the same number of bad (apples) and good (plates) machines. The buyer does not distinguish apples from plates. Therefore, the seller decides to give some of the computers sold a one – year warranty, which fully covers the cost of repairs. It is known that during the year the expected cost of repairing apples is 10($) and plates – 50($).

The rules of the game are as follows. First, the buyer makes the move – he chooses the computer. This is a random move. The seller then says whether he gives a guarantee for the selected product. The next move of the buyer – offers its price: 200($) or 300($). Transactions will take place unless a price is offered for a plate 200($).
The signal game has:
1. many types of seller: *T={T, N}* where it means *T* – a good computer (plate), *N* – a bad computer (apple);
2. many messages from the seller *M= {W, J}*: where *W* – a computer with a warranty, *J* – a computer without a warranty;
3. set of actions of the buyer *R ={220;330}: 220* – the buyer offers 220 ($), *330* – the buyer offers 330 ($).
4. the set cost of computers *Q = {S, Z},* where *S* – is the cost of an apple 150($), Z – is the cost of a plate 200($);

The imagination that the buyer chooses an apple or a plate, ie the imagination of the buyer about the signals of the seller is $\mu(N) = \mu(T) = 0{,}5$.

The signal game tree has the following form (Fig. 1). The strategic form of the game is as follows: (Table 1). Find the mathematical expectation of players winnings.

Whereas the payment matrix acquires the following values $\begin{pmatrix} (10;25) & (125;-25) \\ (35;0) & (95;5) \end{pmatrix}$.

Note that this bimatrix game has no balance in pure strategies (Table 2). We will find balance in mixed strategies. Let's use the method of dominant strategies – reduce the size matrix 4×4 to 2×2. Strategy [220;220] dominates [220;330] and [330;330]. After that we see that the strategy JW dominates the strategy JJ, and the strategy WW dominates WJ (Table 3). We have the following payment matrix.

We will look for solutions to the bimatrix game by solving systems for the first and second players, respectively:

$$\begin{cases} (p-1)(-55q+30) \ge 0, \\ p(-55q+30) \ge 0. \end{cases}$$

$$\begin{cases} (q-1)(55p-5) \ge 0, \\ q(55p-5) \ge 0. \end{cases}$$

The equilibrium point will be $(p^*;q^*) = \left(\frac{1}{11};\frac{6}{11}\right)$, where mixed strategies $p^* = (p;1-p) = \left(\frac{1}{11};\frac{10}{11}\right)$, $q^* = (q;1-q) = \left(\frac{6}{11};\frac{5}{11}\right)$.

The probability distributions will be as follows:

$$p^*_{WW} = \frac{1}{11},\ p^*_{WJ} = 0,\ p^*_{JW} = \frac{10}{11},\ p^*_{JJ} = 0,\ q^*_{[220;220]} = \frac{6}{11},\ q^*_{[220;330]} = 0,\ q^*_{[330;220]} = \frac{5}{11},\ q^*_{[330;330]} = 0.$$

Then the price of the game for the first player is:

$$H_S\left(\frac{1}{11};\frac{1}{6}\right) = 10\cdot\frac{1}{11}\cdot\frac{6}{11} + 125\cdot\frac{1}{11}\cdot\frac{5}{11} + 35\cdot\frac{10}{11}\cdot\frac{6}{11} + 95\cdot\frac{10}{11}\cdot\frac{5}{11} = \frac{685}{11} \approx 62.$$

For the second player:

$$H_R\left(\frac{1}{11};\frac{6}{11}\right)=25\cdot\frac{1}{11}\cdot\frac{6}{11}-25\cdot\frac{1}{11}\cdot\frac{5}{11}+0\cdot\frac{10}{11}\cdot\frac{6}{11}+5\cdot\frac{10}{11}\cdot\frac{5}{11}=\frac{25}{11}\approx 2.$$

The use of signals allows the seller (player *S*) to increase their winnings 35($) without signals from before winning 62($) with signals. Then the signal game tree will acquire the following values (Fig. 2).

Bayesian balance of the game looks like. In an equilibrium situation, the seller always gives a guarantee for a quality computer: $\tilde{p}^*(T)=\begin{pmatrix}\tilde{p}^*_W(T)\\ \tilde{p}^*_J(T)\end{pmatrix}=\begin{pmatrix}1\\0\end{pmatrix}$, and on a bad computer gives a guarantee at random: on average, one guarantee for 11 computers: $\tilde{p}^*(N)=\begin{pmatrix}\tilde{p}^*_W(N)\\ \tilde{p}^*_J(N)\end{pmatrix}=\begin{pmatrix}\frac{1}{11}\\ \frac{10}{11}\end{pmatrix}$.

Instead, the buyer always offers a price for the computer without a guarantee: $\tilde{q}^*(J)=\begin{pmatrix}\tilde{q}^*_{220}(J)\\ \tilde{q}^*_{330}(J)\end{pmatrix}=\begin{pmatrix}1\\0\end{pmatrix}$, and assigns a random price to a gadget with a guarantee: $\tilde{q}^*(W)=\begin{pmatrix}\tilde{q}^*_{220}(W)\\ \tilde{q}^*_{330}(W)\end{pmatrix}=\begin{pmatrix}\frac{6}{11}\\ \frac{5}{11}\end{pmatrix}$, $220(\$)$ with probability $\frac{6}{11}$ and $330(\$)$ with probability $\frac{5}{11}$.

In turn, after the signals of the seller, the buyer has the following opinion. If the seller offered a guarantee, the buyer considers: with the possibility that he chose a bad computer: with probability $\frac{1}{12}$, that he chose a bad computer: $\mu(N|W)=\mu(D)=\frac{1}{12}$; with the probability $\frac{11}{12}$, that he chose a good one: $\mu(T|W)=\mu(G)=\frac{11}{12}$.

If the seller did not offer a guarantee, the buyer believes that he chose a bad product: $\mu(N|J)=\mu(E)=1$, $\mu(T|J)=\mu(F)=0$.

RESULTS

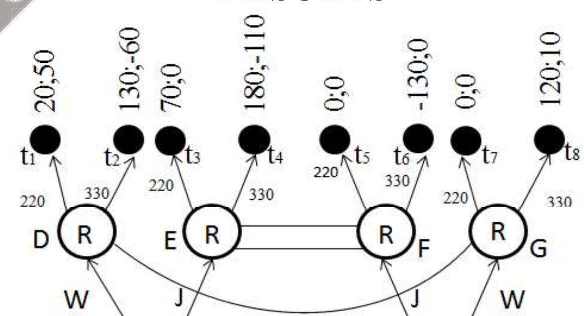

Fig.1. The signal game tree

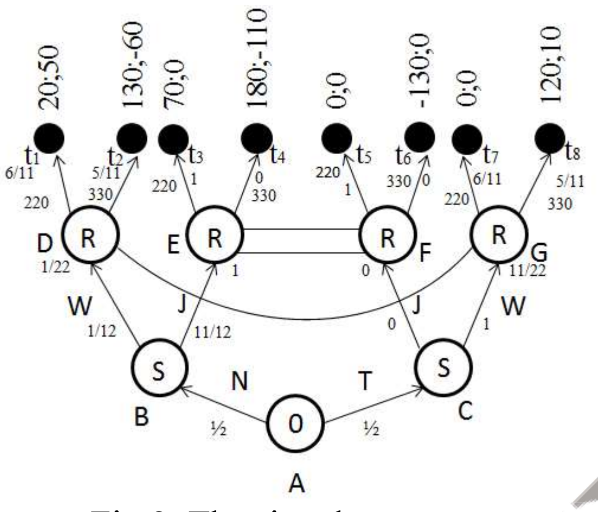

Fig.2. The signal game tree

Table 1. The strategic form of the game

Event	Run	Player	Win
D	t_1	S	$220 - S - W = 20$
		R	$220 + W - N = 50$
	t_2	S	$330 - S - W = 130$
		R	$N + W - 330 = -60$
G	t_7	S, R	The agreement was not made
	t_8	S	$330 - Z - J = 120$
		R	$330 + W - T = 10$
E	t_3	S	$220 - S = 70$
		R	$N - 220 = 0$
	t_4	S	$330 - S = 180$
		R	$N - 330 = -110$
F	t_5	S, R	The agreement was not made
	t_6	S	$330 - Z = 130$
		R	$330 - T = 0$

Table 2. Bimatrix game of dimension 4 × 4

	$[\mathbf{220}; \mathbf{220}]$	$[\mathbf{220}; \mathbf{330}]$	$[\mathbf{330}; \mathbf{220}]$	$[\mathbf{330}; \mathbf{330}]$
WW	$10; 25$	$10; 25$	$125; -25$	$125; -25$
WJ	$10; 25$	$-55; 25$	$65; -30$	$0; -30$
JW	$35; 0$	$90; -55$	$95; 5$	$150; -50$
JJ	$35; 0$	$25; -55$	$35; 0$	$25; -55$

Table 3. Bimatrix game of dimension 2 × 2

	$[\mathbf{220}; \mathbf{220}]$	$[\mathbf{330}; \mathbf{220}]$
WW	$10; 25$	$125; -25$
JW	$35; 0$	$95; 5$

CONCLUSIONS

In this paper, we came to the conclusion that the use of strategy is an important aspect of the functioning of the economic market, for which, of course, the concept of "game" is relevant. The strategy was studied as a means of creating an optimal model for all participants in the "conflict". It has been shown that in the absence of information from buyers, low-quality cheap goods displace expensive quality goods from the range. Based on the analysis, the following conclusions can be drawn about the prospects for the use of game theory and formal models in the study of modern conflicts. An important but insufficiently studied area is the analysis of the actions of opponents in several periods, the strategic behavior of participants in the presence of incomplete information. Another area that is practically not taken into account in both classical and modern research and games is the moral norms, values of society, the moral side of each strategy. The main feature of the studied theory will be the aspect of "uncertainty". Game theory allows you to structure the process of making optimal strategic decisions in a situation of uncertainty, when it is not known how opponents will behave in the game, which, of course, is one of the properties of the economic market.

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