O. HAVRYS, CHANGAN SUN, S. KUCHINA, M. GAVRYS
GAME THEORY AS A TOOL FOR MAKING OPTIMAL BUSINESS DECISIONS IN FOREIGN ECONOMIC ACTIVITY OF ENTERPRISES

The article is devoted to the study of the effectiveness of game theory in making business decisions regarding foreign economic activity by enterprises in conditions of uncertainty. The sources of information on this issue were analyzed and it was found that further development of the application of game theory in the foreign economic activity of enterprises is necessary. It has been established that the ambiguity of economic development trends, which has been especially evident in recent years in Ukraine and the world, and the instability of the market regulation mechanism encourage enterprises to look for new ways to overcome uncertainty in their activities. When solving economic problems, conflict situations often arise, which are caused by the conflicting interests of various structures. The mathematical apparatus for solving this type of problem is game theory, which is the theory of building mathematical models of optimal decision-making in conflict conditions. Game theory is a theoretical direction in science, a set of methods of mathematical analysis and assessment of the rules of behavior of participants in a conflict situation, which involves the interaction of two or more participants (players) in order for each of them to achieve their goals. The advantages of game theory are analyzed, in particular, the possibility of formalizing the process of considering typical scenarios of decision-making by the parties to the conflict and choosing the procedure for coordinating interests that will be optimal for all its participants. The main concepts, principles and classifications of game theory are presented, the foundations for understanding the use of game theory in economics are laid. Analyzing the usefulness of game theory in market competition, development of enterprise development strategy, investment activities and other areas, the possibility of wide application and effectiveness of game theory in decision-making regarding foreign economic activities of enterprises is shown.

Keywords: Game theory; foreign economic activity; business decisions; uncertainty; conflicting interests; decision-making criteria

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ТЕОРІЯ ІГОР ЯК ІНСТРУМЕНТ ПРИЙНЯТТЯ ОПТИМАЛЬНИХ БІЗНЕС-РІШЕНЬ У ЗОВНІШНЬОЕКОНОМІЧНІЙ ДІЯЛЬНОСТІ ПІДПРИЄМСТВ

Стаття присвячена дослідженню ефективності теорії ігор у прийнятті господарських рішень щодо зовнішньоекономічної діяльності підприємствами в умовах невизначеності. Проаналізовано джерела інформації з даного питання і виявлено, що не обхідні подальші розробки застосування теорії ігор в зовнішньоекономічній діяльності підприємств. Встановлено, що неоднозначність тенденцій економічного розвитку, яка особливо проявляється останніми роками в Україні та світі, та нестабільність механізму ринкового регулювання спонукають підприємства шукати нові шляхи подолання невизначеності у своїй діяльності. При вирішенні економічних проблем часто виникають конфліктні ситуації, які викликані суперечливими інтересами різних структур. Математичним апаратом розв'язування такого типу задач є теорія ігор, яка є теорією побудови математичних моделей прийняття оптимальних рішень в умовах конфлікту. Теорія ігор — теоретичний напрям у науці, сукупність методів математичного аналізу та оцінки правил поведінки учасників конфліктної ситуації, що передбачає взаємодію двох або більше учасників (гравців) з метою досягнення кожним із них їхні цілі. Проаналізовано переваги теорії ігор, зокрема можливість формалізації процесу розгляду типових сценаріїв прийняття рішень сторонами конфлікту та вибору процедури узгодження інтересів, яка буде оптимальною для всіх його учасників. Викладено основні поняття, принципи та класифікації теорії ігор, закладено основи розуміння використання теорії ігор в економіці. Аналізуючи корисність теорії ігор у ринковій конкуренції, розробці стратегії розвитку підприємства, інвестиційній діяльності та інших сферах, показано можливість широкого застосування та ефективність теорії ігор у прийнятті рішень щодо зовнішньоекономічної діяльності підприємств.

Ключові слова: теорія ігор; зовнішньоекономічна діяльність; бізнес-рішення; невизначеність; конфлікт інтересів; критерії прийняття рішень

Introduction. Analysis of various games was carried out back in Ancient China, among others, for example, Go stands out - a logical game containing a strategic component, where players compete for territory, but works in which the search for optimal strategies in games was formulated as a mathematical model appeared only in the 17th century. The first studies of games in the economic literature should be considered the works of mathematicians and economists of the 19th century, which considered the problems of production and pricing in an oligopoly. In 1944, game theory was formed as an independent mathematical discipline by American scientists – mathematician J. von Neumann and economist O. Morgenstern. Unlike other branches of mathematics, which are mainly of physical or physical-technological origin, game theory from the very beginning of its development was aimed at solving problems that arise in the economy (namely, in a competitive economy).

Game theory, as a branch of operations research, is a theory of mathematical models of most favorable decision-making in conditions of uncertainty or conflict between several parties with different interests. The essence of the theory is to establish the optimal strategy of behavior in conflict situations. The goal is to determine the optimal strategy for each player, which is understood as a set of rules determining the choice of his actions at each individual move depending on the existing situation. For example, the decision to enter a new market, the definition of a production strategy, entering into a coalition with another market participant.

Game theory and economics are inextricably linked to each other, as game theory problem-solving methods help determine the best strategy for various economic situations, including in the field of foreign economic activity. In general, the methods of game theory help to conduct economic experiments in conditions of uncertainty, to evaluate at a qualitative level various options for the country's strategic economic policy, to make appropriate decisions with maximum benefit, to predict in general terms the consequences of decisions made or changes in the external market situation.

Actuality. In modern economic conditions, the majority of enterprises conduct foreign economic activities. When carrying out any business transaction, there is always the possibility of a negative scenario, but it is foreign economic activity that is the sphere of the company's activity that is most characterized by riskiness and uncertainty. Due to fluctuations in the global economic situation, frequent policy adjustments and rapid technological innovations, businesses face great

challenges when making business decisions. In Ukrainian realities, martial law and constant shelling of the territory is added to this. In this context, it is especially important to find a tool that will help enterprises make optimal business decisions in conditions of uncertainty. This article discusses the application of game theory in economics, including the foreign economic activity of enterprises and its impact on enterprise decision-making and market competition.

Review of the recent literature and formulation of the research problem. Game theory as a way of solving various economic problems was and continues to be in the field of interest of many economists. It should be noted that the Nobel Prize in Economics was awarded several times specifically for developments related to game theory.

It is worth noting that at the current stage quite a lot of Ukrainian and foreign scientists are investigating various aspects of using game theory in solving problems of an economic nature [1-14]. In particular, we should note T.I. Oleshko , M.O. Lobanov [1], I.O. Moroz [9], O.V. Korzachenko [2], N.I. Havlovsk [13], who in their works proved the usefulness of applying this theory to improve economic decisions in conditions of uncertainty. Studies of the development of the use of game theory methods in foreign economic activities show that domestic scientists did not pay enough attention to this aspect. But here it is necessary to emphasize the thorough scientific research on this issue by D. V. Kulish, who is working on the development of a model of the antagonistic game of choosing the strategy of foreign economic activity in the modern digital environment [5].

Foreign scientists are also studying the general issues of using game theory in economic activity, here, for example, we note the works of J. McMillan [7], L. Samuelson [10] and others. Chinese scientists pay special attention to the study of game theory, in particular, the field of scientific interests of Yu Chen, Anthony G. O. Yeh, Yingxuan Zhang [12] is the political and economic analysis of China's regional cooperation, C. Liang, N. Liu, Y. Liu [3] investigate the peculiarities of trade cooperation between China and USA in the context of game theory. The work of such scientists as V. L. Mughwai [4], G. Askari, M. E. Gordji, S. Shabani, J. A. Filipe [6], Chaitanya Khurana [8] and others is also devoted to international trade.   S. Hidalgo-Gallego, R. Núñez-Sánchez and P. Coto-Millán [11] explore the application of game theory and port economics.

The above analysis of sources of information on this issue proves that further development of the application of game theory in the foreign economic activity of enterprises is necessary.

The purpose of the study. In business, decision-making is often influenced by the actions of other decision-makers. Such interconnectedness and strategic interaction significantly complicates the decision-making process. Game theory allows modeling the behavior of several subjects, when the decision-making criterion of each depends on the decisions made by others, is a powerful tool for understanding and analyzing this complexity. The purpose of the proposed work is the study of the application of game theory in the foreign

economic activity of enterprises and the analysis of its influence on decision-making and market competition.

Presentation of the main research material. When solving a number of economic problems, conflict situations often arise, generated by the conflicting interests of different structures. The mathematical apparatus for solving this type of problem is game theory, which is the theory of constructing mathematical models for making optimal decisions in conditions of conflict. An important task of game theory is also the development of recommendations regarding the rational actions of participants in a conflict situation.

The game is a model of conflict situation. Permissible actions of each of the players aimed at achieving a certain goal are called the rules of the game. In the economy, players are partners who are parties to the conflict. The player's task is to find the optimal strategy, which, under the condition of multiple repetitions of the game, provides this player with the maximum possible average profit. The result of the conflict is the winning or losing of one of the players [1].

The game differs from a real conflict in that it is conducted according to certain rules, for its description you need to know:

− number of subjects – players participating in the conflict;

− action options for each of the players, which are called strategies;

− functions of winning or losing (payment) of the conflict result.

Authoritative sources in economic science consider this theory as the main direction for analyzing situations that require coordination of the interests of the parties. The advantage of game theory is, among other things, the possibility of formalizing the process of considering typical decision-making scenarios by the parties to a conflict and choosing a procedure for reconciling interests that is most effective for all its participants. This approach is adequate to describe the situation at modern domestic enterprises for the following reasons:

1. Game theory allows to construct and analyze various scenarios and mechanisms for coordinating the interests of the parties to the conflict.

2. Game theory makes it possible to identify those restrictions that affect the results of the coordination of the interests of the parties, and to change them as necessary for key players.

3. Models of economic behavior of the parties, obtained on the basis of game theory, are quite universal and can be applied to a wide range of enterprises of various forms of ownership and sectors of the economy.

4. Models obtained on the basis of game theory can be structured into a database and knowledge that makes it possible to algorithmize the control process [9].

Game theory, as a mathematical theory that studies how decision-making agents choose their own actions in accordance with the behavior of other decision-making agents in a particular environment, provides us with strong support in making optimal business decisions under uncertain conditions. The decision-making structure of game theory includes the basic elements such as

players, a set of strategies, and a payoff function, which together form the basis of decision-making in game theory. In times of uncertainty, these elements can help companies analyze the market environment, competitor behavior, and potential outcomes to make more informed and effective business decisions.

In particular, the game theory decision-making framework under uncertain conditions can help firms:

Identify the players: in a complex market environment, companies need to identify their competitors, partners and other stakeholders to better analyze the impact of their actions on decisions.

Construct a set of strategies: according to the market environment and the company's own strengths, it is necessary to develop a number of possible action plans that constitute a set of company strategies. By creating a set of policies, companies can look at options more holistically and make more flexible and adaptable decisions.

Estimate the payoff function. The payoff function measures how much a business wins or loses under different combinations of strategies. In an environment of uncertainty, enterprises need to pay more attention to the dynamic changes in the payment function in order to timely adjust strategies and respond to market changes.

There are several different criteria that are designed to justify the choice of a certain strategy among others when a decision is made under conditions of uncertainty. The task is to find such a decision option, which is the most profitable (expedient) compared to other options.

To make decisions under conditions of uncertainty and risk using a static game model, the input information is presented in the form of a matrix (table), the rows of which are possible alternative solutions, and the columns are the states of the system (environment). Each decision alternative and each state of the system (environment) corresponds to a result (consequence of the decision), which determines the costs or gain for choosing a given decision alternative and implementing a given state of the system.

Table - Payoff matrix

	S_1	$S...$	S_m
A_1	a_{11}	…	a_{1n}
$A_{...}$	…	…	…
A_n	a_{n1}	…	a_{nm}

Where: A_i is the alternative of the i-th solution (i = n); S_j – possible j-th state of the environment (j=1,m); a_{ij} is the result (consequence of the decision).

When making decisions under conditions of uncertainty, the following decision selection criteria are most often used:

– Wald criterion;
– maximax criterion (criterion of extreme optimism);
– criterion of pessimism;
– Savage's criterion;
– Hurwitz criterion.

In fact, the criterion is an approach, a philosophy of decision-making.

In order to better demonstrate the application of game theory to business decision-making, we will show how to construct game theory models and apply them to real business through concrete cases. These cases will involve competitive strategy analysis, cooperation strategy formulation and other aspects, aiming to help enterprises better understand and apply game theory.

In the analysis of competitive strategy, enterprises can use the game theory model to analyze the behavior and possible results of competitors, to formulate more targeted competitive strategies. For example, an enterprise can predict the pricing strategy of its competitors by constructing a price competition model, and adjust its own pricing strategy accordingly to obtain the maximum profit.

In the formulation of cooperation strategy, enterprises can use the game theory model to analyze the interest relationship and cooperation mode between partners, to formulate a more stable and effective cooperation strategy. For example, enterprises can build a cooperation game model to analyze the income distribution and cost sharing under different cooperation modes, and choose the appropriate partners and cooperation modes accordingly.

In the conditions of global economic development, foreign economic activity is an important factor of economic growth for any state. It can manifest itself in various forms of entry of enterprises to the foreign market. Due to the implementation of foreign economic activities, countries solve the problems of shortage of food and raw materials, energy carriers, and so on.

Every enterprise strives to make the most optimal business decision, but since foreign economic activity involves the need to act in conditions of a high level of uncertainty, enterprises are usually faced with the choice of several decision-making methods. Besides game theory, there are other methods such as decision trees and Monte Carlo simulation. Let us analyze the advantages and disadvantages of these game theories and how to choose the most suitable decision-making method according to the actual situation in enterprises.

In particular, decision making based on game theory has the following advantages over other approaches:

Analysis of strategic interaction. Game theory can deeply analyze the strategic interactions between participants and help businesses better understand market dynamics and competitor behavior.

Dynamic adjustment: The game theory model can dynamically adjust parameters and strategies according to market changes, making the decision-making process of enterprises more flexible and adaptive.

Long-term perspective. Game theory focuses on long-term benefits rather than short-term gains, which helps businesses develop more stable and sustainable growth strategies.

However, decision making in game theory also has some limitations, such as building a complex model and a large amount of computation. Therefore, in practical applications, enterprises need to select suitable decision-making methods according to their situations and needs.

Game theory helps companies make more informed and effective decisions by providing a mathematical

theory and methodology for analyzing strategic interactions. Here's how game theory is used to make business decisions:

Competitor analysis: game theory can help businesses analyze competitors' intentions and plans of action, and formulate appropriate strategic plans. For example, during market competition, businesses can predict competitors' pricing strategies and product strategies using game theory models to make more informed market positioning and competitive strategies.

Risk assessment decision-making: game theory can assess possible outcomes and rewards, thereby helping companies assess risks and determine the best strategic plan. Businesses can use a game theory model to simulate different market environments and competitive situations, analyze the risks and benefits that different strategies may bring, and choose the best decision-making scheme. Risk management must be based on the identification of all factors of internal and external formation, potentially capable of negatively affecting the company's activities [15].

Predicting market changes: game theory can help companies predict market changes and thus adjust their strategies in advance. For example, when faced with uncertain factors such as changes in market demand, technological progress, or policy adjustments, businesses can use game theory models to analyze the impact of these factors on the pattern of market competition and the behavior of participants to develop coping strategies in advance.

Optimizing cooperation strategy: in cooperation, game theory can help enterprises analyze the relationships of interest between partners and develop more stable and effective cooperation strategies. For example, in supply chain management, enterprises can use the game theory model to analyze the cooperative relationship between suppliers and manufacturers, and formulate a reasonable profit sharing and cost sharing mechanism to achieve long-term stability and optimization of the supply chain.

Building a strategy set: the concept of a strategy set in game theory can help a business build a range of possible courses of action. These programs can be designed according to the market environment and the company's own strengths, so that the company can respond quickly when faced with different situations.

In order to better understand the application of game theory in economics, we need to show how to construct and analyze game theoretic models through concrete cases. Here's a simple example:

Suppose there are two companies in a market, and they need to decide how much they can produce. Each firm's output decision will affect the market price and each other's returns. In this game, each firm needs to consider the other's output decisions and make their own output plans accordingly. By constructing a game theory model, we can analyze market prices and firm profits under different combinations of output and find an equilibrium solution. This equilibrium solution is the optimal output decision of two firms under given conditions.

By constructing and analyzing game theory models, we can gain a deeper understanding of strategic interactions among market participants and the formation of equilibrium outcomes. This helps us to better predict market changes and corporate behavior, providing strong support for corporate decisions.

In short, game theory provides a systematic analytical framework and tools to help businesses better understand and cope with complex and changing market environments in order to gain competitive advantage. However, it should be noted that game theory is not a panacea, it is only a tool to facilitate decision-making, enterprises also need to combine their own real situation and market environment for comprehensive consideration and decision-making.

Conclusions and prospects for further research. This article explores game theory as a tool for making optimal business decisions under conditions of uncertainty for the foreign economic activities of enterprises. By presenting the decision-making framework of game theory under uncertain conditions, creating and applying models, and comparing with other methods, the broad application and unique benefits of game theory in business decision making are demonstrated. Applying game theory to real-life business has been proven to increase the likelihood of making the most rational decisions to solve problems that arise in uncertain markets and achieve success. At the same time, businesses are encouraged to pay attention to the simplification and practicality of the model and combine it with other methods when applying game theory to better meet the real needs of enterprises.

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