Turkish Journal of Engineering

https://dergipark.org.tr/en/pub/tuje

e-ISSN 2587-1366

Ship tonnages determined by the world economic growth with game theory

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Keywords
Decision Making
Competition Environment
Game Theory
Maritime Companies
Mathematical Model

Abstract

Game theory is a discipline that examines subjects such as negotiation, conflict and cooperation between individuals, organizations, and companies by using mathematical models. Game theory is interested in understanding interaction between companies each other companies and individuals, particular decisions made by individuals and their effects on other individuals. The aim of the study is to investigate the maritime companies in a competitive environment where economic imbalances take place. For this purpose, the economic data reached through the International Monetary Fund (IMF) have been used. In this study, the effect of the increase in the economy over the increase in the tonnage of maritime transport and the effects of the tonnage over the excess or shortage in the market are calculated by using the game theory technique. In this respect, the issue of how long the overall tonnage increase should continue in the economy is taken into consideration. At the same time, moving economically with forward-looking estimates has also made the decision-making process more difficult.

1. INTRODUCTION

The economy is growing day by day in the developing world. This growth is due to the factors of profit and loss in the economy. The growth of the economy is generally achieved through the hand-over of products. As the products change hands, the value they receive increases or decreases. This is part of the transportation industry wherein the transport distance of a product, the amount of transport, the costs of the product formation increase the cost of that product (Sahin and Soylu, 2020). An increase in cost will also increase the selling price of the product. The sale price will be added at a certain level. Increases in cost are derived from products. Profit is one of the biggest factors for economic growth (Yazir and Sahin, 2017). Products often need to be replaced to change hands. The displacement is provided by transport. The greatest part of the world's transport is done through maritime transport. This mode of transport is specialized in transporting large quantities of products at long distances with minimal cost. Therefore, the share of ocean transportation is great in the continuity of the economy that has been going on for centuries. Maritime transport contributes to the economy. But the impact on the economy is reciprocal. The higher the rate of economic development, the more transportation activities increase in proportion. The number of vessels or tonnages must increase for the transport activities that tends to increase (Sahin and Yip, 2017). The more the products need to be transported, the transport tonnage gets greater. In that case, newbuilding ships are built so that the transportation tonnage is increased (Sahin et al, 2020). The carrying capacity, i.e., tonnage, increases so that the economy improves. Then, maritime companies tend to build more ships. For more vessels, the production capacity in the shipyards increases (Yazir et al, 2021). As it can be seen, there are trade-offs during this process and game theory can be utilized to decide on the tonnage of transportation which can change maritime companies making forward-looking plans to be strong in the economy. They need to make decisions with

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Cite this article

Yazır D, Şahin B & Yip T L (2022). Ship tonnages determined by the world economic growth with game theory. Turkish Journal of Engineering, 6(4), 300-305

Research Article / DOI: 10.31127/tuje.1001664

Received: 27/09/2021; Accepted: 24/10/2021

the stability they follow. The use of the decision-making structure comes into front here. Decision making can be defined as selecting the most appropriate one from two or more options. The choices to be taken here are whether or not shipbuilding will be done. Certain factors which are controlled and uncontrolled are involved in this decision-making process. The amount of production of variable new vessels that can be controlled in the subject matter in question. Uncontrollable is the irregular growth and shrinkage of the economy. These two variables and the person who makes the decision finally arrive. The result is the final decision. Decision-making process is an inevitable influence in game theory. Because there is not a single sea company in the world. The number of players in the marine transportation industry is very high. Apart from being too many players, the standards and categories are too high. In terms of freight they carry, maritime transport has a diversity of players. In this case, the interests of all the players who are going to be able to collectively make a load of goods are affected. The new tonnage at a maritime company is linked to the increase and decrease in tonnage that other companies will create.

2. LITERATURE REVIEW

The economy is greatly influencing the world order. However, it is very difficult to make a comment on the future while the history of the economy can be recorded literally. However, game theory is a big help when making economic decisions. The game theory which known as Nash theory, earned the Nobel Prize in 1994 for the mathematician John Nash. Nash calculated that there might be a balance on a game and changed the way of looking at the economic structure going on until that time. This simple concept helps economists learn how to set prices for competing firms, how governments should design their auctions to get the most from bidders, and how groups will sometimes explain self-fulfilling decisions. Stanford University's Business Institute publishes an essay on Nash equilibrium. In this study, it was written that optimizing Nash equilibrium would be especially dynamic games. Accordingly, the player must change his tactics so that the balance remains constant and not distorted. A player decides and implements it absolutely. Because the best-case strategy is in the middle. In Nash game theorem, it is assumed that the players always fit into their initial plans (Govindan and Wilson, 2005). In a study conducted at the University of Chicago Economics department, it was mentioned that Nash completely changed the price theory. Prior to theorem, pricing was a more analytical methodology in the economy. This analytical analysis has become a valuable guide for economists as well as being easy and practical. That's why he did not think it could be another approach to anyone. But the system was very narrow. It was very difficult to intervene in these price theories. Firms have different information and different negotiation situations. This has not been applied to their standard price theory. The wider analytical perspective of gaming theory has freed practical economic analysis from these methodological constraints. Methodological limitations cannot prevent us from evaluating market and non-market systems on an equal footing and accepting basic links between economic, social and political institutions in economic development (Myerson, 1999).

The Economist magazine handled the Nash equilibrium by taking the darkest example in a number in 2016. A good example is that there are two suspects of a murder. Two suspects are cross-examined. And if they confess to this question, they will be given information about how much punishment they will receive. The two suspects have to decide each other unaware. Depending on the situation, the penalties may fall, they may not be punished at all, or both may be punished. This is reflected in the economy in the decision-making process. The game theory is that everyone in a group makes the best decision for themselves (according to what others expect to do). And nobody can do better by changing the strategy. Each member of the group makes the best of it. Economists who apply this theory to the real-world use Nash equilibrium to predict how companies will respond to the prices of their competitors (URL-1, 2016). The subject of mathematics is often uncontrolled variables. In other words, changes in the system considered by our own decision are the undetermined variables. In mathematical problems, it is revised in game theory. If there are two persons in the game, the parties must play in accordance with the rules and make the strategy fit numerically. In a game played in this way, each player tries to maximize his winnings or points and tries to minimize his opponent's. Whether or not the game has any optimum or fixed result depends on whether a player is taken as a target to the min-max situation, depending on that of the other player. For this reason, game theory has to do with economic problems. Thus, game theory can be formulated with mathematical terms or expressions. Mathematical game theory, which is defined as the technical relations network, helps the economic problems in a particular group (Alien, 1956).

In a study written by Meca et al. (2004), collaborating companies have distributed their collaborative game theory model and inventory costs with the help of proportional rules, together with their specific inventory costs information. In case of cooperation, they have reduced their own inventory costs and total stock costs. They examined the economic production model with a collaborative game theory model. In the case of stockless and in the case of firms producing, they proposed an alternative distribution rule similar to the proportional rule in reducing and distributing costs (Meca et al., 2004).

In order for an enterprise to operate effectively and efficiently, the items and materials used in the production or sold must be supplied on time and in the required amount. According to each business activity area, it is necessary to have some items or materials available in order to perform the production or to respond to the requests of the customers. These items and materials that are held by the company are generally referred to as stocks (Chase et al., 1981; Sulak, 2008).

He et al. (2020) has mentioned the future prospects and challenges for the application of game theory in integrated energy systems. New game models were introduced to the integrated energy system and a mixed

game model was considered to solve the related problems (He et al., 2020).

Lin et al. (2021), noted that environmental sustainability is playing an increasingly important role in the maritime industry. Green strategies such as speed reduction, fuel switching, alternative fuels can reduce harmful emissions from ships and increase environmental sustainability. An evolutionary game theory framework embedded in the pricing model in shipping has been proposed (Lin et al., 2021).

In this study, the effect of the increase in the economy over the increase in the tonnage of maritime transport is investigated by using the game theory technique.

3. METHOD

Game theory is an interdisciplinary approach that has its own characteristics that examine human behavior (Aktan and Bahçe, 2013). John Nash writes in his "Unclear Games" article about n-person ending games and defining the balance point of these games. This article initially tells us that Nash is the most important part of the theory of equilibrium and adds: "This idea allows us to generalize the solution concept of our two-person zero-sum games. As a result, the set of equilibrium points of two-person zero-sum games is simply a set of counter-good strategies". In other words, a balance point is a strategy profile, where each player's strategy is the best response, they can give to other players' strategies. This equilibrium point is called Nash equilibrium (URL-1, 2016; Alparslan, 2018). At the core of the Nash equilibrium concept is the best response approach. According to Nash, the strategy of each of the players forming the strategy pair, which is the candidate for a solution of a two-player game, should be the best answer to the other strategy, which is anticipated to be played by the opponent player. In other words, Nash equilibrium; is a set of strategies for each player making the best they can, while his opponent is figuring out his strategies. In this balance, which is one of the bases of the uncooperative game theory, no player wants to change his choice when the action of the opponent player is fixed. In other words, no player can increase his profits by changing his own action when his opponent's strategy is fixed. To say that the Nash equilibrium puts forward self-conflicting and strategic stability characteristics are the best response that no player can express on the basis of a deviation from his stated strategy. Regardless of whether the opponent player chooses which strategy to dominate, there is a process in which players try to find out the best they can do themselves. The resulting dominant strategy balance is the only Nash equilibrium in its rank.

In the static game model, assuming that each player chooses the strategy that the other player will create the best answer to the selection of the actual strategy, the strategy pairs with this feature will be the game solution. This argument contains two elements.

1. Each player must choose a strategy, which will create the best response to the opponent's anticipated strategy selection.
2. In the event of equilibrium, the beliefs of the players, of their opponents about strategy choices, should be rational in the sense that these expectations have been fulfilled.

While assuming that these requirements will try to predict the strategy that a player will choose from his opponent, the second requires that the same player's expectations of his opponent's game are consistent with the strategies actually played by his opponent.

The elements of a decision problem can be considered as follows:

1. Decision maker: Responsible and decision-making.
2. Controllable variables: There are two or more strategies for making decisions. Strategies are part of the system and are under the control of the decision maker. The chosen strategy will be able to fulfill the desired goal as best as possible.
3. Uncontrollable variables (events): These variables are variables that affect the achievement of the goal and are outside the control of the decision maker. These variables are outside the system, and it is not known exactly which one is going to happen. For example, economic, political, social, cultural and ideological factors, climatic conditions, technological developments, competitions and laws.
4. Conclusion: The result of any strategy being chosen by the decision maker and a certain uncontrolled variable taking place.

It is possible to determine the method to be followed when considering the issue of decision making and all the elements of the process.

1. A decision criterion is selected first.
2. The possible outcomes of the decision process and possible decisions are defined.
3. It is determined what kind of probability distribution is to be applied in the decision process and the possible probability values are given to the inputs of the decision matrix.
4. A function to measure the benefit is determined.
5. An experiment is made for decision options.
6. The possibilities given to the inputs are reviewed and corrected if necessary, according to the test results.
7. For each possible decision, the risk of process entry is calculated.
8. Using the probabilities given to the inputs, the expected risk of each possible decision is calculated.
9. The minimum expected risky decision is optimal.

Thinking about events in all possible ways and anticipating what might be the result, then choosing the best can be made contradictory. For this reason, game theory is based on maximizing the winnings of the decision-maker or the elector and minimizing the losses. Decision matrix is used to select the best strategy in the decision process. The decision matrix is as follows (Rençber, 2012).

Table 1. Decision Matrix (Rençber, 2012)

STRATEGİES	EVENTS N1N2…… …… …… Nn
S1	X11……X1n
S2	X21……X2n
Sm	Xm1……Xmn

In the decision matrix;

S1, S2, ..., Sm: Strategies (m variables that can be controlled).
N1, N2, ..., Nn: Events (n uncontrollable variables).
Xij: The choice of the intellectual strategy by the decision maker.

Conclusion
(i = 1, 2, ..., m): Index of strategy.
(j = 1, 2, ... n): Index of events.

4. APPLICATION

The research material is the changes in information from the IMF for world economic growth between 2015, 2016 and 2017. During this time, the same increases in freight rates and transport capacities of all the vessels worldwide have been adapted to the situation in the last 3 years as deadweight. In the meantime, UNCTAD's reports on the yearly maritime sector are taken as references. In this case, the growth of world economic growth and transport is described as interconnected strategies. Freight rates affecting the world economy and its first impact freight and the amount of freight that can be carried will change accordingly (UNCTAD, 2015; UNCTAD, 2016; UNCTAD, 2017). Analysis of the studied progeny was carried out using the Lindo pre-packaged program. The matrix method was used in the analysis. Maximin in the game matrix of the subject; as seen in Table 2 is equal to 3,5 and Minimax = 3,5. So Maximin = Minimax, there is the balance point of the game. The best strategy for this situation is the solution of the project. The formulas to be applied by the competitors in the matrix method are as follows (Rençber, 2012).

Table 2. The Matrix Method (URL-2: IMF)

Year	Real gross world product growth (Annual percent change)	Transport and insurance costs of international trade (Percentage share of the value of imports)	World fleet by principal vessel type (Thousands of dead-weight tons and percentage share)
2015	3,5	14,2	3,5
2016	3,2	15,4	3,48
2017	3,8	16,2	3,15

$$[\,X1, X2\,, X3\,] = \frac{\text{Iadj}A}{\text{Iadj}AI'} \tag{1}$$

$$\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} = \frac{\text{adj}AI'}{\text{Iadj}AI'} \tag{2}$$

$$g = \frac{|A|}{\text{Iadj}AI'} \tag{3}$$

Meanings of symbols:

[X1, X2 , X3]: The positive and negative effects of years on the selection of strategies.
$[Y_1, Y_2, Y_3]$: The probability of choosing strategies.
A: Coefficient matrix.
adjA: The additional matrix of a matrix.
| A |: Determinant of a matrix.
I: A row vector whose elements are one (1) and equal to the size of matrix A.
I': Transposition of row vector I.
g: Game value

It is found that the coefficients of the project are in the matrix;

The coefficient matrix for the project is given below:

$$A = \begin{bmatrix} 3{,}5 & 14{,}2 & 3{,}5 \\ 3{,}2 & 15{,}4 & 3{,}48 \\ 3{,}8 & 16{,}2 & 3{,}15 \end{bmatrix} \tag{4}$$

If we denote the transpose of the matrix A by the symbol A':

$$A' = \begin{bmatrix} 3{,}5 & 3{,}2 & 3{,}8 \\ 14{,}2 & 15{,}4 & 16{,}2 \\ 3{,}5 & 3{,}48 & 3{,}15 \end{bmatrix} \tag{5}$$

The additional matrix of A is also:

$$\text{Adj } A = \begin{bmatrix} -7{,}866 & 11{,}97 & -4{,}484 \\ 3{,}144 & -2{,}275 & -0{,}98 \\ -6{,}68 & -2{,}74 & 8{,}46 \end{bmatrix} \tag{6}$$

Row and column vectors are;

$$I = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \tag{7}$$

$$I' = [1 \quad 1 \quad 1] \tag{8}$$

The changes and developments in the market have been calculated as follows with the change of the strategies. The rise in tonnage in transportation has been calculated as the rise in freight rates resulting from economic growth.

$$[\,X1, X2, X3\,] = \frac{[1 \quad 1 \quad 1] \begin{bmatrix} -7{,}866 & 11{,}97 & -4{,}484 \\ 3{,}144 & -2{,}275 & -0{,}98 \\ -6{,}68 & -2{,}74 & 8{,}46 \end{bmatrix}}{[1 \quad 1 \quad 1] \begin{bmatrix} -7{,}866 & 11{,}97 & -4{,}484 \\ 3{,}144 & -2{,}275 & -0{,}98 \\ -6{,}68 & -2{,}74 & 8{,}46 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}} \tag{9}$$

$$\frac{[-11{,}402 \quad 6{,}955 \quad 2{,}996]}{-1{,}451} = \frac{-11{,}402}{-1{,}451}, \frac{6{,}955}{-1{,}451}, \frac{2{,}996}{-1{,}451} \tag{10}$$

Here is the result:

$$\begin{aligned} X_1 &= 7{,}858028946 \\ X_2 &= -4{,}7932466037 \\ X_3 &= -2{,}06478 \end{aligned} \tag{11}$$

values are found.

According to years, we can reach the comments that can be made about the exchange and the progress of the data by the results of Y values. If the above is applied while Y values are found, the results are as follows.

$$\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} = \frac{\begin{bmatrix} -7{,}866 & 11{,}97 & -4{,}484 \\ 3{,}144 & -2{,}275 & -0{,}98 \\ -6{,}68 & -2{,}74 & 8{,}46 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}}{\begin{bmatrix} 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} -7{,}866 & 11{,}97 & -4{,}484 \\ 3{,}144 & -2{,}275 & -0{,}98 \\ -6{,}68 & -2{,}74 & 8{,}46 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}} = \frac{\begin{bmatrix} -0{,}38 \\ -0{,}111 \\ -0{,}96 \end{bmatrix}}{-1{,}451} \tag{12}$$

The Y values obtained after the operations are as follows:

$$\begin{aligned} Y_1 &= 0{,}261888353 \\ Y_2 &= 0{,}07649996 \\ Y_3 &= 0{,}661612681 \end{aligned} \tag{13}$$

Accordingly, the overall rating for equilibrium is Nash's equilibrium economic market and the rate that can be used is equal to the value of the game in the new year.

Game value:
As the determinant of matrix A is

$$|A| = -6{,}2662 \tag{14}$$

$$g = \frac{-6{,}2662}{-1{,}451} = 4{,}318538939 \tag{15}$$

Game value:

g = 4,318538939

According to the analysis, the economic growth rate is increased by about 0,26 and the freight rates are having a value of 0,07. Against this value, the carrying capacity should also increase by 0,66 which in both cases can achieve optimum gain. In this case, according to game theory, depending on the world economic structure, the balance point between freight and transport capacity should develop in this way. In this development, the parties have reached the economic equilibrium and achieved the most favorable earnings. In this case, both the economy will grow, and the freight price will increase with the change in freight price. The maximum increase in the freight price is determined by the game value, according to the growth rate of the economy and the increase in the carrying capacity.

3. CONCLUSION

According to game theory, depending on the economic structure of the world, the freight rate between the load and the carrying capacity is 0,07 while the carrying capacity should increase by 0,66 so that optimum gain can be achieved. Under these circumstances, the parties reach economic equilibrium and achieved the most favorable gain. In this case, both economies will grow, and freight prices will increase with the change in freight price. This study searched, how to transport, which is an economic activity, if it could develop within the transport sector, depending on the result of the Nash Equilibrium and the outcome given to us by the equilibrium. During this research, it is shown how freight rates change overall, as well as the impact of economic growth and the balance of transportation. The development in the world economy and the change in freight rates can be proportionally balanced over the world combined with the transport tonnage. If the growth in the future periods is in this situation, the growth in the sector will be reflected in the freight rate, which will cause the tonnage to increase. The study can provide forecasts on the market by providing different equilibrium ratios when estimated values of future years are put in place. This manuscript will help increase tonnage to future decision-making and the market and at the same time, this study will be the source of new studies on similar issues.

Author contributions

Devran YAZIR: Investigation, Methodology, Writing-Original draft preparation. **Bekir ŞAHİN:** Writing-Reviewing, Validation, and Editing. **Tsz Leung Yip:** Investigation, Writing-Reviewing, and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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