Applications of Game Theory in Microeconomics

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Abstract. Game theory has been used as a potent analytical tool by numerous areas since its inception. It has been more popular in microeconomic analysis in recent years. It is not an exaggeration to claim that it completely rewrites microeconomics. The major ideas of game theory are summarized in this paper, as well as their application in microeconomics. This study examines the three elements and key types of game theory in its fundamental material. The Nash equilibrium and other equilibria expanded by Nash equilibrium are then reviewed in game theory equilibrium. Then, the Cournot model, Stackelberg model, and Bertrand model are discussed in game theory and market analysis. Finally, in the section on game theory and auction, it explained that, within the context of the game, English auctions and second-price sealed-bid auctions should use comparable strategies, however Dutch auctions and first-price sealed-bid auctions should conceal their own valuations.

Keywords: Game Theory, Nash Equilibrium, Cournot Model, Stackelberg Model, Bertrand Model, Auction.

1. Introduction

Game theory examines how players in a game choose their strategy and applies abstract concepts to mutual combat scenarios. As part of the notion of rational behavior, American mathematicians John von Neuman and Oskarl Morgensten developed game theory. The essential framework for game theory was provided by their co-authored Theory of Games and Economic Behavior (1944) [1]. Between 1950 and 1954, John Forbes Nash, an American mathematician and statistician, wrote a series of works on game theory, laying the groundwork for the contemporary disciplinary structure of game theory and developing the crucial notion of Nash equilibrium. Game theory was first researched in competitive scenarios like chess, poker, and other board games. Game theory has become widely applied in various sectors, including economics, politics, military science, biology, and management science, as it has evolved over the decades. In the subject of economics, game theory is a way for analyzing conflicts of interest and coincidences by combining a specific economic problem into a game model, which then transforms it into a game scenario that can be researched and analyzed.

Nash Jr J F discussed n-person game equilibrium points in 1949 [2]. Nash developed game theory to address the bargaining problems in 1950. He considered the bargaining problem to be a nonzero-sum two-person game [3]. Martin Shubik proposed his dollar auction in 1971, believing it may be a valuable experimental game since it had a relatively simple escalation feature. Once a contest is entered, the probabilities are that the outcome will be disastrous for all participants [4]. In 1988, Camerer and Weigelt used sequential equilibrium to see if a model of reputation development in an imperfect information game can predict player behavior in an experiment. They offer an abstracted loan game, which they believe may be applied to theoretical scenarios in which people make decisions [5]. Moore J and Repullo R study the application of stage mechanisms in implementation difficulties in the same year, and they believe that practically any decision rule can be implemented in economic situations [6]. Iris Bohnet and Bruno S. Frey utilized the prisoner's dilemma in 1999 to analyze communication. They discovered that communication isn't always necessary. In the prisoner's dilemma and dictator games, silent identification is sufficient to boost solidarity [7]. In 2006, G' erard P. Cachon and Serguei Netessine used the newsvendor game to demonstrate how game theory may be applied to supply chain management, and they discussed both noncooperative and cooperative game theory in static and dynamic situations. Supply chain management has been discovered to be an excellent option for game theory applications [8]. In 2010, Liu Z, Zhang X, and Lieu J used signaling game theory to analyze the primary electrical bidding mechanisms in the auction marketplaces, with the degree of information disturbance being an essential aspect to consider when assessing bidding strategies. They also suggest the Generator Semi-randomized Matching (GSM) process as a novel incentive electricity bidding system [9]. Pineiro-Chousa J, Vizcano-González M, and López-Cabarcos M used game theory to investigate the three-dimensional link between company reputation and sustainability in 2016. They believe that if the entrepreneur views reputation as a source of risk, the analysis is framed as a prisoner's dilemma schema, which is addressed by defending against reputational risks from a long-term business strategy. If the firm considers reputation to be a competitive advantage, the innovator's quandary is answered by gaining reputational opportunities from the firm's long-term viability. Finally, if reputation is viewed as a strategic asset, the coordination game schema leads to the development of a reputational intelligence talent, which has the potential to be critical for a firm's long-term success [10]. In 2017, Hsin P H and Chen C I refined the Nash nonlinear Grey Bernoulli model (NNGBM) using trembling-hand perfect equilibrium and improved forecasting accuracy. In addition, the NNGBM with trembling-hand perfect equilibrium is used to forecast the GDP of four fast-growing countries: Brazil, Russia, India, and China (abbreviated as BRIC). The findings demonstrate that the GDP of the BRIC countries is continuing to rise [11].

This paper discusses the direction of research and research ideas in a broader context, as well as the classification of game theory and the corresponding models and solutions. It also presents the results and research progress in the application of auction theory based on the game theory approach, as well as the results and research progress in the application of auction theory based on the game theory approach.

2. The basic content of game theory

Game theory aims to explain how players' decisions and outcomes interact in situations where decisions and payoffs are interconnected.

There are three fundamental parts of a simple game: (1) Players: There must be at least two players in the game. A person, a group, or an objective situation can all be considered players. And all of the players are logical. It means that each participant is aware of the game's rules and is aware that everyone is aware of the rules. (2) Strategy space: each participant must be aware of the strategies used by the other. (3) Payoffs: the important benefit or cost that the participants are most concerned with while making decisions. All participants' tactics are mapped into the payoffs they receive by using functions.

Simultaneous play games and sequential play games can be classified in game theory based on the sequence in which players conduct actions. The first basically indicates that each player chooses his or her own plan at the same time, while the second means that one person plays ahead of the other. The first player in a sequential game is the leader, while the second player is the follower.

In addition, there are three main games that may be played simultaneously. The first is a coordination game, in which participants earn the most payment if they coordinate their activities. In contrast to a coordination game, in a competition game, every rise in one player's payoff equals an identical loss in the other player's payoff; the game is also described as a constant-sum game. The coexistence game, for example, may be used to represent how individuals of a species interact with one another. Commitment games are a popular type of sequential play game. In a commitment game, one player decides on a course of action before the other. And the action of the first player is both irrevocable and visible to the second player. The first player also knows that his or her action is seen by the second player.

3. Equilibria in game theory

3.1 Nash Equilibria

Game theory, in addition to the three parts, tries to investigate each rational player's behavior choice. An equilibrium is the best possible outcome a game can achieve. There are several types of equilibrium in game theory, with Nash equilibrium being the most significant. In each Nash equilibrium, each player picks the optimal response to all of the other players' choices.

In a pure strategy, each player can choose only one strategy in a particular circumstance. To define Nash equilibrium in a pure strategy, we may simply use a game with restricted players and strategies:

(1) Assume there are players, with.

(2) Player selects from pure strategies, set the strategies set as, where denotes a typical strategy in.

(3) Each player's strategy set vector, and the entire strategies set is.

(4) for strategies set and a strategy for player: define as strategies set

(5) for each player and each strategies set, is 's expectant utility.

So, in a pure strategy, a Nash equilibrium is a strategy set: for every and, there exist, which means if other players don't modify their strategies, than no one can increase his or her utility by raising his or her.

In a matrix strategy, mixed strategies refer to when the player does not pick a single pure strategy, but rather a set of pure strategies with varying probability. Assume that is mixed strategies in and is the set of all. Assume =, and mixed strategies set is, is the same as. So represents the expectant utility for player, and the utility function can be expanded to: That is the definition of Nash equilibrium of mixed strategies.

3.2 Equilibria in extended form

A Nash equilibrium is highly helpful, but it is not flawless; a game may have more than one Nash equilibrium, or it may not have any Nash equilibrium of any kind. As a result, a variety of Nash equilibria have been developed, including refining Nash equilibrium, subgame perfect equilibrium, proper equilibrium, sequential equilibrium, and so on. Subgame perfect equilibrium is the most typical of these extended forms. The player's best decision in the game may be influenced by the behavior of a strategy set in its impossible subgame. As a result, in order to gain favorable results, players might proclaim in advance that they will conduct exceedingly unfavorable acts to force their opponents at any costs in certain subgames that are nearly impossible to appear (call them incredible threats). As a result, some Nash equilibria may be the result of incredible threats being posed to some players. To avoid Nash equilibria with incredible threats, a subgame perfect equilibrium requires that each player's conduct in all subgames be optimum, regardless of whether this subgame will be accomplished or not.

Subgame Perfect equilibrium is appropriate for economic use. It can be used to analyze entrant games, for example. Imagine that firm Z is a potential entrant considering whether or not to enter an industry where the incumbent is a monopolist. If the entrant chooses to enter the market and incumbents opt to accommodate the entrant, both will get a 5. However, if the entrant wishes to enter the market regardless of whether the incumbents battle and start a price war, the reward for both parties will be -3. If the entrant decides not to enter the market, the entrant's reward will be 0 while incumbents' payoff would be 12. A game tree can be used to describe this game, and the potential entrant is the leader:

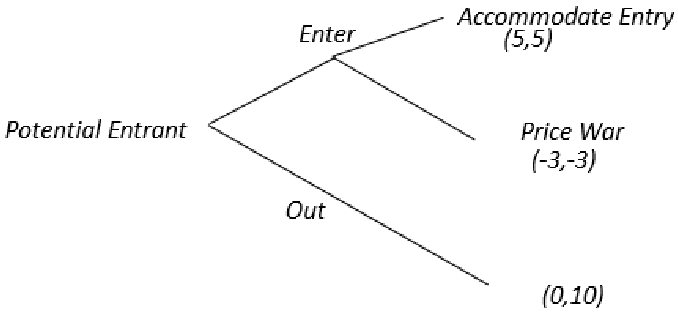

Figure 1. Enter Game

And after bid shading, bidder can anticipate that bidder ’s valuation is. The probability that wins the auction is. And the expectant payoff of is, which is greater than the bidder doesn’t hide his or her valuation. So, in a Dutch auction and a first-price sealed-bid auction, bidders should shade their bids to acquire higher surplus

So, what are the best reactions from the monopolist? When a new entrant seeks to enter the market, the monopolist's best answer is to accept it, because fighting will only yield it a -3 payoff, which is less than 5. The monopolist will obtain anything it attempts if the newcomer stays out of the market. The entrant is rational, and he or she acknowledges that if he or she comes on the market, the monopolist will choose to accommodate, even if the monopolist scares him or her with a price war, which is insane. As a result, the equilibrium has been reached (Enter, Accommodate Entry).

Matter of fact, when players in a game pursue the Nash equilibrium strategy, "their hands may tremble," implying that they may occasionally make mistakes and stray from the equilibrium. Even if you make a mistake, the player should select an equilibrium point that causes other players to choose according to their best response strategies. Trembling-hand perfect equilibrium is the name given to this moment. It is implied that while choosing tactics, players should evaluate the likelihood of making mistakes and do their best to prevent losses caused by other players changing their strategies

4. Game theory and market analysis

As previously said, game theory is useful in analyzing economic issues. As a result, game theory may be used to investigate how corporations' strategies affect the payoffs of individual participants in various markets. An industry with two enterprises is known as a duopoly. The Cournot duopoly model is a valuable tool for analyzing this circumstance. Manufacturers determine the number of factories in this model. They also make a homogeneous product and offer it for the same price. In a equilibrium, no one will earn more money by altering their plan unilaterally. The Cournot model may be used to oligopoly situations. In general, if there are m manufacturers and their production costs are equal, each manufacturer's output is completely competitive.

Another model thinks the output of manufacturers as a means of competition is Stackelberg model. This model is used to analyse duopoly. Imagine company 1 is the leader and company 2 is the follower, and company 1 choose as its output. At this situation, company 2 will pick its output at. What’s more, company 1 anticipates company 2’s strategy to any perfectly, and the price is for company, the cost is for company. This makes the leader’s profit function as. So, the leader will choose to maximaze its profit. At this model, the leader determines the output of the market, which is a constant, and the follower decides its output according to the fuction of the leader’s output.

Unlike the previous two models, Bertrand model thinks that a firm's competitive means is pricing rather than output. If all companies set their prices simultaneously, then each company's marginal cost of production is always constant at. When a company sets its pricing, it must anticipate the price established by all the other companies in the industry. In the Bertrand equilibrium, all companies set their prices equal to the marginal cost when selling identical products. Let's say one company sets its price higher than the other. The higher-priced company would therefore be without consumers. As a result, in order for an equilibrium to exist, all companies must establish the same price. Assume that all companies adopting a common price that is greater than marginal cost c. Then one company may just increment its price slightly and sell to all of the purchasers, boosting its profit. As a result, is the sole common price that forbids undercutting

5. Game theory and auctions

Auction is another fantastic use of game theory in economics. The probability of bidders' expected success, expected costs, and expected revenue under various auction methods may be studied using game theory. An English auction is one in which the auctioneer begins with a reserve price, which is the lowest price at which the seller will part with the item. Bidders raise their bids one by one, with each bid often exceeding the preceding one by a little amount. When no one wants to raise their price any higher, the item is awarded to the highest bidder. The auctioneer at a Dutch auction starts with a high price and progressively reduces it until someone is willing to buy the item. One of the advantages of Dutch auctions is that they may go quickly. A first-price sealed-bid auction is one in which bidders privately write down and submit their bid. The highest bidder receives the thing and pays his or her bid. In a second-price sealed-bid auction, the top bidder receives the object but must pay the second-highest bid.

In a Dutch auction and a first-price sealed-bid auction, the optimal bidder methods are comparable.

Suppose that every bidder knows his or her own valuation, but doesn't know the others' valuation. And every bidder's valuation fro the item is follows a uniform distribution, for bidder, if his or her valuation is, his or her bid must be a share of his or her own valuation, where, and assume is constant over all bidders. The valuation to the left in the horizonal axis represents points were. The mapping to the vertical axis gives. Valuations to the right side of of describe points were. Mapping these points into the vertical axis gives. If doesn't hide his or her valuation, the expectant surplus for is 0.

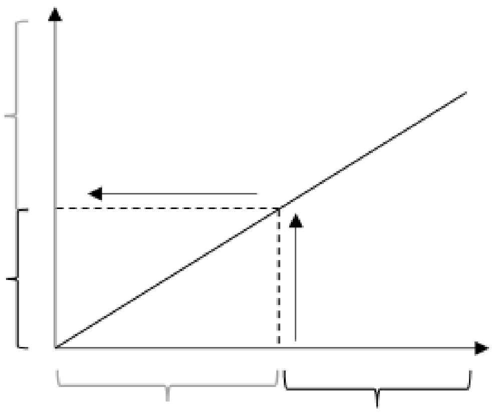

Figure 2. Bidder 's valuation before hiding

And after bid shading, bidder can anticipate that bidder 's valuation is. The probability that wins the auction is. And the expectant payoff of is: which is greater than the bidder doesn't hide his or her valuation. So, in a Dutch auction and a first-price sealed-bid auction, bidders should shade their bids to acquire higher surplus.

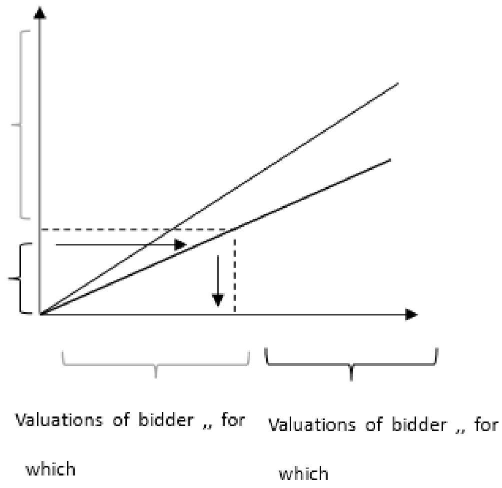

Figure 3. Figure 2. Bidder ’s valuation after hiding

The optimum technique in an English auction and a second-price sealed-bid auction is identical when the bidder only knows the item's worth to himself. The bidder in a second-price sealed-bid auction bids according to the item's value to himself, and if he wins the bid, he pays the second highest price. In an English auction, the bidder can win the auction by studying the previous game's behavior and bidding slightly higher than the second highest bidder. Both an English auction and a second-price sealed-bid auction is plainly Pareto efficient since the individual who believes the item's worth is the highest wins the auction. Bidders will share their bids in both a Dutch auction and a first-price sealed-bid auction, thus the individual with the highest value may lose the auction. As a result, both auctions may not be Pareto efficient

6. Conclusions

To begin, this paper examines the successes of game theory applications in numerous domains. The paper then goes through the three elements of game theory: participants, payoff, and strategies, as well as the two most prevalent game types: simultaneous and sequential games. Following that, it discusses Nash equilibria and alternative equilibria derived from Nash equilibrium, with an emphasis on subgame perfect equilibria and trembling-hand perfect equilibria. The applicability of game theory in microeconomics is examined based on the foregoing. Firstly, discuss the use of game theory in market analysis. The Cournot model, stackelberg model and Bertrand models are explained in this section, and it is discovered that the major competitive means of firms in the first two models is output, while the key competitive means of enterprises in the third model is price. Finally, game theory's use in auctions is examined. English auctions, second-price sealed-bid auctions, Dutch auctions, and the first-price sealed-bid auctions are introduced. When bidders only know the item's worth to themselves, the techniques used by bidders in the first two auctions are found to be comparable. Bidders in the last two auctions should conceal their value in order to gain a greater surplus.

In the future, based on Nash equilibrium, we can investigate the equilibrium, taking into account more realistic aspects in order to improve the accuracy of the final analysis result. Game theory can be used in conjunction with stakeholder theory and behavioral economics in microeconomics.

References

[1] Morgenstern O, Von Neumann J. Theory of games and economic behavior [M]. Princeton university press, 1944.

[2] Nash Jr J F. Equilibrium points in n-person games [J]. Proceedings of the national academy of sciences, 1950, 36(1): 48-49.

[3] Nash Jr J F. The bargaining problem [J]. Econometrica: Journal of the econometric society, 1950: 155-162.

[4] Shubik M. The dollar auction game: A paradox in noncooperative behavior and escalation [J]. Journal of conflict Resolution, 1971, 15(1): 109-111.

[5] Camerer C, Weigelt K. Experimental tests of a sequential equilibrium reputation model [J]. Econometrica: Journal of the Econometric Society, 1988: 1-36.

[6] Moore J, Repullo R. Subgame perfect implementation [J]. Econometrica: Journal of the Econometric Society, 1988: 1191-1220.

[7] Bohnet I, Frey B S. The sound of silence in prisoner's dilemma and dictator games [J]. Journal of economic behavior & organization, 1999, 38(1): 43-57.

[8] Cachon G P, Netessine S. Game theory in supply chain analysis [J]. Models, methods, and applications for innovative decision making, 2006: 200-233.

[9] Liu Z, Zhang X, Lieu J. Design of the incentive mechanism in electricity auction market based on the signaling game theory [J]. Energy, 2010, 35(4): 1813-1819.

[10] Pineiro-Chousa J, Vizcaíno-González M, López-Cabarcos M Á. Reputation, game theory and entrepreneurial sustainability [J]. Sustainability, 2016, 8(11): 1196.

[11] Hsin P H, Chen C I. Application of trembling-hand perfect equilibrium to Nash nonlinear Grey Bernoulli model: an example of BRIC’s GDP forecasting [J]. Neural Computing and Applications, 2017, 28(1): 269-274.