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An Overview of Game Theory: A New Way to Analyze Conflict Situations and Obtain Competitive Solutions

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Abstract
Game Theory is the mathematical science that analyzes conflict situations and seeks competitive and cooperative solutions through models, or carries out a study of individual decisions in situations in which there are interactions between the different subjects, such that the decisions of a subject they can affect the results achieved by a rival, according to a feedback mechanism. Therefore, it represents a discipline that has as its object of analysis the decision-making situations in which several subjects find themselves making choices, on the whole of which the final result depends. This type of problem occurs frequently in economic theory. In the present work, after a brief introduction, we will highlight precisely these aspects and finally we will focus on the Nash equilibrium.

Keywords:game theory, innovation, Nash equilibrium

1 Introduction

The first question to which we must dare to answer, before starting to talk about game theory, is the following: but what is game theory. A game is a model of a conflict situation. On a chessboard, the knights and the queen, the pawns and the bishops defend their king and attack the opposing king: it is a battle model in which each player commands his side and tries to beat the opponent with cunning and rationality. On a soccer field eleven players work together with the aim of putting the ball in a certain position and preventing it from entering another (the "goal" actually means "goal, goal"). Here, in addition to cunning and rationality, technique and athletics are involved, but the representation of a real-life conflict remains. The examples could continue with Monopoly (typical economic model), cards (in which the luck-skill ratio varies according to the context but is always present, as in everyday life) and in almost all competitive sports and board games. All these models bring an individual (as a pastime, physical exercise, etc.) but also social utility, because they discharge tensions and energies that would otherwise find an outlet in far more dramatic contexts. They can also serve other purposes: to train through solving real problems simulations; to evaluate, again by means of simulations, the optimal strategies for problems of a much greater significance; Where possible, indicate cooperative solutions that make conflicts of all kinds bloodless. Some of these models can be rationally evaluated with the use of mathematics. Game theory is the theory of mathematical models of conflict situations between rational decision makers. The field of application of this theory was initially limited to parlor games (in this case it was a question of mathematical models of games, that is "model models" of conflict situations), but subsequently it extended to numerous sectors of real life: from war economics, politics, social sciences, information technology, biology, philosophy, religion. Its birth also gave significant impulses to recent developments in mathematics: starting from linear programming and duality, which were born precisely to solve game problems, gradually up to topology, set theory, probability, combinatorial analysis, fixed point theorems, control theories and dynamical systems. Currently, Game Theory has by now conquered a stable place in the manuals adopted in the basic courses of Microeconomics and Business Strategy. Typically, these manuals deal with the subject with a few examples (we usually start from the prisoner's dilemma ...) and some hints to Nash's concept of equilibrium (popularized by the film A beautiful Mind, winner of several Academy Awards). The risk is that of passing at high speed on topics that require a greater degree of in-depth analysis. In these pages my goal is, on the one hand, to offer a slightly more formal treatment of some basic concepts, without requiring the reader to know sophisticated notions of mathematics; on the other hand, highlighting both the lights and the shadows of the application of Game Theory to the study of Business Strategy. The dominant reason will be to emphasize how, in order to try to rigorously analyze the strategic interaction of agents whose objectives may be in conflict, it is necessary to make assumptions about the type of rationality that these agents have. In particular, to obtain more precise solutions to complex problems, the game theory approach is to make strong (and therefore restrictive!) Assumptions on the rationality of agents. A final observation concerns, in a nutshell, the usefulness and, at the same time, the problematic nature of game theory for those approaching the study of Business Strategy. This matter sometimes has positive purposes (understanding how companies behave), sometimes regulatory purposes (what a manager should do when he has to make concrete decisions). Game theory offers contributions in both directions. The usefulness lies in formally addressing issues that are usually left to intuition, common sense or (worse!) To ex-post rationalization of corporate behavior. The important thing, and here we are at the problem, is to understand what the limits are in both directions mentioned above: from a positive point of view, economic reality is generally more complex than a game, from a regulatory point of view only rarely do the actors economists know game theory and therefore be careful to behave by following its rules when interacting with such individuals. So game theory deals with situations of strategic interaction between decision makers who are assumed to be 'intelligent' and 'rational'. Intelligent means that they understand the situation they are in and are able to make correct logical reasoning. Rational means that they have consistent preferences on the final outcomes of the decision-making process and that they aim to maximize these preferences. Each individual has his own utility function on the set of goods. For example, if the set of goods is a slice of cake, a book, a holiday, a diploma, everyone is able to numerically quantify its usefulness for each of the goods. The utilities of two distinct people for the same good may not necessarily be the same. The rationality required of the players dictates that the transitive property in preferences is valid: if the diploma is preferred to the vacation and the vacation to the book then the diploma must be preferred to the book. Game theory is based on these elements.

2. An overview of Game Theory

Game Theory is the mathematical science that analyzes conflict situations and seeks competitive and cooperative solutions through models, or carries out a study of individual decisions in situations in which there are interactions between different subjects, such that the decisions of a

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subject they can affect the results achieved by a rival, according to a feedback mechanism. Therefore, it represents a discipline that has as its object of analysis the decision-making situations in which several subjects find themselves making choices, on the whole of which the final result depends. This type of problem occurs frequently in economic theory; the most common example is the case of oligopolistic competitive contexts in which each company must take into account what other companies do. However, there are many other applications of game theory that concern fields of economic theory other than the theory of industrial organization. At the microeconomic level, for example, models that formalize exchange processes (such as bargaining models or auction models) make use of game theory. At an intermediate level of aggregation, financial theory and labor economics consider models with strategic behavior by companies on the input markets (rather than on the product market, as in the case of the oligopoly). Even within the company there are decisions that involve several individuals: the various divisions of a company, for example the marketing sector and the logistics sector, can compete with each other to secure a greater share of the funds intended for investments.

Therefore, the various possible final outcomes are evaluated differently by the decision makers involved; standard assumptions are that decision makers are "rational", that is, that they have coherent preferences on the complex of potential final outcomes, and that each tries to determine, as far as in his power, the outcome he prefers the most. Another standard hypothesis is that decision makers are intelligent, which means that they are able to represent the situations they face, they can analyze them, they can formulate hypotheses and make inferences about their own and others' behavior, etc. What has just been described briefly represents the central nucleus of game theory, even if its conceptual and formal apparatus is now also used outside the framework outlined. Among the most ancient games of strategic interaction there are the so-called war games or Kriegspiede or "war games" used by the military staffs and academies of many countries, with the aim of reproducing hypothetical situations of war conflict. However, these games represent a very rudimentary prototype of current game theory. The authorship of modern game theory is to be attributed to the American mathematician John von Neumann in 1928, the year in which the scholar published an article in which he highlighted the first applicative perspectives of game theory; the first applications found use in the Second World War.The mathematician is, in fact, one of the fathers of the legendary ASCC (covered by military secret), precursor of the Mark1. Therefore, although some articles on the theory of games regulated by chance were first published by the French mathematician. Emile Borel, we can certainly, although previously pointed out, that the authorship belongs to the mathematician Von Neumann. As regards the origins of the discipline, there is a general and motivated consensus, in fixing a precise date of birth: 1944, the year in which the book, destined to revolutionize the relations between Mathematics and Economics, "Theory of Games and Economic Behavior", even if other authors (such as Ernst Zermelo, Armand Borel and Von Neumann himself) had written, ante litteram, of Game Theory. This volume, born from the meeting in Princeton between Von Neumann and the economist Oskar Morgenstern, is a working thesis: starting from the analysis of "table" games (or "society" we refer to chess, poker, and even to simple games such as "odd or even" or "Chinese morra") to develop tools for the analysis of economic behavior whose fulcrum is identified precisely in the action and interaction of various decision makers (consumers, producers), in particular on the market, but not only limited to it.The strange

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couple of game theory creators consisted, in order, of a mathematician and an economist. We can informally describe the idea of these two scholars as an attempt to mathematically describe human behavior in those cases where the interaction between men involves the winning, or sharing, of some type of resource. From the book comes the name of the discipline: a name that is partly unfortunate because it is the origin of possible misunderstandings and in any case not suitable for identifying the field of primary interest. Attempts to change the name, interactive decision making, have currently not been successful. The work of Von Neumann and Morgenstern was not born in thin air, Von Neumann himself was responsible, sixteen years earlier, for a fundamental publication on the existence of solutions for "zero-sum" games, and a further relevant contribution which appeared in 1937 : the so-called Von Neumann growth model. This previously appeared, however, is not comparable to the work of 1944 in terms of its organic nature, much less for its impact on the scientific community. In fact, considerable expectations were created for this new theory which had the ambition to provide the "new" mathematical-formal language for the study of economic phenomena. The successes in the early years were notable, followed however, as often happens, by a phase of diminished impulse if not also of disillusionment, which ends towards the end of the 1960s: since then the theory of games has had an extraordinary, expanding between the other considerably its sphere of influence, well beyond the economy. To give an idea of the meaning that game theory has had for economic theory, from the very beginning, it may be sufficient to recall, on the one hand, the analysis of the bargaining problem made by Nash as early as 1950, or the demonstration that (under appropriate hypotheses of course) Walras's model of general economic equilibrium admits solution: result published in 1954, and proved by Arrow and Debreu through the transformation of the given problem into a "game" of which they prove the existence of an equilibrium (using previous results by Nash and Debreu Now, the situation is such that some parts of the economy (think of "industrial organization", or the information economy) could be defined as applied game theory.An important aspect of the development of Game Theory is also given by its ability to go beyond the scope of strictly economic applications. Where the paradigm of the rational and intelligent decision-maker can be proposed as an interpretative key, it is natural to expect that game theory can intervene: I am referring to the social sciences in a broad sense (political science but also sociology, law, to arrive at typical problems of " practical reason ", primarily ethics). But the expansion of game theory has still gone beyond this sphere, as is natural to expect for a mathematical-formal core: thus we are witnessing the application of game theory to contexts such as evolutionary biology, into which it falls, at least the recruitment of intelligent decision makers, and the methods of game theory (suitably adapted) are applied to interspecific or intraspecific competition, to understand the "social" behaviors of some species of spiders. The most famous scholar who subsequently dealt with "Game Theory", in particular with regard to "non-cooperative games", is the mathematician John Forbes Nash jr., To whom Ron Howard's film "A Beautiful Mind is dedicated. ". In light of the above and comparing the date of birth of game theory, 1944 with that of the birth of geometry or physics, we conclude that we are talking about a child science.

It therefore has all the merits and also, perhaps, the few defects of a young creature. In particular, it has extraordinary interests and potential in itself. Its interest lies, in my opinion, in its two-faced aspect: on the one hand it has remarkable, interesting, new applications: it is a practical

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discipline. On the other hand, it is instead capable of proposing, in an original way, profound questions, which are linked to other disciplines and not only, but also to the most important aspects of human thought. It is interesting to highlight how the developments in game theory have triggered, in recent years, a real revolution in the social sciences. Although the theory has mainly concerned economic theory, in which the use of mathematical language is more consolidated, important and significant applications are found in philosophy, engineering and even advanced biology. Today, game theory offers a powerful language for interpreting the processes of strategic interdependence, both between competing companies and between actors with opposing interests within the same organization. This theory concerning the analysis of decisions involving several individuals, finds application, alongside the economic field, also within the company as here there are a whole series of decisions that involve several individuals: the various divisions of a company they can compete with each other to secure a larger share of investment funds. Therefore, at present, game theory is a very vast science, both in terms of "corpus" of formal results, and in terms of extension of application, so it is now difficult to be updated on the whole of its developments: there is a feeling that it is in progress a fragmentation of this discipline, for which what Aumann conjectured, and expressed in the world conference in Bilbao in 2000, could come true, or rather that the substantial methodological unity that has characterized game theory up to now could be lost. After this brief summary on the birth of game theory, as well as on the evolutions that have taken place, we continue our journey by first highlighting the Nash equilibrium, which is essential for understanding the functioning of "Game Theory". Subsequently some types of most used games will be proposed.

3. The Nash equilibrium

Between 1949 and 1950 Nash elaborated his masterpiece, which he realized in just twenty-seven pages of doctoral thesis entitled Non-Cooperative Games and which guaranteed him the Nobel Prize for this science in 1994.Game theory was born in the 1920s by attempts by one of the greatest mathematicians of recent centuries, John Von Neumann, to quantitatively study human behavior. Together with Oskar Morgenstern, Von Neuman then formalized the theory in the famous book The Theory of Games and Economic Behavior in 1944. The choices of the participants in the game are made according to the rules and with the attempt to maximize the gain, be it the victory of a board or card game, be it a business or economic bargaining. Nash, fascinated by the possibility of applying game theory to economics, political relations between states, military strategies, faced the problem in an original and revolutionary way compared to Von Neumann. He extended the discussion to games to more participants (while Von Neumann had dealt with games for two) and discovered an equilibrium solution in which each agent finds the best strategy compared to the best strategy of all the others (the "dominant strategies"). The games studied by Von Neumann were instead "zero-sum", where the victory of one of the two necessarily corresponds to the defeat of the other. The Nash equilibrium, together with Von Neumann's minimax theorem, is today one of the cornerstones of game theory and is constantly applied to the most diverse fields: from economics to biology. But what is a Nash equilibrium? To understand what Nash equilibrium really is, it is necessary to start from the definition that Nash gave that is: Given N players and a set of N strategies, one has a Nash equilibrium if each of the N strategies represents an optimal response to other N-1 strategies of the considered set. In simple terms, a Nash equilibrium can be seen as a situation in which each player chooses a strategy that ensures the maximum payout given the strategies chosen by the other participants in the game. Nash equilibrium can also be defined as a list of strategies, one for each player, such that no one benefits, in the sense of improving their gain, from deviating from their own equilibrium strategy. The purpose of game theory is to help us understand and predict economic facts.

In the case of Nash equilibrium, we can say that in some situations players are able to define their best choices and those of their rivals. In such cases it is obvious that these actions constitute a Nash equilibrium, otherwise one or more players would modify their choices. Therefore, a set of strategies adopted by all the players constitutes a Nash equilibrium if no one agrees to change his, in the event that all the others keep their choice fixed. For example, consider a game made up of several players, each with a finite number of strategies ordered according to a certain criterion. Suppose the payout rule assigns positive winnings to all players if they all choose their first strategy together; still positive winnings to all, in the event that all together choose the latest strategy of each; no winnings at all, otherwise. It is easy to verify that the set of choices for which each plays his first strategy constitutes a Nash equilibrium; similarly the set of choices for which everyone plays their latest strategy. Of course, not all games are that simple. In 1953 Nash faced the problem of cooperation strategies between players and the distribution of the winnings obtained. The "Nash cooperative solution" for two-person games is an important contribution to conflict resolution. An example of Nash's equilibrium can be found in the film “a beautiful mind”: A very beautiful girl enters the room together with four others, less beautiful but certainly not despicable. One of the group launches the competition for the conquest of the most beautiful, and everyone seems to accept. But one of the boys objects that this will probably turn out very badly: after being courted by everyone, she may not give herself to anyone. Everyone would then fall back on their friends, but these, wounded in pride for having been considered second choice, would disappear. In this and many other situations it is much more rational to cooperate than to compete. Therefore it is better to completely neglect the most beautiful and immediately focus each on one of the others. Starting from this simple story, one can come to understand the Nash equilibrium: Two players are in a situation of equilibrium when neither of them, at the end of a game - that is when, knowing also the opponent's move, they can analyze the whole played in hindsight - he would make a different move than he did. Nash has shown that for every game over with two players, it is possible to find at least one point of balance. What is Nash equilibrium? Nash answered this question in a very short article of 1949 where he explained his idea of intimately merging two apparently very distant positions: that of a "fixed point" in a transformation of coordinates, and that of a more rational strategy than a player he can adopt, when he competes with an opponent who is also rational. There is a Nash equilibrium when all agents can make a choice from which all have a slight advantage or disadvantage. The typical example to illustrate a Nash equilibrium is the so-called prisoner's dilemma, in which the possible choices for two prisoners in different non-communicating cells can speak, accuse the opponent, or not speak. If both do not speak they will have a light sentence, if both speak they will have a slightly heavier sentence, if they make different choices the one who speaks will have freedom and the other will have a very heavy sentence. If both know these rules and do not make agreements, the choice you agree, the choice that corresponds to the Nash equilibrium is to speak, for both. From this example it can be seen that in real cases the Nash equilibrium is not necessarily advantageous. It is clear that when the "game" is economic phenomena or the financial market, the possibility or certainty that there are balance choices takes on crucial importance for those who have to make decisions. It is for this reason on the ante litteram example of Nash that it is increasingly easier today for mathematicians and game theory experts to work on market problems with the aim of maximizing the savings invested. It is good to highlight, before moving on to a practical application example, that the Nash equilibrium solves a game even if there are no dominated strategies. Moreover, a solution for elimination of dominated strategies is always also a Nash equilibrium while the opposite is not always true (a Nash equilibrium is not always also a solution for dominated strategies): and this is the reason why this type of equilibrium is so important. At this point we can see how the dominant strategy proposed by Nash merges with the game of the "Prisoner's Dilemma" becoming an integral part of it.

Example: The famous bandits Bonnie and Clyde have been stopped by the police because they are suspected of having taken part in a robbery. The police say that the two participated in the criminal action, but having no evidence, they have no possibility of establishing their role without a confession. In an attempt to shed light on the matter, the police decide to question the two suspects separately. In case of confession by both, the two will be sentenced to eight years imprisonment, which constitutes the sentence appropriate to what they have committed. However, each of the two is offered a much greater penalty (20 years of imprisonment) if he is the only one to keep silent, while the other confesses: the latter is guaranteed the freedom for the collaboration given to the solution of the case. If they were both silent, both would be sentenced to 1 year for illegal possession of weapons. The game is represented in the following figure. In each box, in addition to the possible choices of the two prisoners, the relative utilities that they can derive on a scale of 1 to 4 are also entered (the maximum benefit is to obtain the minimum penalty and the other way around).

We note that the choice "to be silent" corresponds for each of them to that of "cooperating" with the other, since if the other behaves in the same way, they will both get the minimum penalty; while the choice of "confessing" corresponds to that of "not cooperating" since it puts the other at risk of suffering the maximum penalty if he decides to remain silent, that is precisely not to cooperate. It quickly becomes apparent that Bonnie has a dominant strategy and this is "confess", that is, "don't cooperate". In fact, if she confesses and Clyde is silent, she goes free. And if Clyde also confesses, they will both be sentenced to 8 years in prison. If she were to keep quiet, she would run the risk of Clyde confessing and she would take a 20-year sentence. In fact, it may be that even Clyde does not confess and in this case they would both be sentenced to only 1 year: but the risk of taking 20 years against 8 is too great to run. The same kind of reasoning obviously applies to Clyde as well. In essence, the choice is made regardless of considerations as altruistic as they are cooperative: even if Bonnie loves Clyde, she does not risk taking a heavy sentence just because she does not know how he will behave; and the contrary. The two dominant strategies represent a Nash equilibrium in the sense of the definition: in fact neither Bonnie nor Clyde have an interest in changing strategy. This situation can also be defined as a weak equilibrium, to distinguish it from a strong equilibrium, in which the players have an interest not to change strategy. The Nash equilibrium therefore requires that, given a set of strategies:

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a) each strategy constitutes, for the player who implements it, a response that maximizes the result with respect to the strategies that he envisages playing the opponents;
b) each player's prediction is correct (as in the Cournot equilibrium).

In other words, in order for a strategy profile to be a Nash equilibrium, once all the strategies that make up the profile are known, everyone must ascertain that they have correctly predicted the strategies of the others and therefore that they have made the best choice: no one will have to regret the strategy. choice. Verifying whether a Nash equilibrium is present in a set of strategies is useful since the latter can be understood in many cases as a necessary condition for those strategies to constitute a plausible prediction about the outcome of a game.

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