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Cooking up Game Theory: A Practical Application in a Multi-Stage Cooking Competition

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Abstract

Game Theory is a widely studied and fascinating subject in the field of economics, with applications in microeconomics, macroeconomics, and various other areas. However, in both undergraduate and advanced courses, Game Theory is often presented using classic scenarios. We propose exploring alternative examples to engage students and illustrate the practical applications of Game Theory. In this paper, we analyze a practical application of Game Theory in a multi-stage cooking competition, as presented by a contestant on a popular Italian cooking show (MasterChef Italia). Through this example, we demonstrate the relevance and utility of Game Theory in various decision-making contexts.

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1 Introduction

Understanding economics and economic theories can be a challenging task for many students. One of the most effective ways to comprehend complex economic concepts is through the use of practical examples. This is especially true for the subject of Game Theory, which can be quite abstract and difficult to understand without real-world applications.

Examples allow students to see how economic theories and concepts work in the real world. They also help students to visualize and understand the underlying logic behind these theories. For instance, a game of chess can be used to introduce Game Theory. In chess, each move made by a player can influence the outcome of the game. This is similar to how economic players interact with each other in the market.

Furthermore, concrete Game Theory cases can be found in everyday life. For instance, a simple scenario like deciding what restaurant to go to for dinner can illustrate concepts such as decision-making, risk assessment, and strategic thinking. Another example is the allocation of resources among different family members. This can illustrate concepts such as supply and demand, as well as scarcity and opportunity costs.

In addition to everyday life, practical examples can also be found in movies, TV shows, and other forms of media. For example, the popular TV show "The Big Bang Theory" often references Game Theory and its applications to real-life scenarios. The movie "A Beautiful Mind" is also a great example of Game Theory in action, as it portrays the life of John Nash, a mathematician who applied Game Theory to economics.

Recent papers that adopt this approach include O'Roark and Grant (2018), and O'Roark (2017), who use superheros novels to illustrate Game Theory and economic principles. Other paper include Geerling et al. (2021), who use examples from the Netflix series Squid Game to teach Game Theory, Cleveland et al. (2016) who use examples from the young adult book series Hunger Games, and Luccasen and Thomas (2010), who use examples from The Simpsons.

These papers follow the suggestion of Dixit (2005), who ask the discipline to restore fun to Game Theory, and the one of Becker (2000), who suggested that educators should explore new teaching methods and tools to actively engage students and enhance their understanding of the subject matter. This means that teachers should go beyond the traditional use of the blackboard as the sole teaching tool and explore innovative ways of teaching to make learning more effective and engaging.

Indeed, it is crucial for economics professors to provide practical examples when teaching Game Theory. This approach can help students to grasp the subject more easily and see the relevance of the theory to their daily lives. By using relatable examples, students can understand the importance of economic principles and how they apply to the world around them.

In other words, the importance of practical examples in understanding economics cannot be overstated. The aim of this paper is to provide an illustrative example of Game Theory in action. To accomplish this, we will utilize an episode of the popular television show MasterChef Italia as a practical application of Game Theory. By analyzing the strategic decisions made by the contestants, we can demonstrate the real-world relevance and implications of Game Theory in a captivating and engaging manner. This example will provide a valuable tool for educators seeking to engage their students and enhance their understanding of Game Theory concepts.

2 The Tv Show: MasterChef Italia

MasterChef Italia is a successful television show that debuted on Mediaset networks in 2011. The series, based on the international format of the same name, is a talent show that focuses on the competition between aspiring professional chefs from all over Italy. During the course of the show, the contestants compete in various culinary challenges in which they must demonstrate their skills and creativity, while overcoming the obstacles imposed by the jury.

The program features three renowned Michelin-starred chefs (Bruno Barbieri, Antonino Cannavacciuolo, and Giorgio Locatelli) who evaluate the dishes prepared by the contestants and determine who will advance to the next phase of the competition. MasterChef is known for its fast-paced and highly competitive environment, which challenges the culinary skills of the participants. In the elimination challenge, those with the lowest scores from previous challenges compete to remain in the program, with the one who prepared the worst dish in the last challenge being eliminated.

What sets MasterChef apart is that contestants are often required to think strategically and apply Game Theory concepts to succeed.

The episode of MasterChef Italia here analyzed is the twenty-second of the tenth season (2021).[1]

In this elimination challenge, four participants compete: Aquila, Antonio, Azzurra and Monir. The test is structured as follows: In the first round, all participants must select four ingredients from a list of twelve and cook a dish. The best cook at the end of this round will be safe, while the other three will cook again in the second round. In the second round, the three remaining participants must select another four ingredients from the original list (excluding those already chosen) and cook another dish. Once again, the best cook is safe, while the other two must compete in the final round. In the third and final round, the two contenders must cook a dish using the remaining ingredients, and the worst cook will be eliminated. After the first round of ingredient selection, the judges ask the players why they chose those particular ingredients.

The Game Theory aspect of this challenge comes from the fact that each contestant had to decide which ingredients to use, based on what they believed

[1] Although all pertinent information, including dialogues, is provided in the current section, we recommend that interested readers watch the video to gain a comprehensive understanding of the lesson (and the paper). The video referred to in our note can be viewed at the following internet addresses: https://www.youtube.com/watch?v=cKB7yDJdjrE, https://www.docenti.unina.it/webdocenti-be/allegati/materiale-didattico/34554585, or it can be requested from one of the authors.

their competitors would choose. If a contestant chose the best ingredients right away, they risked being left with the worst ingredients for the subsequent rounds. On the other hand, if they chose the worst ingredients at the beginning, they would likely lose that round, however remaining with better ingredients for the following ones.

The strategy used by Monir is particularly interesting, as it differs from those explained by his rivals. He states (minute 2.00 in the video summary): "(In the first round) I have chosen ingredients that I am not familiar with, so if I'm lucky, I will be safe immediately. If not, I will have other ingredients that I am familiar with, and I will be able to cook better in the next rounds". Essentially, Monir employs backward induction reasoning, aiming to end the competition with the easiest ingredients, thereby strategically utilizing the more challenging ones in preceding stages. His approach not only distinguishes him from the other contestants but also arouses the uproar and curiosity of all judges and other contestants. After the first round, one of the most able competitors on the show, Antonio, is safe, while Monir, Azzurra, and Aquila must compete again. Ultimately, Aquila, (who eventually will win the competition), is safe. In the final round, Monir and Azzurra must cook to avoid elimination. Thanks to the saved resources, Monir manages to create an excellent dish using ingredients that were easier to cook with respect to the ones used by Azzurra. At the end of the episode (minute 4.50 in the video summary) judge Giorgio Locatelli makes a remark: "You have presented an excellent dish [...] You certainly deserve to pass to the final of MasterChef".

Considering the fatigue, psychological pressure, and the limited time available, Monir's strategy might seem bold'; however, it serves as a brilliant example of Game theory at work, and this episode can serve as a problem set for an introductory course on Game Theory. The primary challenge for students will be to comprehend how to simplify the decision tree, which initially appears to be very complex. With four players, numerous possible strategies, and apparently stochastic payoffs, the game may seem daunting. However, in the following section, we will illustrate how the entire game can be interpreted as an intertemporal prisoner's dilemma between Azzurra and Monir, and how Azzurra ultimately fails due to playing a strictly dominated strategy.

3 The game

In this game, we have four players who have to compete by choosing a combination of ingredients to cook a dish that will allow them to be declared the best. At first glance, this game can be seen as a three-step sequential game with a very complex tree, in which each player needs to take into account every possible combination of ingredients, the quality of the dish, and the taste of the judges, while also considering that the other players are doing the same. However, because this complicated setting can be misleading, we need to introduce some assumptions.

As first assumption, we posit that the combinations of the available ingre-

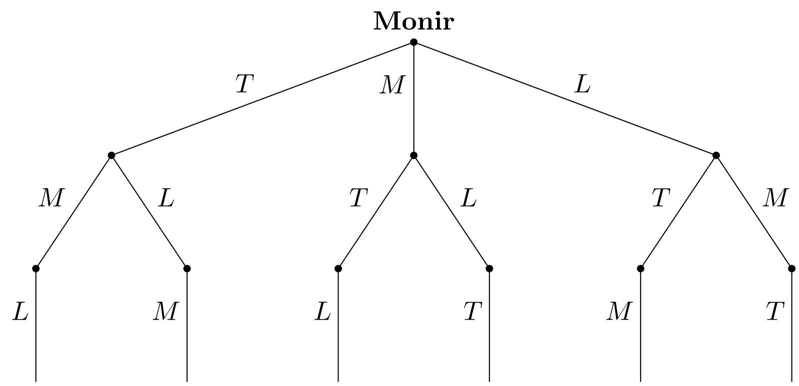

Figure 1: A possible sketched tree of Monir's strategies.

dients may result in three possible qualities θ for the dish: top, medium, and low. Each competitor may choose a different combination according to his or her strategy. The quality θ of each combination can be summarized as follows:

$$\theta = \begin{cases} \text{T} & \text{in case of top quality dish;} \\ \text{M} & \text{in case of medium quality dish;} \\ \text{L} & \text{in case of low quality dish.} \end{cases} \tag{1}$$

The complete tree of the game, which some of the smartest students in the course try to draw, is very complex. The game involves four players playing simultaneously, and in each stage one of them is removed from the tree, as well as a strategy (in the first stage there are 4 players and 3 possible strategies for each, in the second 3 players and 2 strategies, in the third 2 and one). Therefore, obtaining the game's equilibrium through backward induction may be very complicated. Figure 1 illustrates a possible sketched tree, in which only the strategies of Monir are represented, while avoiding the representation of the winning probability, the final payoff, and the strategies of the other players (which are identical to the ones of Monir).

However, introducing more (reasonable) assumptions may simplify the tree and make it easier to find the equilibrium of the game.

The second assumption we introduce to simplify the game is that the impact of the chosen dish on the likelihood of winning the round is directly related to the abilities of each player. In other words, all else being equal, the player with higher ability is more likely to win. Therefore, we can view these alternatives as strategies and leverage the players' abilities to determine the payoffs and the probability of winning the round, which ultimately determines the payoff in this scenario. In other words, *ceteris paribus*, the payoffs in this game are a function of player i's ability and the abilities of all other players.

The following equation specifies the probability P_i to win the game for the player i:

$$P_i = \begin{cases} \frac{A_i}{NA_{N-i}} & \text{if } \theta_i = \theta_{N-i}; \\ 0+\epsilon & \text{if } \theta_i < \theta_{N-i}; \\ 1-\epsilon & \text{if } \theta_i > \theta_{N-i}. \end{cases} \quad (2)$$

Where N is the number of players i in each round (4 in the first, 3 in the second, and so on); A_i is the ability of the player to cook the dish in the round. In this context, as the episode being analyzed is one of the last in the program A_i is common knowledge: each player knows the ability of the others;[2] the parameter $\epsilon \sim N(0,1)$ accounts for the possibility of errors during the test. Given the quality of each plate described in equation (1), we can determine the probability of winning under different scenarios. For example, $\theta_i > \theta_{N-i}$ means that player i chooses T (or M), while the others choose M or L (or L); therefore, the probability of winning is $1-\epsilon$. Similarly, $\theta_i < \theta_{N-i}$ means that player i chooses L (or M), while the others choose T or M (or T), resulting in a higher likelihood of losing the round. If all plates have the same quality (i.e., if $\theta_i = \theta_{N-i}$), then each player will have a chance of winning determined by their ability relative to their rivals.

Two distinct scenarios are possible: one where all players possess the same ability, and another, which we believe this example pertains to, where there are asymmetric abilities.

3.1 The symmetric case

If $\bar{A}_i = \bar{A_{N-1}}$, each player knows that the only way to increase their chances of winning is to choose the top-quality plate when the other players select the medium or the worst one, or the medium one when the other players select the worst one. As a result, it becomes clear that there is no pure-strategy equilibrium. One can reasonably expect two scenarios to arise: either **all** players will select the best plate in the first round (when the probability of winning is the smallest), or they will do the opposite and save the top quality dish for the last step. It is possible to imagine a probability distribution between these two extremes, but analyzing this case is beyond the scope of this text.

3.2 The asymmetric case

This is the scenario that we are examining in this episode. Monir, being at the final stage of the competition, has learned about his rivals' abilities and is aware that Antonio and Aquila are excellent cooks, certainly better than him. [3] However, Monir believes that he can compete with Azzurra. Given this information set, Monir's strategy is as follows: recognizing that Antonio and Aquila are likely to outperform him regardless of his choice of dish, Monir anticipates

[2] To provide clarification: The episode being analyzed is the 22nd out of 24, and the remaining contestants have been competing against each other for several weeks. Monir acknowledges that he is less skilled than Aquilia and Antonio, but he perceives himself to be on the same level as Azzurra.

[3] In fact, Aquila will emerge as the winner and Antonio will be one of the finalists.

that he will face Azzurra in the final round of the competition. In the first round, Monir understands that his sole opponent is Azzurra, and he must decide when to create the best possible dish. Although it may seem like a complex multi-stage game, it is, in fact, a relatively straightforward simultaneous game involving only two players. However, it is more intricate than a typical exercise because both players must decide their strategies in the present moment while also considering the implications for the three subsequent rounds.

To simplify the representation of the game further, we can assume that at every round, they must decide when to prepare the top-quality dish, considering that Antonio and Aquila possess superior ability and will receive the final payoff in the last round. In the first round, they can either make the best dish immediately (N) or wait (W). The game is represented in table 1:

Table 1: Game Representation

		AZZURRA	
MONIR		**N**	**W**
	N	1/2 ; 1/2	0+ϵ ; 1-ϵ
	W	1-ϵ ; 0+ϵ	1/2 ; 1/2

Given the table representation, solving the game is a straightforward exercise: considering that ϵ is negligible, the payoff for Waiting is higher regardless of the opponent's action in every stage of the game. In fact, $1 - \epsilon > \frac{1}{2}$, and $\frac{1}{2} > \epsilon$.

In other words, it is evident that Waiting is a dominant strategy for both players. In the second round, the game remains exactly the same, and the dominant strategy for each player remains to wait. In the third round, there is no strategic interaction, as the outcome is predetermined. This is a classic example of intertemporal choice (or resource allocation in this specific case) between a sophisticated (rational) agent and a naive (myopic) agent. The sophisticated agent recognizes the asymmetry in abilities and the hidden structure of the game, and acts optimally by following the dominant strategy. On the other hand, the myopic agent sticks to the symmetric version of the game. Note that this example could also be further explored in a course on behavioral Game Theory, by attempting to identify biases such as overconfidence bias.

4 Conclusion

This note highlights the practical application of Game Theory and underscores the importance of using real-world examples to teach students. Such cases can be used to supplement traditional textbook problems.

In other words, by incorporating everyday examples, economics professors can make the subject more relatable, interesting, and comprehensible for their students. Using such scenarios as supplementary material in introductory courses of Game Theory can enrich students' learning experiences and stimulate their curiosity, helping them to understand the practical applicability of Game Theory. Real-life situations, such as the one presented in this note, provide students with a familiar context to work on seemingly complicated games. In fact, the case we present here can serve as a starting point to encourage students to find similar examples in TV shows, comics, or films. Applying Game Theory to such situations helps students see the subject in a new light, making it less abstract and more relatable.

Furthermore, utilizing familiar scenarios such as the one presented in assignments can create a more engaging and interactive learning experience, which can result in a deeper understanding not only of the subject matter but also of the world we live in. By analyzing familiar situations through the lens of Game Theory, students can gain a more profound appreciation of how decision-making processes shape our daily lives, whether it be in personal relationships, politics, or business. This kind of critical thinking can enhance their problem-solving skills and help them become more informed and responsible members of society. By providing students with opportunities to explore and apply Game Theory concepts to real-world scenarios, educators can prepare them to tackle complex problems in a variety of fields and industries.

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