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An Oligopoly Market Analysis in the Food and Beverage Sector Using Game Theory

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Abstract:

Food and beverage production firms are socially active workplaces by their very nature. They function in an oligopoly market environment with their competitors. Conflicting interests of competitors create tradeoff game situations that impact many business decisions. The purpose of this paper is to conduct an oligopoly market analysis in the food and beverage sector using game theory. Data from two leading competing brands in the industry were collected for analysis. Five social interaction-related decisions were the focus of this study: marketing campaigns, price war, investment in R&D, the introduction of a new product, and a new policy. The designed games were based on the Prisoner's Dilemma, Deadlock, and Extensive-Form game models. Games, players, strategies (actions), assumptions (payoffs), representations, analysis, and results are addressed in a series of phases for each of the five studied decisions. Implications of this study include assisting decision-makers in the food and beverage industry in developing reactive and proactive strategies for competitor actions and maintaining competitive advantage.

Keywords: Game Theory; Mathematical Models; Social Science; Non-Cooperative Games; Social Interactions.

1. Introduction

These days, game theory is used in a wide variety of businesses to understand human behavior better, particularly when it comes to decision-making [1]. However, more research needs to be conducted in the food and beverage sector. This research will examine five issues related to social interactions for two canned food brands, X and Y.

In the beginning, there's the Marketing Campaign, which both businesses are preparing. They must, however, consider the projected results while evaluating their

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campaign spending. Due to their mutual impact throughout the marketing effort, both parties should consider each other and make an informed choice. The Price War is the second issue. Oligopolistic competition exists between the two brands, X and Y. Large corporations are engaged in a "Price War" to win market share by slashing their profit margins to attract new consumers. Financially speaking, they stand to lose out if the rivalry drags on. R&D funding is the third issue. Research and development (R&D) expenditures are being increased by both businesses X and Y, but this requires time and effort to meet customers' expectations. Companies had to decide whether to invest in operations or R&D. Releasing a New Product is the fourth issue. New goods and a broader client base are common strategies used by businesses looking to get a larger piece of the market. However, if anything goes wrong, the firm might suffer the consequences of losing clients and money. New Policy is the last issue. Brand X is considering implementing a new policy on employee advancement and the annual reclassification scheme. When it comes time for workers to get their bonus at the end of the year, it would mean that they would be given out on a curve to save money. However, staff who fear their end-of-year bonuses would be harmed may resist this new approach.

The purpose of this paper is to conduct an oligopoly market analysis of two leading competing brands in the industry, X and Y, using game theory. Five social interaction-related decisions were the focus of this study: marketing campaigns, price war, investment in R&D, the introduction of a new product, and a new policy. The designed games were based on the Prisoner's Dilemma, Deadlock, and Extensive-Form game models. Games, players, strategies (actions), assumptions (payoffs), representations, analysis, and results are addressed in a series of phases for each of the five studied decisions. This is to assist decision-makers in developing reactive and proactive strategies for competitor actions and maintaining competitive advantage.

2. Game Models

Evidence for the presence of oligopoly market cases among food sector firms, particularly food retailers, was reported in the literature [2-7]. Based on the mathematical modeling of strategic behavioral interaction, the game theory attempts to determine the best option for decision-makers. This could be seen in various fields, from social sciences like psychology and economics to science and political science [1]. Furthermore, it is the ability to forecast how individuals respond to situations to maximize their interests [8].

For example, Ullah et al. [9] provide a utility function model based on game theory for companies dealing with unpredictable demand, risk attitudes, and various warranty and maintenance service alternatives. Concerning pricing, the manufacturer has a clear idea of how much they should charge, whereas the third-party agent has a clear picture of how much they should charge.

Also, a well-known and basic example of game theory that explains the situation is a Prison's Dilemma, where two opponents, "Players," commit a crime and get arrested by the police. The police separate them into different rooms, and their cooperation influences their sentence in jail (turning on each other), yet no one knows what the other would say. If both say nothing, they will go to three years in jail. If both collaborate, they will go for one year in jail; if only one collaborates, they will go free, and the other will go for five years. Therefore, each player has a combination of actions and payoffs [10].

Another example is the Deadlock game, where Nash Equilibrium dominates, unlike the Prisoner's Dilemma, where players seek their interest's action dominates. This difference makes Deadlock less attractive [11]. Madani [8] has examined the game theory using a sequence of non-cooperative in water resources management and resolving conflicts. The study applied the structure of the Prisoner Dilemma, Stack Hint, and Chicken Game to solve related problems among stakeholders where the assumption is different from optimization techniques that assume stakeholders are eager toward the best systems.

Another problem consists of two farmers for groundwater using the matrix of ordinal payoff and Prisoner's Dilemma structure. Both farmers shared an aquifer with two different pumping rates: the cooperative lower cost (Pumping Rate 1) and the non-cooperative higher cost (Pumping Rate 2). However, one choice will influence the other economically and the groundwater. The payoff for both farmers is the revenue minus the cost of pumping water. If both choose pumping rate 1, the groundwater level will remain steady; if both choose pumping rate 2, the groundwater level will decline. Another scenario, if one chooses the cooperative pumping rate one while the other chooses the non-cooperative pumping rate two, will keep the groundwater level. However, would they trust each other to keep the water resources system or choose their interests? [8].

Bennett et al. [12] have applied game theory to facilitate international conflicts between Syria and Turkey over the Euphrates River, which could happen in many areas worldwide. In such a case, upstream countries have the upper hand over the quantity of water over the downstream countries. The paper suggested applying an interconnected game to the negotiation by linking other non-water issues to leverage one position. In this case, Turkey has claimed that Syria has supported the Kurds against Turkey to influence negotiation. Turkey's and Syria's positions are influenced by each other's actions. Turkey behaves better when Syria chooses not to support the Kurds, whereas Syria acts better when Turkey chooses to share water. However, Turkey has the leading strategy to decide not to share the water, while Syria's best reaction is to support the Kurds.

Liu et al. [13] have implemented the game theory on the Blockchain network by conducting a survey to fill the gap in this field. The study addressed several problems in Blockchain, such as security issues, reward allocation, and several other issues. Table 1 summarizes the key factors of game theoretical applications and reviews game models proposed to tackle common problems.

Game theory is an old method that has been used over decades; it undergoes many developments and has been used widely in many recent years' applications. Choi et al. [14] have studied the applications of game theory in production and business operations in recent years. The study has explored challenging topics in the field, such as the sharing economy, manufacturing systems, supply chain, and several other issues, by evaluating the strategic behavior of decision-makers. The study concluded that game theory is a powerful and insightful tool, especially for multi-methodological analysis, technological-driven studies, and systems engineering approaches [14]. In this paper, data from two leading competing brands in the food and beverage industry were collected based on the historical data of their sales and competitive strategy in oligopoly environments.

3. Games Design

Before designing the games used in this research study, a few terms must be explained, as listed in Table 1. Payouts, tactics, and kinds of players are all taken for granted in this research. Players, on the other hand, are attempting to maximize their gains. For this research, Table 1 lists the games that will be used. In-game theory, games are represented in the Normal form (or Strategic form), the Extensive form, and the Characteristic function form. In this study, only Normal and Extensive forms are executed.

Table 1. Game Terminologies

Terminology	Definition
Players	Any decision-makers (individuals, companies, etc.)
Strategies	Any chosen options in a setting
Payoffs	Players' preferences (Cardinal or Ordinal)
Cooperative	When players can form obligatory commitments
Non-cooperative	When players cannot form obligatory commitments
Simultaneous	When both players move (make actions) simultaneously without knowledge of the other player's actions
Sequential	Every player is aware of what the other party chose as a strategy.

The extensive form in those games is played on the decision tree [15]. The node represents the player's choice. Each player is listed in the tree, where lines represent the possible actions. The bottom node represents the payoffs [16]. However, Black Induction must be utilized. This is to resolve an extensive game that defines the rational player that would make the last move in the tree and take that action to the previous step to evaluate how players would rationally act to that action until the game reaches the first node in the tree [17]. This research will use well-known game theory concepts, such as the Prisoner's Dilemma and Deadlock, to assist Brands X in handling its social relationships more effectively. Figure 1 demonstrates the general flowchart used for solving the designed games in this study.

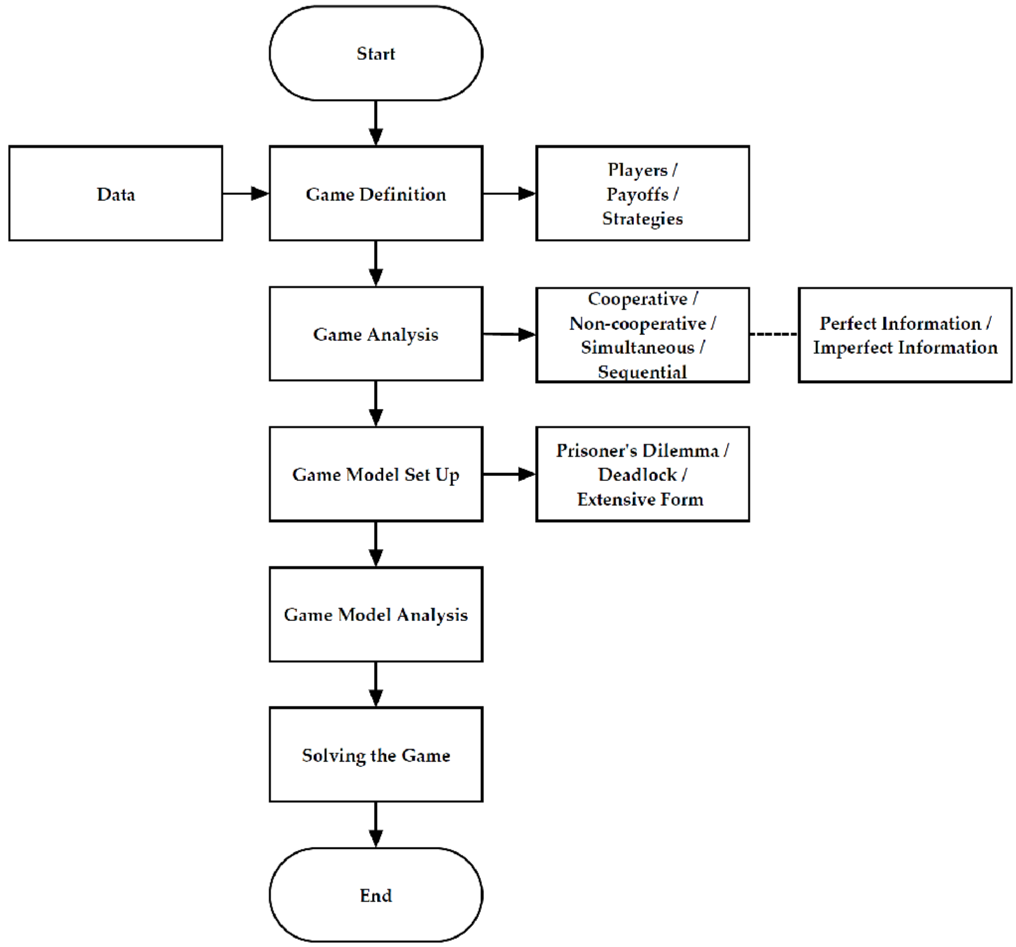

Figure 1. General flowchart for solving the designed games

4. Games Strategy and Structure

The company of interest in this study encounters a lot of social interactions while working in its environment. Whether it is outside or inside the environment, for an external environment, interactions examples could be competitors, consumers, and government extra. On the other hand, inside environment interactions, examples are own workers, managers, and lawyers extra. This section presents the analysis of these interactions using Game Theory using applications of famous games in Game Theory like the Prisoner Dilemma, Deadlock, and Extensive Form games. To look at social interactions like Marketing Campaigns, Price Wars, Releasing a New Product, Investing in Research and Development (R&D), and Adapting a New Policy. All the previous interactions can be viewed as games. Each game is analyzed through a series of steps: Game, Players, Strategies (Actions), Assumptions, Payoffs, Representations, and Analysis & Results.

4.1 Games

For the Brand X Food Company, social interactions, including marketing campaigns and price wars, can be handled using the Prisoner's Dilemma Game Theory. For the same company, interactions like Investing in R&D and releasing new products can be considered Deadlock Game Theory. The Extensive Form of Game Theory can be applied to the last interaction, known as the new policy, for the Brand X Food Company.

Brand X Food Company (Marketing Campaign Game) features two competing brands, Brand X and Brand Y, in the Prisoner Dilemma Game. They are debating whether or not to launch a marketing campaign against each other. In this game, there are four potential outcomes. In the first scenario, a marketing campaign is launched by Brand X and not by Brand Y. The second possibility is the exact polar opposite of the first. Each company launches marketing campaigns in the third scenario. Neither of them will launch a marketing effort in the fourth case scenario. Non-Cooperative games, such as this one, are the case here.

In an oligopoly market structure, Brand X and Brand Y compete against each other in the Price War Game. This game examines the consequences of a pricing war between these two corporations. This game has four potential outcomes. To begin with, Brand X maintains pricing, while Brand Y reduces it. The second possibility is the polar opposite of the first one mentioned below. Both firms lower all prices in the third scenario. Fourth, the pricing is kept the same by both firms. Non-Cooperative games, such as this one, are the case here.

Both Brand X and Brand Y, competing businesses, are debating whether or not to engage in R&D to better meet their consumers' needs in the Investing in R&D Game (Deadlock). In this game, there are four potential outcomes. Brand X invests in R&D, but Brand Y does not. Unlike the previous example, this is the reverse of what is happening. In the fourth case, both firms contribute to developing new products. Fifth, Brand X wants to adopt a new policy for employee promotions and the yearly bonuses system. That would make the bonus get distributed on a curve in an attempt to reduce cost by reducing the number of people who get bonuses at the end of the year. Non-Cooperative games, such as this one, are the case here.

4.2 Players

Two players (decision-makers), Brand X and Brand Y are included in the first four games. Both are working in the food and beverage sector. For the last game, there are two players (i.e., decision-makers), Brand X and its employees.

4.3 Strategies (Actions)

In the Prisoner Dilemma Game in Brand X Food Company (Marketing Campaign Game), each company must decide whether to engage in a marketing campaign. In the Price War Game, each company must decide whether to keep the prices as it is or lower them. In the Application of Deadlock games in Brand X Food Company (Investing in R&D Game), each company must decide whether to invest in R&D. For releasing new product games; each company must decide whether to launch a new product or not. Application of Extensive Form games in Brand X Food Company (New Policy Game) each party has a set of strategies that depends on the other party's decision (strategy).

4.4 Rationality of Strategies

Aiming to maximize profits in the first four games, each firm. Thus, each business (agent) has its own agenda. There is no conflict between them, but rather the fact that each agent acts under its own definition of states [18]. The states are their own source of profit and income in the current circumstances.

As a simultaneous move game, the Marketing Campaign is an incomplete information game in the first four games since it is still being determined what the other side is doing when making choices. As a result, all players access information about competitors like Brand Y as part of the Marketing Campaign, Price War, R&D Investment, Releasing a New Product, and New Policy games. As a result, participants' benefits, rewards, methods, and "types" are well-known [19].

In the Prisoner Dilemma Game in Brand X Food Company (Marketing Campaign Game), each company would want to advertise alone rather than with a competitor. This raises the first scenario as the most preferred outcome for Brand X and the second scenario as the most preferred outcome for Brand Y. On the other hand, the third scenario is ok for both if they both advertise and create a marketing campaign. But looking at the fourth scenario, they rather if both did not advertise to avoid buying for marketing campaign expenses. The reason to deal with the Marketing Campaign game as a simultaneous move game rather than a sequential move game is that when the results of the campaign are obtained, it is already too late to react to it. For example, if Brand Y decides to make a back-to-school campaign theme. It will take them at least a whole month to prepare it. When it is time to start advertising the campaign, it will be too late for Brand X to come back and make a back-to-school campaign because Brand Y has one month lead over Brand X.

In the Price War Game, each company would want to lower the prices and take a larger market share, which would only happen if only one of them did. This makes the first scenario the most preferred outcome for Brand X and the second scenario the most preferred outcome for Brand Y. On the other hand, the third scenario is ok for both if they both lower their prices. But looking at the fourth scenario, they rather if both did not lower the prices. Because that will not increase their sales if both companies do it, causing their marginal profit to go down.

The Price War game is a simultaneous move game and not a sequential move game because when the market share is getting more prominent because of lowering the prices, it is already too late to react to it. For example, if Brand Y decides to lower the prices. They are going to gain more market share, potentially Brand X consumers. By that time, it will be too late for Brand X to make the same move because the consumers have switched brands, and it will take a lot more than lowering the price to match Brand Y to win them back.

In the Application of Deadlock games in Brand X Food Company (Investing in R&D Game), Each company would rather invest in R&D without a race with its competitor. This makes the first scenario the most preferred outcome for Brand X and the second scenario the most preferred outcome for Brand Y. On the other hand, the third scenario, where they don't invest in R&D, is ok for both parties. Thus, looking at the fourth scenario, they both invested in avoiding being left behind in the market. Both parties prefer the fourth scenario because if both companies decide not to move forward and innovate, other companies might see this as an opportunity to enter the market and take a market share from both.

The reason for investing in the R&D game as a simultaneous move game rather than a sequential game is that when the results of the R&D department are realized, it will be already too late to react. For example, if Brand Y decides to make a new kind of packaging for its products, that would extend its expiry date with less cost and materials. It will take a long time. They need to research and run tests to ensure that the new packaging is high quality and safe for use. When it is time to introduce the new packaging to the market, it will be too late for Brand X to come back and make a smellier thing because Brand Y has a considerable lead over Brand X.

In the Releasing New Product Game, each company would instead release a new product faster than its competitor to gain a more significant market share. This makes the first scenario the most preferred outcome for Brand X and the second scenario the most preferred outcome for Brand Y. On the other hand, the third scenario, where they don't release any new product, is ok for both parties. Thus, in the fourth scenario, they instead both release a new product to stay caught up in the market and gain new customers. Both parties prefer the fourth scenario because if both companies decide not to move forward and innovate, other companies might see this as an opportunity to enter the market and take a market share from both.

The reason the Releasing a New Product game is a simultaneous move game rather than a sequential game is that when the new product sales are seen, it is already too late to react to it. For example, if Brand Y decides to make a new product. It will take a long time. They need to research and run tests to ensure that the new product is good, high-quality, and safe. When it is time to introduce the new product to the market, it will be too late for Brand X to come back and make a smellier thing because Brand Y has a considerable lead over Brand X.

Each side in the Brand X Food Company (New Policy Game) Application of Extensive Form games aims to maximize their own advantages. Each party (agent) is motivated by its own self-interest. No, there is not a conflict between them, but rather the fact that each agent acts under its own definition of states [18]. In our case, the states represent the people's financial well-being, well-being, and employment status.

Brand X would issue the new policy to cut some expenses. The employees, however, would like to avoid having this new policy. They will fight it, but not at the cost of their career. So, if they knew that Brand X would enforce the policy, they would not revolt, fearing losing their jobs. Because of the dependency of the decisions made in this game by the players and decisions made sequentially, the representation of this game is an extensive form game rather than a typical form game.

4.5 Payoffs

The idea that the reward for one player is determined by the strategy used by the other player is fundamental to the study of game theory. When an outcome is reached as a result of the combined activities of all of the agents, this is simply the reward given to every agent who contributed to reaching that outcome. The historical information on sales and market share rivalry between Brand X and Brand Y is the source of information used to compile the anticipated payment for each participant in these normal-form games. Brand X provided this information. To make the payoffs more understandable, integer values ranging from 0 to 4 symbolize the amount of money each participant has gained or lost in revenue multiples. For example, if the payback is evaluated as (4,0), the first player will earn four times the sales income the second player will.

The payoffs for Marketing Campaign Game are represented in Ordinal payoffs. There are four potential outcomes for this game. Knowing the utilities for each outcome for every player, the first outcome Brand X gets four utility points while Brand Y receives zero. Second outcome Brand X gets zero utility points while Brand Y gets four utility points. Third outcome Brand X gets one utility point while Brand Y receives one. Fourth outcome Brand X gets three utility points while Brand Y gets three.

The payoffs for Price War Game are represented in Ordinal payoffs. There are four potential outcomes for this game. Knowing the utilities for each outcome for every player, the first outcome Brand X gets four utility points while Brand Y receives zero. Second outcome Brand X gets 0 utility points while Brand Y gets four utility points. Third outcome Brand X gets one utility point while Brand Y receives one. Fourth outcome Brand X gets three utility points while Brand Y gets three.

The payoffs for Investing in R&D Games are represented in Ordinal payoffs. There are four potential outcomes for this game. Knowing the utilities for each outcome for every player, the first outcome Brand X gets three utility points while Brand Y receives zero. Second outcome Brand X gets zero utility points while Brand Y gets three utility points. In the third outcome, both companies receive one utility point. In the fourth outcome, both companies receive two utility points.

The payoffs for Releasing New Product Games are represented in Ordinal payoffs. Knowing the utilities for each outcome for every player, the first outcome Brand X gets three utility points while Brand Y gets zero. Second outcome Brand X gets zero utility points while Brand Y gets three utility points. The third outcome is that both companies receive one utility point. In the fourth outcome, both companies receive two utility points.

The payoffs for New Policy Game are represented in Ordinal payoffs. This game has four potential outcomes before setting the payoffs as a quick reminder of the definition. Payoffs represent player preference according to the assumptions. In Game Theory, payoffs are represented through utilities, which describe the player's choices in this case. Utilities of each outcome for every player being known, the first outcome was that Brand X decided not to issue the new policy, Brand X gets a payoff of zero, and the employees get a payoff of one. The second outcome is that Brand X issued the new policy, and the employees accepted it. Payoffs are Brand X's three utilities and employees' zero utilities. In the third outcome, employees revolt against the company, and the company enforces the policy. Payoffs are Brand X zero utilities and employees negative one utility. Fourth and last outcome, Brand X backs off and does not enforce the new policy. Payoffs are Brand X negative one utility and employee's three utilities.

4.6 Representations

Figure 2 (a) depicts the game Marketing Campaign in its standard version (Matrix). Which is the best method for presenting a large amount of information clearly and concisely? Figure 2 (b) shows a standard representation of the Price War game (Matrix). Which is the best method for presenting a large amount of information clearly and concisely? Figure 2 (c) shows the R&D investment game in a typical form (Matrix). It's hard to think of a better approach to summarize a large amount of information clearly and concisely. Figure 2 (d) depicts the release of a new product game in a usual manner (Matrix). What good approach to condensing much information into a clean, concise format? Figure 2 (e) depicts the New Policy game more expansively (Game Tree). Is it possible to summarize much information in a clear, easy-to-understand manner and express consecutive movements in games? The open circle, referred to as a decision node, is where the interaction starts. Only after Brand X issues the policy will the Employees have an option about how they will respond to it.

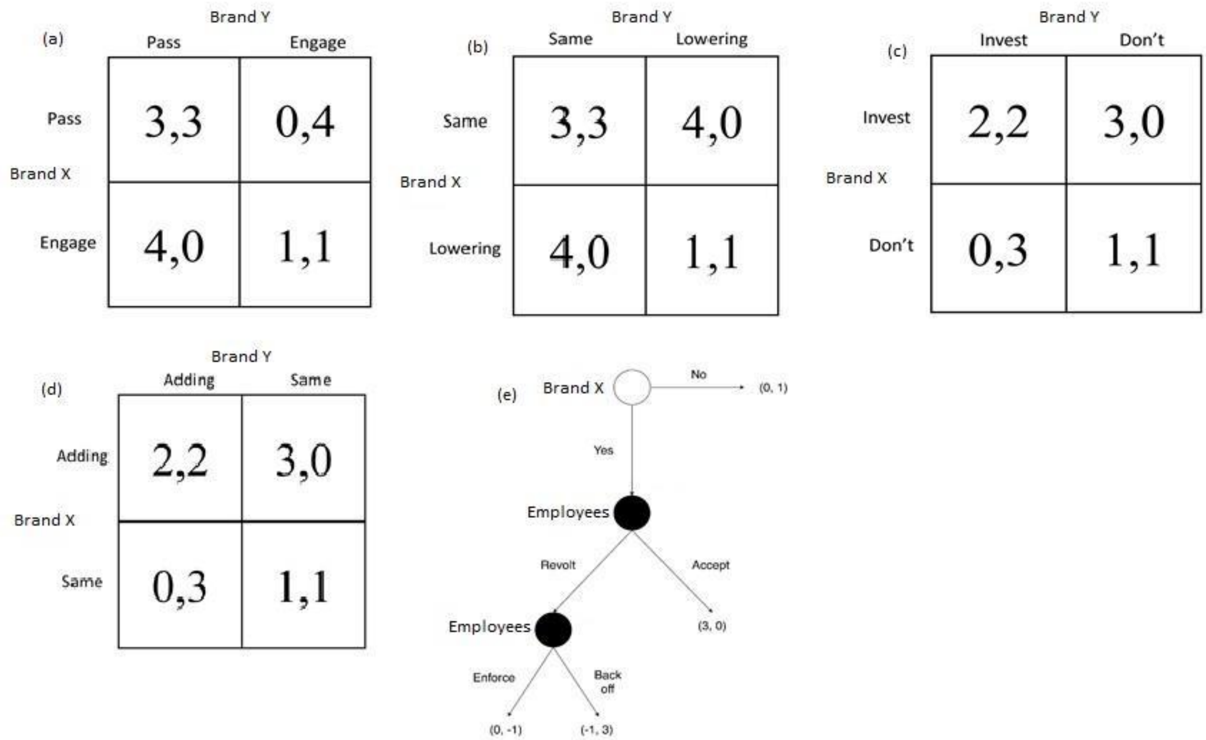

Figure 2. Representations of all five games
(a) Marketing campaign game; **(b)** Price war game; **(c)** R&D investment game; **(d)** release of a new product game; **(e)** New policy game.

5. Results and Discussion

5.1 Marketing Campaign Game

Knowing how to comprehend standard form representation in this game is crucial since it's utilized often. This is a two-player game. The first player's Brand X tactics (e.g., "Engage") and the second player's Brand Y strategies (e.g., "Pass") are arranged in columns and rows, respectively. Brand X payoffs are mentioned first for each result, and Brand Y payoffs are listed second. Brand X receives zero payment if it engages and Brand Y passes; Brand Y gets a payout of four, on the other hand.

It is necessary to look at each move in isolation to know which strategy each player should choose. This solution approach is called case analysis. Consider the game from the Brand X perspective. Suppose it is known that Brand Y would engage (see Figure 3). How should Brand X respond to Brand Y? Since Brand X only cares about its payoffs, Brand X can block out Brand Y's payoffs with question marks: should Brand X engage?

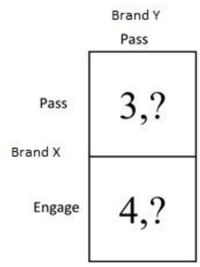

Figure 3. Brand X move with isolation to Brand Y's payoffs

If Brand X passes, it will get a payoff of three. However, if it engages, it receives a payoff of four. Since Brand X prefers more payoff points, engaging produces the best outcome (see Figure 4). Note that Brand Y's payoffs are entirely irrelevant to Brand X's decision in this context; if Brand X knows that Brand Y will pass, then Brand X only needs to look at their payoffs to decide its preference strategy. Thus, the question marks hiding Brand Y's payoffs could be any number at all, and Brand X's optimal decision will remain the same given Brand Y's move. On the other hand, suppose Brand X knew that Brand Y would engage. What should Brand X do?

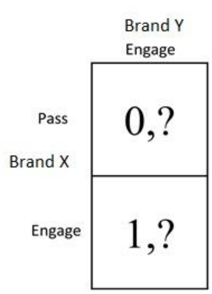

Figure 4. Brand X's move with isolation to Brand Y's payoffs

Engage wins a second time: engage leads to one utility point, whereas passing zero utilities. So, Brand X would want to engage if Brand Y engages (see Figure 5). Combining these two parts of information to reach a significant conclusion—Brand X is better off engaging regardless of Brand Y's strategy. Thus, Brand X can effectively ignore whatever they think Brand Y will do since engaging gives Brand X more utilities in either scenario.

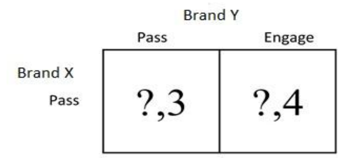

Figure 5. Brand Y's move with isolation to Brand X's payoffs

From Brand Y's perspective, if they knew that Brand X would pass, even though it could be realized, they should not (see Figure 6). The situation of Brand Y is that it should engage, as Brand X will get a payoff of four rather than three. Finally, suppose Brand Y knew that Brand X would engage. How should Brand Y respond?

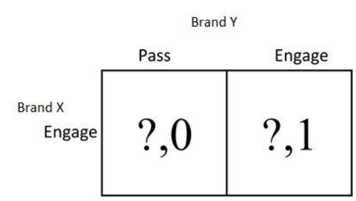

Figure 6. Brand Y's move with isolation to Brand X's payoffs

Unsurprisingly, Brand Y should engage. Once more, Brand Y prefers engaging regardless of what Brand X does (see Figure 7). Thus, a solution is found: both players engage, and both players get a payoff of one.

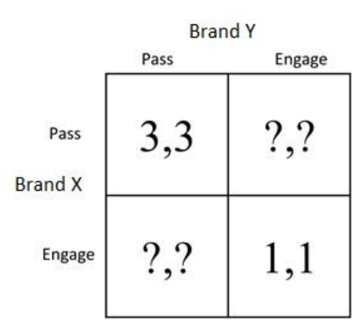

Figure 7. Comparing <pass, pass> outcome to <engage, engage>

This outcome confuses many people who are new to the field of game theory. Compare the <pass, pass> outcome to the <engage, engage> outcome.

Considering the game matrix, people realize that the <pass, pass> outcome leaves both players in a better position than the < engage, engage> outcome. They then consider why players cannot coordinate on passing the marketing campaign. However, promises not to make a marketing campaign are unsustainable. Brand X wants Brand Y to avoid making a campaign, so when Brand X engages, Brand X walks away with four utility points. The same goes for Brand Y. As a result, the <pass, pass> outcome is inherently unbalanced. Finally, players finish in the second class (but sustainable) <engage, engage> outcome.

As a result, each player has a single dominating strategy: to interact. In each Nash equilibrium game, if a player's strictly dominating strategy is accessible, this player will use this strategy. There will be only one pure strategy Nash equilibrium if both participants in the game have access to these dominating tactics. This Nash equilibrium, however, may not be the most "efficient" for both players since there may be superior non-equilibrium outcomes [20, 21].

In addition, it is essential to note that this game does not contain a Nash equilibrium, a weakly dominated strategy, or any other mixed strategy. Each player's best approach is to 'engage, engage.'

5.2 Price War Game

The solution to the Prisoner Dilemma is always the same. To summarize, the only way to get a competitive advantage is to decrease the price. In each Nash equilibrium game, if a player's strictly dominating strategy is accessible, this player will use this strategy. Meanwhile, if both players have access to these dominating tactics, there will be a single Nash equilibrium <lowering, lowering>. Both players may have superior non-equilibrium outcomes if the Nash equilibrium is not "efficient" [20, 21]. In addition, it is essential to note that this game does not contain a Nash equilibrium, a weakly dominated strategy, or any other mixed strategy. Each player's best answer is to 'lower, lower.'

5.3 Investing in R&D Game

This game is best played with two people. For Brand X, the rows represent "first player" tactics ("Invest" and "Don't"), whereas for the second player, "Brand Y," the columns represent "Brand Y." Brand X payoffs are mentioned first for each result, and Brand Y payoffs are listed second. Example: The top right payoffs show what happens when one brand spends while another doesn't. Brand X earns three points, while the other gets zero points. It must concentrate on one player's payoffs at a time to uncover dominant tactics. When looking for a tightly dominated strategy, it is essential to filter out irrelevant payoffs and tactics (see Figure 8). What is the best approach for each company? What should be done is to examine each action individually. It's called case analysis. Consider it from the standpoint of Brand X. Suppose he had known that Brand Y would invest. What action should Brand X take in response?

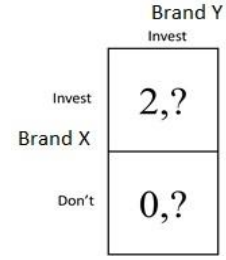

Figure 8. Brand X move with isolation to Brand Y's payoffs

If Brand X did not invest, it would get zero payoffs. However, if it invests, it receives a payoff of two. Since Brand X prefers high utility points, investing produces the best outcome. Keeping in mind that the rewards of Brand Y are meaningless in this context, Brand X must only consider its own rewards to decide which strategy to pursue when it is inevitable that Brand Y will fail. Assuming that the question marks might be any number, the best course of action for Brand X is to stay the same in light of Brand Y's change (see Figure 9). However, assume Brand X was aware that Brand Y would not invest in the project. What should Brand X be doing next?

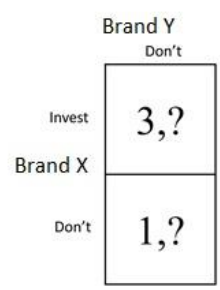

Figure 9. Brand Y's move with isolation to Brand X's payoffs

Investing wins a second time: Investing leads to three utility points, whereas it does not receive zero. So, Brand X would want to invest if Brand Y does not.

A significant assumption was reached by placing these two parts of information together. Brand X is better off investing regardless of Brand Y's strategy. Thus, Brand X can effectively ignore whatever he thinks Brand Y will do since investing gives him more utility in either scenario.

From Brand Y's perspective, assume they knew that Brand X would invest (see Figure 10). Here is Brand Y's situation.

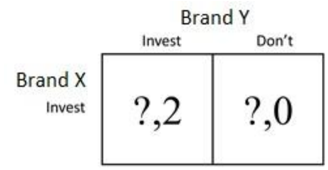

Figure 10. Brand Y's move with isolation to Brand X's payoffs

Brand Y should invest, as Brand X will get a payoff of three rather than zero (see Figure 11). Finally, suppose Brand Y knew that Brand X would not invest. How should Brand Y respond?

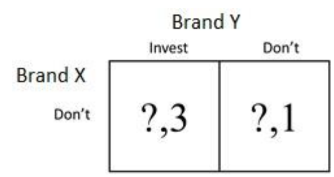

Figure 11. Brand Y's move with isolation to Brand X's payoffs

Unsurprisingly, Brand Y should invest. Once more, Brand Y prefers investing regardless of what Brand X does. Thus, a solution has been found in which both players should invest, and both players get a payoff of two, which is the strict dominance strategy for both players.

To summarize, each player's primary strategy is to make investments. There is a Deadlock game where the Nash Equilibrium dominates, unlike Prisoner's Dilemma, where players pursue their interest's actions are dominated. Because of this, I'm less interested in checking out Deadlock [22]. A strategy Nash equilibrium is one in which invest, invest> is the most profitable for both parties. In addition, it is essential to note that this game does not contain a Nash equilibrium, a weakly dominated strategy, or any other mixed strategy. Each player's best option is to <invest, invest>.

5.4 Releasing New Product Game

The solution is the same for all Dead Lock games. Finally, each player's objective is to introduce a new product, their only means of dominance. There is a Deadlock game where the Nash Equilibrium dominates, unlike Prisoner's Dilemma, where players pursue their interest's actions are dominated. Due to this discrepancy, Deadlock is no longer enticing. A pure strategy Nash equilibrium may be shown here, with both players benefiting by <adding, adding >. In addition, it is important to note that this game does not contain a Nash equilibrium, a weakly dominated strategy, or any other mixed strategy. Addition and subtraction are the optimal responses for each player.

5.5 New Policy Game

There are ways to reach Nash equilibrium since this is an extended-form game. Backward Induction and Perfect Equilibrium are examples of subgame perfect equilibrium. The extended-form game could be converted into a matrix using the subgame perfect equilibrium. Then the Nash equilibria of the game could be found, and the logic of the game tree could be worked through to discover whether any of those Nash equilibria relied on fantastic threats.

Backward Induction may be employed when there are no simultaneous movements, which is the simplest approach to solving large-form games. Due to the lack of simultaneous movements in the new policy game, Backward Induction is the method of choice.

For Black Induction to work, the logical last mover must analyze how other players would logically react to their actions. This evaluation must be done backward from that point until the game reaches the initial node in the branching tree [17]. After all, the best course of action today is contingent upon the outcome of tomorrow's events.

Backward Induction may seem hard, but it's rather simple to implement. Assuming Brand X will enforce the new policy or back off, that point might be the start of the game. If Brand X decides to enforce, Brand X earns zero. If Brand X backs off, Brand X earns a negative one. Since zero is greater than a negative one, Brand X will enforce if he has the opportunity (see Figure 12)

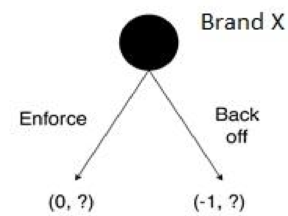

Figure 12. Brand X move with isolation to the employee's payoffs

For the employee's decisions between revolts and acceptance, they know that Brand X will enforce the new policy if they revolt. As such, they can functionally ignore the outcome where Brand X backs off, as they know that Brand X will never play that strategy. Consequently, they can focus their decision on two outcomes (Figure 13).

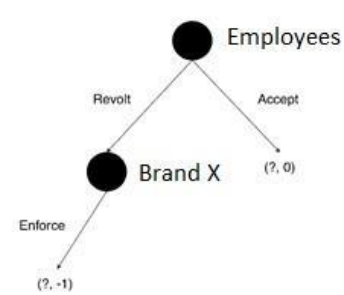

Figure 13. Employees move with isolation to Brand X's payoffs

Essentially, the back-off outcome from the game has been erased. This allows concentrating on the employees' decision between revolting and accepting, knowing that Brand X will follow with enforcement. If they accept, they earn zero. If they revolt, Brand X will enforce, and they earn a negative one. Since zero beats a negative one, the employees will accept.

They knew it could move to the beginning of the game, where Brand X chooses whether to accept the status quo or issue a new policy. It is known that if Brand X issues the policy, employees will accept it, which is the preferred outcome for Brand X based on the assumptions. However, there is still one more option to go with.

If Brand X issues the policy, Brand X earns three. If Brand X doesn't, Brand X earns zero. Since three is greater than zero, Brand X issues the policy, and the game will end with the employees accepting the new policy. This makes the outcome where Brand X issues the policy, and the employees accept it a pure strategy Nash equilibrium (see Figure 14).

In addition, it is important to note that this game does not contain a Nash equilibrium, a weakly dominated strategy, or any other mixed strategy. A policy issued by Brand X and accepted by workers is the ideal answer for each player. Table 2 presents all the previous games presented in one table, summarizing some key factors and features

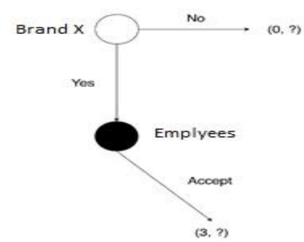

Figure 14. Brand X move with isolation to the employee's payoffs

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Table 2. Summary of key factors for the previous games

Game	Players	Strategies per player	Number of pure strategies Nash equilibrium	Number of mixed strategies Nash equilibrium	Sequential	Perfect Info.	Compete Info.
Application of Prisoner's Dilemma							
Marketing campaign	2	2	1	0	No	No	Yes
Price war	2	2	1	0	No	No	Yes
Application of Deadlock							
Investing in R&D	2	2	1	0	No	No	Yes
Releasing a New Product	2	2	1	0	No	No	Yes
Application of Extensive Form							
New Policy	2	2	1	0	Yes	Yes	Yes

6. Conclusions

Using game theory, this study aimed to conduct an oligopoly market analysis in the food and beverage sector. Data from two food industry's leading and competing brands, X and Y, were collected for analysis. Five social interaction-related decisions were the focus of this study: marketing campaigns, price war, investment in R&D, the introduction of a new product, and a new policy. The designed games were based on the Prisoner's Dilemma, Deadlock, and Extensive-Form game models.

Results of the analysis show that, in a Prisoner Dilemma-style Marketing Campaign game, each player has a single dominating strategy: engage. Pure strategy Nash equilibrium is <engage, engage> in this game and is unique. Each participant in the Prisoner's Dilemma-style Price War game has a single, unwavering goal: to decrease the price. Therefore, finding an approach to reduce Nash equilibrium is a must to win. Investing in R&D is a pure Nash equilibrium in a Deadlock game because each player has a dominating strategy: keep investing. To achieve a pure Nash equilibrium in the game of Releasing a New Product, which also follows a Deadlock strategy, each player must choose a dominating strategy, which is to keep introducing new products. New Policy does not follow a specific game strategy for the final game and is portrayed as a tree strategy for the game. Assuming the policy is issued by Brand X and is accepted by the workers, the game is in pure Nash equilibrium.

Implications of this study include assisting decision-makers in the food and beverage industry in developing reactive and proactive strategies for competitor actions and maintaining competitive advantage. Conducting such oligopoly market analysis of other competing companies in the same industry or in other industries, using other game theory models or other approaches, is a future research direction.

References

[1] **Myerson, R. B.** (1997). *Game theory: analysis of conflict*. Harvard university press.

[2] **Dereva, M., Rajčániová, M.** (2021). Variation of market power across different food supply chains. *Globalization and its Socio-Economic Consequences*, 92,06004. https://doi.org/10.1051/shsconf/20219206004

[3] **Gazdecki, M., Leszczyński, G., Zieliński, M.** (2021). Food Sector as an Interactive Business World: A Framework for Research on Innovations. *Energies*, 14(11), 3312.

[4] **Lan, H., Wang, X.** (2019). Estimating market power in the Chinese pork-packing industry: a structural approach. *China Agricultural Economic Review*, 12(1), 57-70.

[5] **Dai, J., Wang, X., Yuan, G.** (2020). Market power and allocative efficiency loss: a comparative analysis on China's tobacco and food industries. *Journal of Agribusiness in Developing and Emerging Economies*, 10(3), 327-339.

[6] **Ngo, C. T.** (2021). An industrial organisation model for the Vietnamese food retail market. *Economic Annals*, 66(229), 61-97.

[7] **Axelsson, J.** (2019). Game theory applications in systems-of-systems engineering: A literature review and synthesis. *Procedia Computer Science*, *153*, 154-165.

[8] **Madani, K.** (2010). Game theory and water resources. Journal of Hydrology, 381(3-4), 225-238

[9] **Ullah, A., He, Y., Ayat, M., Huang, W., Jiang, W.** (2022). Game-Theoretic Models for Warranty and Post-Warranty Maintenance with Risk-Averse Service Providers. International Journal of Industrial Engineering: Theory, Applications, and Practice, 28(5).

[10] **Axelsson, J.** (2019). Game theory applications in systems-of-systems engineering: A literature review and synthesis. Procedia Computer Science, 153, 154-165.

[11] **Von Neumann, J.,Morgenstern, O.** (2007). Theory of games and economic behavior (commemorative edition, 60th-Anniversary Edition). Princeton university press.

[12] **Bennett, L. L., Ragland, S. E., & Yolles, P.** (1998). Facilitating international agreements through an interconnected game approach: The case of river basins. In Conflict and cooperation on transboundary water resources (pp. 61-85). Springer, Boston, MA.

[13] **Liu, Z., Luong, N. C., Wang, W., Niyato, D., Wang, P., Liang, Y. C., & Kim, D. I.** (2019). A survey on applications of game theory in Blockchain. arXiv preprint arXiv:1902.10865.

[14] **Choi, T. M., Taleizadeh, A. A., & Yue, X.** (2020). Game theory applications in production research in the sharing and circular economy era.

[15] **Leyton-Brown, K., Shoham, Y.** (2008). Essentials of game theory: A concise multidisciplinary introduction. *Synthesis lectures on artificial intelligence and machine learning*, *2*(1), 1-88.

[16] **Fudenberg, D., Tirole, J.** (1991). Perfect Bayesian equilibrium and sequential equilibrium. *journal of Economic Theory*, *53*(2), 236-260.

[17] **Williams, Paul D.** (2013). Security studies: An introduction. In *Security Studies*. Routledge. pp. 55–56.

[18] **Kenton, W.** (2019). Conflict theory. *Investopedia. Market and Economy*.

[19] **Harsanyi, J. C.** (1967). Games with incomplete information played by "Bayesian" players, I–III Part I. The basic model. *Management Science*, *14*(3), 159-182.

[20] **Nash, J.F.**, 1950. Equilibrium points in n-person games. Proceedings of National Academy of Sciences of the USA 36, 48–49.

[21] **Nash, J.F.,** 1951. Non-cooperative games. The annals of mathematics, Second series, 54(2), 286-295.

[22] **Stirling, W. C., Goodrich, M. A., & Packard, D. J**. (2002). Satisficing equilibria: a non-classical theory of games and decisions. Autonomous Agents and Multi-Agent Systems, 5(3), 305-328.

تحليل سوق إحتكار القلة في قطاع الأغذية والمشروبات باستخدام نظرية الألعاب

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مستخلص. تعتبر شركات إنتاج الأغذية والمشروبات مكان عمل اجتماعيًا بطبيعتها. تعمل في بيئة سوق احتكار القلة مع منافسيها. تؤدي المصالح المتعارضة للمنافسين إلى إحداث مواقف لعب تتأثر بها العديد من القرارات التجارية. يهدف هذا البحث إلى إجراء تحليل لسوق احتكار القلة في قطاع الأغذية والمشروبات باستخدام نظرية الألعاب. تم جمع البيانات من اثنين من العلامات التجارية الرئيسية المنافسة في الصناعة للتحليل. كانت خمس قرارات متعلقة بالتفاعل الاجتماعي محور هذه الدراسة: حملات التسويق، حرب الأسعار، الاستثمار في البحث والتطوير، إطلاق منتج جديد، وسياسة جديدة. تم تصميم الألعاب على أساس نماذج لعبة السجين الأخلاقي والتعطل والشكل الشامل للألعاب. يتم التطرق إلى الألعاب واللاعبين والاستراتيجيات (الإجراءات) والافتراضات (المكافآت) والتمثيلات والتحليل والنتائج في سلسلة من المراحل لكل واحدة من القرارات الخمس المدروسة. تتضمن نتائج هذه الدراسة مساعدة صناع القرار في قطاع الأغذية والمشروبات في وضع استراتيجيات رد فعلية واستراتيجيات استباقية لتحركات المنافسين والحفاظ على الميزة التنافسية.

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