GAME THEORY REPORT SUBMISSION

[FINANCE & ECONOMICS CLUB,IITG]

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Report on Cournot Duopoly Game Theory Analysis for IIT Placement Scenario

1. Introduction

- **Objective**: To analyze the strategic decisions of IIT students during placement season using the Cournot duopoly model. The scenario focuses on whether to concentrate on preparing for a single dream company or multiple companies, considering the effort and competition levels.
- **Relevance**: This model reflects real-world situations where individuals must decide how to allocate limited resources (effort and time) to maximize their outcomes in a competitive environment.

Theory About the Cournot Economic Model

2.Cournot Duopoly Model

- **Definition**: The Cournot duopoly model is a framework in economics where two firms (or players) compete on the quantity of output produced, assuming each one's output decision affects the market.
- **Application to Placement Scenario**: In our context, students are the 'firms', and their 'output' is the level of effort they invest in preparing for placements. Each student's decision on how much effort to put into either focusing on a dream company or multiple companies affects their own and the other's chances of success.

3. Key Concepts

- **Nash Equilibrium**: A situation where neither student can improve their payoff by unilaterally changing their strategy, given the strategy of the other student.
- **Strategic Interaction**: Each student's effort level decision impacts not only their chances of success but also the competitive landscape for the other student.

Detailed Explanation of the Cournot Duopoly Game (IIT Placement Scenario)

4. Rules of the Game

4.1 Players: Two IIT students (A and B).

- **Choices**:
    1. **Focus**: Decide whether to concentrate on a single dream company or multiple companies.
    2. **Effort Levels**: Choose a level of effort—Low, Moderate, or High.
- **Outcomes**: The payoff for each student depends on their choice of focus and effort level, the competition level for the dream company, and the number of companies applied to.

4.2 Mathematics Involved

- Probability of Selection:
    - For the **Dream Company**: $P_d = \frac{E}{E+C}$, where E is the effort level and C is the competition level.
    - For **Multiple Companies**: $P_m = \frac{E}{N}$, where E is the distributed effort and N is the number of companies.
- Payoff Functions:
    - **Dream Company Only**: $\pi_{\text{dream}} = P_d \times V_{\text{dream}} - C(E)$, where V_{dream} is the reward from the dream company, and $C(E) = kE^2$ is the cost function with effort E.
    - **Multiple Companies**: $\pi_{\text{multiple}} = \sum_{i=1}^{N} P_{m_i} \times V_{m_i} - C(E)$, where V_{m_i} is the reward from each company, and the cost is the same $C(E)$.
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5. Assumptions While Analyzing the Data

- **Rationality**: Both students aim to maximize their expected payoffs.
- **Effort Distribution**: Effort is evenly distributed when applying to multiple companies.
- **Fixed Competition**: Competition level CCC for the dream company is fixed and known to both students.
- **No Collaboration**: Each student works independently with no shared preparation or information.
- **Symmetry**: Both students have similar capabilities, access to resources, and risk appetites.

6. Link to the Spreadsheet with Data

- [https://drive.google.com/file/d/1CghzeqWzUGQjqVfx_EPWeRBd1i0f4UfA/view?usp=sharing]
- **Data Description**: The spreadsheet includes various scenarios with different effort levels, competition levels, number of companies, and the resulting payoffs for each strategy.

7. Code Link

- [https://drive.google.com/file/d/1nJNFJBNf2NaG_xvLbBJifvr82OMXKydd/view?usp=sharing]
- **Code Description**: The code simulates the Cournot duopoly scenario, calculating payoffs for each combination of strategies and visualizing potential outcomes.

8. Data Overview

The dataset includes information for 10 students, covering:

- Effort Level allocated to the Dream Company
- Effort Level allocated to Multiple Companies
- Probability of Selection for the Dream Company
- Probability of Selection for Multiple Companies
- Payoff for the Dream Company
- Payoff for Multiple Companies
- Optimal Strategy chosen

9. Analysis of Optimal Strategy

9.1 Distribution of Optimal Strategies

- **Summary of Optimal Choices:**
    - The optimal strategy is determined by comparing the payoffs for the Dream Company and Multiple Companies. The strategy with the higher payoff is deemed optimal.
- **Findings:**
    - The majority of students selected the "Dream Company" strategy, reflecting a preference for focusing efforts on a single high-value target. Specifically:
        - **Number of Students Choosing "Dream Company":** 8
        - **Number of Students Choosing "Multiple Companies":** 2

9.2 Payoff Analysis

- **Average Payoff Comparison:**
    - The average payoff for students choosing the Dream Company strategy is compared with the average payoff for those choosing Multiple Companies.
- **Results:**
    - **Average Payoff (Dream Company):** 38.5
    - **Average Payoff (Multiple Companies):** 9.85
    - These results indicate that the Dream Company strategy generally provides a higher payoff, validating the benefit of concentrating efforts on a single high-value target.

9.3 Effort Allocation and Its Impact

- **Effort Levels and Payoffs:**
    - The relationship between effort levels and payoffs was analyzed to understand the impact of effort distribution on outcomes.
- **Observations:**
    - Students who allocated more effort towards the Dream Company achieved higher payoffs compared to those who allocated more effort to Multiple Companies. This reinforces the advantage of focusing on the strategy with higher payoff potential.

10. Insights and Conclusions

10.1 Effectiveness of Optimal Strategy

- The data confirms that following the optimal strategy—based on maximizing payoff—leads to better outcomes. The observed trend supports that focusing efforts on the Dream Company results in higher average payoffs.

10.2 Impact of Non-Optimal Play

- Students who did not adhere to the optimal strategy often experienced lower payoffs. This highlights the importance of strategic decision-making based on calculated payoffs rather than personal preferences or other non-quantitative factors.

10.3 General Observations

- The predominant choice of the Dream Company strategy among students suggests a common preference for targeting high-value opportunities. The data underscores the benefits of optimizing effort allocation in strategic decisions.

11. Recommendations

- **For Students:**
    - It is advisable to allocate efforts based on the strategy that offers the highest payoff potential. Accurate assessment of probabilities and associated costs is crucial for maximizing outcomes.
- **For Future Research:**
    - Further investigations could explore additional variables such as risk tolerance and personal preferences to gain a more comprehensive understanding of decision-making in strategic scenarios.

Game2 : Modified Bertrand Competition with Variable Marginal Costs and Demand Curves

1. **Objective:** The goal is to simulate a Bertrand competition game where two firms, Lohit Canteen and Disang Canteen, set their prices in a competitive market. The game aims to find the equilibrium prices and profits under varying conditions, including product differentiation and variable marginal costs.

2. **Rules:**

1. **Firms:**
    - Two firms: Lohit Canteen and Disang Canteen.
    - Each firm competes by setting a price for their product.
2. **Price Setting:**
    - Both firms select initial prices within a specified range.
    - Prices are adjusted iteratively to maximize profits based on the competitor's price.
3. **Market Demand:**
    - Consumers prefer products based on price, with the assumption that a lower price will attract more customers.
    - The demand curve and consumer preferences are affected by price differences and product differentiation.
4. **Marginal Costs:**
    - Each firm has a marginal cost associated with producing their product.
    - Marginal costs are randomly assigned for each experiment to introduce variability.
5. **Profit Calculation:**
    - Profit for each firm is calculated as: Profit=(Price−Marginal Cost)×Quantity\text{Profit} = (\text{Price} - \text{Marginal Cost}) \times \text{Quantity}Profit=(Price−Marginal Cost)×Quantity
    - Quantity is assumed constant in this model.
6. **Price Adjustment Mechanism:**
    - Firms adjust their prices iteratively to respond to the competitor's price.
    - Each firm aims to set a price that maximizes its profit, given the competitor's price.
7. **Termination:**

- The price adjustment process continues until the changes in prices are minimal (below a threshold), indicating that equilibrium is reached.

Mathematics Involved:

1. **Profit Calculation:**
   - For a firm i with price p_i and marginal cost c_i: $\text{Profit}_i = (p_i - c_i) \times \text{Quantity}$
   - Quantity is assumed to be constant (e.g., 100 units) for simplicity.
2. **Best Response Function:**
   - Each firm's best response is determined by maximizing its profit given the competitor's price.
   - The function to determine the best price p_i^* for firm i given the competitor's price p_{-i} is: $p_i^* = \arg\max_{p_i} [(p_i - c_i) \times \text{Quantity subject to } p_i < p_{-i} + \text{Margin}]$

3. **Equilibrium Determination:**
   - Prices converge to an equilibrium when both firms' prices are stable and no further adjustments are beneficial.
   - The iterative process continues until the changes in prices are below a specified threshold.

3. Results Summary

Here is a summary of the experiment results:

Experiment	Initial Price Lohit	Initial Price Disang	Final Price Lohit	Final Price Disang	Profit Lohit	Profit Disang
1	38.25	27.22	50.00	50.00	4202.29	3876.09
2	17.79	37.24	50.00	50.00	3917.77	4308.47
3	31.77	18.13	50.00	50.00	3798.65	4034.62
4	25.40	47.15	50.00	50.00	3436.12	3892.35
5	35.37	20.29	50.00	50.00	3933.44	3812.38
6	38.13	29.87	50.00	50.00	3166.30	3914.00
7	27.46	25.74	50.00	50.00	3434.58	4383.82
8	24.68	30.62	50.00	50.00	3695.01	3499.29
9	41.55	15.58	50.00	50.00	4138.86	3961.93
10	23.01	23.78	50.00	50.00	3607.45	3488.38

4. Assumptions While Analyzing the Data:

1. **Product Differentiation:**
   - Products are differentiated, leading to imperfect substitution and allowing both firms to potentially maintain positive profits.
2. **Constant Quantity:**
   - The quantity of products sold is assumed to be constant, simplifying the profit calculation.
3. **Variable Marginal Costs:**
   - Marginal costs are randomly assigned for each experiment, reflecting variability in production costs.
4. **Demand Response:**
   - Demand is responsive to price changes, with consumers preferring lower prices but still considering product differentiation.
5. **Price Rigidity:**
   - Prices are allowed to be set within a range but are not adjusted frequently beyond realistic market constraints.
6. **Market Conditions:**
   - The model assumes a competitive market where each firm reacts to the pricing strategy of the other, leading to a dynamic pricing environment.
7. **Equilibrium Concept:**
   - The game aims to find a stable price equilibrium where firms' profits are maximized given the competitor's pricing strategy.

5. Outcome Analysis:

- **Data Analysis:**
    - Analyze the final prices and profits for each firm to determine the equilibrium prices and profitability.
    - Review the variability in results due to different marginal costs and initial pricing strategies.
- **Best Strategy:**
    - If all firms play optimally, equilibrium prices will reflect the marginal costs and demand conditions.
    - If firms do not play optimally, deviations from equilibrium can lead to different pricing and profit outcomes.

6. Appendix

- **Link to Spreadsheet with Data:** [https://drive.google.com/file/d/1kQZEwBj4Um7UUOxqP_77d4UHPis1ixlN/view?usp=sharing]
- **Code Link:** [https://drive.google.com/file/d/1LTREuIL6RCwfgb_czzUDicerF_6NYeRn/view?usp=sharing]

4. Analysis

1. **Final Prices:**
    - In all experiments, the final prices for both Lohit Canteen and Disang Canteen converged to 50.00. This indicates that both firms settled on the same price in each experiment, reflecting the competitive nature of Bertrand competition where firms undercut each other until prices equalize.
2. **Profits:**
    - **Lohit Canteen:**
        - Profits range from $3166.30 to $4202.29.
    - **Disang Canteen:**
        - Profits range from $3488.38 to $4383.82.
    - Despite the price being constant, profits vary due to different initial price settings and varying marginal costs, which affect the final equilibrium price and the firms' costs.
3. **Impact of Initial Prices:**
    - Initial prices have a limited impact on the final equilibrium price in this simulation. Both firms eventually reached the same price point, highlighting the competitive pressure to lower prices.
4. **Variable Marginal Costs:**
    - The variability in marginal costs contributes to differences in final profits, although prices are equal. This reflects the realistic scenario where firms with different cost structures can still end up with similar prices but differing profit levels.

6. Conclusions

1. **Price Convergence:**
    - Prices converged to 50.00 in all experiments, demonstrating the theoretical outcome of Bertrand's competition where firms eventually charge the same price.
2. **Profit Variation:**
    - Despite identical final prices, profit levels varied due to differing marginal costs, illustrating the importance of cost structures in determining firm profitability.
3. **Strategy Implications:**
    - Firms should consider their marginal costs when setting prices. In a competitive market, achieving a competitive advantage may require focusing on cost efficiency rather than just pricing strategies.
4. **Model Limitations:**
    - The simplified model assumes constant demand and product differentiation, which may not capture all real-world complexities.