STRATEGIC ANALYSIS

A Brief Study of Prisoner's Dilemma

Introduction

Game theory studies the interactive choices, where the outcomes for each player is determined by the actions of all others. This means that if a player is playing such a game, he/she/they must consider the preferences of all other players while deciding on a strategy or course of action and not just his/her/their own. [Robert Gibbons, 1992]
Nash equilibrium is a state during which the strategy chosen by one player gives the highest payoff, given the other player's strategy and vice versa.

Prisoner's Dilemma
The name arises from a situation involving two crime suspects who were given incentives to confess against one another. There are multiple situations where participants are given incentives similar to the suspects, hence, it is a relevant example to study the fairness of human behaviour. [Martin J. Osborne, 2000]
Prisoner's dilemma is a situation where the players have to decide between cooperating and competing with each other, which correlate to the following payoffs:
For a single shot of the game, the players get payoff equal to 1 if both compete and a payoff of 3 if both cooperate. However, if one competes and the other cooperates, the former gets a payoff of 5 and the latter gets -1. The goal is to maximize your payoff and not just to be better than other players.

Player 2

Player 1		Compete	Cooperate
	Compete	1/1	5/-1
	Cooperate	-1/5	3/3

Table 1

Now let's try to find out the nash equilibrium. We can see that if player 1 chooses to cooperate, best strategy for player 2 will be to compete as it'll give the maximum payoff, i.e. 5. Whereas if player 1 chooses to compete, best strategy for player 2 will still be to compete. Hence, the dominant strategy for player 2 is to compete. On the other hand, when player 2 chooses to compete, best response for player 1 will be to compete to get the better payoff. Hence, the dominant strategy for player 1 would also be to compete. In conclusion, the nash equilibrium will be found where both of the players compete and gain a payoff of 1 each. It is important to note that the optimal decision would be for both the players to cooperate because they'll both gain a payoff of 3 each.

Data Analysis

The data provided to us as excel sheet consists of 56 players who played a game with two players each for 5 rounds per game. However, the data given to us is disorganised. Using MS-Excel, the data is manually put together in a more organised way to facilitate analysis.

Game	Player A	Round 5	Round 4	Round 3	Round 2	Round 1	Sum
1	Player 47	1	1	1	0	0	3
2	Player 51	1	1	1	1	1	5
3	Player 11	1	1	1	1	1	5
4	Player 37	1	1	1	1	1	5
5	Player 10	1	1	1	1	1	5
6	Player 19	1	1	1	1	1	5
7	Player 50	0	0	1	1	1	3
8	Player 27	1	1	0	0	0	2
9	Player 56	1	0	1	0	1	3
10	Player 21	1	1	1	1	0	4
11	Player 17	1	1	0	1	1	4
12	Player 36	1	1	0	0	0	2
13	Player 38	0	0	0	0	0	0
14	Player 45	1	1	0	1	1	4
15	Player 43	0	1	1	1	1	4
16	Player 53	1	1	1	0	1	4
17	Player 40	1	0	1	1	1	4
18	Player 31	1	0	1	0	1	3
19	Player 16	1	1	0	0	1	3
20	Player 15	1	1	1	1	1	5
21	Player 25	1	1	1	1	1	5
22	Player 1	1	1	0	0	1	3
23	Player 46	1	1	1	1	1	5
24	Player 4	0	1	0	1	1	3
25	Player 2	1	1	0	0	0	2
26	Player 24	1	1	1	1	1	5
27	Player 42	1	1	1	1	1	5
28	Player 49	1	1	1	0	1	4
29	Player 47	1	1	0	0	0	2
30	Player 14	1	1	1	1	1	5
31	Player 51	1	1	1	1	1	5
32	Player 33	1	1	1	1	0	4
33	Player 11	1	1	1	1	1	5
34	Player 13	1	1	1	1	1	5
35	Player 37	1	1	1	1	1	5
36	Player 28	1	1	0	1	1	4
37	Player 10	1	1	0	1	1	4
38	Player 20	1	1	1	1	1	5
39	Player 19	1	1	1	1	1	5
40	Player 30	1	1	1	1	1	5
41	Player 50	0	0	1	1	1	3
42	Player 55	0	0	1	1	0	2
43	Player 27	1	1	1	1	1	5
44	Player 9	1	1	1	1	1	5
45	Player 56	1	1	1	1	1	5
46	Player 48	1	1	1	1	1	5
47	Player 21	1	1	1	0	0	3
48	Player 34	1	1	1	1	1	5
49	Player 17	1	1	0	1	1	4
50	Player 39	1	0	1	0	1	3
51	Player 36	1	1	0	0	0	2
52	Player 35	1	1	1	1	1	5
53	Player 38	0	0	0	0	0	0
54	Player 3	1	1	0	1	0	3
55	Player 45	1	1	0	1	1	4
56	Player 44	1	0	1	0	0	2
		49				No. of 5s=	24

Figure 1

Cpt=1
Coop=0

Game	Player B	Round 5	Round 4	Round 3	Round 2	Round 1	Sum
1	Player 14	1	1	1	1	1	5
2	Player 33	1	1	1	1	1	5
3	Player 13	1	1	1	1	1	5
4	Player 28	1	1	1	1	1	5
5	Player 20	1	1	1	1	1	5
6	Player 30	1	1	1	1	1	5
7	Player 55	1	1	1	0	1	4
8	Player 9	1	1	1	1	1	5
9	Player 48	1	1	1	1	1	5
10	Player 34	1	1	1	1	1	5
11	Player 39	1	1	1	1	0	4
12	Player 35	1	1	1	0	1	4
13	Player 3	0	0	0	0	0	0
14	Player 44	1	1	1	1	0	4
15	Player 54	1	1	1	1	0	4
16	Player 12	1	0	1	1	1	4
17	Player 7	1	1	1	1	1	5
18	Player 41	0	1	1	1	0	3
19	Player 18	1	1	1	1	1	5
20	Player 23	1	1	1	1	0	4
21	Player 5	1	1	1	1	0	4
22	Player 29	1	0	1	0	0	2
23	Player 26	1	1	1	1	1	5
24	Player 6	1	1	1	1	0	4
25	Player 22	1	0	0	0	0	1
26	Player 8	1	1	1	1	1	5
27	Player 52	1	1	1	0	1	4
28	Player 32	1	1	1	1	1	5
29	Player 43	1	1	1	0	1	4
30	Player 54	1	1	1	1	0	4
31	Player 53	1	1	1	1	1	5
32	Player 12	0	1	1	0	1	3
33	Player 40	1	1	1	1	0	4
34	Player 7	1	1	1	1	1	5
35	Player 31	1	1	1	1	0	4
36	Player 41	1	1	1	1	0	4
37	Player 16	1	0	0	0	1	2
38	Player 18	1	1	1	1	1	5
39	Player 15	1	1	0	1	0	3
40	Player 23	1	1	1	1	0	4
41	Player 25	1	1	1	1	1	5
42	Player 5	1	1	1	0	0	3
43	Player 1	1	1	1	1	1	5
44	Player 29	0	0	1	0	0	1
45	Player 46	1	1	1	1	1	5
46	Player 26	1	1	1	1	1	5
47	Player 4	1	1	0	1	0	3
48	Player 6	1	1	1	1	0	4
49	Player 2	1	1	1	1	0	4
50	Player 22	1	1	1	1	0	4
51	Player 24	1	1	1	1	1	5
52	Player 8	1	1	1	1	1	5
53	Player 42	1	0	0	0	0	1
54	Player 52	1	0	1	0	1	3
55	Player 49	0	1	1	0	1	3
56	Player 32	0	1	0	1	1	3
							23

Figure 2

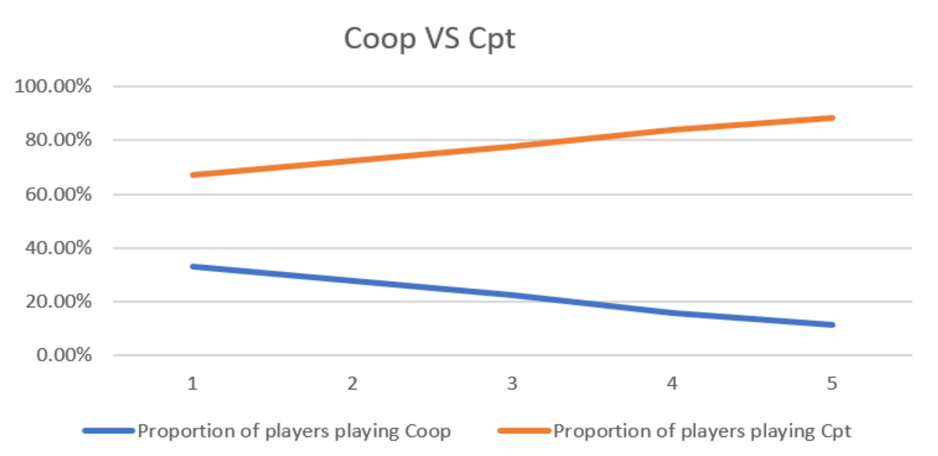
Figures 1 and 2 show the cleaned and organised data. In a game, two players A and B are playing against each other. The data is divided into two datasets-- Player A's and Player B's of each game. This is done to study the behaviour of individual players in each game. The values of 'Cpt' and 'Coop' are replaced by 1 and 0 respectively and the red highlighted cells are the players who only chose to compete in every round.

The total number of players who chose to compete in every round is 24 and 23 in each dataset of Player A and Player B, respectively.

According to the given data, the following can be determined:

Round	1	2	3	4	5
Proportion of players playing Coop	33.04%	27.68%	22.32%	16.07%	11.61%

Round	1	2	3	4	5
Proportion of players playing Cpt	66.96%	72.32%	77.68%	83.93%	88.39%



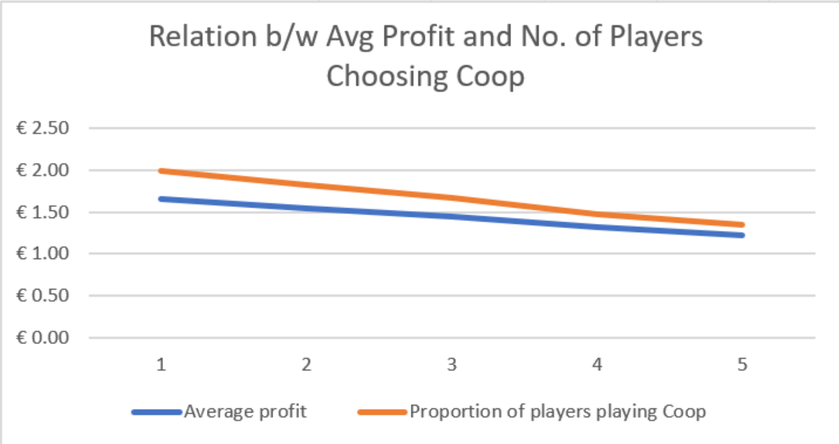
Graph 1

This line graph shows the downward trend of the proportion of players choosing to cooperate versus the upward trend of the proportion of players choosing to compete through consecutive rounds. The curve of 'cooperate' depicts how number of players who chose to cooperate declined through rounds 1 to 5. During round 1, where 33.04% players chose to cooperate declined drastically to 11.61% in round 5. On the other hand, curve of 'compete' show how number of players who chose to compete increased from 66.96% in round 1 to 88.39% in round 5. We can also see more than half of the players chose to compete right in the first round.

As discussed above, when both players choose to cooperate, the optimal decision is achieved where both the players get the highest payoff. Hence, we can see from the graphs that in initial rounds, number of players cooperating is higher because they assume that their opponent would also choose to cooperate as that is socially fair for both players and also gives a good payoff. However, many players assumed that the opponent would choose to cooperate and, for selfish reasons to gain more profit, they choose to defect. In such a scenario the player will gain a payoff of 5 and the opponent would get -1. It's interesting to note that in this same situation, when the same strategy is followed by the opponent, i.e. to compete assuming the other player will cooperate, both will end up competing and achieving the nash equilibrium where the payoff for both the players is 1 each.

Round	1	2	3	4	5
Average profit	€ 1.66	€ 1.55	€ 1.45	€ 1.32	€ 1.23

Round	1	2	3	4	5
Proportion of players playing Coop	33.04%	27.68%	22.32%	16.07%	11.61%



Graph 2

This graph shows a downward trend in the average profit gained through consecutive rounds of the game. The curve of 'average profit' shows the similar trend as that of 'cooperate'. This means that when the number of players choosing to cooperate declines, the average profit also declines. This happens because the highest payoff for one or both players can be achieved when either one or both players cooperate, respectively. Hence, when the players who choose to cooperate decreases, the chances of one or both players gaining higher payoffs also declines. Therefore, the average profit declines with the decline in the number of players choosing to cooperate. We can also see that towards the last few rounds of most of the games, both players opt to compete and hence achieving nash equilibrium.

Conclusion

Looking at the dataset and the analysis above, we can deduce the following:

- Many players played the same strategy for 2-3 rounds to observe the oppoents strategy and opt a new strategy as a response to the opponent's strategy (example: games 1 & 7). This is also called the probing strategy.
- Highlighted cells in figures 1&2 show how most of the players choose to only compete. Even though the maximum payoff can be achieved by cooperating and taking slight risk, humans choose to minimize the risk of loss instead and play safe.
- Socially optimal decision is when both the players cooperate and gain a better payoff, however, the players are tempted to defect since that will give them the highest payoff if the opponent cooperates and gain a decent payoff even if the opponent competes.
- The participants have selfish motives rather than altruistic motives.
- Majority of players choose to compete during rounds 4&5 and hence majority of the games end up achieving nash equilibrium.
- In contrast to our findings, in a real life situation of prisoner's dilemma, the nash equilibrium can also be achieved when both players cooperate.

Real World Applications

- **OPEC** was a group of oil producing countries that form a cartel to control oil prices. In OPEC meetings, the countries make a choice to cheat or collude with another competitor by stating the quantity of oil they'll produce. If OPEC is better off when each of the countries is worse off than they could be with the alternative option, the prisoner's dilemma situation arises. For instance, if Saudi Arabia cheats and sells more oil than they stated, they can make much more money and gain a larger market share. However, this would result in lower price of oil and lower revenues and OPEC will be worse off. On the other hand, if Saudi Arabia cooperated with the rivals and reduced its oil production, the price of petroleum would increase and as a result, so would everyone else's revenues, improving the group's overall utility.

- **Tinder**, the dating app, has two strategies that people use,

    - Deliberate: right swipe for people you like, left swipe for people you don't like. If you get a match, connect with them.

    - Corrupt: right swipe on all. Decide if you like them and would connect or ignore them only after you get a match.

  This results in Prisoner's Dilemma between two matched parties:
  - If both players play as deliberated, a match will be genuine and should be activated as part of the deliberated play (mutual cooperation).
  - If both players play corrupted, it'll result in a potentially meaningless match. However, since both are aware of their corrupt play, they're not going to put much effort since they're aware that this match is likely pointless (mutual defection).
  - If A plays deliberate and B plays corrupt, Knowing in advance that A likes them will help B make decisions (temptation to defect). A will encounter silence from someone they assumed liked them, which is a bad experience for A, if B does not like them.

  Users choose the corrupt strategy after becoming tired of unactivated matches in which they had invested. This has a snowball effect, producing more inactive matches for other users.

References

1. A Primer in Game Theory by Robert Gibbons, 1992
   https://d1wqtxts1xzle7.cloudfront.net/33690404/A_Primer_in_Game_Theory-_Gibbons-with-cover-page-v2.pdf?Expires=1668880854&Signature=fTHFQAz56LHIFGqyhi7jvq21VD2~6nTSTSL1fBCiK~kpJRVkWo3T~Fzm3G33449ZNOhvOiAcO1RGBuT7ZLwLTU0KUY~0~g9t79lR8qyzsS-bpfUQPMMhaZKvnk3sexnFCXB4gIWcMtVQMoAGLvVu3xL9V33UH6X7L84yQq~E4JkjJfKqMYb3xqBn9ImU9zRo0ZMmWKUfRcU3aZfH0X3l0Awf0QeH5HVXG~lH1ilTZg2ABJO~Prz87mW2VXWtQW7WCHT3jU6og30U1130~ihI0exRV6RfDf9pPOKS0~-7vynRBJTcS1Qb-mMKhkS114Hf6EJUk3ZSBhMiHITI~3Gwqg__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

2. An Introduction to Game Theory by Martin J. Osborne
   https://d1wqtxts1xzle7.cloudfront.net/32188651/An_Introduction_to_Game_Theory-with-cover-page-v2.pdf?Expires=1668879513&Signature=BfcWh0yt3fasWJ8ELiJvbcwDyb0zNVSMlIF0BkGHZLRQ7HUxELPLL1Z0~LwqIle4P~MHOtslEi57o81jgINWlr~2Mt8TC30h2xjHLIBbxunW~aa6-J~GAJF-s72DOHANN37wEp4SsIOGSFujEv1JJeGTeYOR~K309X0NClFybr-kosXz3jCc~wxn80wXTbsyR0ivzf7EPw7Q0ojJz~60s0raw3tIXqpVIJhJkLnYgMZdAyrHfLcJWxXYJ921Wj~wxkJKNDY~Ad5g4JLdGQWqvEC03xqAtr~s5WVfwLHvB4Lu~7o8-uMJuDlcS6r1RNYvMOnbyrmKF2ov8f~Ao4jP7Q__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

3. The Dynamics of Norms, edited by Cristina Bicchieri; Richard Jeffrey; Brian Skyrms
   https://books.google.co.uk/books?hl=en&lr=&id=ddc9AAAAIAAJ&oi=fnd&pg=PA1&dq=prisoner%27s+dilemma+research+paper&ots=0ygxOwwFV3&sig=8AV93YO-4sI6dBqPHkXJWvqrSyo#v=onepage&q=prisoner's%20dilemma%20research%20paper&f=false

4. Bland, AR, Roiser, JP, Mehta, MA, Schei, T, Sahakian, BJ, Robbins, TW & Elliott, R 2017, 'Cooperative behavior in the ultimatum game and Prisoner's dilemma depends on players' contributions', Frontiers in Psychology, vol. 8, no. JUN, 1017.
   https://doi.org/10.3389/fpsyg.2017.01017

5. How Game Theory Strategy Improves Decision Making by Elvis Picardo
   https://www.investopedia.com/articles/investing/111113/advanced-game-theory-strategies-decisionmaking.asp