Strategic Analysis of Evolutionary Dynamics during Pandemic

Eren Arkangil

I. Introduction

The concept of the iterated prisoner's dilemma (IPD) created for the software by Robert Axelrod when he firstly mentioned about this idea in his book The Evolution of Coorperation (1984). He organized a tournament for prisoners dilemma with N iteration in which opponents have to update their strategy in each step and have memory of their previous encounters.

The result shows greedy strategies tended to give poor outcomes in the long run while coorperative strategies did better which states self interest does not mean selfishness. [adam Smith]. Axelrod enquired the mechanism for the evolution of coorperation from initially purely selfish strategies by natural selection. Whereas the best strategy fort he one time prisoners dilemma game is defection and it is true under all possible composition of opponents. However, the optimal strategy in the iterated prisoenrs dilemma game depends on the strategies of likely opponents, and how they will act against defect or cooperate strategies.

The behaviour of the agents may vary due to sociologic history of the countries. Consider a scenario where the number of defectors overweight in a country, In such a population, the optimal strategy for an individual is to defect every time. But note that overall points that the country gets will be lower that cooperative countries. I modified the prisoners dilemma game into a social contract game under an epidemic spread such as Covid-19. The cooperation strategy is contributing to social distancing and defection is applying herd immunity or not contributing to social distancing so to say.

II. Problem Statement

This project seeks the answer what is the best strategy to prevent pandemic and importance of the human decision for it. It also proposes an analysis of strategies such as social distancing or herd immunity during pandemic in different perspectives.

The world has been suffering from coronavirus spread for the last 2 months, what could be the optimal strategy to deal with it? Could it be the herd immunity strategy that has been declared by UK or social distancing as Italy has been applying for the last 2 weeks. There are also some other countries like Turkey who has been applying mixed strategies. These countries does not put travel bans inside of country but make socializing harder. Depends on the country, the mixed strategy can be close to herd immunity or social distancing.

The project is inspired by public good games from game theory. In the public good games, each player can donate $1 to the pool or keep their money in their pocket. Total contribution by players is multiplied by 1.5 each turn and distributed half and half to the players.

In the payoff matrix its clearly seen if both corporate they get maximum benefit however if there is coordination problem and they go

with different strategies its again seen making a contribution is bad for the player. Therefore, their dominant strategy is not to contribute here. It is called ''free-rider" problem here, which means ''market failure" in economics.

		Player Y	
		A	B
Player X	A	$(1.5, 1.5)$	$(0.75, 1.75)$
	B	$(1.75, 0.75)$	$(1, 1)$

Lets return back our Coronavirus spread example. Consider the matrix below to visualize for easy interpretation. Each number multiplied by 4.

		Player Y	
		A	B
Player X	A	$(6, 6)$	$(3, 7)$
	B	$(7, 3)$	$(4, 4)$

In our model when you contribute to social distancing while others not you get 3 points because you isolated yourself in quarantine while others did not care much and spread becomes bigger which means you have to spend more time in quarantine. If you are successful to cheat other player get 7 points. The city is a great place when it is not crowded and you are the only one around who can enjoy market shopping without big lines and empty roads for a ''free ride". Both player get 6 In the corporation points because it ends spread in a shorter time, still it is less than 7 because individuals are more advantageous when the city is not crowded and 4 is the herd immunity strategy, so to say. Life continues in a ''diseases" way for a while.

Agents have two strategies here. First option is contributing social distancing without any government regulation. The second option is ignoring the spread and keep socializing. There is a social contract here, the best payoff you get in the long run is determined by your opponent. Therefore, Individuals of each countries follows a different strategy in this game

Germany is our first case, Germany didn't need for government intervention thanks to common sense of the agents. The spread and death rate is considerably low in the Europe.

Let consider Italy as the second case. Italy was the one of the countries which let make the decision for players, the results shows didn't go well. Italy is a nice example for the ''market failure". In addition, China is a good example for the game, when the spread first occurred Chinese government didn't intervene in freedoms of people , but they were obliged to do so when the spread becomes pandemic. The government forced people to stay at home with strict regulations, and they applied it well, the spread rate is cut-off. Germans are open for cooperation and get the huge benefit of it ,thus this project also offers a good sociologic analysis of countries.

III. FORMULATION

A. *Ecological environment*

Ecological Axelrod is a round-robin style tournament where each strategy plays against each other and after each iteration according to points the agents get their population and payoff matrix is updated. The points that agents get in each game interpreted as measure of fitness. The strategies which have get relatively higher payoffs will increase their ratio in overall population. This type of Axelrod tournament called ''ecological" because it concerned the interaction and differential reproduction success of set of strategies.

The unit payoff for each player in a turn is the sum of the payoffs obtained from playing with all other players, scaled by the size of the opponent's population. Thus, it is expected that Defector eventually took over the population because the tournament has only two agent. We are going to use Moran process

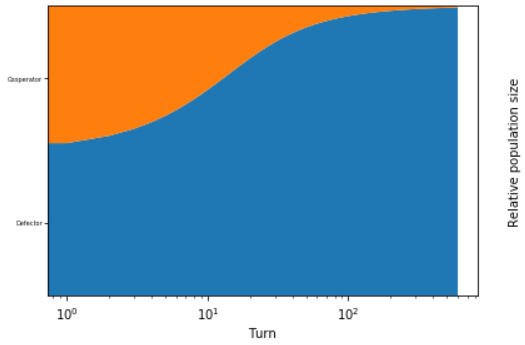

Fig. 1: Ecological Axelrod

to see how cooperation evolves in different environment.

B. Moran Process

Finite populations can also be studied using a model called a Moran Process First step of the moran process is selection for reproduction. Selection for reproduction happens relative to the fitness. In other words, Individuals who are doing well based on the frequency of the types of individuals in the population are more likely to get picked. In the second step the death process is applied to the population randomly. The main idea behind moran process apply these two steps consecutively until the population consist only one type of agent. How we define the reproduction probabilities comes from the payoff matrix.

IV. SIMULATION AND EXPERIMENTAL RESULTS

We have set of countries with different population dynamics as components. Since the ratio of the cooperator and defector differs for each country, the best strategies and final results of the moran process will be different for each country. The ratio is given according to the precautions the countires applied. For example the rate of is defectors in Italy is than in Germany. Each country is appointed number of players. This players represents proportion of stratagies in the country which are followed by their citizens. After the moran process is done, each country will have a winner strategy. Then the total score of the countries will be compared. The recent data from newspapers shows importance of social distancing during the spread. Additionally, it shows social distancing is a better way to reduce death rate. I am going to simulate different scenarios. I will use moran process and axelrod games in order to analyse situtations.

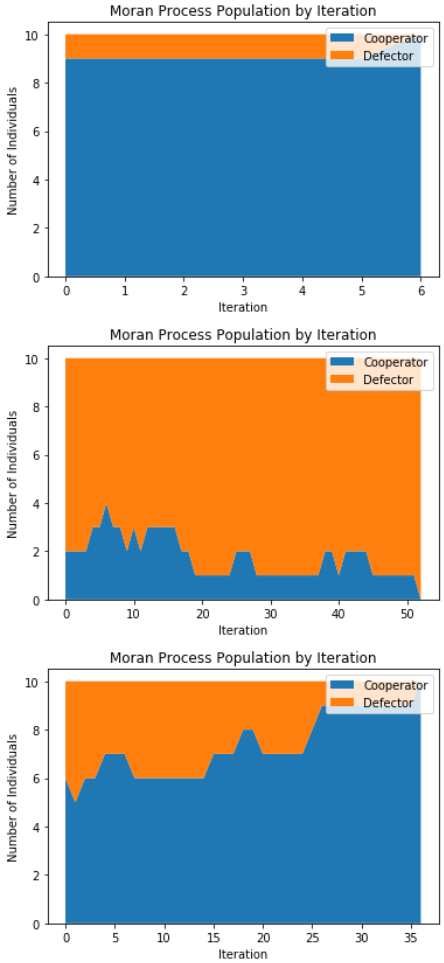

Fig. 2: Analysis of Germany, Italy and Turkey cases

V. Conclusion

This paper proposed an analysis of cooperative behaviour and its outputs with respect to game theory during pandemic. The temptation of defecting others costs the agents longer time to get rid of pandemic. This behaviour applies to cases that cooperative strategy wins at the end of the tournament. In some cases where defector number outweights substantially, the ideal strategy become to defect, but if there is a chance to cooperate, it is a better strategy with respect of price of anarchy on a larger scale which is having the pandemic longer period of time. the price of anarchy is having pandemic longer period of time.

References

[1] Ahn, Y., Ahnert, S., Bagrow, J. et al. *Flavor network and the principles of food pairing.* . Sci Rep 1, 196 (2011).

[2] Yummly cuisine prediction dataset
`https://www.kaggle.com/kaggle/recipe-ingredients-dataset/home`

[3] Page, Y. Brin, S. *The anatomy of a large-scale hypertextual Web search engine*.
Computer Networks and ISDN Systems, Volume 30, Issues 1–7, April 1998, Pages 107-117 (1998).