Group 2
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CS711 Project Proposal - Confinement Economy Trade-off during Pandemics

Introduction to the problem:

We attempt to simulate the spread of a pandemic in terms of loss of life and the effect on the economy based on the choices of individuals and the government. The existing SIR model[1] uses differential equations over the population counts of the susceptible, infected and recovered/deceased to track the spread of a pandemic. This doesn't account for individuals confining themselves at home or the government imposing a lockdown.

In more recent literature[2,3], we see the lifetime utilities of individuals and governmental constraints being computed and optimized globally based on dynamic variables representing their choices. In contrast to this, we attempt to model the same via repeated bayesian games, where each individual maximizes their own utility at each iteration. We believe this is more intuitive as most people lack the insight to optimize their lifetime expectations.

Objectives:

We intend to do the following sequentially -

1. ***Simulate one person in an environment*:** Some existing pandemic models, say the SIR, will be used to simulate the environment. Our individual will be "playing" a one person repeated bayesian game, where his type may be "Healthy"/"Infected", and will choose from the strategies "Work"/"Home". The individual would have incomplete information of his own type (to handle asymptomatic individuals, as done in Jones et. al.[3] rather than the complete information model assumed in Eichenbaum et. al.[2] where the utilities of susceptible and infected are computed with complete knowledge of their types), and will choose the optimal strategy every day, with a utility parameterized on

   i. the external environment (infected population, government actions etc),

   ii. his personal parameters (desperation for work, risk aversion etc) and

   iii. his expected belief of his own type.

   In this stage we would see how our agent ends up (infection status, economic gain/loss) based on his personal parameters (which would remain constant over the simulation) and the environment.

2. ***Simulate a group of people in an environment*:** For this case, we would focus on a small group of individuals working in the same environment, they would all choose, independently, to either come to work or stay at home. Here the chance of contracting an infection at work increases significantly if some of them already are infected. As they may be asymptomatic, or showing minimal symptoms (modeled as the belief over types of other players which each player will have) players will have to maximize their expected utility in balancing economic gains from work or safety at home. Note that the payoff from working will be proportional to no of people who choose to work
   Again, all players will have their own personal parameters such as job risk (a virtual job has no extra risk even if players choose to work), the age group they belong to etc, and be a part of a daily changing global scenario, and we will model how the group turns out (infection status of the members, the total work done etc) based on these.

3. ***Simulate a group of people that constitute the environment*****:** At this point, we will be simulating a larger number of people. All individuals may choose between work/home, and the infection will be more likely to spread among working individuals and proportional to the number of infected working individuals (who would not know their own type, and may believe themselves healthy). We will work with aggregate beliefs, strategies and utilities as modeling every individual here may not be computationally feasible.
4. ***Simulate the role of the government*****:** Here we introduce the government to the model developed at stage 3. The government is the mechanism designer and will have some influence over the payoff matrices of the population. As the mechanism designer, the social choice function of the government will obviously involve all individuals of type infected to choose home (quarantine) and may occasionally involve healthy people to also choose home (lockdown). We will assign a 'utility' to the government to represent this social choice function, this will be a cartesian product of types of all players, and the outcome mapping to a real value. This value added to the "effort" (a negative value) the govt spent in changing the payoff matrices (via lockdowns/ economic relief etc) would be the total utility of the govt, and it would choose to act in a way to maximize the same.

   At this point we would expect the outcomes of our model to match with the results seen in existing literature[2,4].

Advanced Work (to be done if time permits):

1. ***Checking Incentive Compatibility:*** To check for incentive compatibility theoretically, we will see if every player honestly reporting their belief over their own types may lead to a Bayesian equilibrium or not. That is, we will see if it is possible/feasible for the government to come up with a mechanism design where the utilities of players (as a function of the global scenario and their own parameters) are maximized by true reporting of their beliefs on their own types.
2. ***Grouping population into workspaces:*** In parts 3, 4 of our basic objectives, we may introduce the concepts of groups as in part 2. Rather than assigning the probabilities of each individual contracting the virus based on the total number of working infected, we may assign a higher probability of contracting the virus if some individuals in their own 'group' are infected. This would better model the pandemic situation, but would require more effort to implement.

Deliverables:

All simulation models we develop (ie. codes for parts 1 to 4, and if possible part 2 of advanced work), as well as any theoretical results we show/use (such as showing the existence of a bayesian incentive compatible mechanism in part 1 of advanced work) will constitute the deliverables.

Additionally, we will run our simulations to see how they compare with existing models/data. The results/graphs obtained will also be a part of our deliverables.

References:

[1] Kermack, William Ogilvy, A. G. McKendrick, and Gilbert Thomas Walker, A contribution to the mathematical theory of epidemics | Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character 1927, 115 (772), 700–721

[2] The Macroeconomics of Epidemics

[3] NBER WORKING PAPER SERIES OPTIMAL MITIGATION POLICIES IN A PANDEMIC: SOCIAL DISTANCING AND WORKING FROM HOME

[4] Optimal Targeted Lockdowns in a Multi-Group SIR Model