Game Theoretical Modelling and PrEP Adoption

Agent Based Simulation

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- COIVD-19 is a global epidemic outbreak.

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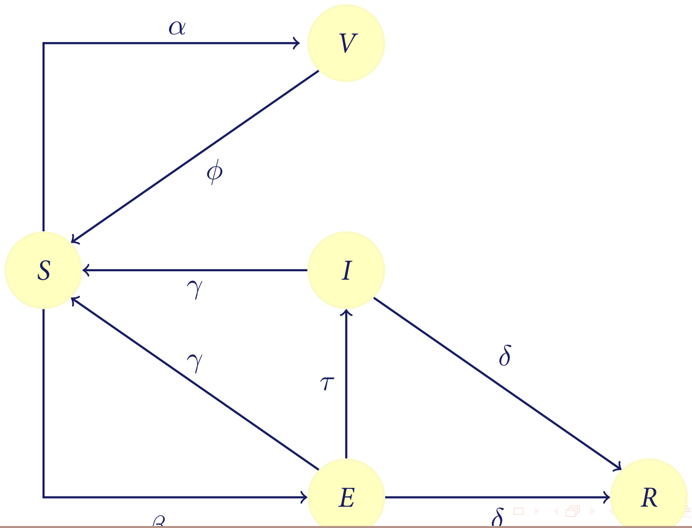
- Declined HIV infections (Grulich et al. 2018).

Section 1

Compartment Modelling

SIRV Model



Epidemic Parameters

- α - Adoption rate (vaccine/ treatment)
- β - Transmission rate
- γ - Recovery rate
- δ - Removal rate
- ϕ - Vaccine/ treatment wear off
- τ - COVID-19 testing rate

$R_0 = \frac{\beta}{\gamma}$ Basic reproduction rate (COVID-19: $\sim$ 2.6)

Factors to COVID-19

Socio-economical factors:

- Social contact
- Certain jobs (e.g. health worker, essential worker)
- Age
- Gender

Purpose of Study

To study:

- Prediction of pandemic upon the factors.
- Different socio-economical effects upon vaccine adoption.

Section 2

Methods

Simulation

Simulation:

- $N \geq 10000$
- Initial values
  - $\beta = 0.14$
  - $\gamma = 0.02$
  - $\phi = 0.000005$

Available on Github.

Time steps

Agents may

1. infect disease
2. take vaccine
3. recover
4. wear-off vaccine
5. take COVID-19 test

in each time step.

Immune Time

- Not able to reinfect after recovered some time.
- 0 days, 60 days, 180 days and 210 days tested.

Longitudinal Social Network

- Preferential attachment (Babarasi-Albert network).
- Update: Xulvi-Brunet–Sokolov algorithm
  - Preserve degree distribution
  - Assortativity/ disassortativity rewiring
  - Rewiring probability controls assortativity/ disassortativity changes

Bounded Rationality

Probability to vaccinate:

$$P_i(X) = \frac{e^{\alpha\lambda\, r_s}}{\sum_s e^{\alpha\lambda_i\, r_s}} = \frac{e^{\alpha\lambda\, r_s}}{e^{\alpha\lambda_i\, r_V} + e^{\alpha\lambda_i\, r_{\neg V}}} \tag{1}$$

- λ - rationality parameter
  - $\lambda \rightarrow 0$ - random decision
  - $\lambda \rightarrow \infty$ - Nash equilibrium

Opinion Dynamics

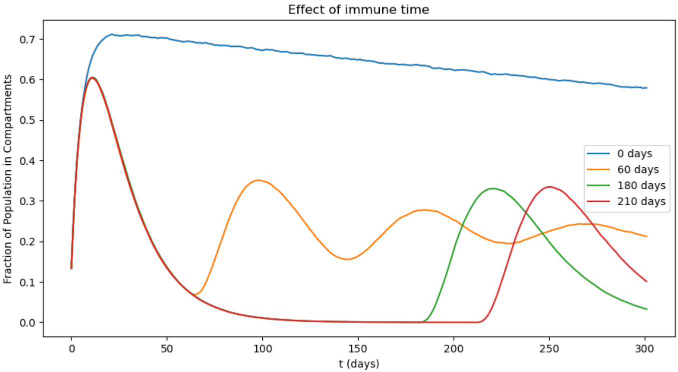
Local Majority Rule

- Population form local info network.
- Generate consensus based on local majority
- Personality:
  - Inflexible - Position fixated
  - Balancer - Contrary to group consensus

Section 3

Results

Immunity Period



Immunity Period

- Immunity period make realistic.
- 60 days produce decay oscillation.
- More than 60 days produces subsequent waves.

Longitudinal Social Network

Low number of links

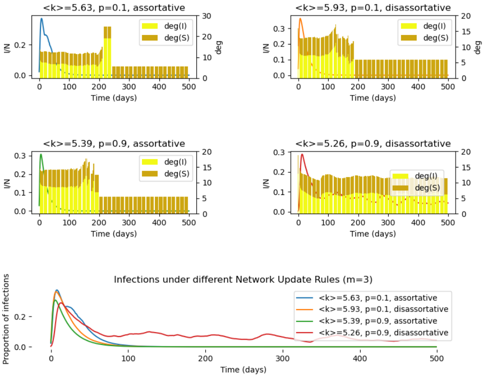


Figure: Low links and average degree

Longitudinal Social Network

High number of links

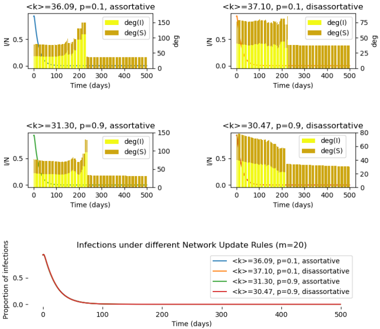


Figure: High links and average degree

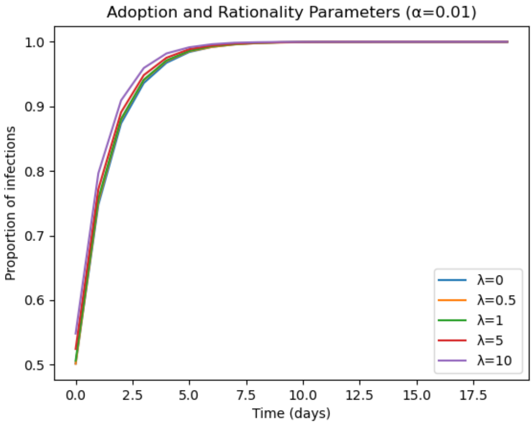
Longitudinal Social Network

Analysis

- High links has higher epidemic peak.
- One peak (not always with second waves).

Bounded Rationality

$$\alpha = 0.01$$



Bounded Rationality

$\alpha = 0.8$

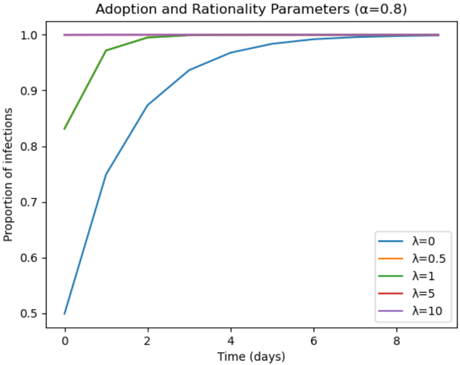


Figure: Time series

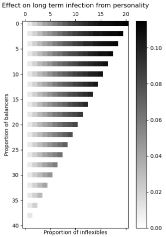
Bounded Rationality

Analysis

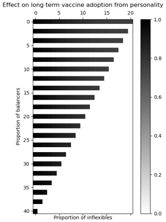
- Very quick adoption.
- Lower bound $P(X) = 0.5$.

Opinion Dynamics

Different inflexible and balancer proportion.



(a) Effect on infection



(b) Effect on vaccination

Figure: Results of infection and vaccinated proportion at time $t = 500$.

Discussion and Conclusion

- Immune period is realistic.
- Cost of infection boosts vaccine adoption.
- Adoption rate is very fast (bounded rationality).
- Low balancer and inflexible boosts pro-vaccine proportion.

Critical Evaluation and Outlook

- Combination of factors.
  - Contact network and overseas travel (external infection).
  - Game theory and opinion dynamics.
- Bounded rationality has lower bound $P(X) = 0.5$.
- Realistic value of vaccination and infection remains unknown.