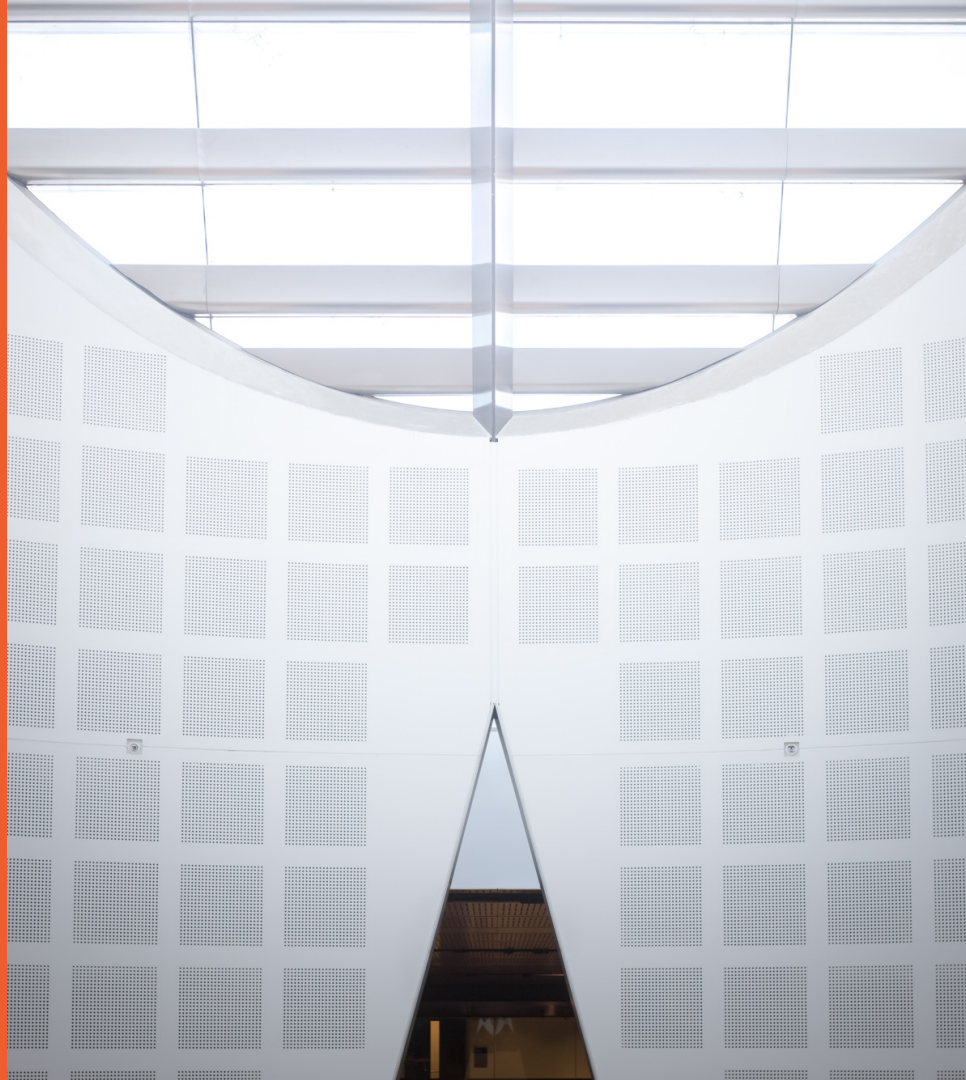
Impact of committed vaccine recipients on vaccination behaviours in a SIR-network model

Presented by
Sheryl Le Chang
Centre for Complex Systems
The University of Sydney, Australia

Conference on Complex Systems (CCS)
Singapore, 2019
Satellite Session: **Challenges in Epidemiological Modelling**

THE UNIVERSITY OF SYDNEY

Venue:LHN-TR+09
Date: 3 October 2019

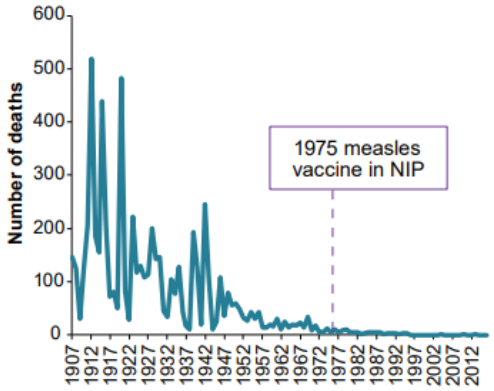


Introduction

Measles:

- Recent measles alert
- MMR vaccination provides life-long immunity

How does the existence of committed vaccine recipients affect aggregate vaccination and epidemic dynamics?

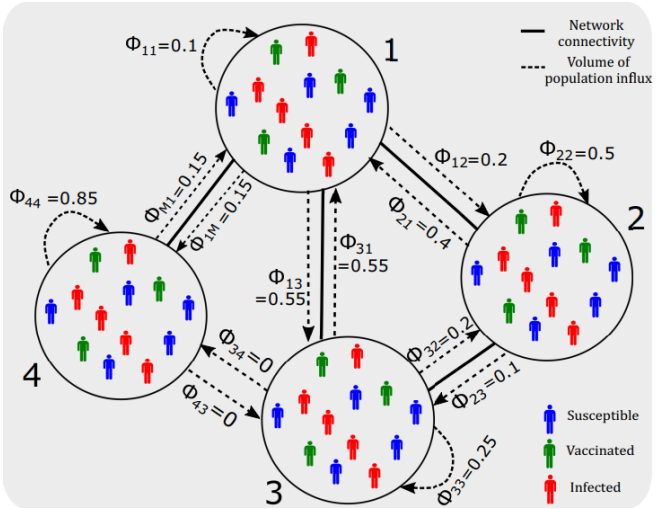


Sources: AIHW analysis of National Mortality database; AIHW 2010 GRIM books

Model: mobility

Travelling pattern on network:

- Topology defined by population influx matrix ϕ
- Meet, exchange information and infect
- New infection counted at residential node



Schematic of a sample travelling network

Model: voluntary vaccination decision

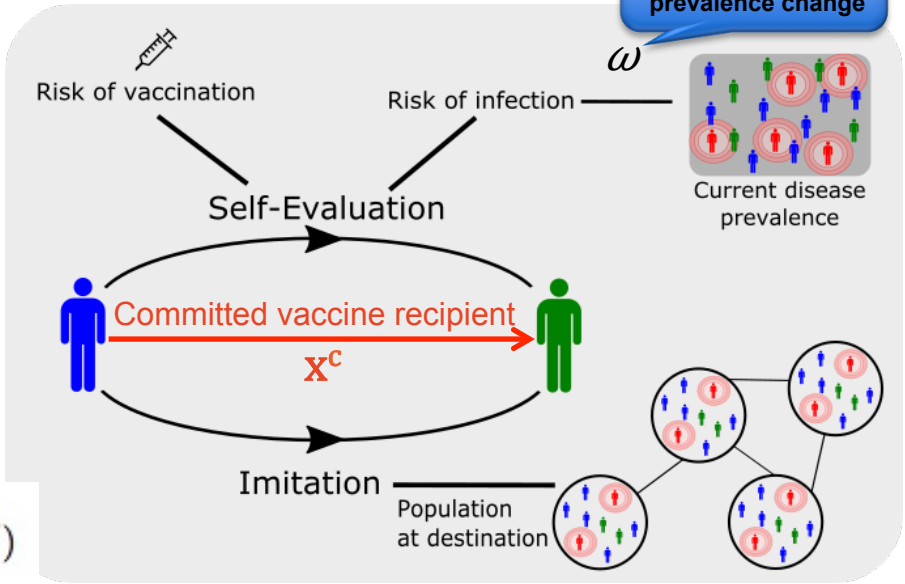
Vaccination decision

- Self-evaluation
- Committed vaccine recipient

Imitation

- Other people's decision

$$\dot{x}_i = \kappa(1 - x_i - x^c)\sum_{j=1}^{M}\phi_{ij}(-1+\omega I_j)\sum_{k=1}^{M}\phi_{kj}(x_k + x^c)$$



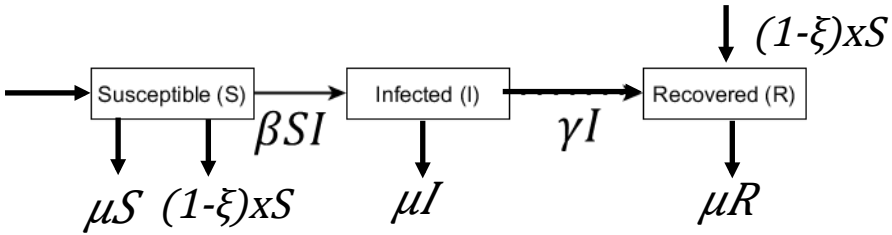
Schematic of the decision making process

Model: voluntary vaccination decision

SIR model

- Susceptible(S) –Infected(I)-Recovered(R)
- Vaccination available to entire susceptible class (x)

How much impact does committed vaccine recipients have?

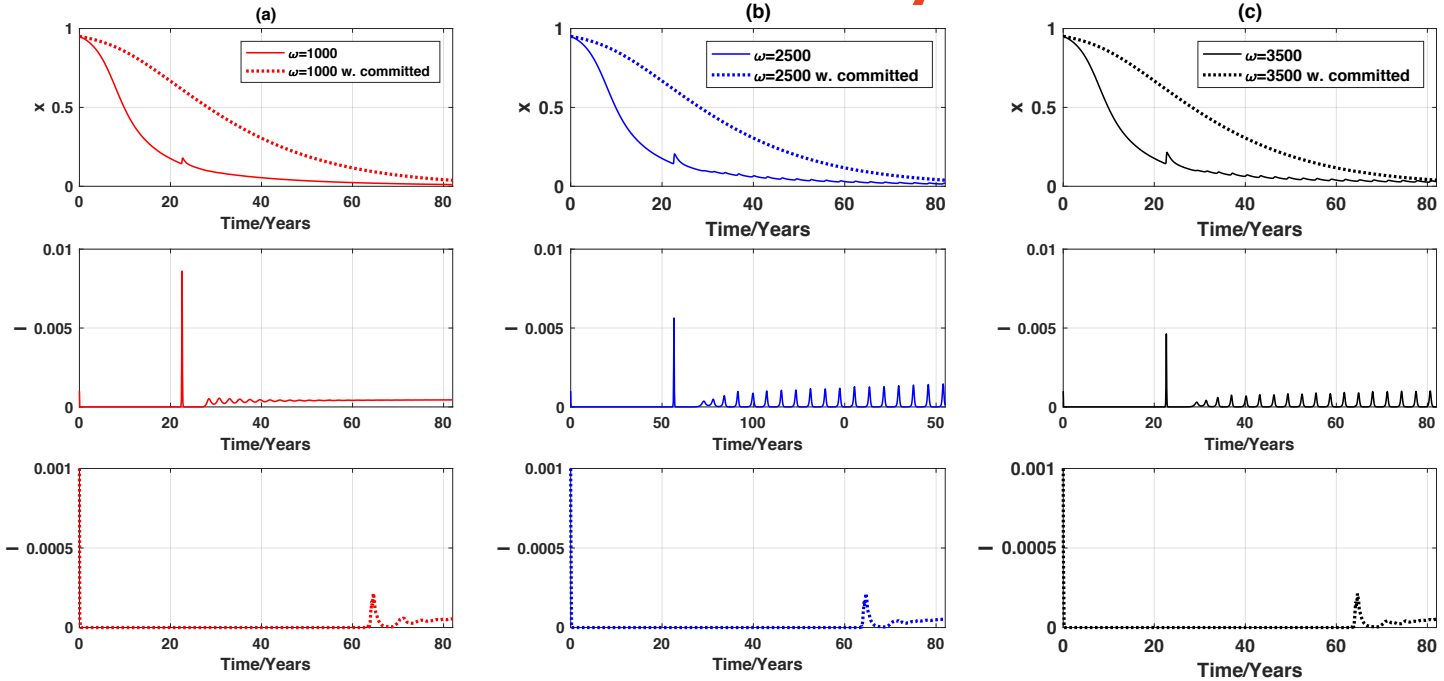


$$\dot{S}_i = \mu - \sum_{j=1}^{M}\sum_{k=1}^{M} \beta_j \phi_{ij} \frac{\phi_{kj} I_k}{\epsilon_j^p} S_i - \mu S_i + (\zeta - 1)[(x_i + x^c) S_i]$$

$$\dot{I}_i = \sum_{j=1}^{M}\sum_{k=1}^{M} \beta_j \phi_{ij} \frac{\phi_{kj} I_k}{\epsilon_j^p} S_i - \gamma I_i - \mu I_i$$

$$\dot{x}_i = \kappa(1 - x_i - x^c) \sum_{j=1}^{M} \phi_{ij}(-1 + \omega I_j) \sum_{k=1}^{M} \phi_{kj}(x_k + x^c)$$

Results: 3000 node Erdos-Renyi random network



Erdos-Renyi random network. N=3000, <k>=4, x^c=0.0002; Initial conditions: S_0=0.05, I_0=0.001, x_0=0.95.

Conclusion

- Small fraction of committed vaccine recipient could prevent outbreak
- Full-length paper:

S. L. Chang, M. Piraveenan, M. Prokopenko, (2019). **The effects of imitation dynamics on vaccination behaviours in SIR-network model**, *Int. J. Environ. Res. Public Health, 16(14):2477*

Parallel session Diseases & Epidemics 3 Friday LHN-TR+12

References

- S. L. Chang, M. Piraveenan, P. Pattison, M. Prokopenko, Game theoretic modelling of infectious disease dynamics and intervention methods: a mini-review, arXiv e-prints, arXiv:1901.04143.
- X. Liu, Z. Wu, L. Zhang, Impact of committed individuals on vaccination behavior, Physical Review E 86 (2012), 051132.
- C. T. Bauch, Imitation dynamics predict vaccinating behaviour, Proceedings of the Royal Society B 272 (2005) 1669-1675.
- J. Arino, P. van den Driessche, The basic reproduction number in a multi-city compartmental epidemic model, in: L. Benvenuti, A. De Santis, L. Farina (Eds.), LNCIS, Vol. 294, Springer, Berlin, Heidelberg, 2003.
- S. L. Chang, M. Piraveenan, M. Prokopenko, The effects of imitation dynamics on vaccination behaviours in SIR-network model, Int. J. Environ. Res. Public Health 16 (2019), 2477.
- C. Zachreson, K. M. Fair, O. M. Cliff, N. Harding, M. Piraveenan, M. Prokopenko, Urbanization affects peak timing, prevalence, and bimodality of influenza pandemics in Australia: Results of a census-calibrated model, Science Advances 4 (12).
- O. M. Cliff, N. Harding, M. Piraveenan, E. Erten, M. Gambhir, M. Prokopenko, Investigating spatiotemporal dynamics and synchrony of infuenza epidemics in Australia: An agent-based modelling approach, Simulation Modelling Practice and Theory 87 (2018) 412-431.