Pandemic control in Econ-Epi Networks

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Covid: Disease on spatial networks

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Main idea

- COVID-19 pandemics: how to reduce disease spread with minimal economic disruption?
- Network theory useful tool: infections and economic activity happen through same network of human interactions

ECON-EPI network

Today

- Intro to ECON-EPI Networks
- Quantitative analysis of first wave of COVID-19 in the New York metro
- Assess:
  - Ability of set-up of explaining data, given policies/behavior
  - Impact of alternative policies
  - Lessons

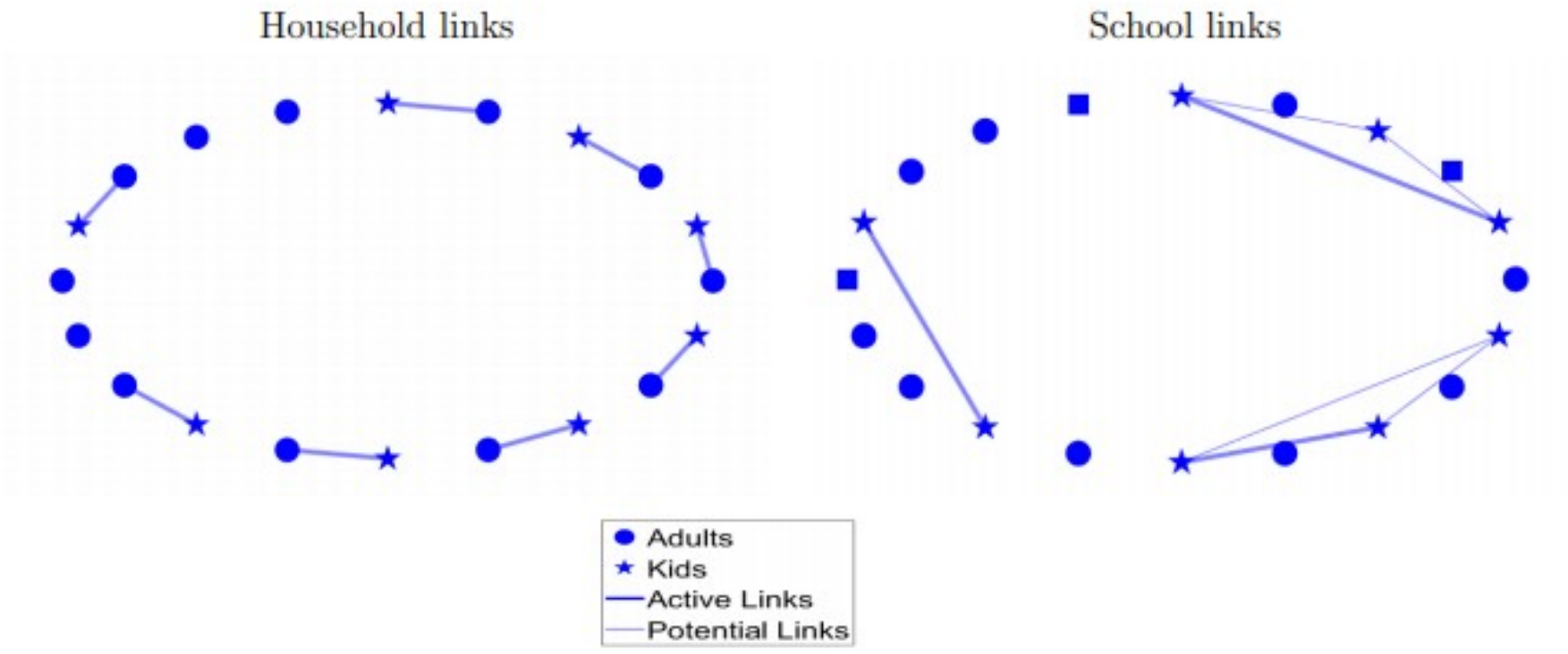
The three components of the ECON-EPI Network

- The NETWORK: Matrix of human contacts
- The ECON: How economic value is created on the network
- The EPI: How disease spreads through the network

Preliminaries

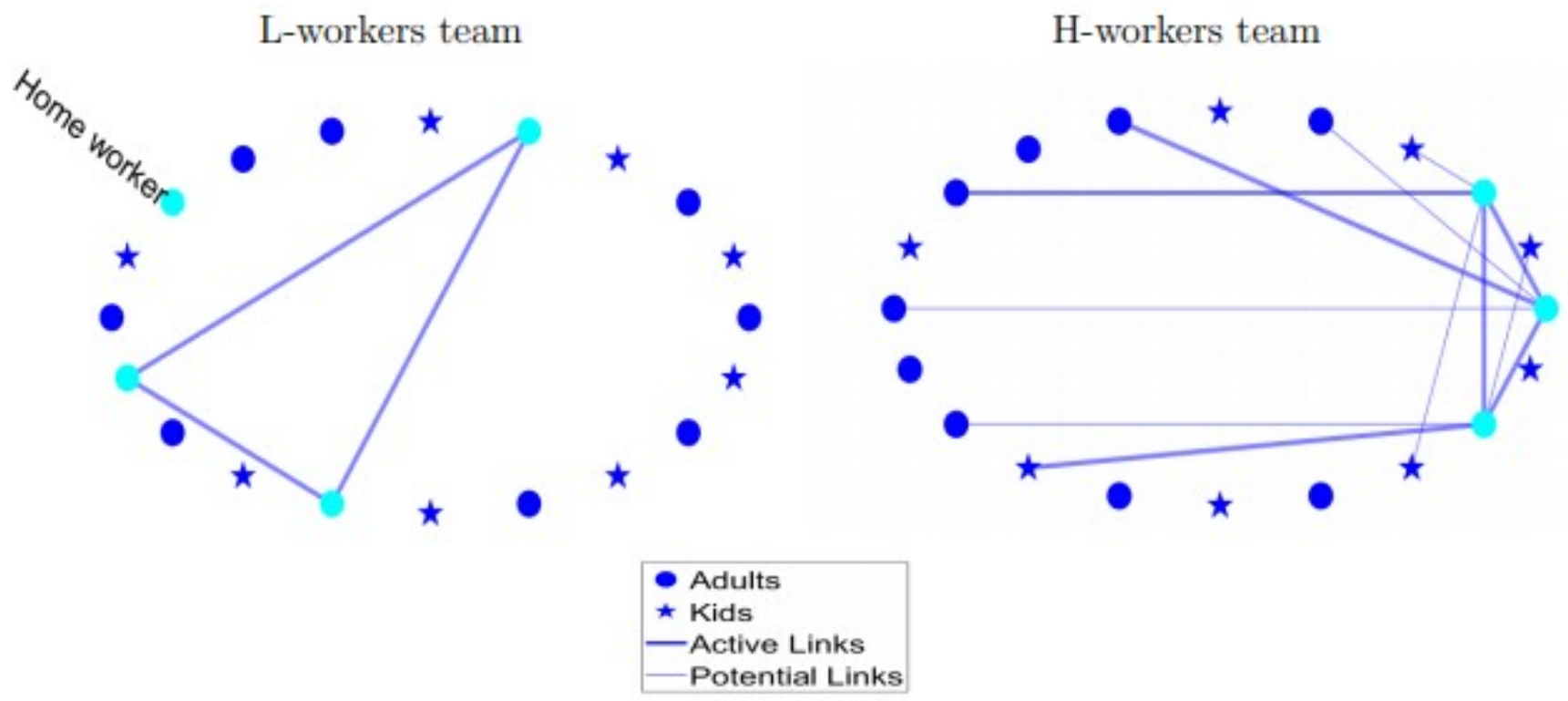
- Network:
  - Set of M nodes
  - Set of edges/links connecting nodes (MxM symmetric matrix G of 0/1)
  - Links can be active or potential
- Each node/person has economic (e.g. worker, shopper, student..) and health status (e.g. susceptible, recovered..)
- Evolution of economic and health status depends on health and economic status of active links

Network Layers:
Households and schools

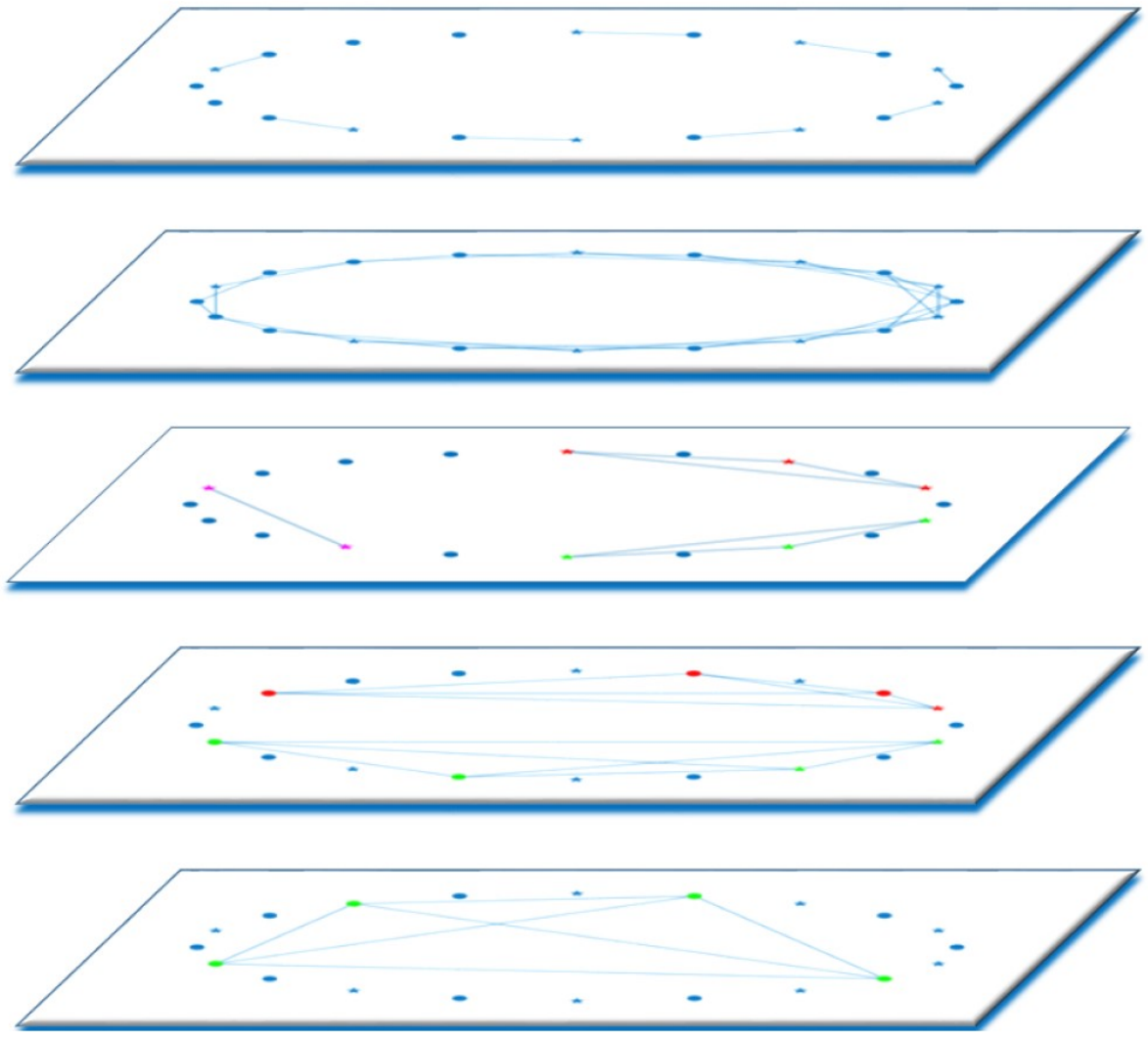


Network Layers: Workplaces

- Low contact (research dept.)
- High contact, local base (Whole Foods, etc.)
- High contact, global base (NBA game, etc.)



A multilayered network



Household:G^H

Neighborhood:G^N

Schools:G_t^S

Transportation:G_t^P

Workplace:G_t^W

- Key Features of contacts: Degree, Reach, Stability, Weight

The ECON component

H-Sector

Global

Local

Faster spreading, lower wages

$Y_i = F(k, \min(c,l))$

L-Sector

Non-home workers

Home workers

Slower spreading, higher wages

$Y_i = F(k,l)$

Establishment labor demand

- Two sectors producing homogeneous good (numeraire)
- Inelastic labor supply in each sector
- Production takes place in establishments with set capital K_L, K_{Hi}
- L-sector

$$\max_{n_L} K_L^{\alpha} n_L^{1-\alpha} - w_L n_L$$
given w_L

- H-sector

$$\max_{n_{Hi}} K_{Hi}^{\alpha} \left(\min \left\{ n_{Hi}, \frac{K_{Hi} d}{\mu} \right\} \right)^{1-\alpha} - w_H n_H$$
given w_H, d

- Production in H requires customers d and workers

Pre-pandemic city equilibrium

- L-sector: w_L, n_L such that:
  - given w_L, n_L chosen optimally,
  - L-Labor market clears

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- L-sector: w_L, n_L such that:
  - given w_L, n_L chosen optimally,
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- H-sector: w_H, n_{Hi}, d such that:
  - given w_H and d, n_{Hi} chosen optimally,
  - H-Labor market clears
  - Total shopping trips equals shopping capacity

$$Ms = \int n_{Hi}\mu$$

Note: implicitly s driven by congestion considerations

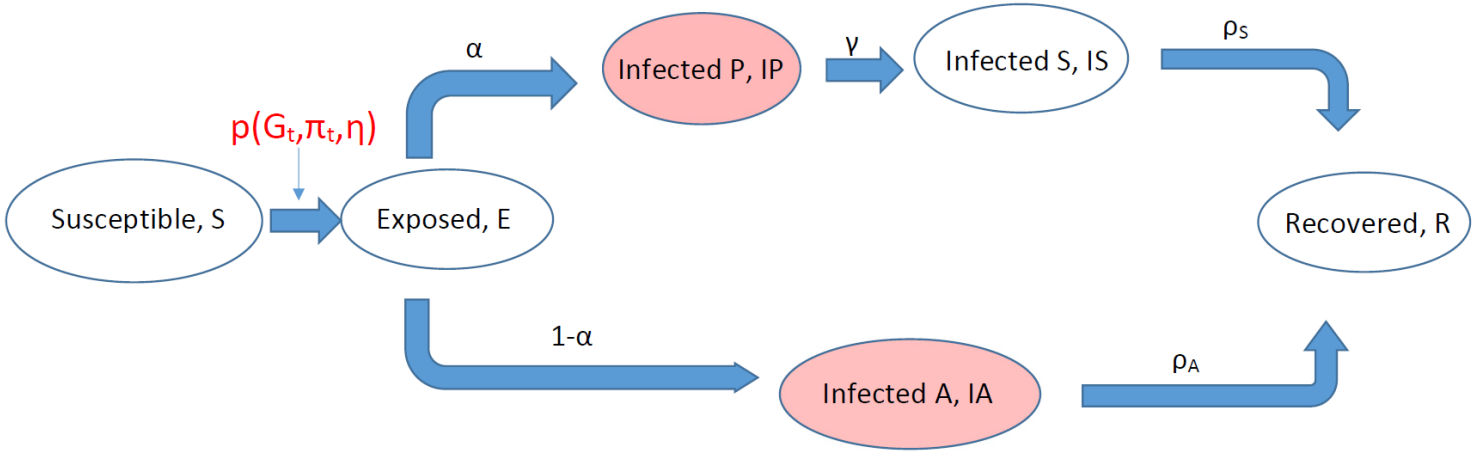
Production during a pandemic

Pandemics affects output in both sector through three channels

- Some workers shut down by policy
- Sick workers quarantined and do not work
- Sick shoppers do not shop (possible to introduce also fear driven reduction)

No labor reallocation across establishments/sectors (short run)

The EPIdemiological component



- π_t is cyclical, following Atkeson (2021)

Calibration (NY metro)

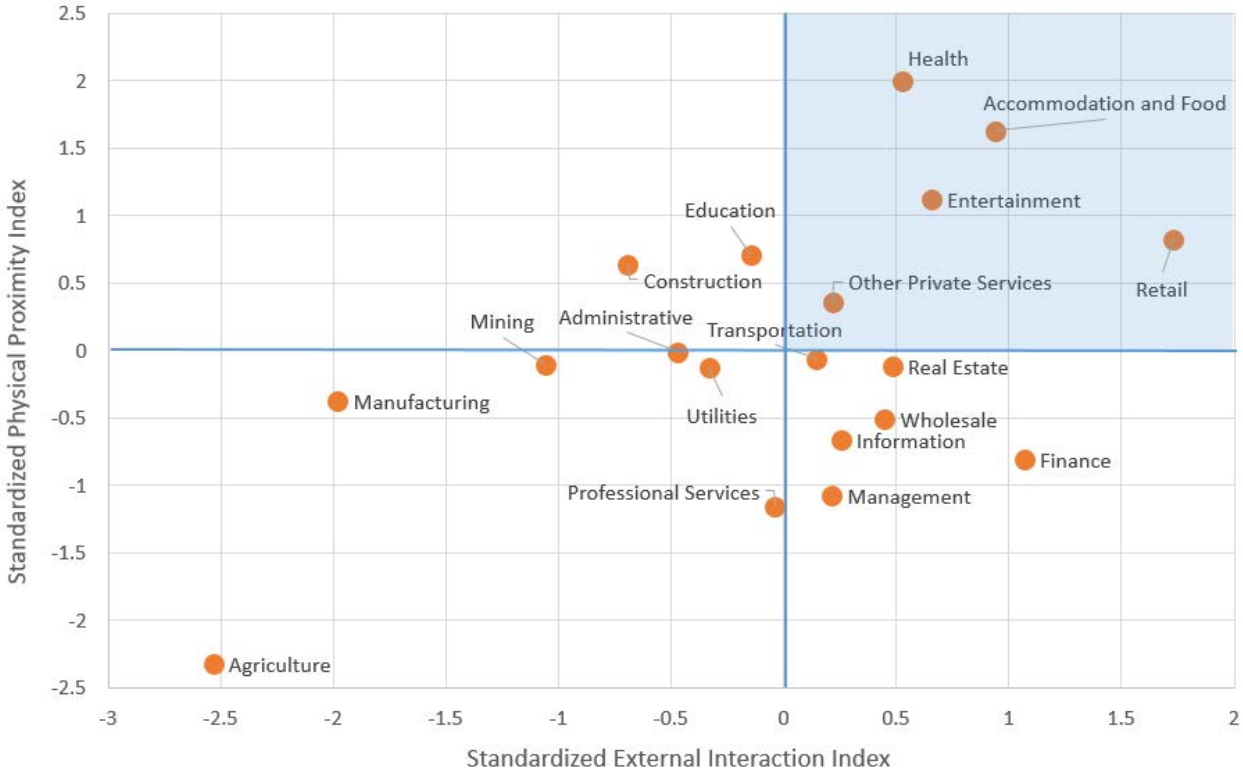
- $\simeq$ 1 million people (nodes)
- Links and weights calibrated using:
  - Network contacts: Diary of face to face daily human contacts (Mossong et al, 2008)
  - Household, schooling, and public transport characteristics from NY.

- We use SUSB, ACS to measure salary differences across sectors, workers (home vs workplace), $\%$ working from home, establishment characteristics.

- We identify H-sector and L-sector
  - ONET Questions: physically proximity + interaction w/ customers
  - Crosswalk from occupation to sector

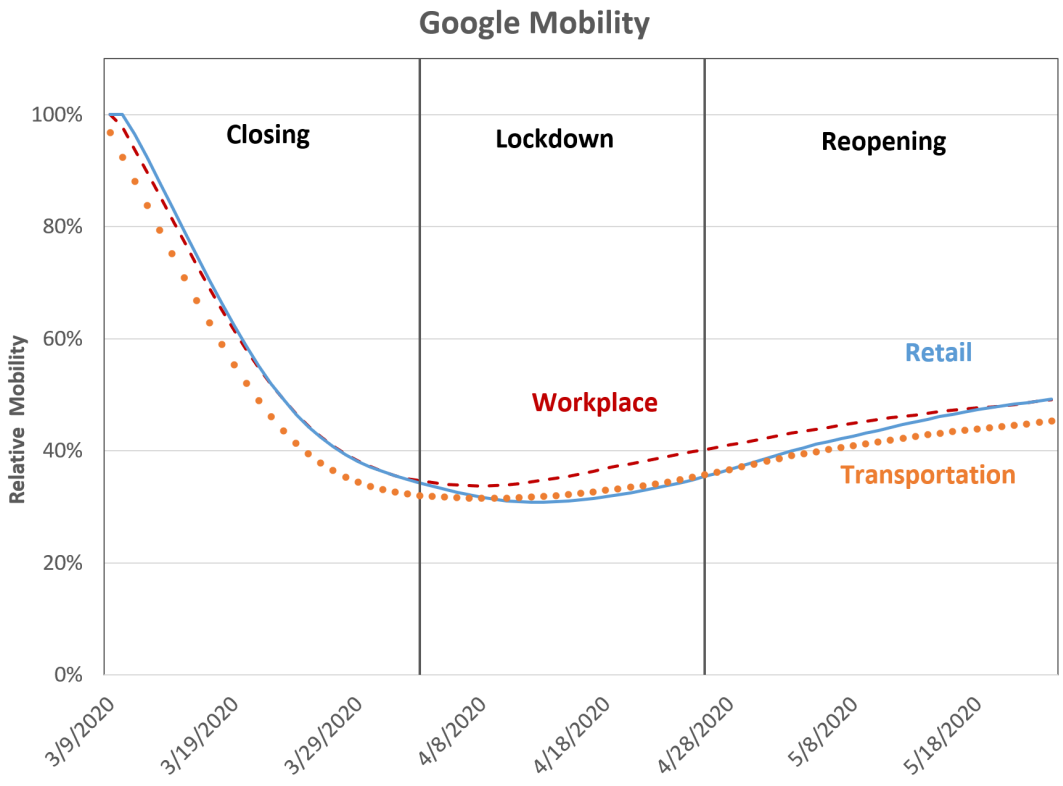
Identifying H and L sectors

- ONET Questions on physically proximity and interaction with external customers
- Crosswalk from occupation to sector



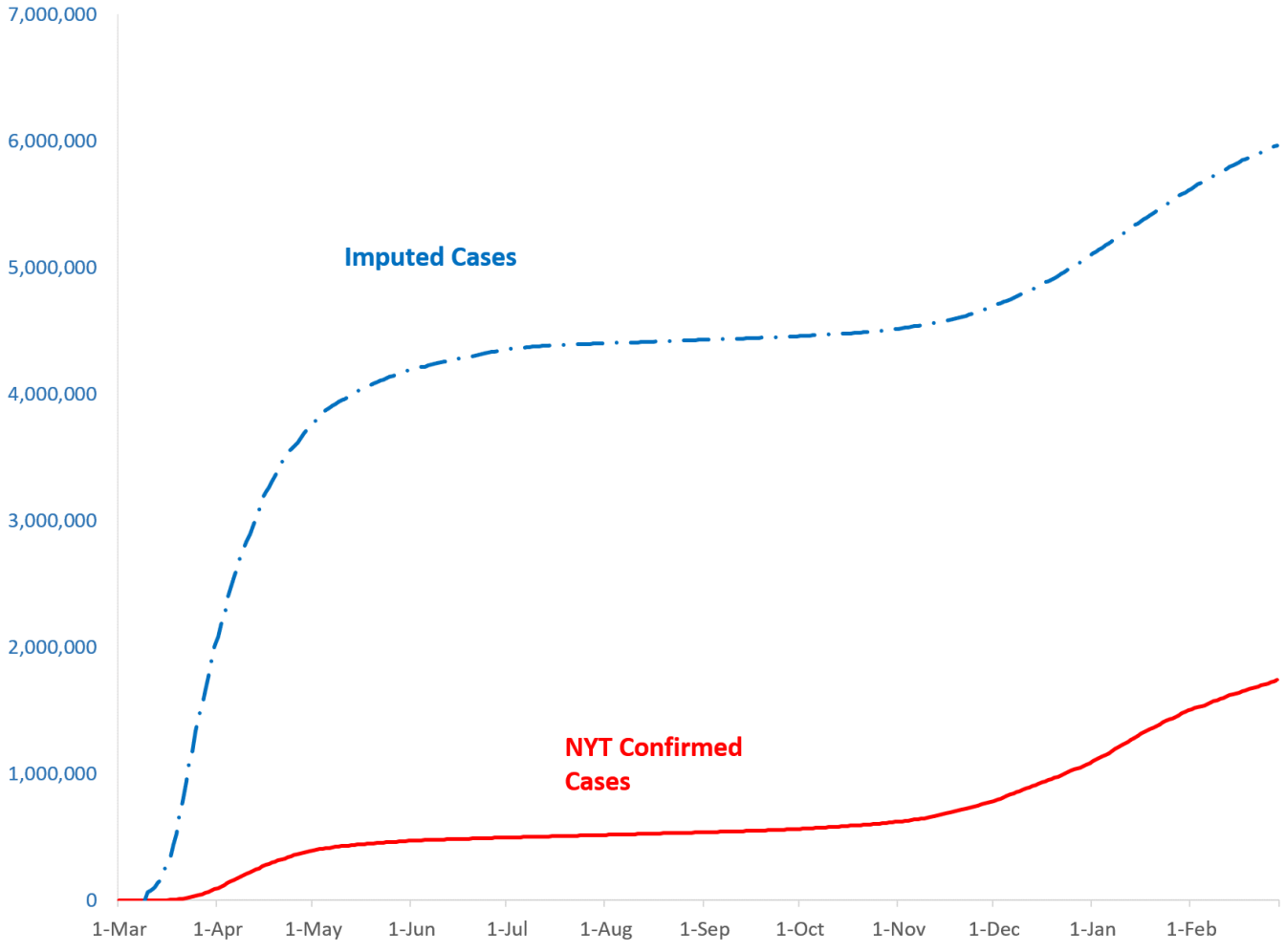
	Share	Avg. yearly wages ($)	Share Home workers
L-sector	54%	94k	7%
H-sector	46%	40k	3%

Policies/Behavioral responses



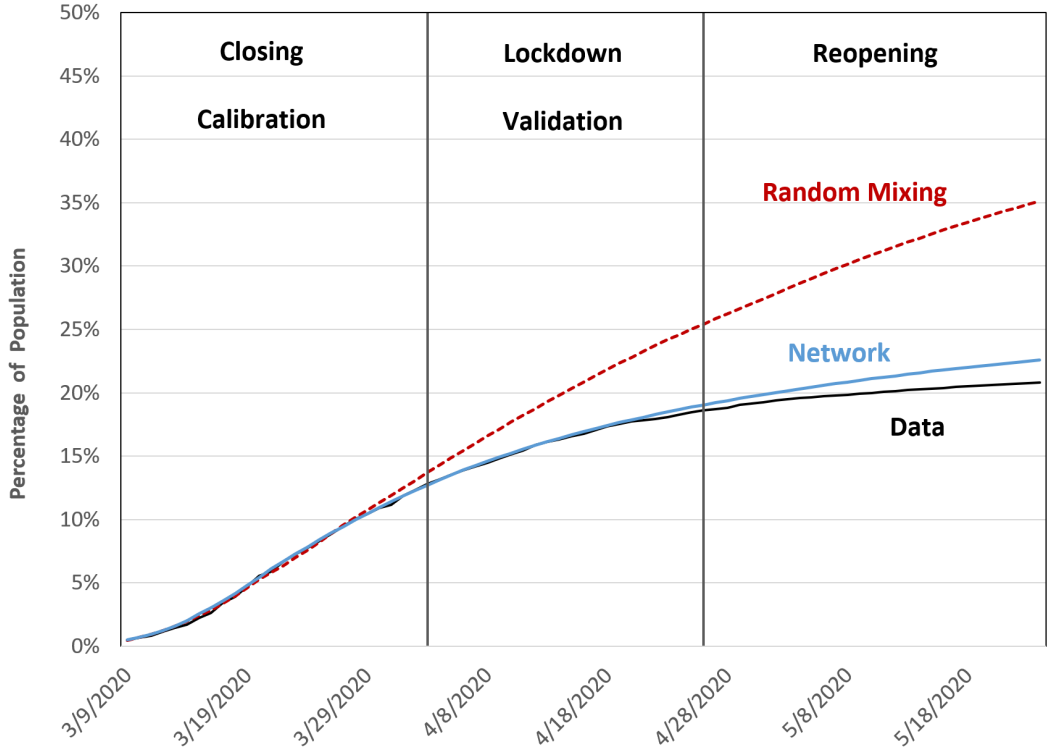
- Shut down L-workers and allow 1/3 of workers to telecommute to match workplace mobility
- Shut down H-workers to match retail mobility
- Shut down PT to match transportation mobility
- School, Events (>500) closed March 16th

Imputing series for cases



- Use estimated infection fatality ratios from Ferguson et al. (2020)
- Use median symptom-onset-to-death by age to adjust series

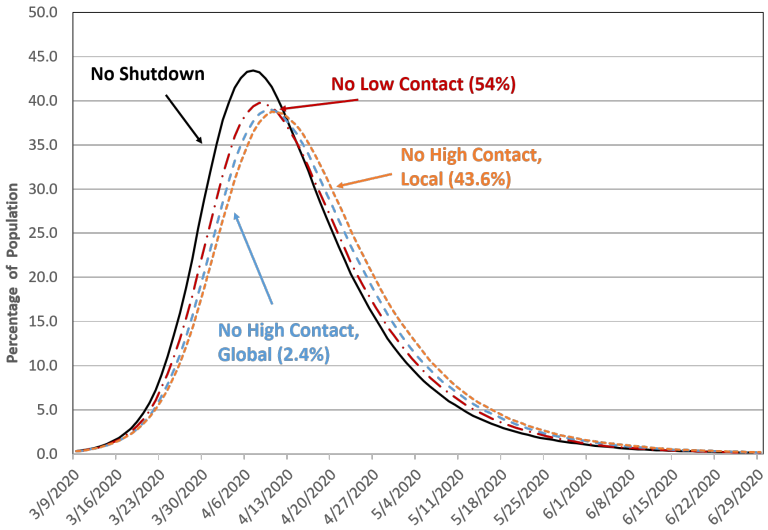
Prediction for infection curve



- Both SIR and Network calibrated to match initial phase
- Network model predicts more contained infection growth
- In network where unstable and far reaching links are shut down, local herd immunity is reached and disease stops early

Importance of different layers and complementarities

Active cases (calibrated $\pi = 0.212$)



Active cases (lower $\pi = 0.163$)

Importance of different layers and complementarities

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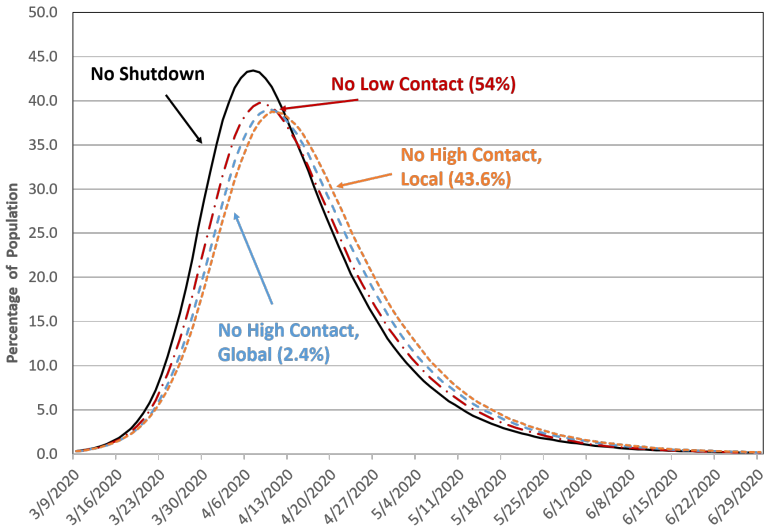

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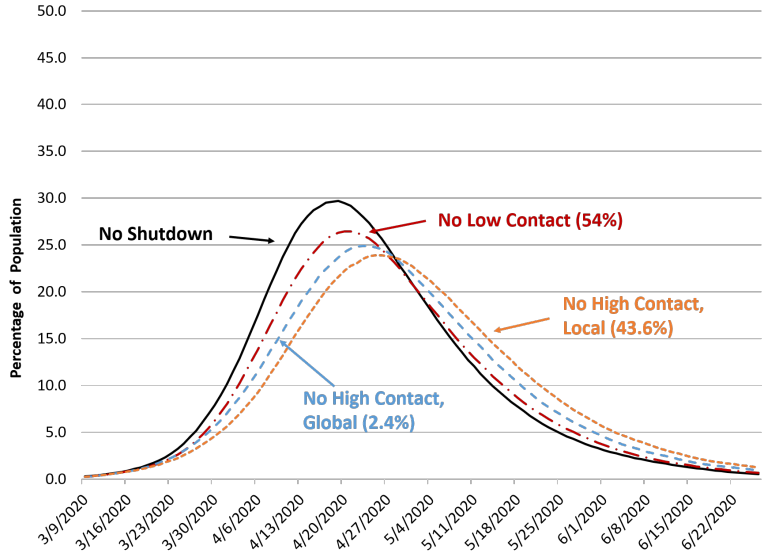
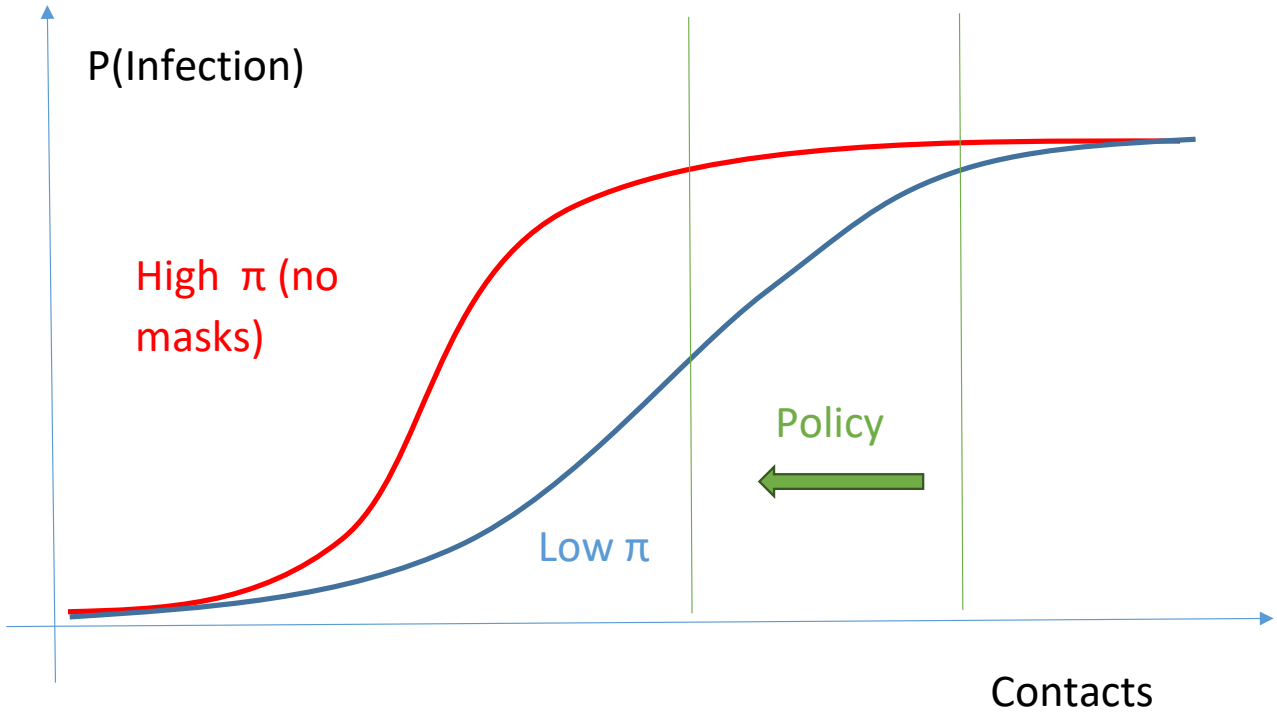


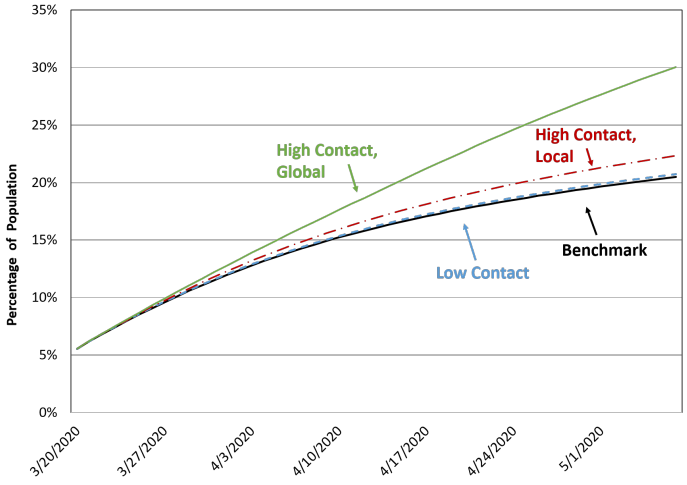
- Benchmark is no policies/behavioral response
- Shutting down global high contact has the largest impact on infection per worker
- Shut-down more effective with lower transmissibility (masks). Complementarities between policies

Understanding complementarities

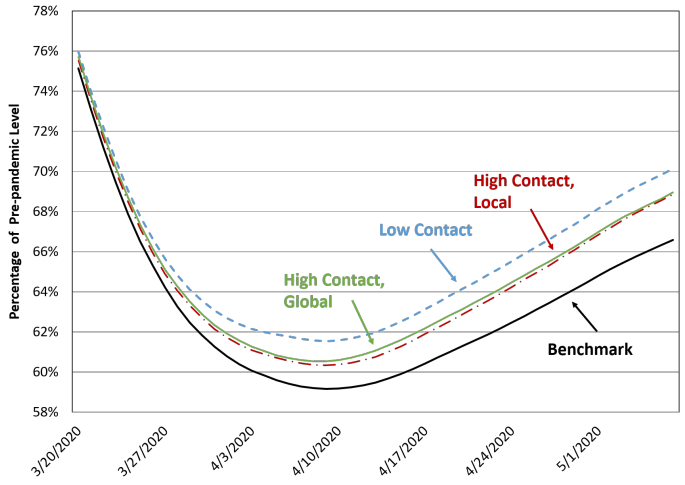


Designing a smart mitigation

Infection Diffusion



Metro GDP



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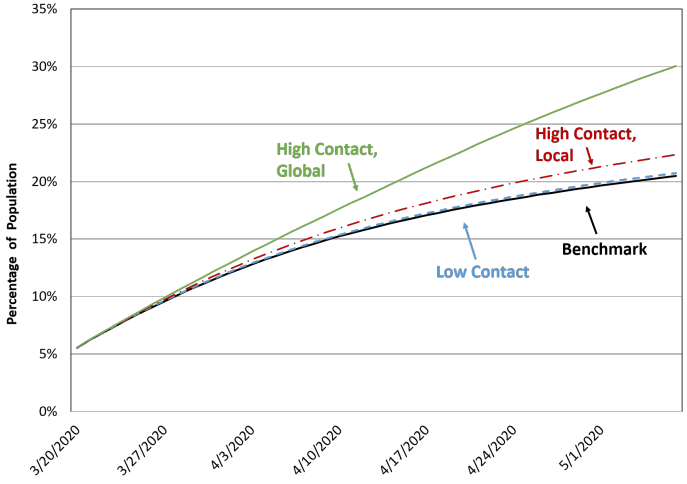

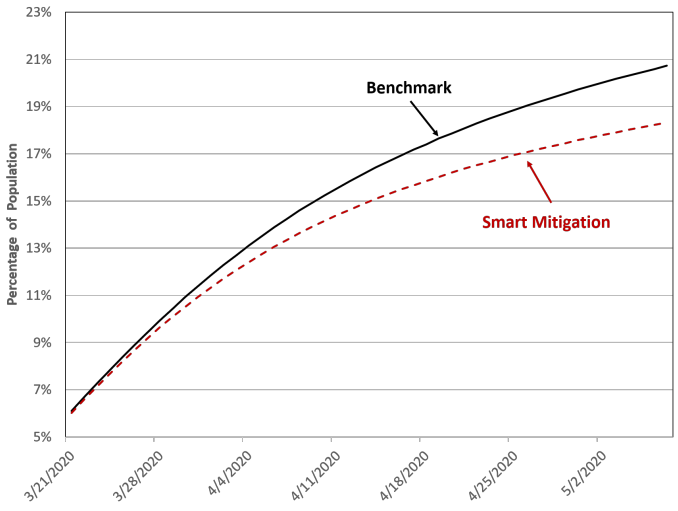

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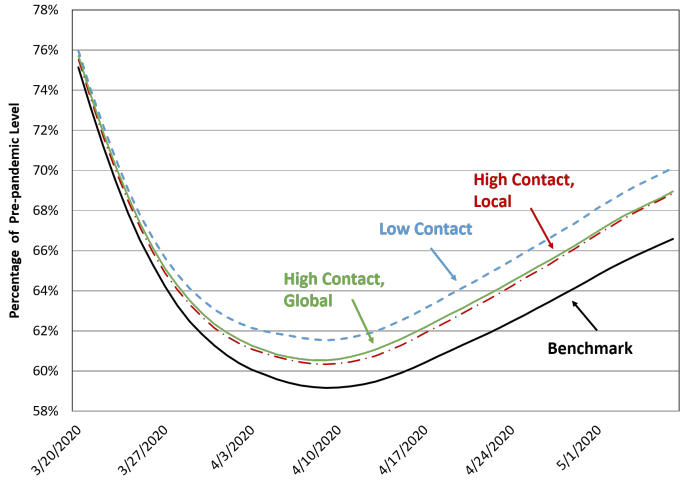
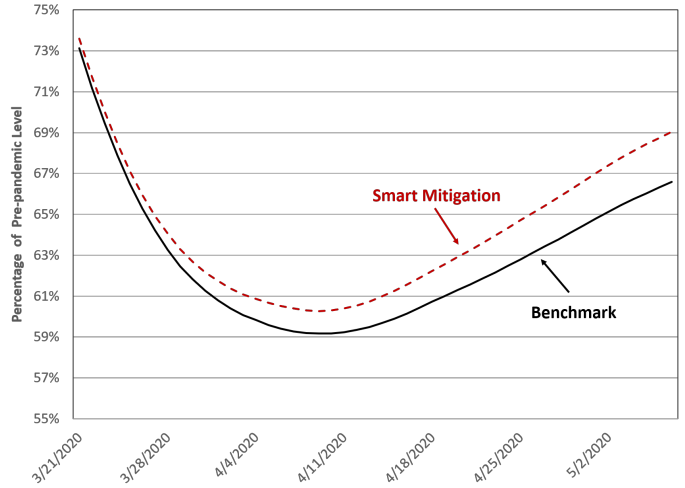
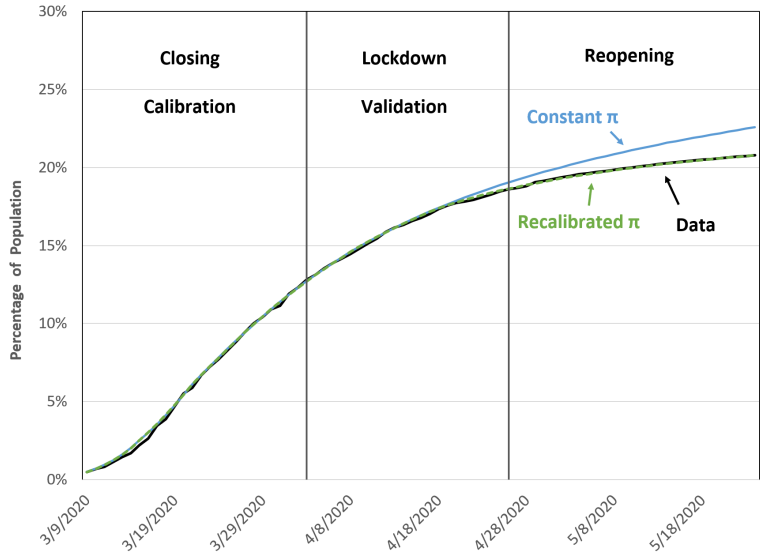




- Shut down L-less, H more: more output less infection

A reopening scenario



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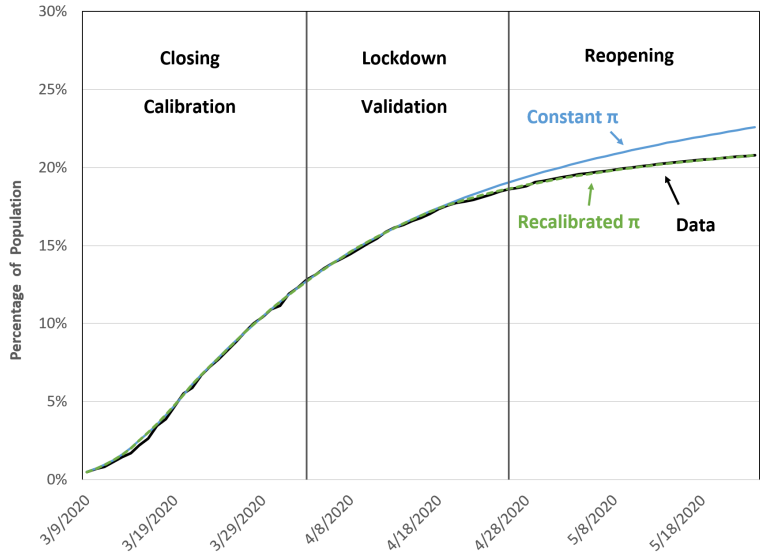

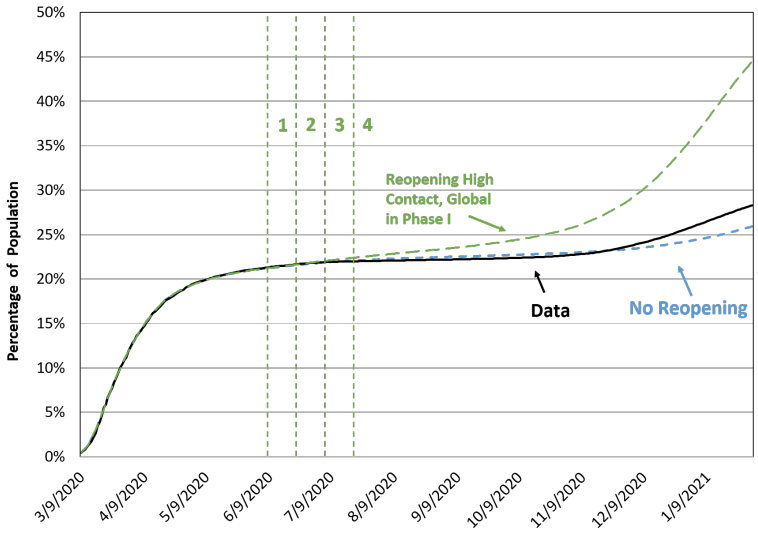

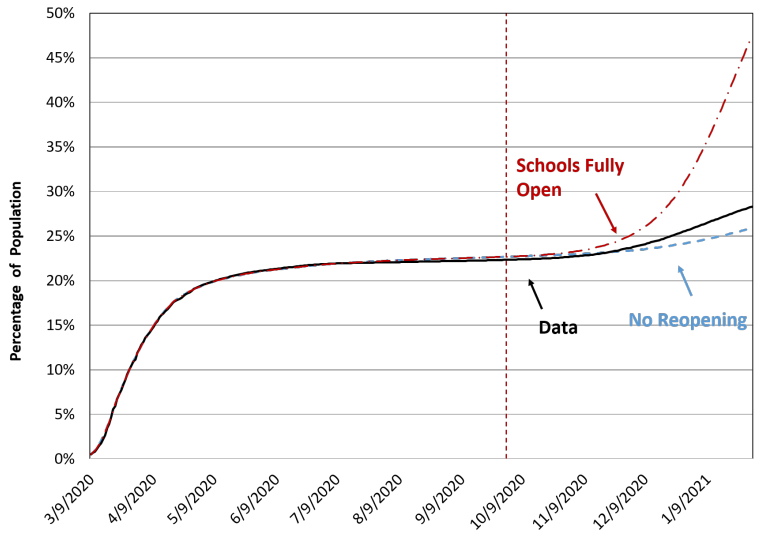

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- Networks slow spread but add to the persistence of the pandemic.
- The structure of production (capital, wage differential, shopping contacts, etc.) is important for designing effective policies.