Advanced Network Analysis

Network Analysis and Causal Inference

Olga Chyzh [www.olgachyzh.com]

Reading

- Olga V. Chyzh. 2024. How to stop contagion: Applying network science to evaluate the effectiveness of covid-19 vaccine distribution plans. *Journal of Politics* 86 (1): 18-35.

- Karthik Rajkumar, Guillaume Saint-Jacques, Iavor Bojinov, Erik Brynjolfsson, and Sinan Aral. A causal test of the strength of weak ties. Science, 377(6612):1304--1310, 202

Very Healthy Cereal

Empirical Observation

- This cereal sticks to a magnet.

Why Did it Stick?

- Propose a theoretical model (that includes a causal mechanism) to explain the observation.

- Suppose our causal mechanism is that this cereal sticks to a magnet because of its iron content.

- A testable hypothesis: cereals that are high in iron stick to a magnet.

Test

Vitamin A	10%	15%
Vitamin C	10%	10%
Calcium	0%	15%
Iron	2%	2%
Vitamin D	10%	25%

Does It Stick?

- This cereal does not stick to a magnet.

Causal Effect

- Unit of analysis: cereal type

- Treatment variable (causal variable of interest) T: iron content (high/low)

- Treatment group (treated units): Total cereal

- Control group (untreated units): Honey Smacks cereal

- Outcome variable (response variable) Y: whether it sticks to a magnet (yes/no).

Causality

- Counterfactual: Would Total cereal stick to a magnet if it did not have iron?

- Two potential outcomes: $Y(1)$ and $Y(0)$

- Causal effect: $Y(1) - Y(0)$

- Fundamental problem of causal inference: only one of the two potential outcomes is observable.

- Cannot calculate individual causal effect $Y(1) - Y(0)$!

- Can calculate the average treatment effect by comparing the means of a treatment and a control group.

- Importance of control group: must be identical to the treatment group on all factors but the treatment.

The Problem

- Causal inference is predicated on comparing the observed to the counterfactual.

    - Example: To show that the Medici rose to power due to their high network centrality, we must compare the Florentine network to a counter-factual, in which the Medici did not hold a central position.

- Often cannot change one aspect of the network while holding all else constant

    - Cannot change an actor centrality without changing centrality of other actors.
    - Example 1: Cannot observe what a policy diffusion process across US states would look like in the absence of New York and California.
    - Example 2: What would the post-World War II international alliance network would look like without the United States?

A Causal Approach

- Experiment

  - Randomly assign features to nodes/edges in networks

  - Examples: LinkedIn experiment

- Natural experiment

  - Find a sample of social networks, such that some features (e.g.the central nodes' transmission potential) are disabled in some of the networks, but not the others.

  - Examples: Covid-19 vaccine prioritization policies in the US, censorship on Twitter

- Simulations to study different scenarios

Assumptions

- Unconfoundedness

- SUTVA--stable unit treatment value assumption: treatment assignments for other units do not affect the outcome for unit i and that each treatment defines a unique outcome for each unit

- Parallel trends

Simulations: Covid-19 Transmission Under Different Vaccine Priority Scenarios
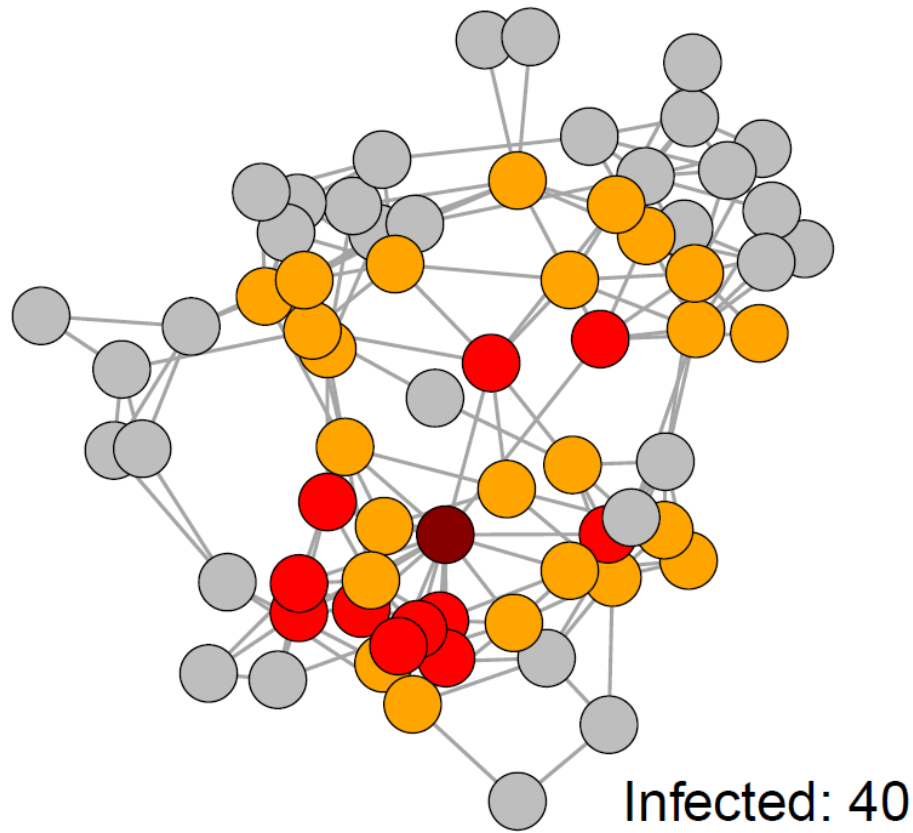
Infected: 40

Figure 2: Contagion in the Interaction Network

Low Degree
High Degree
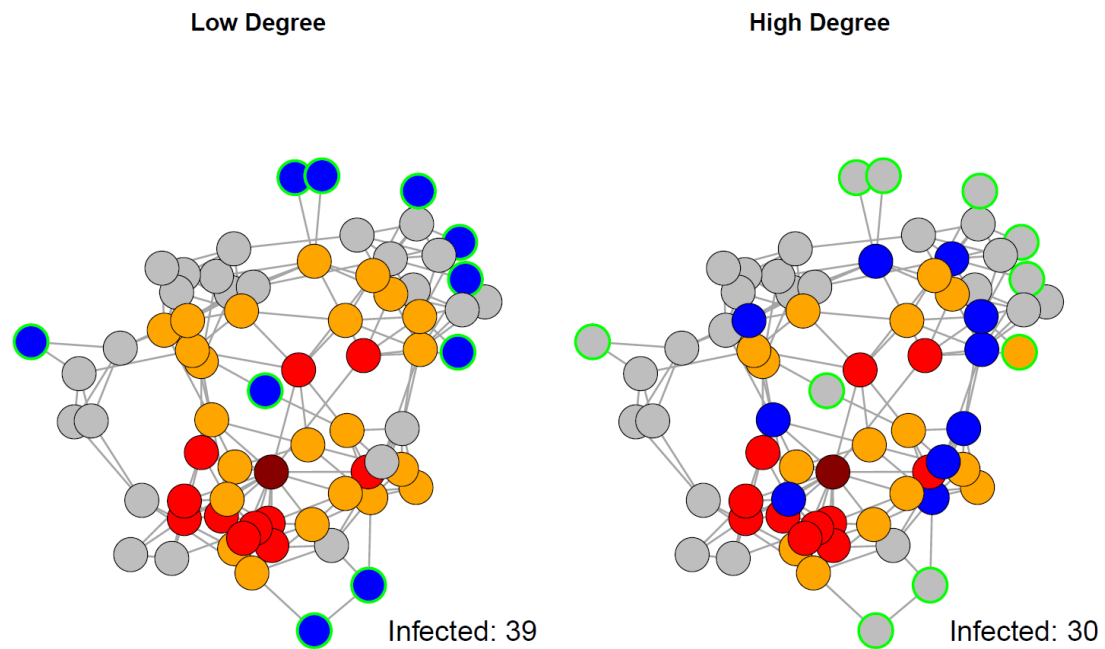
Infected: 39
Infected: 30

Figure 3: Vaccination Scenarios

Table 2: Round 2 Summary for 10,000 Simulations of the Interaction Network among 73 Individuals

|	Vaccinated	Infected	Not Infected	Vulnerable Infected
No Vaccine	0	40.02 (5.50)	27.98 (5.50)	3.35 (1.53)
Low Degree	10	36.60 (5.16)	21.40 (5.16)	0
High Degree	10	24.74 (4.82)	33.26 (4.82)	2.46 (1.39)

Note:
Cell values are means over 10,000 simulations. Numbers in parentheses are standard deviations. *Not Infected* does not include *Vaccinated*.

Natural Experiment: Covid-19 Transmission Under Different Vaccine Priority Scenarios

Natural Experiment

- Most similar cases: California and Oregon counties

- Matching on demographic and economic variables

- Treatment: California opened vaccine eligibility to grocery workers (central nodes) about 1 month earlier than Oregon.
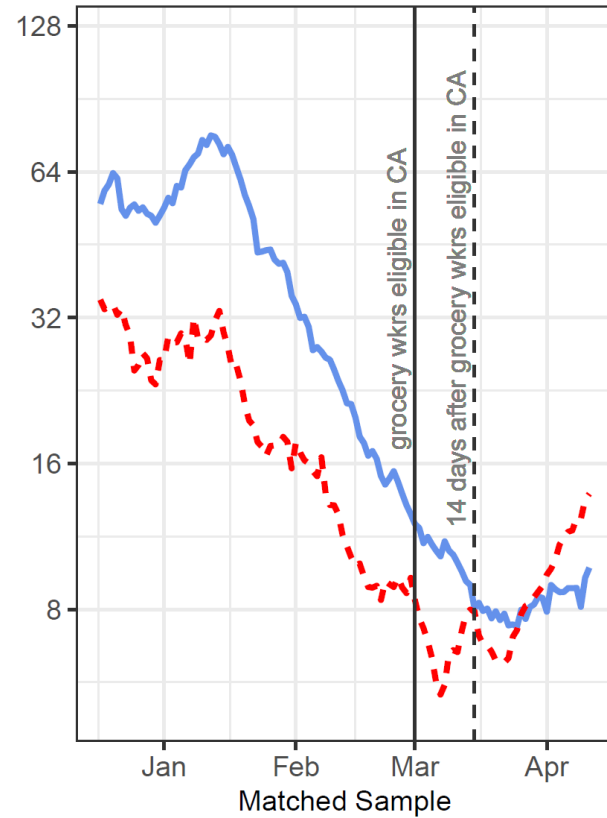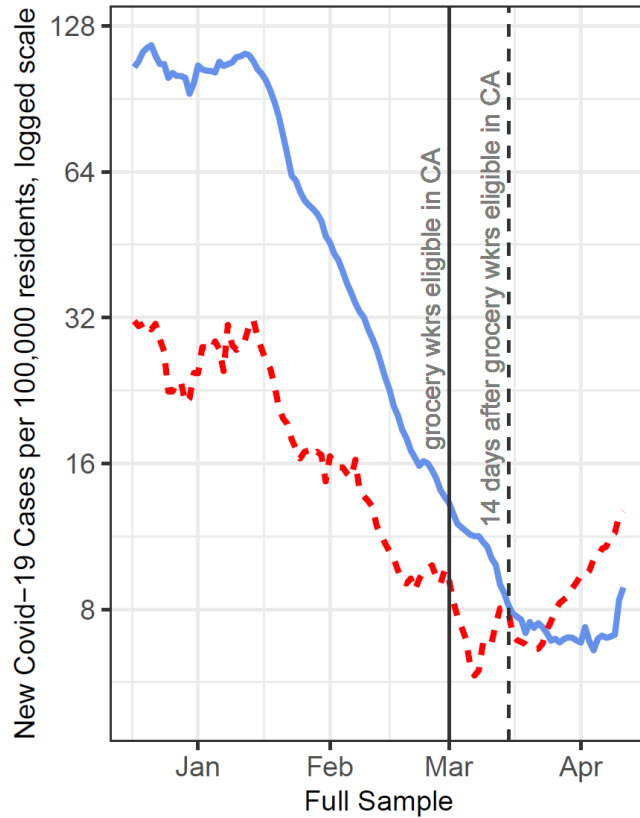
Field Experiment: LinkedIn

Field Experiment

- Randomly vary friend suggestions: weak vs. strong links

- Study the effect of the treatment on job applications and new jobs