Impact of Vaccines and Behavior on Covid-19 Mortality

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Brookings Papers on Economic Activity
28 March 2024
Two main comments

Compartmental models
   Essential for planning/forecasting.
   But how can we judge credibility?

Vaccines
   Vaccines with and without spillovers
   Externalities
Compartmental Models
Compartmental models

Logical framework for thinking about an infectious disease outbreak.

Important tool for assessing possible policy responses.

Perhaps also useful for evaluating policy ex post.
Simple SIR model

Logical and clarifying

Simple structure does not capture dynamics of epidemics.

Assumes random mixing of $S$ and $I$.

No behavioral changes, policies, vaccines.
Expanded Model: SEIHR
The expanded model is intended to be more realistic and accurate.

**Add compartments** to match dynamics, allow viral strains, allow vaccines.

**Add parameters**
- Baseline transmission varies across 4 variants, each introduced at specific times.
- Seasonally varying transmission
- Variant/time varying mortality
- Breakthrough capacity introduced at specific time (omicron)
- Waning immunity

Behavior – Transmission rates respond to daily deaths, semi-elasticity. But fatigue sets in at a specified date reducing the behavioral elasticity.
Key feature: behavior modifies transmission

\[ \beta_i(t) = \bar{\beta}_i \times \exp \left[ -\kappa(t) \frac{dD(t)}{dt} + \psi(t) \right] \]

- Transmission Rate for variant \( i \) in period \( t \)
- Inherent transmissibility of variant \( i \)
- Semi-elasticity of transmission with respect to new deaths
- Seasonality
Predicted mortality from the model lines up well with actual mortality time series

Model has many parameters & compartments

Some chosen to match epi literature

Some chosen to improve model fit.

How to judge performance out of sample?

Predictions about quantities identified in quasi-experimental studies?

Geographic hold out samples?
Vaccines and Spillovers
Vaccines effects

Direct Effects
Vaccination reduces own risk of infection and mortality

Benefits are larger for people with higher mortality risk

Private benefits

Indirect Effects
Vaccinating one person may reduce infection and mortality risk among other people.

Indirect effects may be positive externalities, which may create a role for government
Where do indirect effects come from?

Sterilizing Immunity:
  Vaccination prevents a pathogen from establishing an infection in the body.
  Vaccinated people do not transmit
  Examples: Polio and Measles

Non-Sterilizing Immunity:
  Vaccination does not fully prevent infection and transmission.
  Reduce risk of severe illness and mortality
  Examples: Covid-19 and Influenza
Simple SIR with sterilizing immunity

Vaccine removes people from susceptible compartment.

\[
\text{New Infections} = (1 - v) \left[ \left( S(t) \frac{I(t)}{N} \right) \beta \right]
\]

Increasing the vaccination rate reduces infection risk among unvaccinated.

SEIHR Model considers a vaccine that is not quite sterilizing: allow some waning and a 75% success rate.
Simple SIR with non-sterilizing immunity

Add compartment for infections among vaccinated:

\[ I_v(t) = V(t) \frac{I_u}{N} \alpha_v \]

Infections among unvaccinated: \(((1 - v)S(t)) \left[ \frac{I_u(t)}{N} \beta_u + \frac{I_v(t)}{N} \beta_v \right] \)

Vaccination does not “protect the unvaccinated” if \( \beta_u = \beta_v \).

Full spillover protection if \( \beta_v = 0 \) or \( \alpha_v = 0 \).
Recent work on spillovers

The Effect of Vaccine Mandates on Disease Spread: Evidence from College COVID-19 Mandates

Riley K. Acton, Wenjia Cao, Emily E. Cook, Scott A. Imberman & Michael F. Lovenheim

Direct and indirect effects of vaccines: Evidence from COVID-19

Seth M. Freedman, Daniel W. Sacks, Kosali I. Simon & Coady Wing
Evidence from college vaccine mandates

Acton et al study counties with at least one 4 year residential college.

Event study comparison: vaccine mandate vs no vaccine mandate.

Main result: college vaccine mandate reduces county level Covid cases by about 10% and Covid deaths by about 12%
Evidence from 11 vs 12 year old vaccine eligibility in Indiana

Freedman et al Exploit the delay in vaccine eligibility for 11 vs 12 year olds to study spillover effects in two key settings:

1. Schools – Compare ineligible 6th graders in middle vs elementary schools: do middle school 6th graders benefit from having vaccinated peers?

2. Households – Compare households living with one “newly eligible” child vs one “not eligible” child.
Results

1. Direct effects are clear and large: 80% effectiveness, or -1.3 ppts.

2. Indirect effects are context-specific

   **School Setting:** No detectable spillover created, despite shift from 5→25 ppts vaccinated schoolmates

   **Household Setting:** Substantial spillover, extra vaccinated person reduces infection among other household members by about 2/3 the size of direct effect of vaccine.

3. Mechanisms

   Indirect effects seem to depend on level of mixing.

   Households mix more than school children.

Summary and implications
Implications

If vaccine effects depend on context and mixing, compartmental models that weaken the “random mixing” assumptions may be important.

Future research:
- when and where are mandates apt to be helpful?
- when are spillovers internalized?
- how do “mixing” patterns depend on policy levers?