Behavior and the Transmission of COVID-19

Andy Atkeson, Karen Kopecky, and Tao Zha
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Motivation: After an initial phase of high growth, the growth rate of COVID-19 has stayed within a relatively narrow band around zero for months now. 

![Graph showing growth rate of daily deaths from 69 countries and 34 US states through Nov 12](image)
Economists emphasize endogenous response of behavior to disease prevalence as key to understanding the growth of epidemics.

Predicted growth rates of daily deaths from simple reduced form BSIR model estimated from the initial phase of the pandemic.

Is this a big empirical success?
Patterns our BSIR model cannot match

Italy: rapid decline of daily deaths after initial peak, second wave analytical results
Patterns our BSIR model cannot match

Japan: similar patterns on a smaller scale
Patterns our BSIR model cannot match

Arizona: slow build to first peak
Outline

• Behavioral SIR model

• Analytical results on what it cannot match

• Business Cycle Accounting (CKM) style accounting for disease dynamics into model predictions with and without wedges

• Measuring wedges

• Results
Behavioral SIR model

\[ \beta_i(t) = \bar{\beta}_i Y_i(t)^\alpha \exp(\psi_{\beta,i}(t)) \]

Transmission

\[ Y_i(t) = \exp(-\kappa_i \dot{D}_i(t) + \psi_{y,i}(t)) \]

Behavior

\[ \beta_i(t) = \bar{\beta}_i \exp(-\alpha \kappa_i \dot{D}_i(t) + \psi_i(t)) \]

Reduced form

\[ \psi_i(t) \equiv \alpha \psi_{y,i}(t) + \psi_{\beta,i}(t) \]

Composite wedge

\[ \mathcal{R}_i(0) = \frac{\bar{\beta}_i}{\gamma} \]

Basic reproduction number

\[ \alpha K_i \]

Semi-elasticity of transmission wrt daily deaths
Uncovering the composite wedge

\[ \psi_i(t) = \log \left( \frac{\beta_i(t)}{\bar{\beta}_i} \right) + \alpha \kappa_i \dot{D}_i(t) \]

\( \bar{\beta}_i, \alpha \kappa_i \) Estimated for each region from beginning of epidemic

\( \beta_i(t), \dot{D}_i(t) \) From data on deaths in the region. Transmission rate backed out from SIR model

\[ \beta_i(t) = \bar{\beta}_i \exp(-\alpha \kappa_i \dot{D}_i(t) + \psi_i(t)) \]

Wedge is shift in transmission rate holding disease prevalence constant
Phase diagram for BSIR model

Single peak
Slow decline in Daily deaths

Can’t get multiple waves or sharp decline in deaths after initial peak as in Italy and Japan

\[ \bar{S} = \frac{\gamma}{\beta} \]  
Herd immunity
Phase diagram with wedges

Phase Diagram for St and It

Three years with Big seasonal fluctuations in wedge R(0) shifts from 2.5 to 1.25
Big wedges give small fluctuations in equilibrium growth rates

The effective reproduction number

Daily Deaths

3 years simulation
Model Estimation from Early in Epidemic

Italy

Arizona

Japan
Big wedges needed to account for COVID

Cross-sectional distribution of wedges over time
Wedge dynamics in Italy

Growth rate of daily deaths

Daily deaths

Cumulative Deaths

BSIR (no gammas)

Logistic

BSIR (with gammas)
Phase Diagram Italy

(S,I) Phase Diagram Italy

- BSIR (no γ's)
- inverted SIR
- $I$ locus $t=0$
- $I$ locus $t=7$
- $I$ locus $t=14$
- $I$ locus $t=21$
- $I$ locus $t=28$
- $I$ locus $t=56$
- $I$ locus $t=70$
- $I$ locus $t=84$
Wedge dynamics in Arizona

Growth rate of daily deaths

Daily deaths

Cumulative Deaths
Conclusion

• At a high level, behavioral models a big success
  • Growth rates of daily deaths rapidly falls close to zero
• But a closer look raises new questions
  • Big wedges needed to match
    • Multiple waves
    • Rapid decline in deaths after initial peak
    • Slow build to peak
• Future research: What do these big wedges stand in for?