Behavior and the Transmission of COVID-19

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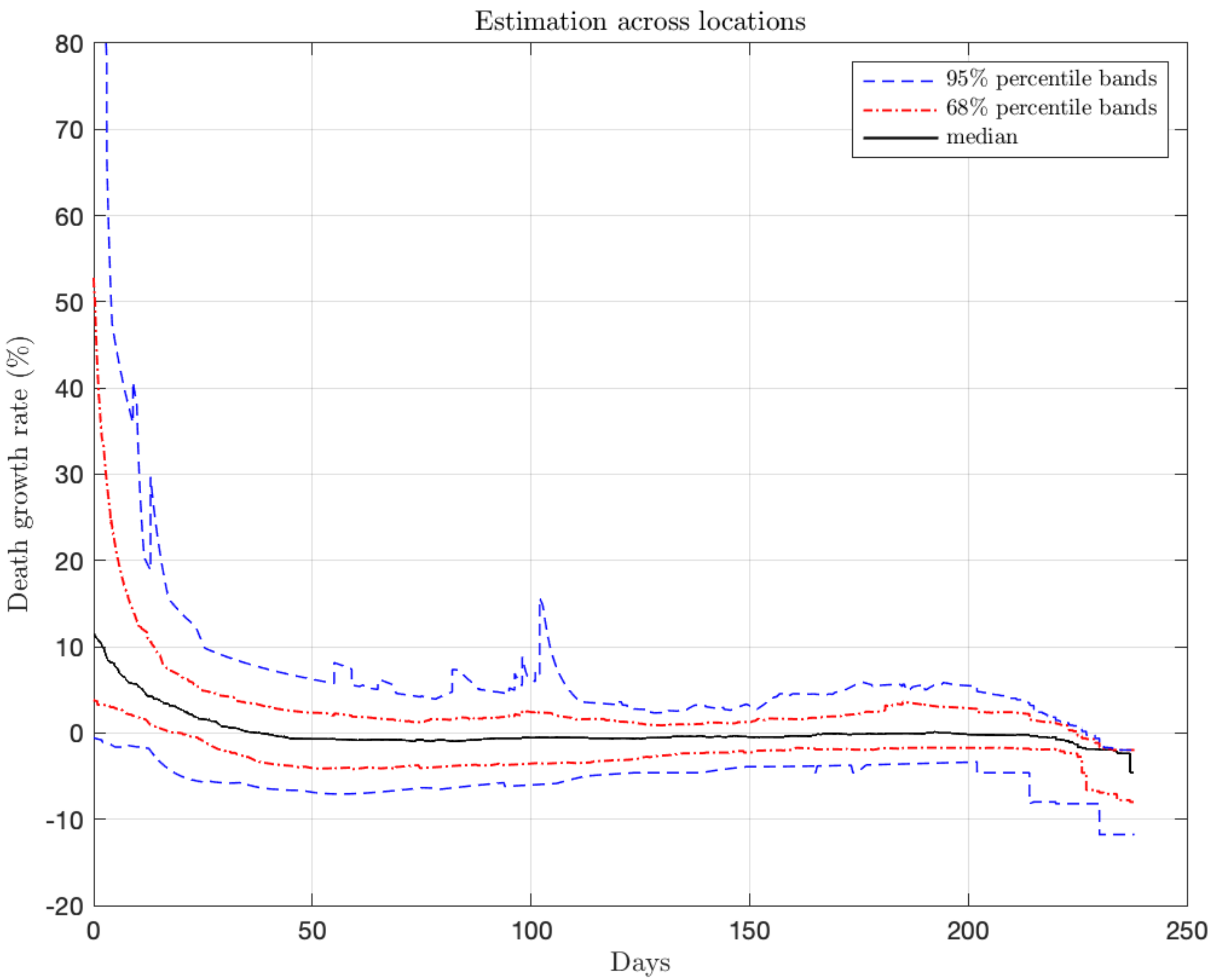
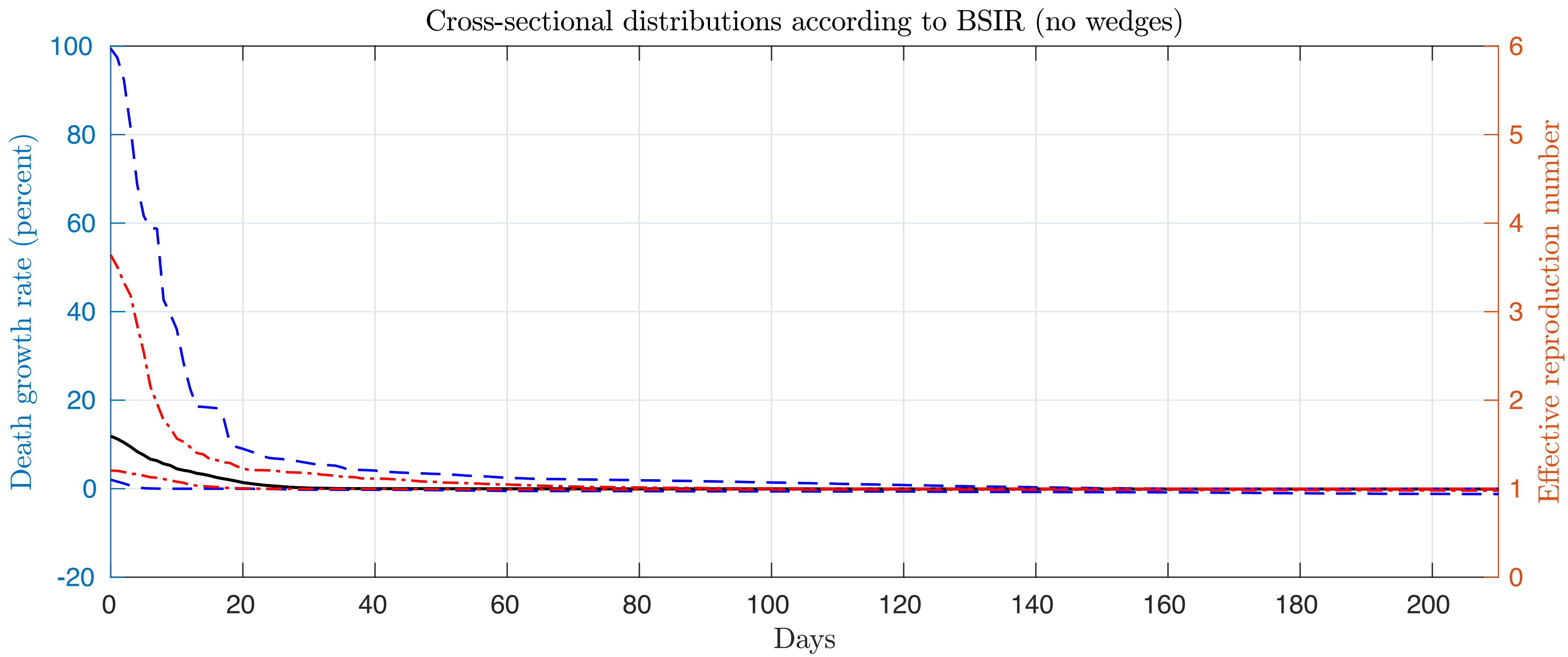
Motivation: After an initial phase of high growth, the growth rate of COVID-19 has stayed within a relatively narrow band around zero for months now



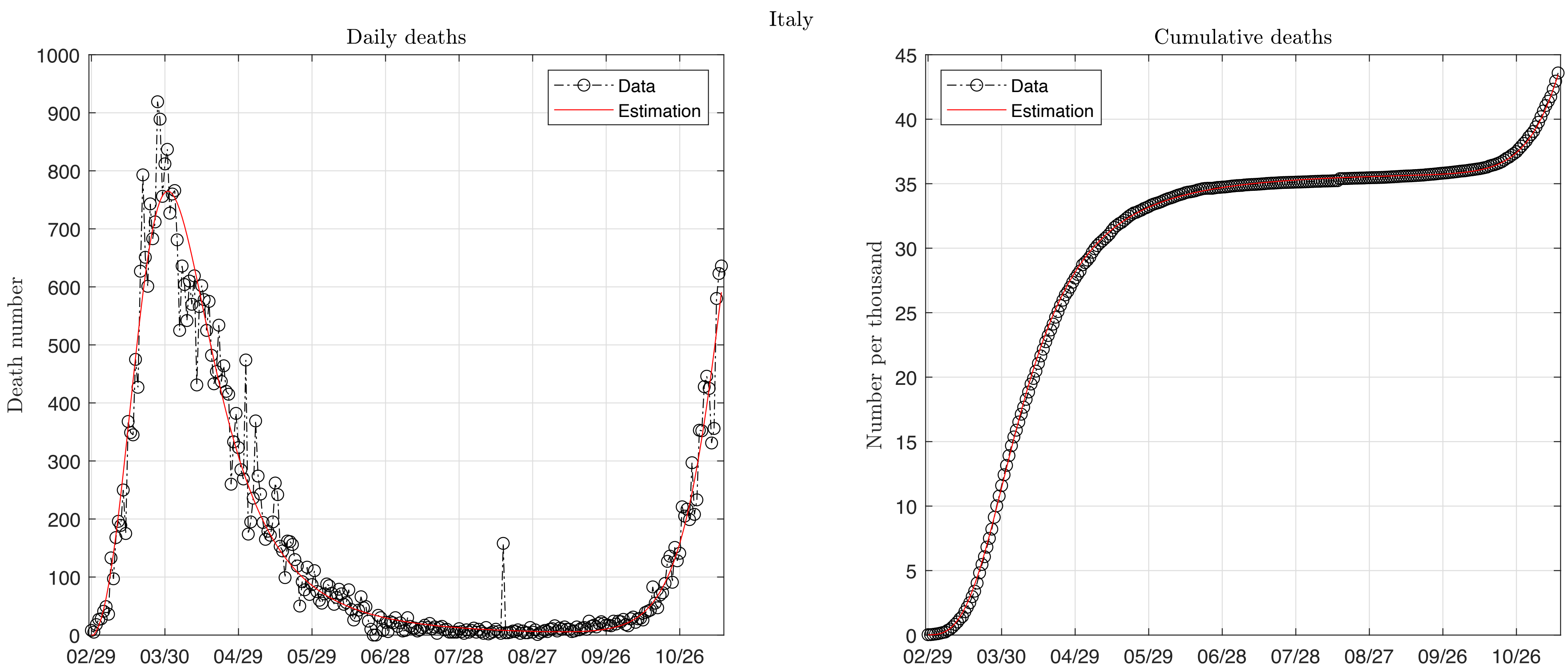
Growth rate of daily deaths from 69 countries and 34 US states through Nov 12

Economists emphasize endogenous response of behavior to disease prevalence as key to understanding the growth of epidemics



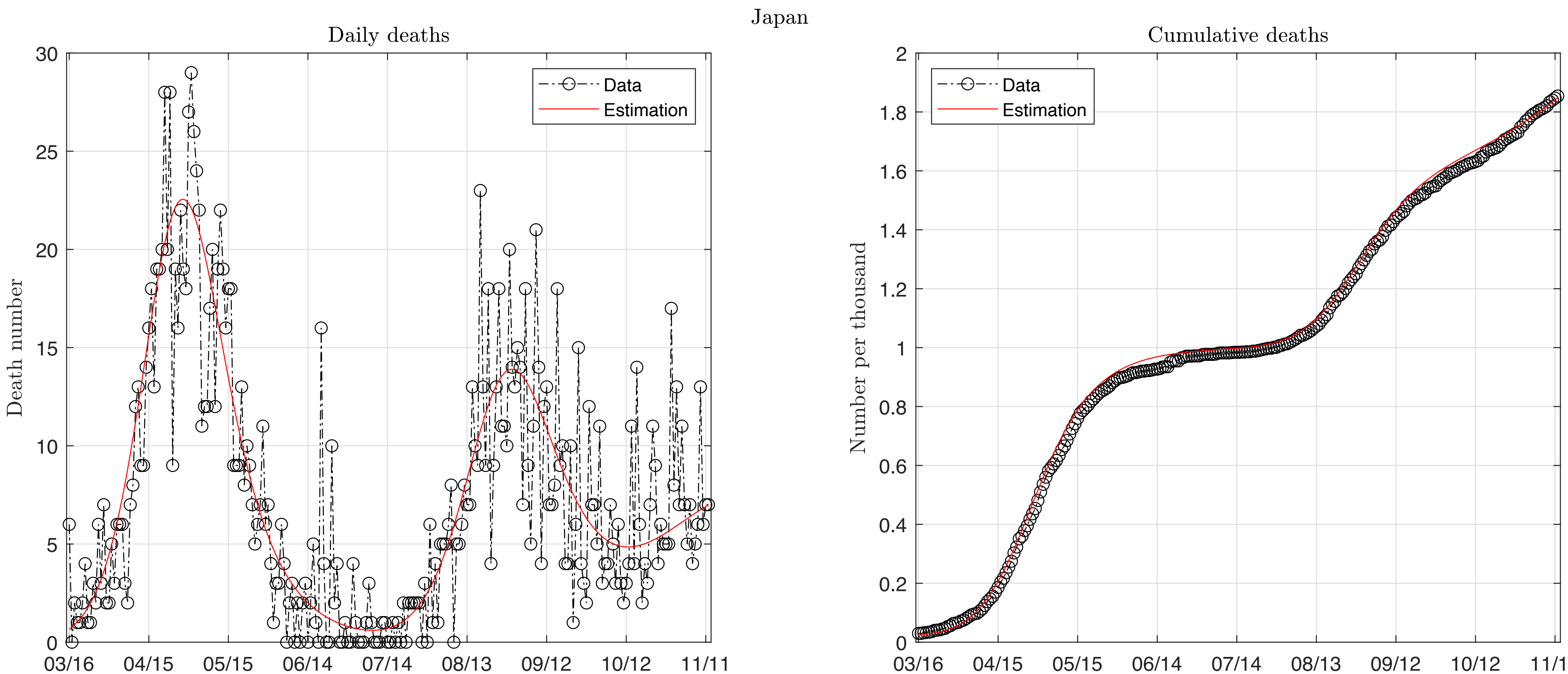
Predicted growth rates of daily deaths from simple reduced form BSIR model estimated from the initial phase of the pandemic
Is this a big empirical success?

Patterns our BSIR model cannot match



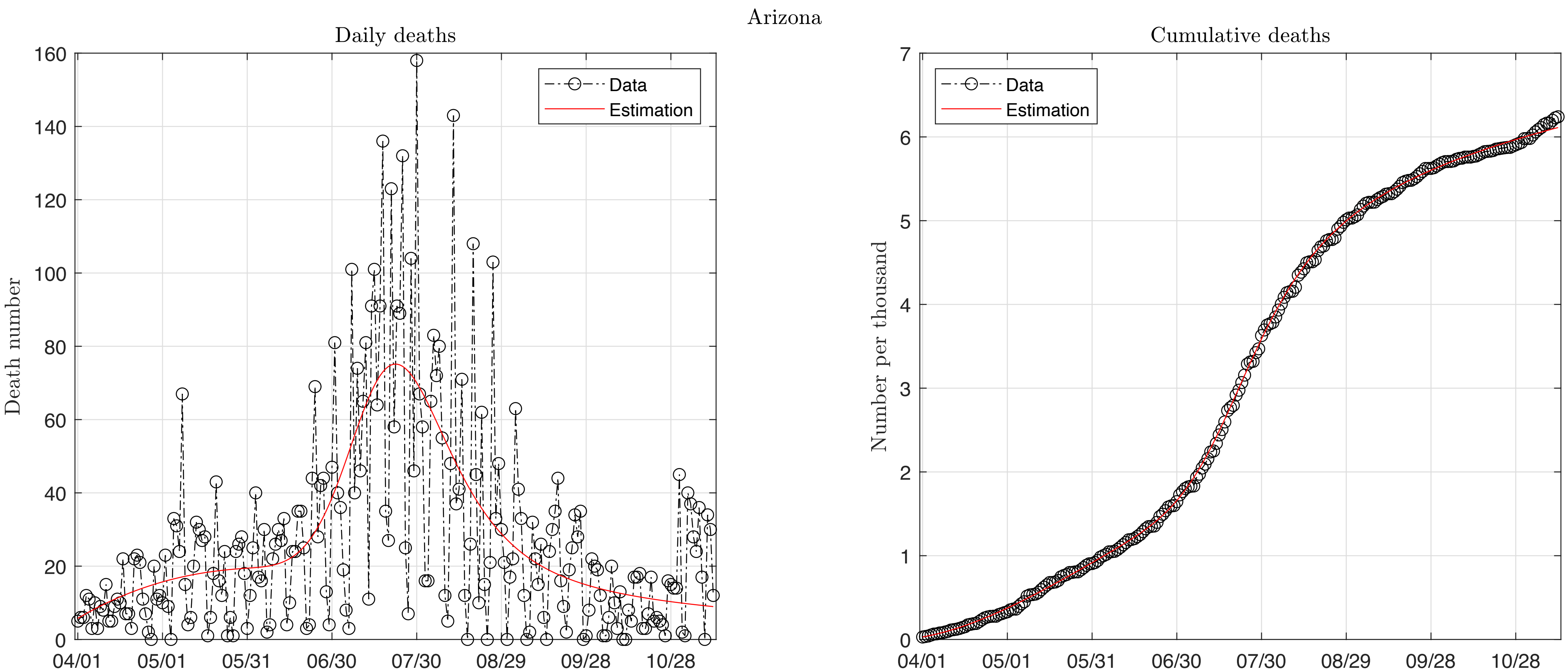
Italy: rapid decline of daily deaths after initial peak, second wave analytical results

Patterns our BSIR model cannot match



Japan: similar patters 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

$$\alpha\kappa_i$$

Semi-elasticity of transmission wrt daily deaths

Uncovering the composite wedge

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

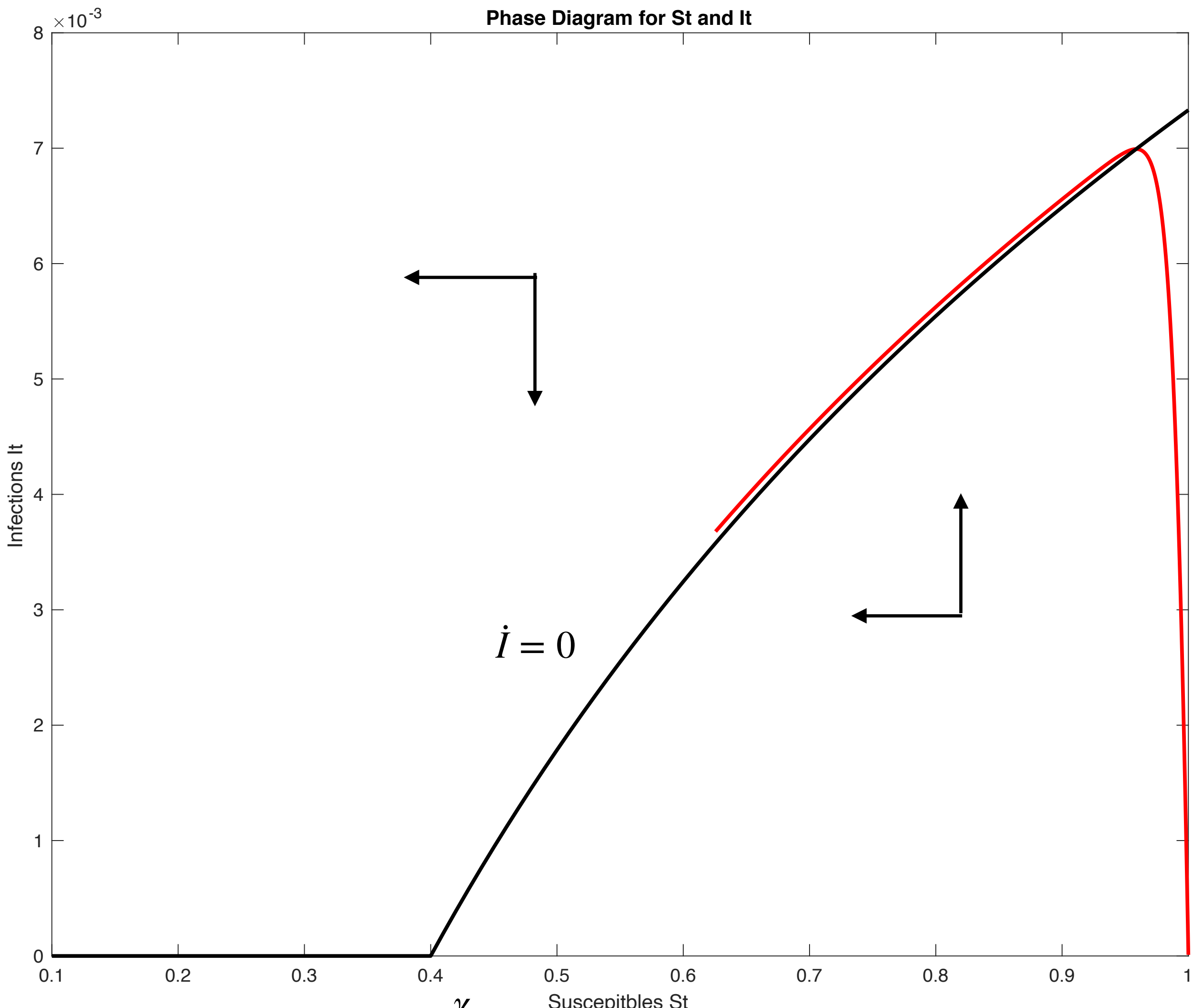
$\bar{\beta}_i, \alpha\kappa_i$ **Estimated for each region from beginning of epidemic**

$\beta_i(t), \dot{D}_i(t)$ **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



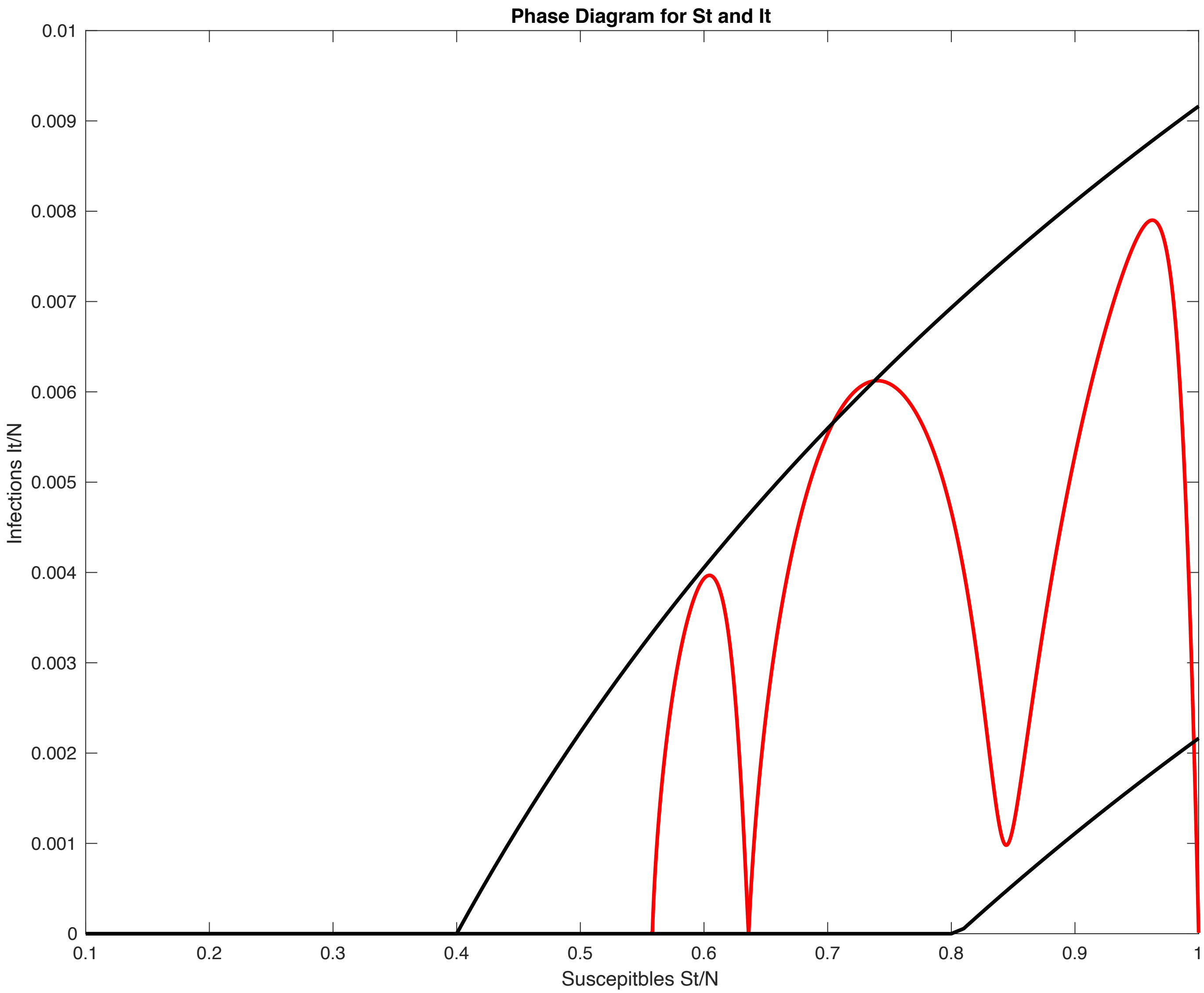
$\bar{S} = \frac{\gamma}{\bar{\beta}}$

Herd immunity

Single peak
Slow decline in
Daily deaths

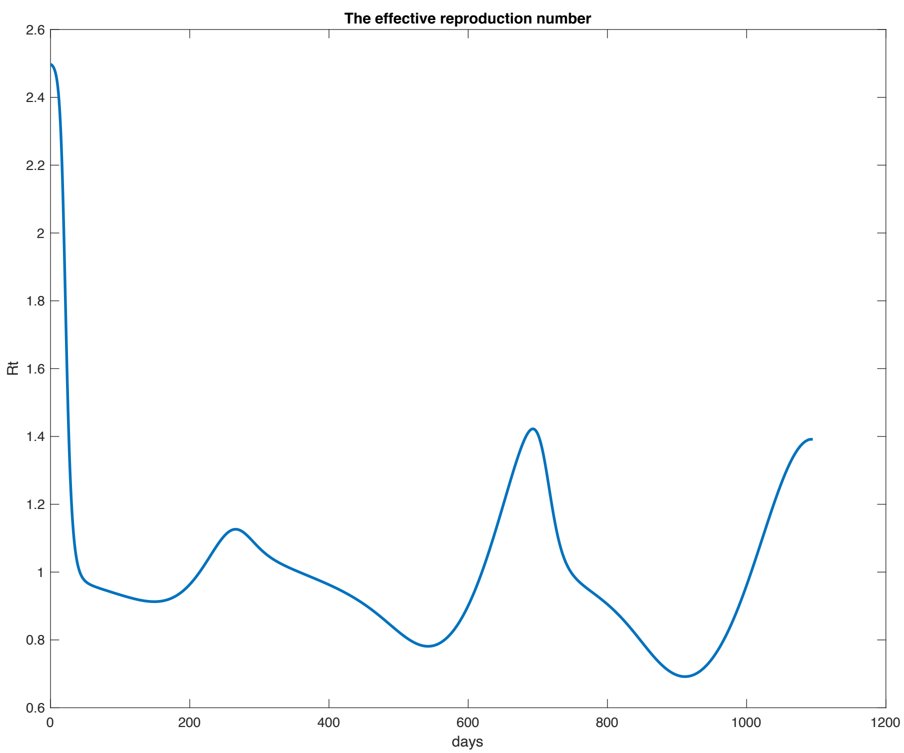
Can't get
multiple waves
or sharp decline
in deaths after
initial peak
as in Italy and
Japan

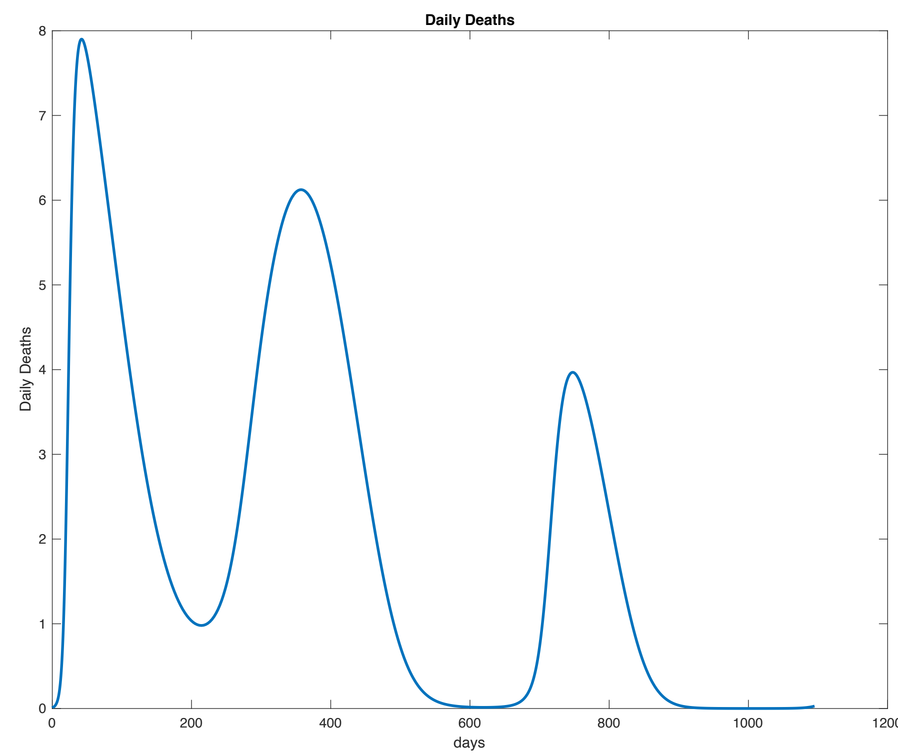
Phase diagram with wedges



Three years with
Big seasonal
fluctuations in wedge
R(0) shifts from
2.5 to 1.25

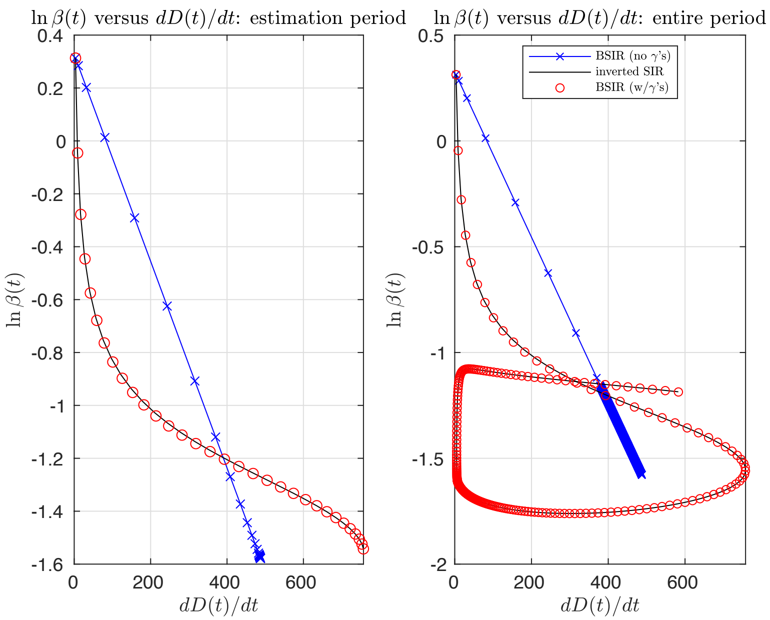
Big wedges give small fluctuations in equilibrium growth rates



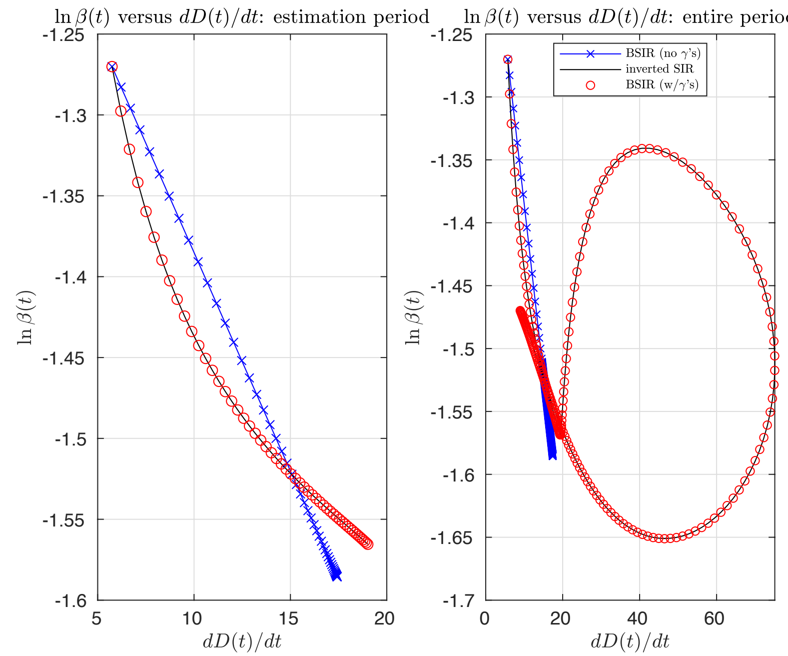


3 years simulation

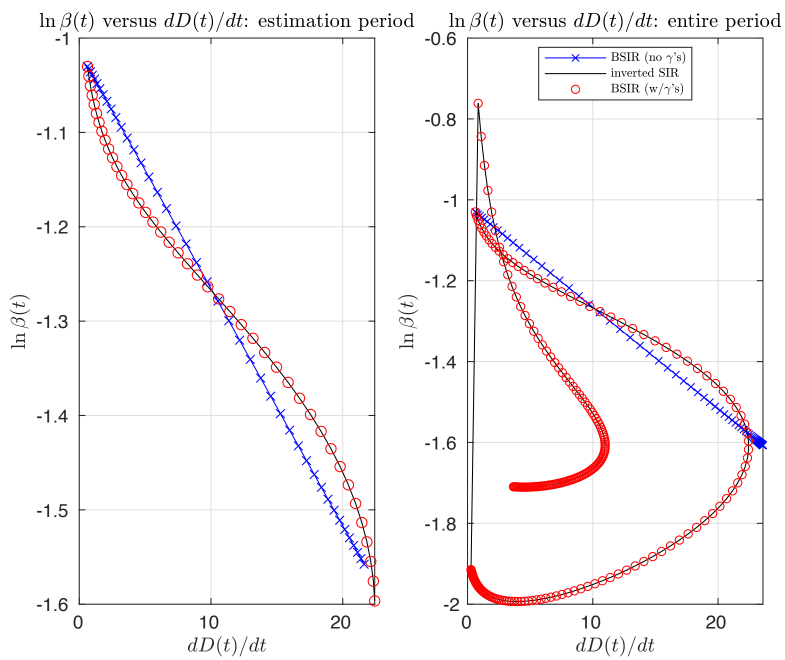
Model Estimation from Early in Epidemic



Italy

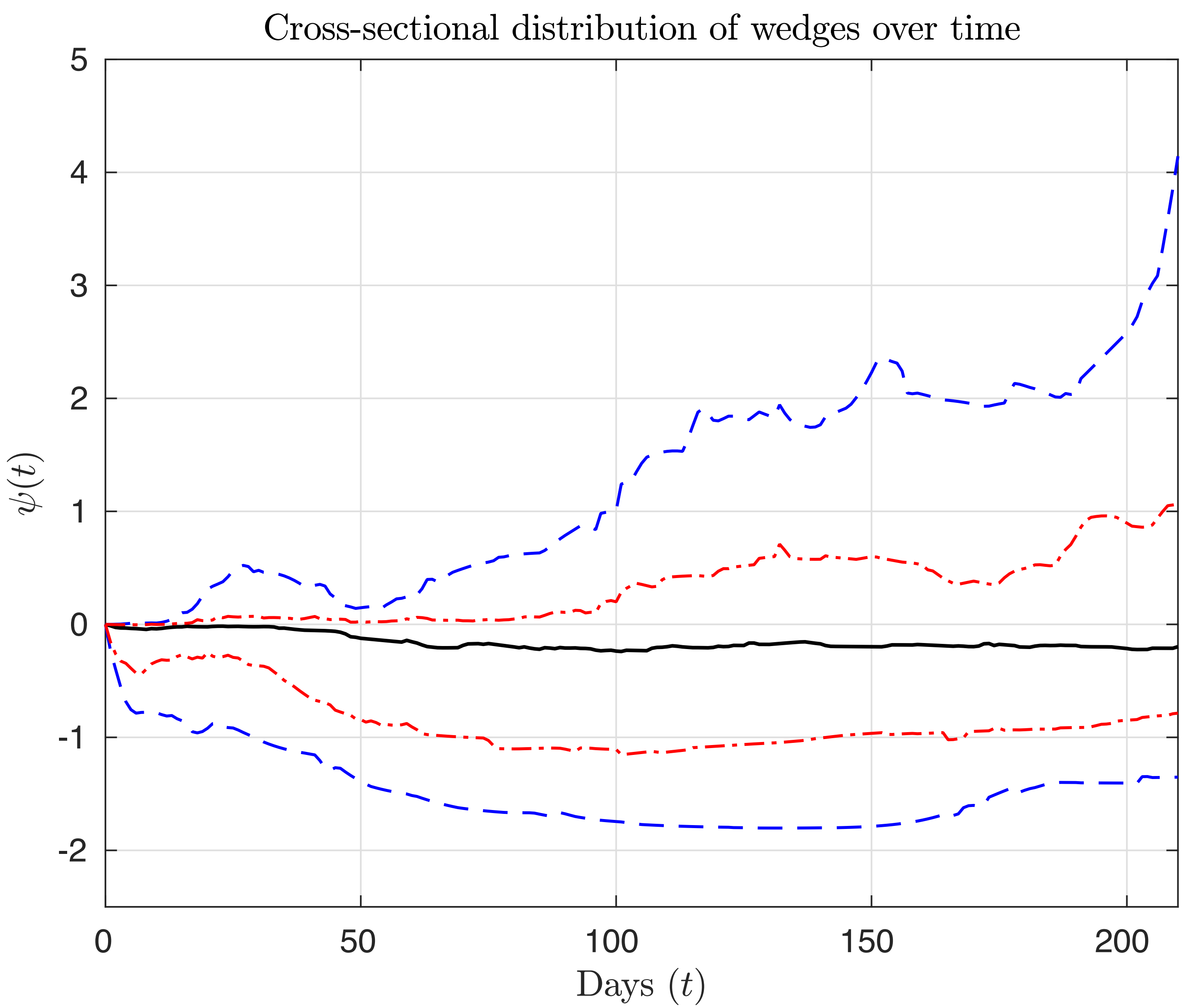


Arizona

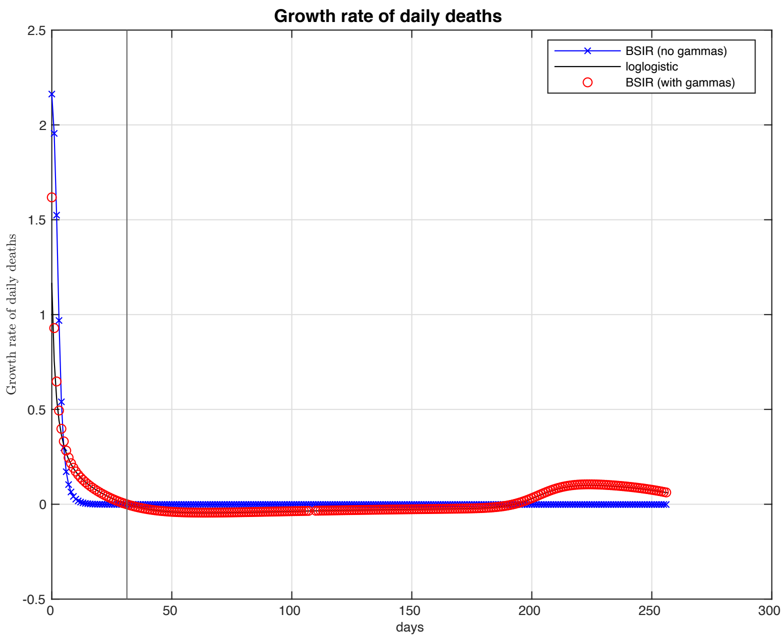


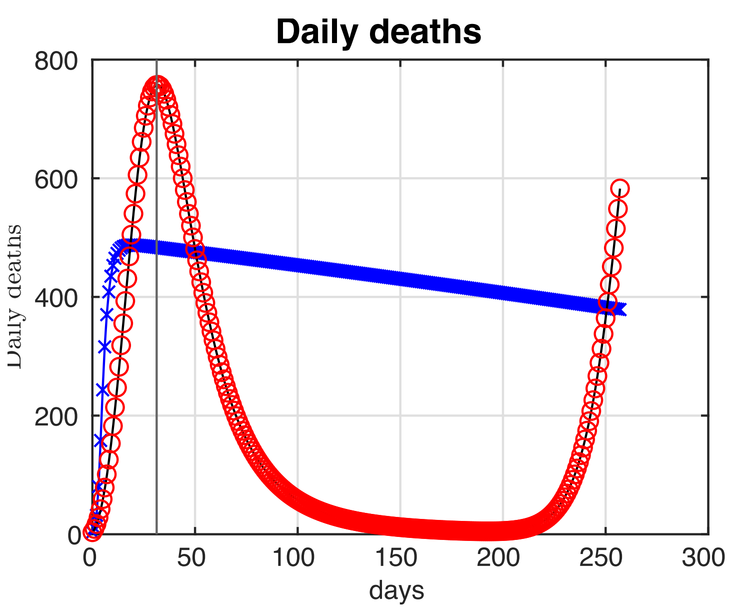
Japan

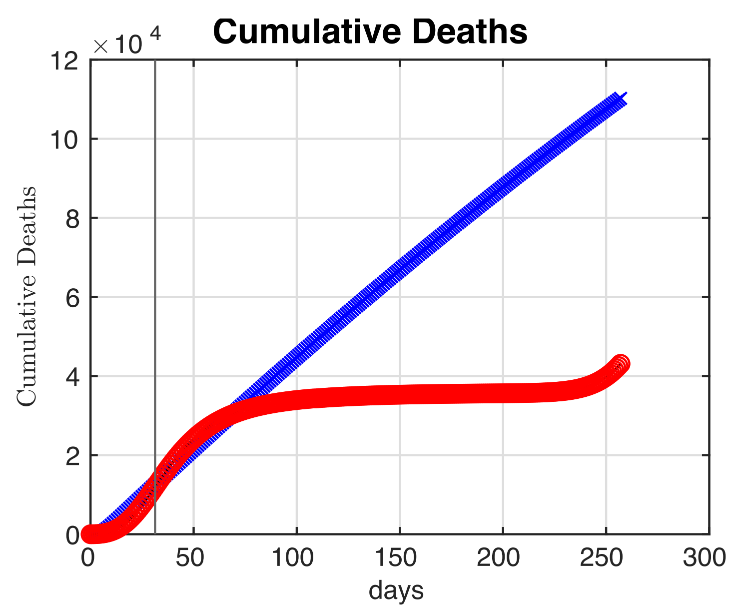
Big wedges needed to account for COVID



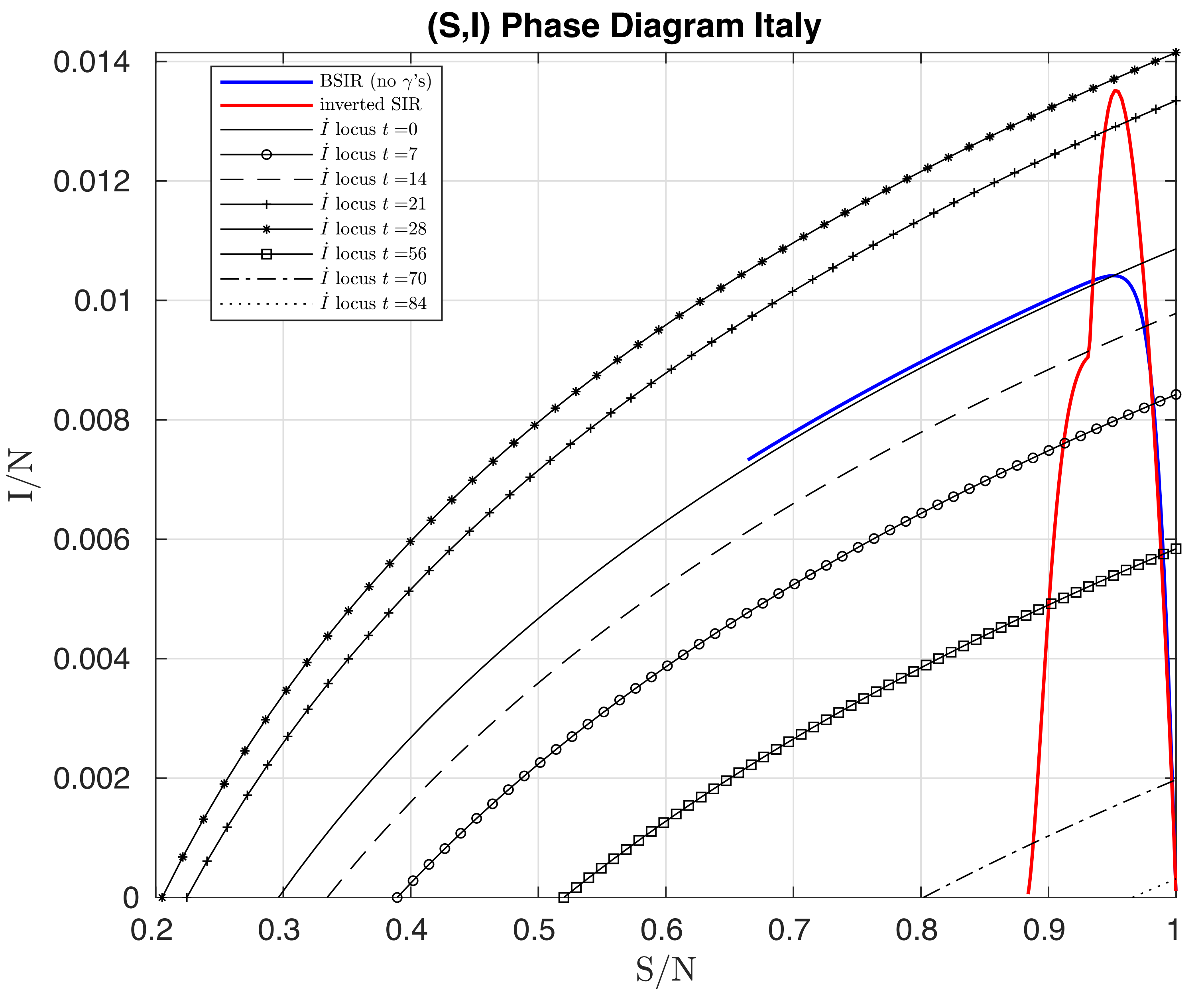
Wedge dynamics in Italy



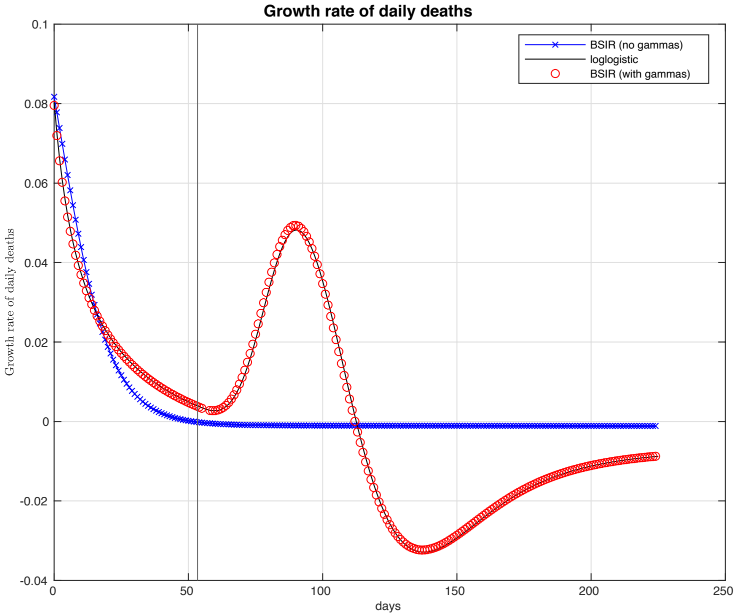


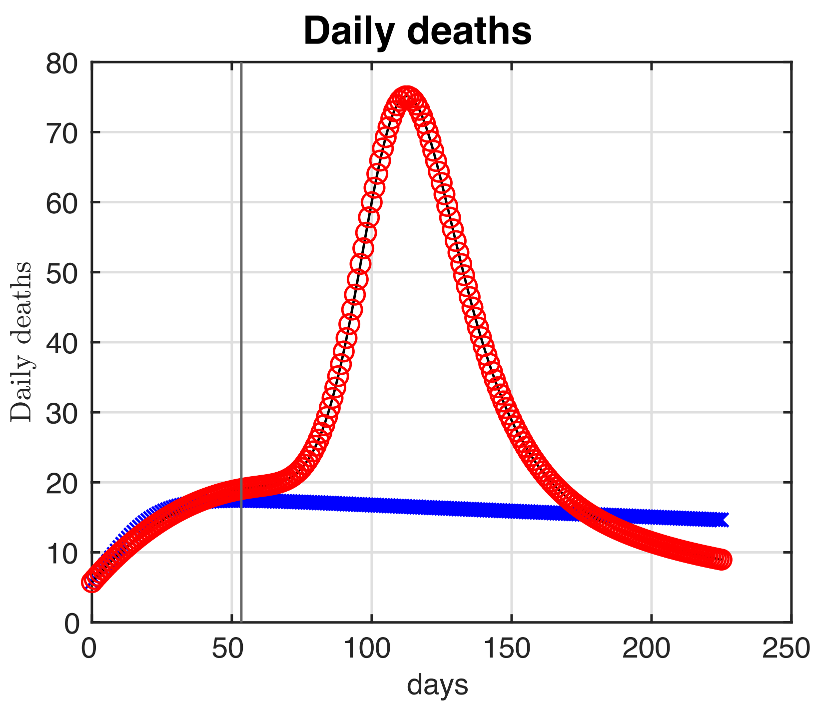


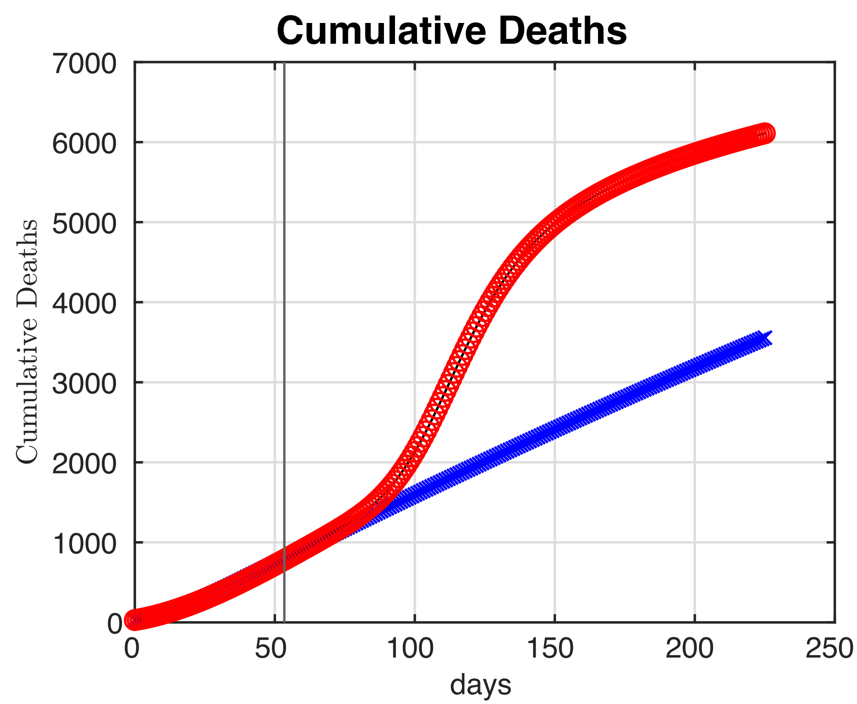
Phase Diagram Italy



Wedge dynamics in Arizona







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?