



Estimating and Simulating a SIRD Model of COVID-19 for Many Countries, States, and Cities

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Extended results for Tennessee
Based on data through October 9, 2020

Outline of Slides

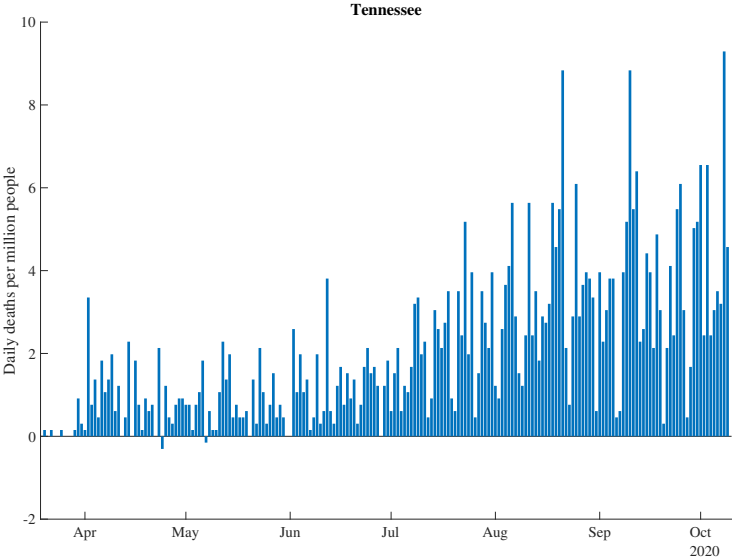
- Basic data from Johns Hopkins CSSE (raw and smoothed)
- Brief summary of the model
- Baseline results ($\delta = 1.0\%$, $\gamma = 0.2$, $\theta = 0.1$)
- Simulation of re-opening – possibilities for raising R_0
- Results with alternative parameter values:
 - Lower mortality rate, $\delta = 0.8\%$
 - Higher mortality rate, $\delta = 1.2\%$
 - Infections last longer, $\gamma = 0.15$
 - Cases resolve more quickly, $\theta = 0.2$
 - Cases resolve more slowly, $\theta = 0.07$
- Data underlying estimates of $R_0(t)$



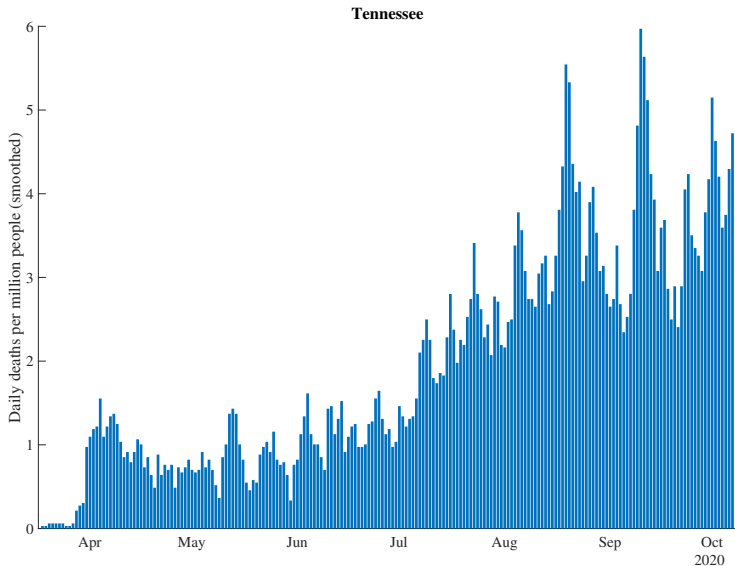
Underlying data from Johns Hopkins CSSE

- Raw data
- Smoothed = 7 day centered moving average
- No “excess deaths” correction (change as of Aug 6 run)

Tennessee: Daily Deaths per Million People



Tennessee: Daily Deaths per Million People (Smoothed)



Brief Summary of Model

- See the [paper](#) for a full exposition
- A 5-state SIRDC model with a time-varying R_0

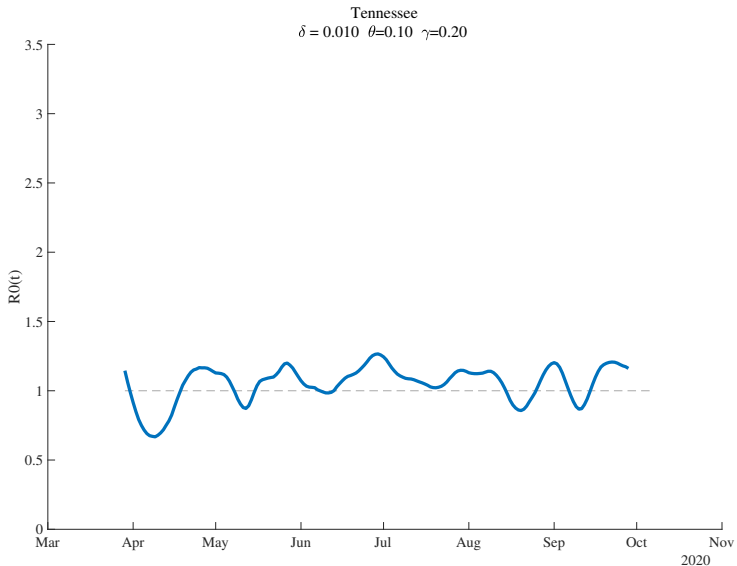
Parameter	Baseline	Description
δ	1.0%	Mortality rate from infections (IFR)
γ	0.2	Rate at which people stop being infectious
θ	0.1	Rate at which cases (post-infection) resolve
α	0.05	Rate at which $R_0(t)$ decays with daily deaths
R_0	...	Initial base reproduction rate
$R_0(t)$...	Base reproduction rate at date t (β_t/γ)



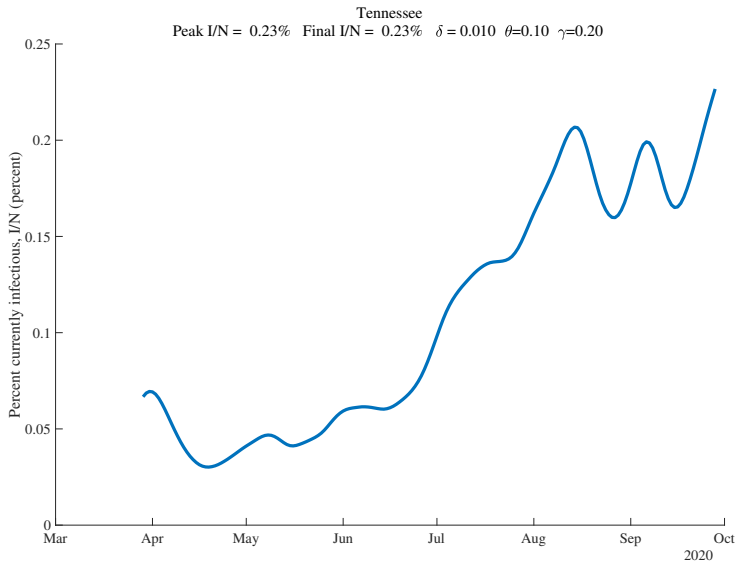
Estimates of Time-Varying R_0

- Inferred from daily deaths, and
 - the change in daily deaths, and
 - the change in (the change in daily deaths)
- (see end of slide deck for this data)

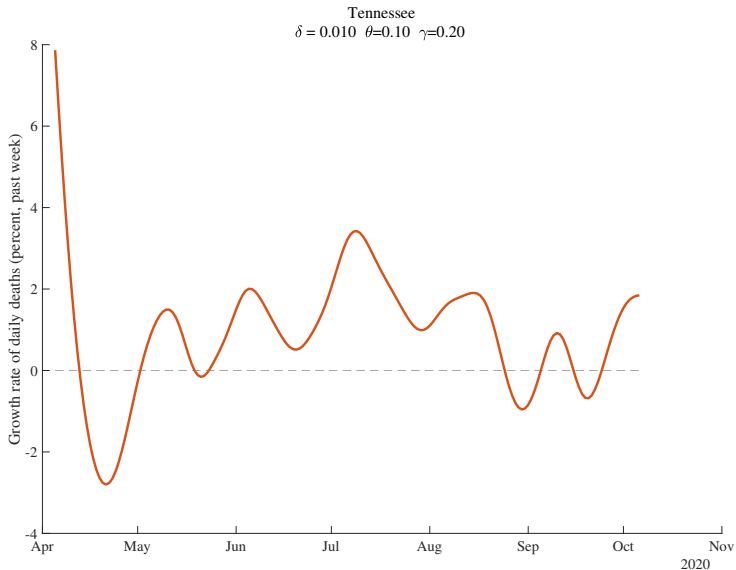
Tennessee: Estimates of $R_0(t)$



Tennessee: Percent Currently Infectious



Tennessee: Growth Rate of Daily Deaths over Past Week (percent)





Notes on Intepreting Results

Guide to Graphs

- **Warning:** Results are often very uncertain; this can be seen by comparing across multiple graphs. See the [original paper](#).
- 7 days of forecasts: Rainbow color order!
ROY-G-BIV (old to new, low to high)
 - Black=current
 - Red = oldest, Orange = second oldest, Yellow =third oldest...
 - Violet (purple) = one day earlier
- For robustness graphs, same idea
 - Black = baseline (e.g. $\delta = 1.0\%$)
 - Red = lowest parameter value (e.g. $\delta = 0.8\%$)
 - Green = highest parameter value (e.g. $\delta = 1.2\%$)

How does R_0 change over time?

- Inferred from death data when we have it
- For future, two approaches:
 - ① Alternatively, we fit this equation:

$$\log R_0(t) = a_0 - \alpha(\text{Daily Deaths})$$

$$\Rightarrow \alpha \approx .05$$

*R_0 declines by 5 percent for each new daily death,
or rises by 5 percent when daily deaths decline*

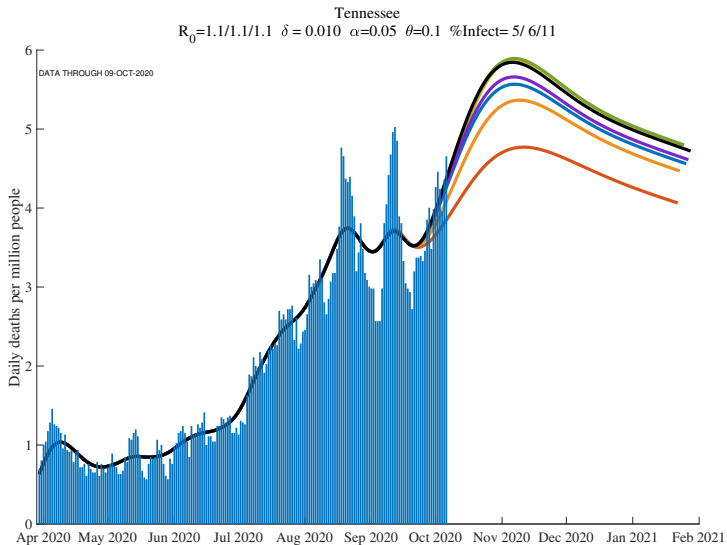
- Robustness: Assume $R_0(t) =$ final empirical value. Constant in future, so no α adjustment $\rightarrow \alpha = 0$



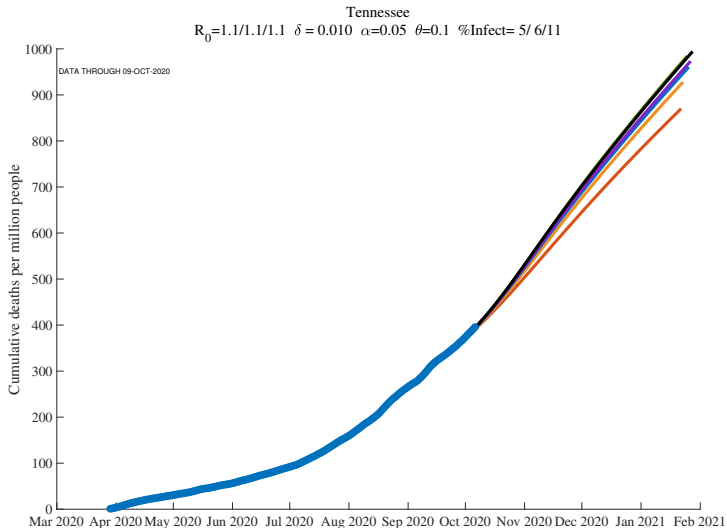
Repeated “Forecasts” from the past 7 days of data

- After peak, forecasts settle down.
- Before that, very noisy!
- If the region has not peaked, do not trust
- With $\alpha = .05$ (see robustness section for $\alpha = 0$)

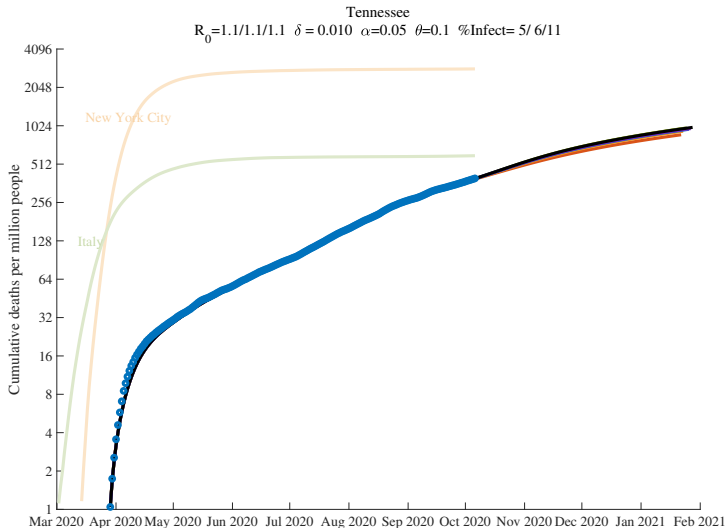
Tennessee (7 days): Daily Deaths per Million People ($\alpha = .05$)



Tennessee (7 days): Cumulative Deaths per Million (Future, $\alpha = .05$)



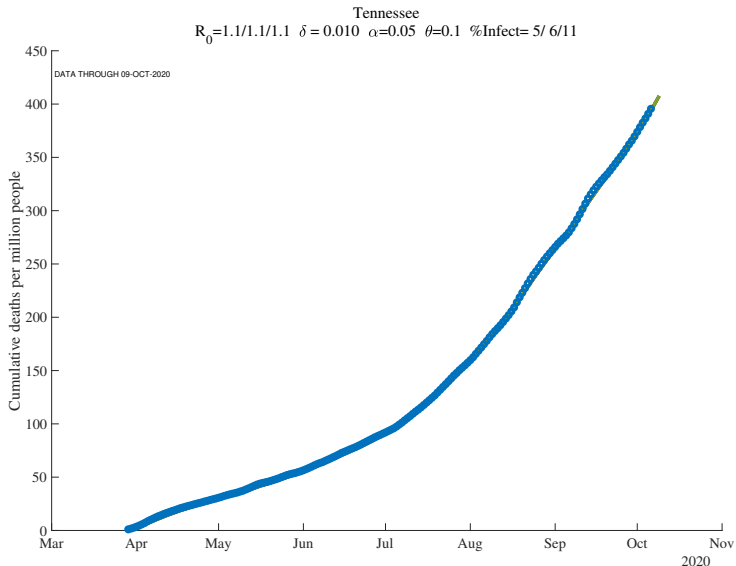
Tennessee (7 days): Cumulative Deaths per Million, Log Scale ($\alpha = .05$)



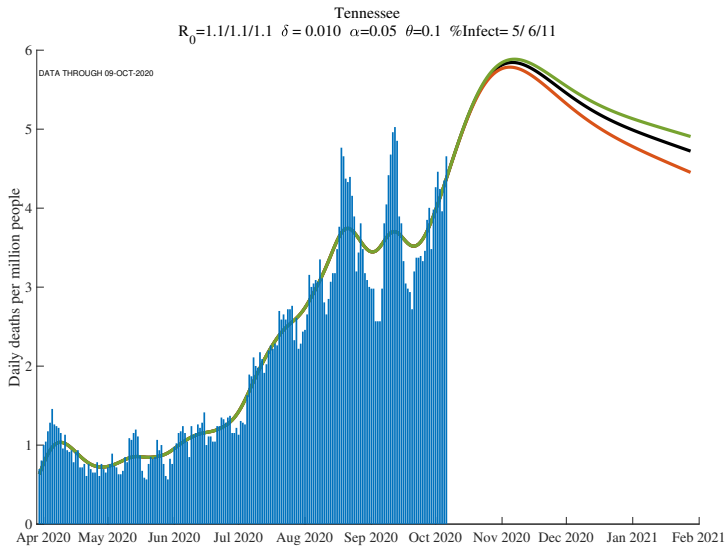


Robustness to Mortality Rate, δ

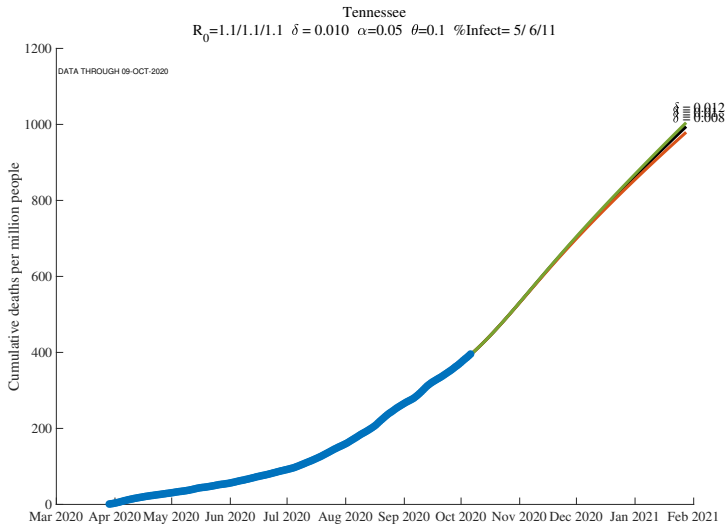
Tennessee: Cumulative Deaths per Million ($\delta = .01/.008/.012$)



Tennessee: Daily Deaths per Million People ($\delta = .01/.008/.012$)



Tennessee: Cumulative Deaths per Million ($\delta = .01/.008/.012$)



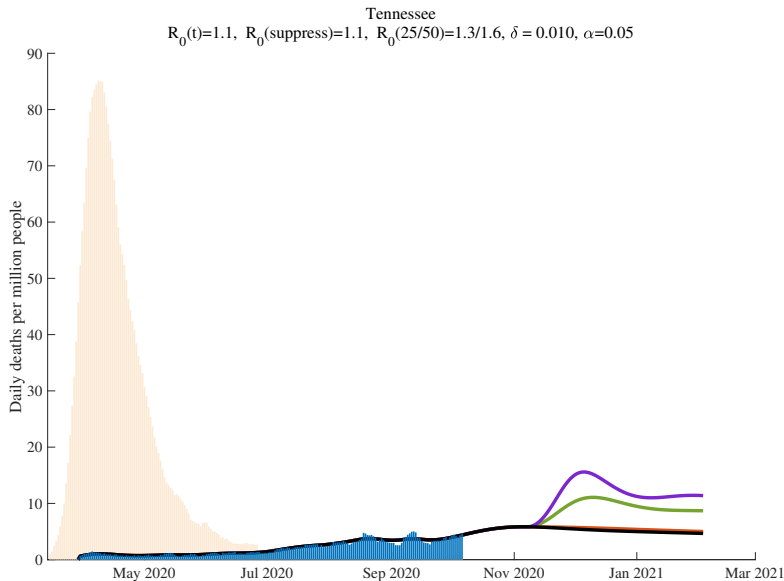


Reopening and Herd Immunity

- Black: assumes $R_0(\text{today})$ remains in place forever
- Red: assumes $R_0(\text{suppress}) = 1/s(\text{today})$
- Green: we move 25% of the way from $R_0(\text{today})$ back to initial $R_0 = \text{“normal”}$
- Purple: we move 50% of the way from $R_0(\text{today})$ back to initial $R_0 = \text{“normal”}$

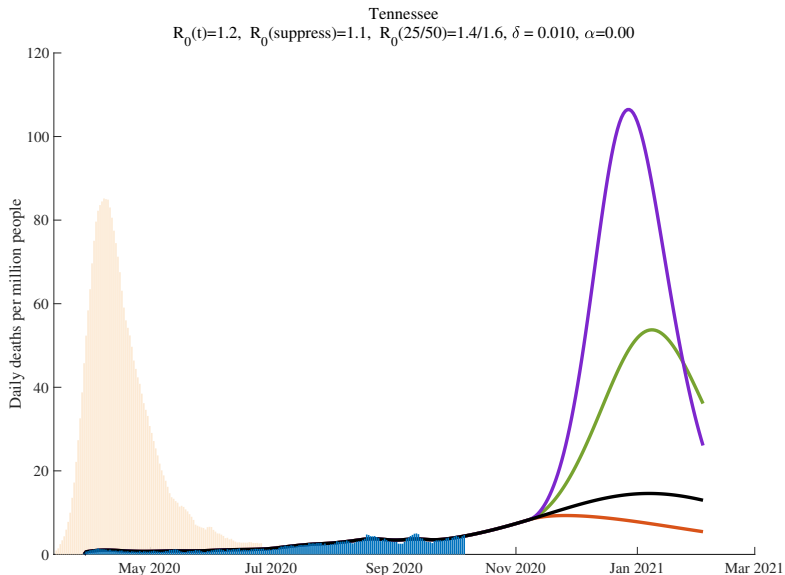
NOTE: Lines often cover each other up

Tennessee: Re-Opening ($\alpha = .05$)



(Light bars = New York City, for comparison)

Tennessee: Re-Opening ($\alpha = 0$)

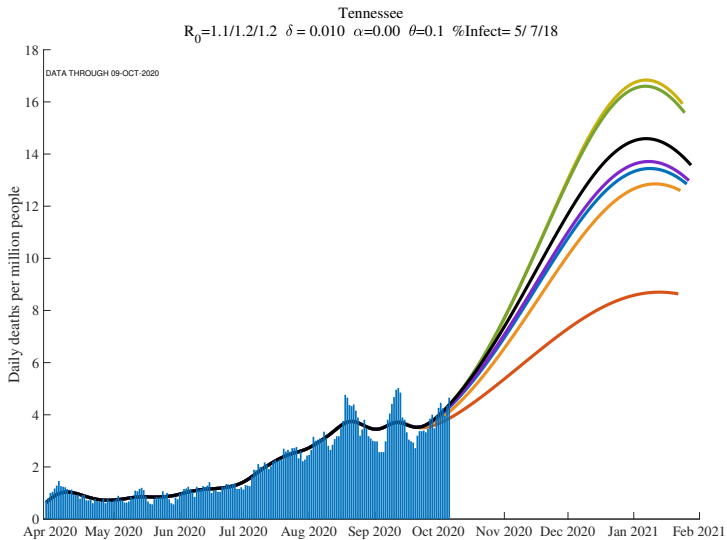


(Light bars = New York City, for comparison)

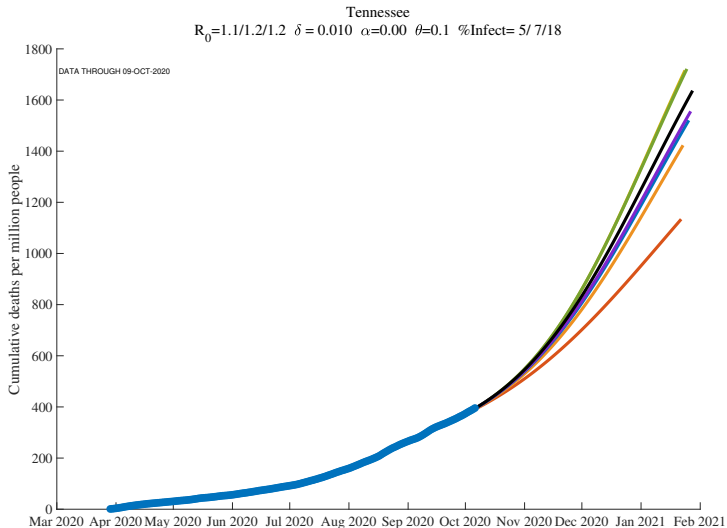


Results for alternative parameter values

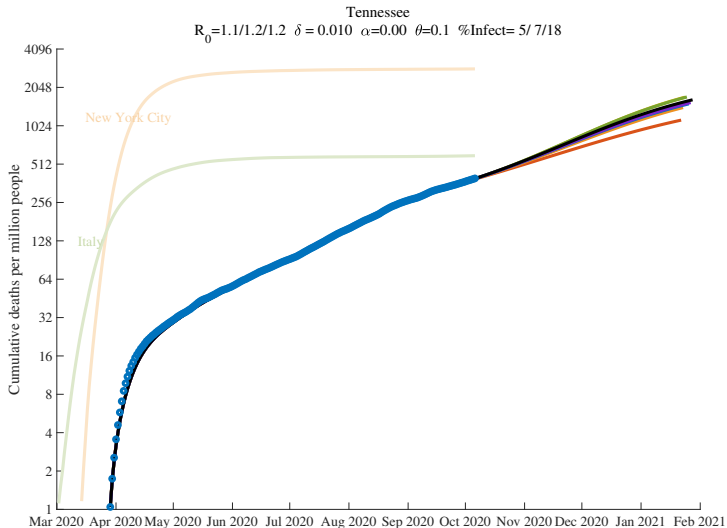
Tennessee (7 days): Daily Deaths per Million People ($\alpha = 0$)



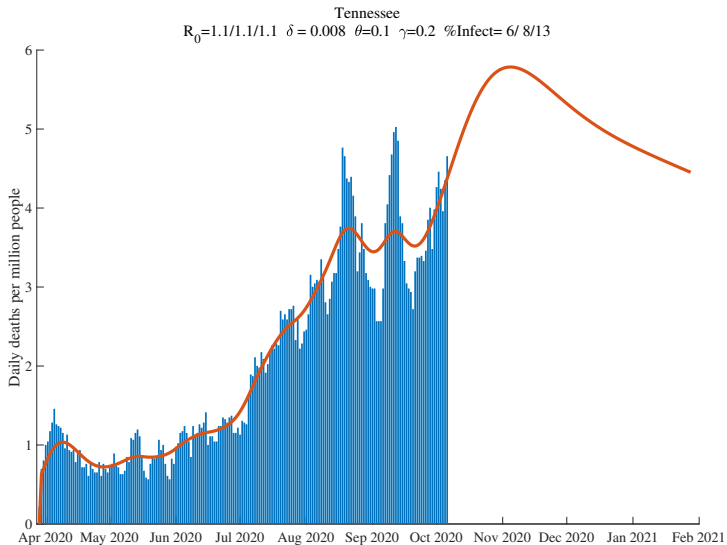
Tennessee (7 days): Cumulative Deaths per Million (Future, $\alpha = 0$)



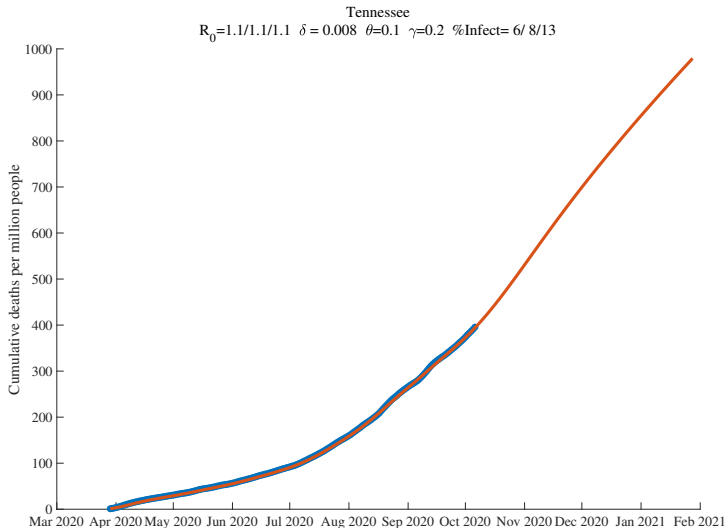
Tennessee (7 days): Cumulative Deaths per Million, Log Scale ($\alpha = 0$)



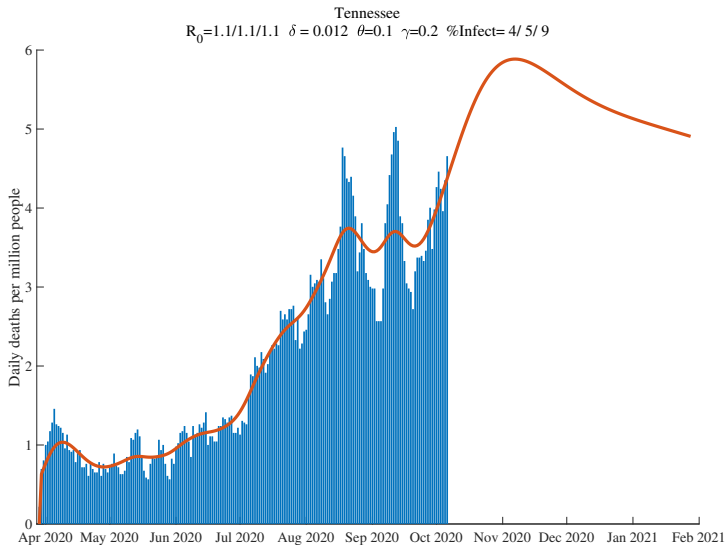
Tennessee: Daily Deaths per Million People ($\delta = 0.8\%$)



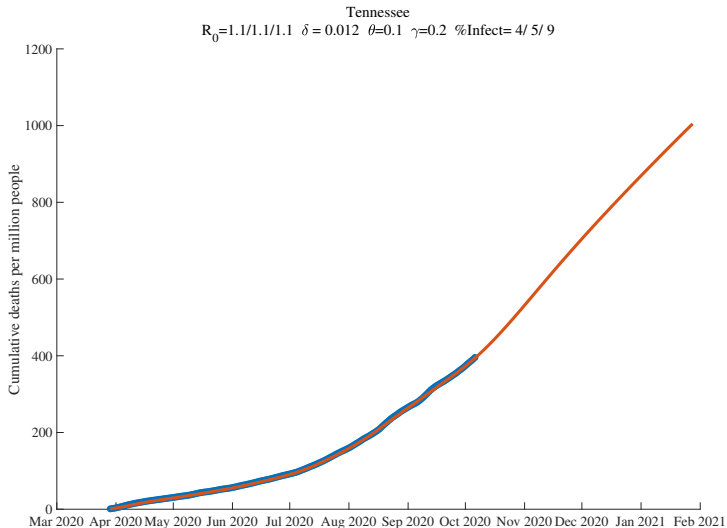
Tennessee: Cumulative Deaths per Million ($\delta = 0.8\%$)



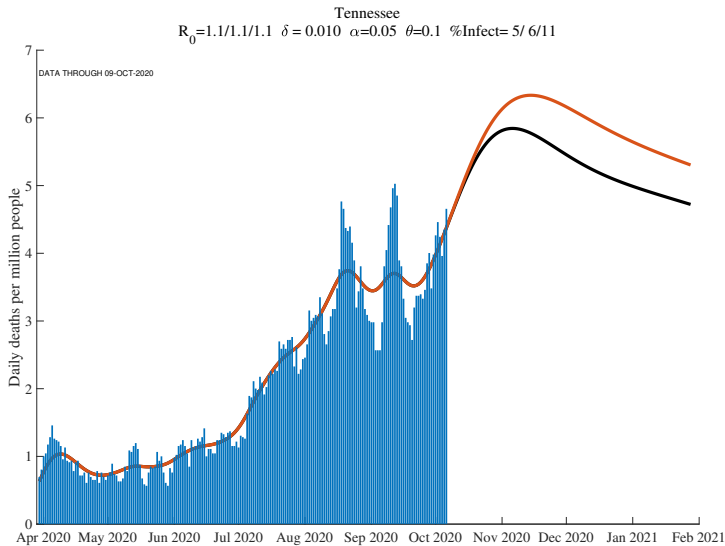
Tennessee: Daily Deaths per Million People ($\delta = 1.2\%$)



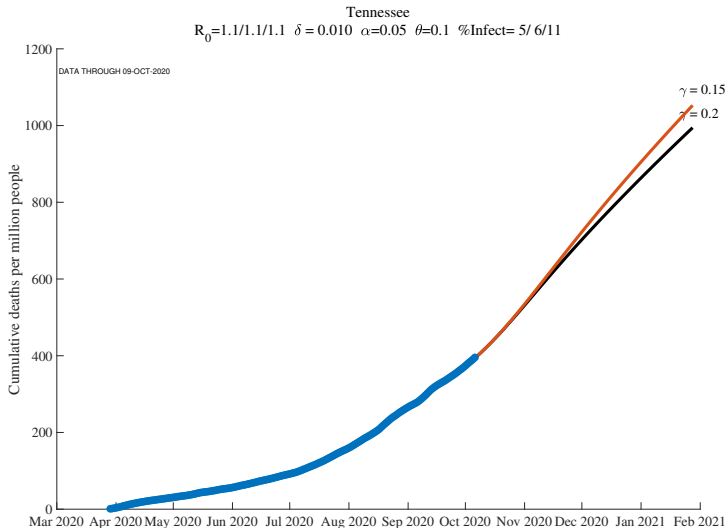
Tennessee: Cumulative Deaths per Million ($\delta = 1.2\%$)



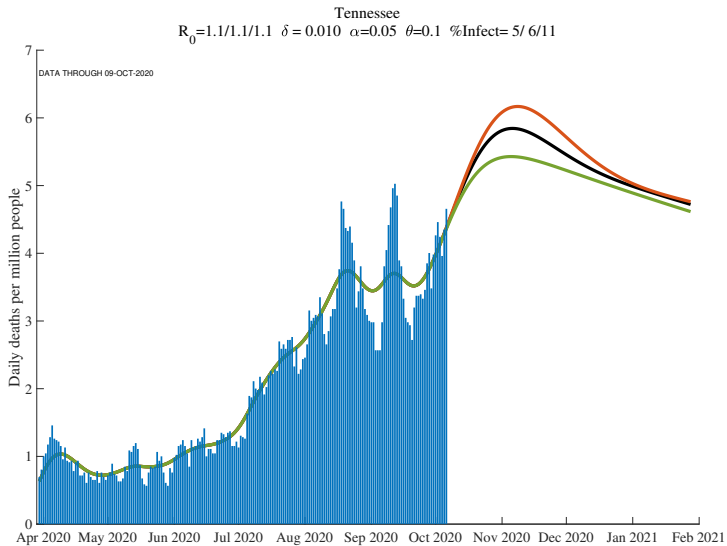
Tennessee: Daily Deaths per Million People ($\gamma = .2/.15$)



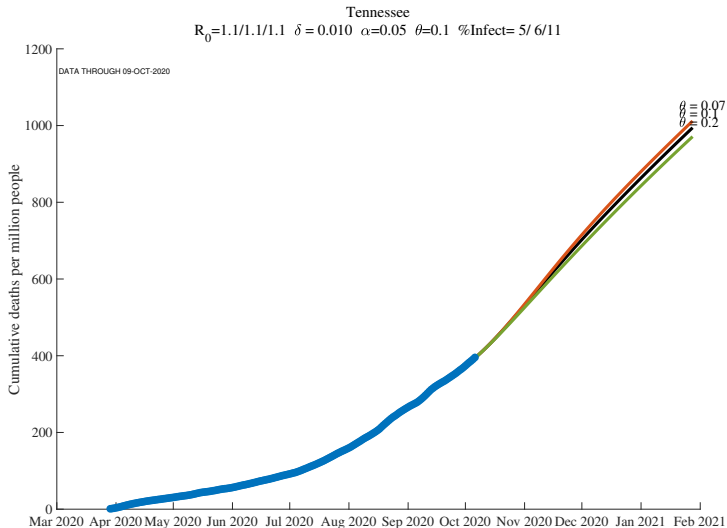
Tennessee: Cumulative Deaths per Million $\gamma = .2/.15$



Tennessee: Daily Deaths per Million People ($\theta = .1/.07/.2$)



Tennessee: Cumulative Deaths per Million People ($\theta = .1/.07/.2$)





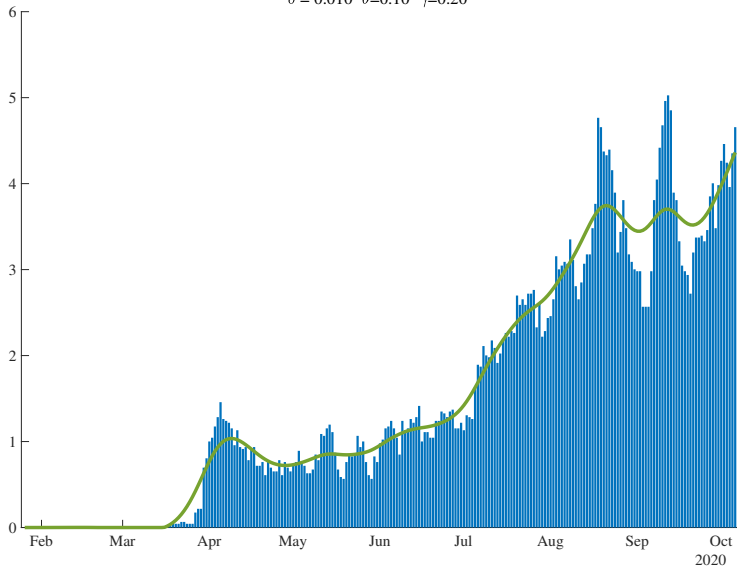
Data Underlying Estimates of Time-Varying R_0

- Inferred from daily deaths, and
- the change in daily deaths, and
- the change in (the change in daily deaths)

Tennessee: Daily Deaths, Actual and Smoothed

Tennessee: Daily deaths, d

$\delta = 0.010$ $\theta = 0.10$ $\gamma = 0.20$



Tennessee: Change in Smoothed Daily Deaths



Tennessee: Change in (Change in Smoothed Daily Deaths)

