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

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Extended results for District of Columbia

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, $\theta = 0.07$
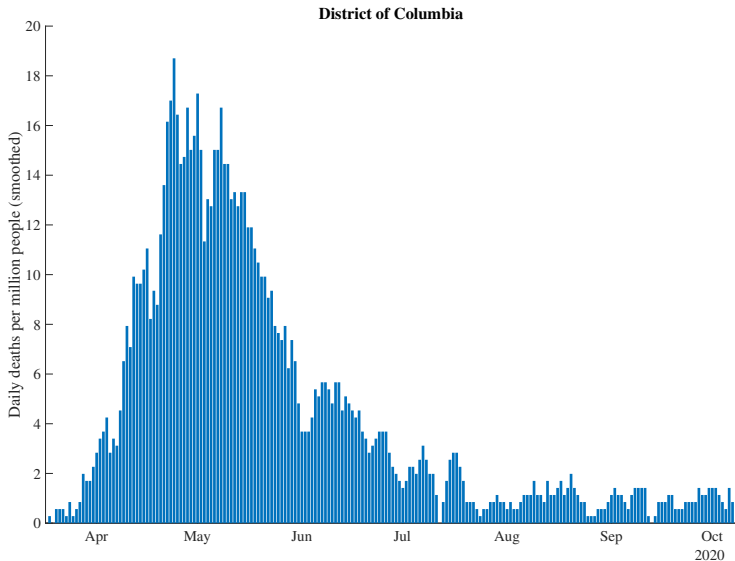
- Data underlying estimates of $R_0(t)$
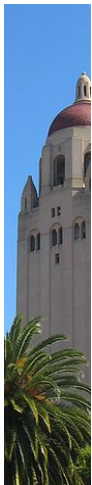
Underlying data from
Johns Hopkins CSSE

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

District of Columbia: Daily Deaths per Million People
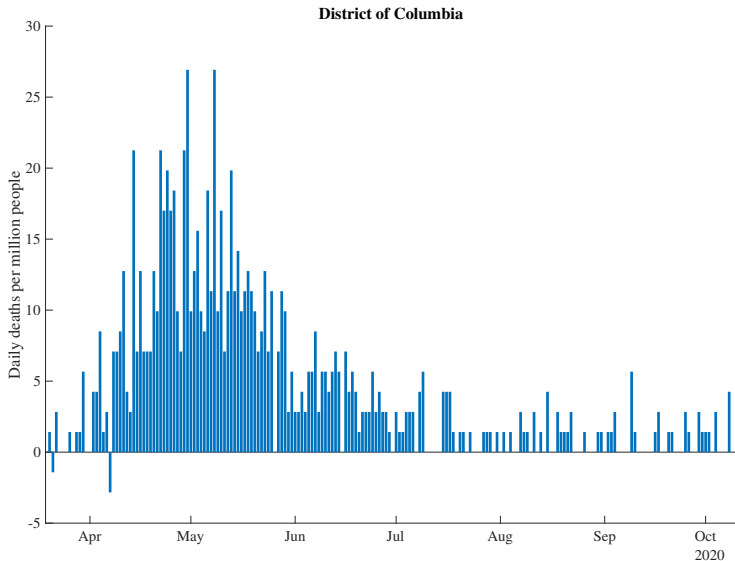
District of Columbia: Daily Deaths per Million People (Smoothed)

District of Columbia

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)
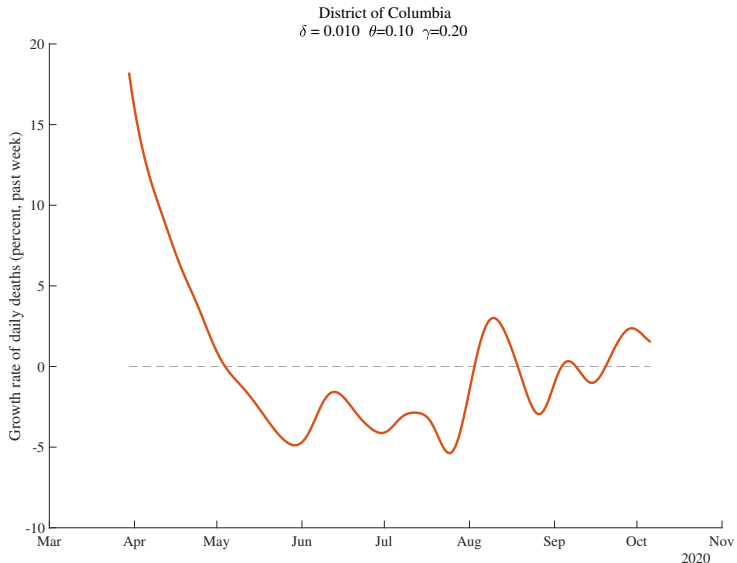
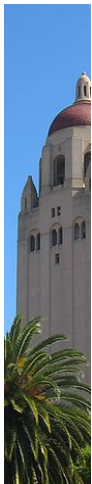(see end of slide deck for this data)

District of Columbia
$\delta = 0.010$ $\theta = 0.10$ $\gamma = 0.20$
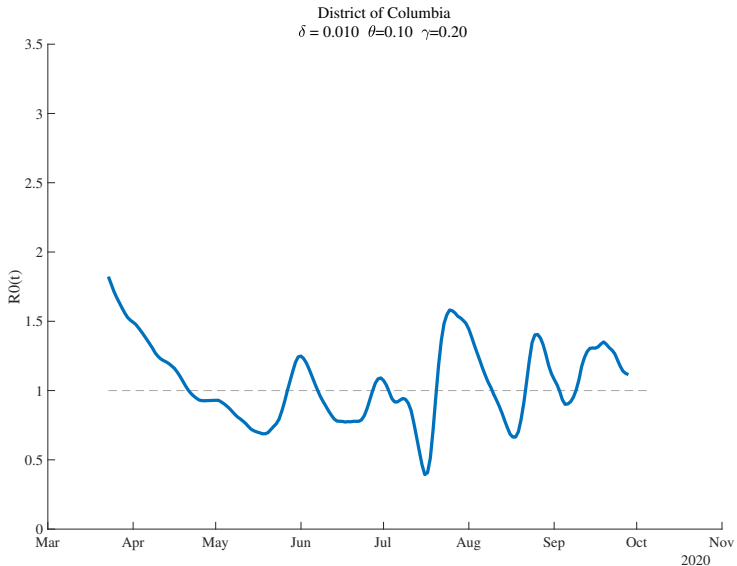
District of Columbia: Percent Currently Infectious

District of Columbia
Peak I/N = 0.88%   Final I/N = 0.06% $\delta = 0.010$ $\theta = 0.10$ $\gamma = 0.20$
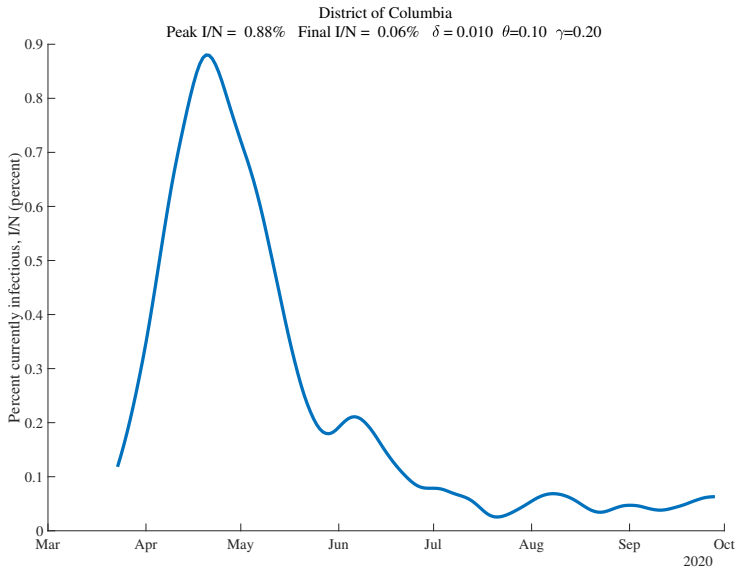
District of Columbia
$\delta = 0.010$ $\theta = 0.10$ $\gamma = 0.20$

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?
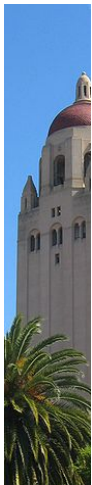
- Inferred from death data when we have it

- 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,
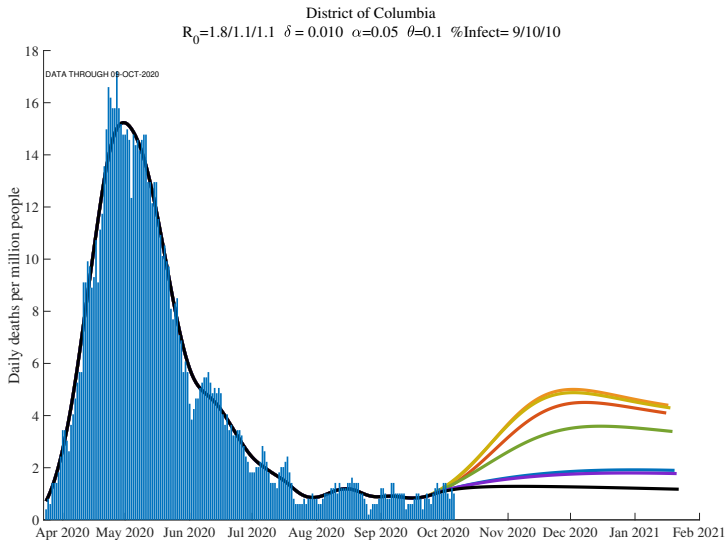 *or rises by 5 percent when daily deaths decline*

- Robustness: Assume $R_0(t) =$ final empirical value. Constant in future, so no α adjustment $\rightarrow \alpha = 0$
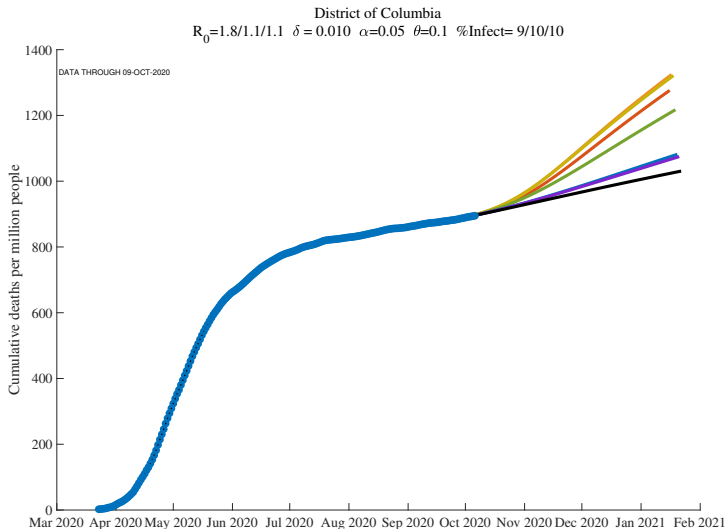
Repeated "Forecasts" from the past 7 days of data

– After peak, forecasts settle down.

– Before that, very noisy!

– If the region has not peaked, do not trust

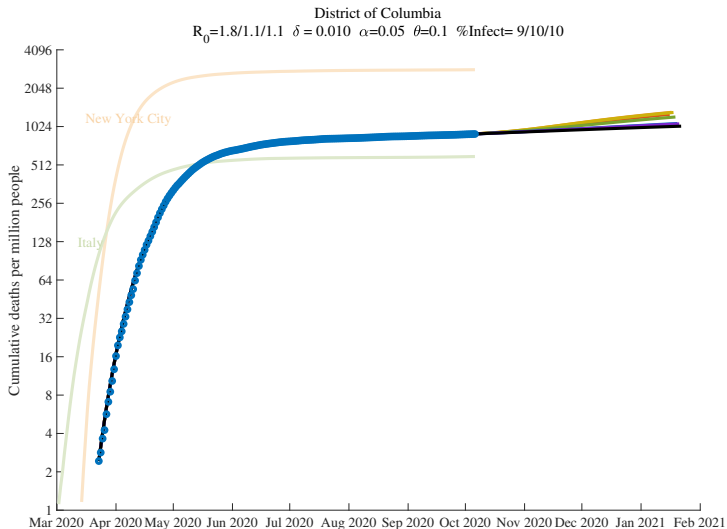– With $\alpha = .05$ (see robustness section for $\alpha = 0$)

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

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.05 θ=0.1 %Infect= 9/10/10

DATA THROUGH 09-OCT-2020

District of Columbia
R_0=1.8/1.1/1.1 δ = 0.010 α=0.05 θ=0.1 %Infect= 9/10/10

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.05 θ=0.1 %Infect= 9/10/10

Robustness to Mortality Rate, δ

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.05 θ=0.1 %Infect= 9/10/10

DATA THROUGH 09-OCT-2020

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.05 θ=0.1 %Infect= 9/10/10

DATA THROUGH 09-OCT-2020

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

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.05 θ=0.1 %Infect= 9/10/10

DATA THROUGH 09-OCT-2020

$\delta = 0.008$

Cumulative deaths per million people
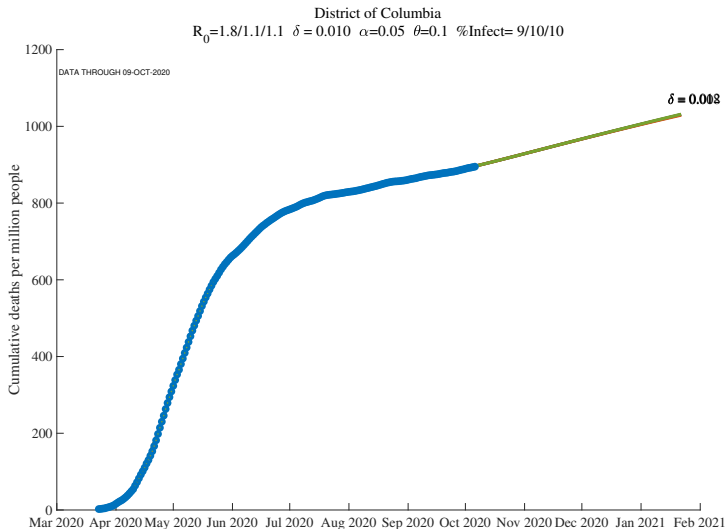
Reopening and Herd Immunity

– Black: assumes R_0(today) remains in place forever

– Red: assumes R_0(suppress)$= 1/s(today)$

– Green: we move 25% of the way from R_0(today) back to initial R_0 = "normal"

– Purple: we move 50% of the way from R_0(today) back to initial R_0 = "normal"

NOTE: Lines often cover each other up

District of Columbia
$R_0(t)=1.1$, R_0(suppress)=1.1, $R_0(25/50)=1.3/1.6$, $\delta = 0.010$, $\alpha=0.05$
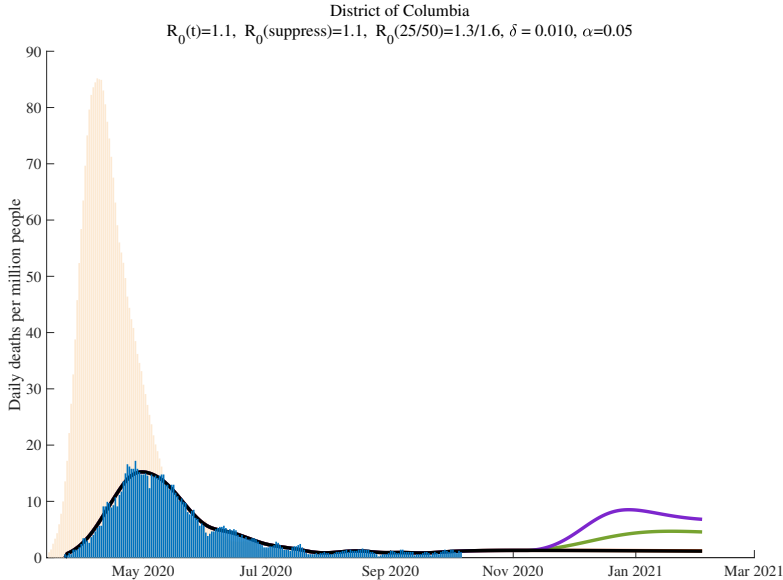
(Light bars = New York City, for comparison)

District of Columbia
$R_0(t)=1.1$, R_0(suppress)=1.1, R_0(25/50)=1.3/1.6, $\delta = 0.010$, $\alpha=0.00$
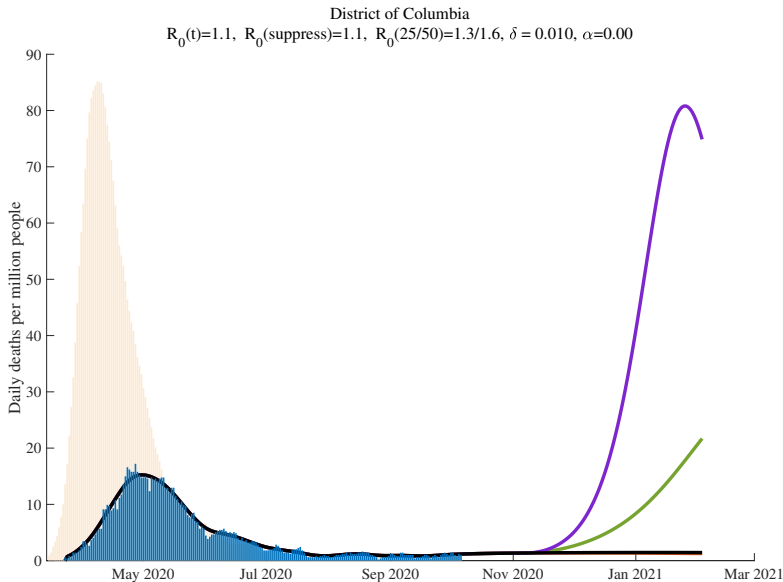
(Light bars = New York City, for comparison)
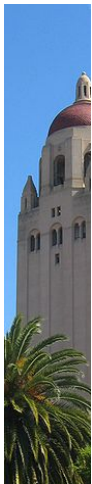
Results for alternative
parameter values

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.00 θ=0.1 %Infect= 9/10/11

District of Columbia
$R_0 = 1.8/1.1/1.1$ $\delta = 0.010$ $\alpha = 0.00$ $\theta = 0.1$ %Infect= 9/10/11

District of Columbia
R_0=1.8/1.1/1.1 δ = 0.010 α=0.00 θ=0.1 %Infect= 9/10/11

District of Columbia: Daily Deaths per Million People ($\delta = 0.8\%$)

District of Columbia
R_0=1.8/1.1/1.1 δ = 0.008 θ=0.1 γ=0.2 %Infect=11/12/13
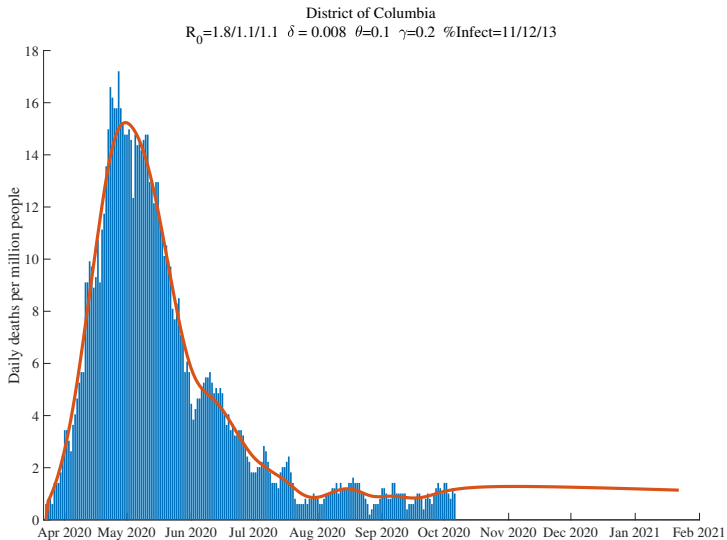
District of Columbia: Cumulative Deaths per Million ($\delta = 0.8\%$)

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.008$ θ=0.1 γ=0.2 %Infect=11/12/13
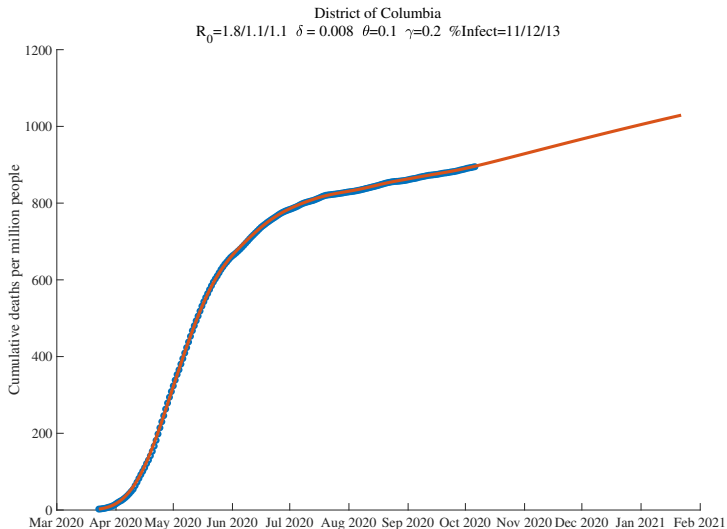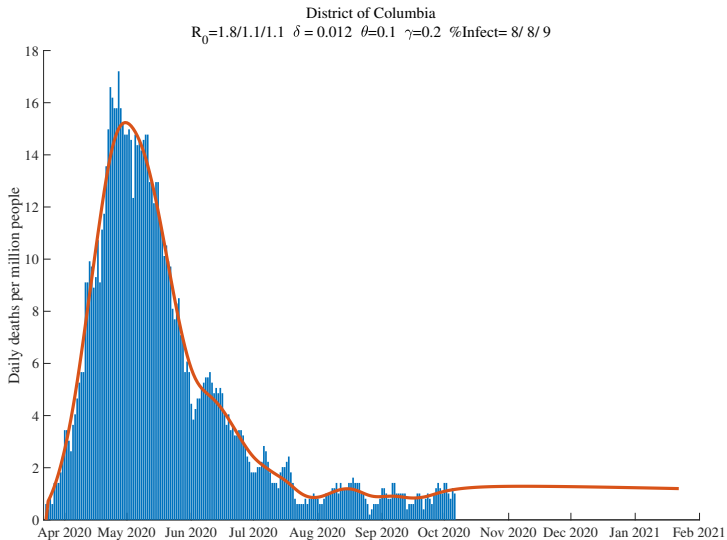
District of Columbia: Daily Deaths per Million People ($\delta = 1.2\%$)

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.012$ θ=0.1 γ=0.2 %Infect= 8/ 8/ 9

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.012$ θ=0.1 γ=0.2 %Infect= 8/ 8/ 9
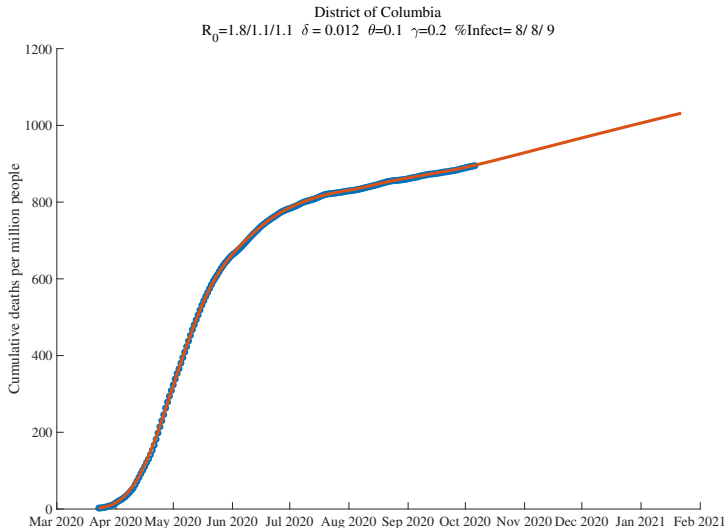
District of Columbia: Daily Deaths per Million People ($\gamma = .2/.15$)

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.05 θ=0.1 %Infect= 9/10/10

DATA THROUGH 09-OCT-2020

District of Columbia
R_0=1.8/1.1/1.1 $\delta = 0.010$ α=0.05 θ=0.1 %Infect= 9/10/10

DATA THROUGH 09-OCT-2020

$\gamma = 0.15$
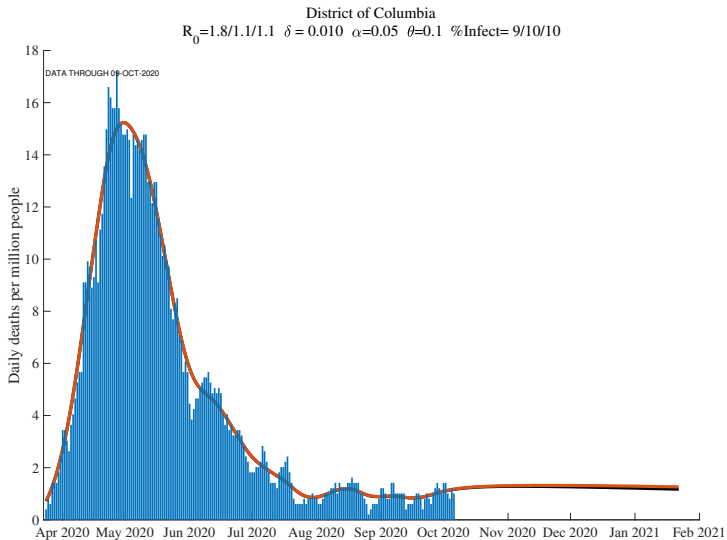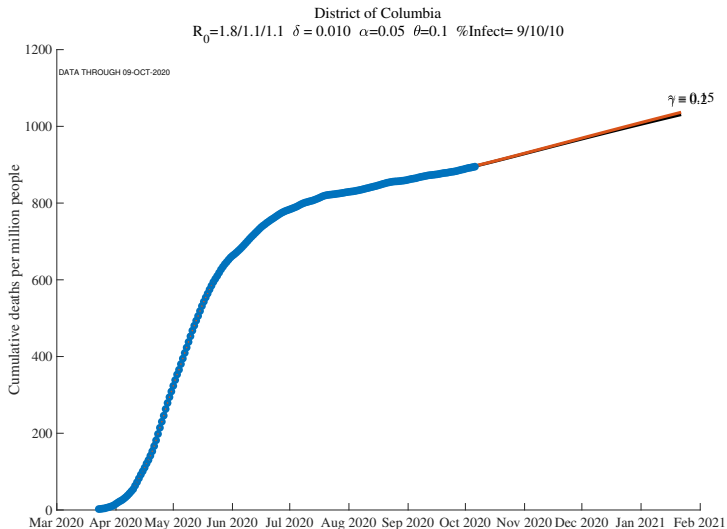
District of Columbia: Daily Deaths per Million People ($\theta = .1/.07/.2$)

District of Columbia
R_0=1.8/1.1/1.1 δ = 0.010 α=0.05 θ=0.1 %Infect= 9/10/10

DATA THROUGH 09-OCT-2020

District of Columbia
R_0=1.8/1.1/1.1 δ = 0.010 α=0.05 θ=0.1 %Infect= 9/10/10
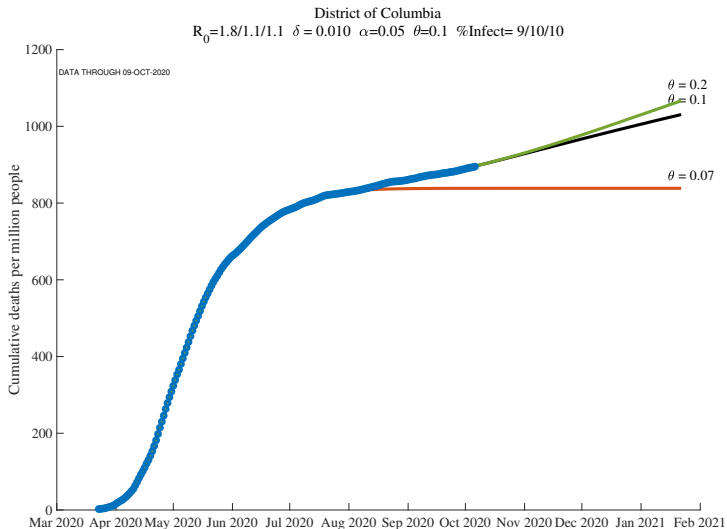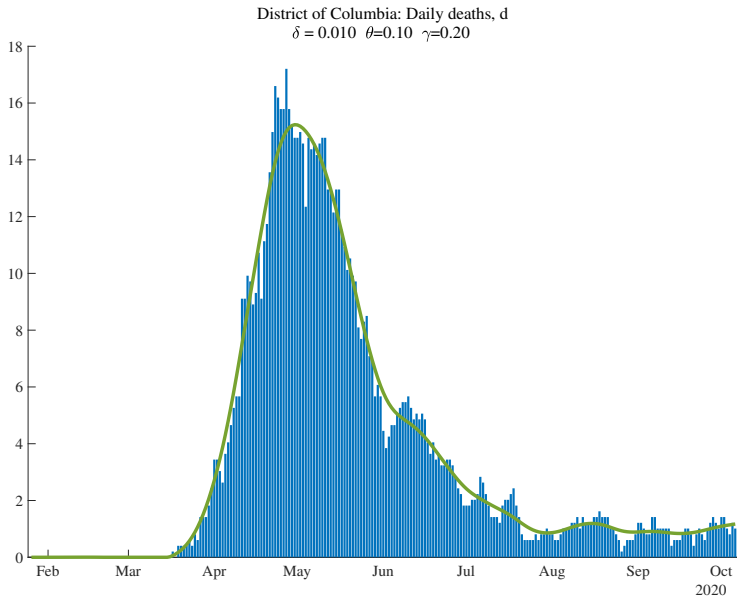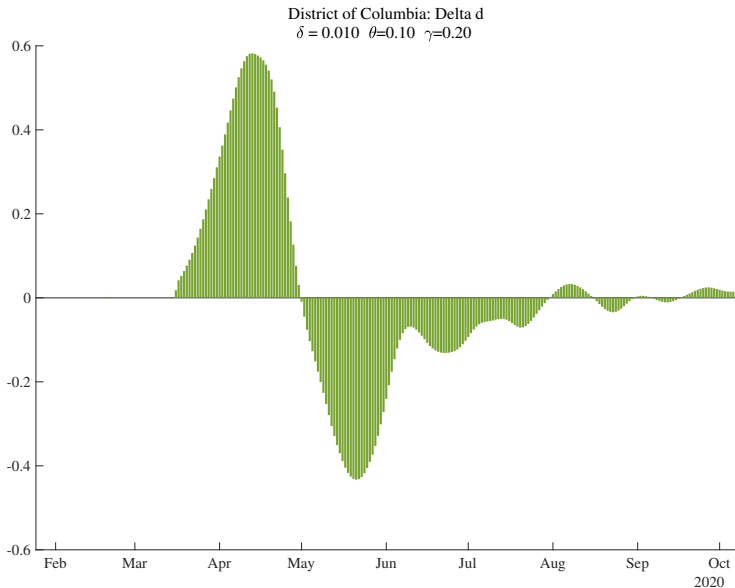
Data Underlying Estimates
of Time-Varying R_0

– Inferred from daily deaths, and

– the change in daily deaths, and

– the change in (the change in daily deaths)

District of Columbia: Daily Deaths, Actual and Smoothed

District of Columbia: Daily deaths, d
$\delta = 0.010$ $\theta = 0.10$ $\gamma = 0.20$

District of Columbia: Change in Smoothed Daily Deaths

District of Columbia: Delta d
$\delta = 0.010$ $\theta = 0.10$ $\gamma = 0.20$

District of Columbia: Delta (Delta d)
$\delta = 0.010$ $\theta = 0.10$ $\gamma = 0.20$