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

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Extended results for Lombardy, Italy

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 $R_0(t)$

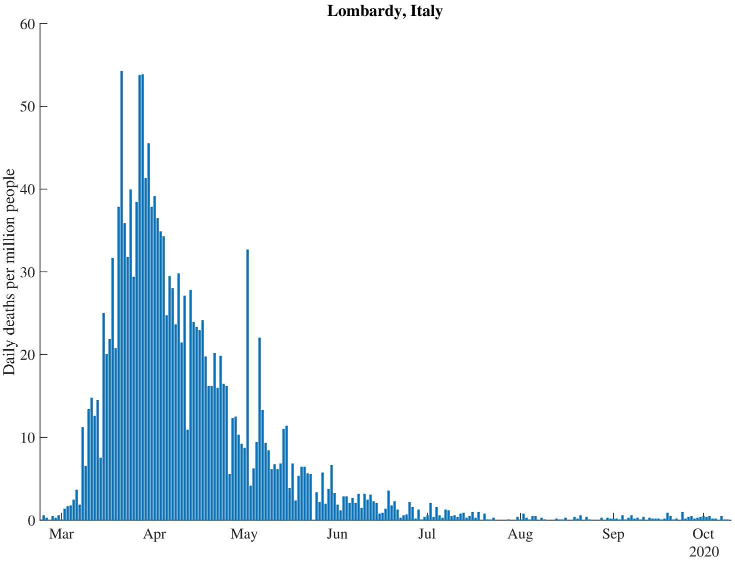
Underlying data from Johns Hopkins CSSE

– Raw data

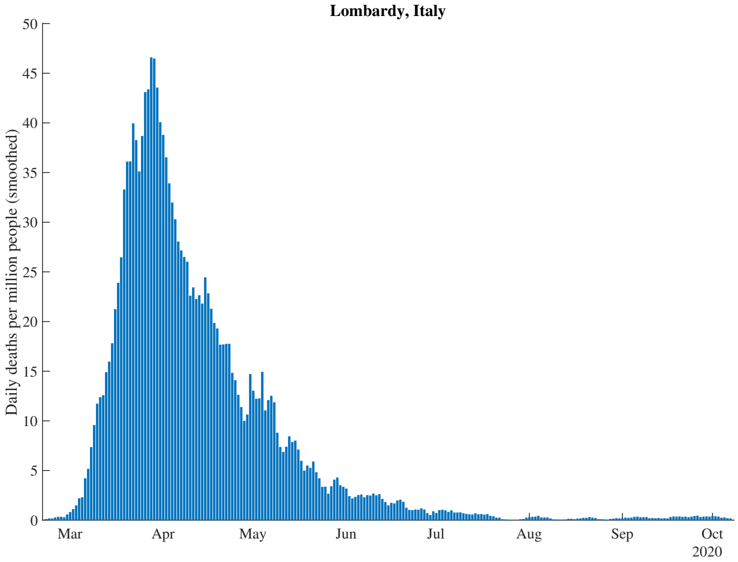
– Smoothed = 7 day centered moving average

– No “excess deaths” correction (change as of Aug 6 run)

Lombardy, Italy: Daily Deaths per Million People



Lombardy, Italy: 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

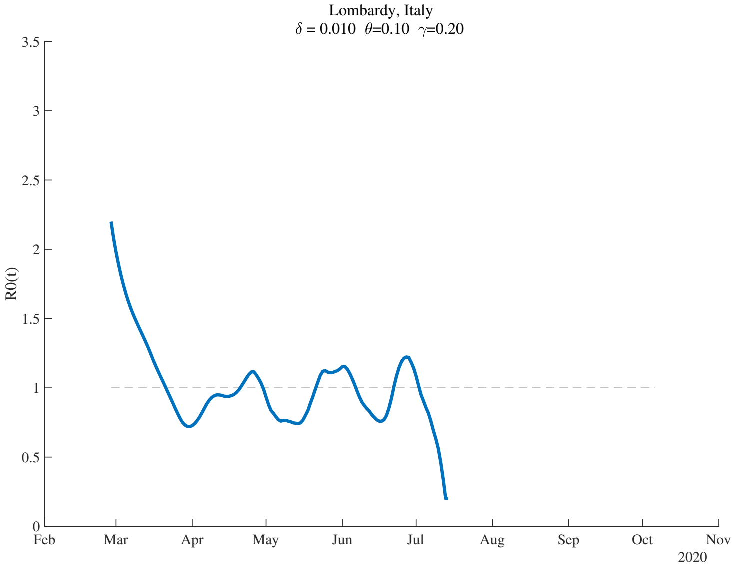
– Inferred from daily deaths, and

– the change in daily deaths, and

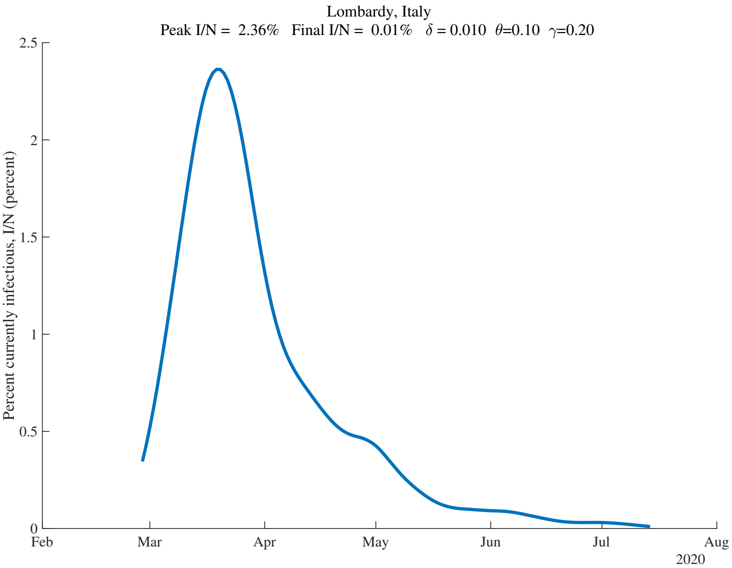
– the change in (the change in daily deaths)

(see end of slide deck for this data)

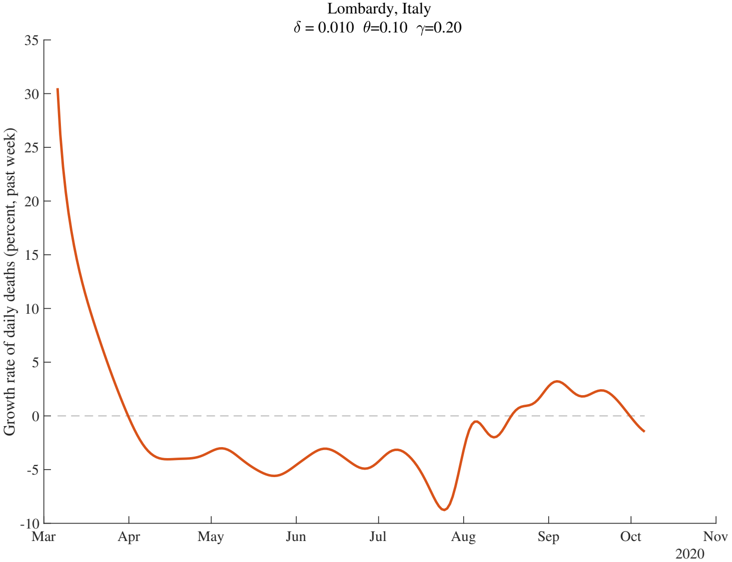
Lombardy, Italy: Estimates of $R_0(t)$



Lombardy, Italy: Percent Currently Infectious



Lombardy, Italy: 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:

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

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

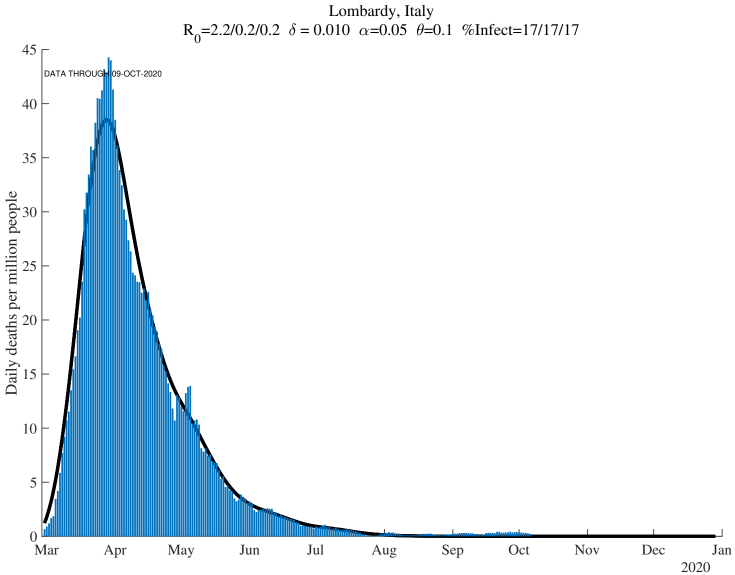
R_0 declines by 5 percent for each new daily death,
or rises by 5 percent when daily deaths decline

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

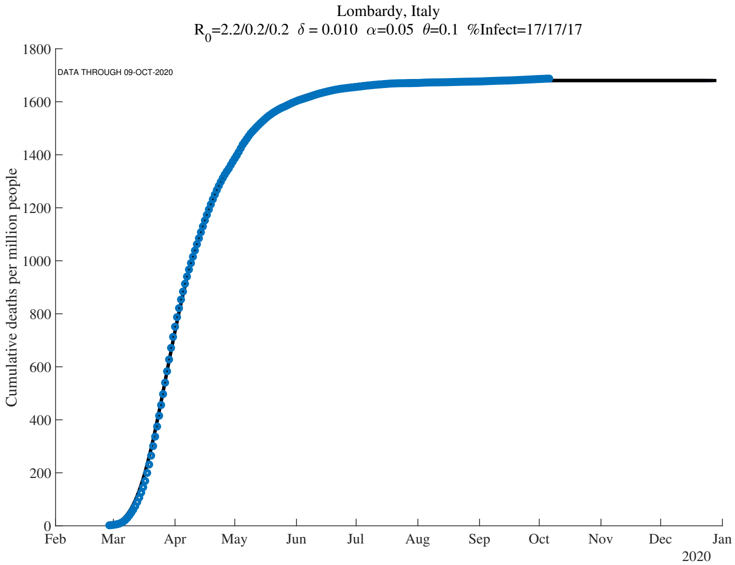
Repeated "Forecasts" from the past 7 days of data

- 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 $\alpha = 0$)

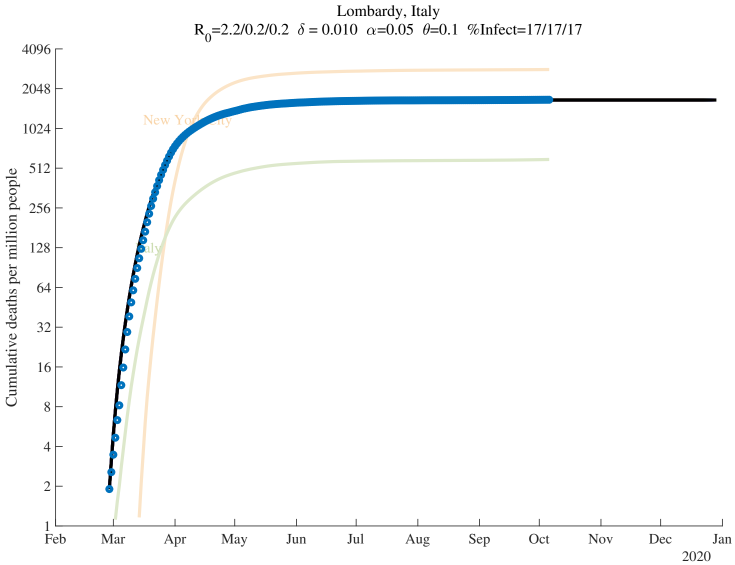
Lombardy, Italy (7 days): Daily Deaths per Million People ($\alpha = .05$)



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

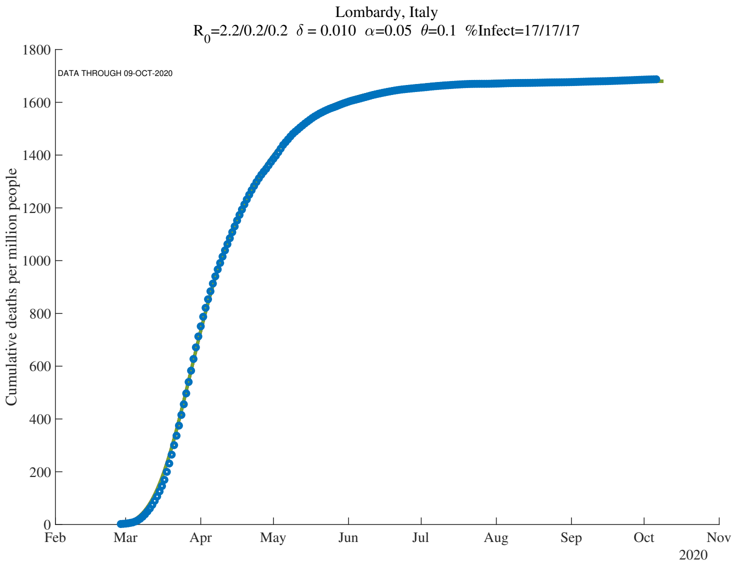


Lombardy, Italy (7 days): Cumulative Deaths per Million, Log Scale (α =

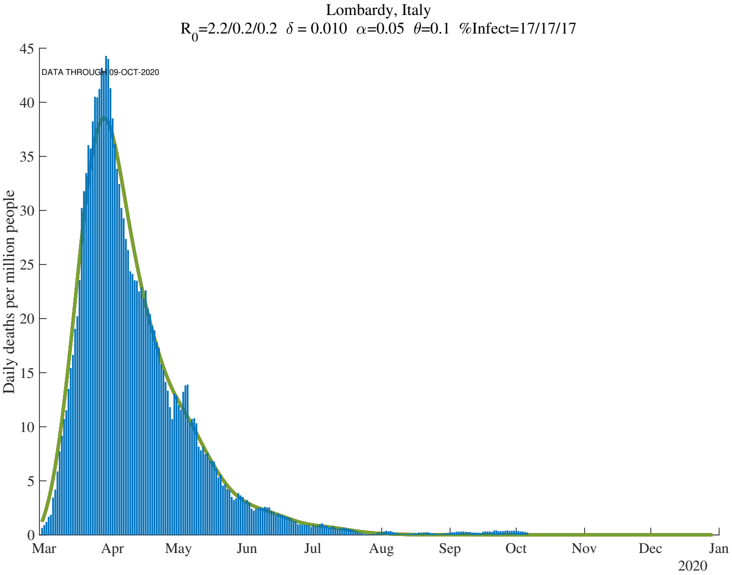


Robustness to Mortality Rate, δ

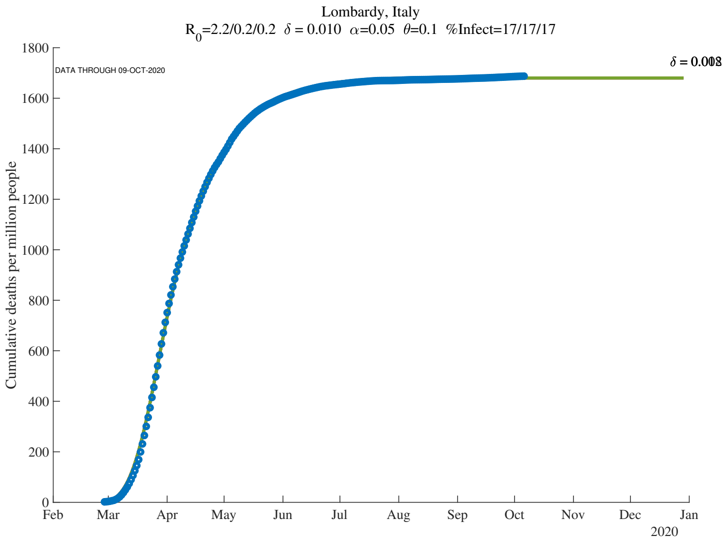
Lombardy, Italy: Cumulative Deaths per Million ($\delta = .01/.008/.012$)



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



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



Reopening and Herd Immunity

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

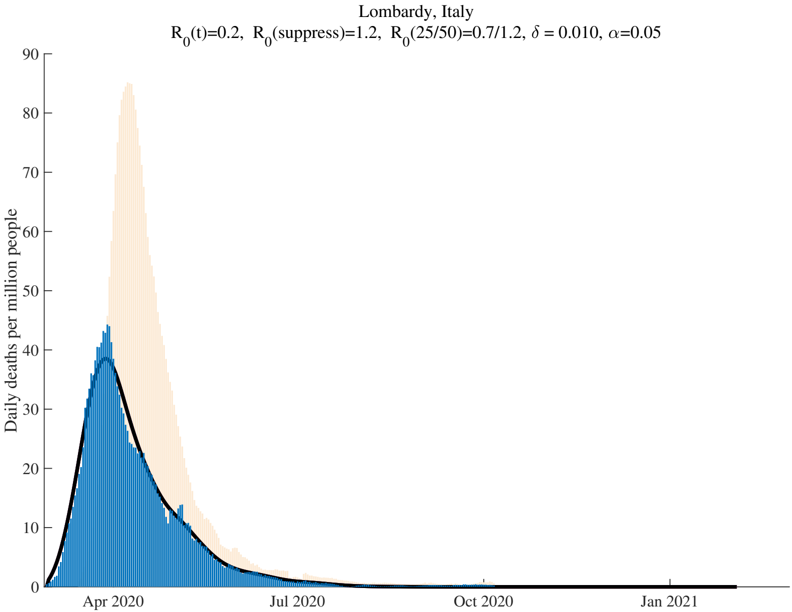
– Red: assumes R_0(suppress)$= 1/s(today)$

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

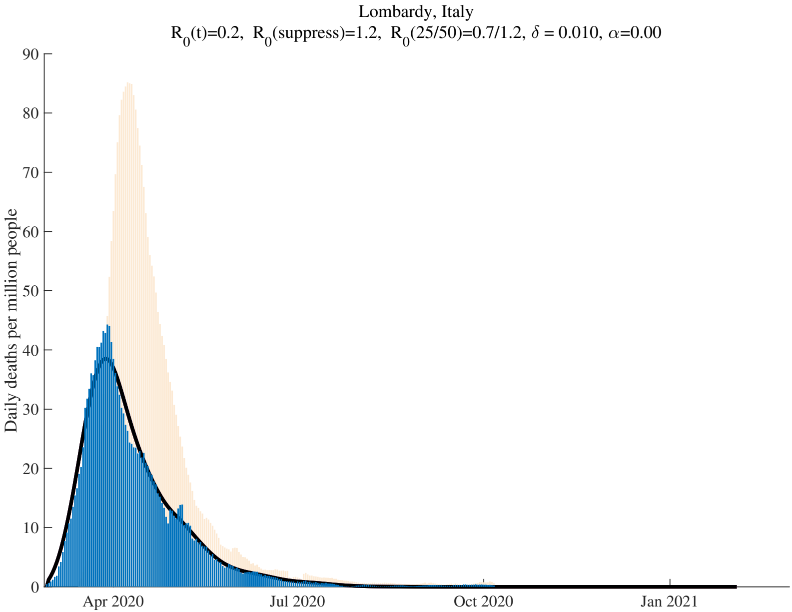
– Purple: we move 50% of the way from R_0(today) back to initial R_0 = “normal”

NOTE: Lines often cover each other up

Lombardy, Italy: Re-Opening ($\alpha = .05$)

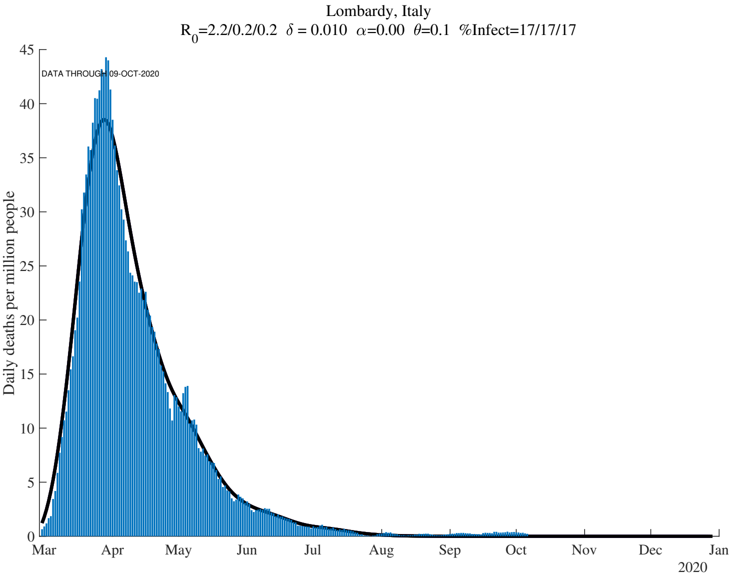


Lombardy, Italy: Re-Opening ($\alpha = 0$)

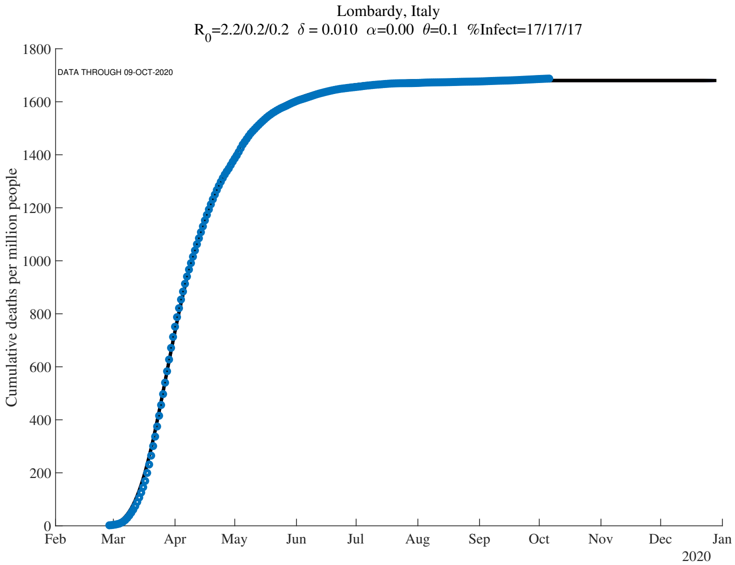


Results for alternative parameter values

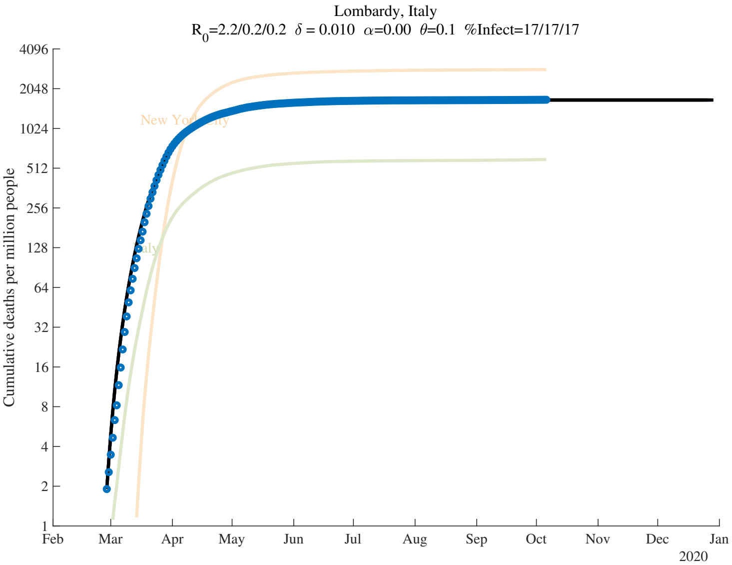
Lombardy, Italy (7 days): Daily Deaths per Million People ($\alpha = 0$)



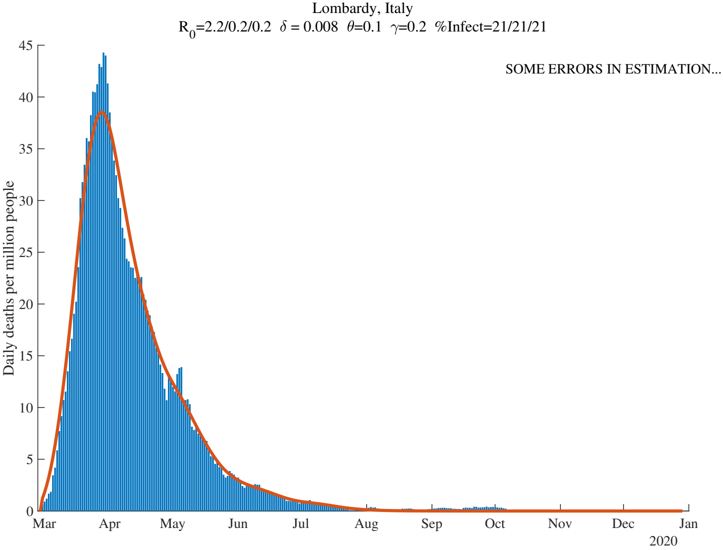
Lombardy, Italy (7 days): Cumulative Deaths per Million (Future, $\alpha = 0$)



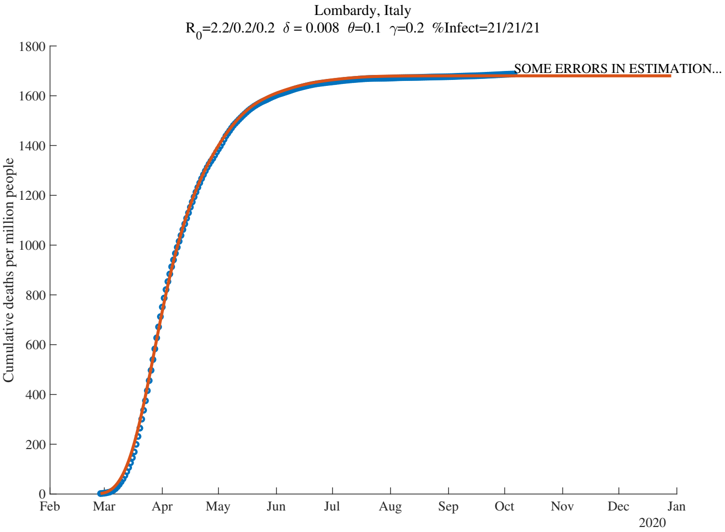
Lombardy, Italy (7 days): Cumulative Deaths per Million, Log Scale (α =



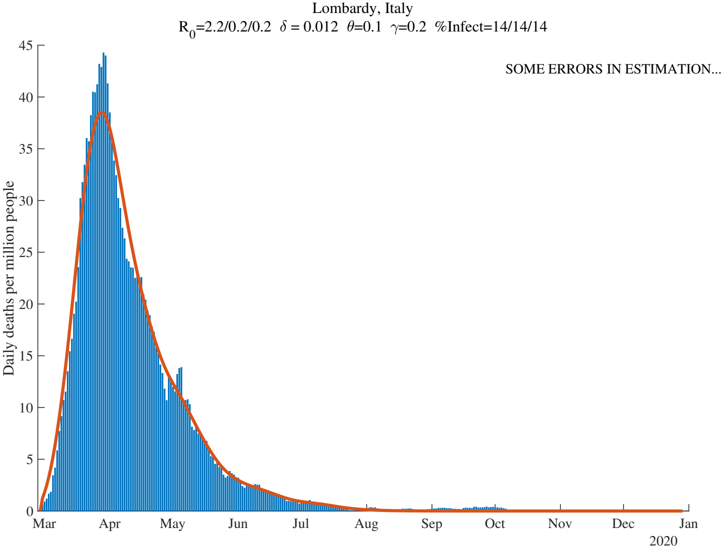
Lombardy, Italy: Daily Deaths per Million People ($\delta = 0.8\%$)



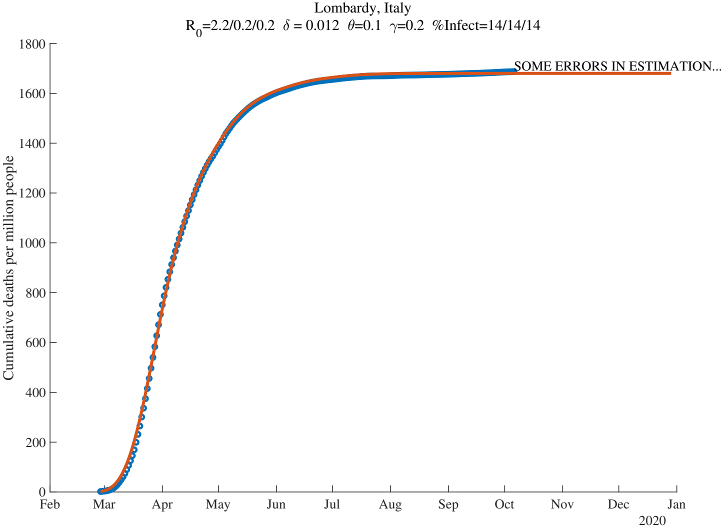
Lombardy, Italy: Cumulative Deaths per Million ($\delta = 0.8\%$)



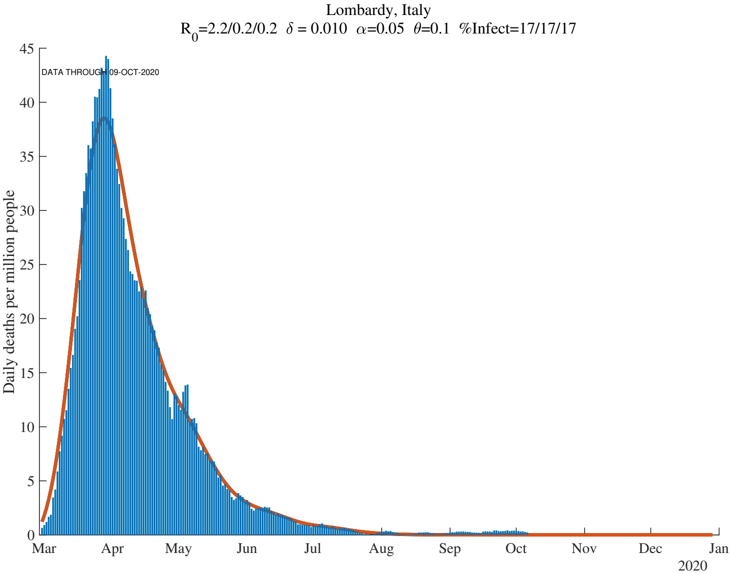
Lombardy, Italy: Daily Deaths per Million People ($\delta = 1.2\%$)



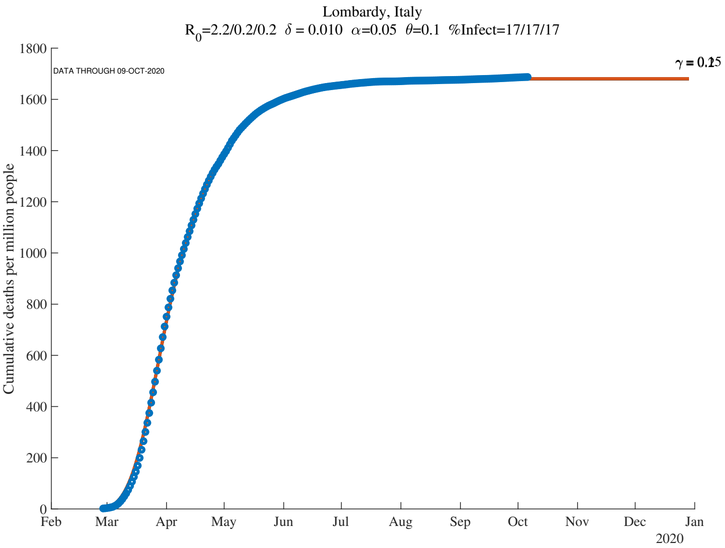
Lombardy, Italy: Cumulative Deaths per Million ($\delta = 1.2\%$)



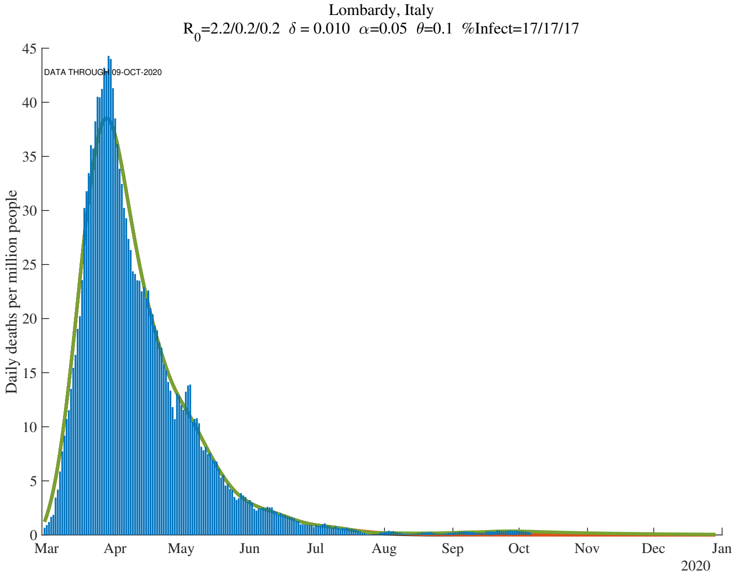
Lombardy, Italy: Daily Deaths per Million People ($\gamma = .2/.15$)



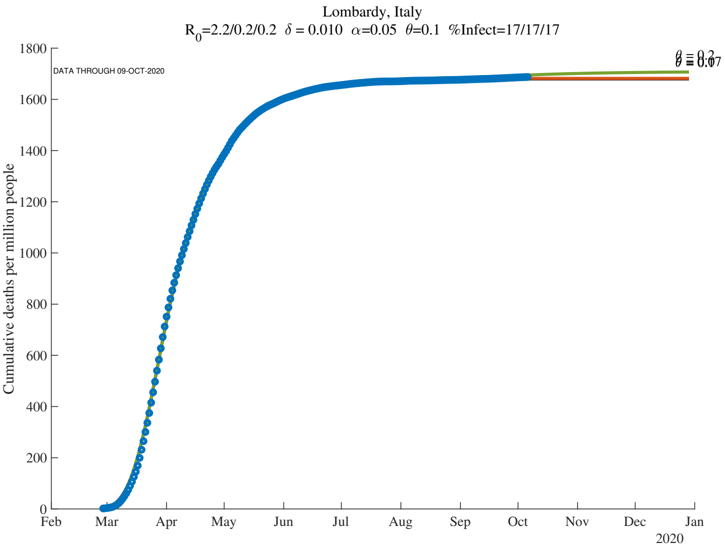
Lombardy, Italy: Cumulative Deaths per Million $\gamma = .2/.15$)



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



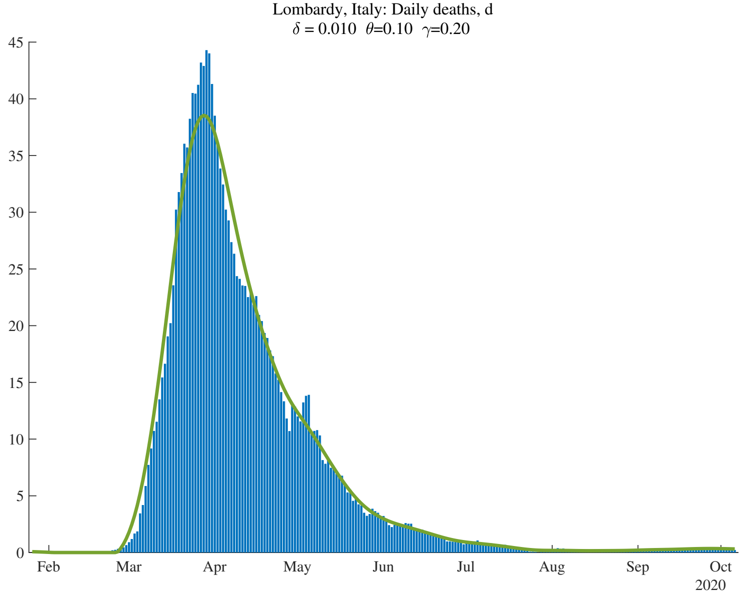
Lombardy, Italy: Cumulative Deaths per Million People ($\theta = .1/.07/.2$)



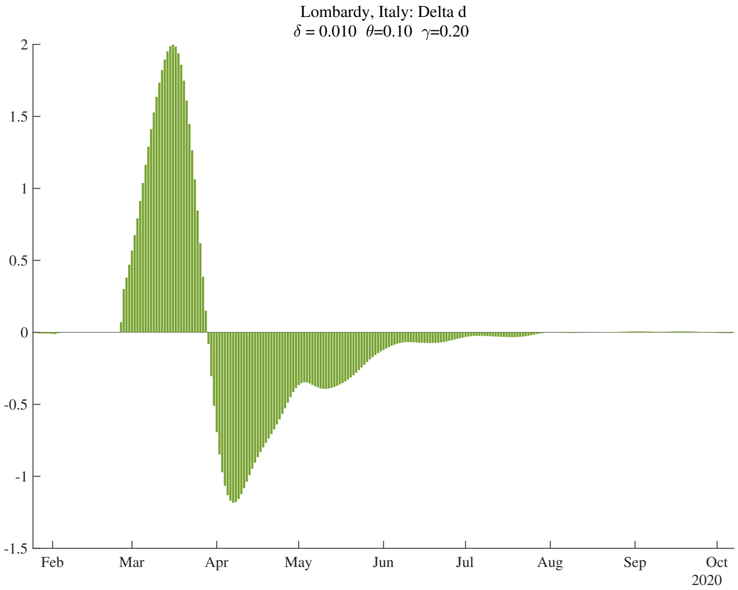
Data Underlying Estimates of Time-Varying R_0

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

Lombardy, Italy: Daily Deaths, Actual and Smoothed



Lombardy, Italy: Change in Smoothed Daily Deaths



Lombardy, Italy: Change in (Change in Smoothed Daily Deaths)