

Behavior and the Dynamics of Epidemics

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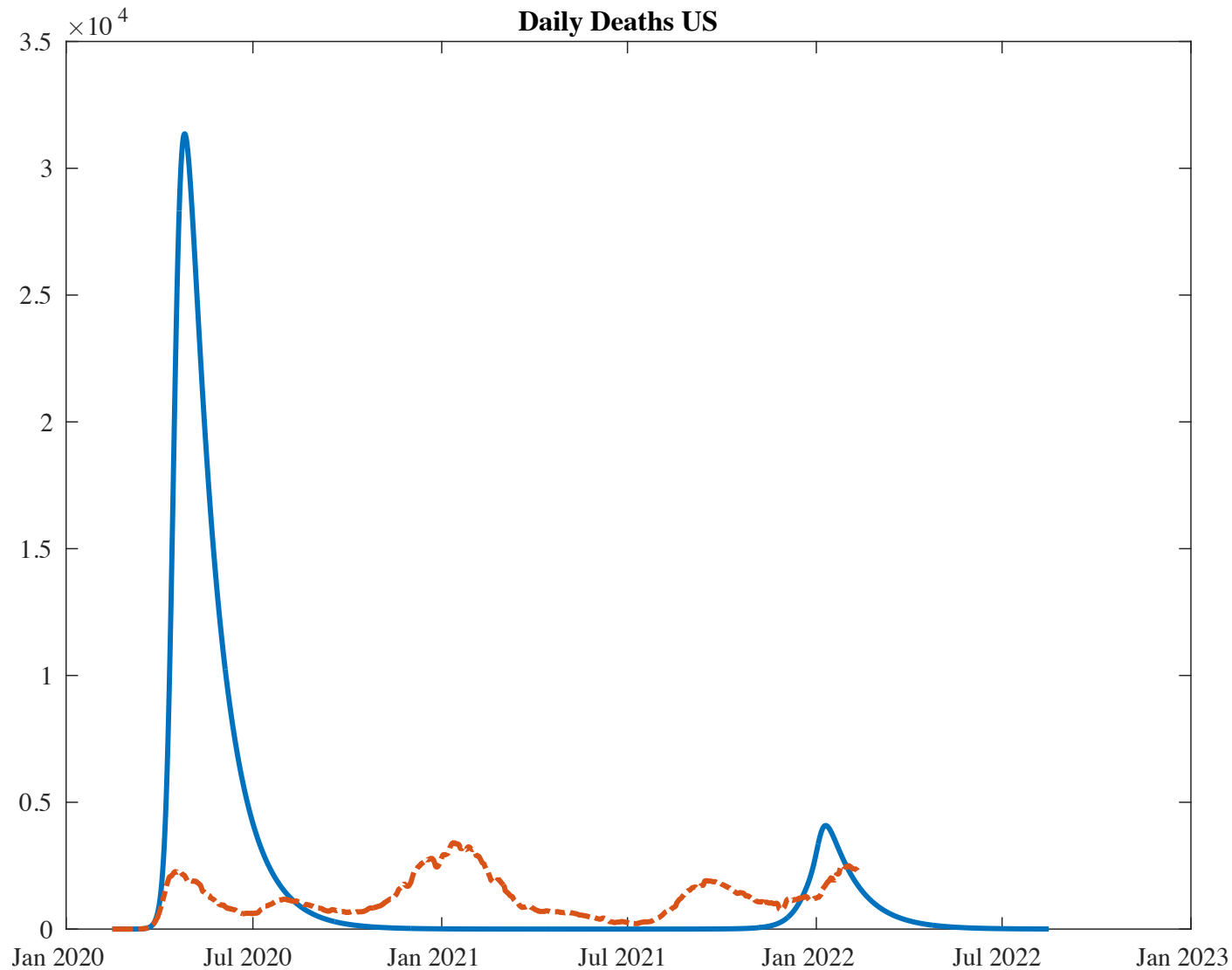
Two Motivating Questions

- What impact does behavior have on the dynamics of infections and deaths from a pandemic?
- How does behavior impact our options for mitigating the impact of a pandemic on public health?
- Address questions with model of dynamics of COVID deaths in US with behavioral response

COVID Dynamics without behavior

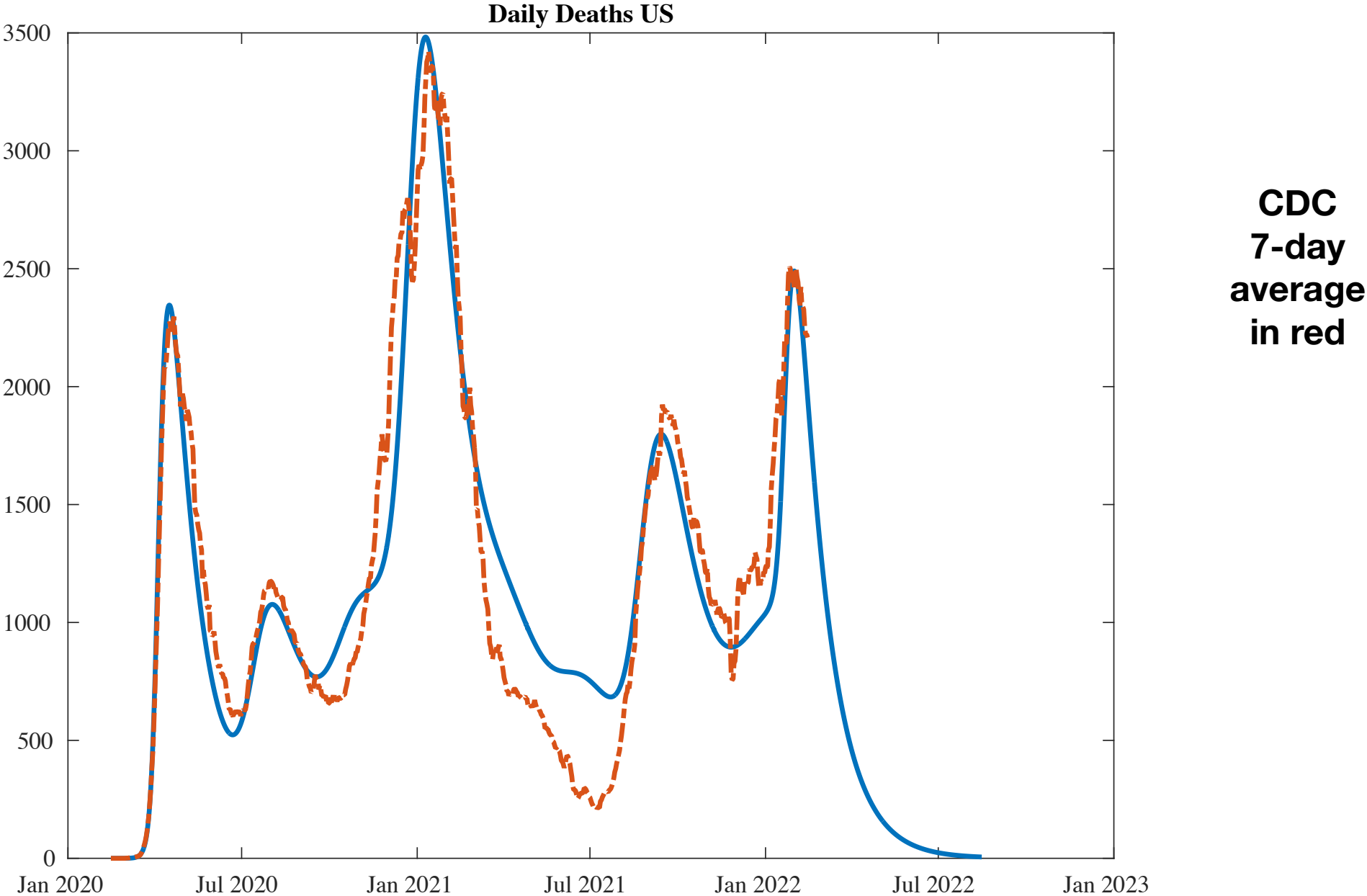
- COVID has a high R_0 and a short generation time
- Standard models predict
 - Very large initial peak of infections
 - More than $1 - 1/R_0$ of the population eventually gets infected
 - Pandemic over quickly
- Infection fatality rate determines implications for deaths

COVID Dynamics of daily deaths without behavior



Predicted Dynamics with Behavior

Dramatically flattens peaks and draws out pandemic



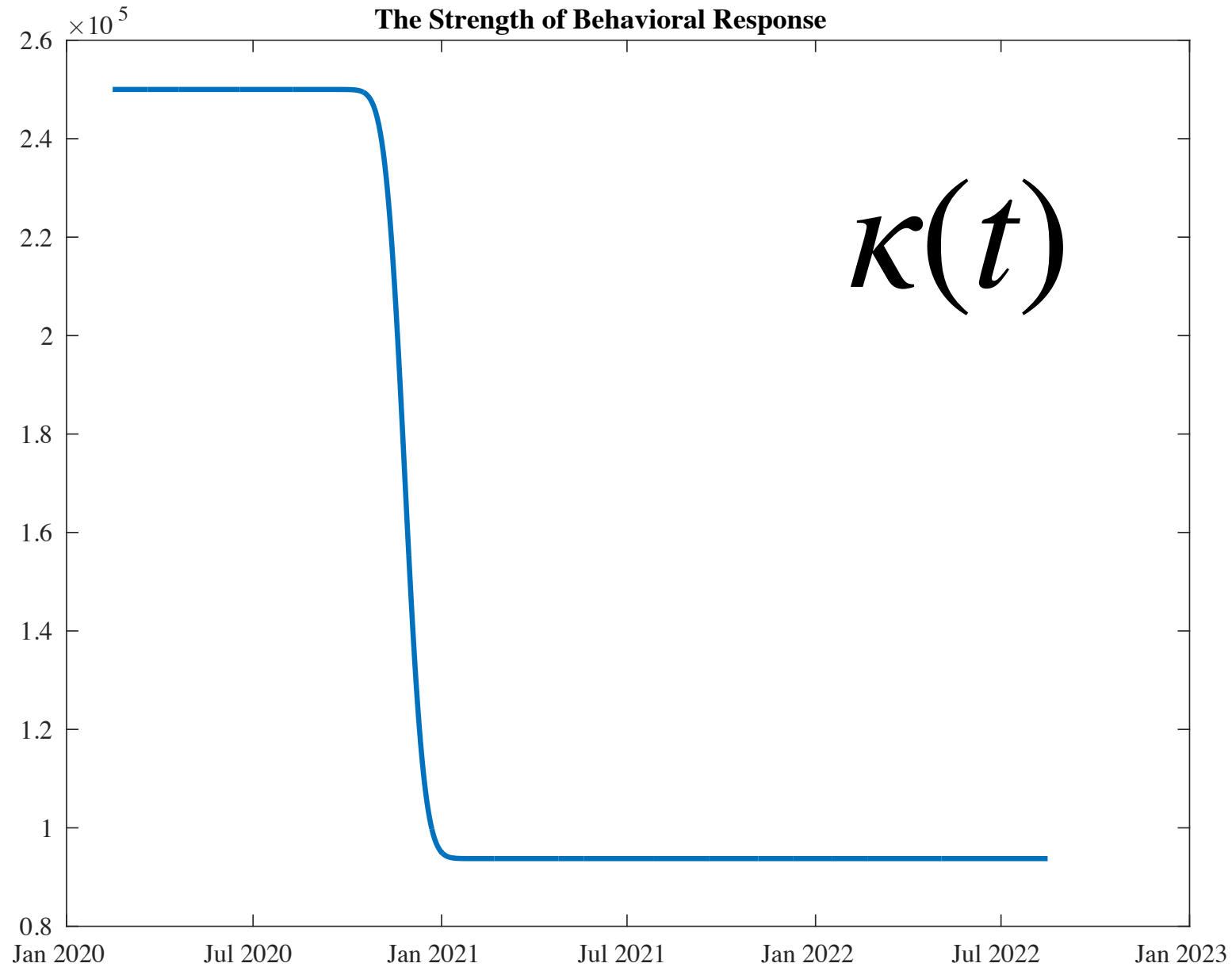
Key Model Elements

- SEIHRD model
 - Variants: Original, Alpha, Delta, Omicron $\beta_i(t)$
 - Reduced form: behavior reduces transmission rate as daily deaths rise
 - Seasonality in transmission
 - Omicron can infect those in R
 - H compartment - delay between infections and deaths
 - Vaccinations: direct from from S to R
 - Waning immunity: flow from R back to S

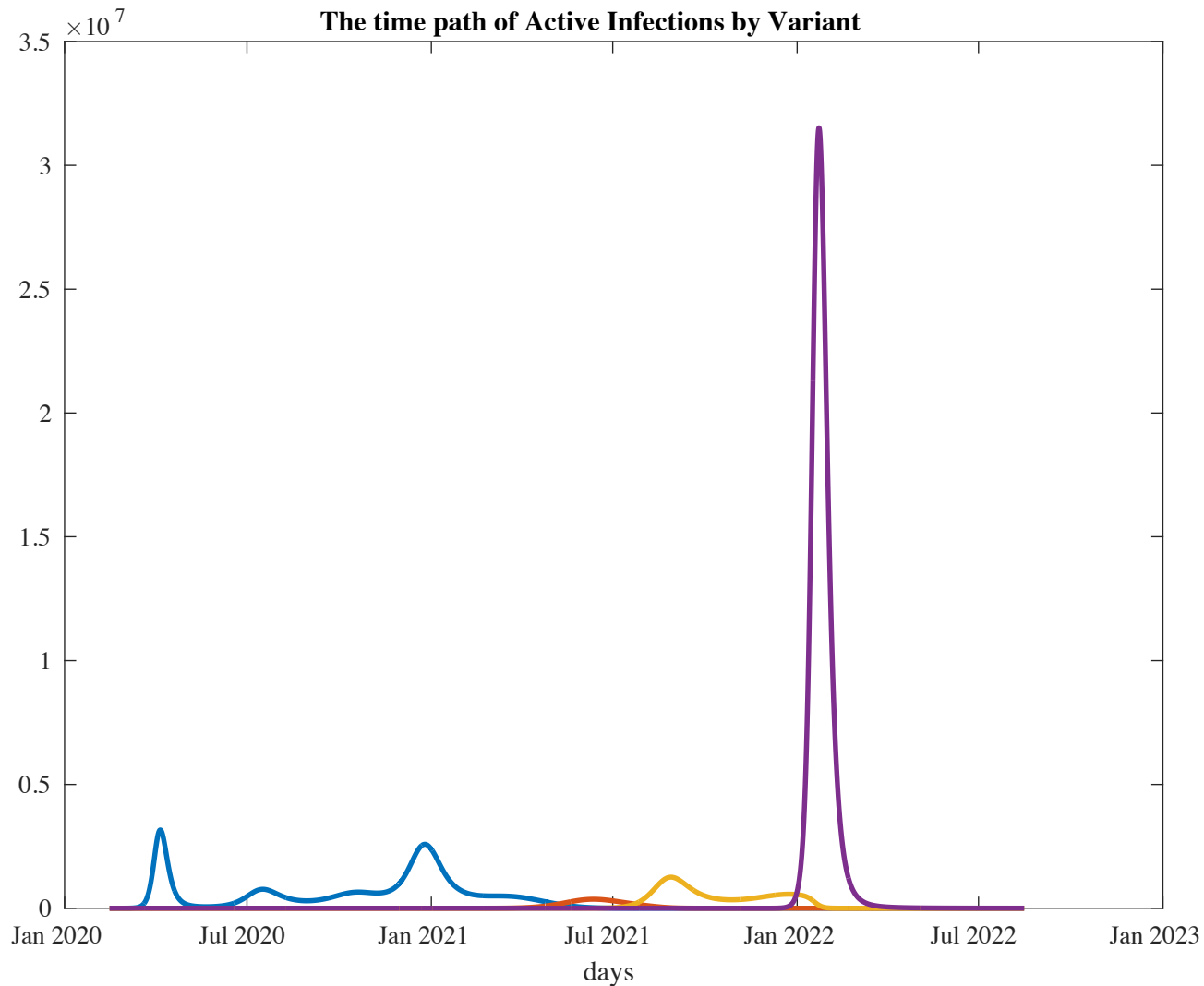
Behavior and Transmission

- Reduced form for impact of public and private mitigation response to daily deaths
- $\beta_i(t) = \bar{\beta}_i \exp(-\kappa(t)\dot{D}(t) + \psi(t))$
- $\bar{\beta}_i$ inherent transmissibility
- $\psi(t)$ seasonal in transmission
- $\dot{D}(t)$ daily deaths
- $\kappa(t)$ strength of behavioral response to daily deaths
- Delay between infection and deaths gives oscillatory dynamics

Strength of behavior and pandemic fatigue



Does Behavior Respond to Infections or Deaths: Omicron vs. prior variants

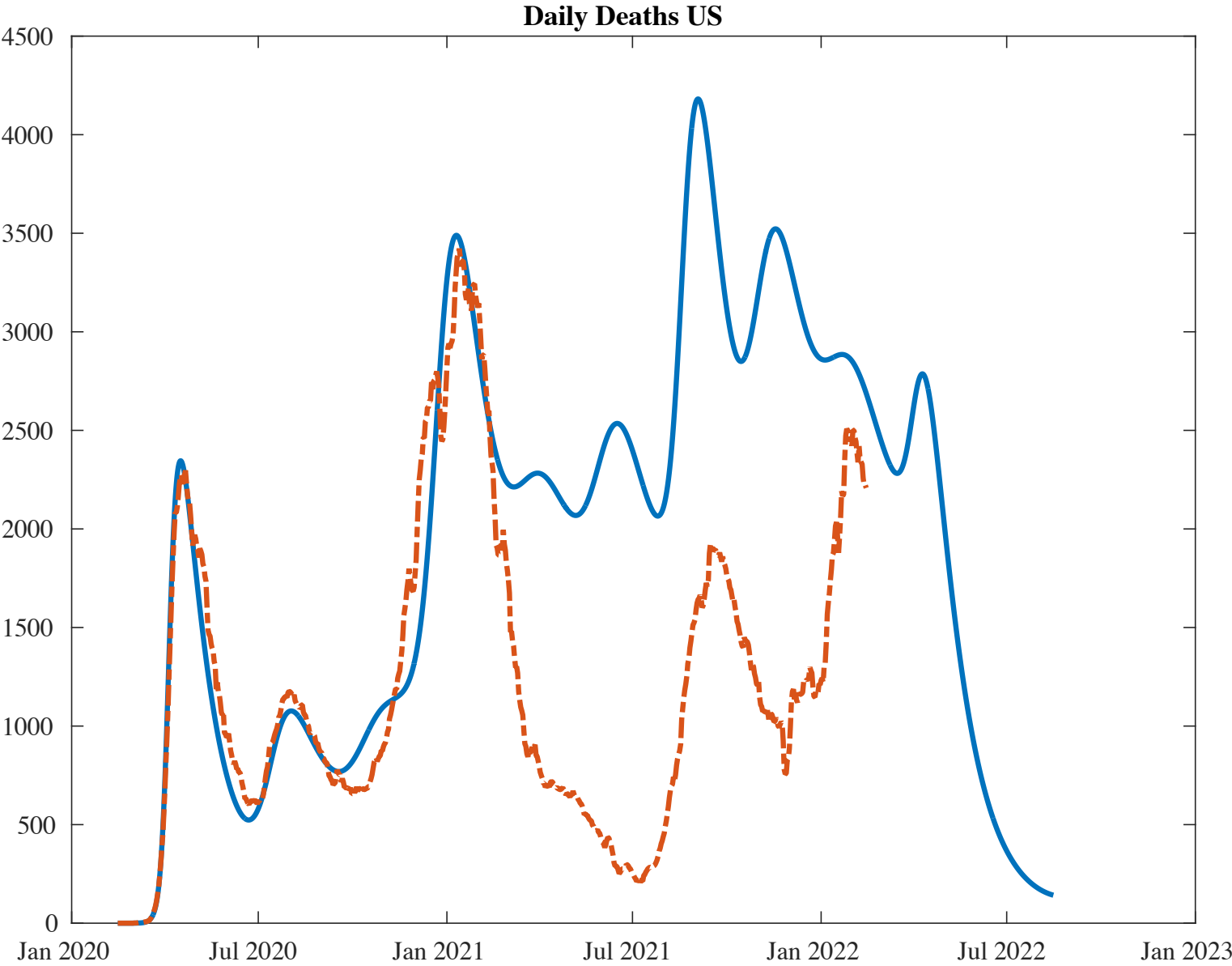


What is impact of stronger mitigation on cumulative deaths?

Case with no vaccines

- Behavior returns to pre-pandemic norms when deaths drop to zero
 - With permanent immunity and no vaccines
 - Pandemic cannot end until S falls below herd immunity threshold with transmission with no behavioral response
 - Stronger behavioral response at mitigation does not reduce long run cumulative deaths if IFR is constant
 - What if immunity wanes?
 - Stronger mitigation can reduce deaths in endemic steady-state
 - Omicron has a lower IFR so delayed disease saves lives

Predicted deaths with no vaccines



Predicted cumulative deaths with no vaccines

Table 1: Model Implied Cumulative Deaths From COVID with No Vaccines

Strength of Behavioral Response	Deaths in 2.5 years	Deaths in 5 years
Baseline	1, 728, 000	1, 950, 000
Twice as strong	1, 314, 000	1, 726, 000
Half as Strong	1, 912, 000	2, 328, 000

10% to 20% impact on cumulative deaths over 5 years

What is impact of stronger mitigation on cumulative deaths? Case with vaccines

- Stronger mitigation saves lives until vaccine arrives
 - With permanent immunity
 - Stronger behavioral response can have a powerful impact on long run cumulative deaths
 - What if immunity wanes?
 - Stronger behavioral response in advance of vaccines is less effective in reducing cumulative deaths

Predicted cumulative deaths with vaccines

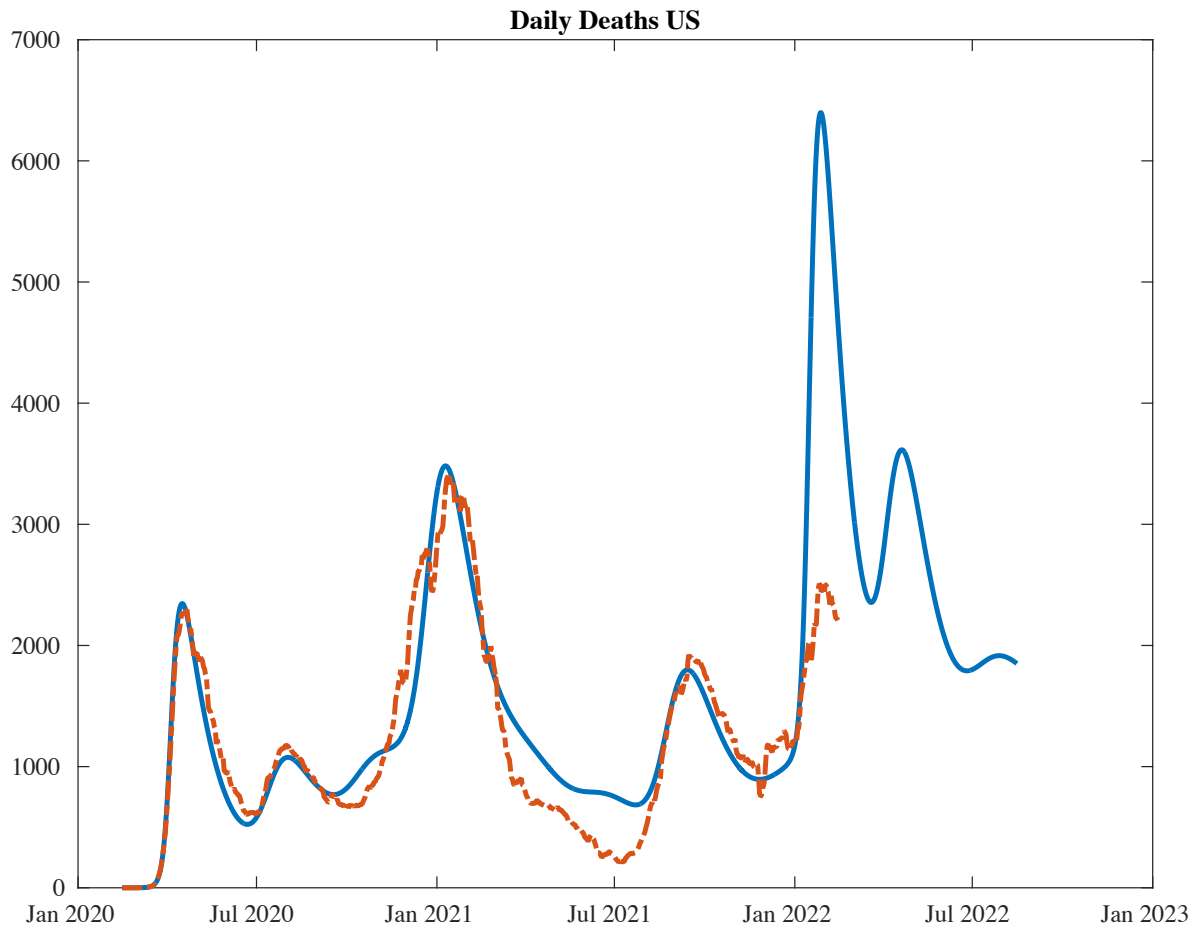
Table 2: Model Implied Cumulative Deaths From COVID with Vaccines

Strength of Behavioral Response	Deaths in 2.5 years	Deaths in 5 years
Baseline	968,000	1,095,000
Twice as strong	688,000	823,000
Half as Strong	1,232,000	1,343,000

Vaccines save 800K to 1000K lives in the long run

Stronger behavior changes long run deaths by about 25%

Are we ready for deadly variants? What if Omicron had the IFR of Delta?



**1.5 million deaths
By mid-August**

What do we need to get ready?