MIT MANAGEMENT SLOAN SCHOOL

How Valuable is COVID-19 Vaccination?

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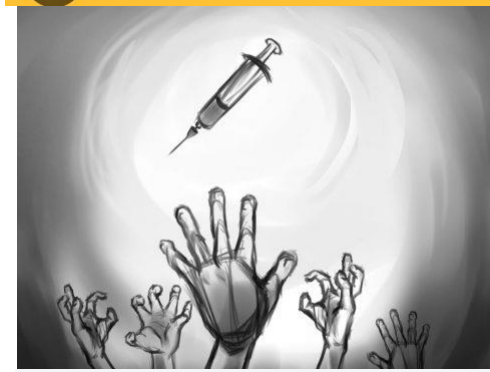
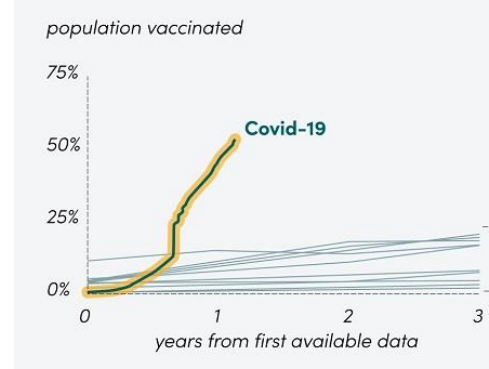
Motivation

- Many policies depend on understanding the value of vaccines, e.g.
  - How costly is vaccine misinformation?
  - How valuable were the programs to speed up vaccine development?
  - How much to pay to get prioritized access to limited vaccines?
  - How much to invest in vaccine capacity?





Research Background

- Existing research in the COVID-19 context:
  - Economic costs of COVID-19 (e.g. Allen 2022; Bonaccorsi et al. 2020; Mandel & Veetil 2020; Adams-Prassl et al. 2022): large, but impact of vaccines less studied?
  - Health benefits of COVID-19 vaccines (Moore et al. 2021; Pearson et al. 2021; Reddy et al. 2021; Sandman et al. 2021):
    - Most common=> Benefits (lives saved; hospitalizations averted; working days) to vaccinated
    - Some include=> Benefits of reduced infections
- Missing from current research (but see Proaño and Makarewicz 2022, Deb et al 2022):
  - Benefits to economy due to reduced Non-pharmaceutical Interventions (NPIs)
    - Learning to avoid economic costs despite NPIs
  - Reduced life savings due to behavioral response

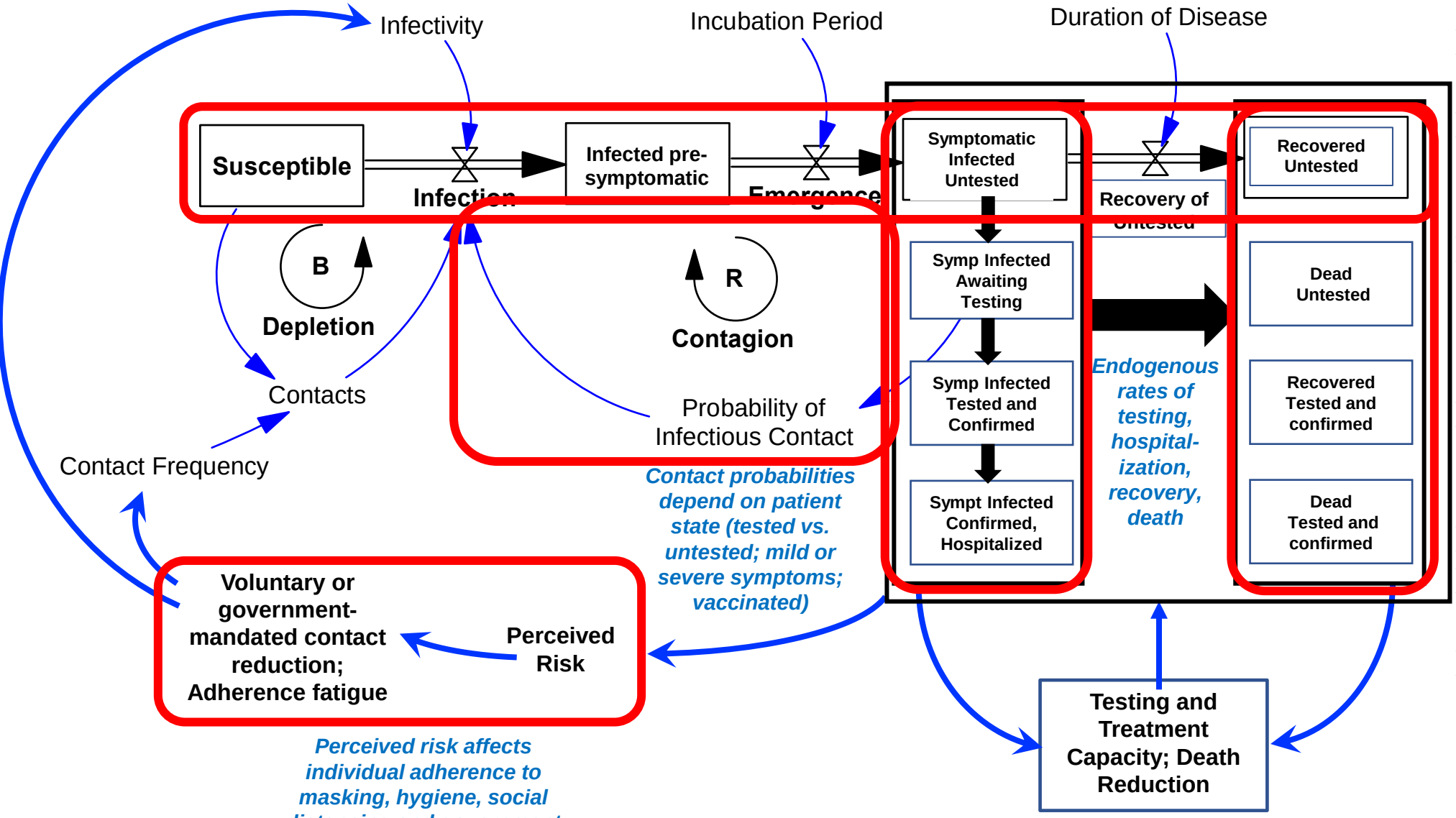
Study Objectives and Scope

- **Objective**: Estimating the value of COVID-19 vaccinations accounting for
  - Lives saved, hospitalizations averted, economic activity enabled
- **Novel features**
  - Incorporating endogenous changes in NPIs and behaviors that impact both economic activity and epidemic progression
  - Accounting for learnings that reduced NPI impact on economic activities
  - Empirically estimated for key relevant functions
- **Scope**
  - Marginal and average value of vaccination (per individual)
  - United States, disaggregated at the state level
  - From beginning of the pandemic until September 2022

Methods

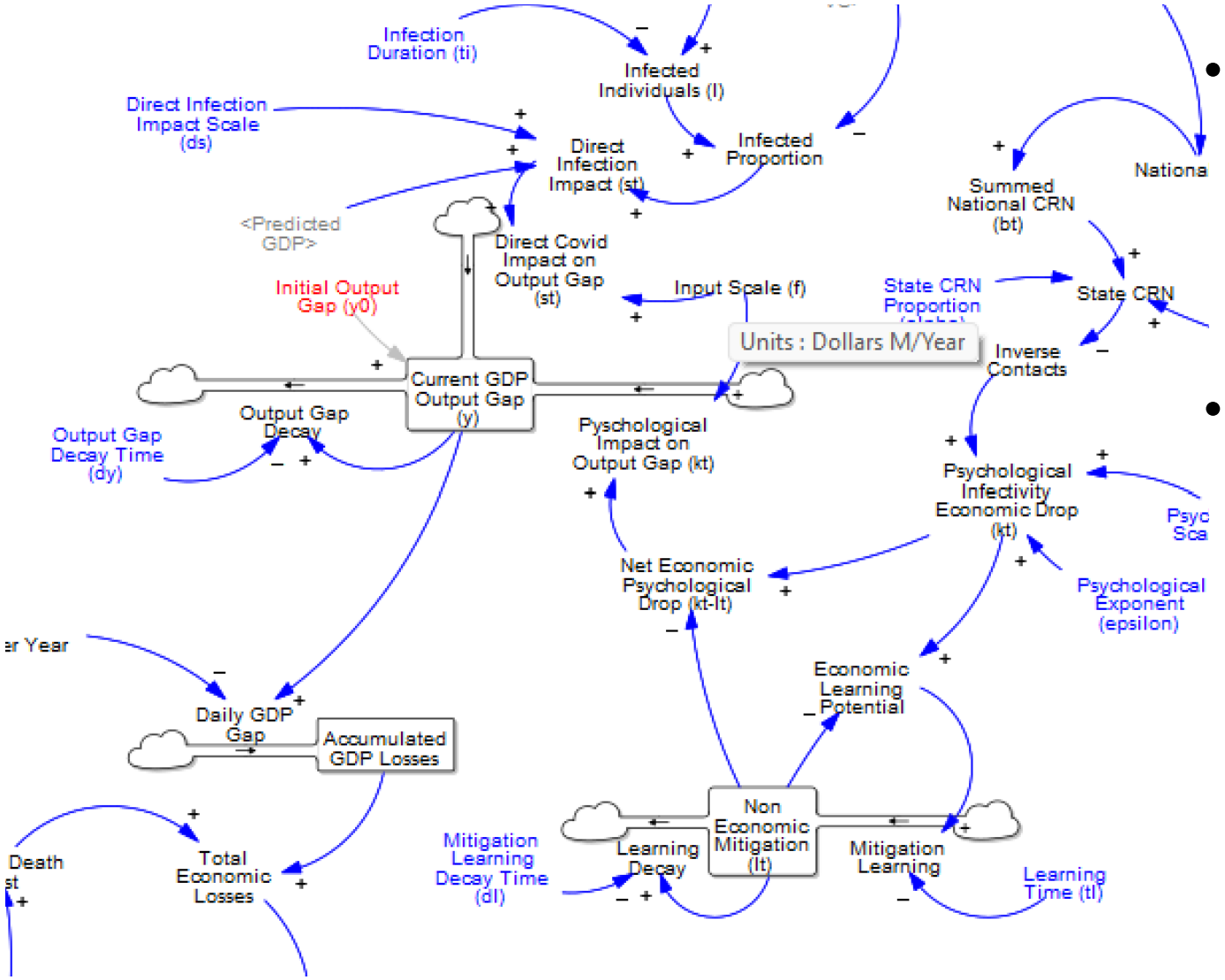
- System Dynamics Model with Two modules:
  - Epidemics module extending SEIR framework to include (adopted from Rahmandad & Sterman 2022)
  - Economic activity module (getting input from epidemic)
- Estimation:
  - Every state in the USA in a hierarchical Bayesian framework
  - Matching cases, deaths, hospitalizations (daily) and GPD (quarterly) from early 2020 till Sep 2022

Epidemic Module Overview



- Disaggregated by states and vaccination status
- Endogenous ascertainment rates (estimating undercounts)
- Acuity-based allocation of hospital capacity to cases, and impact on fatality
- Endogenous Infection Fatality Rate (IFR) reduction
- Loss of immunity
- Variant impacts (Delta, Omicron, BA5)
- Historical vaccinations and tests

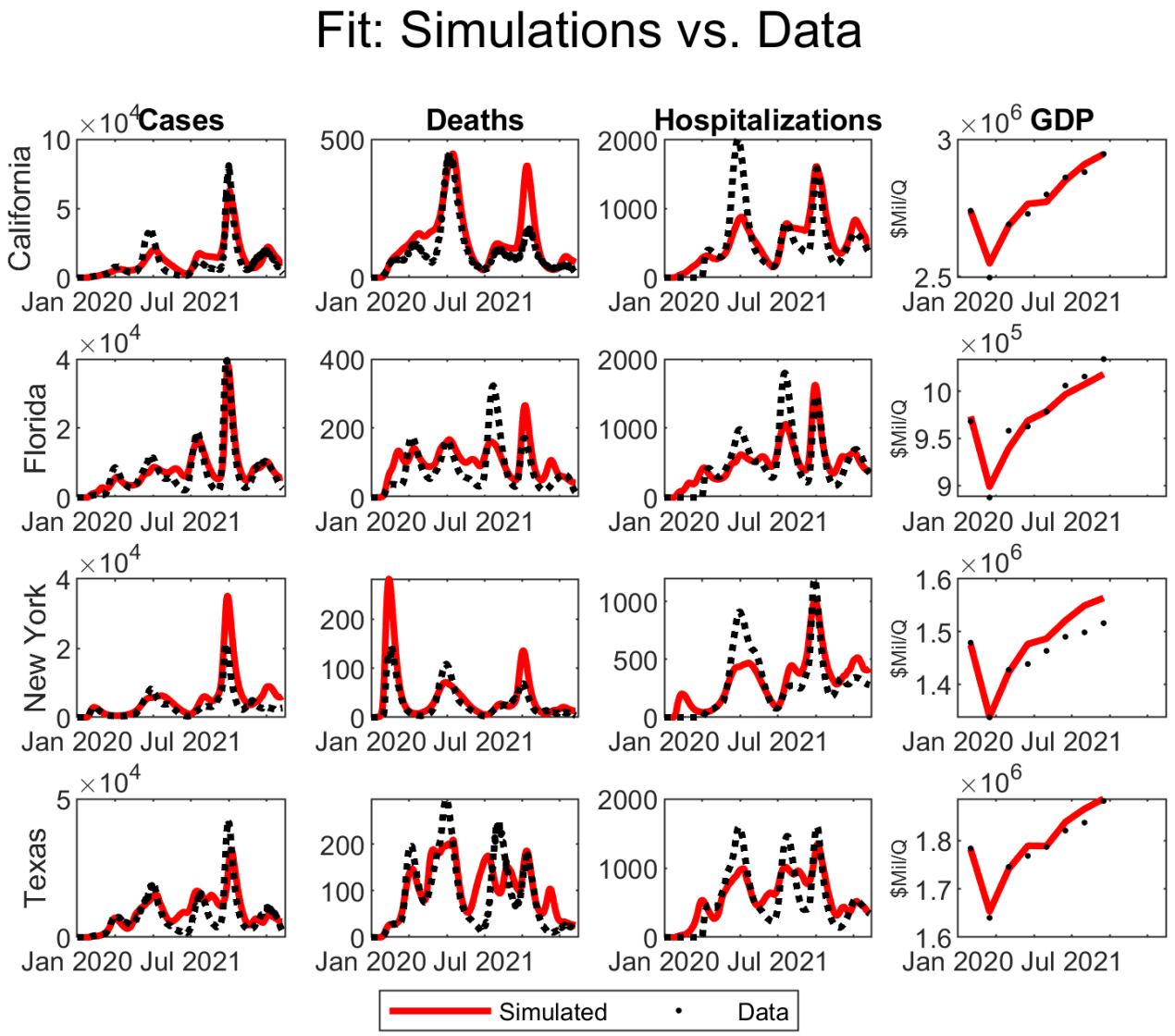
Economic Module



- Comparing state-level GDP with counter-factual absent COVID
  - No-COVID-19 estimate coming from extrapolation of pre-COVID GDP for each state
- The delta explained based on:
  - Direct absences due to COVID infection
  - Reductions due to social distancing and other NPIs (coming from epidemic module)
    - States may vary in being impacted by national NPIs or within state
    - A learning effect makes social distancing more efficient (economically) over time

Results: Historical Match

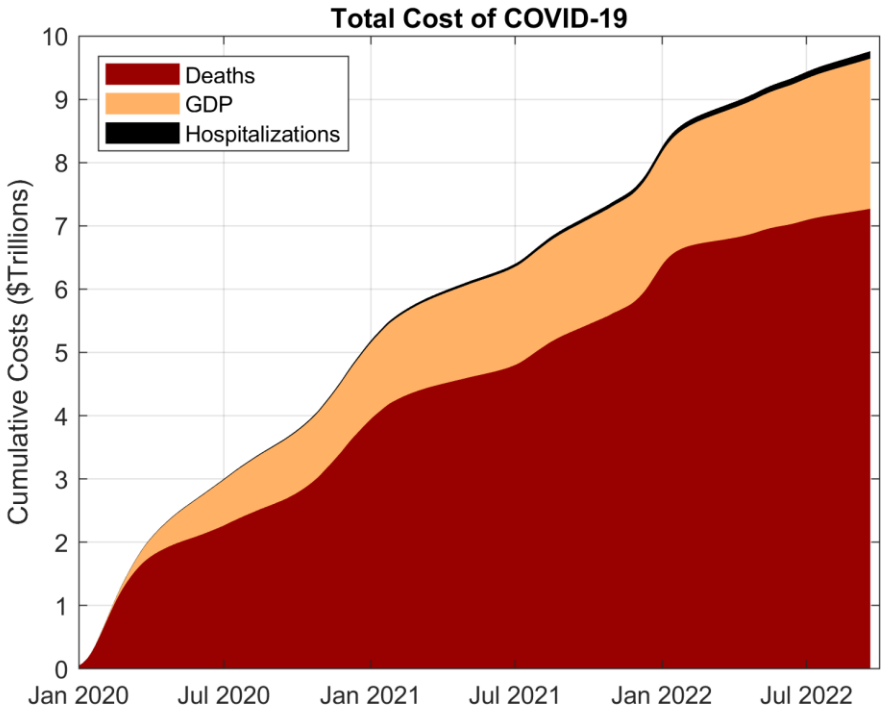
- Good match for a fully endogenous model (without data driving the model). For example average R^2s (across states) are:
  - Cases: 0.83
  - Hospitalizations: 0.80
  - Deaths: 0.79
  - GDP: 0.86

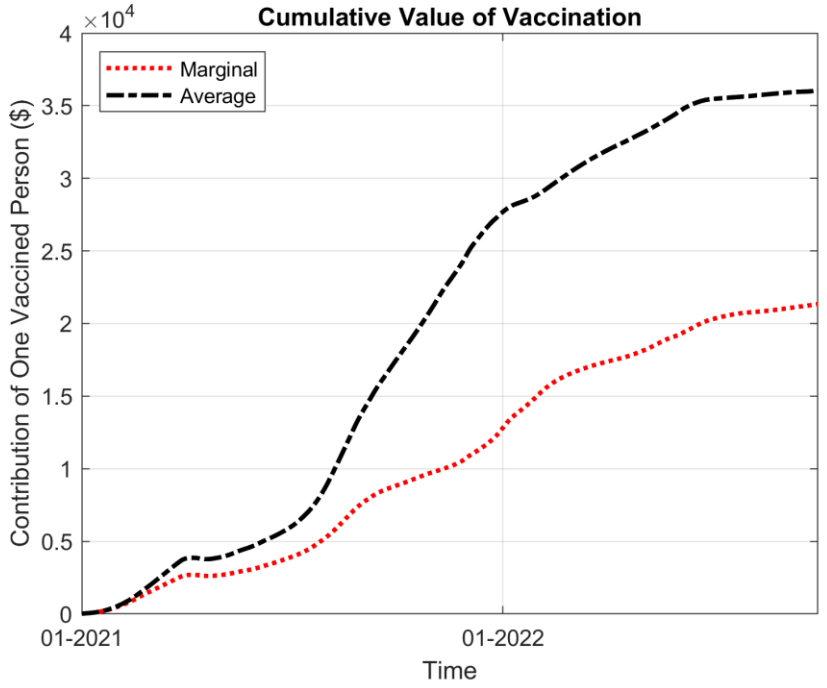


Value of Vaccination

- Total costs of COVID-19 (till Sep 2022) with/without vaccination
  - Deaths (assuming $5 million per life lost): 7.27 $T
  - Hospitalizations (assuming $12k per hospitalization): 0.12 $T
  - GDP loss: 2.37 $T
- Marginal Value of a Single Vaccine Adopter: $21500
- Average Value of a Single Vaccine Adopter: $36200

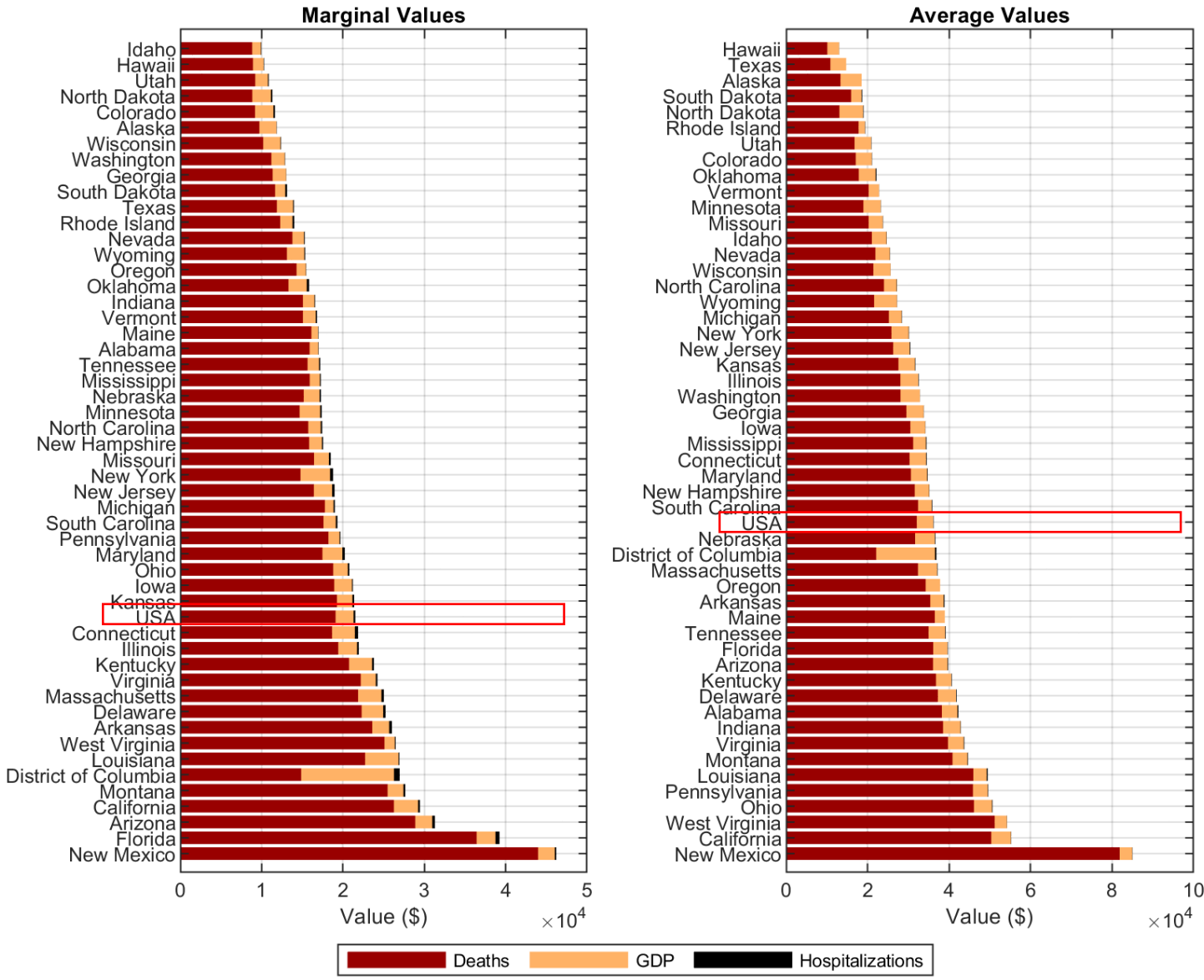
- Novel mechanisms (compared to no behavioral model):
  - Reducing the health benefits (absent vaccination, deaths would not have exploded, because of endogenous contact reduction)
  - Increasing GDP benefits
    - GDP impact primary through NPIs, rather than sick individuals
    - Absent vaccination, NPIs would have been harsher, bringing down GDP even more





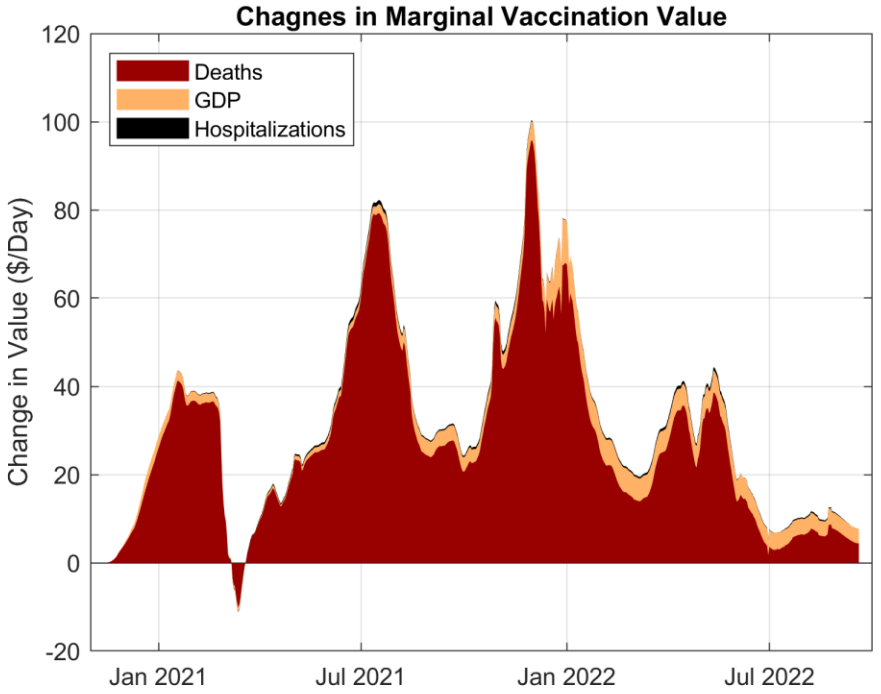
Some Heterogeneity Across States

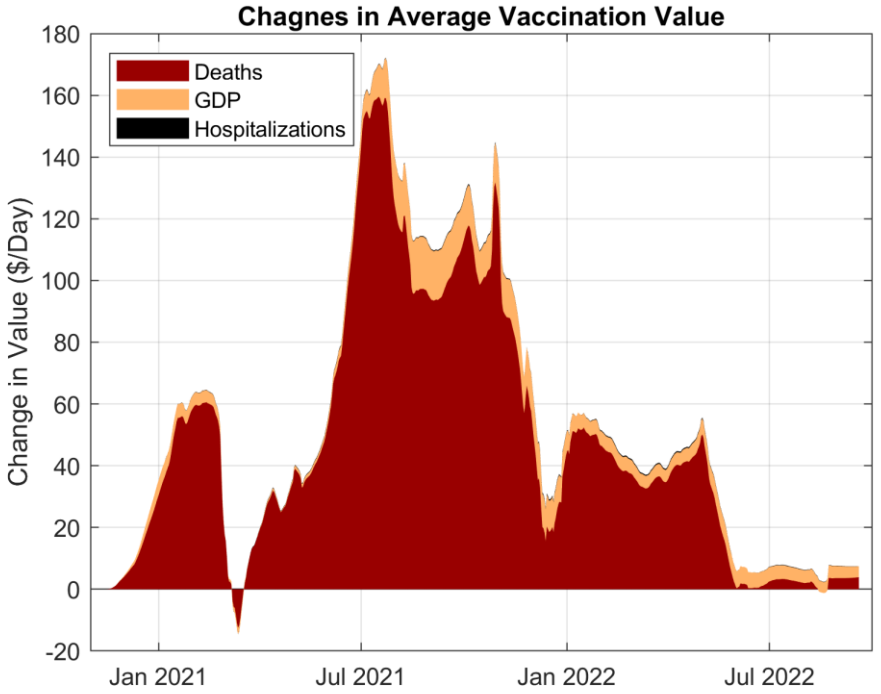
- A mix of effects:
  - Less responsive states had more room for benefitting on the health side but less on the economic side
  - However, less responsive states had a larger fraction develop natural immunity before vaccines were available, reducing later benefits
  - Population (density) by increasing R0 increases marginal value



Value dependent on waves, and decreasing over time

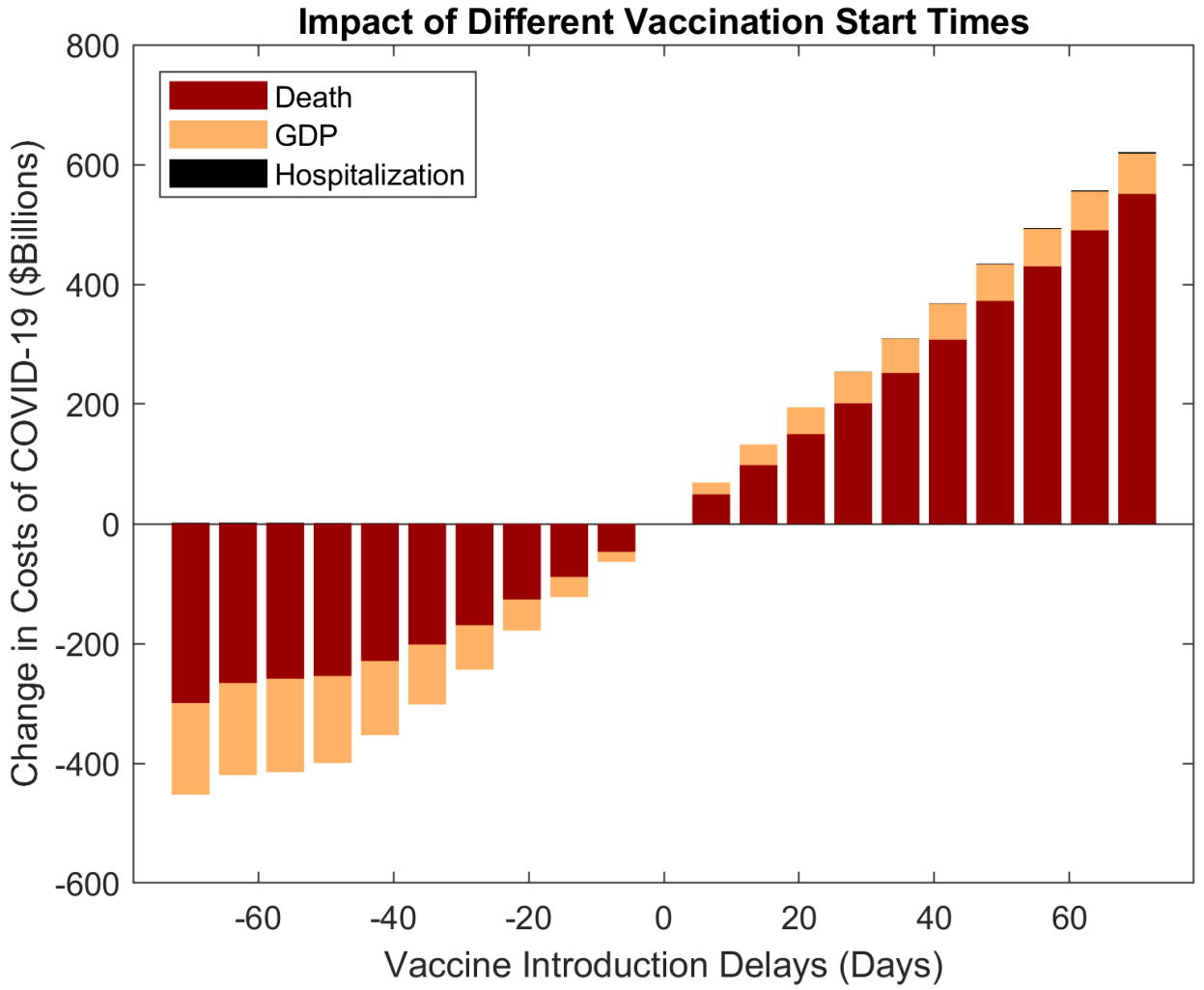
- More natural immunity later on reduces vaccine value for health
  - But that value does not go to zero, as in our estimates vaccine immunity provides better protection
- Milder variants later reduce value
- More economic learning reduces later value
  - But some value remains because of forgetting of that learning
- Vaccine changes the timing of waves. By delaying waves vaccine could have negative value for a few days (but not cumulatively)





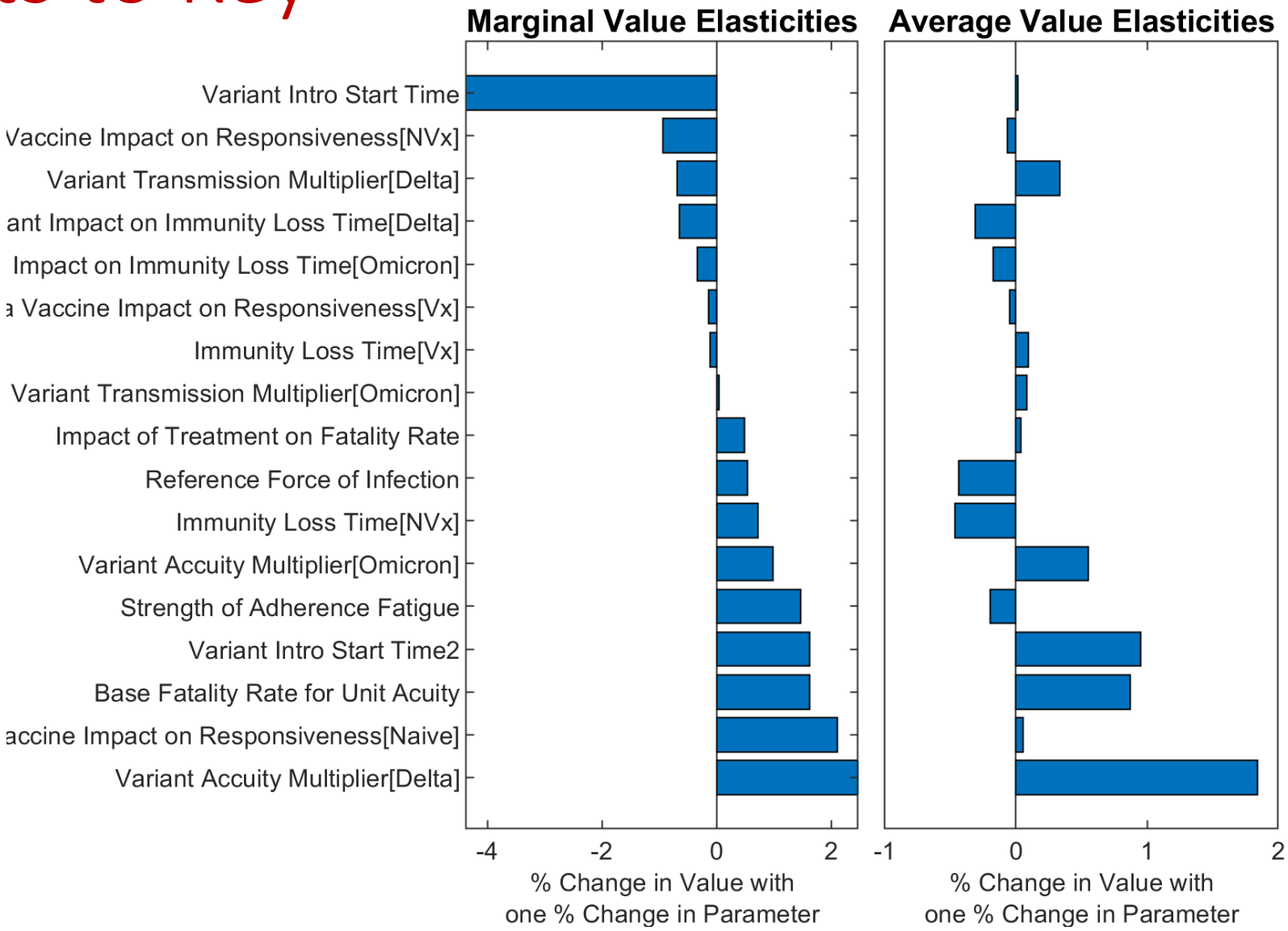
Large value of earlier vaccination start

- Earlier vaccination value as much as **1 $B per day**
  - Timing mattered based on upcoming/earlier waves: most impactful if vaccine changed the impact of a big wave significantly
  - Compare to project warp speed (total costs <20 $B)
- Earlier vaccination could have had even larger economic benefits (by avoiding the biggest lockdowns)



Sensitivity of Results to Key Parameters

- Results sensitive to a few parameters
  - These parameters are estimated, however, reality may be different from estimated values
  - More acute variants, adherence fatigue, and later introduction of omicron (or earlier introduction of Delta) all increase marginal value
  - Effects on marginal value are sometimes less intuitive (since timing of waves matter more)



Conclusions and Discussion

- Large value of vaccine, orders of magnitude bigger than costs (of design and production)
- Larger benefits early on, but ongoing benefits non-trivial
  - Enormous value in speeding up development, building production capacity, and enabling early release
  - Ongoing value generation (at least based on our estimates for vaccine protection against deaths exceeding natural immunity)
- Given heterogeneity in responsiveness across nations, value of vaccination may also be very different; relevant in allocating limited early doses
  - But hard politically: those least responsive should be prioritized, but usually less powerful and it does not feel fair
- Who pays for your tweet? Large externalities associated with vaccine mis-information

Thank you!

- Questions:

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