2021 DMDU
Webinar Series

Nov 29th, 2021

Reopening Under Uncertainty

Stress-Testing COVID-19 Reopening Policies

Pedro Nascimento de Lima

Presented at the DMDU Webinar:
"Informing COVID-19 Policy Under Uncertainty"

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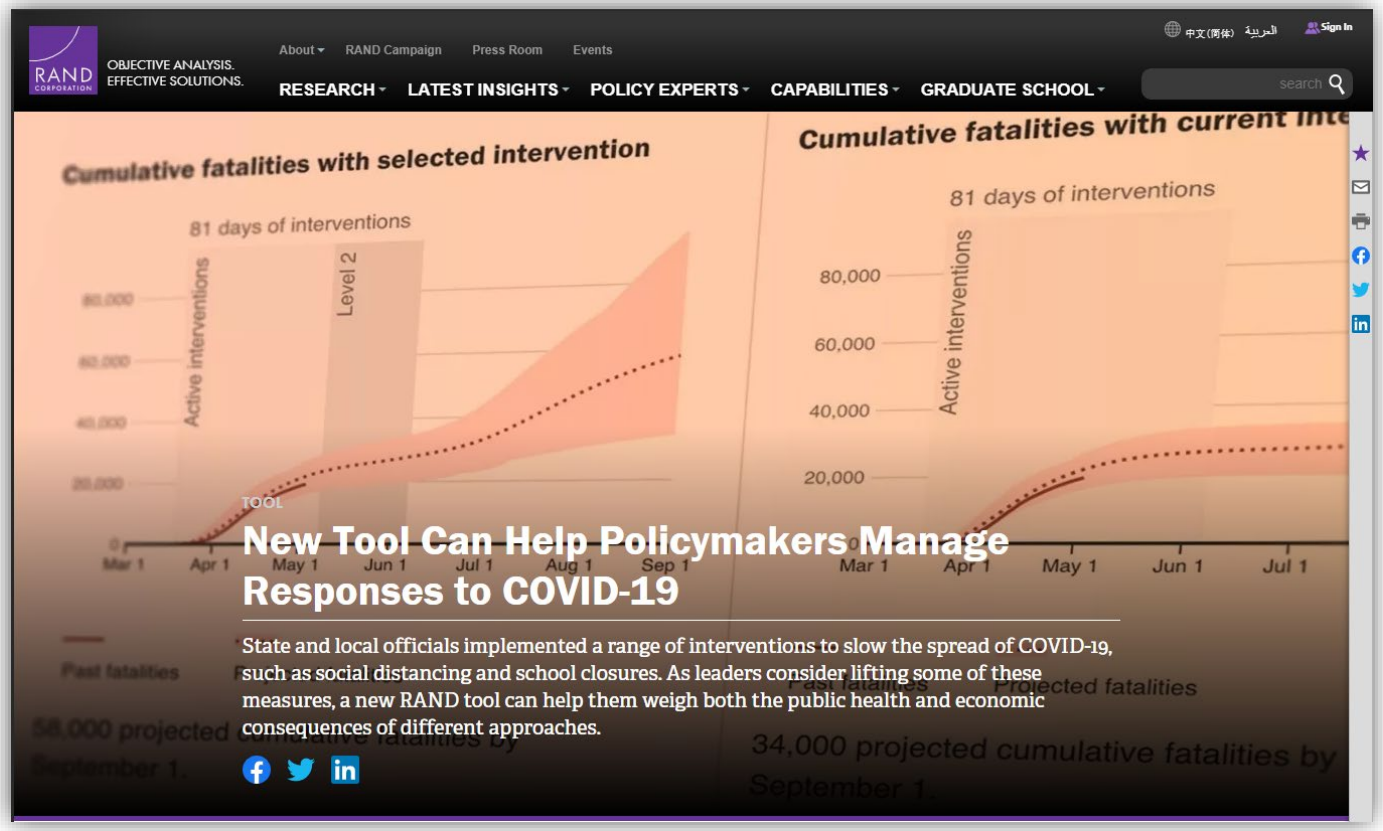
In this talk

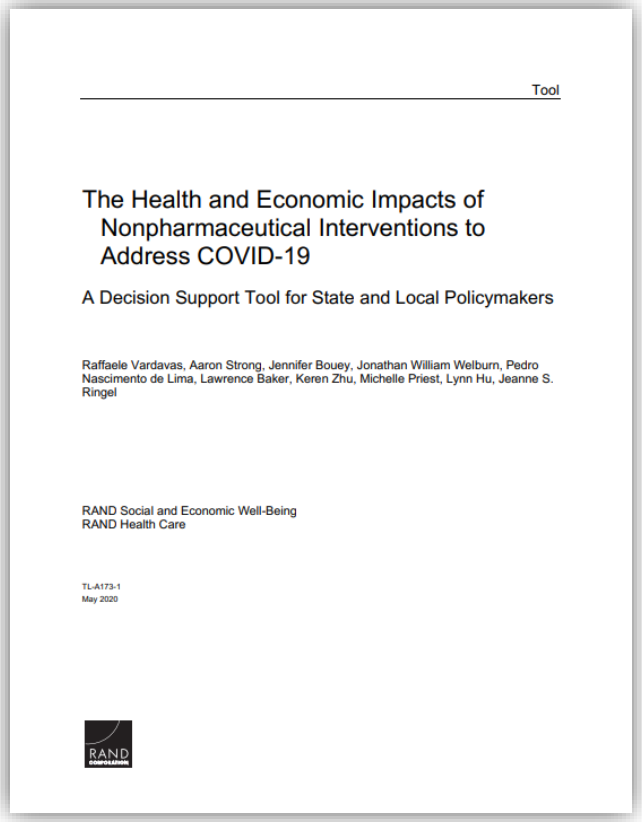
Key findings from recent papers:

1. Nascimento de Lima, et al. 2021. "**Reopening California: Seeking Robust, Non-Dominated COVID-19 Exit Strategies.**". *PLOS ONE* 16 (10): e0259166. https://doi.org/10.1371/journal.pone.0259166
2. Nascimento de Lima, Pedro, et al. 2021. "**Reopening Under Uncertainty: Stress-Testing California's COVID-19 Exit Strategy.**" Santa Monica, CA. https://doi.org/10.7249/PEA1080-1
3. Nowak, Sarah A, Pedro Nascimento de Lima, and Raffaele Vardavas. 2021. "**Should We Mitigate or Suppress the Next Pandemic? Time-Horizons and Costs Shape Optimal Social Distancing Strategies.**" *MedRxiv*. https://doi.org/10.1101/2021.11.14.21266322

Prior Work:

The Health and Economic Impacts of Nonpharmaceutical Interventions to Address COVID-19




Tool

The Health and Economic Impacts of Nonpharmaceutical Interventions to Address COVID-19

A Decision Support Tool for State and Local Policymakers

Raffaele Vardavas, Aaron Strong, Jennifer Bouey, Jonathan William Welburn, Pedro Nascimento de Lima, Lawrence Baker, Keren Zhu, Michelle Priest, Lynn Hu, Jeanne S. Ringel

RAND Social and Economic Well-Being
RAND Health Care

TL-A173-1
May 2020

RAND

https://www.rand.org/pubs/tools/TLA173-1.html

Motivation and Policy Question:

How to manage NPIs in 2021 amidst uncertainty?

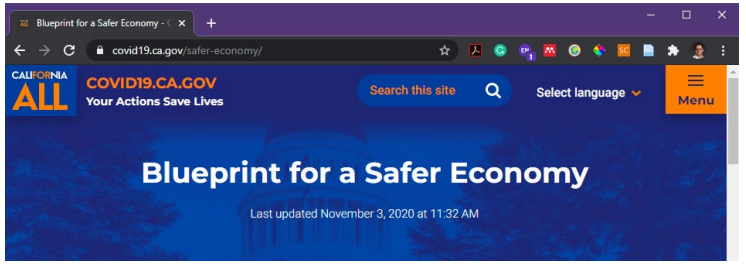
A. Reopening thresholds were defined at the county level in California.

B. California's Blueprint for a Safer Economy plan was highly detailed and contained restrictions on capacity and detailed regulations on *how to reopen*

C. Three types of decisions are involved in any reopening plan:
   A. How **stringent** should the plan be?
   B. What restrictions should apply **to each level**?
   C. How (A) and (B) should be managed ***over time*** *contingent on other conditions?*

D. Key policy questions:
   A. Are we following a ***robust*** exit strategy?
   B. Is our strategy ***pareto-efficient***?

https://covid19.ca.gov/safer-economy/



County risk level	Adjusted case rate* 7-day average of daily COVID-19 cases per 100K with 7-day lag, adjusted for number of tests performed	Positivity rate** 7-day average of all COVID-19 tests performed that are positive	
		Entire county	Healthy equity quartile
WIDESPREAD Many non-essential indoor business operations are closed	More than 7.0 Daily new cases (per 100k)	More than 8.0% Positive tests	
SUBSTANTIAL Some non-essential indoor business operations are closed	4.0 – 7.0 Daily new cases (per 100k)	5.0 – 8.0% Positive tests	5.3 – 8.0% Positive tests
MODERATE Some indoor business operations are open with modifications	1.0 – 3.9 Daily new cases (per 100k)	2.0 – 4.9% Positive tests	2.2 – 5.2% Positive tests
MINIMAL Most indoor business operations are open with modifications	Less than 1.0 Daily new cases (per 100k)	Less than 2.0% Positive tests	Less than 2.2% Positive tests

*Small counties (those with a population less than 106,000) may be subject to alternate case assessment measures for purposes of tier assignment.
**Health equity metric is not applied for small counties. The health equity metric is used to move to a less restrictive tier.

Motivation and Policy Question:

How to manage NPIs in 2021 amidst uncertainty?

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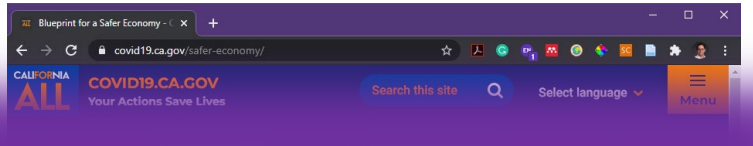
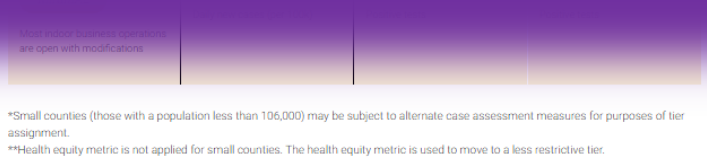


What is our **long-term strategy?**

Are **there any dominated strategies**?

Can we find **robust strategies** given the problem structure

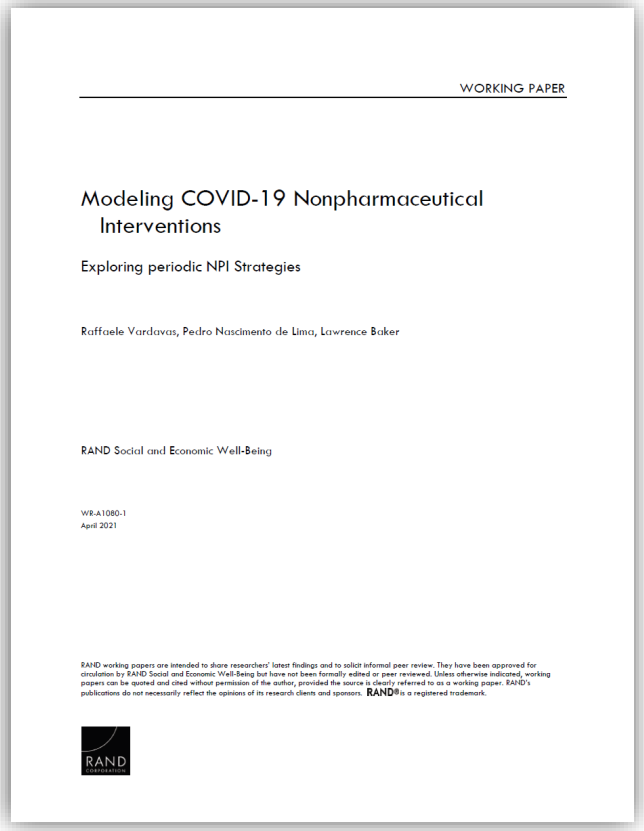
(**as opposed to good predictions** given assumptions)?



https://covid19.ca.gov/safer-economy/

Policy Question

How California and other jurisdictions should approach reopening in the wake of vaccination?



WORKING PAPER

Modeling COVID-19 Nonpharmaceutical Interventions

Exploring periodic NPI Strategies

Raffaele Vardavas, Pedro Nascimento de Lima, Lawrence Baker

RAND Social and Economic Well-Being

WR-A1080-1
April 2021

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RESEARCH ARTICLE

Reopening California: Seeking robust, non-dominated COVID-19 exit strategies

Pedro Nascimento de Lima[1,2,3]*, Robert Lempert[1,2], Raffaele Vardavas[1,2], Lawrence Baker[1,2], Jeanne Ringel[1,2], Carolyn M. Rutter[1,2], Jonathan Ozik[3], Nicholson Collier[3]

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OPEN ACCESS

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Data Availability Statement: The code and data underlying the results presented in the study are available from https://github.com/RANDCorporation/covid-19-reopening-california.

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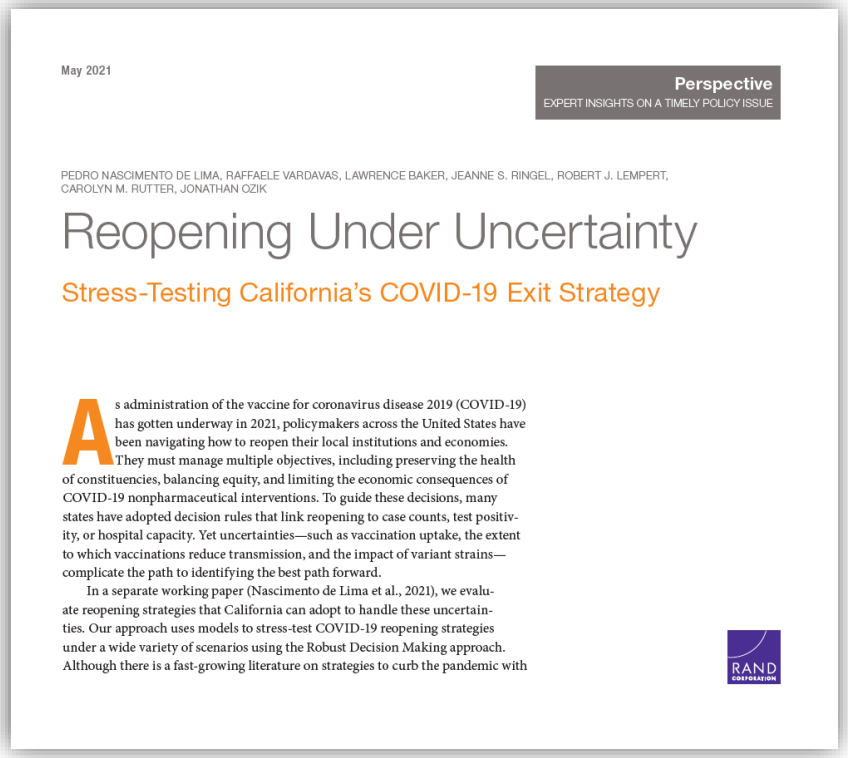
Abstract

The COVID-19 pandemic required significant public health interventions from local governments. Although nonpharmaceutical interventions often were implemented as decision rules, few studies evaluated the robustness of those reopening plans under a wide range of uncertainties. This paper uses the Robust Decision Making approach to stress-test 78 alternative reopening strategies, using California as an example. This study uniquely considers a wide range of uncertainties and demonstrates that seemingly sensible reopening plans can lead to both unnecessary COVID-19 deaths and days of interventions. We find that plans using fixed COVID-19 case thresholds might be less effective than strategies with time-varying reopening thresholds. While we use California as an example, our results are particularly relevant for jurisdictions where vaccination roll-out has been slower. The approach used in this paper could also prove useful for other public health policy problems in which policymakers need to make robust decisions in the face of deep uncertainty.

Introduction

The COVID-19 pandemic has wreaked havoc across the US, causing over 37 million confirmed cases and 600,000 deaths, and state-wide shutdowns of all non-essential businesses. As state officials navigate the pandemic, they must manage both health and economic goals. Generally, reopening plans [1–4] have been proposed as phased strategies, in which the state allows economic activity to resume based on meeting COVID-19 incidence targets. However, pandemics often follow oscillatory waves of infection, and many states have already been forced to revise their plans, either shutting down after new outbreaks or adjusting which activities are allowed in each phase. To ensure long-term success in combating the pandemic, local policymakers need to consider the trade-offs underlying reopening decisions, while accounting for deep uncertainties.

Since one-time lockdowns have proven to be insufficient to control the pandemic, a coherent, long-term strategy is needed. Instead of adopting a stable, pre-defined strategy, local policymakers have changed regulations and instated NPIs adaptively, often adopting NPIs based on the decisions of other jurisdictions [5] without necessarily supporting every deliberation



May 2021

Perspective
EXPERT INSIGHTS ON A TIMELY POLICY ISSUE

PEDRO NASCIMENTO DE LIMA, RAFFAELE VARDAVAS, LAWRENCE BAKER, JEANNE S. RINGEL, ROBERT J. LEMPERT, CAROLYN M. RUTTER, JONATHAN OZIK

Reopening Under Uncertainty

Stress-Testing California's COVID-19 Exit Strategy

As administration of the vaccine for coronavirus disease 2019 (COVID-19) has gotten underway in 2021, policymakers across the United States have been navigating how to reopen their local institutions and economies. They must manage multiple objectives, including preserving the health of constituencies, balancing equity, and limiting the economic consequences of COVID-19 nonpharmaceutical interventions. To guide these decisions, many states have adopted decision rules that link reopening to case counts, test positivity, or hospital capacity. Yet uncertainties—such as vaccination uptake, the extent to which vaccinations reduce transmission, and the impact of variant strains—complicate the path to identifying the best path forward.

In a separate working paper (Nascimento de Lima et al., 2021), we evaluate reopening strategies that California can adopt to handle these uncertainties. Our approach uses models to stress-test COVID-19 reopening strategies under a wide variety of scenarios using the Robust Decision Making approach. Although there is a fast-growing literature on strategies to curb the pandemic with

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https://www.rand.org/pubs/working_papers/WRA1080-1.html https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0259166 https://www.rand.org/pubs/perspectives/PEA1080-1.html

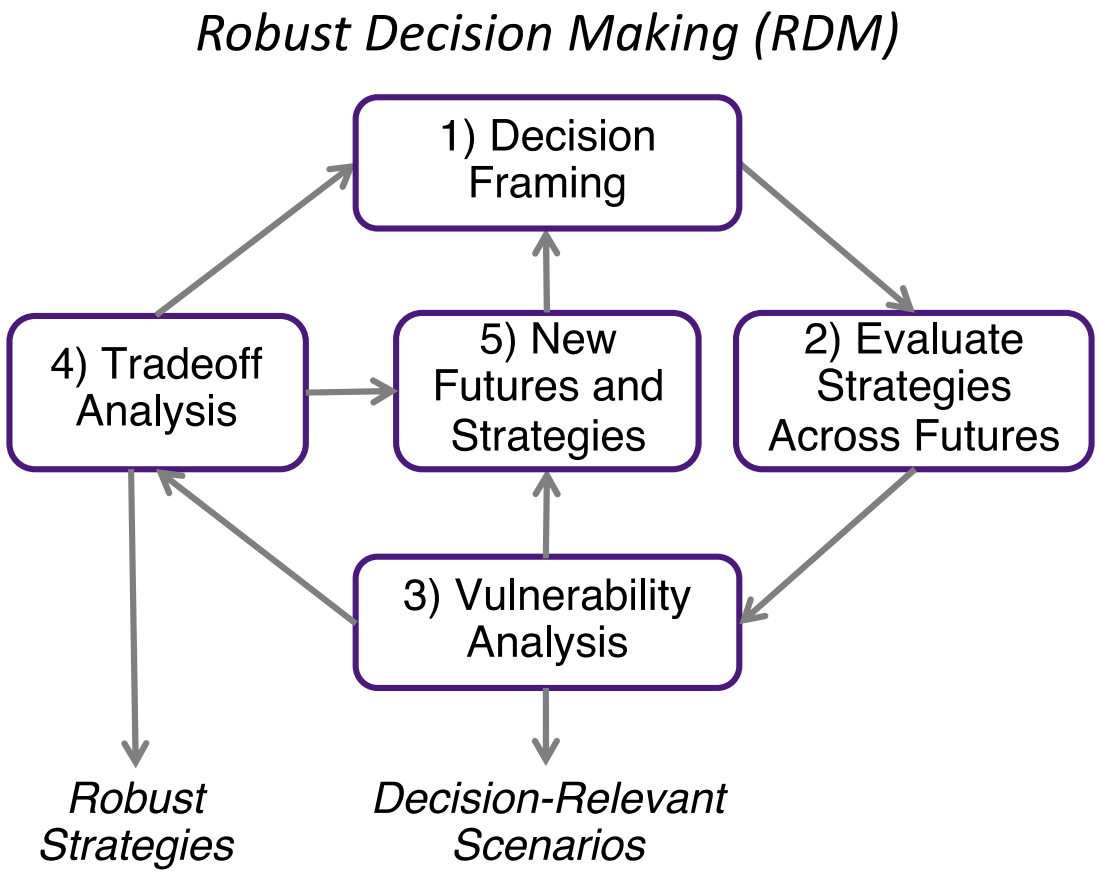
slides & references: bit.ly/covid19dmdu

Approach

Stress-testing reopening strategies with the Robust Decision Making (RDM) approach

1. RDM provides an ***iterative framework*** for evaluating policies while accounting for *deep uncertainty*
2. Uses *models* to **stress-test policies across wide range of futures**, reflecting uncertainties
3. *Quantitative* ***vulnerability analysis*** **identifies the assumptions that lead policies to be successful and unsuccessful**, and informs development of *adaptive strategies*
4. Tradeoff analysis helps balance across **multiple objectives** and identify *robust* strategies
5. RDM Is part of a family of **Decision making Under Deep Uncertainty (DMDU) methods**.

More information on RDM:
https://www.rand.org/methods/rdmlab.html



Decision Framing:

Stress-testing a pandemic "control loop"

New Variants

Behavioral Changes / resistance to NPIs

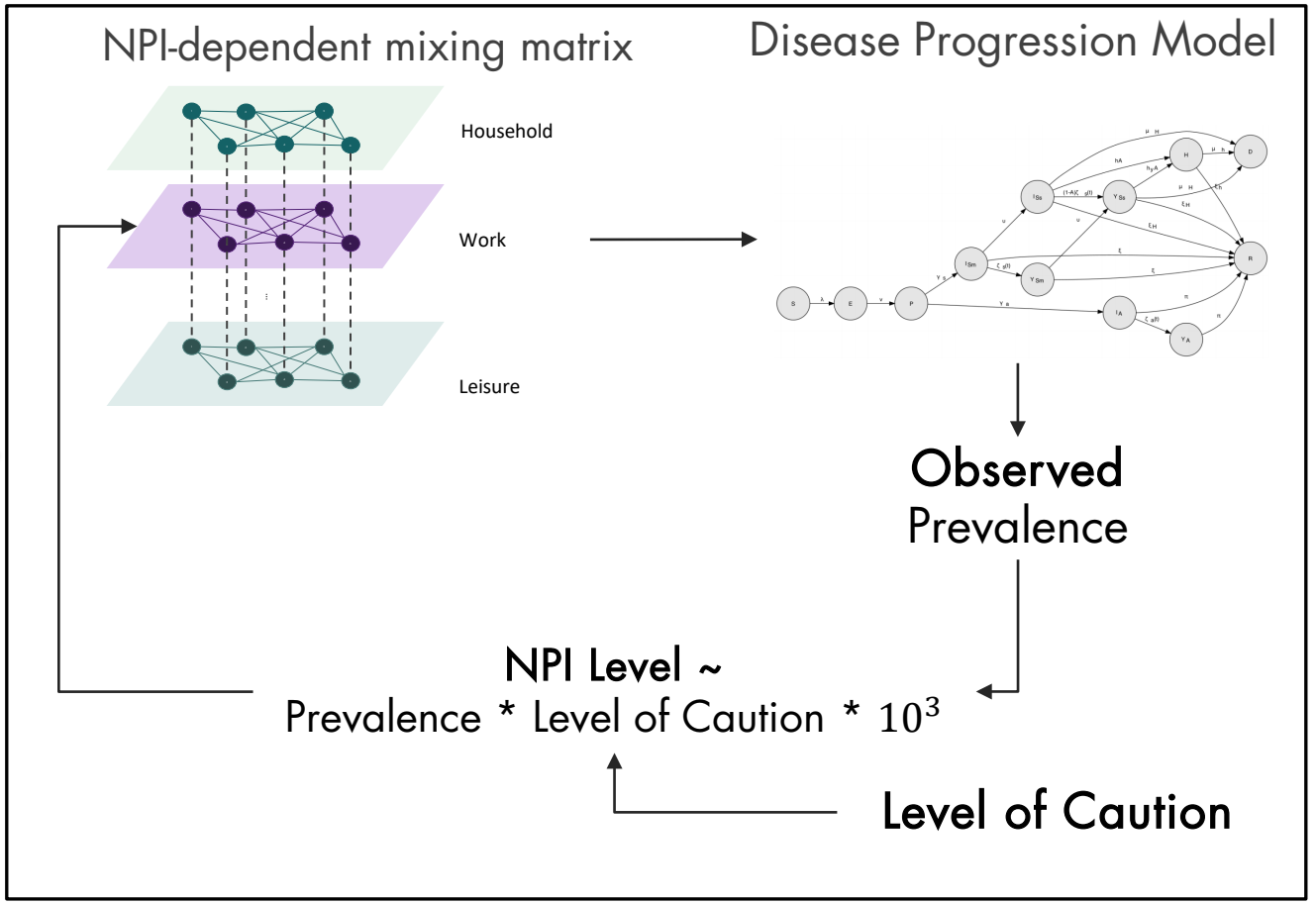
Multiple vaccines with uncertain transmission efficacies

Future willingness to Vaccinate

Behavioral response to vaccination

Seasonal Effects

…



Outputs

Deaths

Cases

Income Loss

Days of NPIs

Paper: Nascimento de Lima, Pedro et al. 2021. "Reopening California: Seeking Robust, Non-Dominated COVID-19 Exit Strategies." *PLOS ONE* 16 (10): e0259166. https://doi.org/10.1371/journal.pone.0259166.

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Mechanistic models are still useful for computational experimentation (even when prediction is out of reach)

New Variants

Behavioral Changes / resistance to NPIs

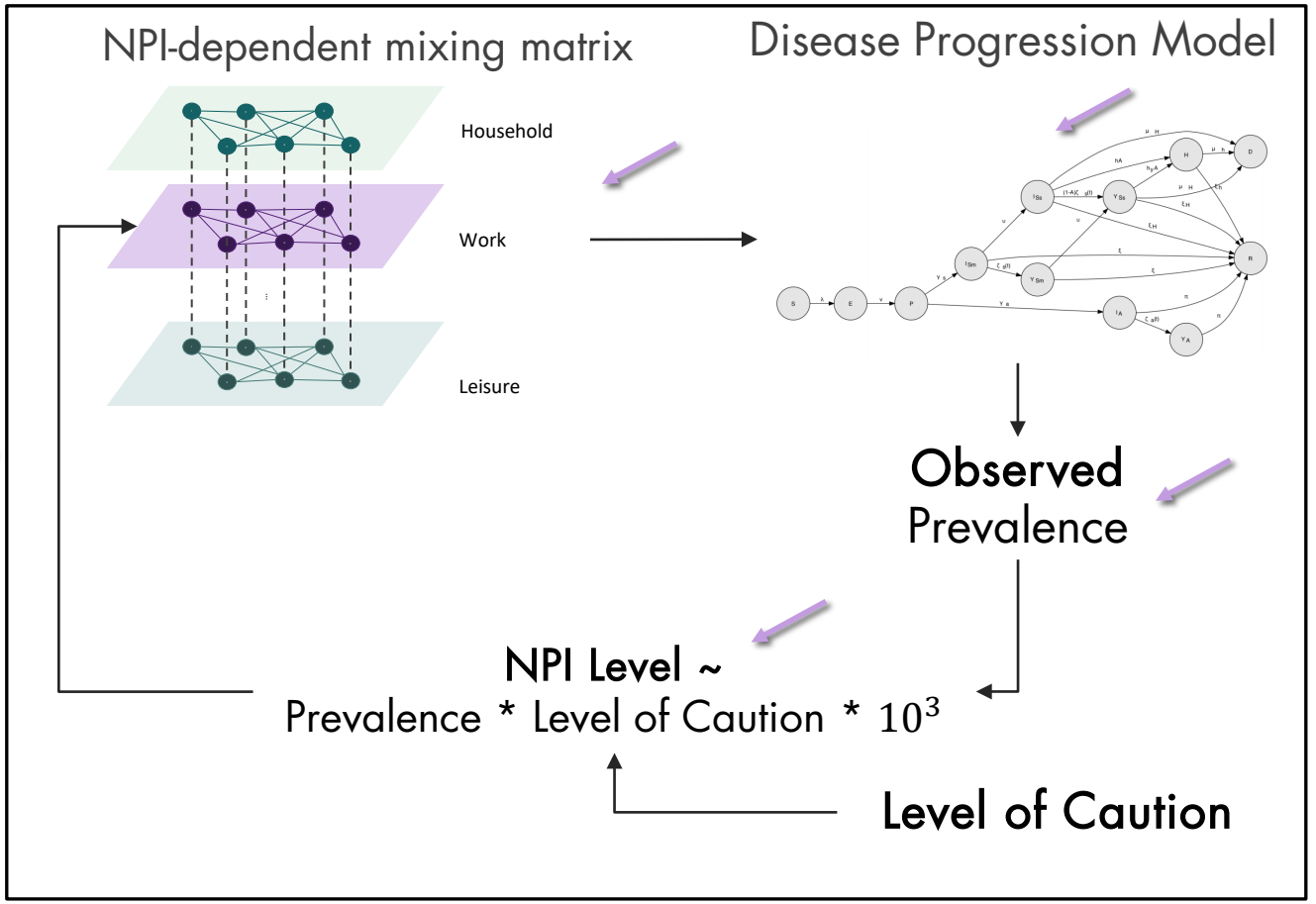
Multiple vaccines with uncertain transmission efficacies

Future willingness to Vaccinate

Behavioral response to vaccination

Seasonal Effects

…



Known Mechanisms

Outputs

Deaths

Cases

Income Loss

Days of NPIs

Paper: Nascimento de Lima, Pedro et al. 2021. "Reopening California: Seeking Robust, Non-Dominated COVID-19 Exit Strategies." *PLOS ONE* 16 (10): e0259166. https://doi.org/10.1371/journal.pone.0259166.

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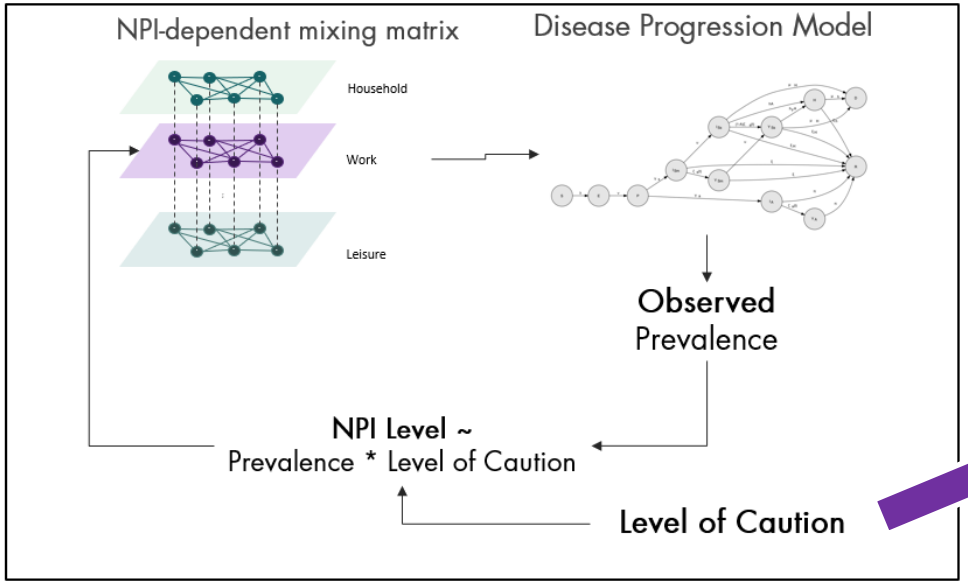
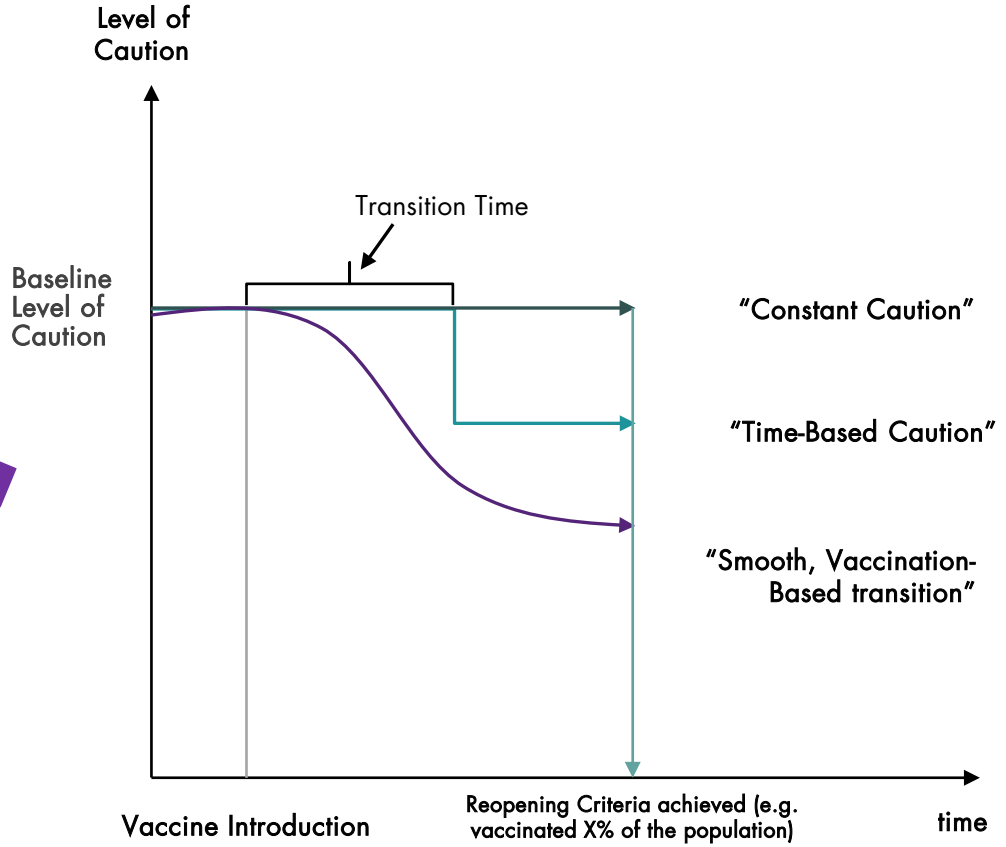
Decision Framing:

Policy question: How to manage this level of caution over time?





Decision Framing:

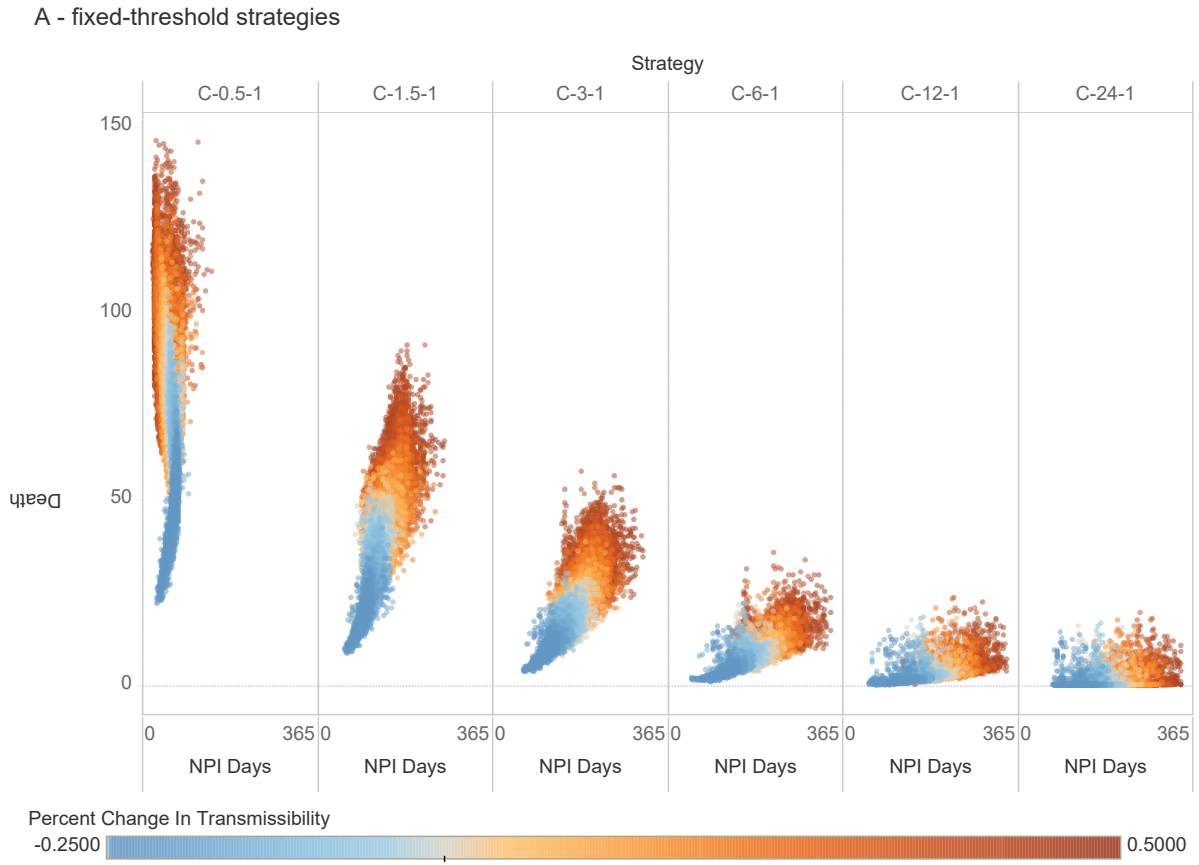
XLRM framework helps by framing the decision under uncertainty problem

Failing to consider some of those elements can lead to incomplete or misleading advice:

1. **Not enough levers** -> Results in a **menu of potentially dominated options**.
2. **Not enough uncertainties** -> Plans can be **fragile** and break.
3. **Ignore important outcomes** -> Can result in **dominated policies (likely ignores precarious values)**

X - Uncertainties	L - Policy levers
• Vaccine efficacy to prevent transmission • Loss of immunity • Behavioral response to vaccination • Willingness to vaccinate • Changes in transmissibility (i.e., induced by variant strains) • Actual vaccination Rate	• Baseline level of caution x_b • NPI strategy $s \in \{C, T, V\}$ • Time-based strategies $s = T$ – Level of caution factor α – Transition date T_α • Vaccination-based strategies $s = V$ – Vaccination reference point V_{mid} – Relaxation rate k_c
R - Relationships (models)	**M - Metrics**
Meta-population deterministic ODE [10, 33] Computable general equilibrium model [36]	75^{th} Regret percentile of deaths / 100 k people, years of life lost, cases, income loss, and days under NPIs

Reopening policies matter: They determine how we confront uncertainties



Yes, the future is uncertain, but we have agency over where we land in this outcome space

In more challenging futures, we can choose more stringent policies and avoid COVID-19 deaths, and that requires more days under NPIS.

California's original policy was close to C-6-1, if left unchanged.

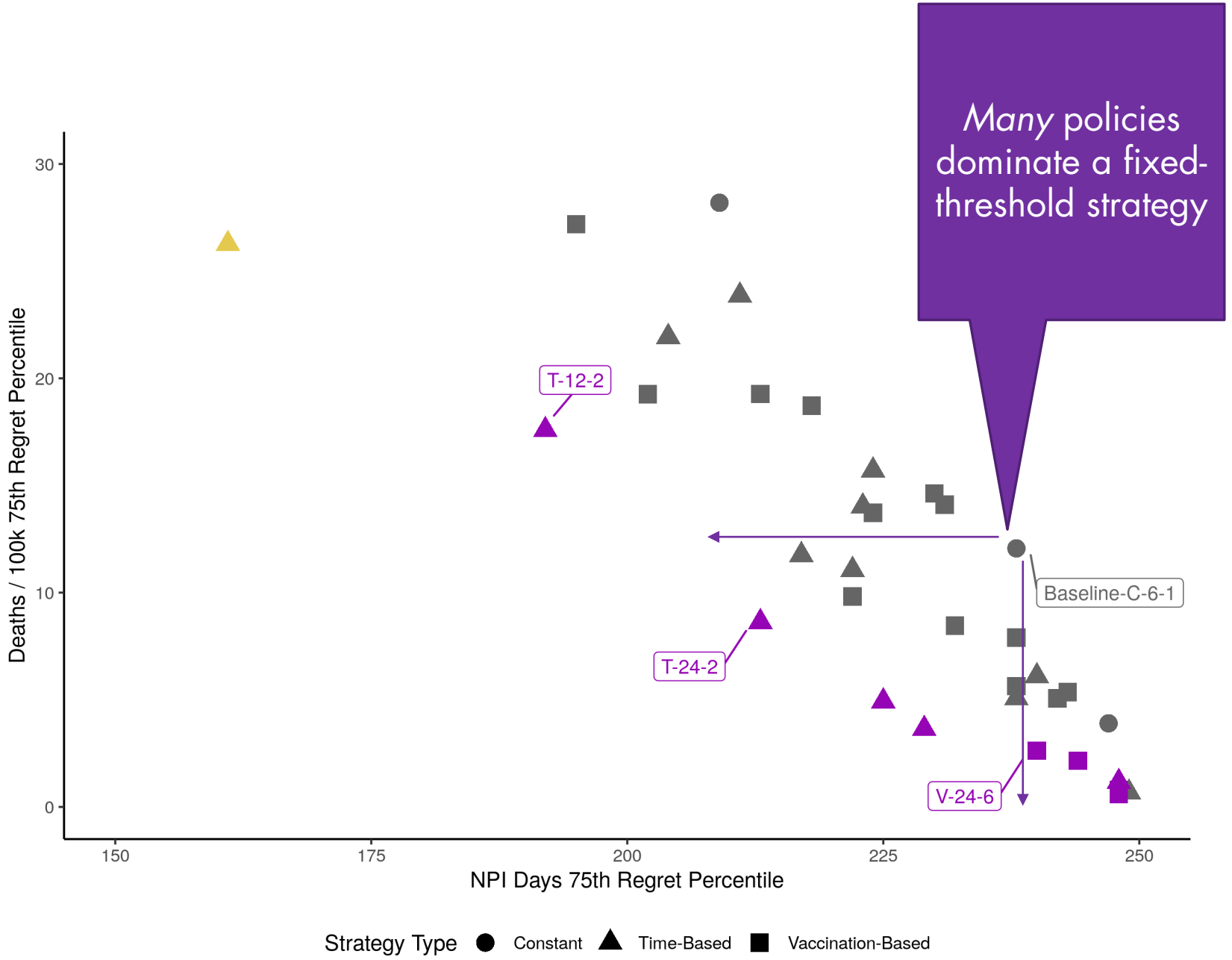
Vaccination-Based or Time-based policies dominate constant-threshold strategies

I. Constant-caution strategies were always dominated.

II. The best strategies combined a high initial level of caution with an adaptive component – either time or vaccination-based strategies worked

III. The only constant-caution policy in the pareto-front is the most-stringent, and the current policy was dominated.

IV. We stop the model in Feb 2022. If we ran the model for more time, these differences could increase.



Vaccination-Based or Time-based policies dominate constant-thres

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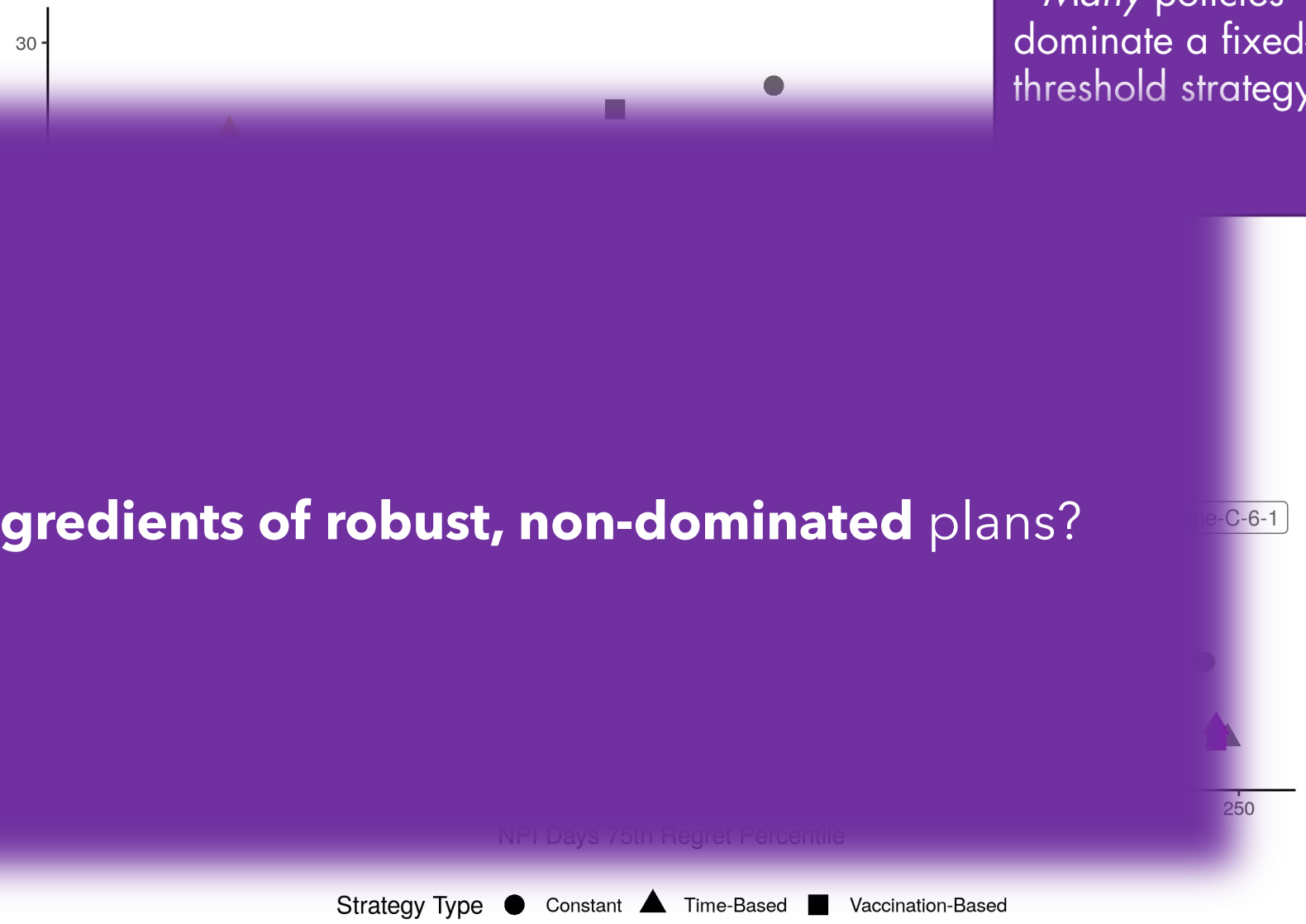
IV. We stop the model in Feb 2022. If we ran the model for more time, these differences could increase.

Many policies dominate a fixed-threshold strategy

What **were the ingredients of robust, non-dominated** plans?



Back to the Policy Question:

Characteristics of Robust, Non-Dominated Strategies

1. **Encourage Inexpensive Adaptation Measures**: Every increase in transmissibility that could be avoided with inexpensive measures makes society systematic worse off.
2. **Begin Cautiously:** Only the initially cautious strategies were robust.
3. **Adapt as People are Vaccinated:** Strategies that did not adapt reopening thresholds based on vaccination were systematically dominated.
4. **Avoid abrupt changes:** Strategies that abruptly relaxed all interventions invited resurgences and were dominated.

All these characteristics are necessary in robust, non-dominated plans.

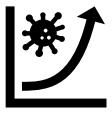
Should we Mitigate or Suppress the Next Pandemic?

In a new paper, we set out to "solve" the social distancing dilemma as a boundary value problem:

Hyper-rational society: Everyone has an SIR model in their heads and behaves rationally.

Society minimizes the "pandemic cost" = Cost of Infection + Cost of NPIs.

Fixed Time-Horizon: We know when the pandemic will "end" and strategize accordingly.



Standard SIR dynamics: SIR dynamics constrain the problem. Sterilizing immunity lasts during the decision-making time-frame.

Should we Mitigate or Suppress the Next Pandemic?

In a new paper, we set out to "solve" the social distancing problem under a set of structural assumptions:

Which strategies ***emerge from the problem*** under those structural assumptions?

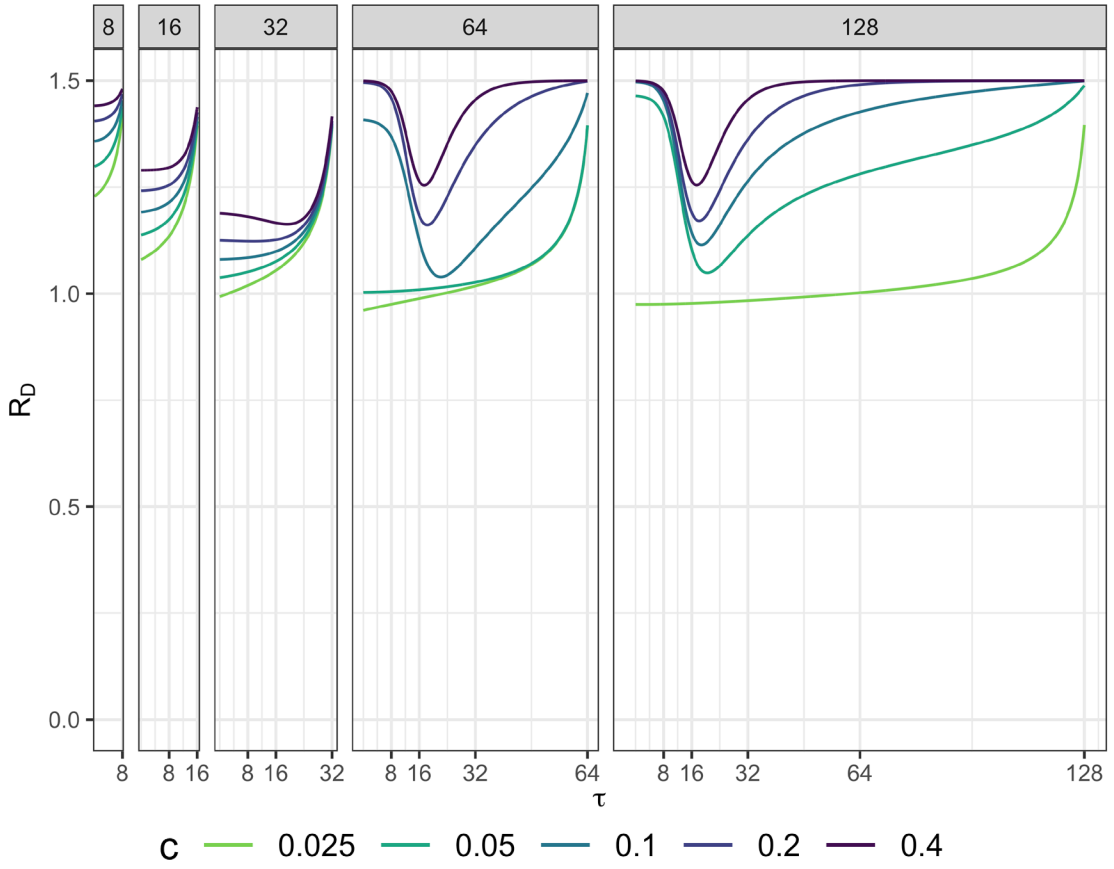
Are they like those **stress-tested for COVID-19**?

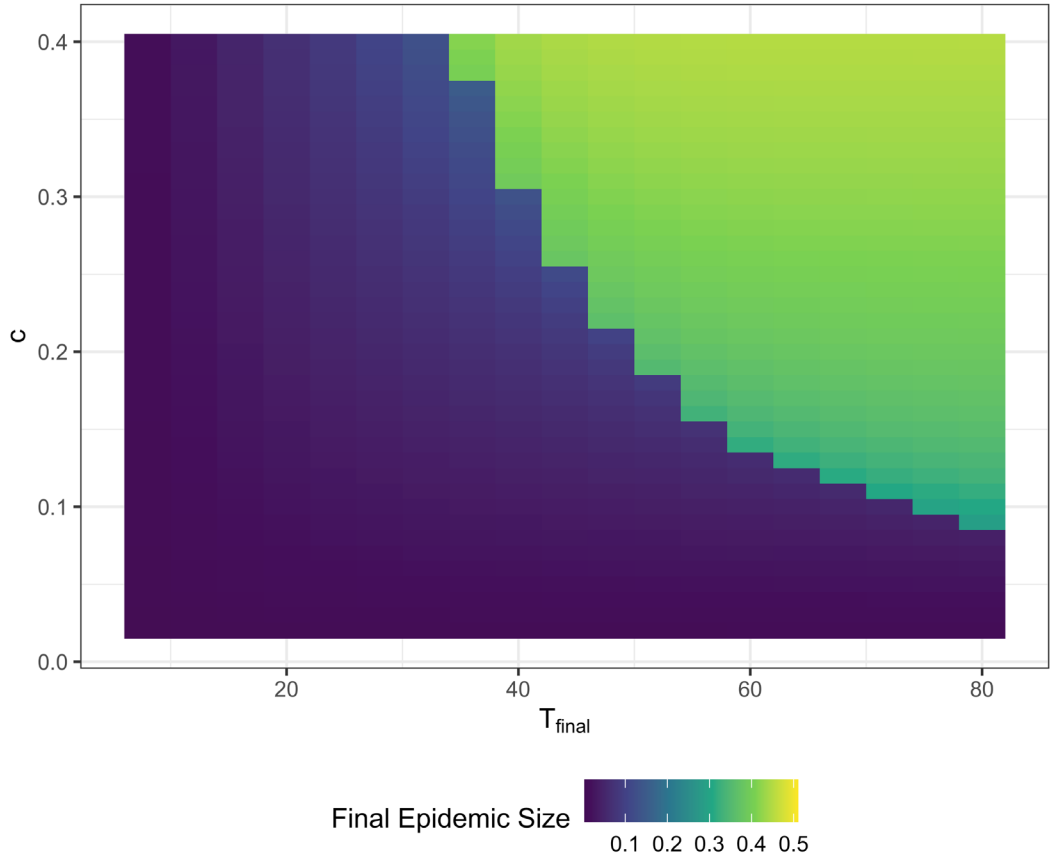
Under which conditions do we sustain a strict suppression strategy?

Standard SIR dynamics: SIR dynamics constrain the problem. Sterilizing immunity lasts during the decision-making time-frame.

Should we Mitigate or Suppress the Next Pandemic?

Time-Horizons and (relative) costs shape optimal distancing strategies





Thanks!

And thanks to the awesome people who contributed to this work

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