Forecasting COVID and vaccination policy

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Agenda

I. Forecasting COVID and planning suppression policy
  - What is the value of forecasting COVID for policy
  - What are the pitfalls of forecasting COVID?
  - What data are required for forecasting?
  - How can and is forecasting used for suppression policy?

II. Developing a vaccination policy
  - What sort of testing is required for vaccination policy?
  - What fraction of the population should be vaccinated?
  - Who should be vaccinated first?
  - Which vaccines should be purchased?

I. Forecasting COVID and suppression policy

Short-term forecasting is critical

- As lockdown fatigue rises, need to target suppression policies
- Forecasting will prove valuable for targeting limited vaccine supplies

But poor data quality, model uncertainty make projections unreliable

Objectives:

A. How can we address data quality and model uncertainty?
B. How can we map forecasts onto suppression policy?

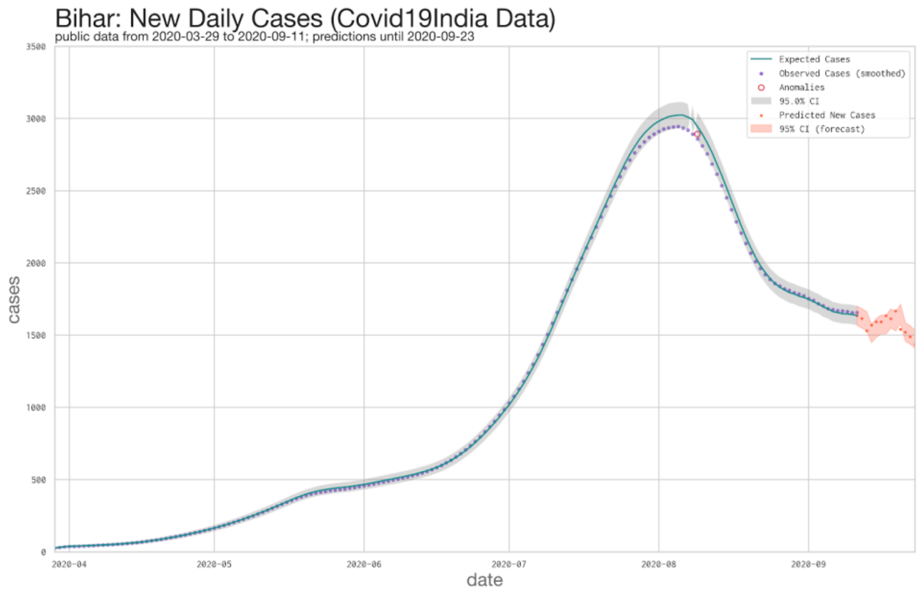
How to generate forecasts

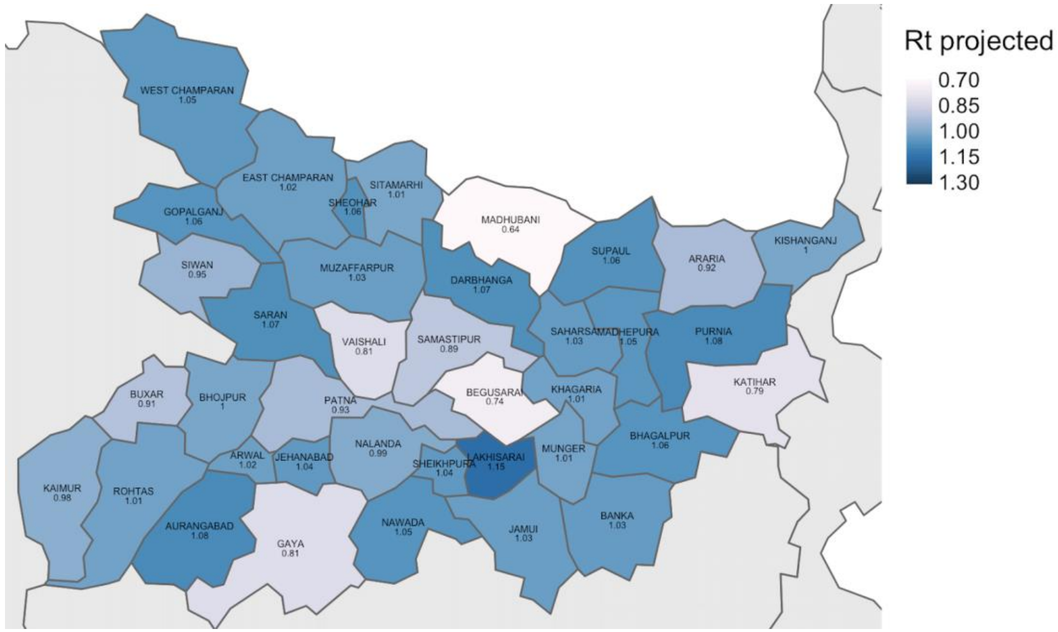
- Basic formula: data + model = forecast

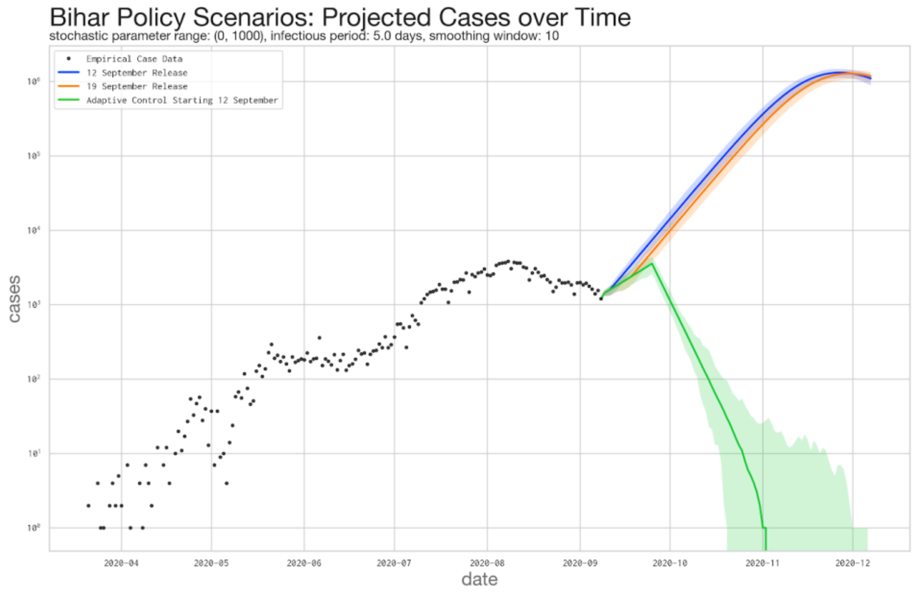
- Data are, e.g., reports of confirmed cases, recovered cases, deaths
    - More testing (for virus, not immunity) is critical
    - Test the right people (not just symptomatic people)
    - Report results quickly

- Epidemiological models use features of the disease to “translate” data into predictions about the future of the disease
    - Choose model that is supported by good data, e.g., cases by location
    - Correct for flaws in data, e.g., selection in testing and delays in reporting
    - Account for uncertainty in data and predictions
    - Constantly recalibrate the model to recent data

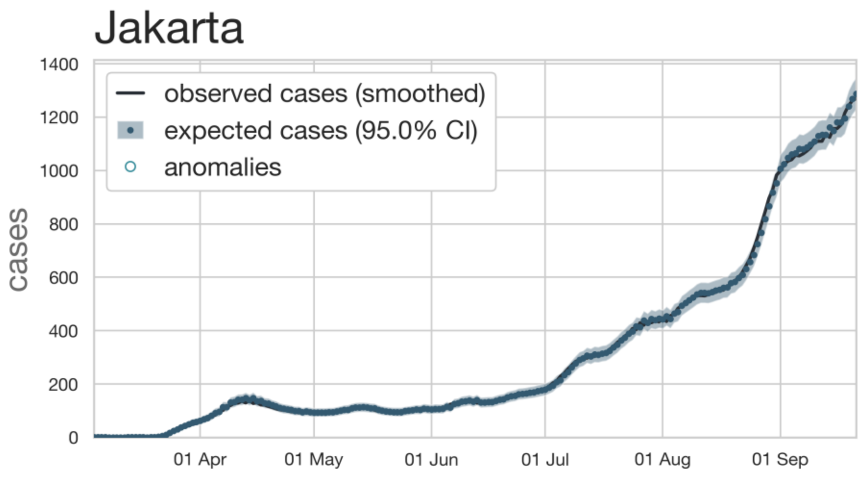
Ongoing work in Bihar, India (100m)

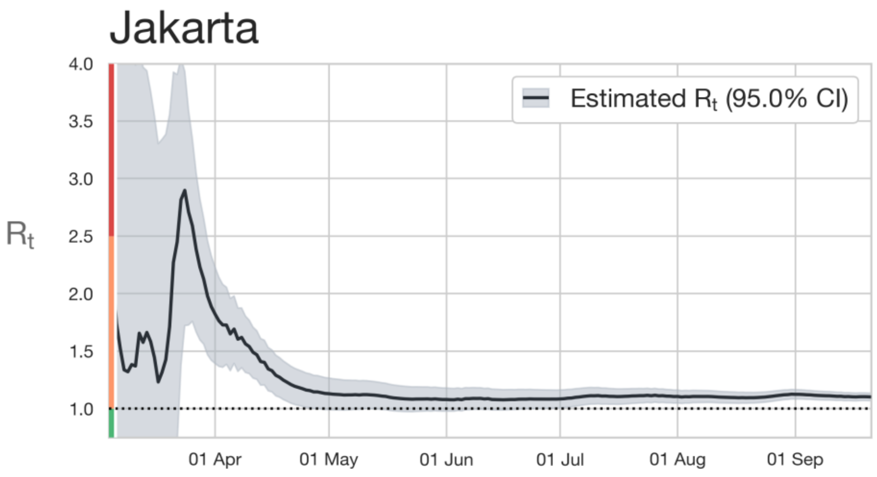


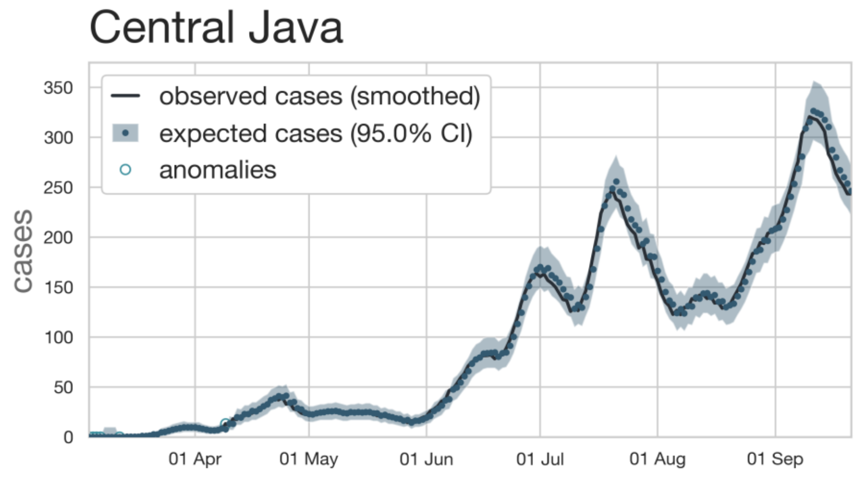


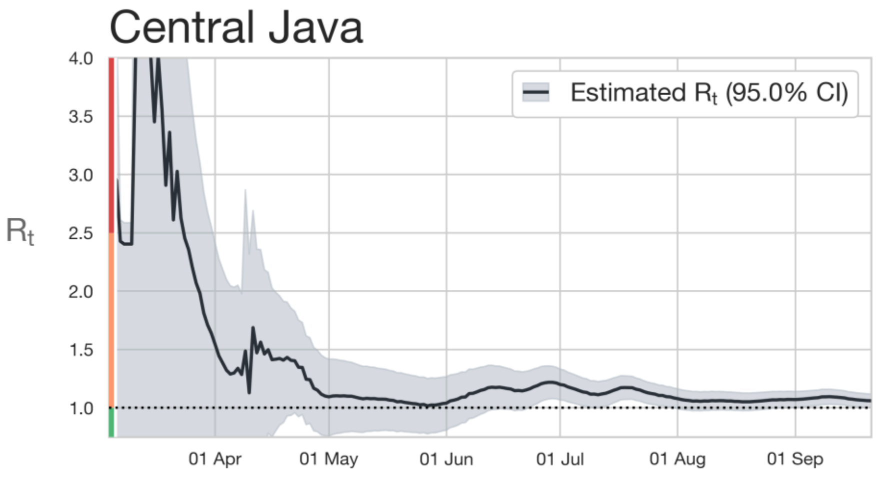


Evolution of cases, reproductive rate

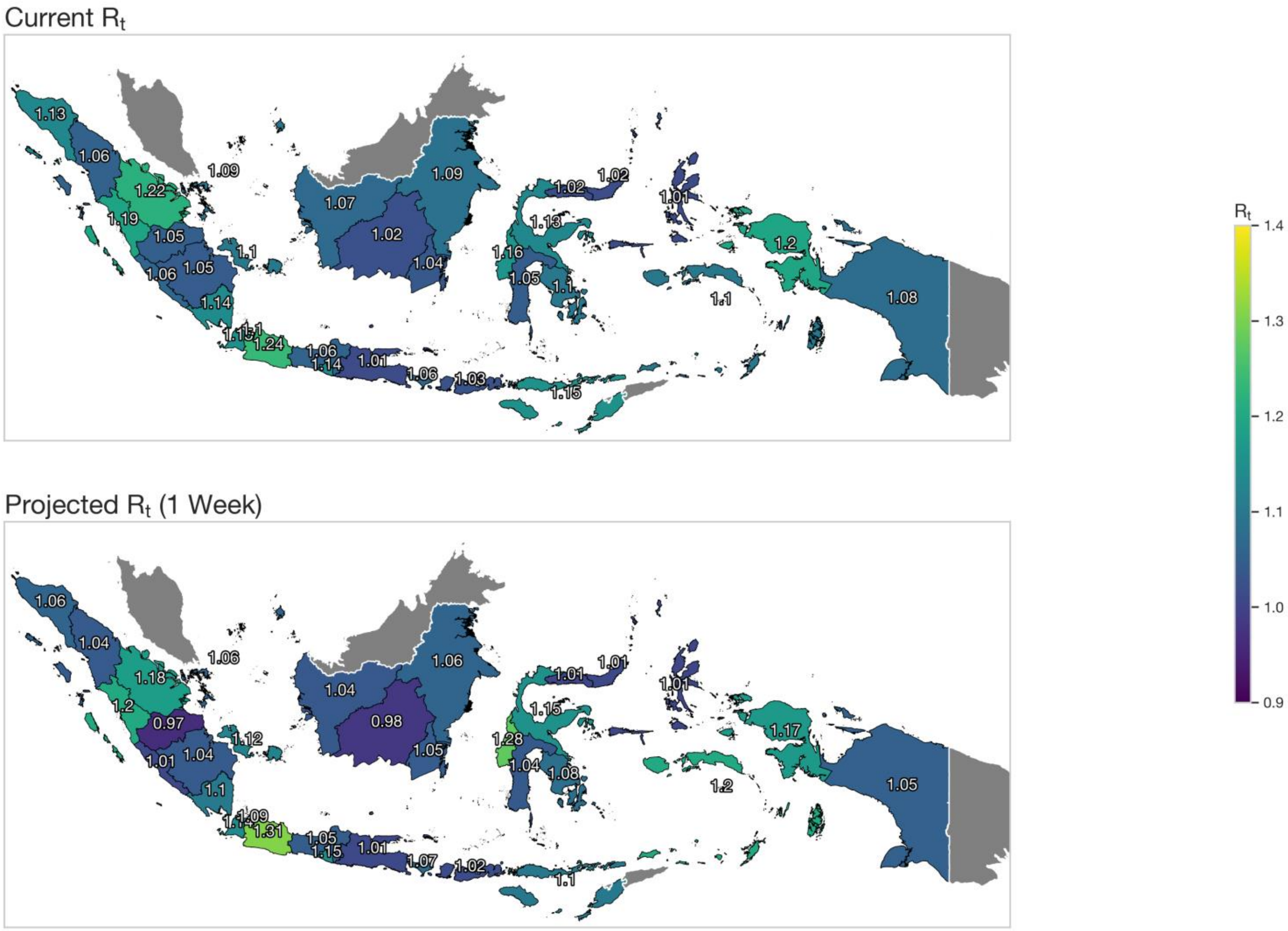




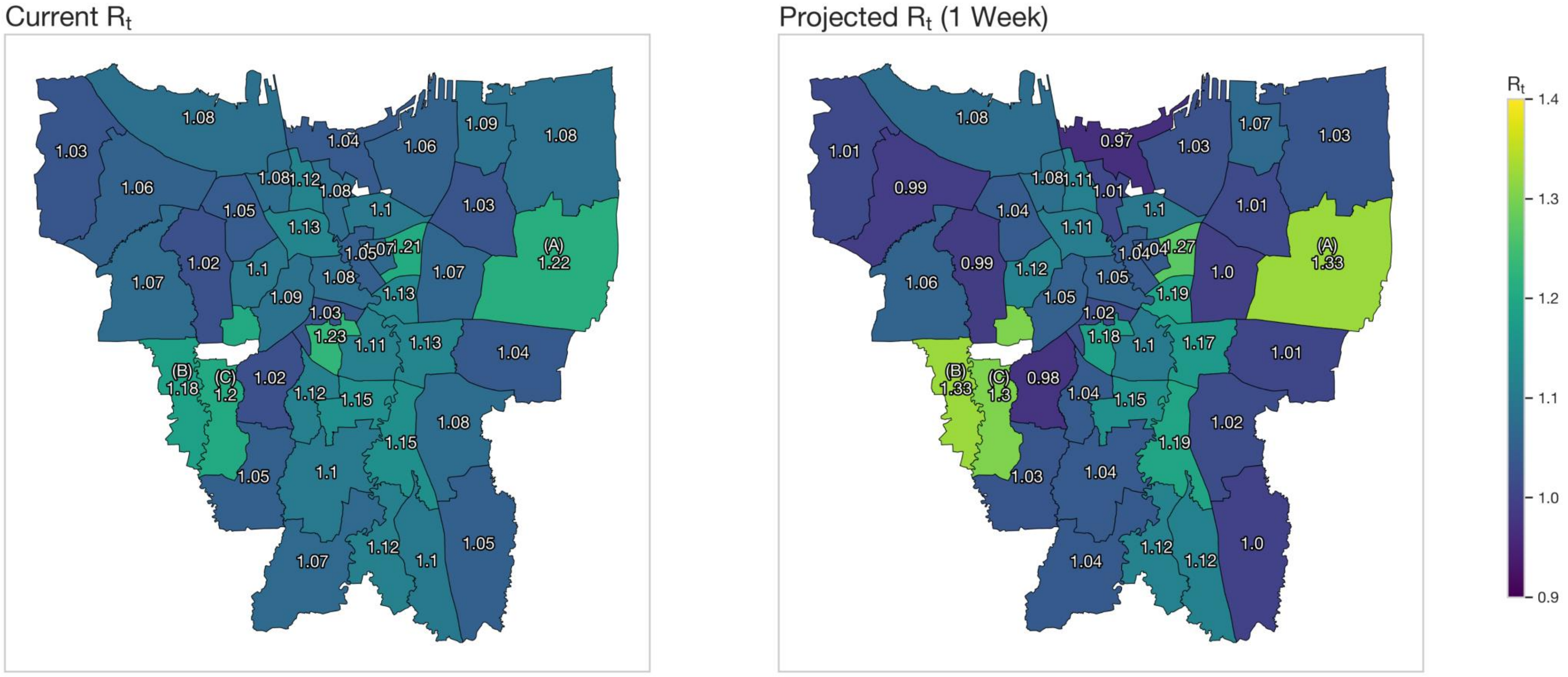




Reproductive rate across Indonesia (current)



Reproductive rate across Jakarta (August)



Forecasts can guide suppression policy

Basic principles of “adaptive control”

1. Suppression should have triggers
   - Reproductive rate
   - Trajectory of deaths
   - Excess capacity in hospitals
   - Combine above with testing rate

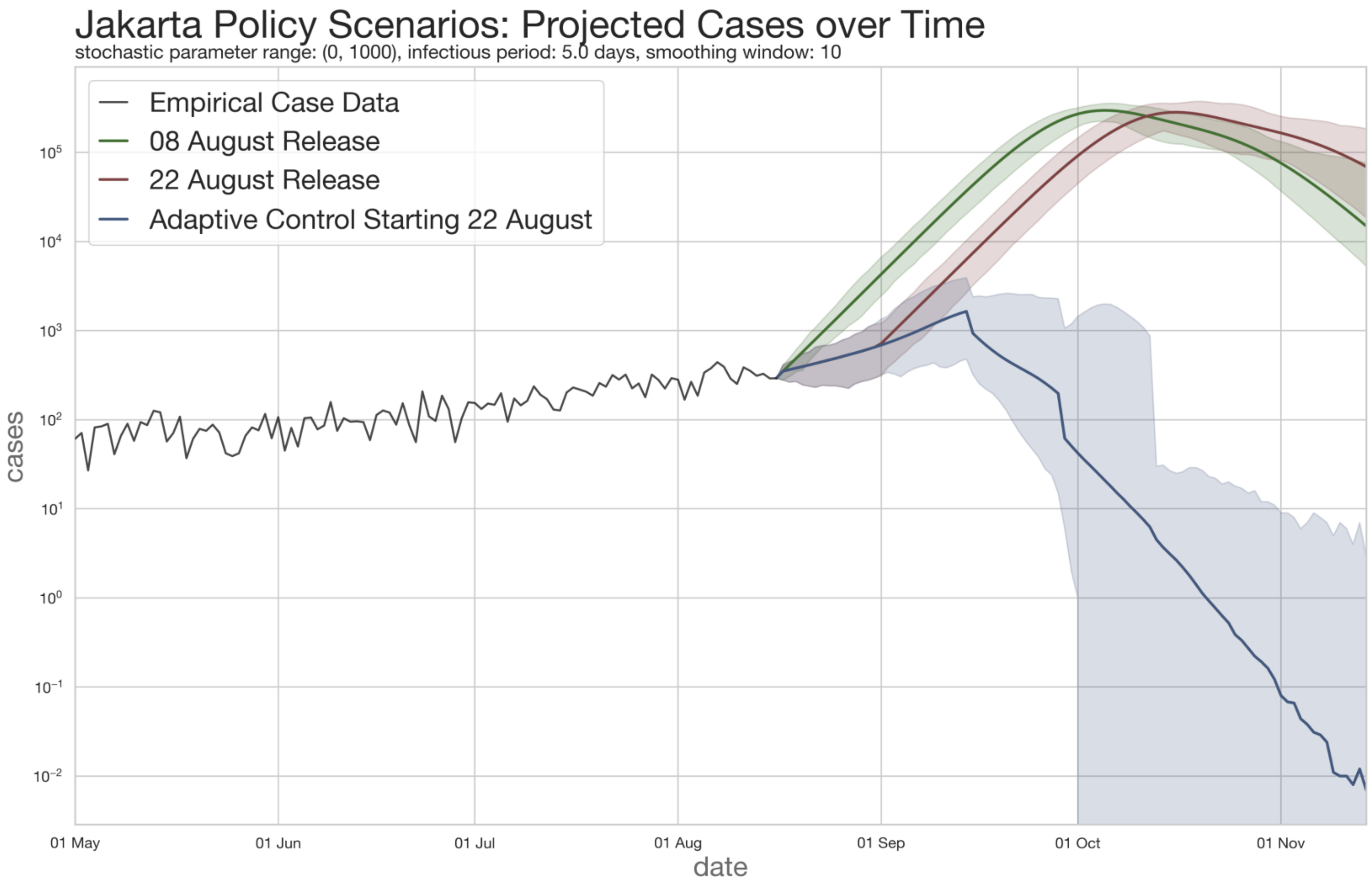
2. Measure triggers locally, periodically

3. Map trigger to mobility targets or specific policies

Trigger	Social distancing policy
$2 \leq Rt$	Maximum lockdown observed
$1.5 \leq Rt < 2$	2/3 to maximum
$1 \leq Rt < 1.5$	1/3 to maximum
$Rt < 1$	Minimum lockdown & voluntary social distancing

Whitepaper: https://www.nber.org/papers/w27532)
Code: https://github.com/mansueto-institute/covin-c2-adaptive-control-wp

Adaptive control tends to mitigate the epidemic



Applications of our paradigm

- Account for the value of economic activity in decision-making
- Cost benefit analysis of different policies
- Account for variation in Rt within local areas (e.g., slums)
- Consider trade-off for hyper-local policy (e.g., containment zones)

II. COVID vaccination policy

A. What fraction of population should a country vaccinate?
B. What groups should a country prioritize for vaccination?
C. What vaccinations should a country procure?

We tackle A first because it helps answer B and C.

WHO Vaccine Agreement: COVAX

- Distribute $2 billion doses of vaccines to over 150 countries
  - Phase 1: doses distributed proportionally based on country's share of the total population, up to 20%
  - Phase 2: consider which countries are more at risk and send more vaccines there

- Limitations: does not offer a target or a framework for within-country distribution policy

CDC and US Advisory Vaccination Policy

Vaccinate by tier:

Tier 1

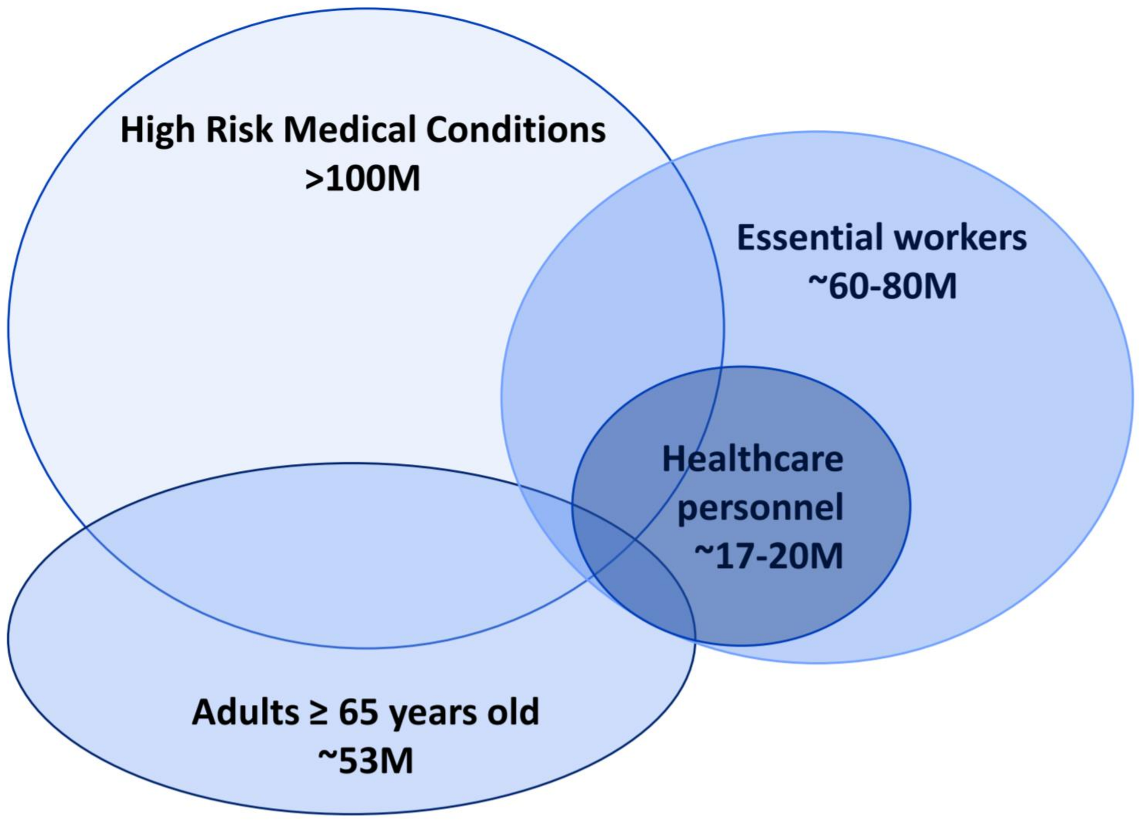
- Essential health care workers
- Those with greatest risk of severe illness death

Tier 2

- Broader healthcare workers
- Those facing barriers to access if became
- Those living or working in spaces that increases risk of infection

Limitations

- Designed for US-specific risks
- Significant variation even within these groups



A. Vaccination target

The purpose of vaccination is to achieve immunity

- Immunity is created via infection or vaccination
- Each increment of immunity counts, but it is difficult to value increments
- Herd immunity is a clear threshold

The fraction of the population you want to give effective doses is

$$\text{Effective target} = \text{Herd immunity threshold} - \text{fraction already infected}$$

- Herd immunity threshold may vary by location, so target will too
- Imperfectly effective vaccine raises the actual target:

$$\text{Actual target} = \frac{\text{Effective target}}{\text{Efficacy}}$$

Setting a target requires serological studies

- Serological studies should be done as close to vaccination date as prevalence changes
  - When vaccination date is uncertain, conduct surveillance repeatedly

- Methodology matters
  - Sampling should be representative
  - Antibodies fade over time, so combine with t-cell assays

B. Vaccination priorities

Assume the country has fewer effective doses than its target. Who should the country vaccinate first, second, etc.?

What is the goal of vaccination?

1. Health: minimize COVID-associated mortality
2. Economics: maximize economic output

We focus on the health benefits

Three targets:

1. The person vaccinated
2. The person infected by person vaccinated
3. The person who helps those infected (health care worker)

We will focus on 1 and 2

Deriving vaccination priorities

Priorities should be implementable at scale

- Based on easy-to-identify attributes (e.g., location, age, gender, occupation)
- Comorbidities are useful, but may be hard to screen on at scale

Risks vary across location, so base priorities on local data

Value of an effective vaccine dose is

(Number of infections averted) x (Probability of death due to infection)

The number of infections averted is

(Probability of infection) x (1 + Number of people an infected person infects)

Predicting Probability of Death given a COVID Infection (in Jakarta)

	Odds Ratio	T-stat
Age <20	Reference	--
Age 20-29	0.87	-0.36
Age 30-39	1.37	0.92
Age 40-49	3.32	3.73
Age 50-59	8.11	6.69
Age 60-69	12.96	8.13
Age 70+	22.49	9.66
Male	Reference	--
Female	0.79	-2.8
Heart Disease	1.28	1.7
Diabetes	1.47	3.03
COPD/Pneumonia	5.49	17.92
Hypertension	1.58	4.05
Chronic Kidney Disease	2.51	4.32
No of Obs	23,806	

Age 70+ with COVID are 22 times more likely to die than younger ages

Those with heart disease, diabetes, COPD/pneumonia, hypertension and chronic kidney disease are significantly more likely to die

Number of COVID Deaths Averted With 1 million Vaccines per Province and Age-Group

DKI JAKARTA

	Population	Prob. of COVID given age	R_t	Pr. Death given COVID and age	Deaths averted (per mn doses)
Age <20	3,309,482	0.0007	1.098	0.006	36
Age 20-29	1,748,884	0.0028	1.098	0.005	139
Age 30-39	2,003,191	0.0027	1.098	0.008	140
Age 40-49	1,548,292	0.0028	1.098	0.020	177
Age 50-59	1,050,213	0.0035	1.098	0.048	322
Age 60-69	551,774	0.0033	1.098	0.079	400
Age 70+	232,391	0.0030	1.098	0.120	489

CENTRAL JAVA

	Population	Prob. of COVID given age	R_t	Pr. Death given COVID and age	Deaths averted (per mn doses)
Age <20	11,008,681	0.0008	1.054	0.005	31
Age 20-29	5,188,148	0.0029	1.054	0.004	114
Age 30-39	4,792,296	0.0028	1.054	0.007	116
Age 40-49	4,804,624	0.0029	1.054	0.016	150
Age 50-59	4,190,826	0.0038	1.054	0.039	285
Age 60-69	2,627,694	0.0041	1.054	0.061	389
Age 70+	1,820,257	0.0028	1.054	0.102	389

Notes: Data from Jakarta, IFLS-5, and Susenas 2018. Probability of COVID calculated from Jakarta data, conditional on age, sex, and comorbidities (heart disease, diabetes, hypertension, COPD/pneumonia, and chronic kidney disease).

Allocate doses to get herd immunity in 1 area or spread reduction in Rt across all areas?

How to incorporate HCW and economics

Front line workers

- How many COVID deaths does a health care worker, including those distributing vaccines, prevent?
- Hospital workers reduce risk of death given infection
- Police and vaccine distribution workers prevent infections

Businesses and workers

- Income has value and generates taxes
- Taxes fund vaccines and social protection
- Political choice on how much to value income, how taxes are spent

C. How to choose a vaccine

- There are 51 vaccines in development, 9 in Phase 3
- Supplies are limited, prices are negotiated and subsidized
- In general: purchase any dose where value > effective price
  - Price should account for efficacy: effective price = nominal price/efficacy
  - Choosing a bad vaccine is akin to overpaying for an effective vaccine
- It is likely that supply constraints eliminate any real choice

Key take-aways

- Suppression policy
    - Viral testing is critical for forecast modeling
    - Forecasting of Rt or deaths should guide suppression levels (adaptive control)
- Vaccination policy
    - Vaccination targets and priorities must be set locally
    - Forecasting of Rt and serological studies should set vaccination targets
    - Individual-level data on who is infected and dies should guide local distribution priorities
    - Vaccine purchase decisions should depend on the cost of each death averted, i.e., adjust for vaccine efficacy and price

END