Vaccine Allocation Priorities Using Disease Surveillance and Economic Data

Application to Tamil Nadu, India

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Intro

Context

India hit hard by COVID. Perhaps 45% of population infected in some areas. Fortunately IFR is relatively low. Even so, economy was hit hard. At perigee daily laborers' income fell 90% relative to 2019.

India has approved 2 vaccines (Covishield and Covaxin). Leading producer that may supply 60% of vaccines for developing world. However, scaling production, logistical issues, and limited demand means it may take 1-2 years to vaccinate hte whole population.

MOH&FW guidance prioritizes HCW, frontline workers and then older individuals and those with co-morbidities. (Currently at > 50 and those 45-59 with certain co-morbidities.) Broadly recommends vaccinating oldest first. Plan vague on regional allocation and gives states "generic flexibility" to prioritize groups where infection prevalence is high.

Aims

We evaluate different vaccination allocation strategies using

- Epidemiological model
- Latest local data on contact rates, infections, deaths, seroprevalence and consumption
- Different methods of valuation

Methods

Data

Epidemiological data:

- Daily case and death data, by age and district (from TN state government)
- New, district population representative sero-prevalence survey in TN with N = 26,140 from October-November 2020 [Malani et al., 2021]
- Contact rates from AP & TN [Laxminarayan et al., 2020]

Economic data:

- CMIE Consumer Pyramids Household Survey (panel of 174,000 households across India, 11,148 in TN, surveyed every 4 months)

SIRD model specific to region (k) with 7 age bins (j). No migration. Mortality rate (μ_j) does and vaccination rate (ϕ_j) can depend on age.

Reproductive rate estimated from daily new infections by age and location (without vaccination). Mortality rate estimated from cumulative deaths and seroprevalence by age.

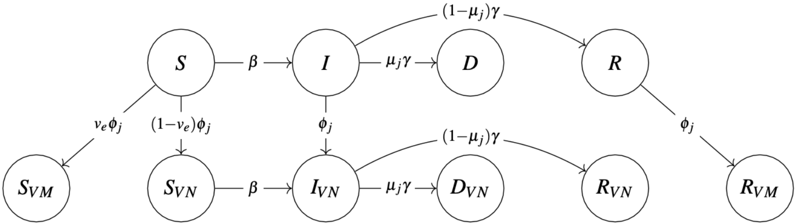


Figure S1. Flow diagram for compartmental model with vaccination

Vaccination policies

We simulate 7 policies:

- No vaccination
- 3 priority schemes below $\times$ 2 speeds (25% and 50% per year)
    1. Random assignment
    2. Contact-rate prioritization
    3. Mortality-rate prioritization

We evaluate these on 5 metrics:

- Health: lives saved, life-years saved
- Economic: VSL, VLSY, social value based on aggregate WTP for longevity and consumption gains

We use random assignment benchmark (a) to decompose social value into gains due to income v. consumption and into private v. external value, and (b) to measure aggregate social demand

Social value and VSLY

Social value of longevity [Murphy and Topel, 2006]:

$$U(\mathbf{x}, t) = \int_t^{t+(T-a)} e^{-\rho(s-t)} q(s, \mathbf{z}) u(c(s, \mathbf{z}))\, \mathrm{d}s$$

Implementation [Rosen, 1981, Garber and Phelps, 1997]:

$$\begin{aligned} W^p(t, \mathbf{z}) - W^0(t, \mathbf{z}) &= \delta \int_t^{\infty} e^{-\rho(s-t)} \cdot \left[q^p(s, \mathbf{z}) c^p(s, \mathbf{z}) \right. \\ &\quad \left. - q^0(s, \mathbf{z}) c^0(s, \mathbf{z}) \right] \mathrm{d}s \\ W^p_{ijkt} &= \delta \sum_{s=t}^{\infty} \beta^{s-t} \Big[(1 - \pi^p_{ijkt}) \hat{q}^p_{ijkt}(v = 0) \hat{c}^p_{jkt}(v = 0) \\ &\quad + \pi^p_{ijkt} \hat{q}^p_{ijkt}(v = 1) \hat{c}^p_{ijkt}(v = 1) \Big] \\ W^0_{ijkt} &= \delta \sum_{s=t}^{\infty} \hat{q}^0_{ijkt} \hat{c}^0_{ijkt} \end{aligned}$$

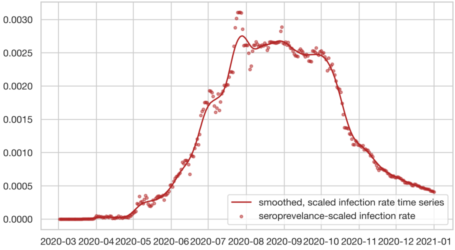
Consumption forecasting

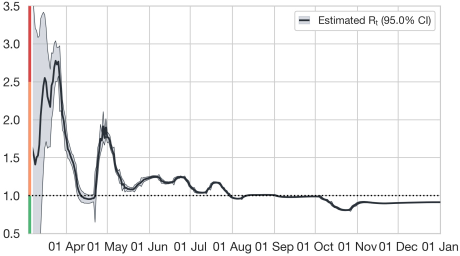
We estimate a consumption forecasting model with 2018-2020 outcome data on household consumption (allocated to household member using OECD method) and health data on new cases and deaths at the district and national level.

We use this model to forecast consumption based on disease forecasts from SIRD model.

Results

Epidemic waning in Tamil Nadu





Epidemic waning in Tamil Nadu (as of Jan 2021)

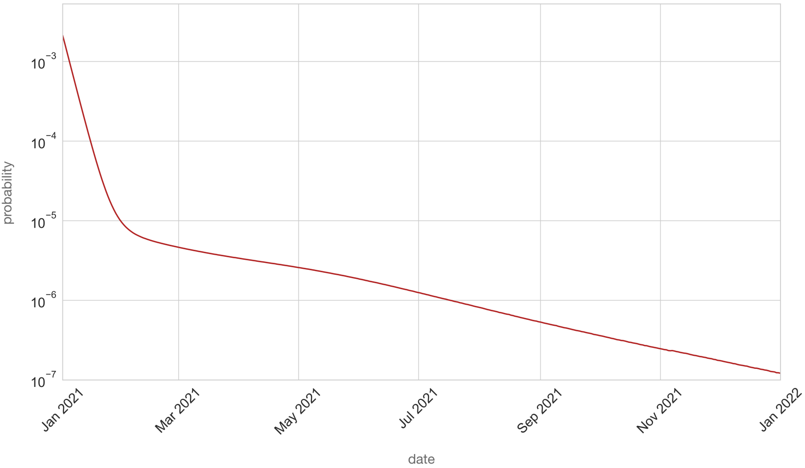
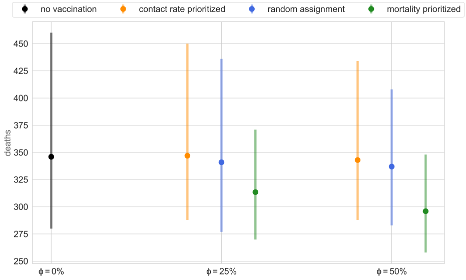
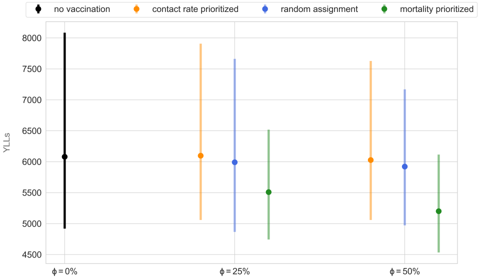


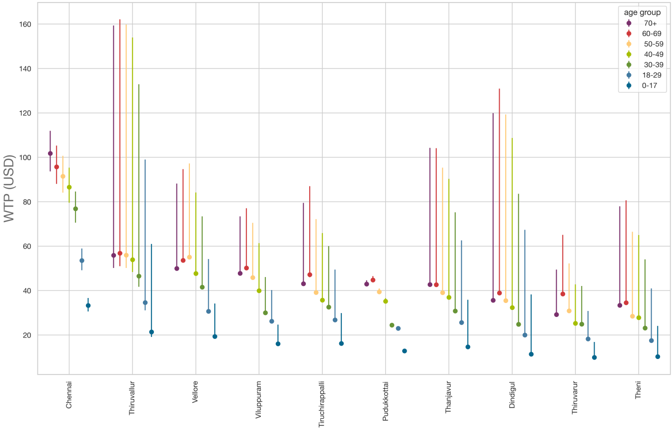
Figure 1: Projected log probability of death

Evaluating vaccination strategies: deaths & YLLs

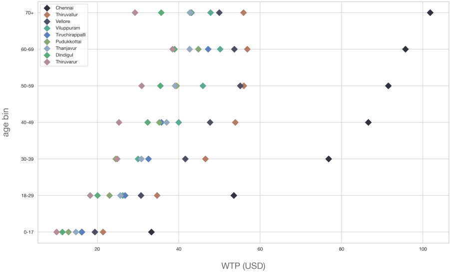


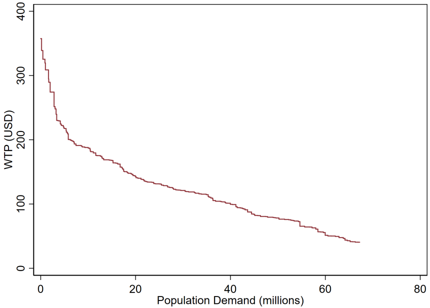


Evaluating vaccination strategies: Social value

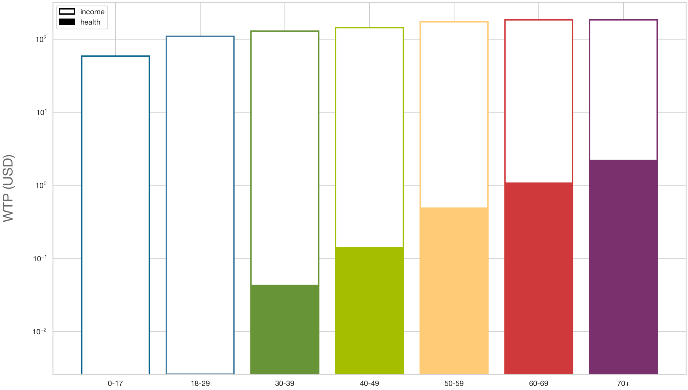


Allocation and procurement





Decomposing value: by age and by health/consumption



Conclusion

Take-aways

1. Age prioritization is optimal within region. But vaccinating 60-69 has more social value than 70+.
2. Vaccinating young in some regions is more valuable than old in other regions.
3. Age prioritization has greater value than speed because a few (old) people are vulnerable.
4. Most value comes from consumption. Health risk is small, but small health risk has large effect on consumption.

Thank you!

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Backup slides

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