9th Webinar on Health Care Insurance

20th November 2021
1600 – 1730 IST

SUTRA: A Mathematical Model for Pandemics in India and Elsewhere

Dr. M. Vidyasagar, FRS, SERB-National Science Chair and Distinguished Professor

Institute of Actuaries of India

Welcome Address

Vishwanath Mahendra, Chairperson, Advisory Group for Health Insurance, IAI

Vishwanath has 25 years of rich experience in analytics, actuarial and finance in some of the reputed organisations in India.

He current working with Max Bupa Health Insurance Company Limited as Director and Chief Actuary and is a key member of the Executive Leadership team. In his previous stint he has worked with Apollo Munich Health Insurance Company Limited for almost 12 years and was holding position of Chief Actuary and Chief Risk Officer at the time of exit as part of the key leadership team.

He is a Fellow Member of The Institute of Cost Accountants of India (erstwhile ICWAI), Associate Member of Institute and Faculty of Actuaries, UK and Fellow Member of Institute of Actuaries of India (IAI) with specialisation in Health and Care Insurance. He is Chairman of Advisory Group on Health Care Insurance of IAI.

Speakers Profile

Topic: SUTRA: A Mathematical Model for Pandemics in India and Elsewhere

Institute of Actuaries of India

Dr. M. Vidyasagar, FRS, SERB-National Science Chair and Distinguished Professor

Mathukumalli Vidyasagar was born in Guntur, India on September 29, 1947. He received the B.S., M.S. and Ph.D. degrees in electrical engineering from the University of Wisconsin in Madison, in 1965, 1967 and 1969 respectively. Between 1969 and 1989, he was a Professor of Electrical Engineering in the USA and Canada. In 1989 he returned to India as the Founding Director of the Centre for Artificial Intelligence and Robotics (CAIR) in Bangalore, under DRDO. In 2000 he moved to the Indian private sector as an Executive Vice President of Tata Consultancy Services, and created the Advanced Technology Center in Hyderabad. In 2009 he retired from TCS and joined the University of Texas at Dallas. In January 2015 he received the Jawaharlal Nehru Science Fellowship and divided his time between UT Dallas and the Indian Institute of Technology Hyderabad. In January 2018 he stopped teaching at UT Dallas and now resides full-time in Hyderabad. Since March 2020, he is a SERB National Science Chair, one of nine in India.

Vidyasagar has received a number of awards in recognition of his research contributions, including Fellowship in The Royal Society, the world's oldest scientific academy in continuous existence, the IEEE Control Systems (Technical Field) Award, the Rufus Oldenburger Medal of ASME, the John R. Ragazzini Education Award from AACC, and others. He is the author of thirteen books and 160 papers in peer-reviewed journals.

During the period June to November 2020, he served as the Chairman of the COVID-19 India Supermodel Committee set up by DST. The SUTRA model was developed after this assignment was completed.

Presidential Address

Institute of Actuaries of India

Mr. Subhendu Kumar Bal, President, Institute of Actuaries of India

Mr Subhendu Kumar Bal, President of IAI, is a Fellow member of Institute of Actuaries of India (FIAI) and a post graduate in statistics from Calcutta University.

Subhendu is having working experience over 28 years in several life insurance companies. Currently, he is the Chief Actuary and Chief Risk Officer of SBI Life Insurance Company Limited.

Subhendu had also been a Visiting Faculty of a Management Institute, teaching courses on Life & Health, Group and Risk Insurance Management.

He served as Chairperson of Advisory Group on Examination and Advisory Group of HR, member of Admin and Finance Committee and also been an examiner of IAI for several years. He has also served as Honorary Secretary of Institute of Actuaries of India.

He has been awarded "Best Actuary – Life Insurance" at the '3rd Insurance Alerts Conclave and Excellence Awards -2019'.

Program Schedule
20th November, 2021

Institute of Actuaries of India

No	Time	Sessions	Speaker
1	04-00 PM to 04-05 PM	Introductory Address	**Mr. Vishwanath Mahendra,** Chairperson, AGHCI, IAI
2	04-05 PM to 04-10 PM	Presidential Address	**Mr. Subhendu Bal**, President, Institute of Actuaries of India.
2	04-05 PM to 05-15 PM	SUTRA: A Mathematical Model for Pandemics in India and Elsewhere	**Dr. M. Vidyasagar,** FRS, SERB-National Science Chair and Distinguished Professor
5	05-15 PM to 05-30 PM	Closing Remarks & CPD	**Mr. Sumit Ramani** Secretary, AGHCI, IAI

Housekeeping Points

Institute of Actuaries of India

Mute

Q&A

IAI support

Recording

Feedback

C P D

SUTRA: A Mathematical Model for Pandemics in India and Elsewhere

M. Vidyasagar FRS

SERB National Science Chair, IIT Hyderabad

Institute of Actuaries of India, 20 November 2021

Collaborators

Prof. Manindra Agrawal
IIT Kanpur

Lt Gen Madhuri Kanitkar
AVSM VSM (Retd)
VC, MUHS

Outline

Outline

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“Spanish” Flu Revisited

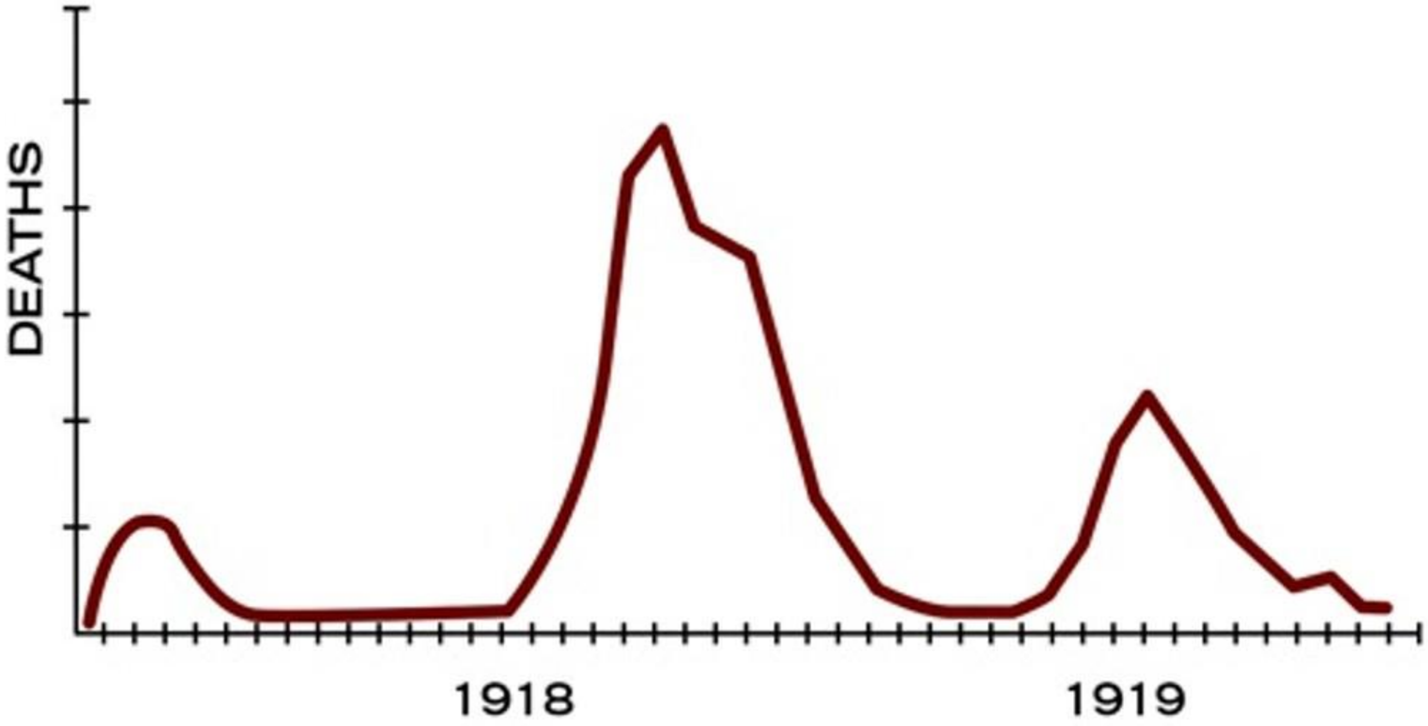

Figure: Case Load of Spanish Flu: 1917 – 1919. Source: https://www.consultant360.com/article/consultant360/1918-what-can-we-learn

Quantitative Aspects of the “Spanish” Flu

- Note three distinct peaks: The middle peak was the deadliest, but even the third peak was higher than the first.
- In the USA, 675,000 died, about the same as in COVID-19.
- But the USA population was only 30% of what it is now. In fact, 6.5% of the population died.
- In India, *at least 21 million – or about 7% of the population* died.
- Estimates of deaths range as high as 30 million, or 10% of the population.

The SIR and SIRS Models

- SIR model proposed by Kermack and McKendrick (1927)
- Divide population into three groups: S = Susceptible, I = Infected, R = Removed (including deaths). All numbers are *fractions of the population* (lie between 0 and 1).
- Premises:
  - Rate of spread is proportional to number of contacts between S and I groups.
  - People who recover are not liable for reinfection
- If some people in R lose immunity over time and return to S, then we get the SIRS model.

Use SIR if getting cured confers lifelong immunity (e.g., smallpox, measles), use SIRS when immunity fades over time (flu).

Depiction of the SIR and SIRS Models

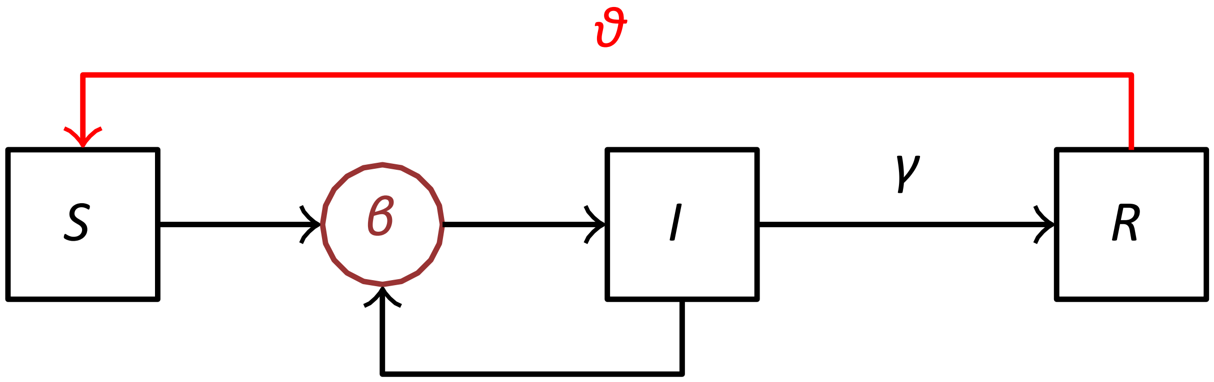

Figure: Flowchart of the SIR and SIRS models

β = infection rate, γ = recovery rate, ϑ = rate of loss of immunity (if applicable).

Dynamics of the SIR Model

- A key parameter is R_0, the "basic reproduction ratio."
- Interpretation: R_0 is the average number of persons that someone in I can infect, before he himself recovers.
- If $R_0 > 1$, the pandemic peaks when

$$S = \frac{1}{R_0}, I + R = \frac{R_0 - 1}{R_0} =: H.$$

- H is called the "herd immunity ratio." It denotes the "tipping point" at which the number of new infections I is at a maximum.
- Example: If $R_0 = 4$, then infection peaks when 75% of people are either currently infected, or were infected in the past.

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Unique Feature of COVID-19: Asymptomatic Patients

Unlike previous infectious diseases, COVID-19 is characterized by the presence of a large number of *asymptomatic* patients.

These are “carriers” who do not manifest any symptoms, and don’t themselves know they are infected – but they can infect others at nearly the same rate (viral shedding) and for the same duration as symptomatic patients.

Challenge: Estimating the number of such patients.

Early Effort: The SAIR Model

Introduced by Robinson and Stilianakis (2013).

- Introduce *two kinds* of persons – asymptomatic A and infected I.
- Contact between S and *either kind* of person leads to S becoming infected, at possibly different rates.
- *All* infected enter only A.
- Then some move to I, others directly to R.
- People in I move to R.

Depiction of the SAIR Model

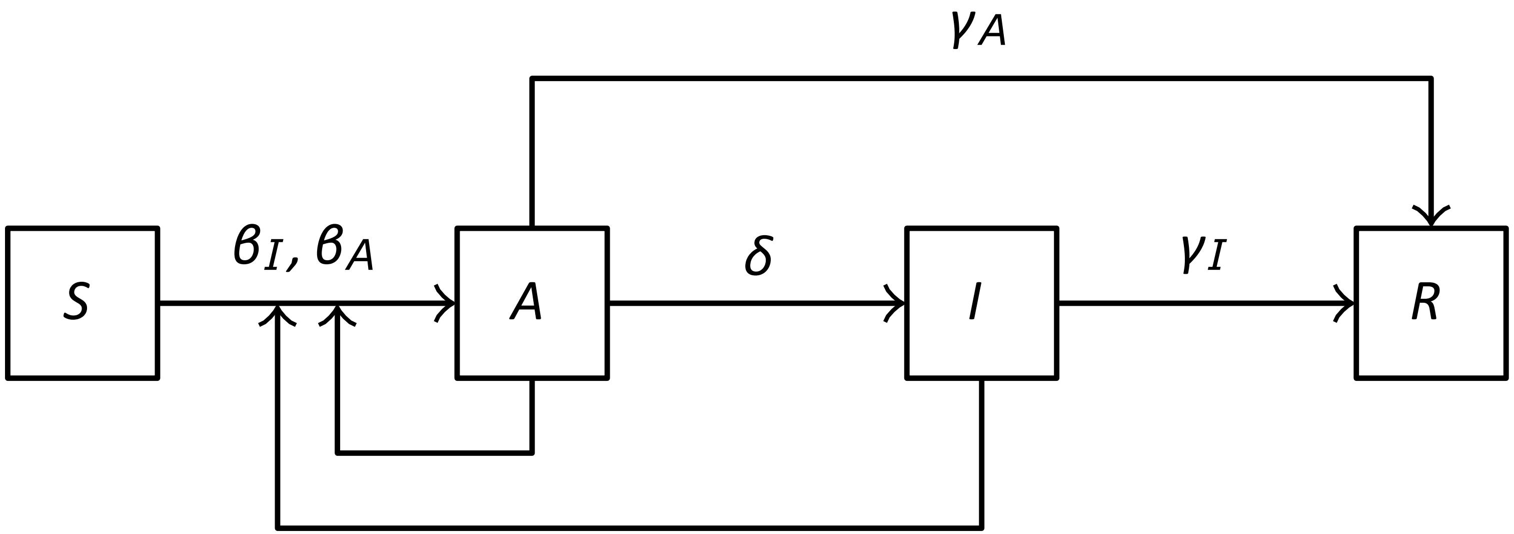

Figure: Flowchart of the SAIR model

Aspects of the SAIR Model

Premises:

- Contact between S and *either* A *or* I leads to a fresh infection.
- Freshly infected people enter A.
- Some people in A move to I; others move to R.
- Everyone in I moves to R.

Assumption: All patients in I can be measured, *all* patients in A escape observation.

Difficulty: The model is difficult to "calibrate": One cannot compute model parameters from the data.

Outline

Premises Behind the SUTRA Model

There are some fundamental assumptions in the SAIR model that *do not hold* in the COVID-19 pandemic. Instead:

- All (or almost all) people in I get detected; most are isolated and do not infect others.
- Due to "contact tracing," some fraction of A also get detected.
- Therefore the correct division is *not* between A and I, but between T (Tested positive) and U (Undetected).
- Within T, most are asymptomatic, and recover. Almost everyone in U recovers.
- A fraction of the *most recent entrants* into U move into T.

The SUTRA Model

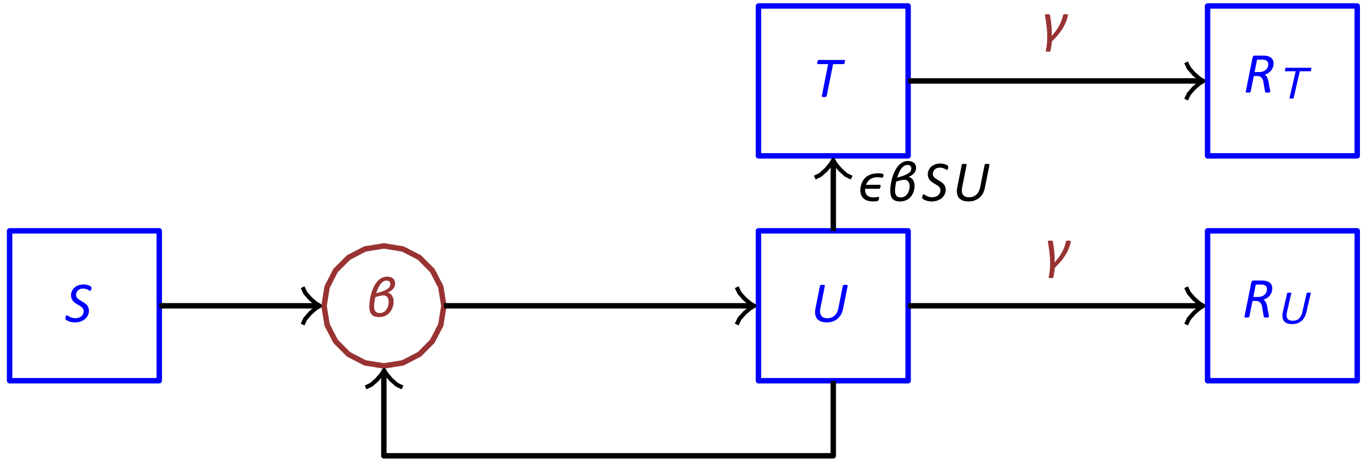

Figure: SUTRA Compartmental Diagram: S = Susceptible, U = Undetected, T = Tested positive, R_U = Removed from U, R_T = Removed from T

β = contact rate, γ = recovery rate, ϵ = undetection rate $T/(U+T)$. So $U/T = (1/\epsilon) - 1$, ρ = reach (implicit parameter).

Fitting the Parameters from Actual Data

- Almost all existing models *ignore* this aspect of parameter estimation.
- In contrast, *robust methods for parameter estimation* are central to our approach.
- There is a *linear relationship* between some measured quantities that allows us to do the estimation. This holds after an initial mismatch period.
- When new data fails to satisfy the linear relationship, we recalibrate (phase change).

Illustration of Linear Relationship

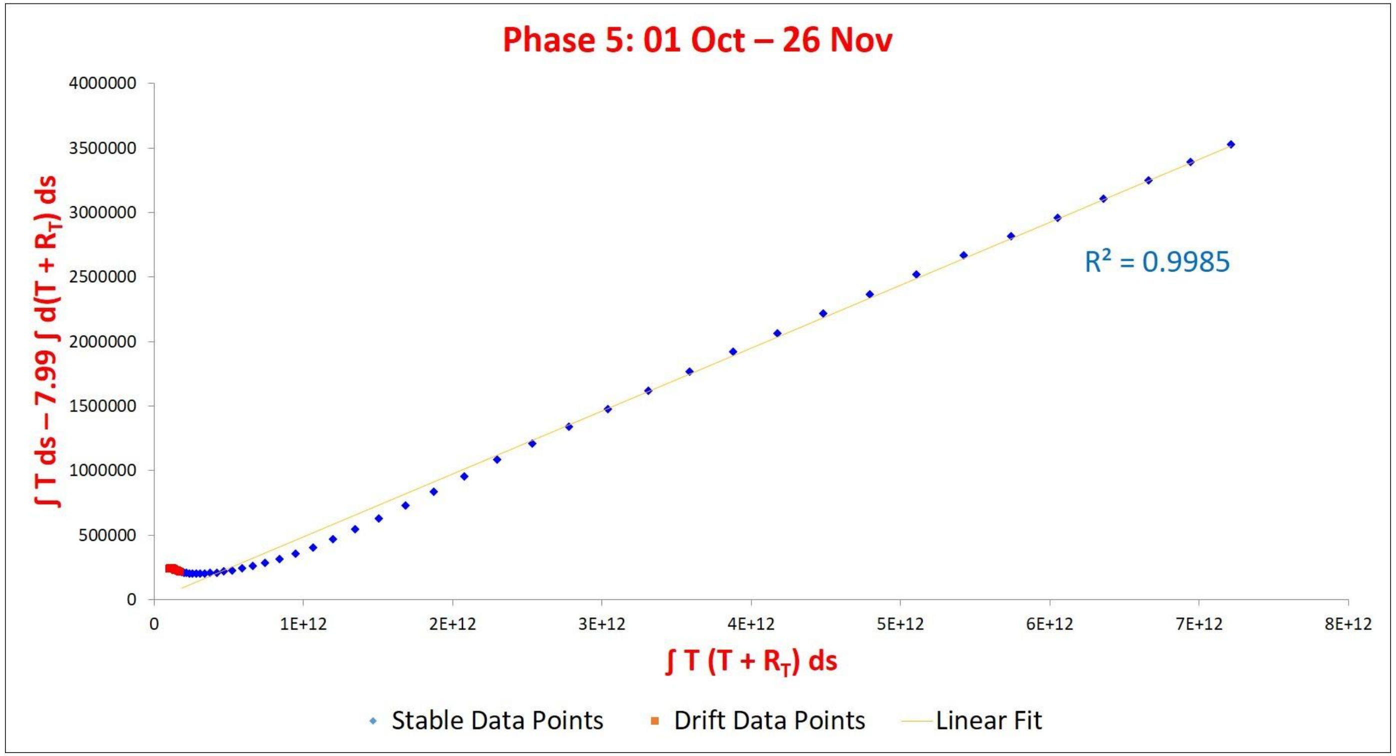

Figure: Phase 5 of Italy Pandemic

Phase Changes

- The model parameters change over time, either gradually or abruptly.
- The contact rate β will *increase slowly* as people start disregarding COVID protocols, and/or as new mutant viruses start spreading.
- β will *decrease suddenly* in response to interventions such as lockdowns.
- The reach ρ starts at zero and increases due to both global and local changes.
  - Global: Pandemic starts in one part of the country and spreads.
  - Local: Within each city, protected "bubbles" such as gated communities get penetrated by the virus and fall within the reach of the virus.

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Summary of SUTRA Predictions

- Predictions were made for ∼20 countries, including USA, UK, Italy, Japan etc.
- USA, UK have had multiple waves, but the spacing has been just a few months.
- Multiple waves explained by large increases in “reach.”
- Next slides show actual and model-fitted case totals.

USA Predictions

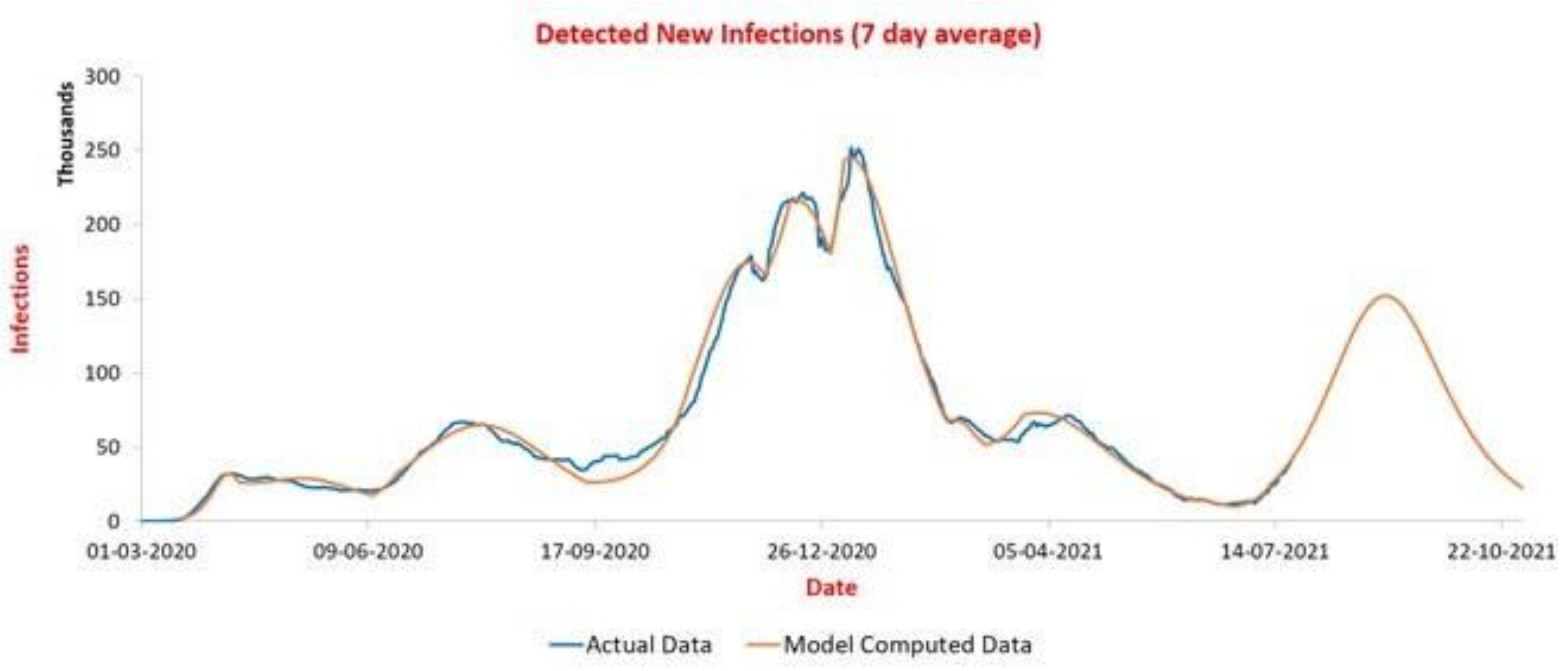


Figure:
Predictions for the USA Using Ten Phases made on 25th July 2021; Source: https://twitter.com/agrawalmanindra/status/1419176814954500096?s=20

UK Predictions

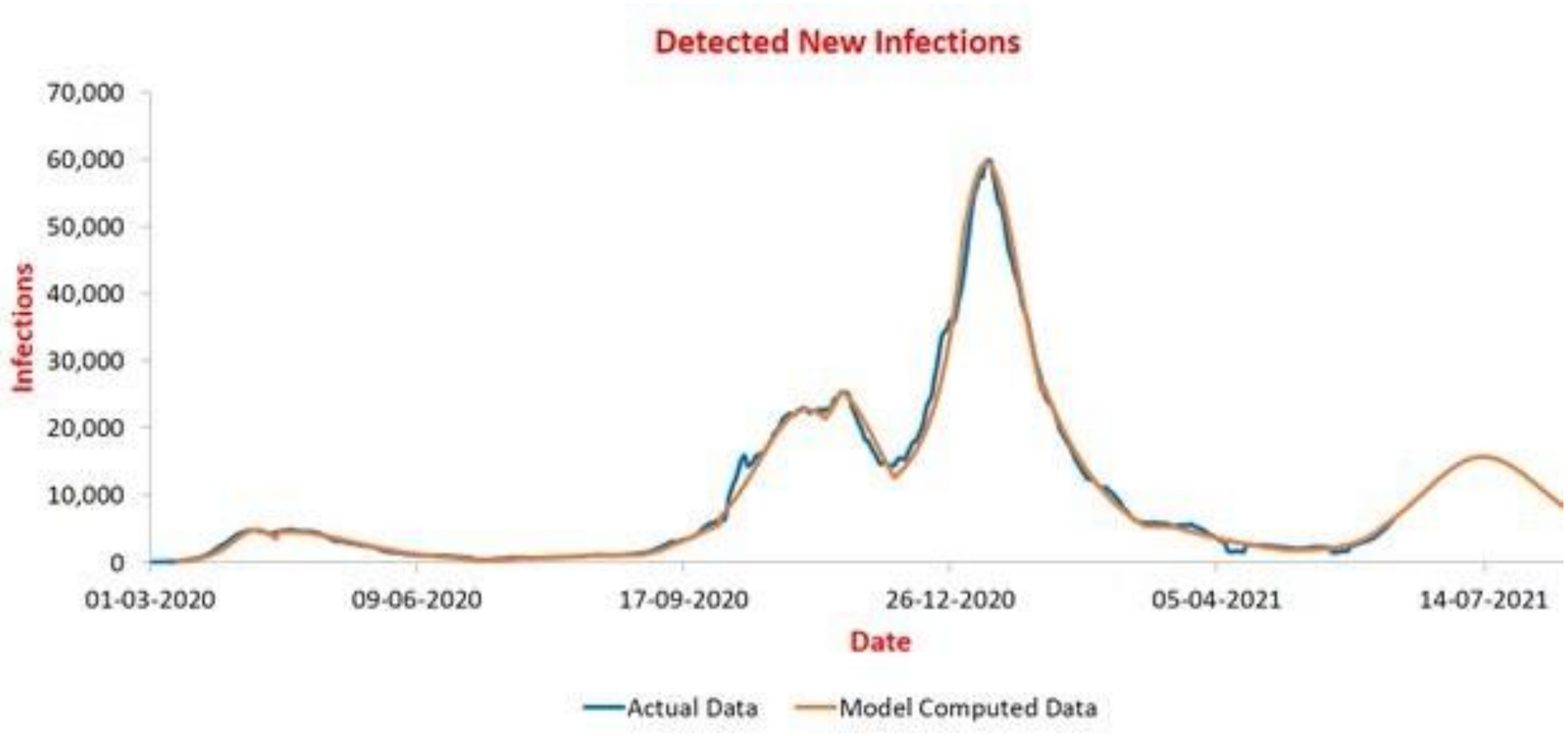


Figure: Predictions for the UK Using Seven Phases. Note that recent rise in cases will not lead to a new peak.

Outline

Outline

Projected Impact of Lockdowns in First Wave

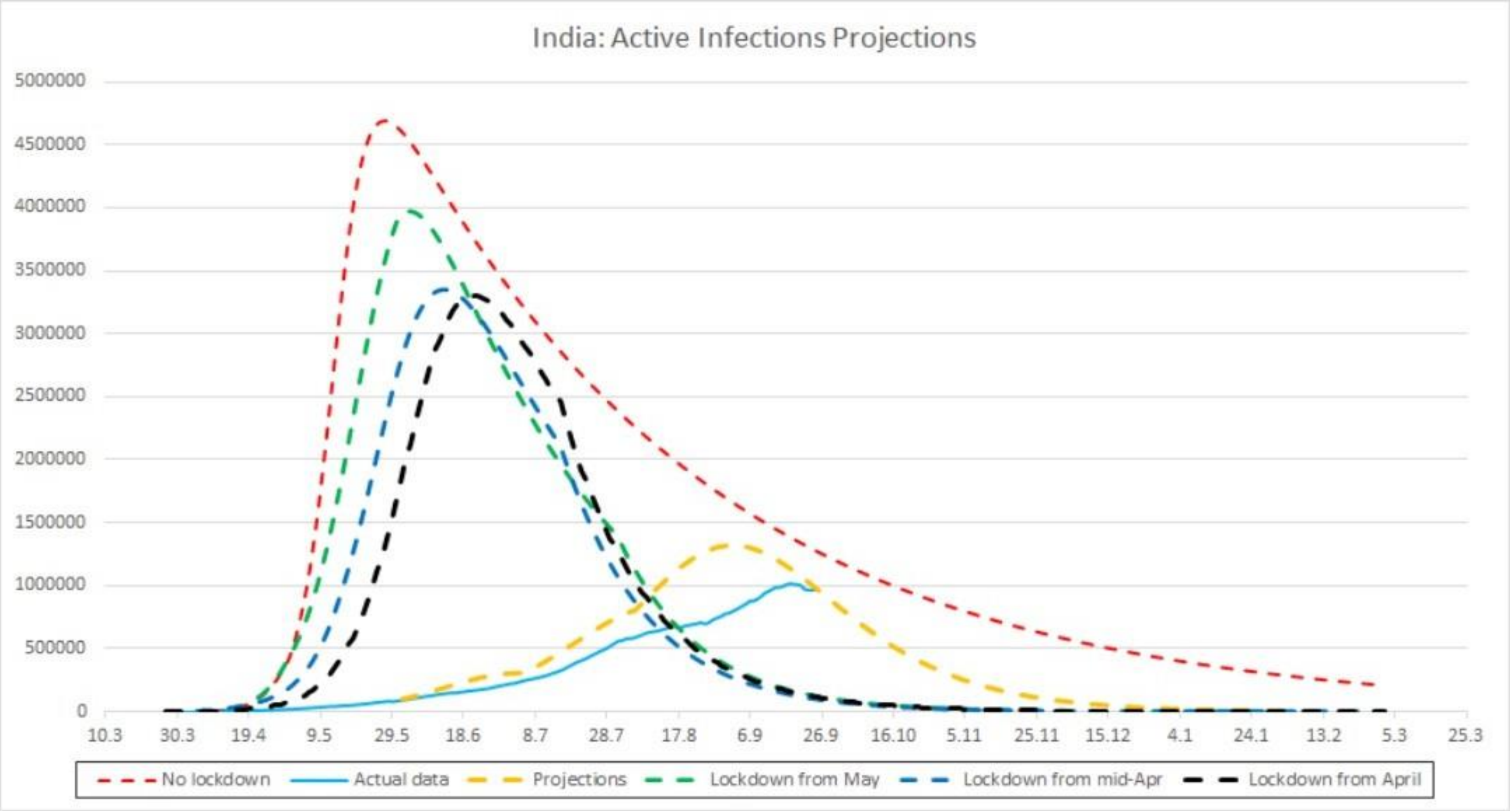
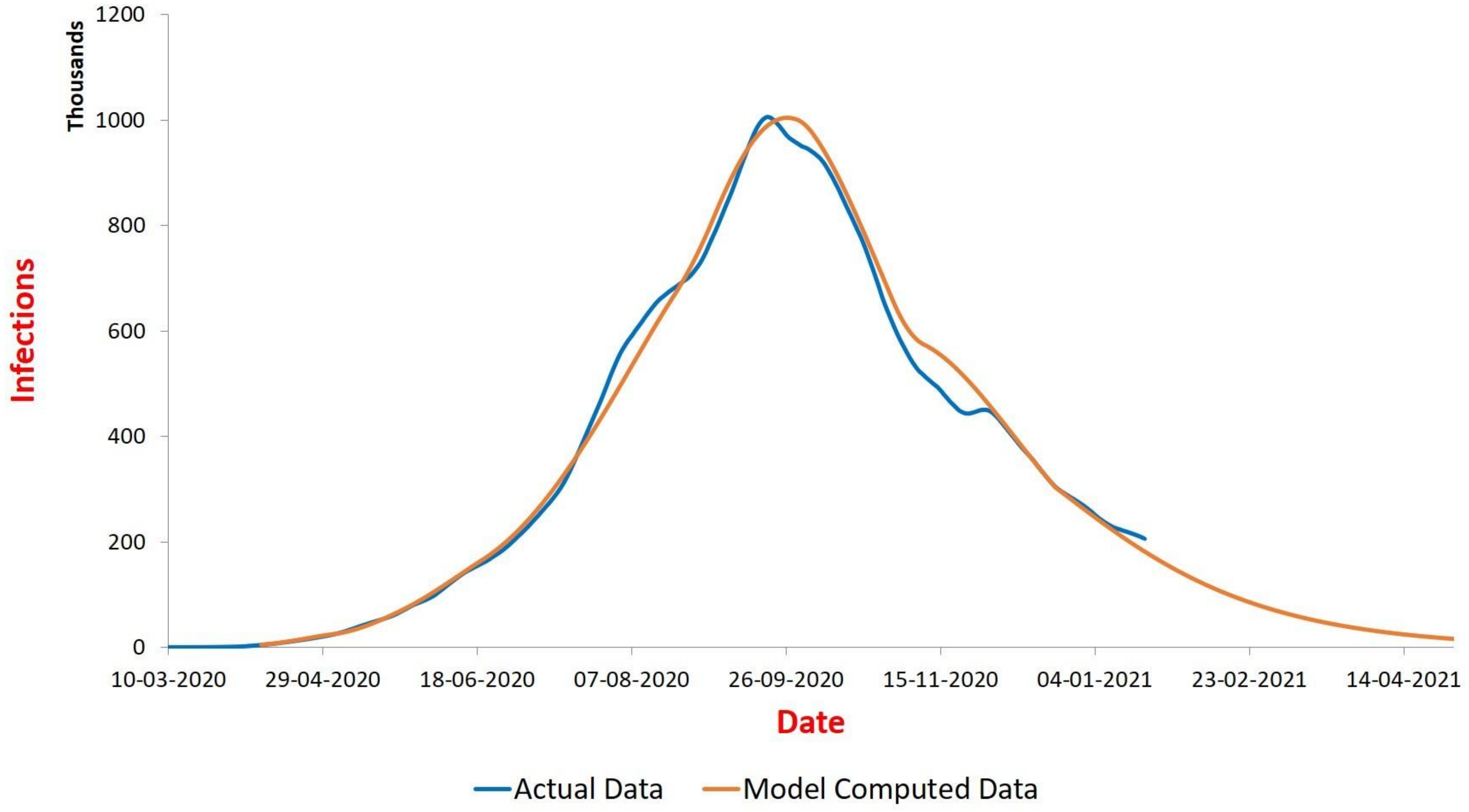


Figure: Impact of first lockdown. Active infections would have peaked at 45 lakhs in May 2020, versus 10 lakhs in September 2020.

SUTRA Model Predictions During First Wave



Outline

Why Did the Second Wave Happen?

- Both the government and the general public became complacent by the end of 2020.
- India *did not build* capability for sequencing virus samples prior to March 2021.
- Delta and Delta-Plus variants happened in India (B.1.617 and B.1.617.2); more infectious than the Alpha variant.
- Vaccination of general public in India started only on 1st March.
- So India had a *vaccine naive* population when the second wav hit.
- India *did not have* a stockpile of vaccines when the second wave hit; instead we had "Vaccine Maitri."

My View: Without these factors, India could have *mitigated but not avoided* the catastrophic second wave.

SUTRA Predictions During Second Wave

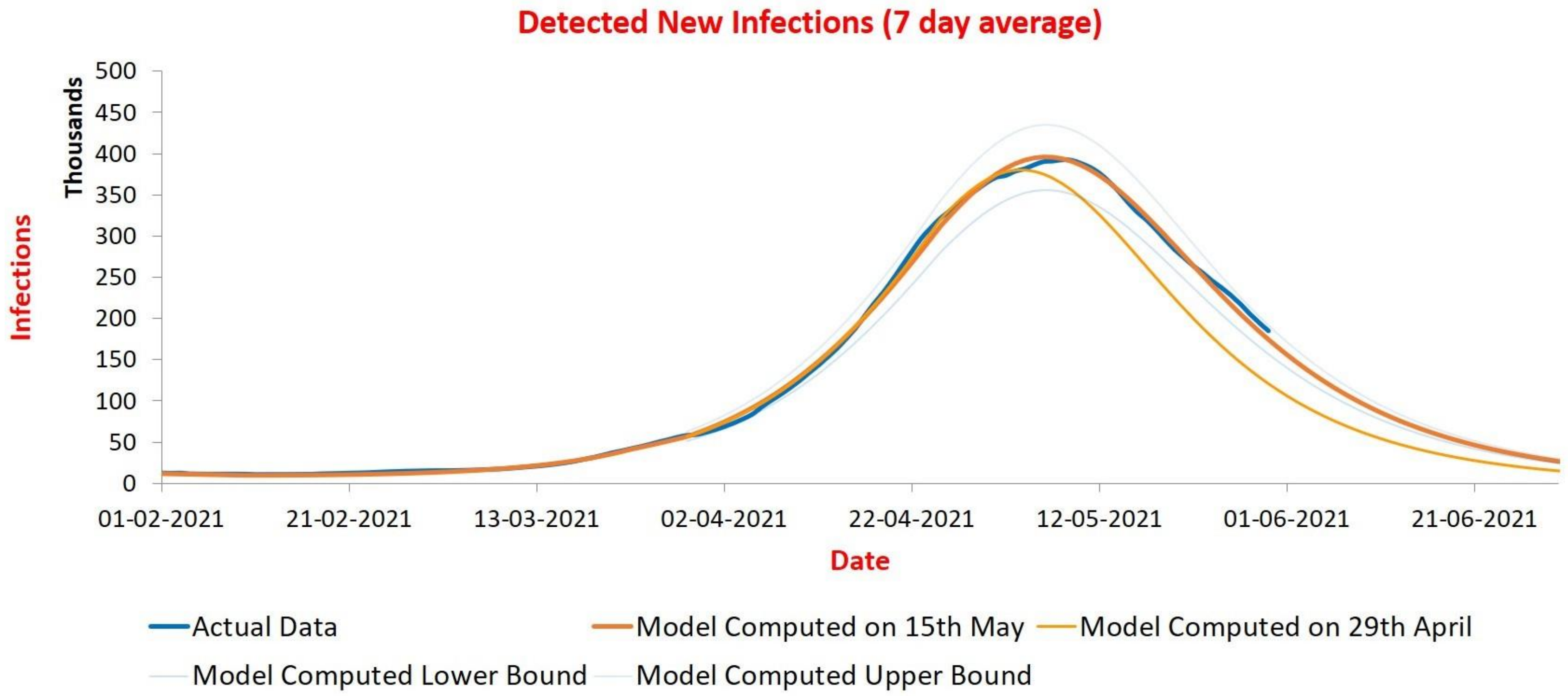


Figure: Prediction on 29 April 2021: peak between May 4 and 8; Source: https://twitter.com/agrawalmanindra/status/1387734516807073792?s=20

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Possible Future Values of β

- With δ-variant spreading, and ignoring COVID protocols, β increased from 0.23 to 0.39 in March.
- At present, with δ-variant spread all over, and most restrictions removed, β is 0.44.
- We simulate two scenarios (most details omitted):
  - No new mutant, β increases to 0.5 by August end.
  - A faster-spreading mutant with $\beta = 0.75$ arrives by September.
- We used two values for $1/\epsilon$, namely 33 and 37. Higher values for $1/\epsilon$ means more people with natural immunity (and lower third wave peaks).

Possible Triggers for a Third Wave

During first wave, peak $R_0 = 1.6$, $H = 37.5\%$. During second wave, peak $R_0 = 3.8$, $H \approx 75\%$.

- Emergence of another mutant, still more infectious than Delta
- Erosion of antibodies developed during prior exposure
- Slow rollout and/or inefficiency of vaccines

Good news:

- Antibodies seem to last much longer than was believed earlier.
- Vaccination roll-out is slower than anticipated, but impact seems to be small.

Impact of Vaccination

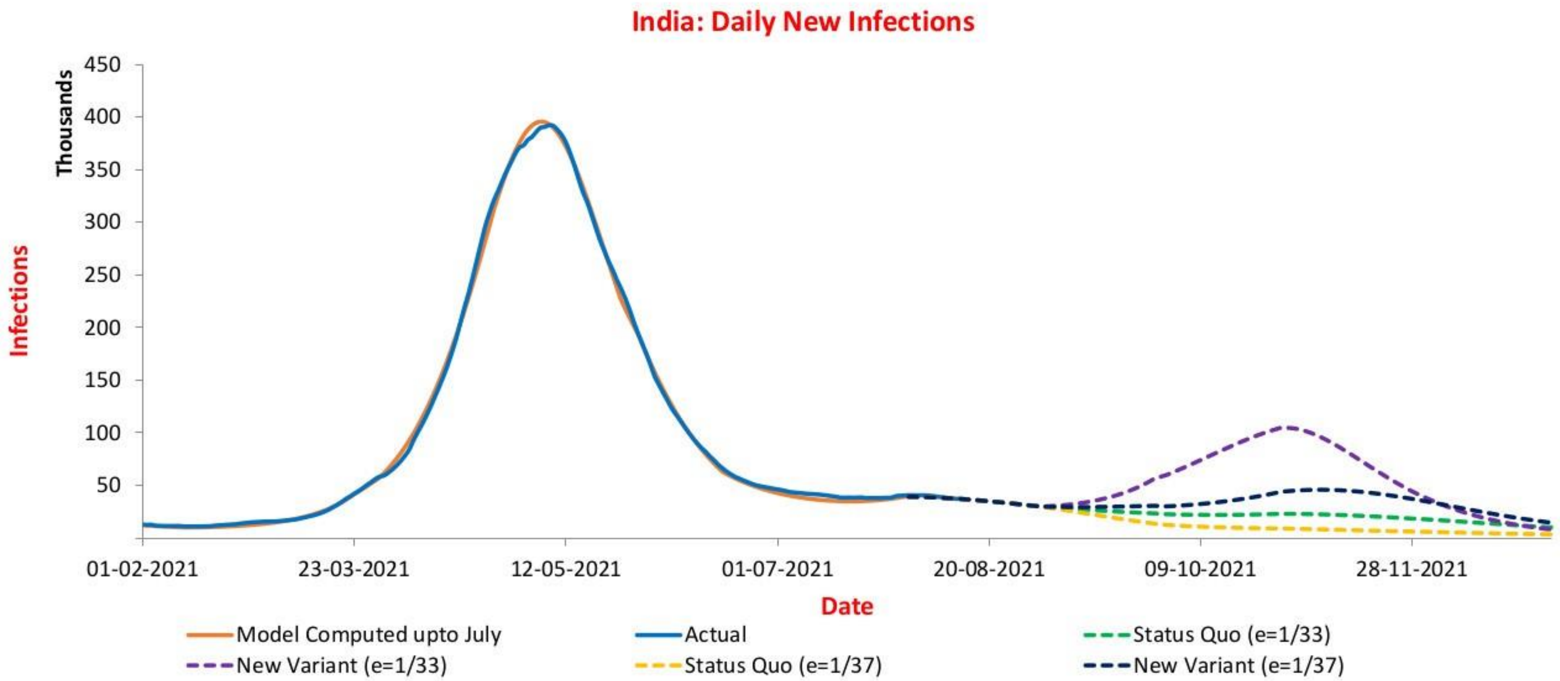
- Vaccination *does not prevent* infection – it offers high protection against *serious infection* and virtually eliminates risk of death.
- Indian vaccines (Covi-Shield and Covaxin) offer $\approx$ 60% protection against infection by the δ-variant. Same seems to be true for Pfizer, despite initial claims of 97% efficacy (cf. Israel, USA)
- People who are vaccinated and get infected shed lower viral load and for a shorter duration.
- Risk of hospitalization for a vaccinated person is $<$ 10% of that for an unvaccinated person.

Waning of Immunity

- Those who develop antibodies through prior infection see a "waning of immunity" over time, and see increased likelihood of reinfection.
- No consensus of how to define "reinfection."
- Of interest to us:
  - Do "reinfected" people infect others at the same rate as "first-time infected" people?
  - Are "reinfected" people at the same level of risk for hospitalization as "first-time infected" people?
  - Answer appears to be "no" to both. Some attempts at quantification.

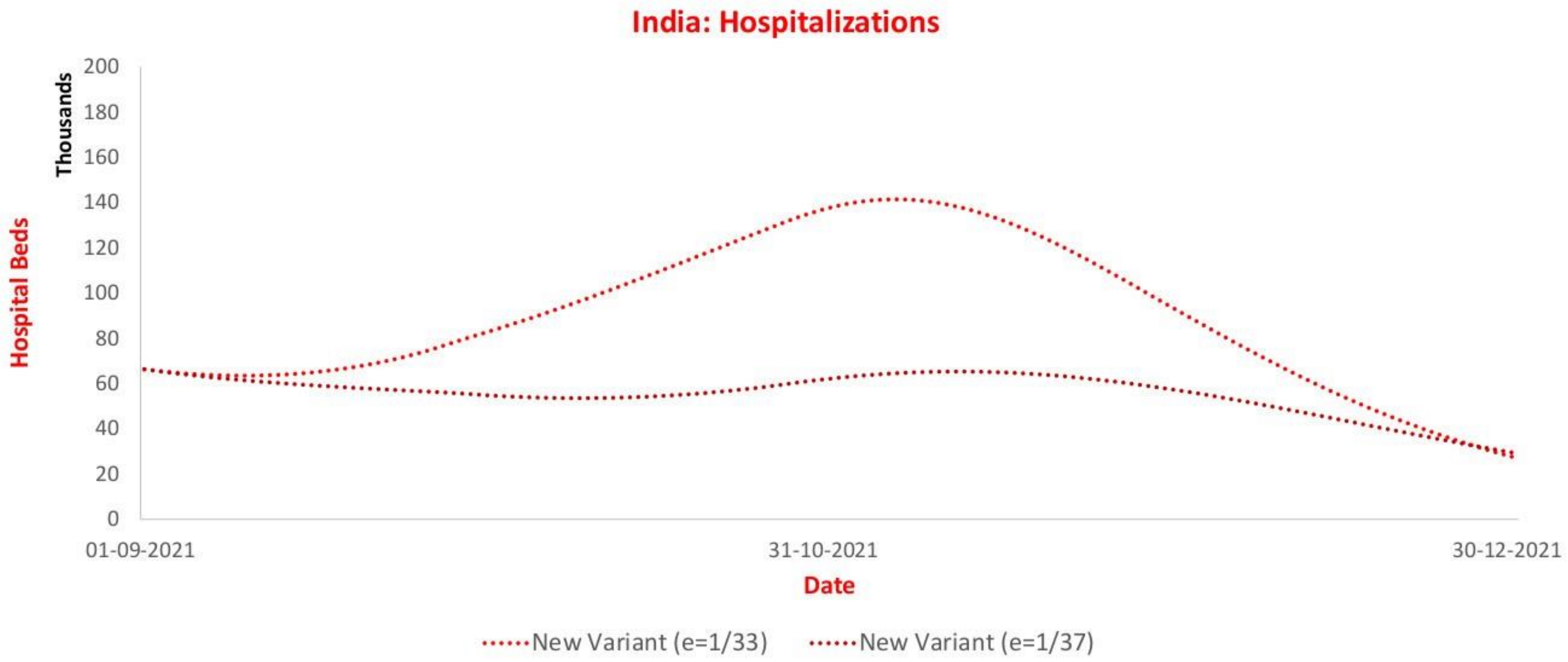
Predictions for the Third Wave – 1: Cases

Plot for Scenarios



Predictions for the Third Wave – 2: Hospitalizations

Plot for Hospitalizations



Summary of Third Wave Predictions

- Under the most pessimistic scenario, daily cases will be < 1.5 lakh per day, and hospitalizations will be < 1.6 lakh at any time.
- Moreover, hospitalizations and deaths will be *proportionately* much less this time around.
- Vaccinations and acquired immunity do not prevent reinfection, but prevent *serious* reinfection, and virtually stave off death.
- This can be seen from recent "fourth wave" of the UK: Case fatality ratio has fallen by a factor of ten.
- India has already been through the Delta variant – the rest of the world will still have to cope with it.
- Constant monitoring is needed to identify new variants.

Useful Site in Q&A Format

https://swarajyamag.com/ideas/booster-doses-vaccination-for-children-sutra-team-answers-your-questions

Booster doses of vaccination: They would be needed at some point in time, but perhaps not just now. The GoI has to take this call.

Vaccination of children: We do not recommend "universal" vaccination of children if the adults in the house are fully vaccinated.

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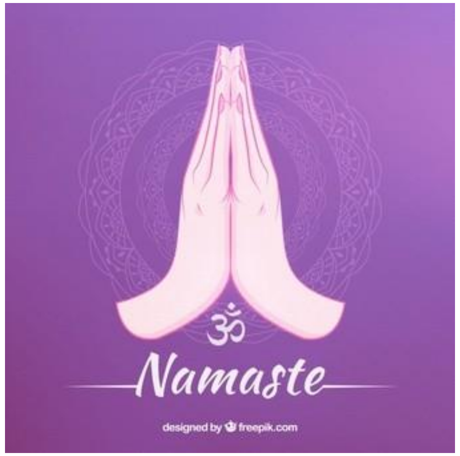
Thank You!



Vote of Thanks

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Sumit Ramani, Secretary, Advisory Group for Health Insurance, IAI

Sumit Ramani is an Information and Communication Technology (ICT) engineer turned actuary. He has about 15 years of experience in (re)insurance industry with a focus on Life and Health insurance and has worked with stakeholders/clients across the globe including Americas, Europe, Australia, and Asia.

Sumit wears two hats - of an InsurTech consultant and an InsurTech co-founder. Over the last 3 years, he has helped dozens of InsurTechs across the globe and recently co-founded ProtectMeWell.com which solves the very first problems of an individual. That is, what type of insurance coverages does one need and how much should be the size of the cover.

Sumit is a Fellow member of Indian and UK actuarial societies and also volunteers for India Insurtech Association (IIA) and helping them build Actuarial Community for the members of IIA

CPD QUESTION

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Thank You

Any Questions ?