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Academic Campuses, Super Spreader Events & Pandemics: Simulation Evidence from Reopening Indian Universities with COVID-19 (IIMA and IIT, 7/29)

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Abstract

What is the message? Universities in India need be cautious about reopening academic campuses. Otherwise, campuses face serious risk of widespread infections and deaths among faculty, staff, students, and families. The authors recommend that without a safe, efficacious vaccine deployed in the next few months, leaders of Indian academic campuses and public policy makers should go fully virtual for the next academic year.

What is the evidence? Analysis based on a simulation study on a stylized campus in India, IIMX.

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Academic Campuses Face Major Risks of COVID Infections

As academic campuses worldwide consider reopening, they fear becoming the next hotspots for super spreader events during COVID-19 due to their nature as small worlds of closely interacting people.[1] Most evidence on the risks until now come from North American campuses, which often have a medical school on campus to scientifically inform and enable academic campus leadership towards their preparation in reopening. By contrast, evidence from developing economies is sparse. We fill this gap by undertaking a simulation study to enrich evidence in this space from India using the stylized setting of IIMX, a fictitious fully residential academic business school campus in India.

The simulation is based on plausible estimates. We assume that IIMX houses 1700 people, including students, faculty and staff, residents, and contractual employees. We assume that there will be 900 students in a two-year program and 140 students, plus 110 family members assuming approximately 80% will live with partners, in a one-year program. All students and family are resident in campus. We also assume 90 faculty members and 180 family members residential on campus; 60 administrative staff and 120 family members; and 100 contractual employees. We then use standard epidemiological models, as detailed below, to understand the impact of reopening.

Study Design

To understand the spread of COVID-19 within a college campus, we start with a simple compartmental model, the Susceptible, Exposed, Infectious, Removed (SEIR) model, which has been used by epidemiologists and governments globally to predict the spread of pandemic.[2] We use the SEIR model in a context where our total population size does not represent a country or a state but the small world of an academic campus like IIMX.[3] We further extend the SEIR model to factor in mortalities and hence create a SEIDR model where D captures death in our baseline SEIR model.[4] Using the SEIDR model, we divide the population of IIMX into five non-overlapping groups corresponding to stages of the disease as a function of time *t* as follows:

- ***S(t)*** is the fraction of susceptible individuals: those able to contract the disease.
- ***E(t)*** is the fraction of exposed individuals: those who have been infected but are not yet

infectious.
- ***I(t)*** is the fraction of infected individuals: those capable of transmitting the disease.
- ***R(t)*** is the fraction of recovered individuals: those who have become immune.
- ***D(t)*** is the fraction of dead people: those who have succumbed to the disease.

The variables give the *fraction* of individuals – that is, we have normalized them so that $S + E + I + D + R = 1$. We then assumed an incubation period of 5.1 days and infectious period of 3.3 days. [5]

We set the Infection Fatality Rate (IFR) at 1%, which is significantly lower than the current perceived Indian national mortality rate of 4%. The IFR is the ratio of deaths over all cases, including asymptomatic and undetected cases; by contrast, the anecdotally reported mortality rate in popular press is usually calculated as the ratio of deaths over detected cases. The value of IFR can be higher in university campuses with older faculty, who are more susceptible to the disease, and also with younger students who have prior comorbidities such as asthma and respiratory conditions that are exacerbated by air pollution and its health burden recently that is common in India.

Next, we iterate with several values of the basic reproduction number, R_0, which is defined as the average number of people who will contract a contagious disease from one person with that disease. The population is said to have *herd immunity* when enough individuals are immune to the virus, which can thereby help to provide a measure of protection to individuals who are not immune. With reinfections rising from COVID-19, whether *herd immunity* is a tangible strategy for nations is also being debated. Nonetheless, assuming there is herd immunity, an outbreak may lead to new cases, but the size of the infected population always decreases. Reduction is achieved when the fraction of susceptible is less than $1/\square_0$.

We also make assumptions on the effectiveness of social distancing. In our context, zero percent effectiveness signifies that in-person classes are being held with no interventions such as masks, sanitizers, face shields, and ventilated classrooms. At the other extreme, one hundred percent effectiveness signifies that IIMX is holding completely virtual classes.

Using the above assumptions, we experiment with several simulations to predict the spread of COVID-19 under different configurations of R_0, initial number exposed, and effectiveness of

social distancing. We examine number infected, recoveries, and mortality rates while using the differential equation system as outlined in the supplementary material. For plotting the figures and running the simulations, we use the Matplotlib library from Python.

Findings

Our findings suggest that for IIMX, the numbers after reopening will manifest as follows. Take the most likely parameters: R_0=3; initial number of people infected=10; 30% effectiveness of social distancing. Recent work has found that R_0 expected from an average of past global studies is 3.32; also see our supplementary material for a defense of our R_0, around which we experiment later in the paper. With these numbers, at the end of 20 weeks, 1392 of 1700 students (81.9%) will be infected, along with 14 mortalities. Within the first 10 weeks itself, 1321 students (77.7%) will be infected along, with 12 mortalities.

Figure 1 plots the rise in number of infections over 20 weeks and compares how the scenario could be vastly different if most classes are held remotely, all precautions are taken, and effectiveness of social distancing is 50%. In such a case, 963 (56.6%) of the total campus population would be infected at the end of 20 weeks, with 541 (31.8%) students being infected within the first 10 weeks. This scenario is significantly lower than the earlier case with 30% effectiveness of social distancing.

To understand the dynamics of how different parameters influence the final number of students exposed on campus, Figure 2 plots the number of infected cases (size representative of number) as we experiment with input parameters of R_0 and social distancing effectiveness in a 3-dimensional figure. In most realistic scenarios, the pandemic is likely to blow up within a college campus with more than 50% students exposed.

A word on limitations of our study, while being conservative about lower bounds of potential true estimates conditioned by size of campus, is merited at this point. We do not model interactions within an IIMX system such as in classrooms, dorms, or people catching the virus from outside the campus. We also do not account for social interactions from canteens and during student events. Including such factors would increase infection probabilities.

Our simulations also do not incorporate a strong testing and contact tracing strategy, which

could help control the spread within the campus. In addition, our simulation findings does not assess exposure campuses have to local healthcare ecosystems, which differ in their metropolitan or non-metropolitan location. This would be relevant for debates on bed availability in city hospitals, shortages in medicines supply, fake ventilators being deployed in hospitals, inadequate isolation wards, and stigma during COVID-19. Future work that incorporates these issues will add richness to our findings.

Figure 1: Simulated Findings of COVID-19 Spread in IIMX

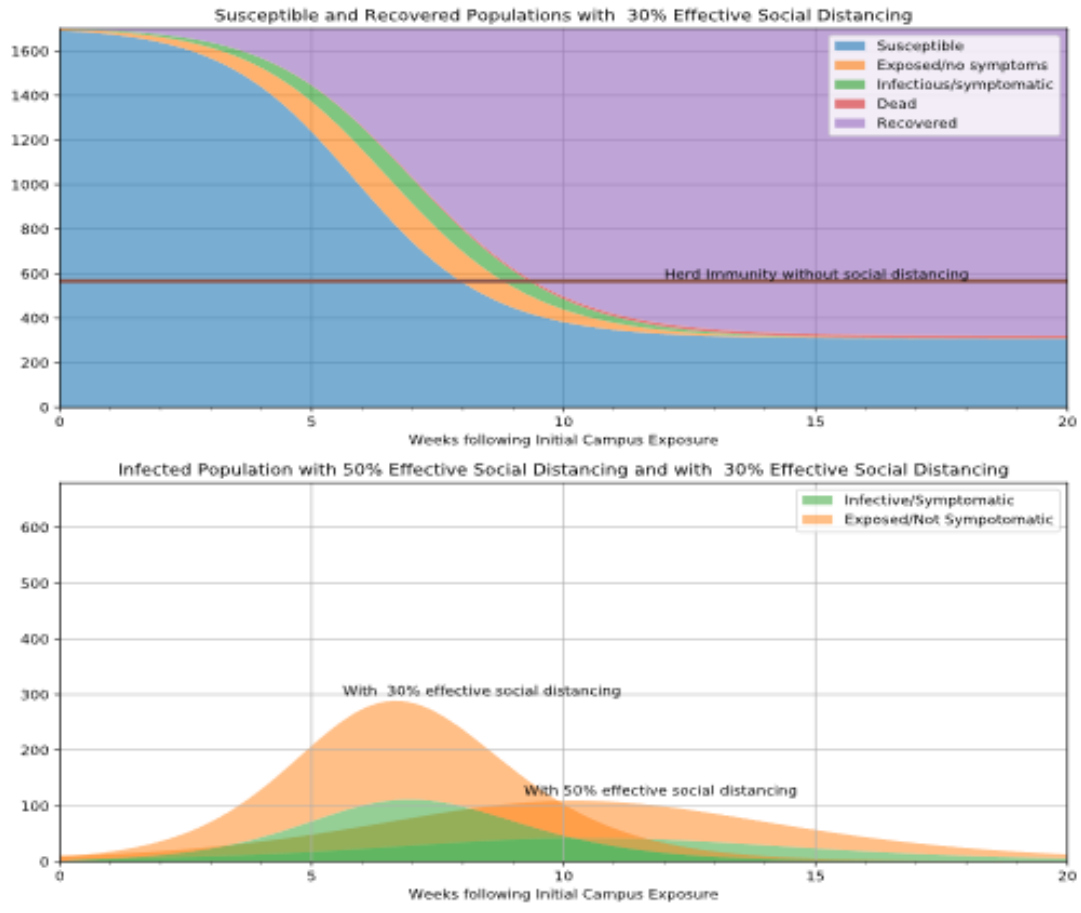
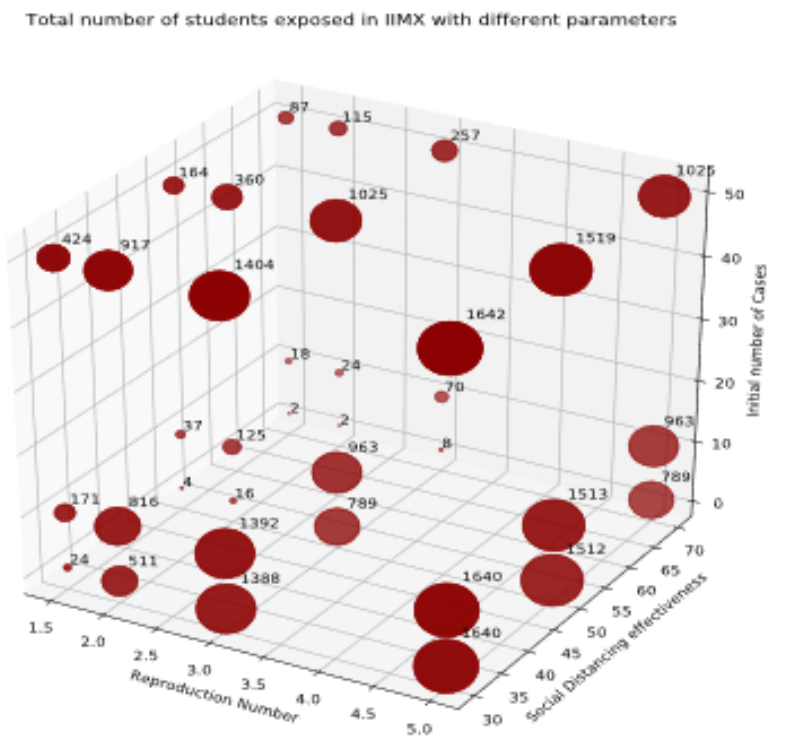


Figure 2: Experiments with R0, Social Distancing and Resulting Infections at IIMX



Discussion and Policy Implications: Stay Virtual

Our simulations show that, if college administrations across India decide to go ahead with in-person classes, COVID-19 could sweep college campuses in India within 10 weeks. Our recommendation to Indian academic campuses would be to stay virtual for the foreseeable future. Remaining virtual is needed until India achieves adequate deployment of vaccines; campuses are prepared with isolation wards, testing capacities, and medicines; and information on these measures is transparently shared with stakeholders in the ecosystem. More broadly, given that risk preferences of individuals are heterogeneous, choice should be provided to students, faculty, and staff on blended models, although this might be operationally complicated and costly to achieve.

Although choice is important, institutes in India such as IIT Bombay have shifted completely virtual for the academic year. IIT Bombay is also raising funds to support students who have

problems with digital access and computers. Following this lead, universities should marshal their high net worth alumni for special endowment funds to provide financial and non-financial support as they prepare as the coming academic year rolls out virtually.

In addition, whatever the ultimate decision, strong enforcement of social distancing is required, especially if some students return to campuses. Here, university faculty can play role models by themselves wearing masks. In addition, penalties both in monetary terms and in academic grades can be considered for all stakeholders involved.

Although some doctors in India are arguing for a herd immunity strategy[6] by reopening campuses, this idea is dangerous. New reports [7] have emerged that people become susceptible to the disease again in few months. If so, or if immunity is weak even in the short term, this would completely negate the idea of such a strategy.

Also, the heterogeneity in quality of healthcare available within and outside the college campus varies greatly in India. IIT Kharagpur in West Bengal, for instance, does not have a well-established hospital equipped with sufficient resources within 130 kms. University leaders need to be transparent about their preparations, while documenting information on health insurance for students, faculty, and staff perhaps through a COVID-19 committee and online website.

There also needs to be clarity on the legal liability implications in case things go out of control. With 6.0% [8] of infected cases needing hospitalization, our estimates suggest that a population size of 1700 would conservatively require at least 50 beds (based on 833 infections and a 6% hospitalization rate) with adequate healthcare equipment and staff. Until now, we cannot find evidence about preparation towards this goal on Indian campuses. As one model to learn from, Indian campuses and many other universities, especially in emerging economies, can look towards Taiwan[1] in their preparations and scientific arrangements towards reopening university campuses.

A final word is merited on co-morbidities arising from asthma and respiratory conditions. Even among the young in campus, students may be suffering from these issues due to India’s air pollution problems. Moreover, these concerns are amplified by the rising incidence of antimicrobial resistance in India over the last decade.

The concerns that the estimates in this analysis raise are serious. University leaders as well as central, state, and local policy makers need to be extremely cautious about reopening academic campuses in India.

References

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Supplementary Material

Basic Model Set-Up

Neglecting demographic processes of birth and death from other causes, and assuming a negligible death rate due to infectious disease at issue, the governing differential equations are as follows:

$$
\begin{aligned}
dS/dt &= -(1-u)\beta SI \\
dE/dt &= (1-u)\beta SI - \alpha E \\
dI/dt &= \alpha E - (\gamma + \varepsilon) I \\
dR/dt &= \gamma I \\
dD/dt &= \varepsilon I
\end{aligned}
$$

The rate processes are modeled as follows:

- $(1-u)\beta SI$ is the rate at which susceptible population encounters the infected population resulting in transmission of the disease. S is the size of the susceptible population. β is a model parameter with units of 1/day.
- u describes the effectiveness on any public health interventions to control transmission of the disease. u=0 corresponds to no effective public health interventions, u=1 implies total elimination of disease transmission.
- αE is the rate at which exposed population becomes infective, where E is the size of the exposed population. The average time in the exposed state is the incubation period of the disease, and equal to 1α.
- γI is the rate at which infected population recovers and becomes resistant to further infection. I is the size of the infective population. The average period of infectious state is $1/\gamma$.
- ε is the virus-induced average fatality rate.

Properties of the SEIR Model

The SEIR model describes key epidemiological phenomena. Here is a brief summary of the key parameters appearing in the SEIR model:

- The parameters α, β and γ have units of inverse time.
- β is the rate constant associated with transmission of the virus.
- α is rate at which individuals convert from the exposed state to the infectious state. The average period of time is $\tau_{incubate}=1/\alpha$.
- γ is the rate of recovery from infections. The associated time constant $\tau_{recovery}=1/\gamma$ is average time to recover from an infection.

The relationships of rate constants to time constants can be summarized as:

$$\tau_{incubate}=1/\alpha \text{ and } \tau_{recovery}=1/\gamma.$$

The SEIR model makes key predictions concerning the outbreak and eventual recovery from an epidemic. These are summarized as follows:

- The infectious population grows only if $\beta s > \gamma+\varepsilon$, that is the rate of infection is greater than the rate of recovery.
- The ratio $R_0 = \beta\gamma$ is the "Basic Reproduction Number". R_0 describes the transmissibility or contagiousness of an infectious disease.
- $R0$ is the average number of people acquiring the virus from an infected individual in an otherwise completely susceptible population.
- The infectious population can grow only if $R_0 s>1$. If $s=1$, then $R_0>1$ is sufficient for growth of the infectious population.
- The infected population, that is number of people in the subpopulations E and I, decreases if $sR_0<1$ or, equivalently, $s<1/R_0$.
- The population has 'herd immunity' when a sufficient number of individuals are immune to the virus. Under this condition, an outbreak may lead to new cases, but the size of the infected population always decreases. This condition is achieved when the fraction of susceptible is less than $1/R_0$.

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