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MS&E 433 The Socio-Economic Impact of the Novel Coronavirus in the Developing World

(Professor Ashish Goel)

Project

Post-Pandemic School Reopening Simulations for Peru

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Abstract

This document is the progress report for the collaborative project for MS&E 433 *The Socio-Economic Impact of the Novel Coronavirus in the Developing World*. It is the deliverable for the first one-month project simulating school reopening scenarios in Peru. We find differential marginal effects on the epidemiological outcomes for the reopening scenarios of reopening schools for 1/2/3/4/5 days a week. The strong sensitivity of the number of infections to the number of days that school reopen for indicates that careful consideration and further modeling are required to identify the specific scenario for school reopening that would maximize students' learning while constraining further spread of the infection.

Current Situation in Peru

Peru is a developing country in Latin America with a population of 32 million people and a GDP of US$ 222B. On March 16th the government declared a 'State of Emergency' and a full scale lockdown where citizens are only allowed to leave their homes to perform critical tasks like acquiring food or going to the hospital. The measure has been extended multiple times, two weeks at a time, and it is currently set to end on May 24th. On April 22nd, the president announced that schools would not reopen until December and soon after 900,000 tablets were deployed throughout the country to enable online learning. Still, the Ministry of Education remains very focused on evaluating reopening strategies. Their intention is to be well prepared for when the time comes.

Collaboration with the Peruvian Government

Our collaboration with the Peruvian Ministry of Education has been very open and productive. Nicolas is from Peru and was working with Dr. Kristian Lopez Vargas (UC Santa Cruz) on a contact-tracing app for the Peruvian Government. Dr. Lopez Vargas became eager to help us in our efforts and mentioned that he had been modelling school reopening strategies for the Ministry of Education. Dr. Lopez Vargas very kindly shared an SIR Model that he had been working on with Dr. Gonzalo Panizo (Universidad del Pacifico) as well as a number of academic works that the pair used as inspiration for the model. We used the provided academic works as inspiration to ideate reopening scenarios and ran these as simulations on the model. We reached some very interesting findings and were able to present these to Vice Minister Sandro Parodi. Sandro is very open to learn more about academic efforts and is excited about collaborating with Stanford.

Research Question & Deliverable

Upon consultation with our advisors, we wanted to focus on an attainable tangible contribution within a short timeline of the first mini-project. To assist the Vice Minister of Education office in Peru, we are modeling school reopening scenarios to provide a comparison of several specific strategies and their epidemiological outcomes.

Research Question

How will specific school reopening scenarios affect the epidemiological outcomes in Peru?

Deliverables

The following deliverables have been completed and circulated with the class participants, advisors and stakeholders. We have also published an accessible form of this report on a website to facilitate more knowledge translation and sharing of findings about pandemic-related research[1].

1. Documentation for the model, including a lay description, assumptions, inputs, limitations (~2 pages) *(in progress)*
2. Edited and debugged code based on the model by Dr. Vargas and Dr. Panizo with estimated alternative scenarios *(in progress)*

Motivation

As COVID-19 outbreaks spread around the world, up to 500 million students have been affected by national and regional school closure[2]. School disruption sets a problem for short- and long term educational outcomes, and broader negative outcomes have been observed especially in developing countries during previous outbreaks with stronger effects for girls found following the Ebola-pandemic induced school closures (UNDP 2014)[3], with similar outcomes expected in the current crisis, as well[4].

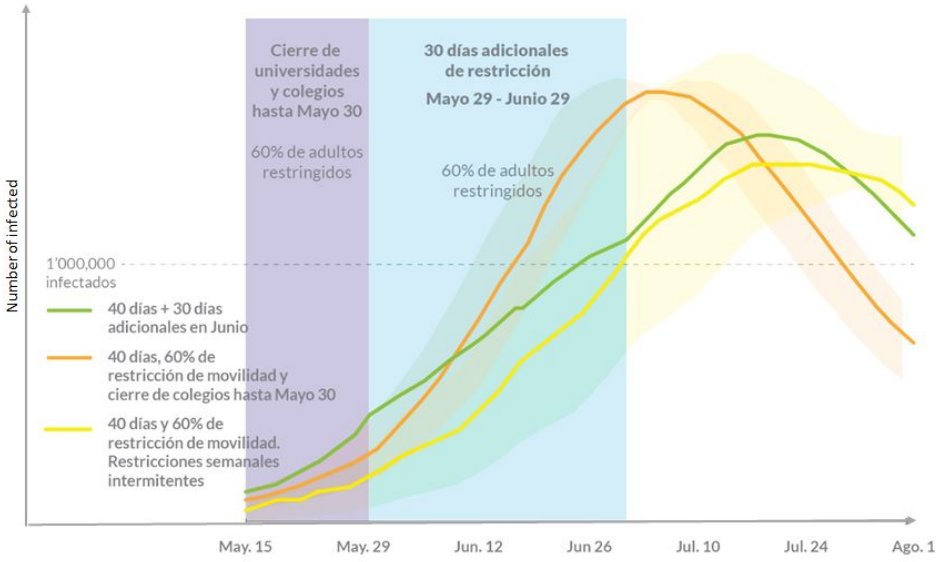
Different countries have adopted a variety of strategies in school closure and reopening, and we have reviewed the proposed policies for school reopening timelines and scenarios in over 20 countries in Europe, Asia, North and South America and other regions. Building on the body of such policies, we have identified differentials tracks for starting the school reopening with different grades (earlier or later school grades depending on intentions). For instance, Denmark has already reopened schools for earlier grades and it might be interesting to see the short-term effects of this change in Denmark (BBC 2020)[5]. In Peru, the new school semester has already been postponed by over a month, as it usually starts in early March, but as of Apr. 20th, the schools and

[1] https://msande433.wixsite.com/mysite-1
[2] El Pais article https://elpais.com/sociedad/2020-03-05/la-unesco-advierte-de-que-el-cierre-de-escuelas-por-coronavirus-puede-aumentar-las-desigualdades-sociales.html
[3] UNDP Report. (2014). *Assessing the socio-economic impacts of Ebola Virus Disease in Guinea, Liberia and Sierra Leone The Road to Recovery* (No. 267621). United Nations Development Programme (UNDP).
[4] UNESCO report https://en.unesco.org/news/covid-19-school-closures-around-world-will-hit-girls-hardest
[5] BBC (Apr 15, 2020) https://www.bbc.com/news/world-europe-52291326

universities have remained closed. Currently, the government is actively looking for the most appropriate strategy to reopen schools.

One of the few white papers specifically studying the scenarios of school reopening (Cordovez et al 2020)[6] finds that reopening of schools and universities (separately of other interventions) would not have a strong effect on increasing infections holding other mobility measures constant. One of the most interesting findings of this report is that the intermittent closure and opening strategies are having the most substantial effect on lowering the peak of the epidemiological curve in the number of infections (see Figure 1). While no specific interpretation or explanation is provided in the report, the intuition supporting these non-intuitive findings is related to the model's set up and assumptions: with the recovery period set to 14 days, the temporary reopening of 2 weeks increases the number of cases of the infection, however, the following 14-day lockdown enable the slowing down on the curve with the infected individuals having time to recover before the following reopening.

Figure 1. Scenarios for Bogota



- ***Orange***: schools closed until May 30
- ***Green***: schools closed until June 29
- ***Yellow***: weekly cyclical reopening (*Open for a week, closed for a week throughout May and June, leading to a lower peak)*

Source: Cordovez et al. (2020)[7].

In this project, we are building on this idea of temporary lockdown and reopening, and will be modelling several cyclical strategies for consecutive school reopening and closure.

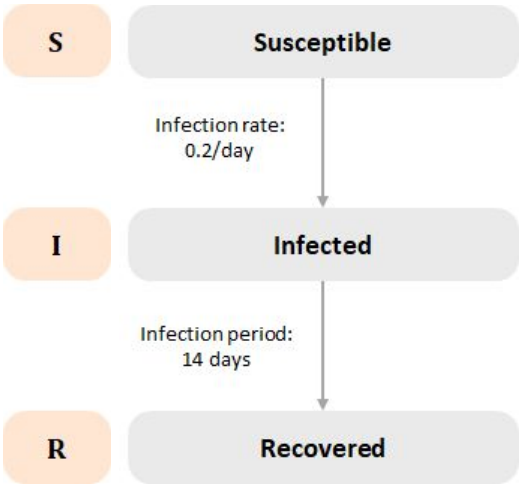
[6] Uni de los Andes (2020) Bogota - Consideraciones para post-quarantine
[7] Ibid.

Current Model

We are building on the SIR (susceptible, infected, recovered) model that was provided to us by Dr. Kristian Lopez Vargas and Dr. Gonzalo Panizo. Here is a brief description of the model and inputs.

Our scenario simulations are based on a simple SIR model that has several predetermined inputs of population and disease spread characteristics. The model predicts daily infections and recoveries based on the population size and composition, and the initial number of infected individuals and infection rate (the chances of contracting the infection if exposed). The model starts with everyone in the population being susceptible and a set share of the population infected. With a certain chance (*infection rate*), an exposed individual (anyone susceptible who is not isolated) would contract the disease, continue being sick for a set number of days (*infection duration*), and then recover. Upon recovery, individuals are removed from the susceptible population thereby gaining immunity.

Figure 2. SIR Model Diagram



Source: original layout

Assumptions:

- Homogeneous population
- School children split by classes
- Immunity after recovery
- Spread of infection only occurs between students, not between teacher and students

Inputs to the model

Socio-Demographic:

- School age population *500,000*
- Number of classrooms *20,000*
- Distribution of students by class size *Normal*
- Weekly school days *vary*

Epidemiological:

- Infection duration *14 days*
- Incubation period *3 days*
- Share of infected at $t = 0$ *0.001*
- Daily infection rate *0.2*

Limitations:

- Invariable infection rate by population group
- Transmission outside of class/school not considered (~ assumes full lockdown and zero transmission outside)
- Teacher and school staff not considered
- Not modeling hospitalizations and ICU patients explicitly

Results & Recommendations

Summary

For the purposes of an executive summary, the results and subsequent recommendations our team suggests can be summarized into two statements. First, after a cost benefit analysis, if the Peruvian government decides that reopening schools is their most advantageous path forward, they should do so with a staggered two weeks on two weeks off policy. Second, if the break of two weeks, sustained over a long period of time, is too much of a disruption to the educational curriculum, we have provided metrics that can be used to determine how many days a week it is worth opening the schools for.

Two week staggered reopening

There are a few important assumptions to recognize before going further.

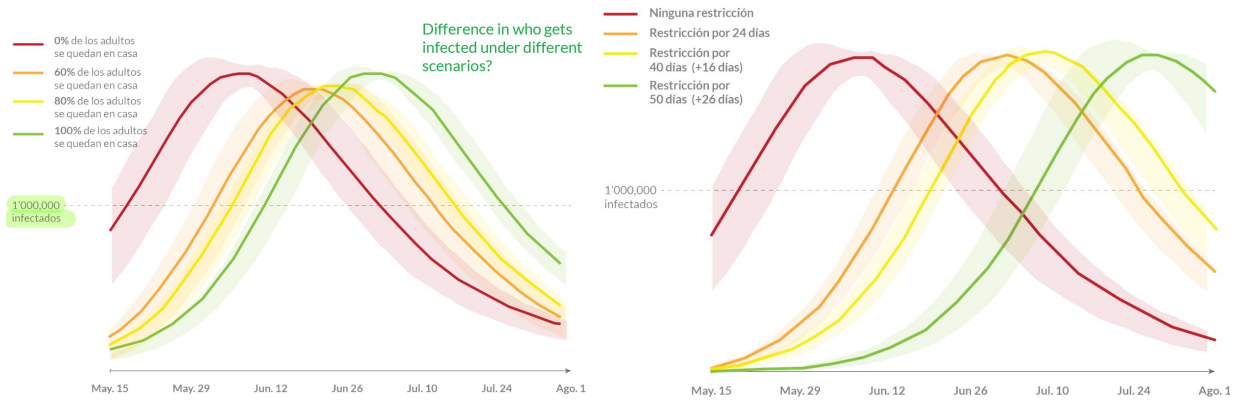
First, the modeling and simulation that produced this recommendation assumed that those who recover from Covid-19 develop immunity to the virus. This fact is not known to be true.

Second, this model was developed for the city of Bogota. The dynamics of movement within a city are understandably different than those which take place within a school and classroom. To begin with, it is hard to control the population density within a city (i.e. citizens are normally free to choose where they walk and spend their time under non-lock down conditions); however, a school can decide how many students are within each class and how closely they sit and interact with one another.

Third, this model simulated adult mobility. The interactions between school children with other school children, school children with their teachers, and school children with their administrative staff is expected to differ. Transmissibility will vary by age, with younger students expected to come into physical contact more frequently than older children.

Now that the key assumptions have been stated, one can understand the important takeaways from the model's findings. The first insight to notice was the drawback that the shelter-in-place policy had Bogota's effort toward decreasing the total number of infected citizens. Intuition would have it that mobility restrictive measures like shelter-in-place will "flatten" the overall curve of infection. However, this is not what Bogota's simulation shows (Figure 3):

Figure 3. Scenarios for Bogota



Source: Cordovez et al. (2020)[8].

As you can see above, mobility restrictions did not decrease the total number of infections, rather it simply delayed the peak. Of the many procedures, policies, and plans simulated, the most effective outcome the Bogota simulation found came through an intermittent lockdown.

For the city of Bogota, a staggered opening and closing of the city, opening it up for two weeks, closing it for two weeks and so on, was the most effective in decreasing the maximum total number of infected citizens. The logical reasoning behind such a policy goes back to our first assumption. Say mobility restrictions were lifted, if an individual were infected during those first two weeks and recovered in the following two, when mobility has again been restricted, they now gain immunity, essentially creating a form of herd immunity within the population. We believe that such modeling can be extended to the educational environment.

In fact, we believe that the control educators exert over class size, density, scheduling, and programming allows such a policy to be more effective within a school than it would be in a less controlled environment. Shelter-in-place or any kind of mobility restriction will not have a guarantee of absolute compliance within a population. Any kind of disobedience of such measures can undermine the whole effort. Unlike a city, a school's administrators can be confident in the compliance with rules they instate. Teachers can enforce and police policies to ensure that students act accordingly. The results will likely cause the efficacy of such efforts to be greatly bolstered.

[8] Uni de los Andes (2020) Bogota - Consideraciones para post-quarantine

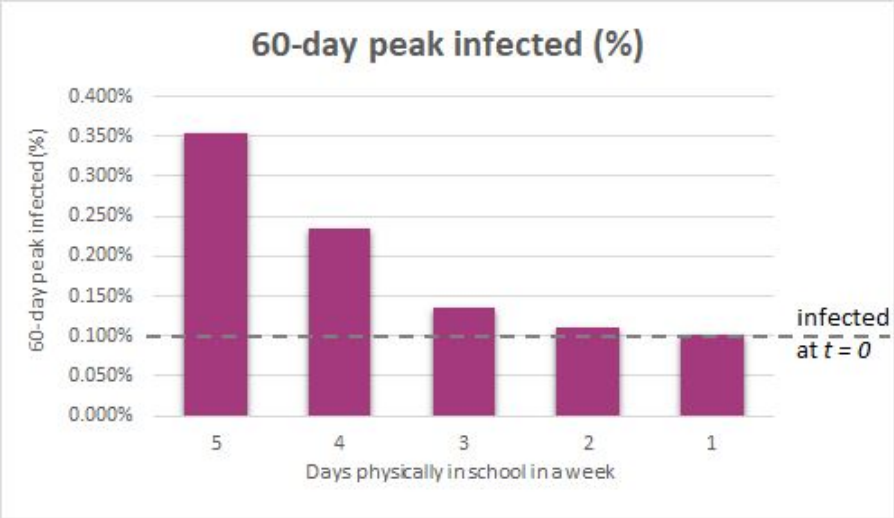
Adjusting the Weekly Schedule

If the staggered two weeks on two weeks off adjustment is too cumbersome for school administrators, an alternative solution exists. The typical school week in Peru, like in most nations, runs Monday to Friday.

Within the confines of that week, there are a variety of scenarios a school could try. On odd weeks, they could have half the class come on Monday, Wednesday, Friday, and the other half come Tuesday and Thursday. Then in even weeks, the half that came Tuesday and Thursday would come to school Monday, Wednesday, Friday (and vice-versa for the other half). Administrators could try having students come only Monday, Wednesday, and Friday. They could try allowing a student to come to school, by themselves, for one hour each week, thereby limiting the interaction that the student has with other students to be essentially negligible.

In order to provide administrators with more clarity into which scenario would be best, balancing both the health and safety of the teachers and students with the educational goals of the curriculum, our team modeled the five main scenarios: what would happen if students only came to school during one day of the week, during two days of the week, during three days of the week, during four days of the week, and during five days of the week. Our results were the following:

Figure 2. New Scenarios



Source: original calculations and layout

This graph illustrates the difference each of those scenarios had in the 60 day peak infection rate. That is, what is the maximum percentage of students, within 60 days, that become infected with the disease. - how many students are infected on a given day that shows the highest number of total cases among students. The basic set of assumptions are the same as in the Bogota model,

however, the simplifications are made in the homogeneity of the population (single age group) and we do not model the hospitalizations separately, they are beyond the score of our model.

While we cannot give a specific recommendation on how many days the school should be open, we hoped to provide administrators with clarity into the margin difference a day can make in the rate of infection the virus takes. The final decision would depend on the weights assigned to keeping the infections at a minimum vs. reducing the educational disruption to current students. Both have substantial social cost, which is why it is up to the policy makers to make a call on how much spread of infection can be tolerated in exchange for the revival of the in-person education activities.

Most notable are the marginal difference of the infection rate between keeping the school open for five days during the week versus four days in the week is drastic compared with the marginal difference between keeping school open for two days in the week versus one day in the week. The marginal difference of infection rate is exponential, the decrease in days is linear.

Thus, for a school administrator who has to decide how many days during the week they wish to keep their school open for, they may see that it is worth decreasing the week to a four day class schedule. Conversely, if the administrator was considering between a two day school week versus a one day school week, he or she may choose the two day, since the additional amount of educational material covered in two days versus one is twice as much, and the increase of the infection rate is incredibly small.

Through our efforts, we compiled our models, ran the simulation, and gathered a set of recommendations we believe are driven by data, fact checked with reputable sources, and informed by peer reviewed research.