Using a mathematical model to predict COVID-19 trends in Southeast Asian countries in 2021, 2022

Nguyen Tuan Kiet, La Khanh Linh, Nguyen Dang Gia Bach, Ho Anh Dung

Phan Huy Chu - Dong Da High School, Vietnam

Advisor: NGUYEN CAO KHANG
khangdhsp@gmail.com

1. Abstract

In December 2019, an outbreak of coronavirus disease 2019 (COVID-19), caused by a novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), occurred in Wuhan City, Hubei Province, China. On January 30, 2020 the World Health Organization declared the outbreak as a Public Health Emergency of International Concern. As of 18 December 2021, the total number of cases worldwide exceeded 274 million, and the total number of COVID-related deaths exceeded 5 million. Perceived risk of acquiring disease has led many governments to institute a variety of control measures over the last 2 years. As a government adjusts its response to the pandemic, its effects on the rate of transmissions and the growth rate of case statistics begin to be clear around a month after the response is applied.

This project conducted a preliminary observation of the number of cases in 8 Southeast Asian countries in periods of long-established COVID response in order to obtain stable trends, and model the trend of roughly 3 to 4 weeks through least squares regression. The model is then used to predict the following 3 days and confirmed to be consistent with real world data, with error margins of 300 cases or lower. The verified model then is used to predict the future trend of COVID cases based on the most recent 30 days. Governments can utilize this prediction model to adjust policy to tighten or relax accordingly, in order to better balance public safety and economic growth.

2. Experiment

2.1 Data

We utilised the data collected from *Our World In Data* [1], an online publication that focuses on large global problems. The publication has collected COVID cases statistics of more than 200 countries, with a daily update on the number of cases as reported by governments.

The countries whose data is used in the project are Vietnam, Thailand, Myanmar, Laos, Cambodia, Malaysia, Indonesia and Singapore.

From the data above, we collected a subset for a period of 3 to 4 weeks from each country, corresponding to around 2 weeks to 1 month after a change in COVID response has been enforced.

2.2 Mathematical model

At the start, when most people are healthy, the spread of disease would be exponential as it would be proportional to the number of infected people. But at some point there will be more ill people around, so there will be more interaction between people who are already infected. As a result, the rate of infection of healthy people will slow down. This explains for the S-shape seen in cumulative-cases-over-time graphs, as the population of healthy people decreases in the latter part of the spread, hence rate will eventually approach zero and cumulative cases will reach a predictable maximum. This behaviour can be modelled using a Logistic function [2][3]:

$$\frac{dN}{dt} = (1 - \frac{N}{C})rN$$

Where C is the maximum infectable population, and N is the infected population, and r is a constant.

This further can be expanded to a form of generalised logistic function:

$$N = \frac{C}{1+ exp(\frac{B-t}{A})}$$

With A, B, C being real number parameters that are adjusted depending on the data input (C being the maximum number of cases and A, B representing the rate of infection)

This is the most simple to apply form of parameterisation that we have found so far in reading.

2.3 Method of computation

In order to fit the collected data into a model, we used Mathematica, a computation software by Wolfram. The software is able to take input of given data points, and fit them onto the above model, producing output of the according values of parameters A, B and C. The software is also able to produce a graph of cumulative cases over time, and output the prediction of cumulative cases each of the following 3 days after the sampled period.

2.4 Verification and Documentation

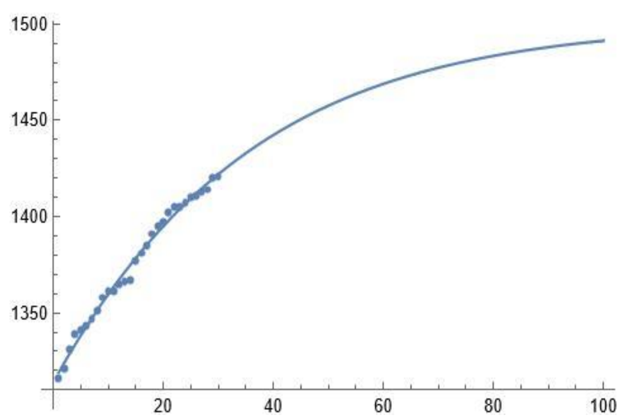
Each of the sampled periods is associated with a reported period of time in which the rate of spreading of COVID-19 is natural and unaffected by new treatment, restrictions or policies. This means the periods taken must be at least 2 weeks to a month after any of those events happened.

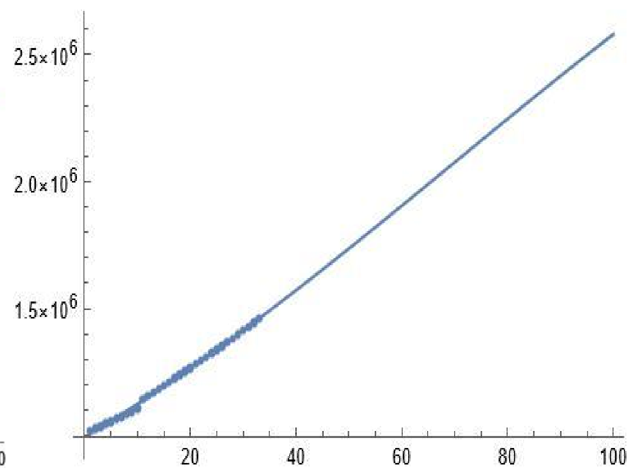
The prediction of the number of cases 3 days after the sampled period would be compared to the actual number of cases recorded, and parameters would be refined to produce output with error margins as small as possible. Once the error margin is at the range of 300 or lower (1000 or lower with large infected populations such as in Indonesia), the population would be confirmed suitable to apply the model to. The model henceforth can be used to predict future trends based on a sample of the latest 3 to 4 weeks.

3. Results & Observation

In all 8 countries sampled below, the model has been verified to have an acceptable error margin. The projected trend of the sampled past period is shown on the left graph of each part, along with the indicated period. The application of the model to predict future trends is shown in the right graph of each part. The output parameters also give info on the predicted maximum number of cases.

<u>3.1 Vietnam</u>





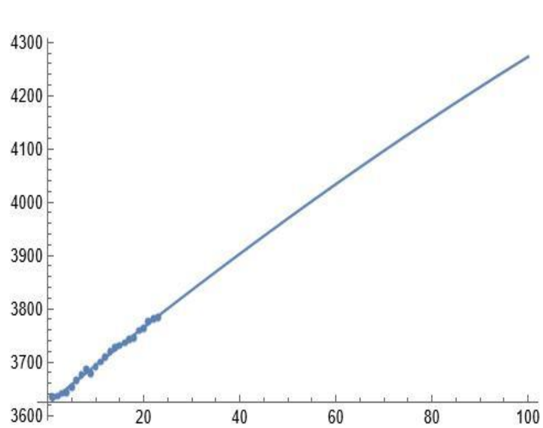
Observation (Left)

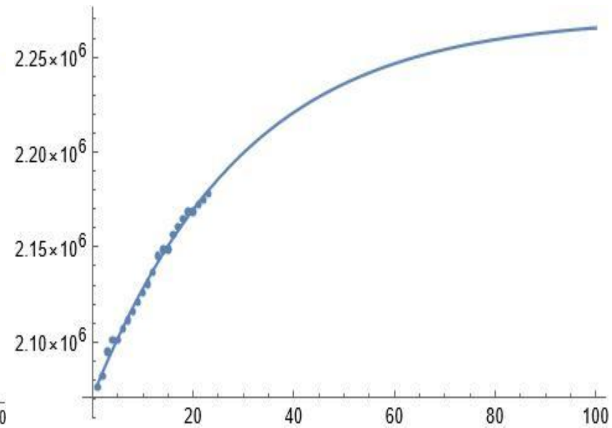
- Sampled from 24/11/2020-23/12/2020
- The country closed its borders from tourists, and most activities are still restricted during the last quarter of 2020 and stay-home orders are still in effect. Hence this is a period of controlling the spread. [4]

Prediction (Right)

- Based on sample from 13/11/2021-18/12/2021
- Predicted maximum number of cases: 5112760
- The national economy has reopened, and travelling is allowed for vaccinated passengers. Commercial flights are also established in January 2022 [5]. Hence we can reasonably expect the number of cases to rise faster than what the model predicts. Caution and better contact tracing systems is therefore essential.

3.2 Thailand





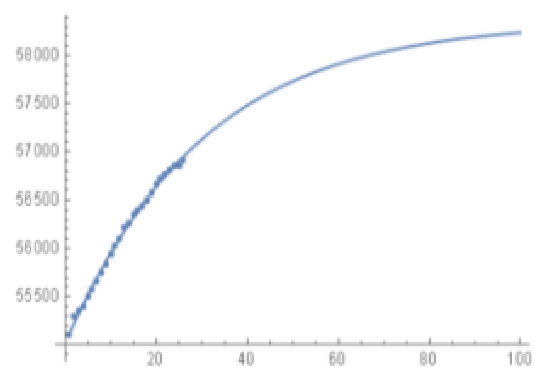
Observation (Left)

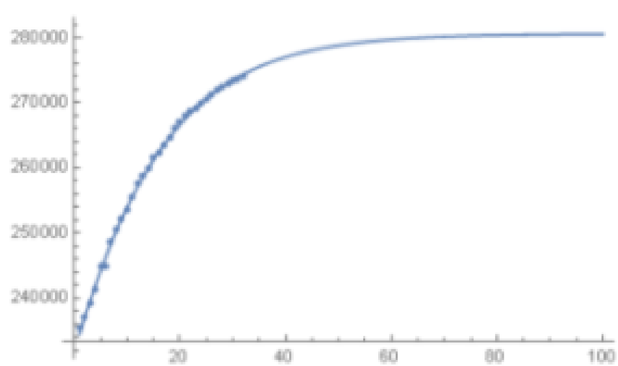
- Sampled from 09/10/2020 - 31/10/2020
- Thai authorities extended the country's state of emergency through October 31, amid efforts to curb the spread [6]. Hence this observed period is a stable rising trend under strict policy conditions.

Prediction (Right)

- Based on sample from 23/11/2021 - 18/12/2021
- Predicted maximum number of cases: 2271160
- Reopening of the new lifestyle in Thailand and the opening of 17 provinces for vaccinated foreign visitors would increase the rate slightly compared to what the model outputs.[7]

3.3 Singapore





Observation (Left)

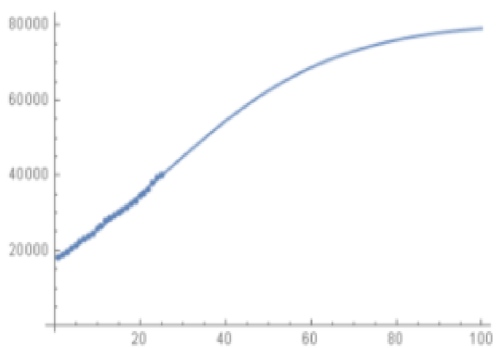
- Sampled from 19/7/2020 -13/8/2020

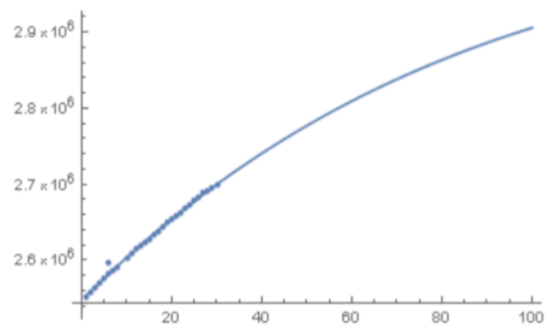
- This period is linked to clusters’ natural growth upon restriction relaxation, hence SIngapore would be going back to stricter measures [8]

Prediction (Right)

- Based on sample from 14/11/2021 - 15/12/2021
- Predicted maximum number of cases: 280609
- Easing of restrictions on 20/11 and the opening of Vaccinated Travel Lane (VTL) with Malaysia would increase the transmission rate slightly compared to predictions, so caution should be exercised [9]

3.4 Malaysia





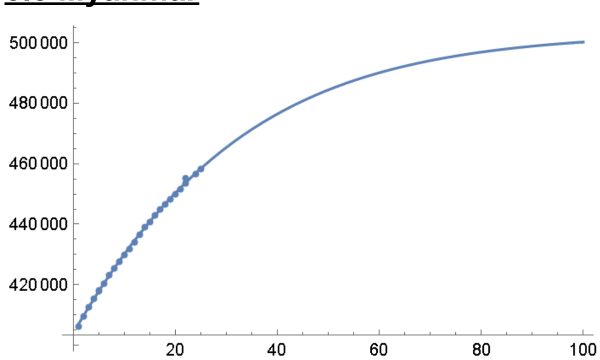
Observation (Left)

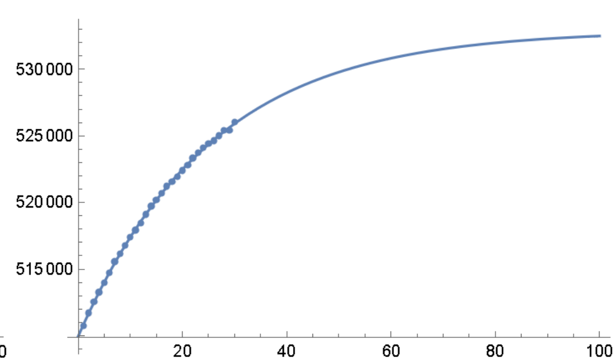
- Sampled from 22/9/2020 -16/10/2020
- Reopening in August and the acceptance of ‘new normal’ lifestyle among Malaysians leads to an expected and stable spread rate [10]

Prediction (Right)

- Based on sample from 15/11/2021 - 15/12/2021
- Predicted maximum number of cases: 3042050
- The opening of Vaccinated Travel Lane with Singapore and eventual opening of borders in January 2022 would result in higher number of cases compared to predictions, hence caution should be exercised.[11]

3.5 Myanmar





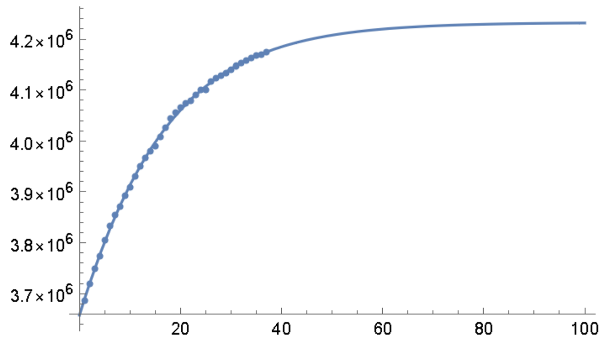
Observation (Left)

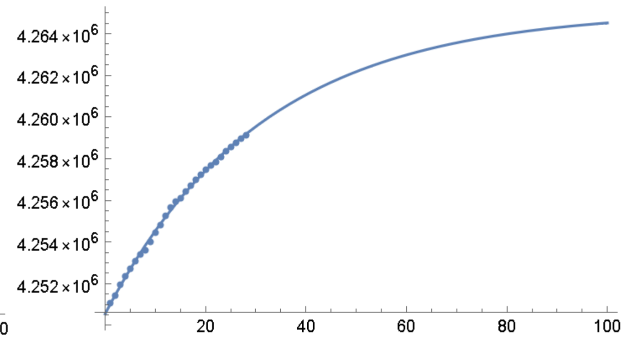
- Sampled from 2/9/2021 - 26/9/21
- This is a period of sustained preventive measures until the end of September[12]

Prediction (Right)

- Based on sample from 11/11/21 - 10/12/21
- Predicted maximum number of cases: 532905
- On 11/12/21 Myanmar relaxed the stay-home notice order in 8 more townships [13] , so we can expect the number of cases to rise faster than predicted.

3.6 Indonesia





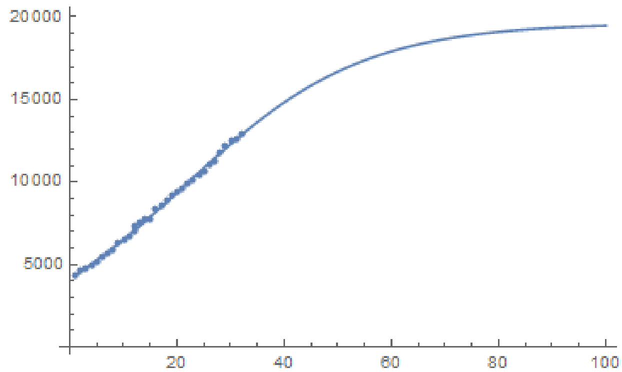
Observation (Left)

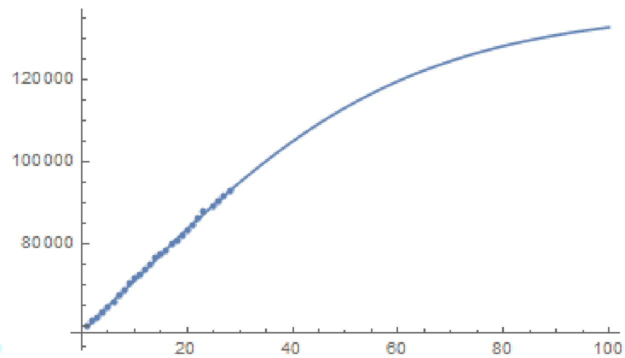
- Sampled from 9/8/21 - 14/9/21
- A period of steady rising number of cases before Indonesian government announce easing of restrictions [14]

Prediction (Right)

- Based on sample from15/11/21 - 12/12/21
- Predicted maximum number of cases: 4265100
- Holiday events and the spread of new Omicron variant can probably make the rate of transmission much higher than predicted, even if more restrictions are put in place[15].

3.7 Laos:





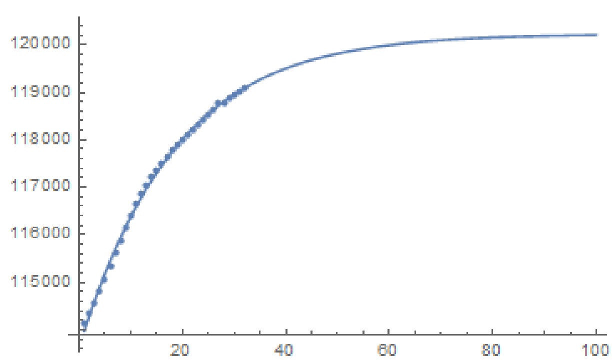
Observation (Left)

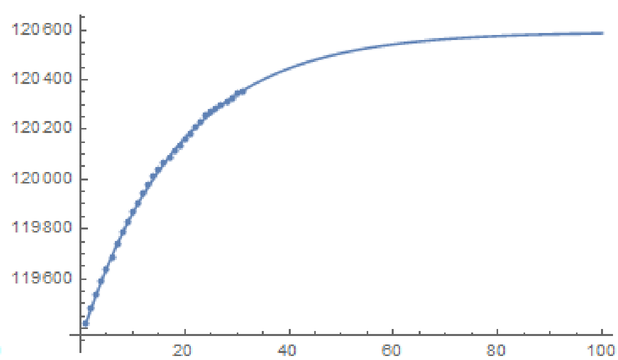
- Sampled from 23/8/21-23/9/21
- An extended lockdown in Myanmar ended on 18/8, and hence this period is the natural transmission trend established some time after that. [16]

Prediction (Right)

- Based on sample from15/11/21-15/12/21
- Predicted maximum number of cases: 137345
- Laos policy currently is to extend the restrictions for densely populated areas, social events, offices and organizations. Laos also reopened schools from 1/11 but the school has to follow the ministry of health regulations. Hence the trend can be expected to be relatively consistent with predictions.[17]

3.8 Cambodia :





Observation (Left)

- Sampled from 9/10/21-9/11/21

- A stable rising period, as the government prepares for reopening.

Prediction (Right)

- Based on sample from 1/11/21-15/12/21
- Predicted maximum number of cases: 120591
- The effect of booster vaccination campaign rolled out in Oct can be observed soon, so there may be fewer cases than predicted.[18]
- However there is also reopening for tourists in 2022, so the trend can be fairly consistent with predictions.

4. Conclusion & Future Plans

This project provided insight on the mechanism of pandemic growth, and how it can be applied to predictions of future trends of the pandemic. This result is useful as a precaution against potential new waves or the appearance of surprise clusters, and a recommendation for governments to prepare. The data also presents the risks of resuming activities, to both governments and citizens. This expectation would be well used by the general public to gauge the level of safety in society, and be able to make decisions regarding going out in public. On the other hand, governments would see the effects and potential harm of reopening economies, and be advised to make a decision that balances public health and economic growth.

In the future, we would like to improve the performance of the mathematical model by refining the process of determining parameters, through filtering the input data to remove periods of incorrect, slow or inconsistent reporting of cases by governments. The model would also be adjusted to account for a slightly lower rate of transmissions, now that vaccinations have been rolled out in most countries and borders are reopening for international travel. These factors would hopefully contribute to the slowing down of the transmission of COVID-19, and the world's recovery from the pandemic.

References/Sources

1. https://ourworldindata.org/
2. *The logistic function,* Evgenii*,* 12 March 2020, https://evgenii.com/blog/logistic-function/
3. Modeling of early COVID-19 cases, Wikipedia, https://en.wikipedia.org/wiki/Logistic_function#In_medicine:_modeling_of_a_pandemic
4. https://www.vietnam-briefing.com/news/covid-19-vietnam-travel-updates-restrictions.html/
5. https://news.lindelatravel.com/2021/10/vietnam-to-begin-fully-reopening-for-tourism-in-december/

6. https://www.tatnews.org/2020/09/thailand-extends-emergency-decree-for-the-sixth-time-to-the-end-of-october/
7. https://www.bloomberg.com/news/articles/2021-10-31/thailand-s-big-reopening-set-to-test-pandemic-era-tourism
8. https://www.gov.sg/article/as-of-20-july-2021-return-to-phase-2-heightened-alert-measures
9. https://www.rappler.com/world/asia-pacific/singapore-eases-covid-19-social-curbs-from-november-22-2021/
10. https://www.wsws.org/en/articles/2021/10/28/mala-o28.html
11. https://www.malaymail.com/news/malaysia/2021/12/14/miti-vtl-land-open-to-all-vaccinated-malaysian-singaporean-travellers-from/2028349
12. https://www.thestar.com.my/aseanplus/aseanplus-news/2021/08/30/myanmar-extends-covid-19-preventive-measures-until-end-of-september
13. https://www.thestar.com.my/aseanplus/aseanplus-news/2021/12/11/myanmar-lifts-stay-at-home-order-in-eight-more-townships-as-numbers-of-new-covid-19-cases-are-decreasing
14. https://www.reuters.com/world/asia-pacific/indonesias-president-says-covid-19-restrictions-be-eased-2021-08-30/
15. https://www.netherlandsandyou.nl/latest-news/news/2021/07/21/latest-covid-19-regulations-updates-in-indonesia
16. https://www.aninews.in/news/world/asia/covid-19-lockdown-in-laos-extended-till-august-1820210803153407/
17. https://en.vietnamplus.vn/laos-reopens-schools-extends-some-other-restrictions/215498.vnp
18. https://english.cambodiadaily.com/health/cambodia-to-start-covid-19-booster-shot-campaign-in-october-174817/