ISYE 6739 Project Final Report

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Introduction

As a group, we decided to analyze the current COVID-19 situation. We investigated the geographic and temporal spread of confirmed cases. The investigation was divided into four parts:

1. Study the effects of quarantine measures on COVID-19 growth rate
2. Analyze weather and geography’s effects on COVID-19 growth rate
3. Examine the distribution of doubling times of COVID-19 cases for a variety of countries
4. Investigate relationship between time and published estimates of COVID-19 basic reproduction number (R_0) in China

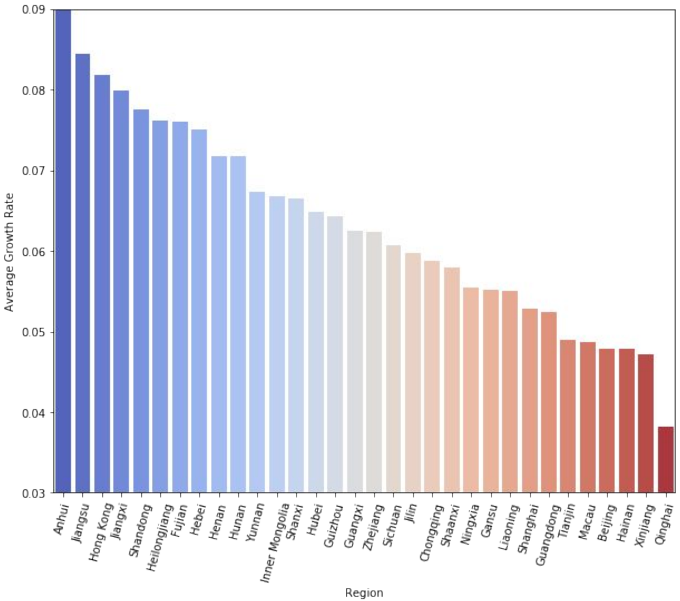
Raw data description

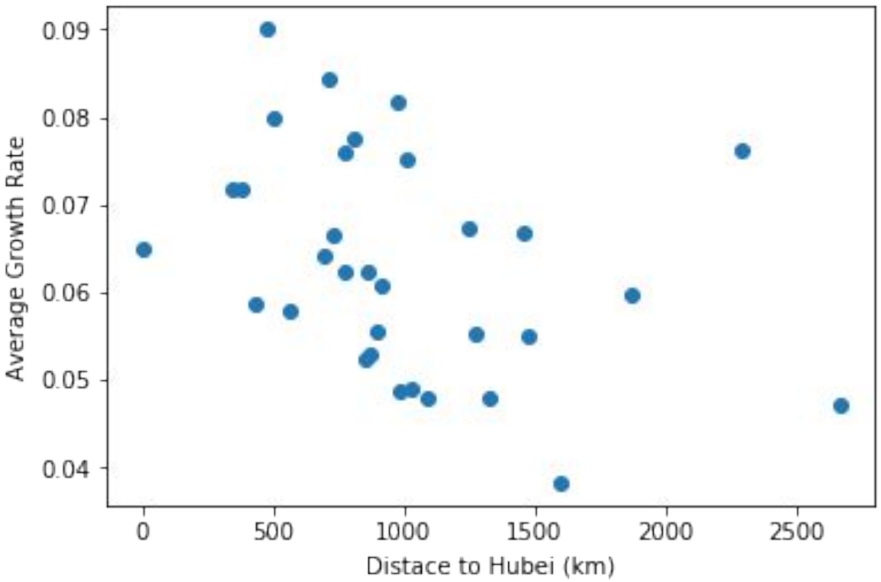
As part of our investigation, we used data sources including:

- John Hopkins University Center for Systems Science and Engineering (JHU CSSE) [6]
- United States National Library of Medicine (NLM) [1]
- COVID-19 Testing Tracker. Foundation for Innovative New Diagnostics [4]
- Variations in government responses. Blavatnik School of Government, University of Oxford [5]

Effect of climate and location on COVID-19 growth rate

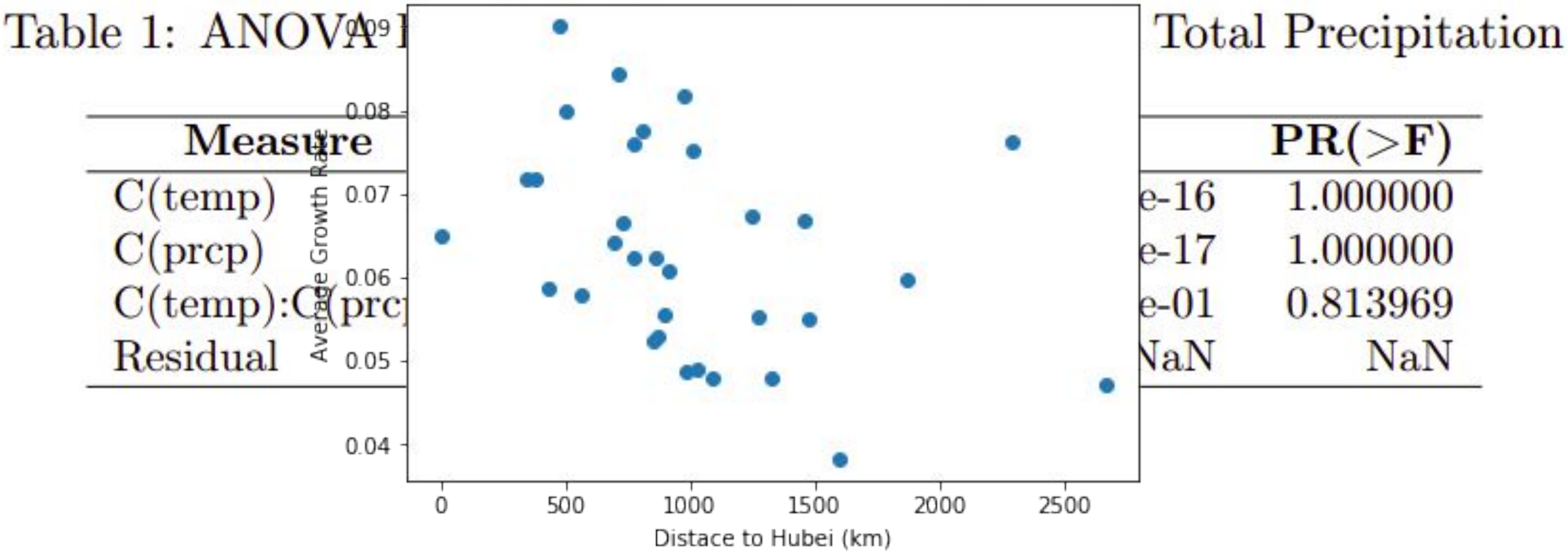
- The average growth rate in each region is not normally distributed
- WIth the increase of distance to Hubei, COVID-19’s growth rate decreases
- The negative correlation has also been demonstrated by a negative covariance



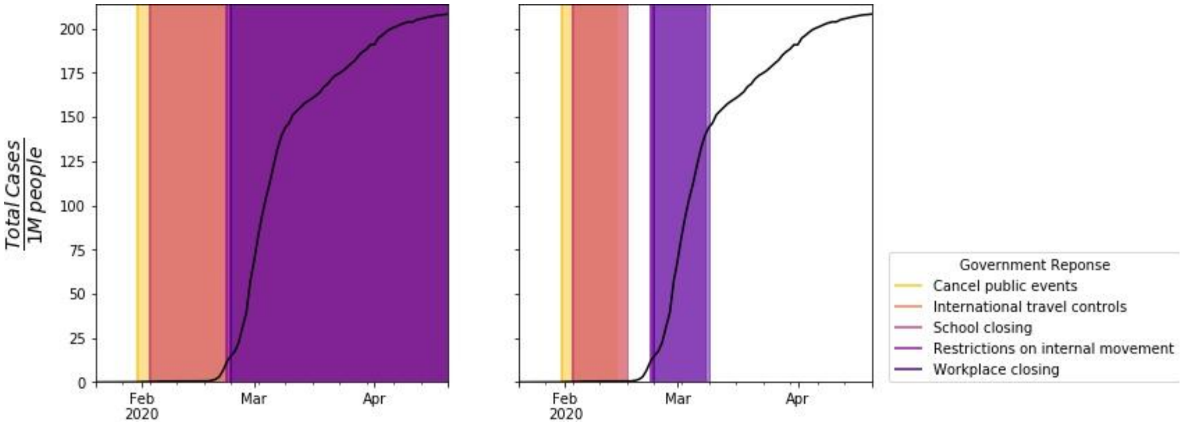


Effect of climate and location on COVID-19 growth rate

- We tried to analyze the relationship between weather and COVID-19’s spread
- We carried out ANOVA for each pair of weather data



Effect of social distancing on COVID-19 growth rate



- Identify most effective quarantine measures
- Total cases per capita time series
- Compare the growth rate before and after each quarantine measure, for each country.

Effect of social distancing on COVID-19 growth rate

$$\rho_i = \frac{1}{\Delta t_{mi}} \log(\frac{\bar{\phi}_m}{\bar{\phi}_i})$$
$$\rho_f = \frac{1}{\Delta t_{fm}} \log(\frac{\bar{\phi}_f}{\bar{\phi}_m})$$
$$\rho = \rho_f - \rho_i \,,$$

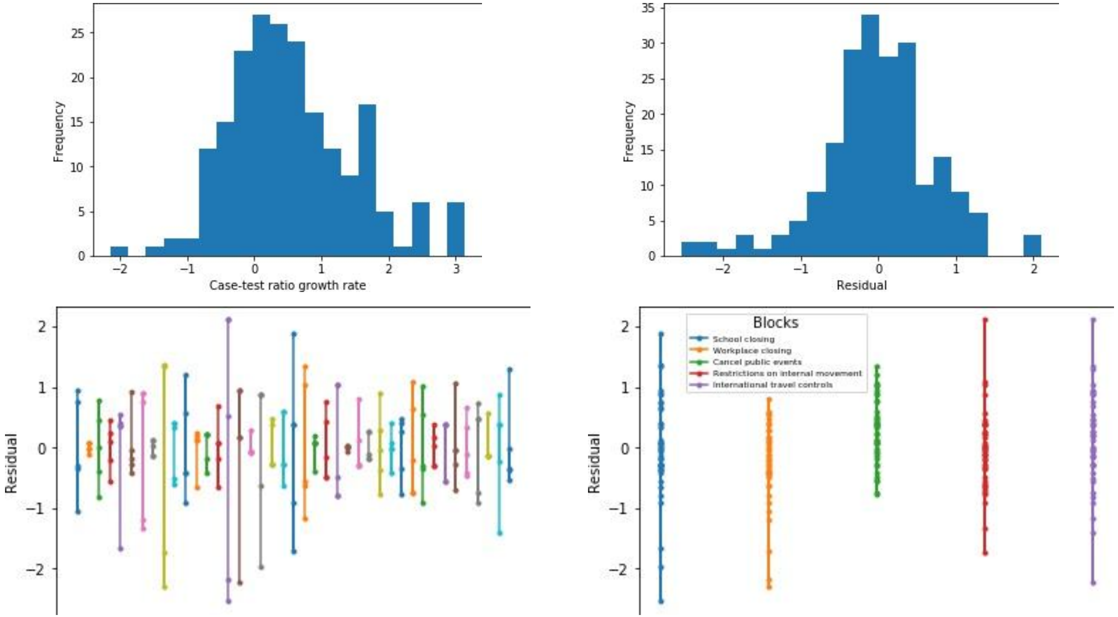
Table 1: Two-Way ANOVA results for change in growth rate by factor

	Sums of squares	d.o.f.	F-stat	p-value
Type	6.757982	4	2.618791	0.037044
Country	71.847056	40	1.8343	0.000003

- Assumed exponential growth
- Use of 14-day averaging windows to attempt to incorporate incubation period
- Two-way ANOVA shows that both quarantine measure and country effect the change in growth rates.

Effect of social distancing on COVID-19 growth rate

Approximately normally distributed values and residuals, and approximately equal variances for blocks (quarantine measures) but not treatments (countries).

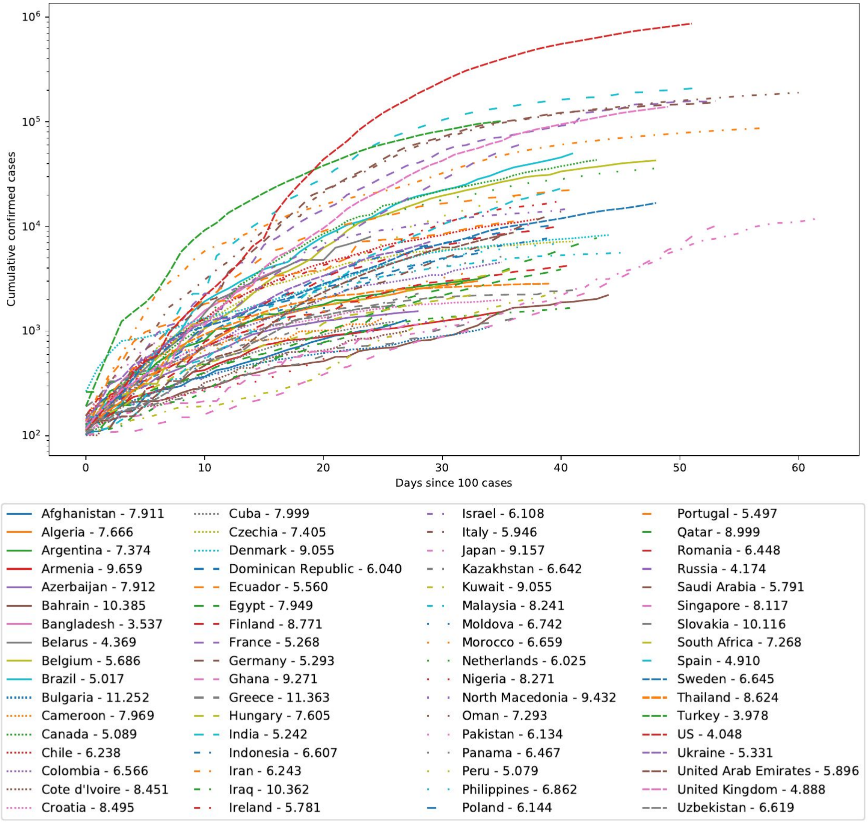


Doubling time by country

- By looking at the doubling time by country, we can get an idea of the distribution
- We can get insight into which countries are growing quicker
- We could use the doubling times to get an idea of how quick we expect it to grow

Doubling time by country
Observations on cumulative cases

- We see that, unsurprisingly, the United States has the largest number of cases
- Curves initially started out increasing faster, but most are flattening due to practices



Doubling time by country
Observations on doubling times

- Countries widely considered developed such as US, United Kingdom, Spain, Canada, France and Germany all are within the top quarter of quickly doubling

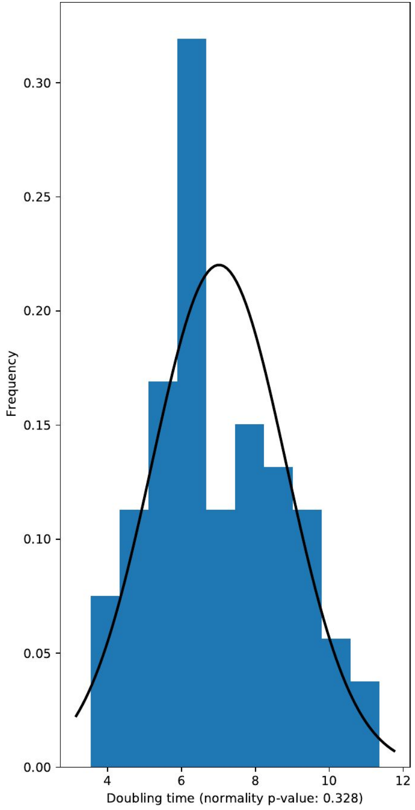
- This may be due to more testing, density of population, or speed of response

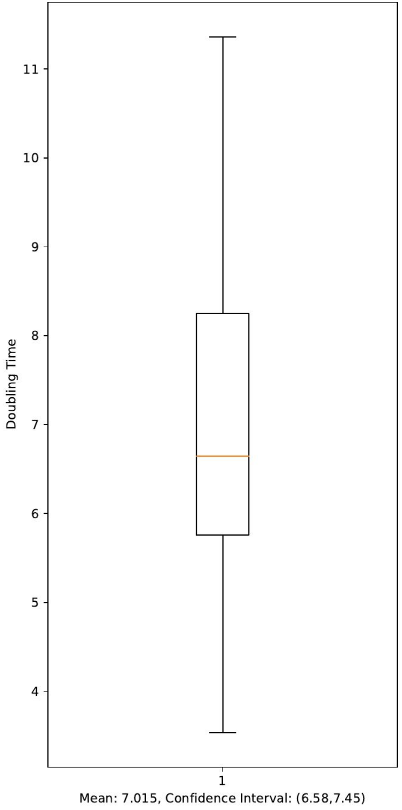
Country/Region	Days	Country/Region	Days	Country/Region	Days	Country/Region	Days
Bangladesh	3.54	Ireland	5.78	Sweden	6.64	Nigeria	8.27
Turkey	3.98	Saudi Arabia	5.79	Morocco	6.66	Cote d'Ivoire	8.45
US	4.05	United Arab Emirates	5.90	Moldova	6.74	Croatia	8.50
Russia	4.17	Italy	5.95	Philippines	6.86	Thailand	8.62
Belarus	4.37	Netherlands	6.03	South Africa	7.27	Finland	8.77
United Kingdom	4.89	Dominican Republic	6.04	Oman	7.29	Qatar	9.00
Spain	4.91	Israel	6.11	Argentina	7.37	Kuwait	9.06
Brazil	5.02	Pakistan	6.13	Czechia	7.41	Denmark	9.06
Peru	5.08	Poland	6.14	Hungary	7.60	Japan	9.16
Canada	5.09	Chile	6.24	Algeria	7.67	Ghana	9.27
India	5.24	Iran	6.24	Afghanistan	7.91	North Macedonia	9.43
France	5.27	Romania	6.45	Azerbaijan	7.91	Armenia	9.66
Germany	5.29	Panama	6.47	Egypt	7.95	Slovakia	10.12
Ukraine	5.33	Colombia	6.57	Cameroon	7.97	Iraq	10.36
Portugal	5.50	Indonesia	6.61	Cuba	8.00	Bahrain	10.39
Ecuador	5.56	Uzbekistan	6.62	Singapore	8.12	Bulgaria	11.25
Belgium	5.69	Kazakhstan	6.64	Malaysia	8.24	Greece	11.36

Doubling time by country
Observations on distribution

- The doubling rates do follow a normal curve
- This indicates methods of analysis that require a normal distribution could be used
- There is a skew to lower doubling times
- The found confidence interval aligns with some estimates in literature

[(A Systematic Review of COVID-19 Epidemiology Based on Current Evidence]

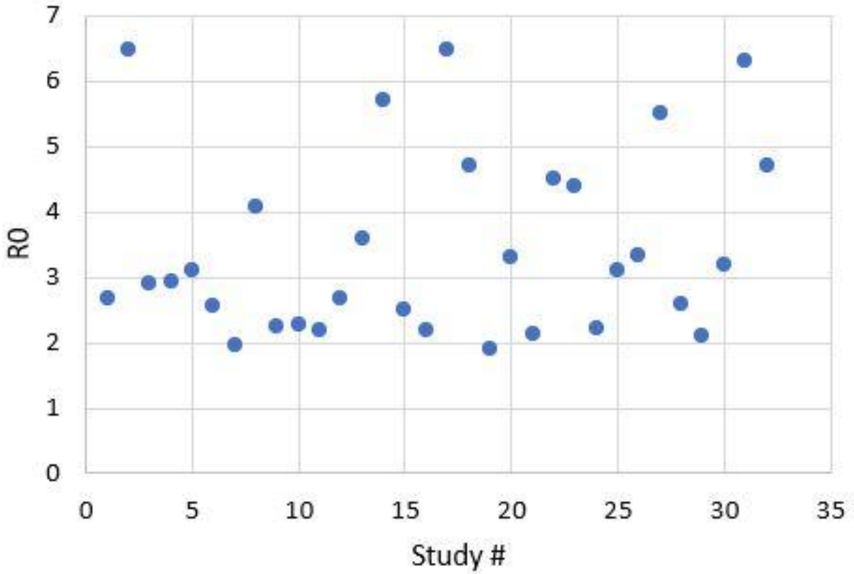




COVID-19 Growth Rate Meta-Analysis

- R_0: average number of people who will contract a disease from one contagious person
  - $R_0 > 0$: number of infected people is likely to increase
  - $R_0 < 0$: transmission of the virus is likely to die out
- Meta-Analysis
  - Growth of COVID-19 in China
  - 32 published estimates for R_0

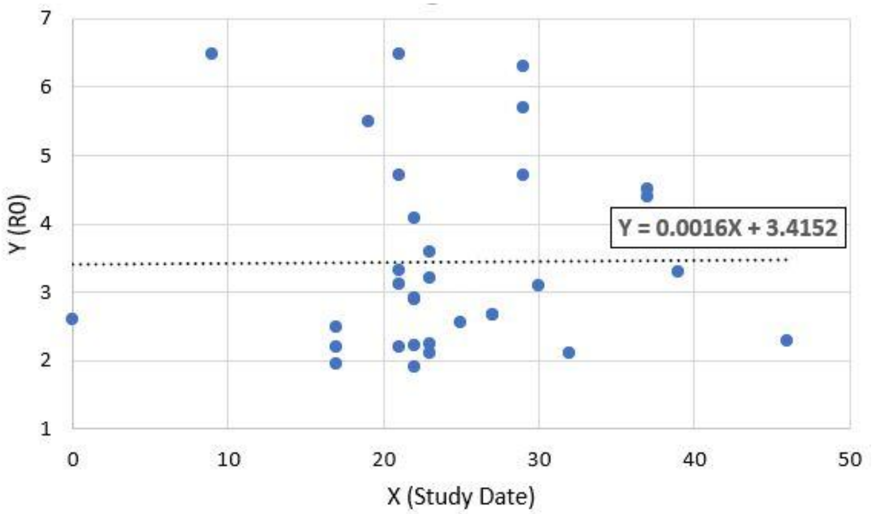
Measure	Result
Mean	3.45
Median (Q2)	3.01
Minimum	1.90
Maximum	6.49
Range	4.59
Standard Deviation	1.41
Variance	1.99
1st Quartile (Q1)	2.27
3rd Quartile (Q3)	4.43
Interquartile Range (IQR)	2.16



COVID-19 Growth Rate Meta-Analysis

- Are published estimates of COVID-19 in China decreasing with time?
  - Chinese government ban on public transportation invoked on January 23, 2020 for five major cities (Wuhan, Huanggang, Ezhou, Chibi and Zhijiang) [2]
- Simple Linear Regression
  - Predictor: Cutoff Date for COVID-19 Cases Reported (“Study Date”)
  - Response: R_0 Estimate

Regression Result	Value
$\bar{X}$	24.16
$\bar{Y}$	3.45
$\hat{\beta}_0$	3.415
$\hat{\beta}_1$	0.0016
SS_{Error}	61.5468
SS_{Total}	61.5525
$SS_{Regression}$	0.0057
Means Squred Error (MSE)	2.0516
α	0.05
df (n - 2)	30
$t\alpha/2$, n-2	2.042
Margin of Error of C.I. (E)	0.5337
95% C.I. for $\hat{y} = 3.45$	(2.9163, 3.9837)



Summary

- COVID-19's growth rate in China is negatively correlated with the distance from Hubei.
- The weather in China has little impact on the spread of COVID-19.
- There are significant effects between different quarantine measures and the countries that implement them.
- The doubling rates of COVID-19 appear to be normally distributed across countries.
- Meta analysis shows no dependence of reproduction number on time

Future work and improvements

1. Wait for quantity and quality of data to increase
2. Further analysis of the spread of initial contagion in China to develop protocols for first responses to new diseases.
3. Find a way to handle the lack of independence between quarantine measures
4. Find and utilize methods which exploit normally distributed doubling rates
5. Continue meta-analyses to validate results.

References

[1] United States National Library of Medicine (NLM): https://www.ncbi.nlm.nih.gov/pubmed/

[2] BBC NEWS. Coronavirus: Wuhan Shuts Public Transport over Outbreak.

[3] Our World in Data. Joe Hasell, Esteban Ortiz-Ospina, Edouard Mathieu, Hannah Ritchie, Diana Beltekian and Max Roser https://github.com/owid/covid-19-data/tree/master/public/data/

[4] Foundation for Innovative New Diagnostics. COVID-19 Testing Tracker. https://finddx.shinyapps.io/FIND_Cov_19_Tracker/

[5] A. Petherick, T. Hale, T. Phillips, S. Webster, Variation in Government Responses to COVID-19. Preprint https://www.bsg.ox.ac.uk/research/publications/variation-government-responses-covid-19

[6] Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE): https://systems.jhu.edu/