

# Modeling and Predicting The COVID-19 Pandemic Trajectory

-Samuel Zhang

The scope of this project is to mathematically model and analyze the growth and trajectory of COVID-19 pandemic using global data provided by John Hopkins Hospital. Since this is a Matlab Live Script Document, all the code and data are transparent and please feel free to criticize and leave your own suggestions. The data is up to date as of March 29, 2020. One can easily add and modify data regarding to one's needs using this livescript.

```
clc
clear
%%Plot Total Confirmed Cases
Country_Names=['Australia','China','Finland','Germany','Iran','Italy','Japan','SouthKorea','Malaysia','Singapore','United Kingdom','US']

Country_Names =
'AustraliaChinaFinlandGermanyIranItalyJapanSouthKoreaMalaysiaSingaporeUnited KingdomUS'
```

## Index Confirmed Cases from <https://github.com/CSSEGISandData/COVID-19>

This portion is the raw data provided by John Hopkins Hospital. The table is split using , and ; with , representing columns and ; representing rows. Rows: Confirmed Cases since Jan 22 2020, Columns: Countries in the order of **Country\_Names**.

```
Confirmed_cases=[0,548,0,0,0,0,2,1,0,0,0,1;
0,643,0,0,0,0,2,1,0,1,2,1;
0,920,0,0,0,0,2,2,0,3,2,2;
0,1406,0,0,0,0,2,2,3,3,2,2;
4,2075,0,0,0,0,4,3,4,4,2,5;
5,2877,0,1,0,0,4,4,4,5,2,5;
5,5509,0,4,0,0,7,4,4,7,2,5;
6,6087,1,4,0,0,7,4,7,7,2,5;
9,8141,1,4,0,0,11,4,8,10,2,5;
9,9802,1,5,0,2,15,11,8,13,4,7;
12,11891,1,8,0,2,20,12,8,16,8,8;
12,16630,1,10,0,2,20,15,8,18,8,8;
12,19716,1,12,0,2,20,15,8,18,10,11;
13,23707,1,12,0,2,22,16,10,24,10,11;
13,27440,1,12,0,2,22,19,12,28,10,11;
14,30587,1,12,0,2,22,23,12,28,12,11;
15,34110,1,13,0,3,25,24,12,30,13,11;
15,36814,1,13,0,3,25,24,16,33,16,11;
15,39829,1,14,0,3,26,25,16,40,16,11;
15,42354,1,14,0,3,26,27,18,45,22,11;
15,44386,1,16,0,3,26,28,18,47,23,12;
15,44759,1,16,0,3,28,28,18,50,24,12;
15,59895,1,16,0,3,28,28,19,58,25,13;
15,66358,1,16,0,3,29,28,19,67,25,13;
15,68413,1,16,0,3,43,28,22,72,25,13;
15,70513,1,16,0,3,59,29,22,75,25,13;
15,72434,1,16,0,3,66,30,22,77,25,13;
```

15,74211,1,16,0,3,74,31,22,81,25,13;  
 15,74619,1,16,2,3,84,31,22,84,25,13;  
 15,75077,1,16,5,3,94,104,22,84,25,13;  
 15,75550,1,16,18,20,105,204,22,85,25,15;  
 15,77001,1,16,28,62,122,433,22,85,25,15;  
 15,77022,1,16,43,155,147,602,22,89,25,15;  
 15,77241,1,16,61,229,159,833,22,89,29,51;  
 15,77754,1,17,95,322,170,977,22,91,29,51;  
 15,78166,2,27,139,453,189,1261,22,93,29,57;  
 15,78600,2,46,245,655,214,1766,23,93,31,58;  
 15,78928,2,48,388,888,228,2337,23,93,36,60;  
 25,79356,3,79,593,1128,241,3150,25,102,39,68;  
 27,79932,6,130,978,1694,256,3736,29,106,52,74;  
 30,80136,6,159,1501,2036,274,4335,29,108,56,98;  
 39,80261,6,196,2336,2502,293,5186,36,110,67,118;  
 52,80386,6,262,2922,3089,331,5621,50,110,102,149;  
 55,80537,12,482,3513,3858,360,6088,50,117,136,217;  
 60,80690,15,670,4747,4636,420,6593,83,130,187,262;  
 63,80770,15,799,5823,5883,461,7041,93,138,241,402;  
 76,80823,23,1040,6566,7375,502,7314,99,150,320,518;  
 91,80860,30,1176,7161,9172,511,7478,117,150,371,583;  
 107,80887,40,1457,8042,10149,581,7513,129,160,441,959;  
 128,80921,59,1908,9000,12462,639,7755,149,178,527,1281;  
 128,80932,59,2078,10075,12462,639,7869,149,178,528,1663;  
 200,80945,155,3675,11364,17660,701,7979,197,200,880,2179;  
 250,80977,225,4585,12729,21157,773,8086,238,212,1238,2727;  
 297,81003,244,5795,13938,24747,839,8162,428,226,1254,3499;  
 377,81033,277,7272,14991,27980,839,8236,566,243,1681,4632;  
 452,81058,321,9257,16169,31506,878,8320,673,266,2137,6421;  
 568,81102,336,12327,17361,35713,889,8413,790,313,2861,7783;  
 681,81156,400,15320,18407,41035,924,8565,900,345,2991,13677;  
 791,81250,450,19848,19644,47021,963,8652,1030,385,4324,19100;  
 1071,81305,523,22213,20610,53578,1007,8799,1183,432,5437,25489;  
 1549,81435,626,24873,21638,59138,1101,8961,1306,455,6192,33276;  
 1682,81498,700,29056,23049,63927,1128,8961,1518,509,7206,43847;  
 2044,81591,792,32986,24811,69176,1193,9037,1624,558,8671,53740;  
 2364,81661,880,37323,27017,74386,1307,9137,1796,631,10226,65778;  
 2810,81782,958,43938,29406,80589,1387,9241,2031,683,12590,83836;  
 3143,81897,1041,50871,32332,86498,1468,9332,2161,732,15612,101657;  
 3640,81999,1167,57695,35408,92472,1693,9478,2320,802,18287,121478;  
 3984,82122,1240,62095,38309,97689,1866,9583,2470,844,20867,140886]

Confirmed\_cases = 68x12

0	548	0	0	0	0 ...
0	643	0	0	0	0
0	920	0	0	0	0
0	1406	0	0	0	0
4	2075	0	0	0	0
5	2877	0	1	0	0
5	5509	0	4	0	0
6	6087	1	4	0	0
9	8141	1	4	0	0
9	9802	1	5	0	2
:					
:					

```
Rate_of_New_Cases=[0,0,0,0,0,0,0,0,0,0,0,0;
0,0,0,0,0,0,0,0,0,0,0,0;
```

Rate\_of\_New\_Cases=[0,0,0,0,0,0,0,0,0,0,0,0;  
0,0,0,0,0,0,0,0,0,0,0,0;  
0,0,0,0,0,0,0,0,0,0,0,0;  
0,254.3333333,0,0,0,0,0,0.333333333,1,0.666666667,0,0.333333333;  
1.333333333,385,0,0,0,0,0.666666667,0.333333333,1.333333333,0.333333333,0,1;  
1.666666667,490.3333333,0,0.333333333,0,0,0.666666667,0.666666667,0.333333333,0.666666667,  
0.333333333,1144.666667,0,1.333333333,0,0,1,0.333333333,0,1,0,0;  
0.333333333,1070,0.333333333,1,0,0,1,0,1,0.666666667,0,0;  
1.333333333,877.3333333,0.333333333,0,0,0,1.333333333,0,1.333333333,1,0,0;  
1,1238.333333,0,0.333333333,0,0.666666667,2.666666667,2.333333333,0.333333333,2,0.666666667,  
1,1250,0,1.333333333,0,0.666666667,3,2.666666667,0,2,2,1;  
1,2276,0,1.666666667,0,0,1.666666667,1.333333333,0,1.666666667,1.333333333,0.333333333;  
0,2608.333333,0,1.333333333,0,0,0,1,0,0.666666667,0.666666667,1;  
0.333333333,2359,0,0.666666667,0,0,0.666666667,0.333333333,0.666666667,2,0.666666667,1;  
0.333333333,2574.666667,0,0,0,0,0.666666667,1.333333333,1.333333333,3.333333333,0,0;  
0.333333333,2293.333333,0,0,0,0,0,2.333333333,0.666666667,1.333333333,0.666666667,0;  
0.666666667,2223.333333,0,0.333333333,0,0.333333333,1,1.666666667,0,0.666666667,1,0;  
0.333333333,2075.666667,0,0.333333333,0,0.333333333,1,0.333333333,1.333333333,1.666666667,  
0,1906.333333,0,0.333333333,0,0,0.333333333,0.333333333,1.333333333,3.333333333,1,0;  
0,1846.666667,0,0.333333333,0,0,0.333333333,1,0.666666667,4,2,0;  
0,1519,0,0.666666667,0,0,0,1,0.666666667,2.333333333,2.333333333,0.333333333;  
0,801.6666667,0,0.666666667,0,0,0.666666667,0.333333333,0,1.666666667,0.666666667,0.333333333;  
0,5169.666667,0,0,0,0,0.666666667,0,0.333333333,3.666666667,0.666666667,0.333333333;  
0,7199.666667,0,0,0,0,0.333333333,0,0.333333333,5.666666667,0.333333333,0.333333333;  
0,2839.333333,0,0,0,0,5,0,1,4.666666667,0,0;  
0,1385,0,0,0,0,10,0.333333333,1,2.666666667,0,0;  
0,1340.333333,0,0,0,0,7.666666667,0.666666667,0,1.666666667,0,0;  
0,1232.666667,0,0,0,0,5,0.666666667,0,2,0,0;  
0,728.3333333,0,0,0.666666667,0,6,0.333333333,0,2.333333333,0,0;  
0,288.6666667,0,0,1.666666667,0,6.666666667,24.33333333,0,1,0,0;  
0,310.3333333,0,0,5.333333333,5.666666667,7,57.66666667,0,0.333333333,0,0.666666667;  
0,641.3333333,0,0,7.666666667,19.66666667,9.333333333,109.6666667,0,0.333333333,0,0.666666667,  
0,490.6666667,0,0,8.333333333,45,14,132.6666667,0,1.333333333,0,0;  
0,80,0,0,11,55.66666667,12.33333333,133.3333333,0,1.333333333,1.333333333,12;  
0,244,0,0.333333333,17.33333333,55.66666667,7.666666667,125,0,0.666666667,1.333333333,12;  
0,308.3333333,0.333333333,3.666666667,26,74.66666667,10,142.6666667,0,1.333333333,0,2;  
0,282,0.333333333,9.666666667,50,111,14.66666667,263,0.333333333,0.666666667,0.666666667,2;  
0,254,0,7,83,145,13,358.6666667,0.333333333,0,2.333333333,1;  
3.333333333,252,0.333333333,11,116,157.6666667,9,461.3333333,0.666666667,3,2.666666667,3.333333333,  
4,334.6666667,1.333333333,27.33333333,196.6666667,268.6666667,9.333333333,466.3333333,2,4.666666667,  
1.666666667,260,1,26.66666667,302.6666667,302.6666667,11,395,1.333333333,2,5.666666667,10;  
4,109.6666667,0,22,452.6666667,269.3333333,12.33333333,483.3333333,2.333333333,1.333333333

```

7.33333333,83.33333333,0,34.33333333,473.6666667,351,19,428.6666667,7,0.66666667,15.33333333,
5.33333333,92,2,95.33333333,392.3333333,452,22.33333333,300.6666667,4.66666667,2.33333333,2.
2.66666667,101.3333333,3,136,608.3333333,515.6666667,29.6666667,324,11,6.66666667,28.33333333,
2.66666667,77.6666667,1,105.6666667,770,675,33.6666667,317.6666667,14.33333333,7,35,61.6666667,
5.33333333,44.33333333,2.66666667,123.3333333,606.3333333,913,27.33333333,240.3333333,5.33333333,
9.33333333,30,5,125.6666667,446,1096.3333333,16.6666667,145.6666667,8,4,43.33333333,60.33333333,
10.33333333,21.33333333,5.66666667,139,492,924.6666667,26.33333333,66.33333333,10,3.33333333,
12.33333333,20.33333333,9.66666667,244,613,1096.6666667,42.6666667,92.33333333,10.66666667,9.33333333,
7,15,6.33333333,207,677.6666667,771,19.33333333,118.6666667,6.66666667,6,29,234.6666667;
24,8,32,589,788,1732.6666667,20.6666667,74.6666667,16,7.33333333,117.6666667,299.3333333;
40.6666667,15,55.33333333,835.6666667,884.6666667,2898.333333,44.6666667,72.33333333,29.6666667,
32.33333333,19.33333333,29.6666667,706.6666667,858,2362.333333,46,61,77,8.66666667,124.6666667,
42.33333333,18.6666667,17.33333333,895.6666667,754,2274.333333,22,50,109.3333333,10.33333333,1.33333333,
51.6666667,18.33333333,25.6666667,1154,743.6666667,2253,13,52.6666667,81.6666667,13.33333333,
63.6666667,23,19.6666667,1685,790,2577.6666667,16.6666667,59,74.6666667,23.33333333,393.3333333,
76.33333333,32.6666667,26.33333333,2021,746,3176.333333,15.33333333,81.6666667,75.6666667,20.33333333,
74.33333333,49.33333333,38,2507,761,3769.333333,24.6666667,79.6666667,80,24,487.6666667,3772.6666667,
130,49.6666667,41,2297.6666667,734.3333333,4181,27.6666667,78,94.33333333,29,815.3333333,3937.6666667,
252.6666667,61.6666667,58.6666667,1675,664.6666667,4039,46,103,92,23.33333333,622.6666667,472.6666667,
203.6666667,64.33333333,59,2281,813,3449.6666667,40.33333333,54,111.6666667,25.6666667,589.6666667,
165,52,55.33333333,2704.333333,1057.6666667,3346,30.6666667,25.33333333,106,34.33333333,826.3333333,
227.3333333,54.33333333,60,2755.6666667,1322.6666667,3486.333333,59.6666667,58.6666667,92.6666667,
255.3333333,63.6666667,55.33333333,3650.6666667,1531.6666667,3804.333333,64.6666667,68,135.6666667,
259.6666667,78.6666667,53.6666667,4516,1771.6666667,4037.333333,53.6666667,65,121.6666667,33.33333333,
276.6666667,72.33333333,69.6666667,4585.6666667,2000.6666667,3961,102,79,96.33333333,39.66666667,
280.3333333,75,66.33333333,3741.333333,1992.333333,3730.333333,132.6666667,83.6666667,103,37.33333333,

```

```
Rate_of_New_Cases = 68x12
```

```
104 ×
```

0	0	0	0	0	0	0	0 ...
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0.0254	0	0	0	0	0	0.0000
0.0001	0.0385	0	0	0	0	0.0001	0.0000
0.0002	0.0490	0	0.0000	0	0	0.0001	0.0001
0.0000	0.1145	0	0.0001	0	0	0.0001	0.0000
0.0000	0.1070	0.0000	0.0001	0	0	0.0001	0
0.0001	0.0877	0.0000	0	0	0	0.0001	0
0.0001	0.1238	0	0.0000	0	0.0001	0.0003	0.0002
:							
:							

## Index Total Confirmed Cases

The following table is the total confirmed cases since Jan 22, 2020. This is later used for modeling curve fit.

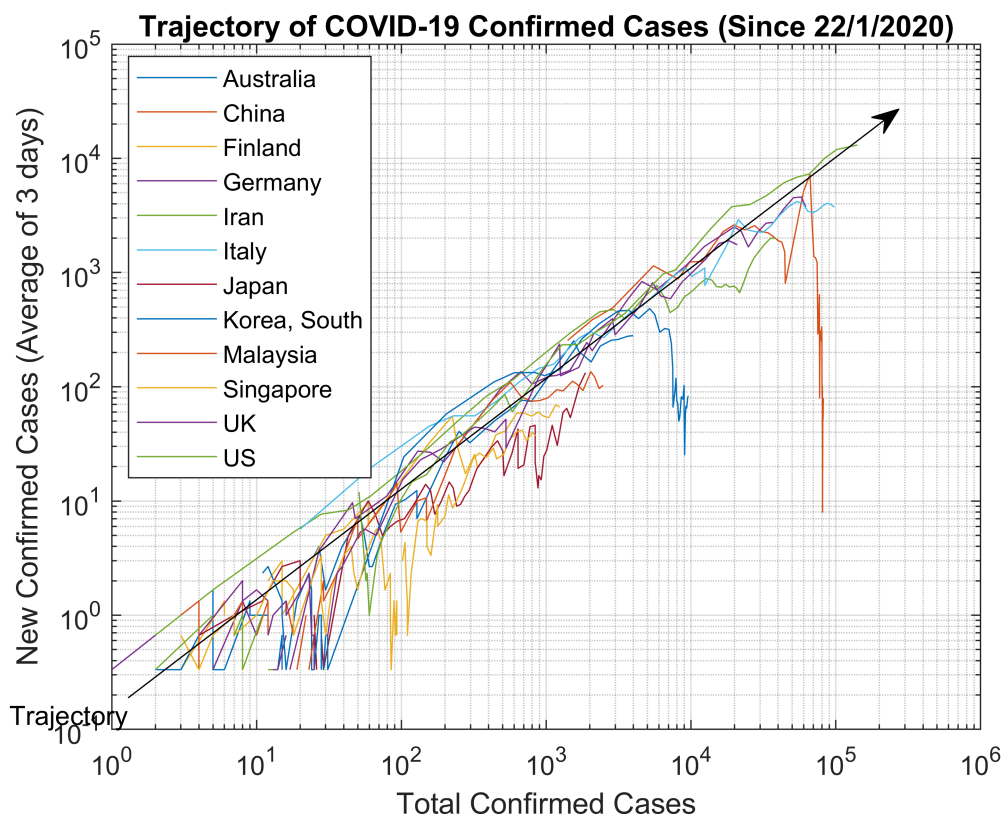
```
total_confirmed_cases=[555,656,943,1436,2120,2929,5580,6168,8236,9929,12044,16793,19889,23900,27900,31900,35900,39900,43900,47900,51900,55900,59900,63900,67900,71900,75900,79900,83900,87900,91900,95900,99900,103900,107900,111900,115900,119900,123900,127900,131900,135900,139900,143900,147900,151900,155900,159900,163900,167900,171900,175900,179900,183900,187900,191900,195900,199900,203900,207900,211900,215900,219900,223900,227900,231900,235900,23900,24300,24700,25100,25500,25900,26300,26700,27100,27500,27900,28300,28700,29100,29500,29900,30300,30700,31100,31500,31900,32300,32700,33100,33500,33900,34300,34700,35100,35500,35900,36300,36700,37100,37500,37900,38300,38700,39100,39500,39900,40300,40700,41100,41500,41900,42300,42700,43100,43500,43900,44300,44700,45100,45500,45900,46300,46700,47100,47500,47900,48300,48700,49100,49500,49900,50300,50700,51100,51500,51900,52300,52700,53100,53500,53900,54300,54700,55100,55500,55900,56300,56700,57100,57500,57900,58300,58700,59100,59500,59900,60300,60700,61100,61500,61900,62300,62700,63100,63500,63900,64300,64700,65100,65500,65900,66300,66700,67100,67500,67900,68300,68700,69100,69500,69900,70300,70700,71100,71500,71900,72300,72700,73100,73500,73900,74300,74700,75100,75500,75900,76300,76700,77100,77500,77900,78300,78700,79100,79500,79900,80300,80700,81100,81500,81900,82300,82700,83100,83500,83900,84300,84700,85100,85500,85900,86300,86700,87100,87500,87900,88300,88700,89100,89500,89900,90300,90700,91100,91500,91900,92300,92700,93100,93500,93900,94300,94700,95100,95500,95900,96300,96700,97100,97500,97900,98300,98700,99100,99500,99900,100300,100700,101100,101500,101900,102300,102700,103100,103500,103900,104300,104700,105100,105500,105900,106300,106700,107100,107500,107900,108300,108700,109100,109500,109900,110300,110700,111100,111500,111900,112300,112700,113100,113500,113900,114300,114700,115100,115500,115900,116300,116700,117100,117500,117900,118300,118700,119100,119500,119900,12044,12098,12152,12206,12260,12314,12368,12422,12476,12530,12584,12638,12692,12746,12800,12854,12908,12962,13016,13070,13124,13178,13232,13286,13340,13394,13448,13502,13556,13610,13664,13718,13772,13826,13880,13934,13988,14042,14096,14150,14204,14258,14312,14366,14420,14474,14528,14582,14636,14690,14744,14798,14852,14906,14960,15014,15068,15122,15176,15230,15284,15338,15392,15446,15500,15554,15608,15662,15716,15770,15824,15878,15932,15986,16040,16094,16148,16202,16256,16310,16364,16418,16472,16526,16580,16634,16688,16742,16796,16850,16904,16958,17012,17066,17120,17174,17228,17282,17336,17390,17444,17498,17552,17606,17660,17714,17768,17822,17876,17930,17984,18038,18092,18146,18199,18253,18307,18361,18415,18469,18523,18577,18631,18685,18739,18793,18847,18901,18955,19009,19063,19117,19171,19225,19279,19333,19387,19441,19495,19549,19603,19657,19711,19765,19819,19873,19927,19981,20035,20089,20143,20197,20251,20305,20359,20413,20467,20521,20575,20629,20683,20737,20791,20845,20899,20953,21007,21061,21115,21169,21223,21277,21331,21385,21439,21493,21547,21601,21655,21709,21763,21817,21871,21925,21979,22033,22087,22141,22195,22249,22303,22357,22411,22465,22519,22573,22627,22681,22735,22789,22843,22897,22951,23005,23059,23113,23167,23221,23275,23329,23383,23437,23491,23545,23599,23653,23707,23761,23815,23869,23923,23977,24031,24085,24139,24193,24247,24301,24355,24409,24463,24517,24571,24625,24679,24733,24787,24841,24895,24949,25003,25057,25111,25165,25219,25273,25327,25381,25435,25489,25543,25597,25651,25705,25759,25813,25867,25921,25975,26029,26083,26137,26191,26245,26299,26353,26407,26461,26515,26569,26623,26677,26731,26785,26839,26893,26947,27001,27055,27109,27163,27217,27271,27325,27379,27433,27487,27541,27595,27649,27703,27757,27811,27865,27919,27973,28027,28081,28135,28189,28243,28297,28351,28405,28459,28513,28567,28621,28675,28729,28783,28837,28891,28945,28999,29053,29107,29161,29215,29269,29323,29377,29431,29485,29539,29593,29647,29701,29755,29809,29863,29917,29971,30025,30079,30133,30187,30241,30295,30349,30403,30457,30511,30565,30619,30673,30727,30781,30835,30889,30943,30997,31051,31105,31159,31213,31267,31321,31375,31429,31483,31537,31591,31645,31699,31753,31807,31861,31915,31969,32023,32077,32131,32185,32239,32293,32347,32401,32455,32509,32563,32617,32671,32725,32779,32833,32887,32941,32995,33049,33103,33157,33211,33265,33319,33373,33427,33481,33535,33589,33643,33697,33751,33805,33859,33913,33967,34021,34075,34129,34183,34237,34291,34345,34399,34453,34507,34561,34615,34669,34723,34777,34831,34885,34939,34993,35047,35101,35155,35209,35263,35317,35371,35425,35479,35533,35587,35641,35695,35749,35803,35857,35911,35965,36019,36073,36127,36181,36235,36289,36343,36397,36451,36505,36559,36613,36667,36721,36775,36829,36883,36937,36991,37045,37099,37153,37207,37261,37315,37369,37423,37477,37531,37585,37639,37693,37747,37801,37855,37909,37963,38017,38071,38125,38179,38233,38287,38341,38395,38449,38503,38557,38611,38665,38719,38773,38827,38881,38935,38989,39043,39097,39151,39205,39259,39313,39367,39421,39475,39529,39583,39637,39691,39745,39799,39853,39907,39961,40015,40069,40123,40177,40231,40285,40339,40393,40447,40501,40555,40609,40663,40717,40771,40825,40879,40933,40987,41041,41095,41149,41203,41257,41311,41365,41419,41473,41527,41581,41635,41689,41743,41797,41851,41905,41959,42013,42067,42121,42175,42229,42283,42337,42391,42445,42499,42553,42607,42661,42715,42769,42823,42877,42931,42985,43039,43093,43147,43201,43255,43309,43363,43417,43471,43525,43579,43633,43687,43741,43795,43849,43903,43957,44011,44065,44119,44173,44227,44281,44335,44389,44443,44497,44551,44605,44659,44713,44767,44821,44875,44929,44983,45037,45091,45145,45199,45253,45307,45361,45415,45469,45523,45577,45631,45685,45739,45793,45847,45901,45955,46009,46063,46117,46171,46225,46279,46333,46387,46441,46495,46549,46603,46657,46711,46765,46819,46873,46927,46981,47035,47089,47143,47197,47251,47305,47359,47413,47467,47521,47575,47629,47683,47737,47791,47845,47899,47953,48007,48061,48115,48169,48223,48277,48331,48385,48439,48493,48547,48601,48655,48709,48763,48817,48871,48925,48979,49033,49087,49141,49195,49249,49303,49357,49411,49465,49519,49573,49627,49681,49735,49789,49843,49897,49951,50005,50059,50113,50167,50221,50275,50329,50383,50437,50491,50545,50599,50653,50707,50761,50815,50869,50923,50977,51031,51085,51139,51193,51247,51301,51355,51409,51463,51517,51571,51625,51679,51733,51787,51841,51895,51949,52003,52057,52111,52165,52219,52273,52327,52381,52435,52489,52543,52597,52651,52705,52759,52813,52867,52921,52975,53029,53083,53137,53191,53245,53299,53353,53407,53461,53515,53569,53623,53677,53731,53785,53839,53893,53947,54001,54055,54109,54163,54217,54271,54325,54379,54433,54487,54541,54595,54649,54703,54757,54811,54865,54919,54973,55027,55081,55135,55189,55243,55297,55351,55405,55459,55513,55567,55621,55675,55729,55783,55837,55891,55945,56000,56054,56108,56162,56216,56270,56324,56378,56432,56486,56540,56594,56648,56702,56756,56810,56864,56918,56972,57026,57080,57134,57188,57242,57296,57350,57404,57458,57512,57566,57620,57674,57728,57782,57836,57890,57944,57998,58052,58106,58160,58214,58268,58322,58376,58430,58484,58538,58592,58646,58700,58754,58808,58862,58916,58970,59024,59078,59132,59186,59240,59294,59348,59402,59456,59510,59564,59618,59672,59726,59780,59834,59888,59942,60000,60054,60108,60162,60216,60270,60324,60378,60432,60486,60540,60594,60648,60702,60756,60810,60864,60918,60972,61026,61080,61134,61188,61242,61296,61350,61404,61458,61512,61566,61620,61674,61728,61782,61836,61890,61944,62000,62054,62108,62162,62216,62270,62324,62378,62432,62486,62540,62594,62648,62702,62756,62810,62864,62918,62972,63026,63080,63134,63188,63242,63296,63350,63404,63458,63512,63566,63620,63674,63728,63782,63836,63890,63944,64000,64054,64108,64162,64216,64270,64324,64378,64432,64486,64540,64594,64648,64702,64756,64810,64864,64918,64972,65026,65080,65134,65188,65242,65296,65350,65404,65458,65512,65566,65620,65674,65728,65782,65836,65890,65944,66000,66054,66108,66162,66216,66270,66324,66378,66432,66486,66540,66594,66648,66702,66756,66810,66864,66918,66972,67026,67080,67134,67188,67242,67296,67350,67404,67458,67512,67566,67620,67674,67728,67782,67836,67890,67944,68000,68054,68108,68162,68216,68270,68324,68378,68432,68486,68540,68594,68648,68702,68756,68810,68864,68918,68972,69026,69080,69134,69188,69242,69296,69350,69404,69458,69512,69566,69620,69674,69728,69782,69836,69890,69944,70000,70054,70108,70162,70216,70270,70324,70378,70432,70486,70540,70594,70648,70702,70756,70810,70864,70918,70972,71026,71080,71134,71188,71242,71296,71350,71404,71458,71512,71566,71620,71674,71728,71782,71836,71890,71944,72000,72054,72108,72162,72216,72270,72324,72378,72432,72486,72540,72594,72648,72702,72756,72810,72864,72918,72972,73026,73080,73134,73188,73242,73296,73350,73404,73458,73512,
```

## Plotting loglog Trajectory of The Selected Countries

```
loglog (Confirmed_cases,Rate_of_New_Cases)
legend({'Australia','China','Finland','Germany','Iran','Italy','Japan','Korea, South','Malaysia',
set(legend,...
    'Position',[0.144982988922427 0.409297035888904 0.216581636927913 0.501360560482978]));
% Create ylabel
ylabel({'New Confirmed Cases (Average of 3 days)'});

% Create xlabel
xlabel({'Total Confirmed Cases'});

% Create title
title({'Trajectory of COVID-19 Confirmed Cases (Since 22/1/2020)'});
grid on
annotation('textarrow',[0.1446 0.8321],[0.1476 0.8476],'String','Trajectory')
```



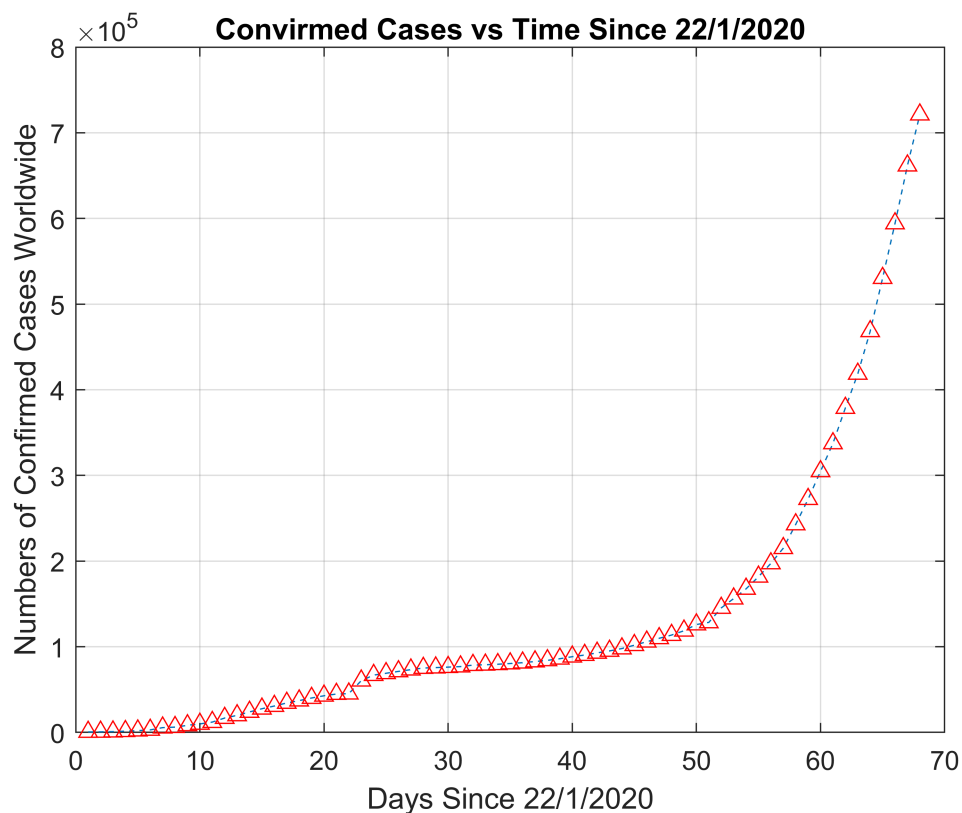
In epidemiology and ecology, nothing in nature can sustain a perfect exponential growth. Population growth is often limited by a maximum capacity where lack of resources will limit the exponential growth and it eventually flatten out. In the case of COVID-19, the limiting factors that prevents it from growing forever are complex. Total available population for infection, healthcare system intervention, social distancing, wearing personal protective equipment that lowers  $R_0$  values are all significant impacts to the virus to follow a perfect natural growth trend. A more realistic mathematic model would be a sigmoid function, log function or many other functions that are better suited for population monitoring. However, it is very difficult to identify the future trend of growth amid the middle. Simply searching for derivatives is not enough in modeling disease like this. The following graph plots the New Confirmed Cases (5 days average) with total confirmed cases to

see the position of growth each country is in where time is implied. The closer a country's curve follows the black arrow, the closer to perfect exponential growth the country is. Any dropping off/deviation from the black arrow represents significant success in disease control, limiting perfect exponential growth. Note that this is a LogLog plot.

### Plot of Total Confirmed Cases Since 22/1/2020

```
plot (total_confirmed_cases,'MarkerEdgeColor',[1 0 0],'Marker','^','LineStyle','--',...
      'Color',[0 0.447058826684952 0.74117648601532])
title('Confirmed Cases vs Time Since 22/1/2020')
xlabel('Days Since 22/1/2020')
ylabel('Numbers of Confirmed Cases Worldwide')

grid on
```



This is a standard Global Confirmed Cases VS Time plot. One can see that it is quite difficult to identify the future projection of the graph. Perhaps it is our silly sapien minds unable to understand the natural language of life and math. However, a simple curve fit could predict confirmed cases growth in the near future relatively accurately.

### Plot of Total Confirmed Cases Since 22/1/2020 Curve Fit

```
% Fit: 'Confirmed Cases of COVID-19 Since 22/1/2020 Fit'.
[xData, yData] = prepareCurveData( [], total_confirmed_cases );

% Set up fitype and options.
ft = fitype( 'exp1' );
```

```

excludedPoints = excludeddata( xData, yData, 'Indices', [16 17 18 19 20 21 22 23 24 25 26 27 28
opts = fitoptions( 'Method', 'NonlinearLeastSquares' );
opts.Display = 'Off';
opts.StartPoint = [8394.59673873853 0.0601158198762684];
opts.Exclude = excludedPoints;

% Fit model to data.
[fitresult, gof] = fit( xData, yData, ft, opts );

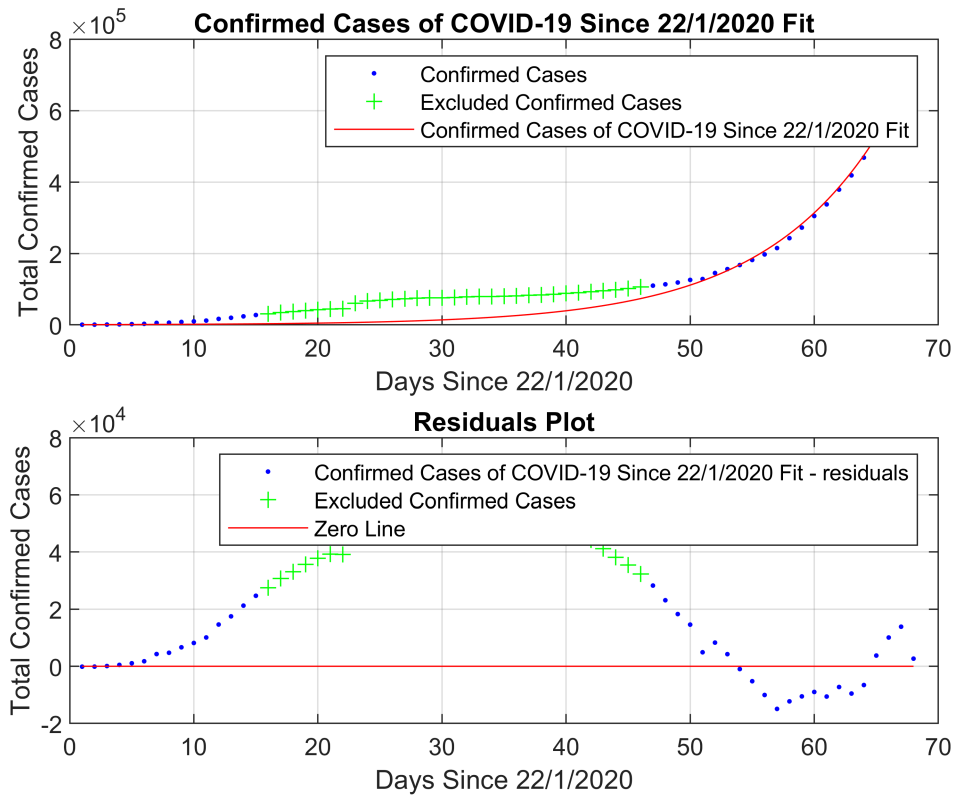
% Create a figure for the plots.
figure( 'Name', 'Confirmed Cases of COVID-19 Since 22/1/2020 Fit' );

% Plot fit with data.
subplot( 2, 1, 1 );
h = plot( fitresult, xData, yData, excludedPoints );
legend( h, 'total_confirmed_cases', 'Excluded total_confirmed_cases', 'Confirmed Cases of COVID-19 Since 22/1/2020 Fit' );
% Label axes
ylabel total_confirmed_cases
grid on

% Plot residuals.
subplot( 2, 1, 2 );
h = plot( fitresult, xData, yData, excludedPoints, 'residuals' );
legend( h, 'Confirmed Cases of COVID-19 Since 22/1/2020 Fit - residuals', 'Excluded total_confirmed_cases' );
% Label axes
ylabel total_confirmed_cases
grid on

subplot(2,1,1)
legend({'Confirmed Cases','Excluded Confirmed Cases','Confirmed Cases of COVID-19 Since 22/1/2020 Fit'})
title('Confirmed Cases of COVID-19 Since 22/1/2020 Fit')
xlabel('Days Since 22/1/2020')
ylabel('Total Confirmed Cases')
subplot(2,1,2)
legend({'Confirmed Cases of COVID-19 Since 22/1/2020 Fit - residuals','Excluded Confirmed Cases'})
title('Residuals Plot')
xlabel('Days Since 22/1/2020')
ylabel('Total Confirmed Cases')

```



Before using the curve fit data to extrapolate information, please note that this plot makes many assumptions, disregards possibility of the growth ever decreasing, trusts the data provided is 100% accurate and gathers all the cases (so unlikely it is impossible), and most importantly ignores any possible future efforts that could be done via governments to slow down infection. Please use this graph and its curve fit results with a grain of salt and in conjunction with the first plot. Green datapoints are excluded for a better fit (yeah yeah i know messing with data to fit my function -\_-). The residual plot shows how much do the data points deviate from the curve fit function.

### Fit model to data.

```
[fitresult, gof] = fit( xData, yData, ft, opts )
```

```
fitresult =
  General model Exp1:
  fitresult(x) = a*exp(b*x)
  Coefficients (with 95% confidence bounds):
    a =      627.4  (486.9, 768)
    b =      0.1036  (0.1001, 0.1071)
  gof = struct with fields:
    sse: 5.1316e+09
    rsquare: 0.9966
    dfe: 35
    adjrsquare: 0.9965
    rmse: 1.2109e+04
```

```
format short
```



Here is your function in the form of  $a \cdot e^{b \cdot x}$ , enjoy! Stay safe!