

COVID-19 Confirmed Cases and Cumulative Mortality Predictions

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Summary of the situation:

- Europe reached 928K confirmed cases today with a 3.2% growth rate, compared with 3.7% yesterday. The outbreak progress increases to 65% from 61.4% yesterday in medium scenario. For the mathematically minded, the slow decay of the after-peak trajectory can be seen from the small estimated parameter a ($=0.19$) in the generalized Richards mode. The number of daily deaths is also entering an after peak trajectory, projecting a total death number of 118K in the end in the medium scenario. It is also important to understand that confirmed infections undershoot actual infections by a very large margin. Figure 1 allows us to suggest that distributions of final confirmed numbers in all rich cool north² countries are converging, while hot north² and S hemisphere² countries are not. However, the distributions of final deaths have not converged in most countries, which can be explained by the fact that confirmed cases are a leading indicator while deaths are a lagging indicator.

- The US records 25K confirmed cases today, with a 4.5% growth rate, compared with 5.2% yesterday. The epidemic in the USA seems to be maturing and reaching an inflection point¹, although the uncertainty is still large given that the trajectory has not yet completely departed from the generalized exponential model. Readers can refer to Supplements to COVID-19 Confirmed Cases Prediction (April 7th, 2020)² for our analysis on the US test numbers and the confirmed case numbers.

- Spain, Switzerland, Austria, Italy, Germany and France are the countries with most mature outbreaks with strong signs that inflection points have been passed. The mortality numbers in these countries also supports an after-peak trajectory, although mortality data from Switzerland is a bit variable. It appears that France may also join this group soon.

- The UK, Belgium, Portugal and Netherlands have not entered an after-peak trajectory and may continue to follow the generalized exponential model, resulting in high uncertainties. All of these four countries have their distributions of final confirmed cases converged today, while regarding the distribution of final deaths, only Netherlands has converged.

- Russia, Brazil, Sweden, Turkey and Japan continue their previous exponential growth, indicating highly uncertain future projections as well, as shown by their non-converged ensemble distributions of final confirmed cases (Figure 1). The transmission in Japan seems to accelerate as do reported deaths, but the death rate figures in Japan are very low and fluctuating from day to day. Unraveling the "epidemic" in Japan remains a work in progress. In terms of per capita deaths, Brazil, Turkey and Japan do not yet have large scale epidemics compared to West European countries.

-The irregular dips and spikes in the data most likely reflect data aggregation and reporting delays where numbers not included one day are included in the following day.

¹On a logistic curve, the inflection point indicates where the curvature changes its sign. As we model the total number of confirmed cases, it is equal to the peak of the daily increase curve, after which the daily number of cases is decreasing. If the inflection point has been passed, the worst of the outbreak is over.

²https://ethz.ch/content/dam/ethz/special-interest/mtec/chair-of-entrepreneurial-risks-dam/documents/Covid-19/Covid_Supplements_7April2020.pdf

Method:

This report updates predictions for the number of COVID-19 confirmed cases and deaths at four time horizons (1-day, 5-day, 10-day and end of the outbreak) and for various countries/regions, based on a phenomenological approach detailed in [1]. We employ 4 versions of the generalized logistic growth equation to model the total number of confirmed cases and deaths, resulting in a positive, medium and negative scenario for the final expected number of cases/deaths as explained in the last page. Note that, for countries/regions at early growth stages, the predictions for long-term horizon (10-day and end of the outbreak) are highly uncertain and will vary a lot as the situation changes. The predicted ranges overlap and, as time passes, we anticipate our methodology to zero in on more reliable numbers. As mortality data, also from ECDC, is much noisier in many countries than the infection numbers, we use 3 days moving average for the fitting and simulations. The data is neither normalized by population nor time-shifted for the calibrations.

Data source: European Centre for Disease Prevention and Control (ECDC) [2] updated every day at 1pm CET, reflecting data collected up to 6:00 and 10:00 CET. Thus the daily data in some countries is one day delayed compared to other online live sources.

Key Figures & Tables:

-In Table 1, we report the latest confirmed cases per million population and the estimated outbreak progress in the positive and medium scenario (today's confirmed cases divided by the estimated total final confirmed case in positive and now additionally in medium scenarios).

-In Table 2 and Table 3, we report the prediction results of confirmed cases (Table 2) and deaths (Table 3) in each selected country/region at four time horizons (1-day, 5-day, 10-day and end of the outbreak) in three scenarios. The detailed fitting results for each country/region are plotted in the figures at the end of this report.













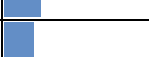
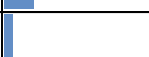

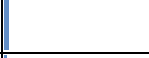
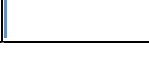


-In Figure 1, we present a distribution of the estimated final total confirmed cases and deaths per million population based on the positive and medium scenario.

-In Figure 2, we show the 1-day prediction error of yesterday's report.

Comment: We need to emphasize that reported confirmed cases are a leading indicator that is subject to a large number of extraneous variables such as sampling rate³, sample targeting and reliability of testing. See note at end of this report. The real number of cases in the population is likely to be many multiples higher than those computed from confirmed tests. **We strongly recommend that national governments should publish the number of daily tests and implement random testing (polling) in the population, to facilitate all modeling work and therefore better understanding of the epidemic to help guide appropriate policy responses.**

³ For instance, The UK is experiencing issues with raising the testing rate linked to a global shortage of certain key reagents and swabs. From since April 1st, all testing is to be targeted at health sector staff and this will obviously bias future data compared with past data.

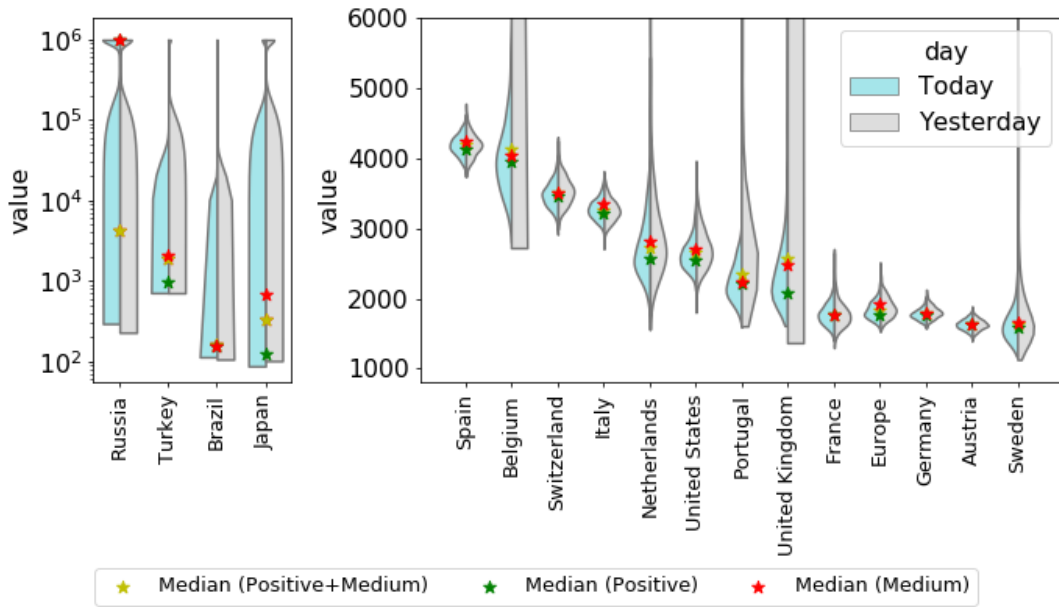
Table 1. Current confirmed cases per million population and estimated outbreak progress in positive and medium scenarios (today's confirmed cases divided by the estimated total final confirmed cases in positive and medium scenario). Numbers in brackets are 80% confidence intervals. As positive scenarios predict a smaller final number of total infected cases, the outbreak progress is thus larger in the positive scenario. Note that the estimated final confirmed numbers tend to underestimate the final results, thus the estimated outbreak progress serves both as a lower bound for future developments and as a guide of the dynamics of the evolution of the epidemics⁴. The number of tests per million population and confirmed cases per test⁵ are presented in the last two columns based on the information from Wikipedia [3].

	Confirmed per Million Population (Apr-14)	Outbreak Progress in Positive Scenario	Outbreak Progress in Medium Scenario	Tests per Million Population (update date in brackets)	Confirmed Cases per Test (update date in brackets)
Spain	 3628	87.7% (83.7%, 91.7%)	85.4% (81.6%, 89.4%)	12839 (Apr 14)	28.2% (Apr 14)
Switzerland	 2994	86.5% (80.9%, 92.5%)	85.4% (79.5%, 91.0%)	22613 (Apr 12)	12.8% (Apr 12)
Belgium	 2678	67.7% (57.4%, 76.8%)	66.1% (51.5%, 80.4%)	9779 (Apr 13)	26.3% (Apr 13)
Italy	 2640	81.9% (78.0%, 85.9%)	79.0% (74.9%, 83.6%)	17357 (Apr 13)	14.9% (Apr 13)
United States	 1781	69.6% (64.2%, 75.2%)	66.0% (58.1%, 73.7%)	9083 (Apr 13)	18.7% (Apr 13)
Portugal	 1647	74.1% (59.6%, 87.2%)	73.9% (62.5%, 83.1%)	15921 (Apr 13)	10.1% (Apr 13)
Austria	 1587	97.5% (91.1%, 104.1%)	97.0% (91.6%, 102.6%)	17051 (Apr 14)	9.3% (Apr 14)
Netherlands	 1541	59.9% (50.4%, 67.3%)	54.5% (43.9%, 69.7%)	7383 (Apr 13)	19.9% (Apr 13)
Germany	 1509	85.7% (81.0%, 89.8%)	84.4% (79.4%, 89.2%)	15850 (Apr 08)	7.8% (Apr 08)
France	 1464	82.5% (72.5%, 92.7%)	82.5% (74.2%, 90.6%)	4981 (Apr 07)	22.3% (Apr 07)
United Kingdom	 1333	64.4% (52.4%, 72.7%)	53.9% (40.4%, 65.1%)	4480 (Apr 14)	29.3% (Apr 14)
Europe	 1243	70.3% (65.5%, 74.3%)	65.0% (60.3%, 70.9%)	NA	NA
Sweden	 1075	67.7% (56.4%, 77.0%)	64.8% (46.9%, 77.2%)	6383 (Apr 07)	13.2% (Apr 07)
Iran	 896	Not reliable	Not reliable	3311 (Apr 13)	26.0% (Apr 13)
Turkey	 742	77.0% (68.0%, 87.0%)	36.0% (16.2%, 50.3%)	4937 (Apr 13)	13.9% (Apr 13)
South Korea	 205	Not reliable	Not reliable	10200 (Apr 14)	2.0% (Apr 14)
Russia	 127	Not reliable	Not reliable	9718 (Apr 14)	1.3% (Apr 14)
Brazil	 112	71.4% (55.6%, 80.3%)	70.7% (57.1%, 82.0%)	261 (Apr 02)	12.5% (Apr 02)
Japan	 60	48.1% (30.3%, 57.8%)	9.0% (0.0%, 24.8%)	710 (Apr 14)	8.5% (Apr 14)

⁴One uncertainty with Italy (and other countries) is whether the main outbreak that is focused on the North may spread through other parts of the country. In other words, does the dynamics aggregated over a whole country represent correctly the dynamics in different parts?

⁵Note that the UK has the highest confirmed case per test, which can probably be explained by the fact that only healthcare workers are tested.

Ensemble Distribution of Final Confirmed Cases per Million Population



Ensemble Distribution of Final Deaths per Million Population

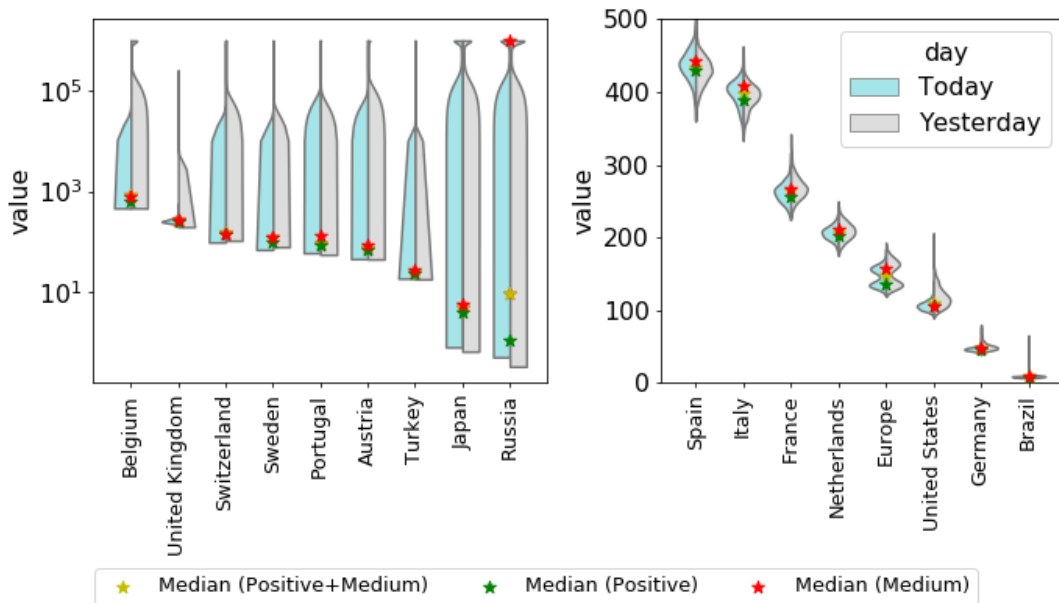


Figure 1. Violin plot of the distributions of the final total number of confirmed cases (upper panel) and deaths (lower panel) per million derived by combining the distributions of the positive and medium scenarios. The left side of each violin in cyan is today's distribution, while the right side of each violin in grey is yesterday's distribution. The model setup in the negative scenario does not incorporate a maximum saturation number and thus cannot be used. The yellow star indicates the median prediction for the combined distribution, while the green and red stars indicate the median of the positive and of the medium scenarios respectively. Note that, where we have >1 million infections/deaths per 1 million of population, the results are deemed to be unreliable (Table 2 & 3).

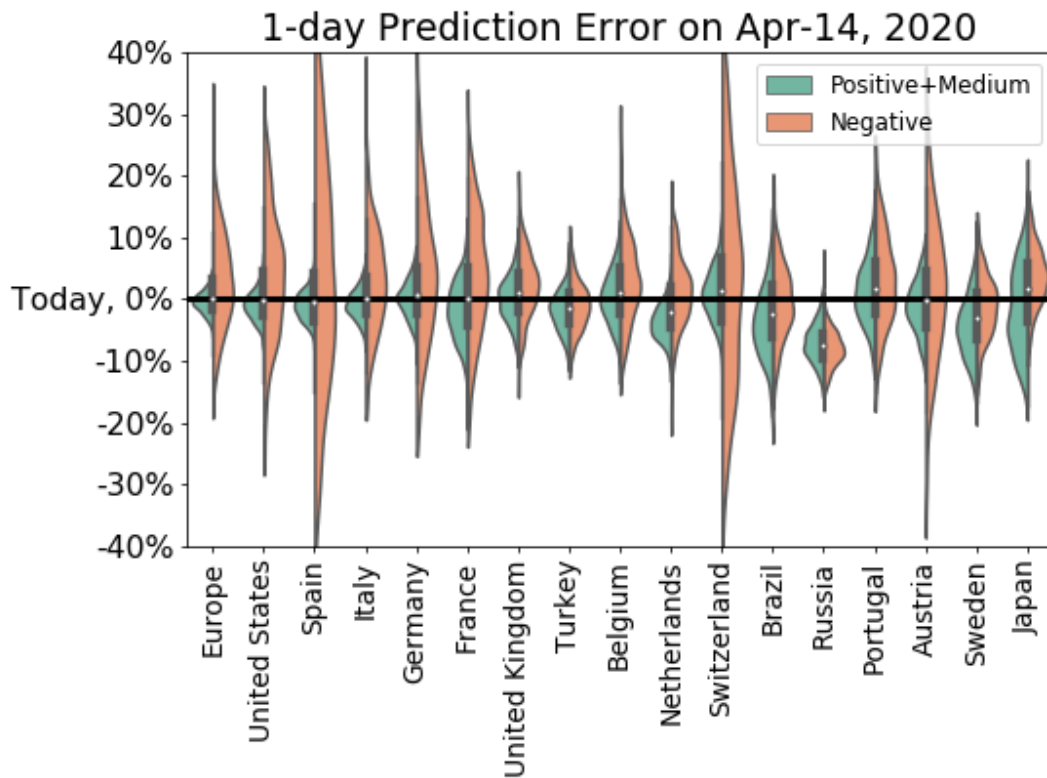


Figure 2. One-day prediction error of the forecast performed yesterday (April 13) for the total number of confirmed case for the 13 countries/regions. The horizontal line corresponds to today's empirical data. We show the full distribution of errors for each of the two scenarios.

Table 2. Predictions for the number of confirmed cases at four time horizons (1-day, 5-day, 10-day and end of the outbreak) and for various countries/regions. The values in parentheses are 80% prediction intervals based on 500 simulations using a negative binomial error structure. In Today's validation column, today's empirical data is presented below yesterday's 1-day predictive interval. "Not reliable" is declared if more than 10% of the simulations produce extreme numbers (larger than total population). All numbers are in thousands.

Country	Scenario*	Today's validation	15-Apr	19-Apr	24-Apr	Final Total Confirmed
Europe	Positive	(901, 949) 928	953 (929, 976)	1060 (1030, 1090)	1150 (1110, 1190)	1320 (1250, 1420)
	Medium	(901, 941) 928	947 (928, 971)	1060 (1030, 1090)	1160 (1130, 1200)	1430 (1310, 1540)
	Negative	(866, 1050) 928	985 (894, 1090)	1180 (1070, 1300)	1450 (1300, 1620)	Not Reliable
United States	Positive	(557, 601) 583	602 (581, 625)	687 (660, 715)	756 (717, 797)	837 (775, 907)
	Medium	(560, 592) 583	600 (583, 617)	689 (664, 712)	766 (727, 809)	883 (791, 1000)
	Negative	(529, 686) 583	627 (541, 721)	803 (686, 920)	1050 (890, 1240)	Not Reliable
Spain	Positive	(163, 175) 169	172 (166, 178)	181 (174, 188)	188 (180, 195)	193 (185, 203)
	Medium	(163, 172) 169	171 (165, 176)	181 (175, 187)	189 (182, 195)	198 (190, 208)
	Negative	(136, 222) 169	177 (135, 224)	213 (160, 266)	258 (192, 329)	Not Reliable

Italy	Positive	(153, 165) 160	162 (157, 167)	171 (166, 177)	179 (173, 186)	195 (186, 204)
	Medium	(153, 162) 160	161 (156, 165)	171 (166, 175)	180 (175, 186)	202 (191, 213)
	Negative	(147, 181) 160	166 (150, 185)	189 (171, 211)	219 (197, 248)	Not Reliable
Germany	Positive	(120, 131) 125	127 (122, 132)	135 (129, 140)	140 (134, 147)	146 (139, 154)
	Medium	(120, 130) 125	126 (122, 131)	135 (130, 140)	141 (135, 147)	148 (140, 158)
	Negative	(112, 151) 125	133 (113, 155)	157 (133, 181)	190 (160, 221)	Not Reliable
France	Positive	(90.2, 102) 98.1	98.8 (92.4, 105)	106 (99.4, 113)	112 (103, 121)	119 (106, 135)
	Medium	(90.3, 103) 98.1	99.2 (92.8, 106)	107 (99.4, 114)	113 (104, 122)	119 (108, 132)
	Negative	(88.8, 115) 98.1	105 (90.5, 118)	124 (107, 141)	151 (129, 175)	Not Reliable
United Kingdom	Positive	(84.2, 93.4) 88.6	91.5 (86.6, 96.4)	109 (102, 117)	123 (113, 138)	138 (122, 169)
	Medium	(84.5, 92.5) 88.6	92.4 (87.4, 96.5)	112 (105, 119)	132 (120, 146)	164 (136, 219)
	Negative	(84.2, 96.8) 88.6	95.8 (88, 103)	126 (116, 138)	174 (157, 193)	Not Reliable
Turkey	Positive	(56.9, 62.5) 61	57.8 (54.3, 61.9)	69.5 (63.7, 74.9)	76.1 (68.4, 84.4)	79.3 (70.2, 89.7)
	Medium	(57.3, 62.3) 61	63.6 (60.9, 66.4)	82.9 (77.7, 88.5)	105 (93.8, 119)	169 (121, 376)
	Negative	(57.3, 63.6) 61	65.1 (61.3, 69.1)	89.2 (83.5, 95.6)	126 (116, 138)	Not Reliable
Belgium	Positive	(29, 32.6) 30.6	31.5 (29.9, 33.1)	35.6 (33.6, 37.7)	39.2 (36.5, 42.5)	45.2 (39.8, 53.3)
	Medium	(29, 32.3) 30.6	31.4 (29.8, 33.1)	35.4 (33.5, 37.7)	39.2 (35.9, 42.8)	46.3 (38.1, 59.4)
	Negative	(28.7, 34) 30.6	32.5 (29.4, 35.3)	39.8 (36.2, 43.9)	50.3 (45.3, 56.2)	Not Reliable
Netherlands	Positive	(26, 28.1) 26.6	27.8 (26.8, 28.8)	31.5 (30.2, 32.8)	35.2 (33.4, 37.4)	44.3 (39.5, 52.7)
	Medium	(25.5, 27.2) 26.6	27.1 (26.2, 28.1)	30.9 (29.6, 32.2)	34.9 (32.6, 37.1)	48.7 (38.1, 60.5)
	Negative	(26.4, 30.5) 26.6	29.4 (27.1, 31.6)	35.4 (32.6, 38.3)	43.9 (39.9, 48.1)	Not Reliable
Switzerland	Positive	(24.7, 27.7) 25.5	26.5 (25, 27.9)	27.6 (26.1, 29.2)	28.5 (26.9, 30.2)	29.5 (27.6, 31.5)
	Medium	(24.8, 27.5) 25.5	26.4 (25.1, 27.8)	27.6 (26.2, 29.1)	28.5 (27.1, 30.2)	29.9 (28, 32.1)
	Negative	(21.3, 33.7) 25.5	27.2 (21.3, 32.9)	31.1 (24.7, 38.2)	36.6 (28.6, 47)	Not Reliable
Brazil	Positive	(20.9, 24.2) 23.4	23.6 (21.7, 25.4)	27.8 (25.5, 30.7)	30.7 (27.9, 35.4)	32.8 (29.2, 42.2)
	Medium	(20.9, 24.5) 23.4	23.7 (21.9, 25.7)	28 (25.5, 30.8)	30.9 (27.5, 35.5)	33.1 (28.6, 41.1)
	Negative	(21.5, 25.3) 23.4	24.7 (22.6, 26.9)	32.7 (29.8, 35.8)	44.5 (39.9, 50.2)	Not Reliable
Russia	Positive	(16.4, 18.1) 18.3	19.5 (18.8, 20.2)	33.4 (30.4, 36.1)	61.5 (44.4, 73.5)	Not Reliable

	Medium	(16.2, 17.4) 18.3	20.1 (19.2, 21)	35.1 (31.8, 37.4)	69.8 (49.2, 79.5)	Not Reliable
	Negative	(16.2, 17.5) 18.3	19.5 (18.8, 20.2)	34.1 (32.4, 36)	65.3 (59.2, 73.1)	Not Reliable
Portugal	Positive	(16, 18.2) 16.9	17.4 (16.3, 18.5)	19.2 (17.8, 20.6)	20.7 (18.7, 22.9)	22.9 (19.4, 28.4)
	Medium	(16.1, 18.5) 16.9	17.4 (16.3, 18.5)	19.3 (17.9, 20.6)	20.8 (19.1, 22.7)	22.9 (20.4, 27.1)
	Negative	(15.8, 19.2) 16.9	17.8 (15.6, 19.9)	21.6 (18.9, 24.2)	26.6 (23.3, 30.1)	Not Reliable
Austria	Positive	(13, 14.7) 14	14.1 (13.3, 15.1)	14.3 (13.4, 15.3)	14.4 (13.4, 15.3)	14.4 (13.5, 15.4)
	Medium	(13.1, 14.7) 14	14 (13.3, 14.8)	14.3 (13.5, 15)	14.4 (13.6, 15.2)	14.5 (13.7, 15.3)
	Negative	(12.1, 16.4) 14	14 (12, 16.6)	16 (13.6, 18.9)	18.6 (15.7, 22.1)	Not Reliable
Sweden	Positive	(9.9, 11.3) 10.9	11.1 (10.4, 11.8)	12.7 (11.9, 13.7)	14.2 (13, 15.6)	16.2 (14.2, 19.4)
	Medium	(9.6, 10.9) 10.9	10.7 (10, 11.3)	12.4 (11.5, 13.3)	14 (12.7, 15.6)	16.9 (14.2, 23.4)
	Negative	(10.1, 11.6) 10.9	11.3 (10.5, 12.1)	13.9 (12.9, 14.9)	17.5 (16.3, 19.1)	Not Reliable
Japan	Positive	(6.68, 7.52) 7.64	7.5 (7.07, 7.96)	9.87 (9.13, 10.7)	12.3 (11, 14.7)	15.9 (13.2, 25.3)
	Medium	(7.47, 8.41) 7.64	8.24 (7.74, 8.77)	11.3 (10.4, 12.2)	16.4 (14.2, 18.7)	Not Reliable
	Negative	(7.46, 8.43) 7.64	8.12 (7.62, 8.65)	11.4 (10.6, 12.2)	17.5 (15.9, 19.3)	Not Reliable
Iran	Positive	(68.7, 74.8) 73.3	73.1 (69.9, 76.4)	75.7 (72.6, 79.7)	77.3 (73.6, 82)	Not Reliable
	Medium	(64, 72.4) 73.3	69.6 (65.6, 73.5)	75.4 (70.6, 80)	80.5 (74.5, 86.2)	Not Reliable
	Negative	(70.3, 83.8) 73.3	78.3 (71.2, 85.9)	89.7 (80.7, 97.9)	105 (94.3, 115)	Not Reliable

Table 3. Predictions for the number of total deaths at four time horizons (1-day, 5-day, 10-day and end of the outbreak) and for various countries/regions, based on the Generalised Richards model [1]. The values in parentheses are 80% prediction intervals based on 500 simulations using a negative binomial error structure. “Not reliable” is declared if more than 10% of the simulations produce extreme numbers (larger than total population). All numbers are in thousands. Note that it is emerging that there can be a large variation in reporting standard between countries. In the UK, it is made clear that reported deaths are for hospital deaths only and do not include deaths in the community. Similarly, data for Belgium is allegedly being revised to account for community deaths.

Country	Scenario*	Today's validation	15-Apr	19-Apr	24-Apr	Final Total Confirmed
Europe	Positive	(72.4, 76.1) 80.6	77.4 (75.4, 79.5)	87.4 (84.9, 90.2)	94.6 (91.5, 98.4)	101 (96.7, 106)
	Medium	(75, 77.5) 80.6	79.2 (78.1, 80.5)	91.6 (90, 93.3)	103 (100, 105)	118 (113, 123)
	Negative	(73.5, 85.4) 80.6	83.5 (75.7, 91)	106 (95.5, 116)	139 (124, 156)	Not Reliable
United States	Positive	(20.9, 22.4) 23.6	23.1 (22.5, 23.7)	28.5 (27.5, 29.6)	32.2 (30.6, 34.1)	34.6 (32.3, 37.3)
	Medium	(21, 22.2) 23.6	23 (22.5, 23.6)	28.5 (27.7, 29.5)	32.3 (30.9, 34.1)	34.8 (32.6, 37.7)
	Negative	(21, 24.2) 23.6	24.4 (22.4, 26.3)	35.1 (32, 38.3)	52.8 (46.6, 60.8)	Not Reliable

Spain	Positive	(16.2, 18.1) 17.5	17.7 (16.7, 18.8)	18.8 (17.8, 20.1)	19.6 (18.4, 20.9)	20.1 (18.8, 21.6)
	Medium	(16.4, 17.4) 17.5	17.4 (16.9, 17.9)	18.8 (18.2, 19.3)	19.7 (19.1, 20.4)	20.7 (19.9, 21.6)
	Negative	(15.5, 19.6) 17.5	17.7 (15.7, 20.3)	21.6 (19.2, 24.7)	26.9 (23.7, 31.6)	Not Reliable
Italy	Positive	(19.2, 21.2) 20.5	20.6 (19.5, 21.6)	21.8 (20.6, 22.9)	22.6 (21.3, 23.8)	23.5 (22.1, 24.9)
	Medium	(19.4, 20.2) 20.5	20.3 (19.9, 20.8)	21.8 (21.3, 22.3)	22.9 (22.4, 23.5)	24.7 (23.9, 25.4)
	Negative	(17.9, 22.5) 20.5	20.9 (18.5, 23.4)	24.3 (21.6, 27.3)	28.9 (25.6, 33.1)	Not Reliable
Germany	Positive	(2.69, 2.95) 2.97	2.91 (2.8, 3.05)	3.36 (3.2, 3.57)	3.64 (3.42, 3.92)	3.81 (3.53, 4.19)
	Medium	(2.69, 2.91) 2.97	2.94 (2.83, 3.05)	3.42 (3.28, 3.58)	3.73 (3.55, 3.96)	3.94 (3.72, 4.28)
	Negative	(2.72, 3.07) 2.97	3.04 (2.81, 3.24)	4.01 (3.68, 4.32)	5.38 (4.9, 6.05)	Not Reliable
France	Positive	(13.3, 14.5) 15	14.4 (13.7, 15)	16 (15.2, 16.8)	16.7 (15.8, 17.8)	17.1 (16.1, 18.3)
	Medium	(13.5, 14.7) 15	14.7 (14, 15.3)	16.4 (15.7, 17.2)	17.4 (16.6, 18.4)	17.9 (17, 19)
	Negative	(13.9, 16.6) 15	15.9 (14.2, 17.6)	20.9 (18.7, 23.4)	28.9 (25.6, 33.2)	Not Reliable
United Kingdom	Positive	(10, 10.9) 11.3	11.1 (10.8, 11.6)	13.8 (13.1, 14.6)	15.7 (14.5, 17)	16.9 (15.4, 19.2)
	Medium	(10, 10.8) 11.3	11.2 (10.8, 11.6)	14 (13.2, 14.7)	16.1 (14.9, 17.6)	17.6 (15.9, 21.2)
	Negative	(10, 11.4) 11.3	11.6 (10.8, 12.4)	16.4 (15.2, 18)	24.3 (22, 27.8)	Not Reliable
Turkey	Positive	(1.13, 1.24) 1.3	1.29 (1.23, 1.34)	1.59 (1.49, 1.7)	1.81 (1.65, 2.02)	1.98 (1.75, 2.37)
	Medium	(1.14, 1.23) 1.3	1.28 (1.23, 1.33)	1.61 (1.51, 1.72)	1.9 (1.71, 2.17)	2.21 (1.83, 3.12)
	Negative	(1.12, 1.27) 1.3	1.3 (1.21, 1.37)	1.8 (1.68, 1.92)	2.57 (2.35, 2.82)	Not Reliable
Belgium	Positive	(3.43, 3.78) 3.9	3.82 (3.66, 3.98)	5.11 (4.78, 5.46)	6.23 (5.56, 7.04)	7.21 (6.12, 9.12)
	Medium	(3.41, 3.66) 3.9	3.75 (3.62, 3.91)	5.16 (4.81, 5.59)	6.61 (5.82, 7.98)	8.8 (6.65, 15.7)
	Negative	(3.42, 3.68) 3.9	3.88 (3.69, 4.07)	5.76 (5.47, 6.09)	8.94 (8.35, 9.72)	Not Reliable
Netherlands	Positive	(2.66, 2.89) 2.82	2.86 (2.74, 2.98)	3.16 (3.02, 3.29)	3.35 (3.18, 3.51)	3.48 (3.29, 3.7)
	Medium	(2.65, 2.78) 2.82	2.81 (2.74, 2.88)	3.14 (3.06, 3.24)	3.39 (3.27, 3.51)	3.63 (3.45, 3.82)
	Negative	(2.59, 3.01) 2.82	2.89 (2.66, 3.17)	3.63 (3.31, 3.99)	4.66 (4.21, 5.17)	Not Reliable
Switzerland	Positive	(0.854, 1.16) 0.858	0.94 (0.853, 1.07)	1.03 (0.931, 1.2)	1.1 (0.98, 1.31)	1.17 (1.01, 1.48)
	Medium	(0.815, 0.928) 0.858	0.884 (0.824, 0.944)	0.99 (0.914, 1.08)	1.07 (0.975, 1.22)	1.17 (1.01, 1.63)
	Negative	(0.8, 0.935) 0.858	0.882 (0.806, 0.965)	1.07 (0.969, 1.18)	1.3 (1.17, 1.48)	Not Reliable
Brazil	Positive	(1.11, 1.21) 1.33	1.24 (1.18, 1.29)	1.5 (1.41, 1.59)	1.64 (1.52, 1.78)	1.69 (1.55, 1.87)

	Medium	(1.17, 1.25) 1.33	1.3 (1.26, 1.35)	1.63 (1.56, 1.71)	1.86 (1.76, 2.03)	2 (1.87, 2.32)
	Negative	(1.18, 1.3) 1.33	1.34 (1.26, 1.42)	1.95 (1.81, 2.08)	2.94 (2.67, 3.28)	Not Reliable
Russia	Positive	(0.068, 0.106) 0.148	0.1 (0.082, 0.128)	0.145 (0.103, 0.287)	0.158 (0.105, 0.802)	Not Reliable
	Medium	(0.122, 0.146) 0.148	0.152 (0.139, 0.166)	0.248 (0.201, 0.297)	0.445 (0.255, 0.618)	Not Reliable
	Negative	(0.121, 0.145) 0.148	0.15 (0.138, 0.164)	0.249 (0.208, 0.295)	0.459 (0.31, 0.609)	Not Reliable
Portugal	Positive	(0.489, 0.571) 0.535	0.57 (0.529, 0.613)	0.676 (0.616, 0.747)	0.772 (0.68, 0.897)	0.9 (0.741, 1.28)
	Medium	(0.468, 0.52) 0.535	0.528 (0.496, 0.559)	0.65 (0.605, 0.697)	0.79 (0.705, 0.891)	1.31 (0.865, 5.94)
	Negative	(0.472, 0.528) 0.535	0.531 (0.503, 0.562)	0.681 (0.64, 0.726)	0.89 (0.829, 0.958)	Not Reliable
Austria	Positive	(0.349, 0.426) 0.368	0.391 (0.362, 0.433)	0.457 (0.415, 0.509)	0.515 (0.453, 0.596)	0.588 (0.485, 0.795)
	Medium	(0.325, 0.374) 0.368	0.363 (0.339, 0.386)	0.438 (0.405, 0.476)	0.517 (0.46, 0.591)	0.732 (0.527, 2.73)
	Negative	(0.326, 0.376) 0.368	0.367 (0.344, 0.392)	0.466 (0.434, 0.499)	0.601 (0.555, 0.654)	Not Reliable
Sweden	Positive	(0.792, 0.962) 0.919	0.86 (0.759, 0.97)	0.943 (0.823, 1.08)	0.971 (0.842, 1.13)	0.98 (0.848, 1.15)
	Medium	(0.871, 1.04) 0.919	0.979 (0.878, 1.09)	1.14 (1.01, 1.29)	1.23 (1.08, 1.47)	1.28 (1.11, 1.66)
	Negative	(0.849, 1.06) 0.919	0.969 (0.83, 1.12)	1.29 (1.08, 1.57)	1.74 (1.4, 2.32)	Not Reliable
Japan	Positive	(0.084, 0.108) 0.109	0.103 (0.09, 0.115)	0.118 (0.103, 0.134)	0.138 (0.116, 0.162)	Not Reliable
	Medium	(0.094, 0.19) 0.109	0.121 (0.101, 0.156)	0.141 (0.115, 0.177)	0.169 (0.129, 0.21)	Not Reliable
	Negative	(0.085, 0.111) 0.109	0.103 (0.09, 0.116)	0.122 (0.105, 0.137)	0.147 (0.125, 0.169)	Not Reliable
Iran	Positive	(4.24, 4.76) 4.58	4.58 (4.3, 4.85)	4.85 (4.56, 5.16)	5.08 (4.76, 5.44)	5.41 (5.01, 5.9)
	Medium	(4.3, 4.72) 4.58	4.62 (4.41, 4.84)	5 (4.76, 5.24)	5.36 (5.07, 5.67)	6.28 (5.74, 7.02)
	Negative	(4.15, 4.96) 4.58	4.65 (4.24, 5.11)	5.32 (4.87, 5.85)	6.2 (5.66, 6.91)	Not Reliable

* Note:

-The scenarios are based on the final total confirmed numbers. On April 11, 2020, we introduced the Generalized Richards Model in addition to our existing three models: Generalized Logistic Model, Logistic Model and Generalized Growth model (see [1] for their presentation). We remove the lowest mean predicted final total confirmed number K among the four models (which is classical statistical method ensuring robustness). Then, the model with the second lowest mean predicted final total confirmed number K is classified as the positive scenario, and the third lowest one is classified as the medium scenario. The negative scenario is based on the Generalized Growth model, which should only describe the early stage of the epidemic outbreak and is therefore least reliable for countries in the more mature stage.

-Trajectories from Iran have largely deviated from a typical logistic type growth (S curve), and can't

be properly described by our models. Although we still report its calibration results in Table 1, they should not be taken as reliable in all scenarios and time horizons. This is probably a result of unreliable reported data from Iran.

Limitations of using the statistics of reported confirmed number

It is important to understand what our prediction models show. The predictions are based on cases identified on the basis of testing and they therefore predict the numbers of future positive tests. Relating positive test results to real levels of infection is subject to a large number of biases. It is a fact that the real number of infections is far higher than those recorded in positive tests since only a tiny fraction of any population has been tested. It is also the case that, in most countries, testing is biased towards those who think they are infected. The first bias, therefore, will underestimate the real number of infections while the second bias will tend to overestimate since it is biased towards those who think they are ill.

There are further complications. Depending on the testing protocols used, in some instances false positive results have been obtained. In other words, someone without the disease tested positive, probably because they were infected with some other coronavirus. And in other cases, false negative results were obtained, as was the case with the early testing deployed in the USA.

One final complication is the fact that tests are conducted sequentially over time. They do not represent a snapshot of a day in time. Many of those tested early, giving a negative result, may today get a positive result. And many, who tested positive early on, may today be cured.

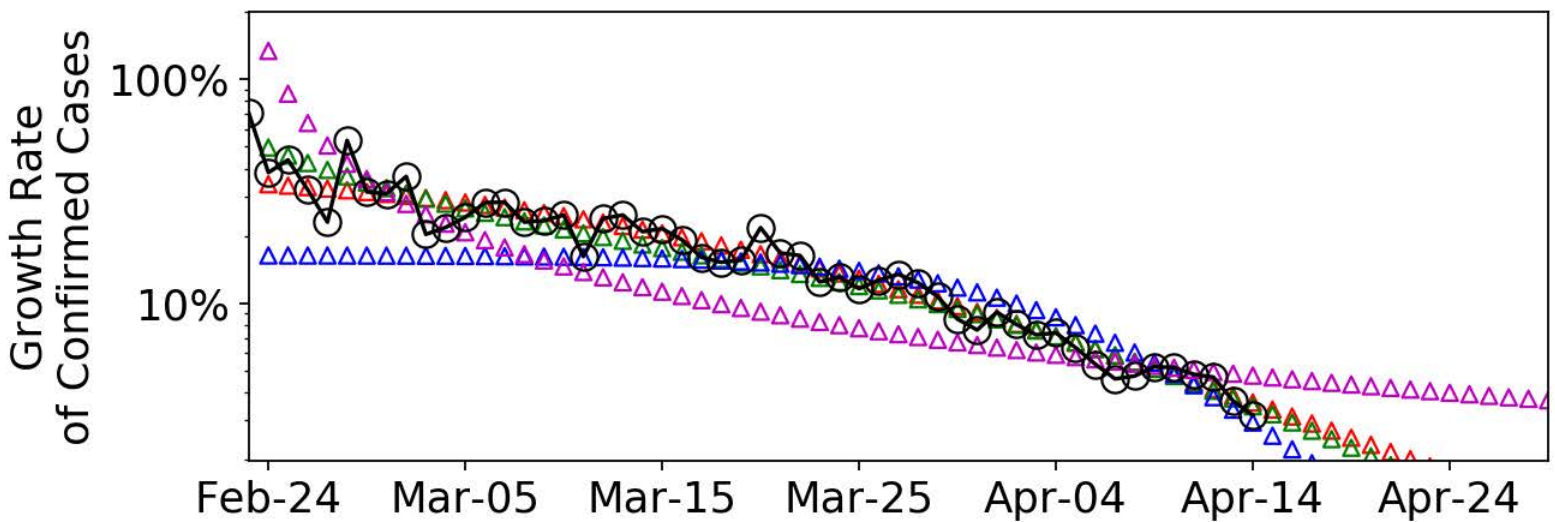
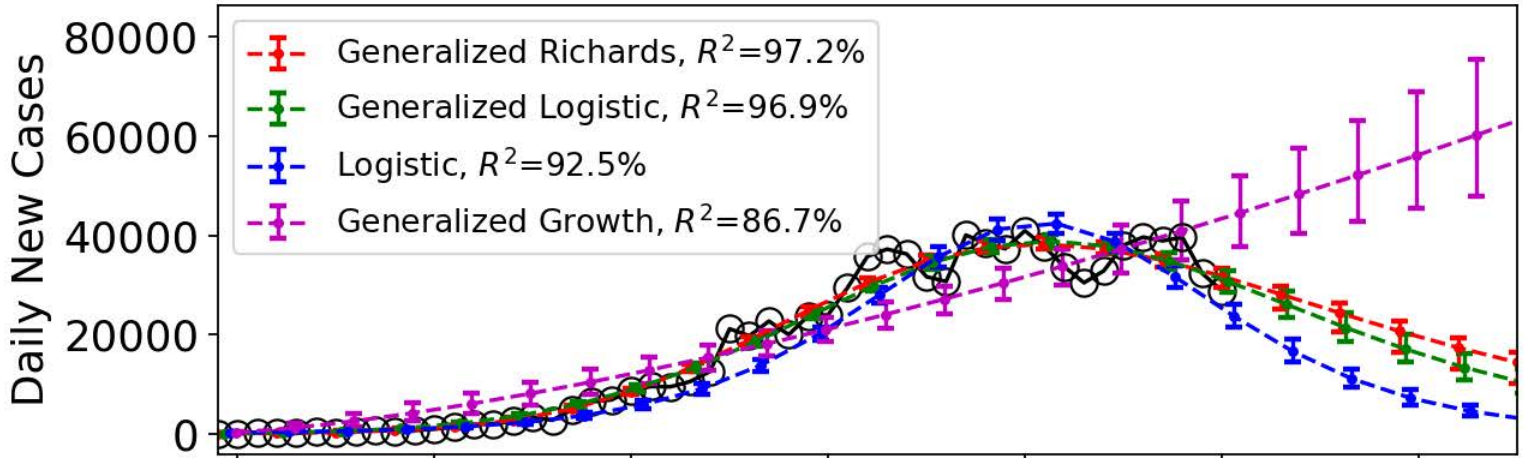
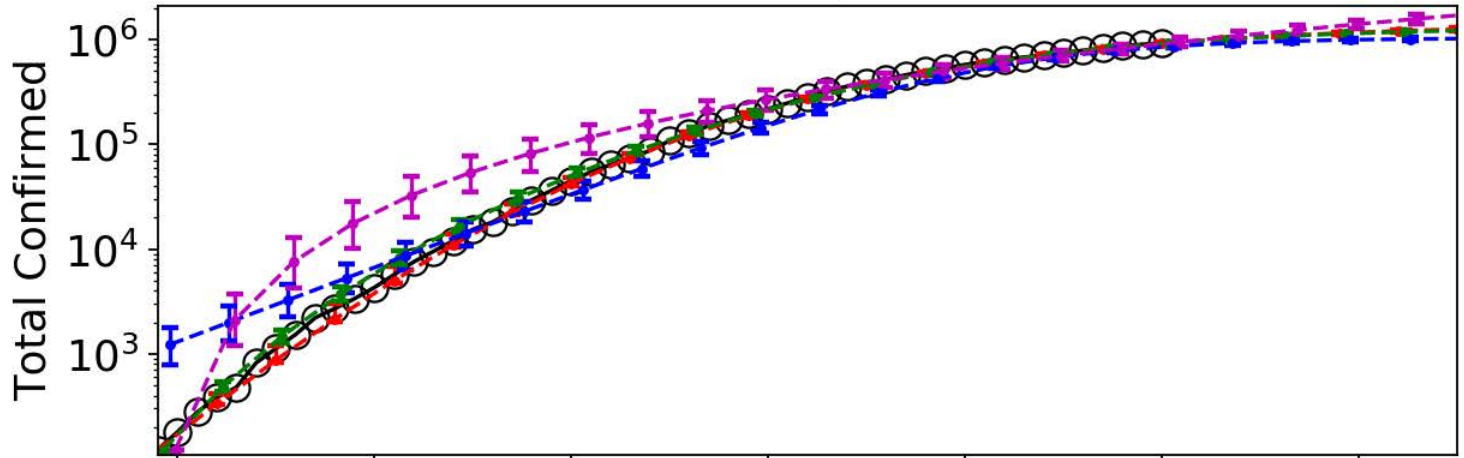
We anticipate that, over time, our methodology will improve and will provide a more accurate picture of the true levels of infection and where they are headed.

[1] Ke Wu, Didier Darcet, Qian Wang and Didier Sornette, Generalized logistic growth modeling of the COVID-19 outbreak in 29 provinces in China and in the rest of the world, preprint at <http://arxiv.org/abs/2003.05681> and medRxiv: <https://medrxiv.org/cgi/content/short/2020.03.11.20034363v1>

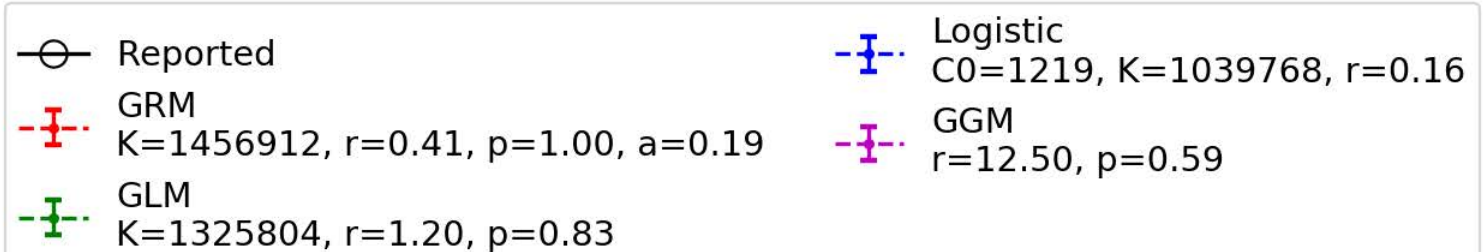
[2] <https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases>

[3] https://en.wikipedia.org/wiki/COVID-19_testing

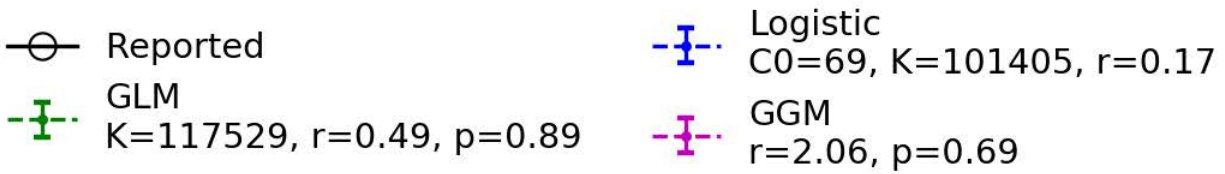
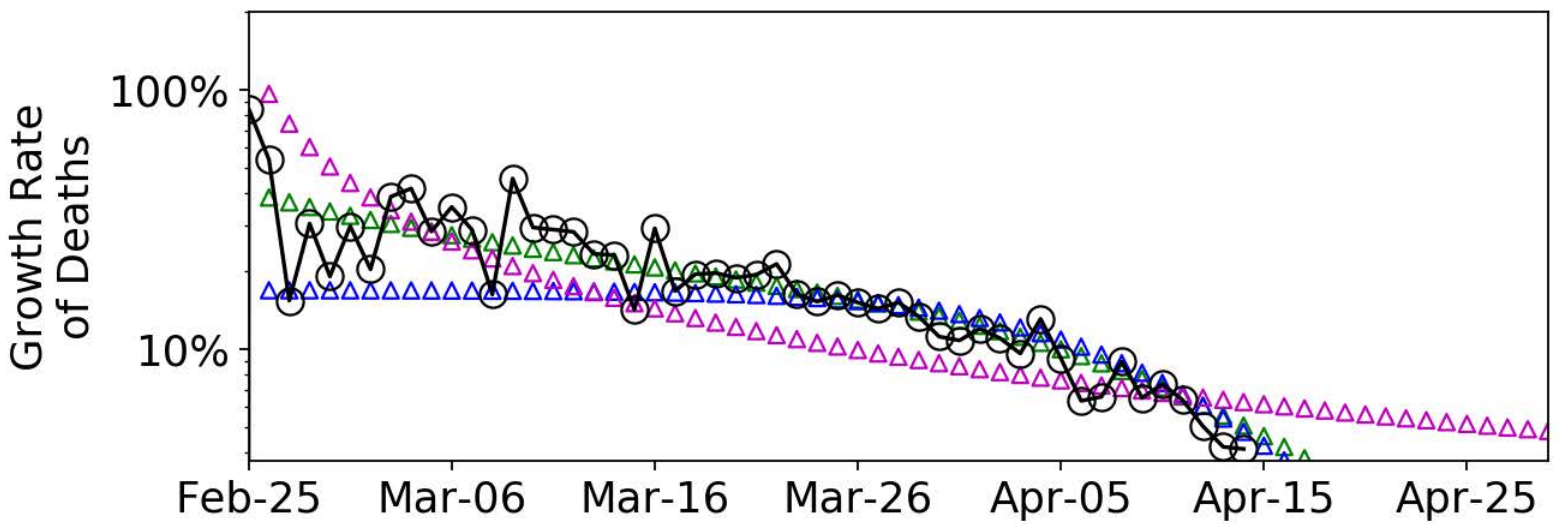
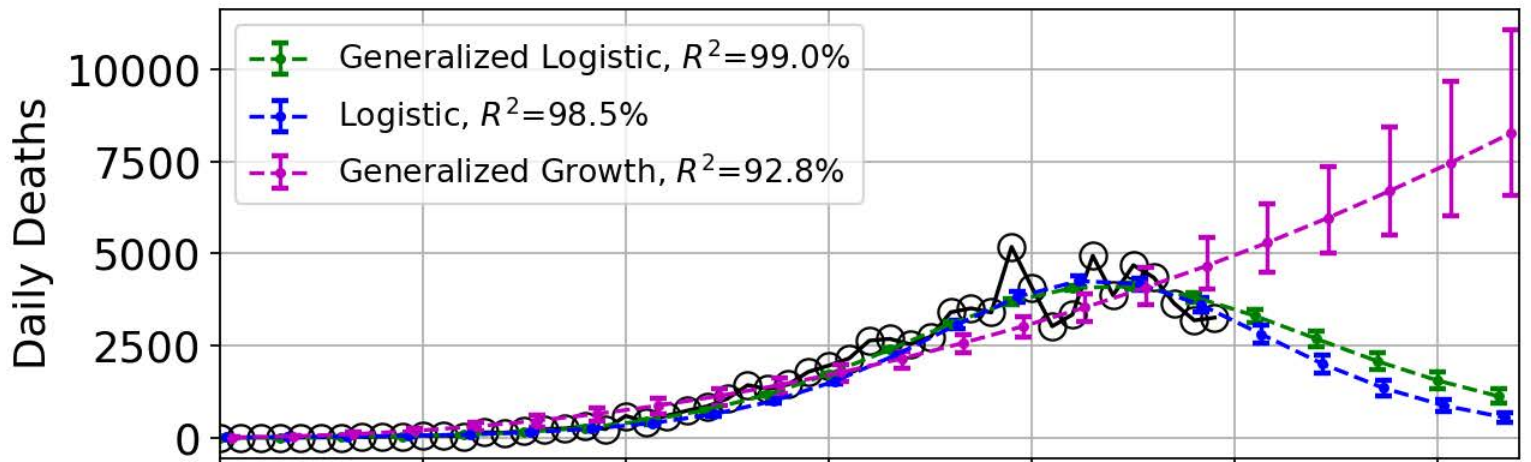
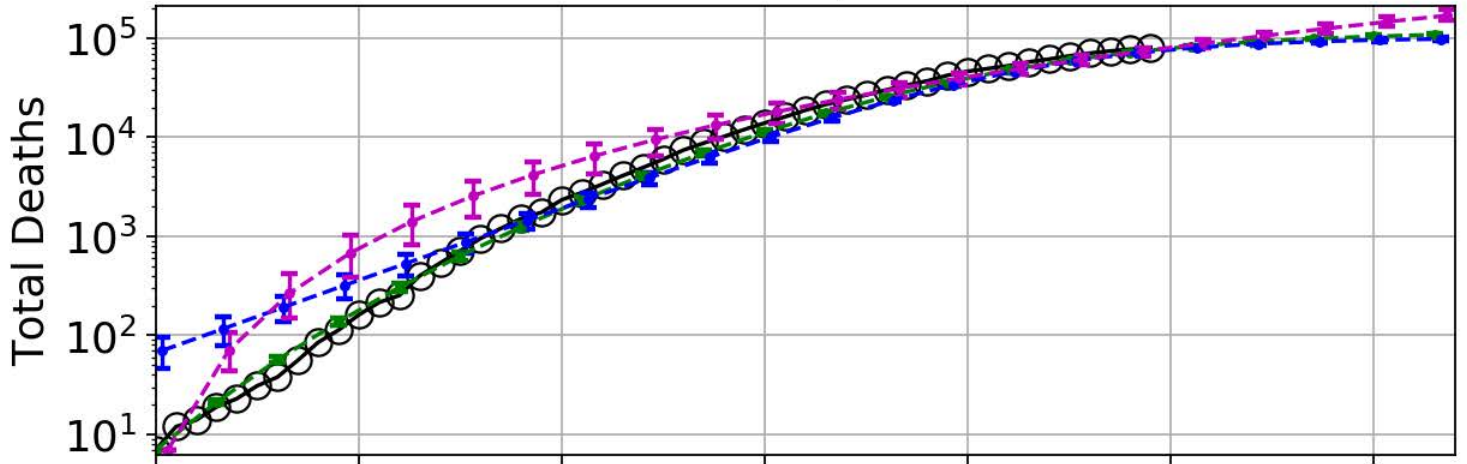
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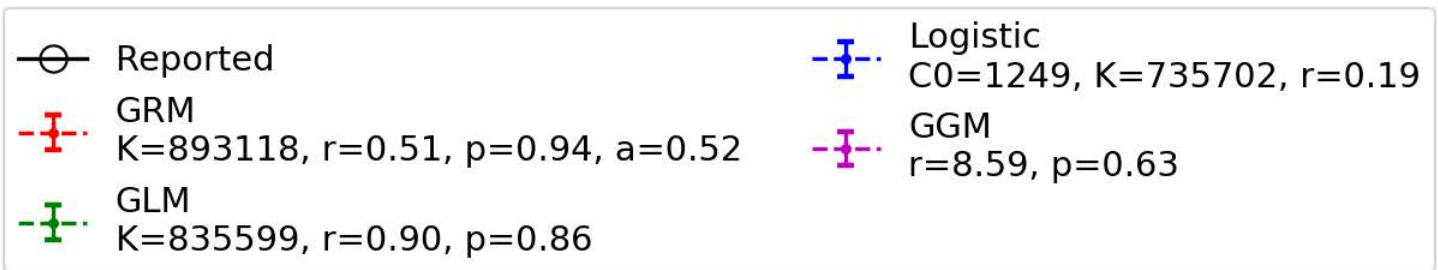
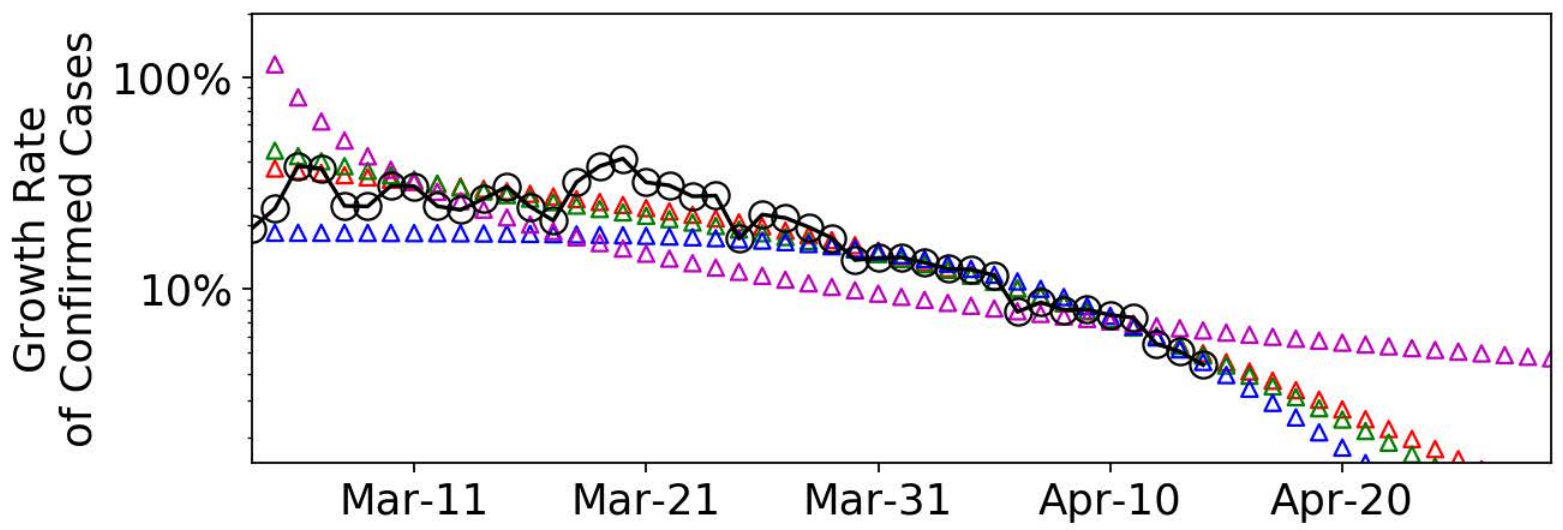
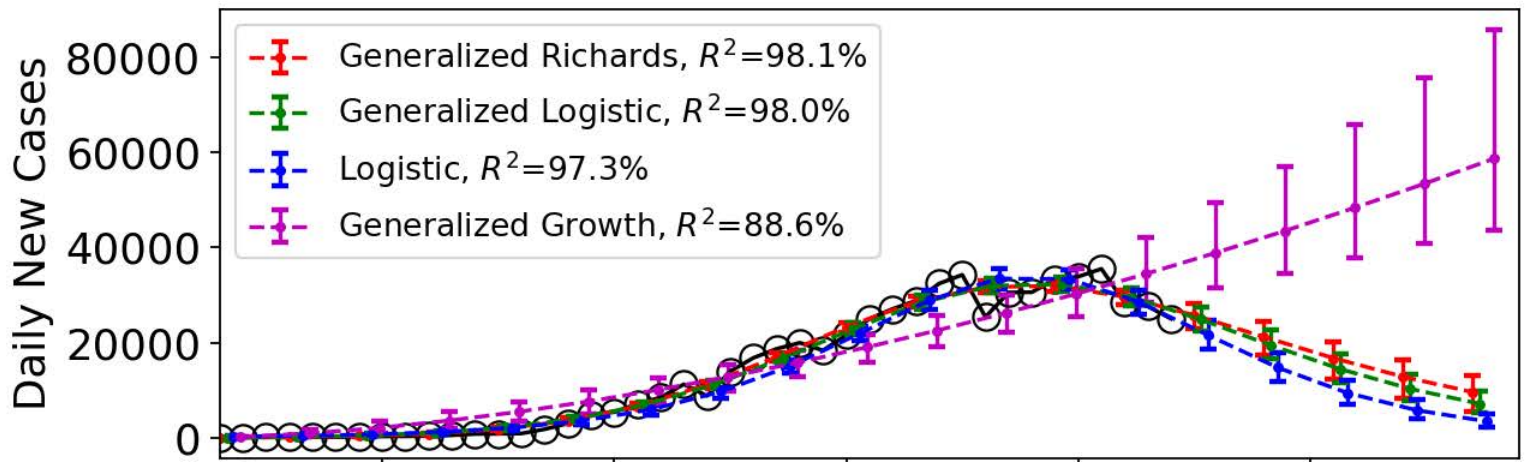
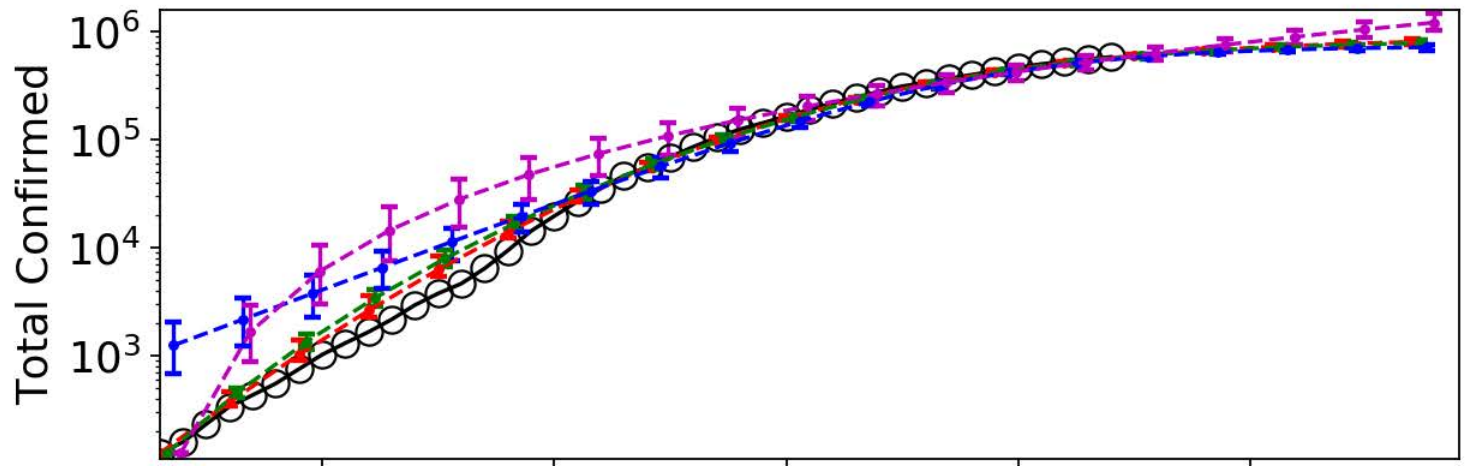
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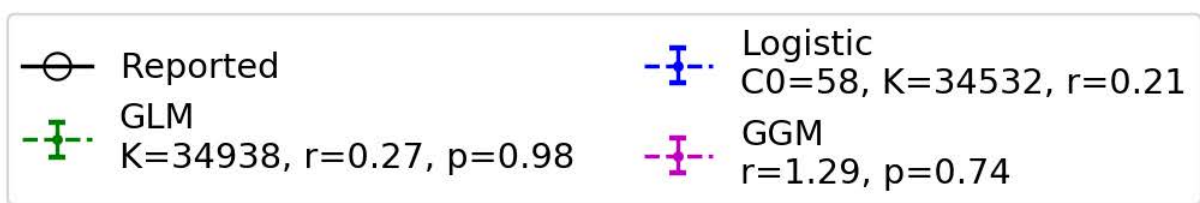
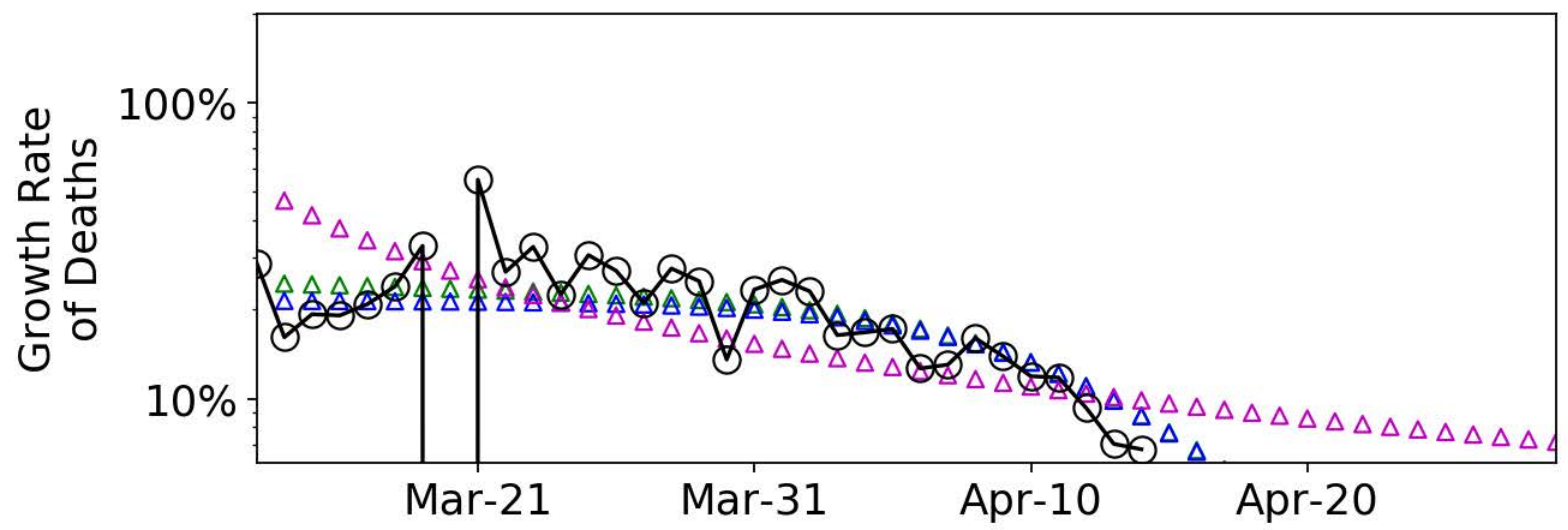
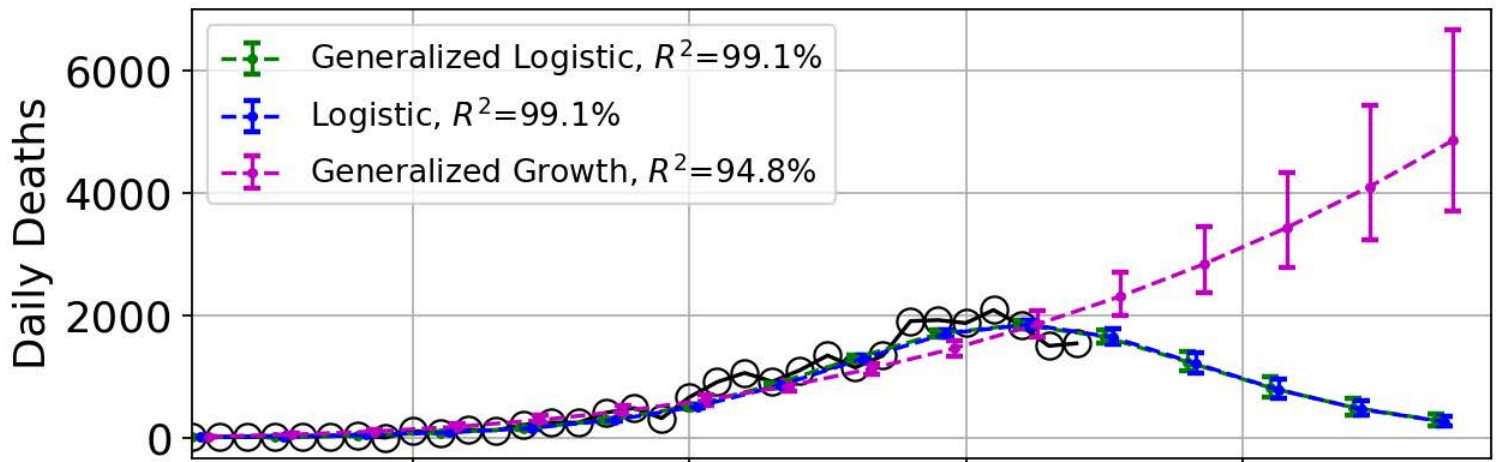
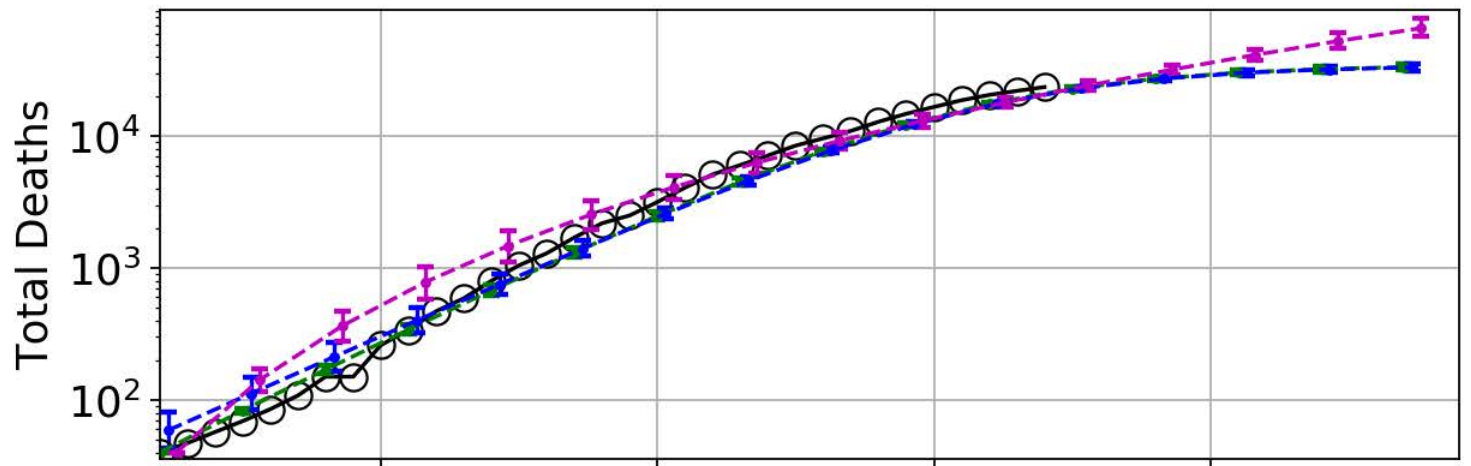
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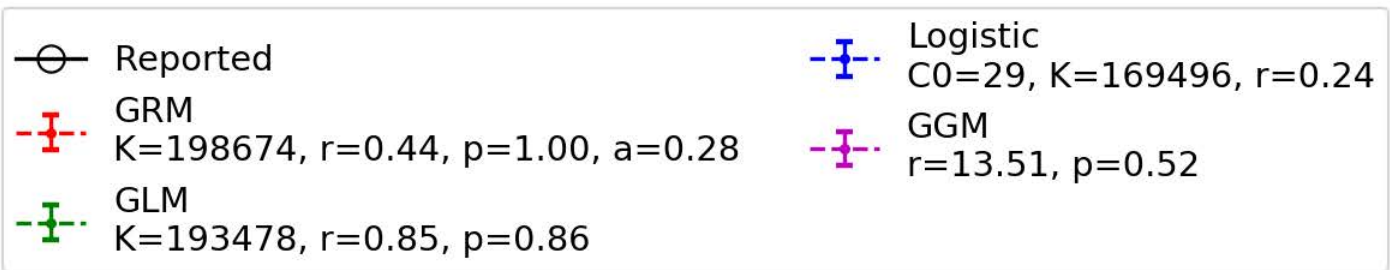
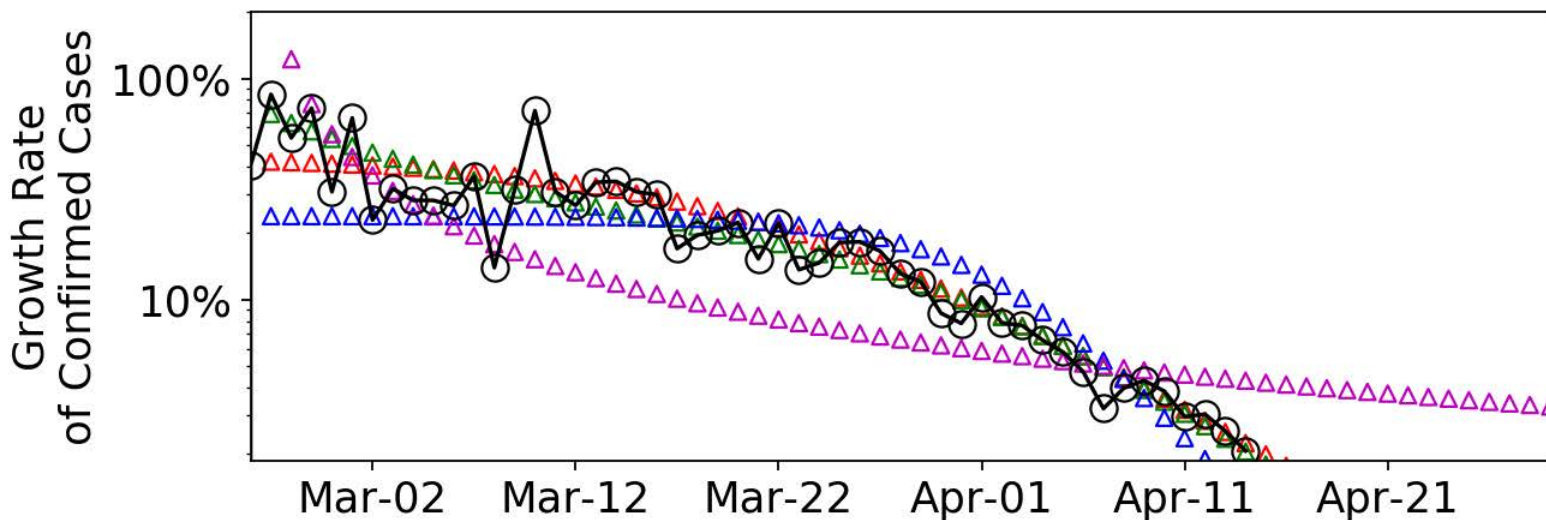
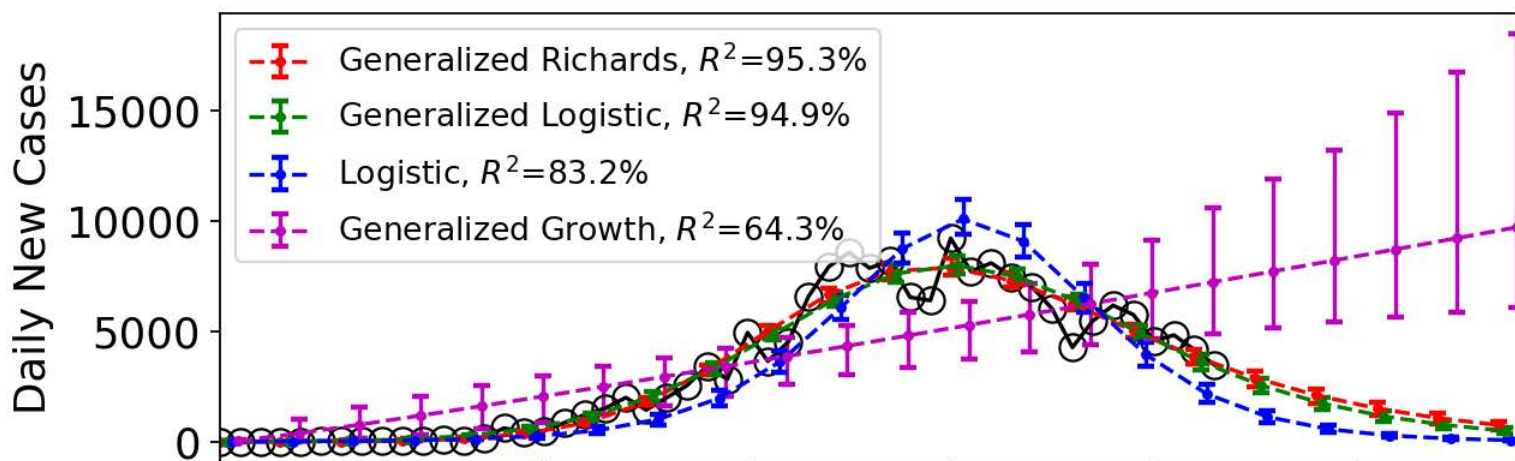
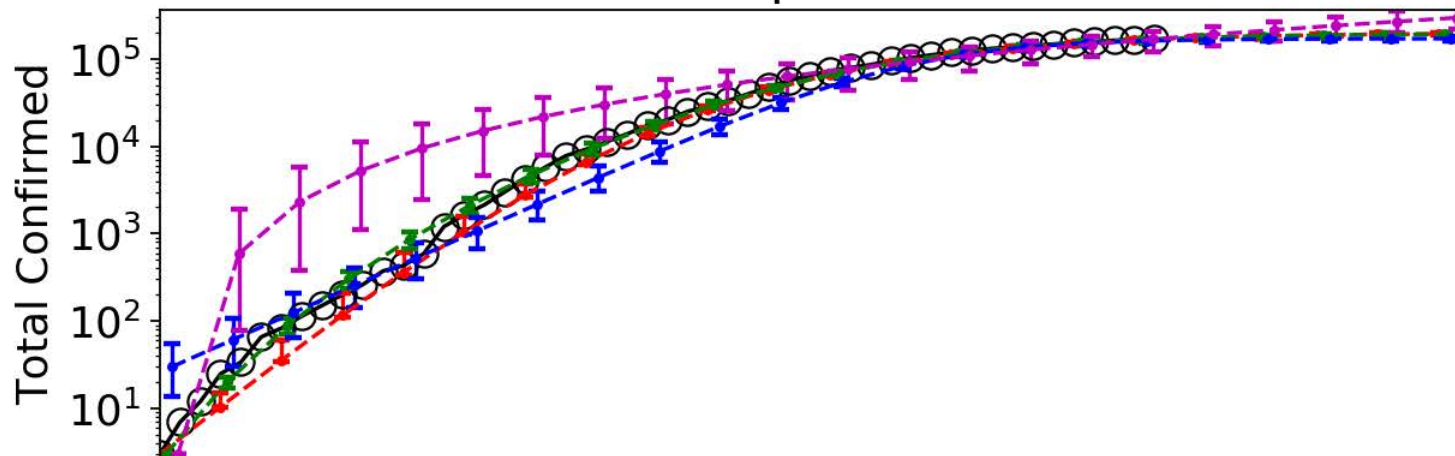
United States



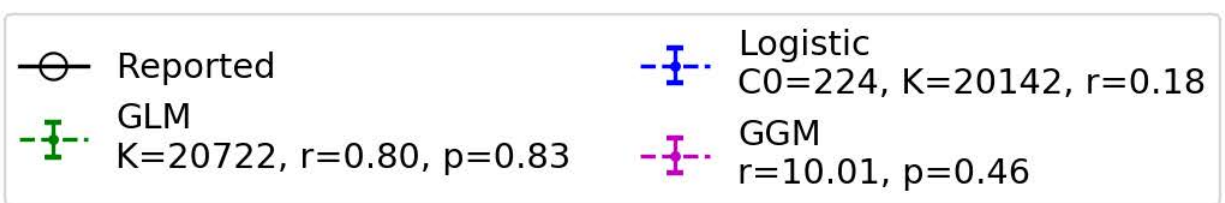
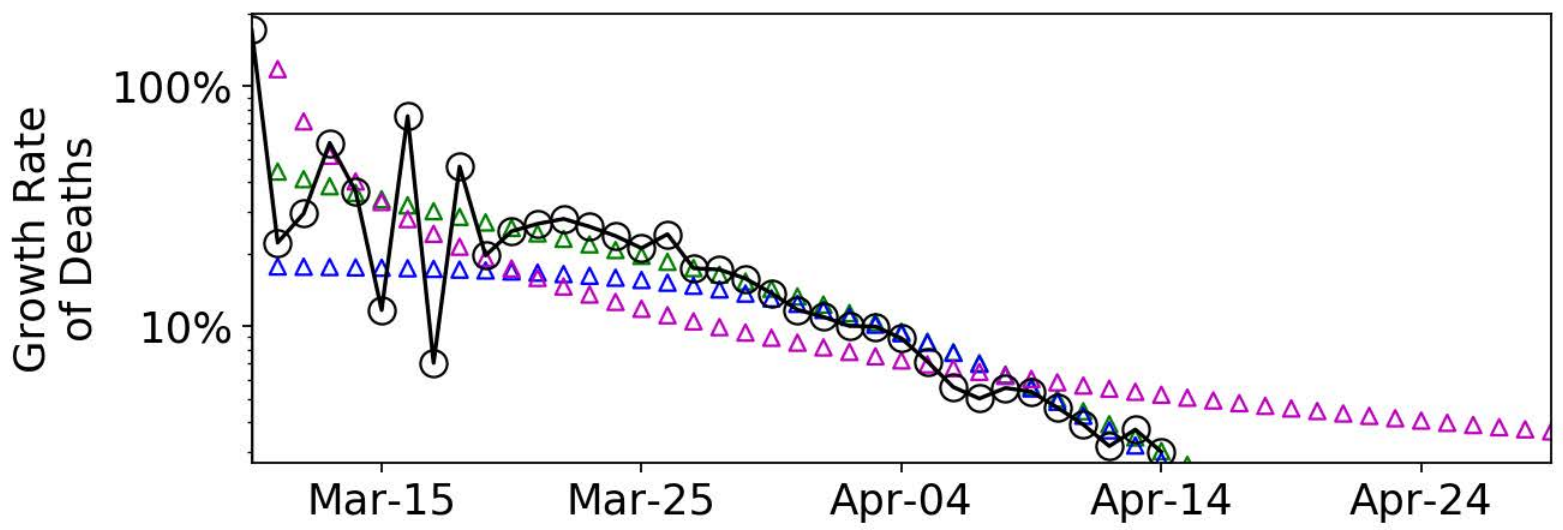
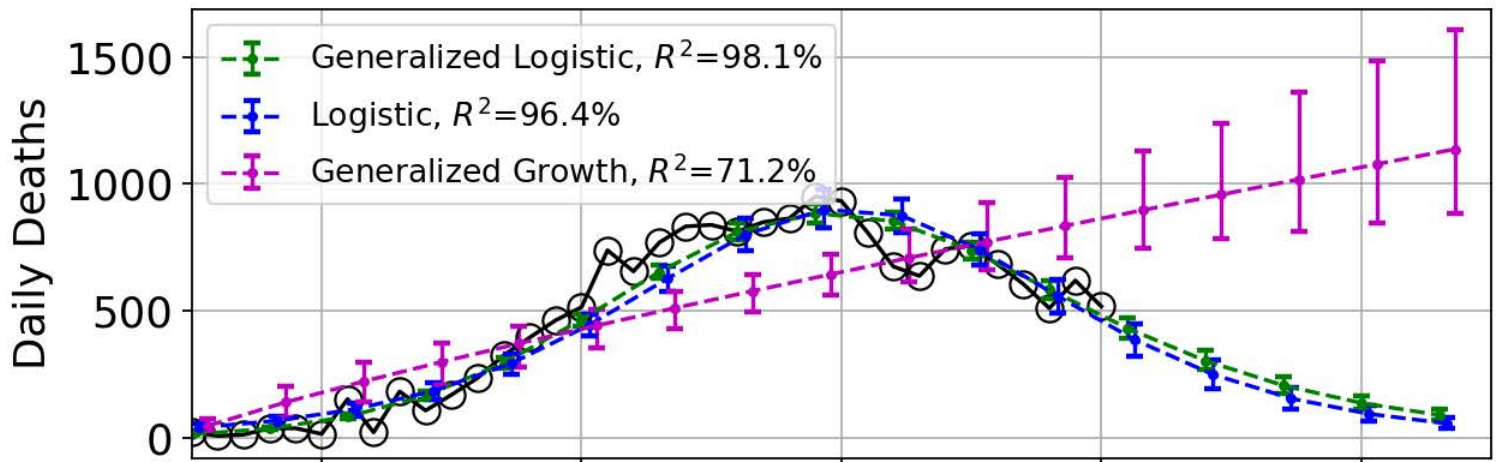
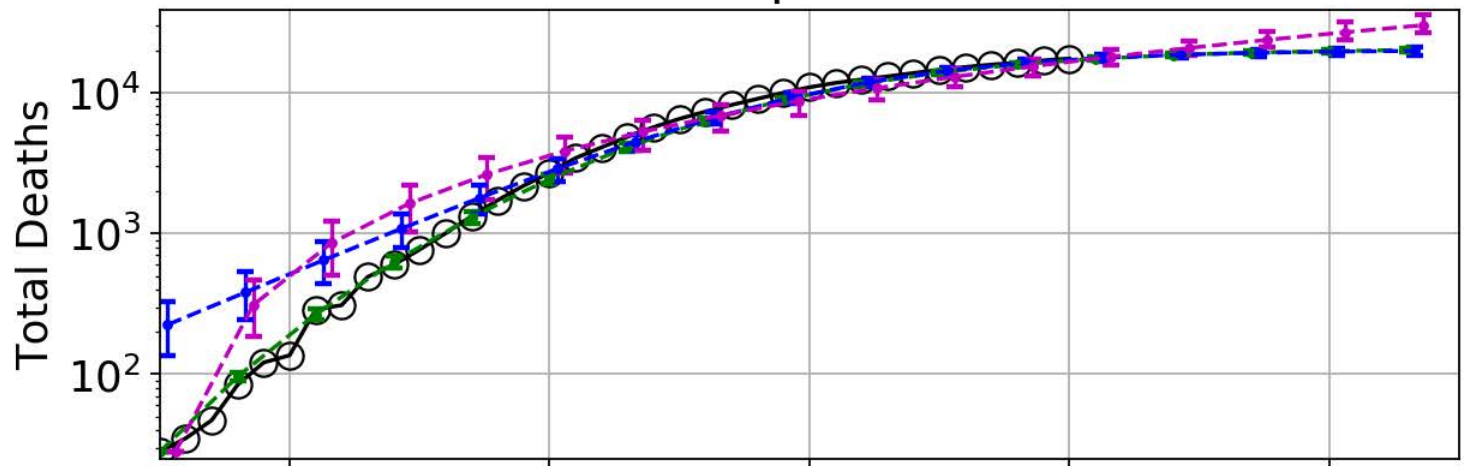
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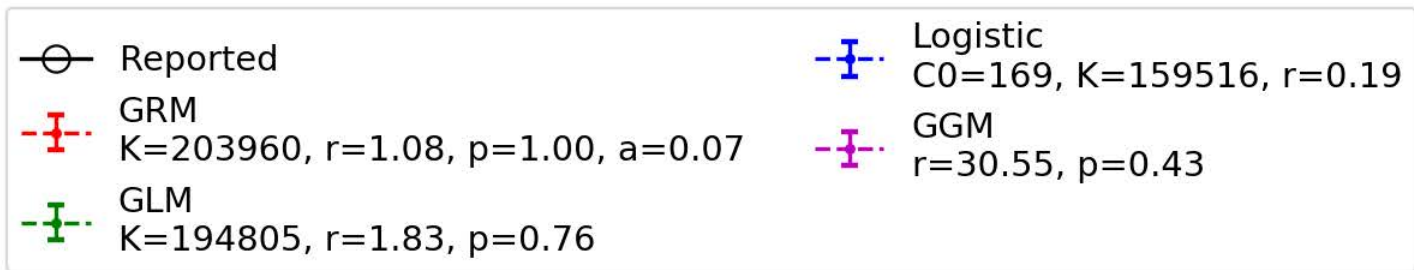
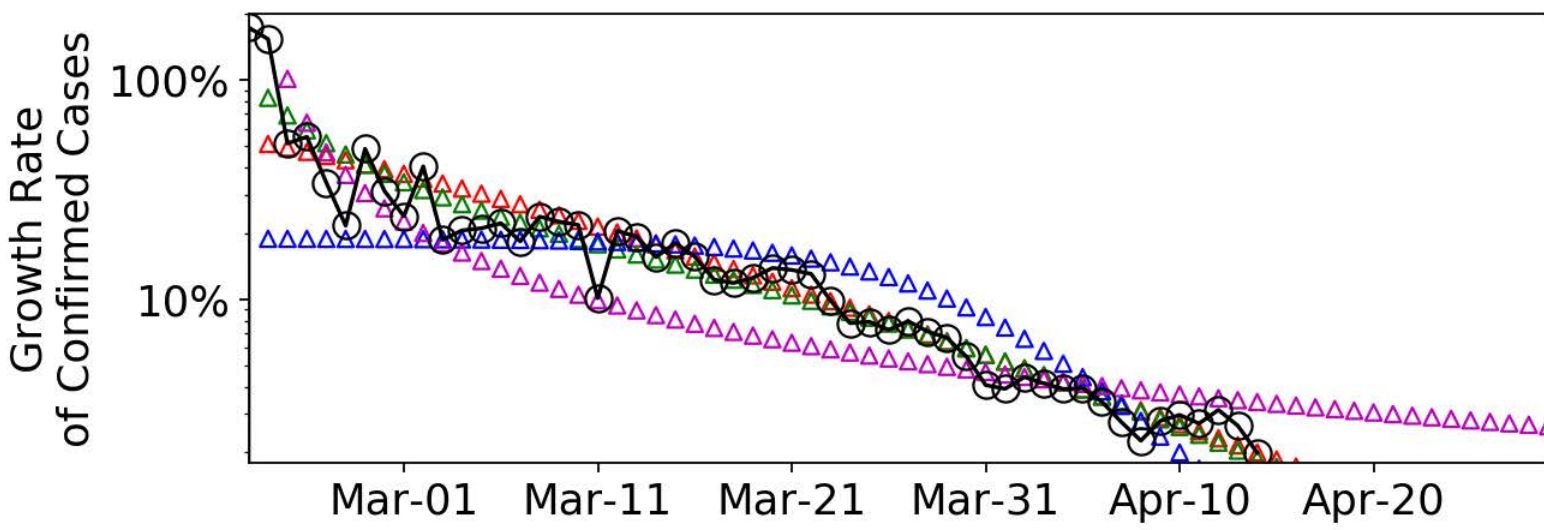
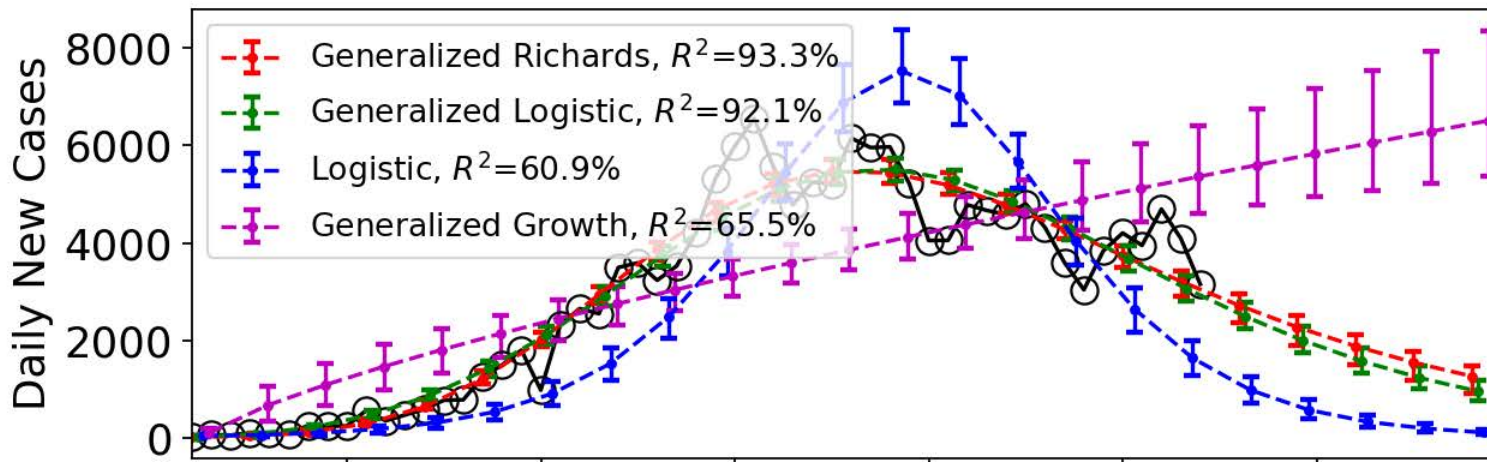
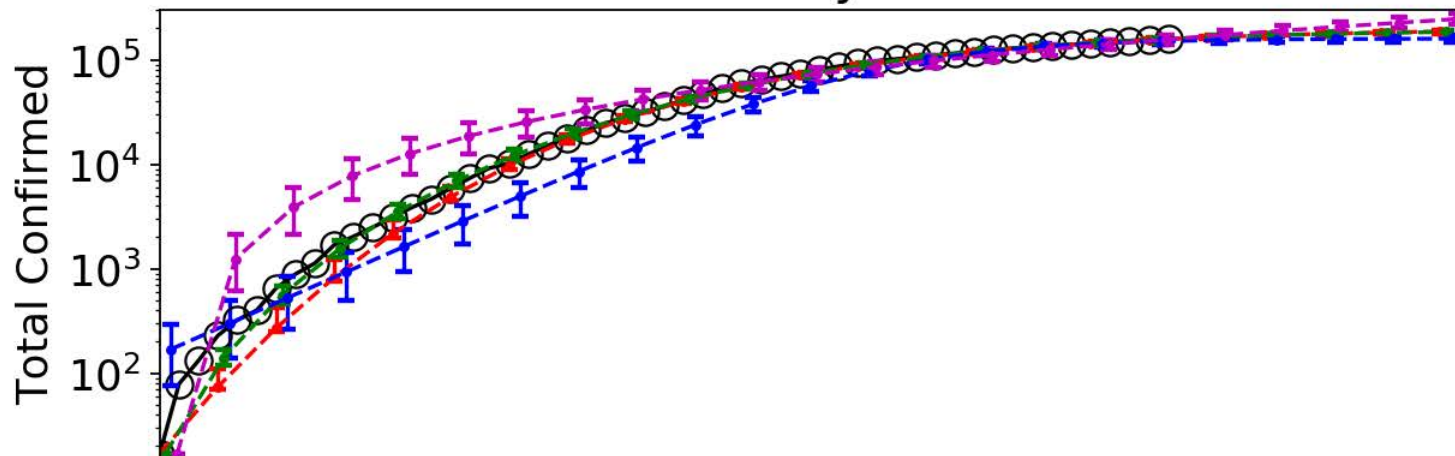
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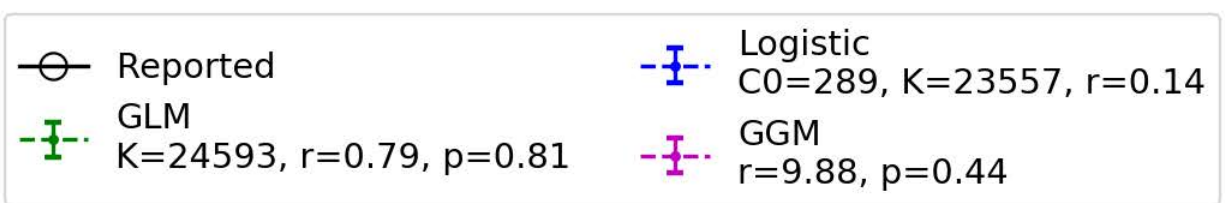
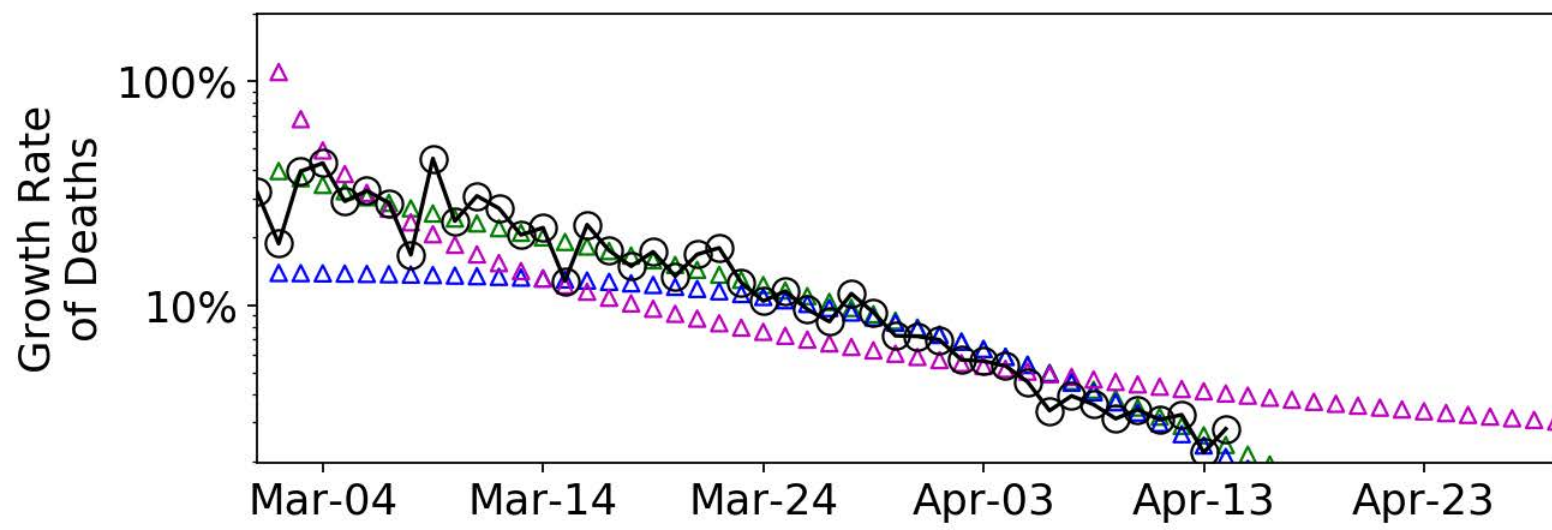
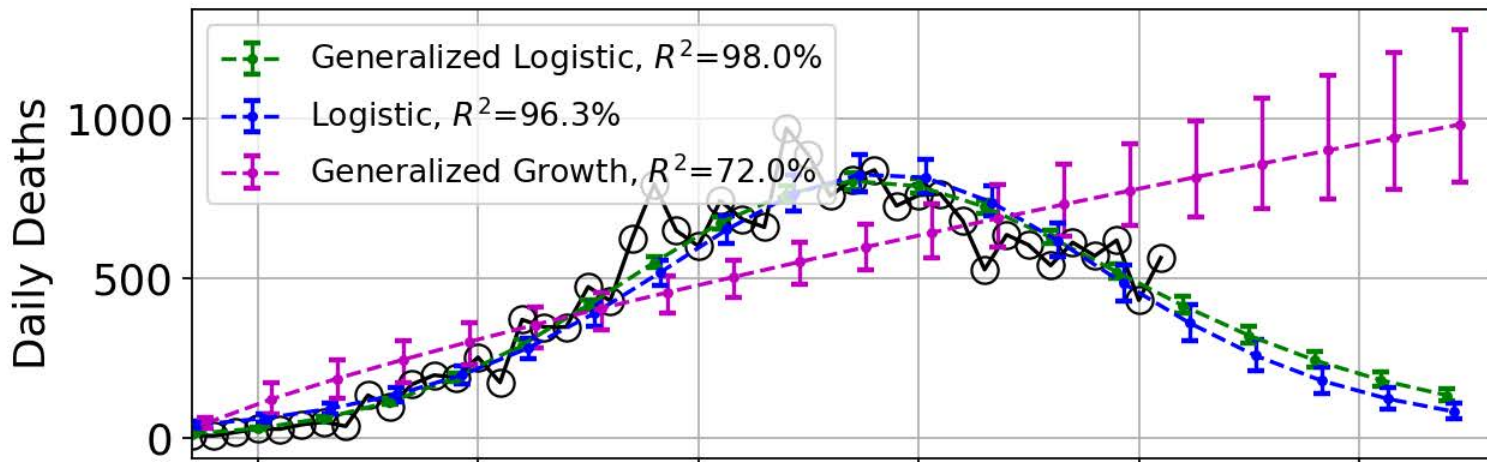
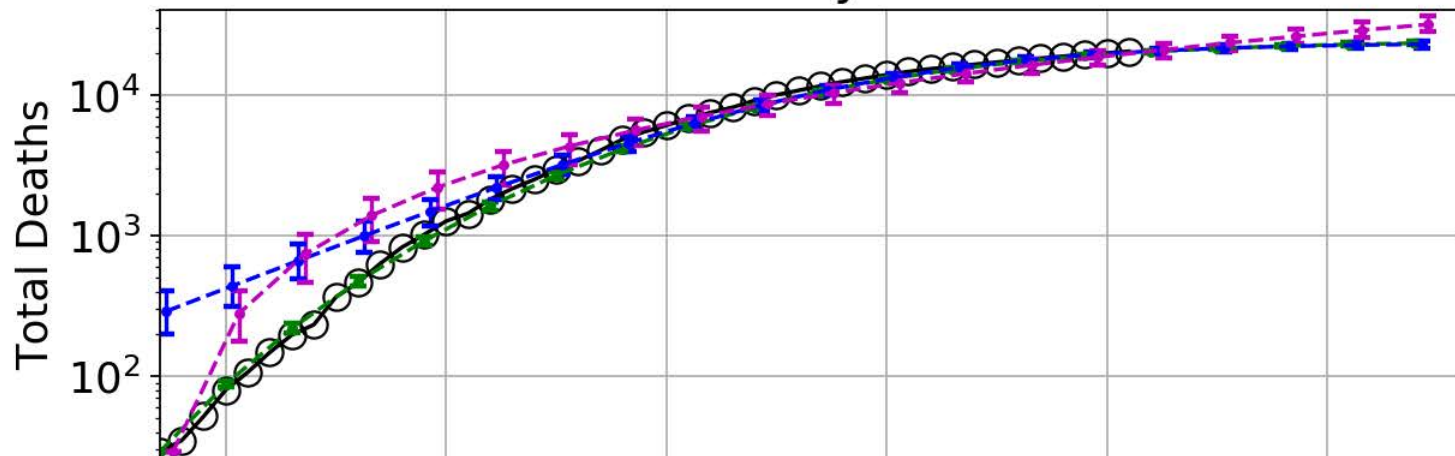
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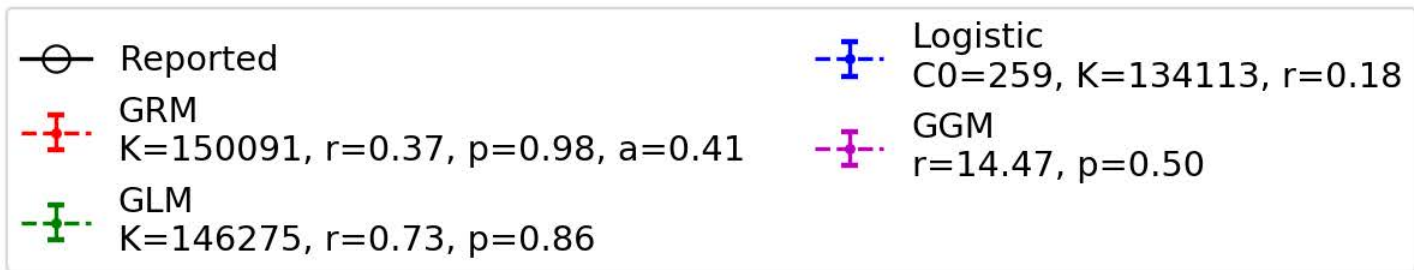
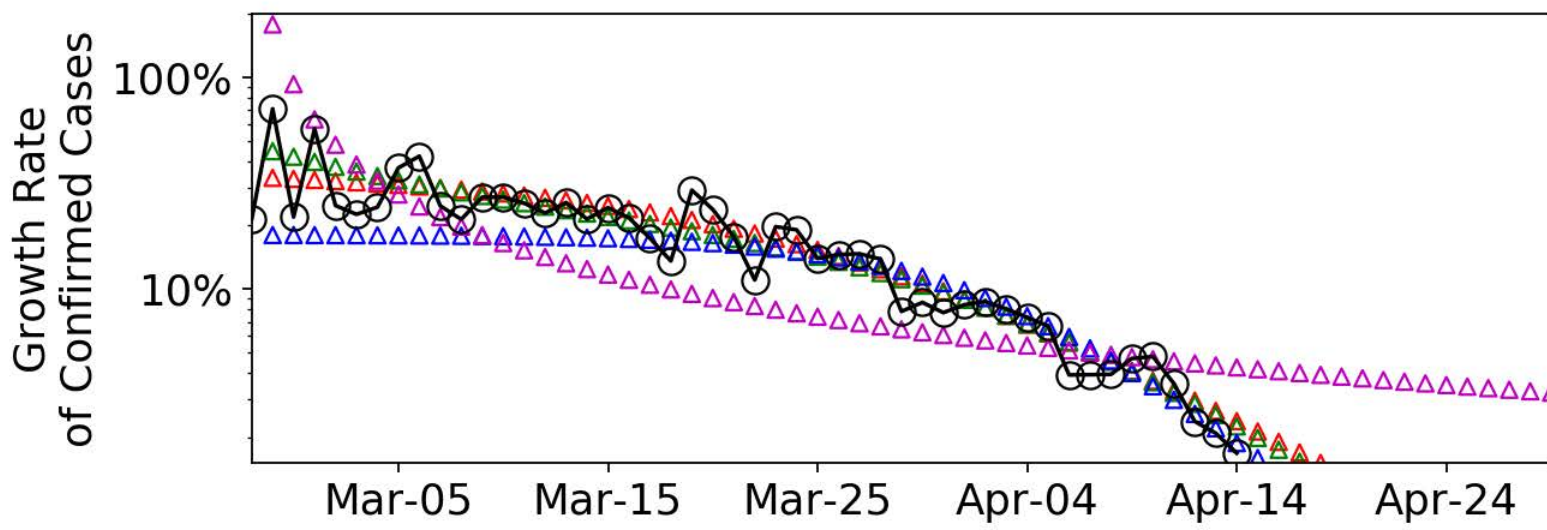
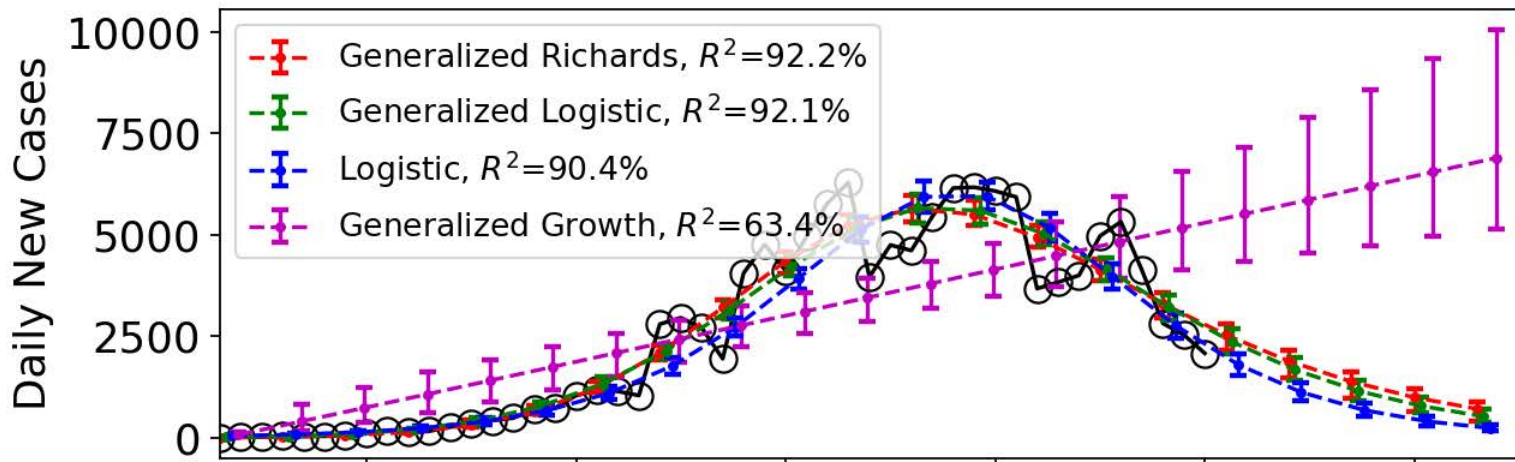
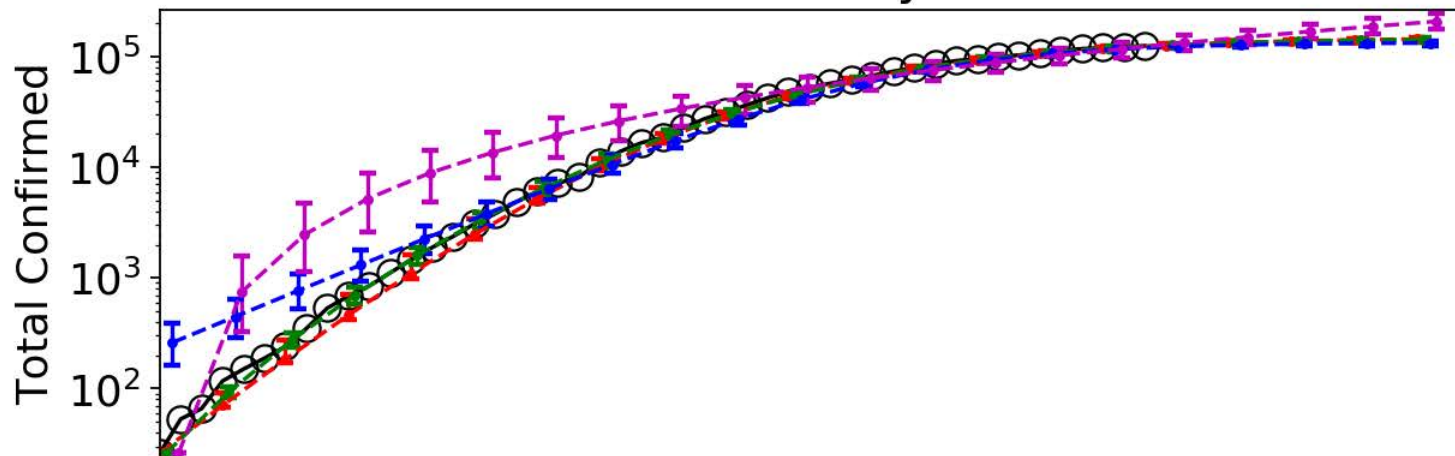
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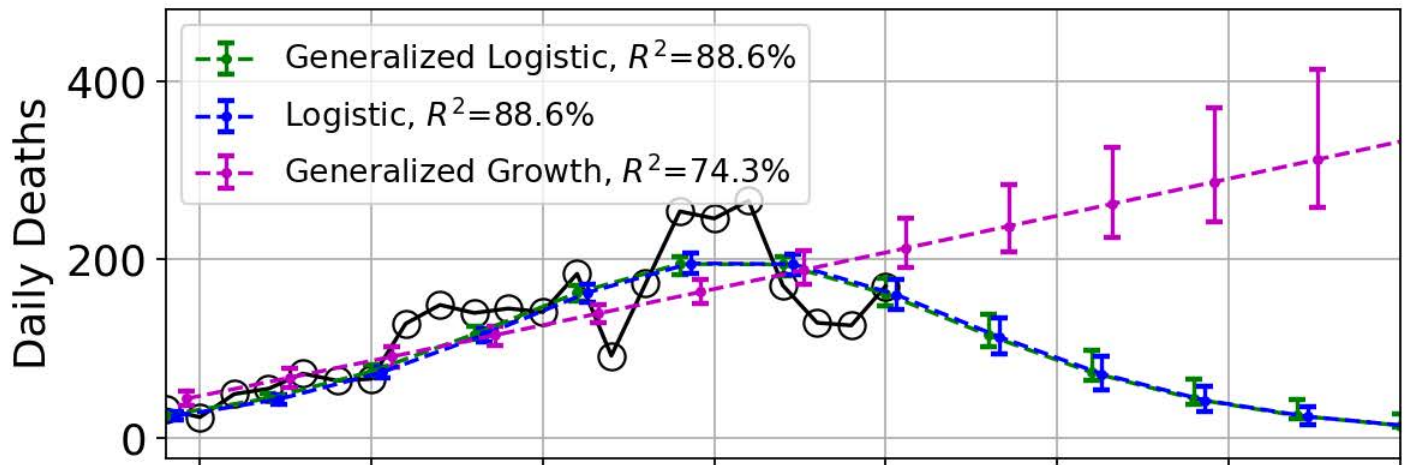
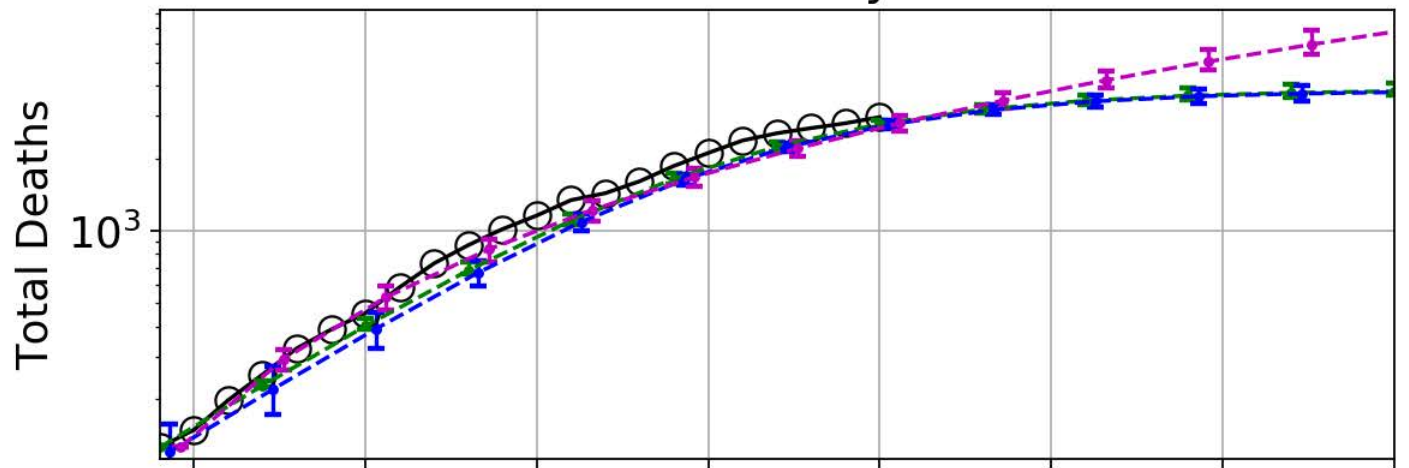
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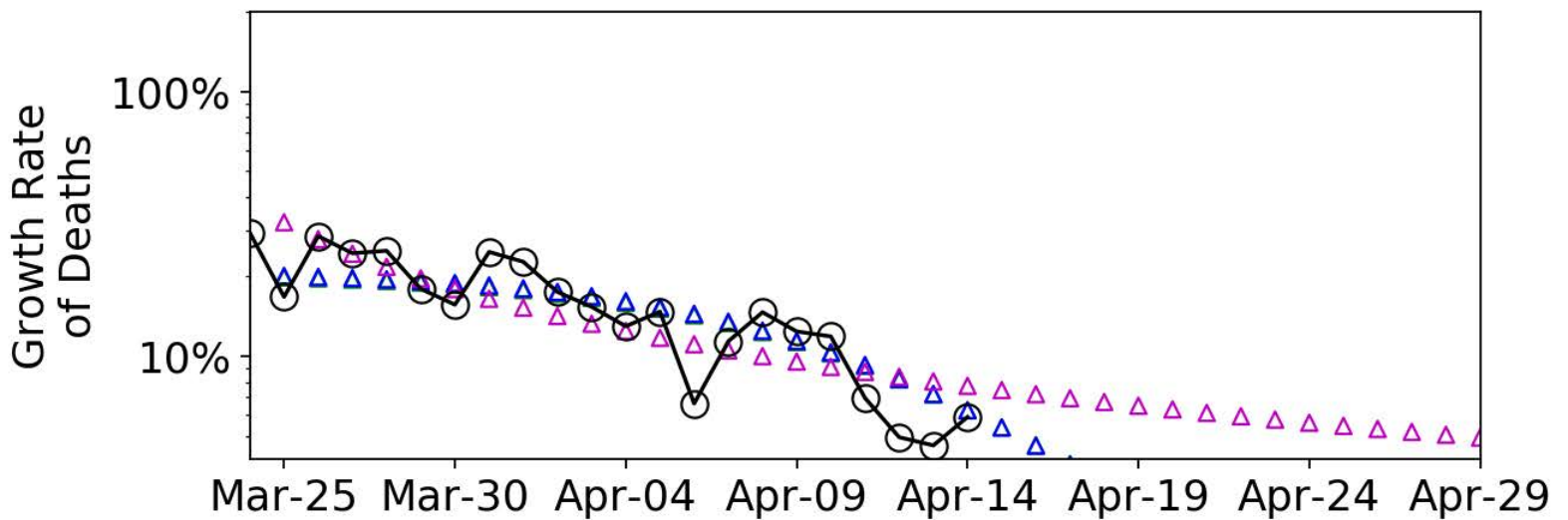
Germany



Germany

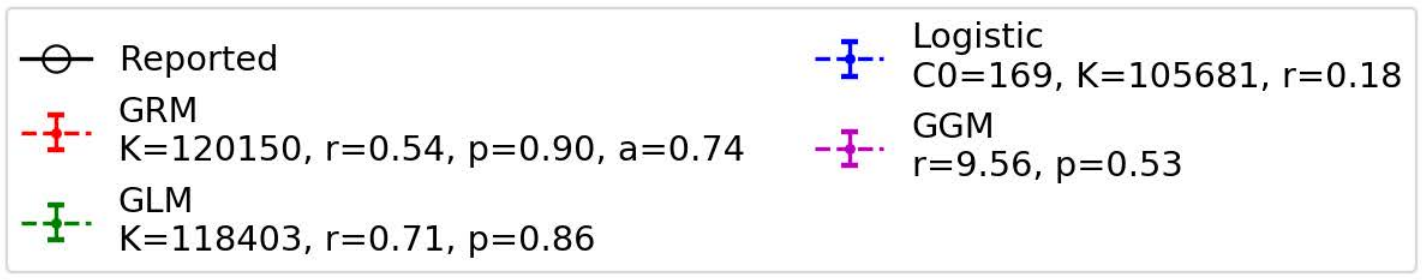
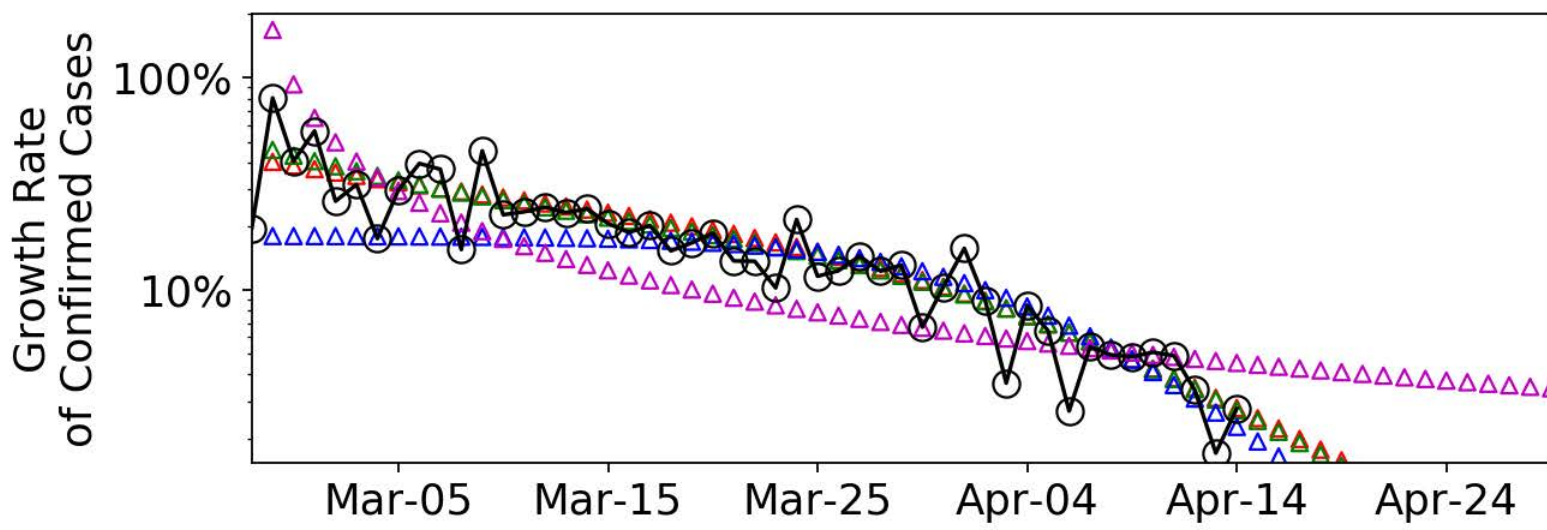
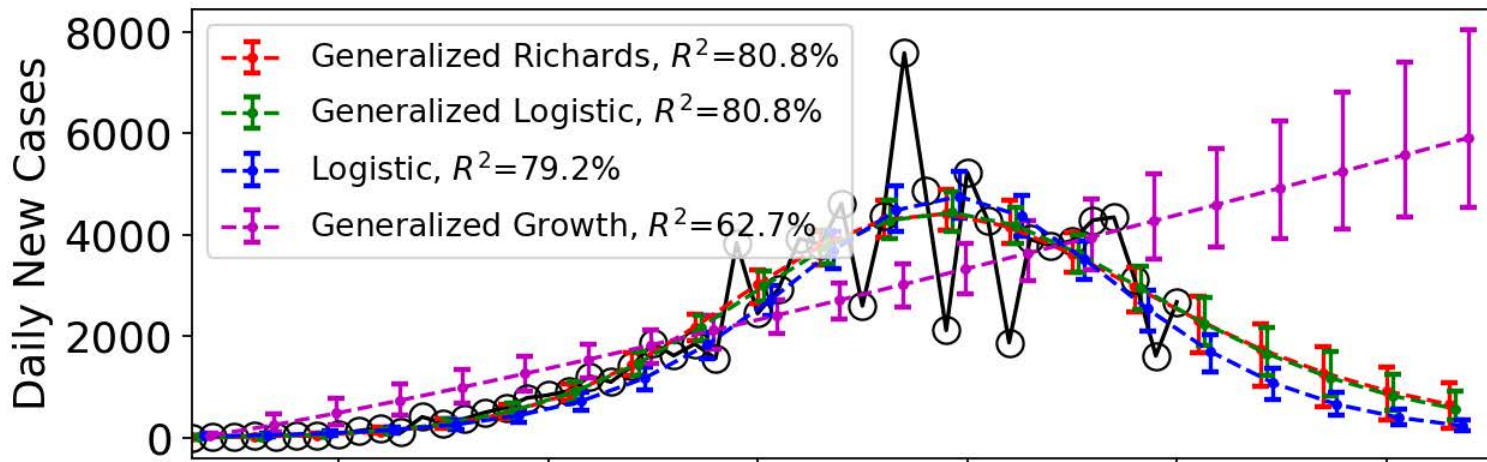
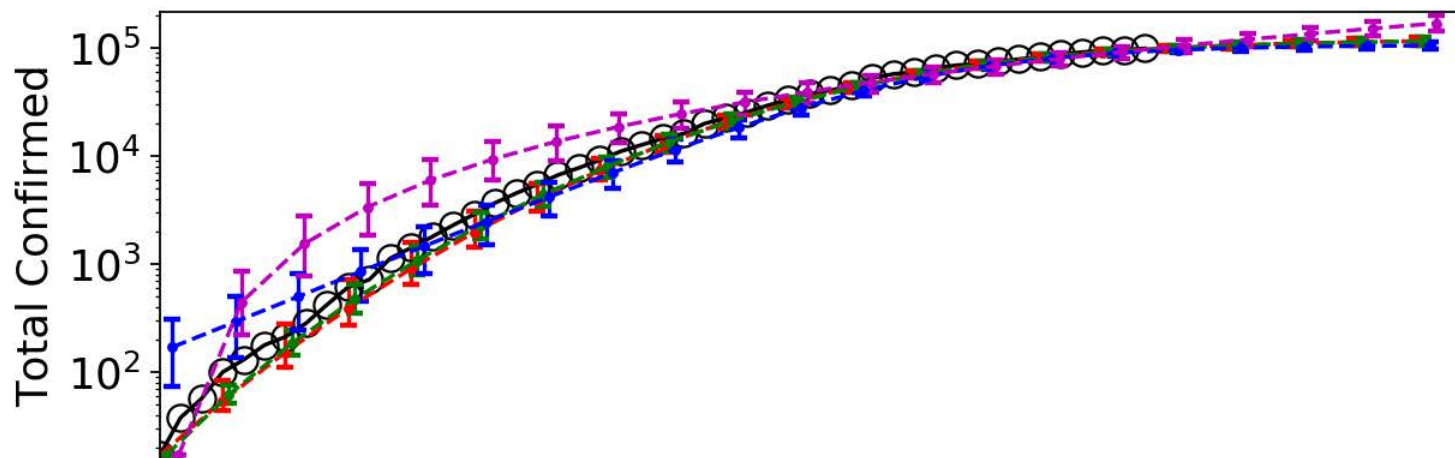


—■— Generalized Logistic, $R^2=88.6\%$
—■— Logistic, $R^2=88.6\%$
—■— Generalized Growth, $R^2=74.3\%$

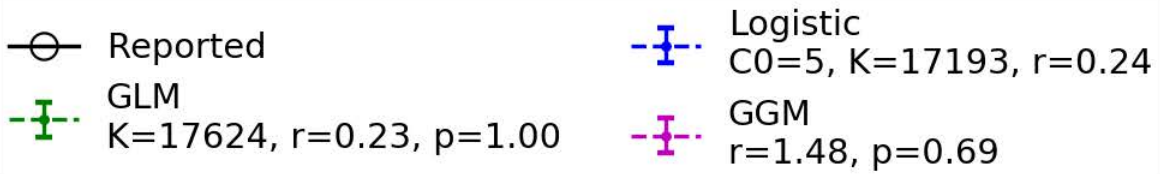
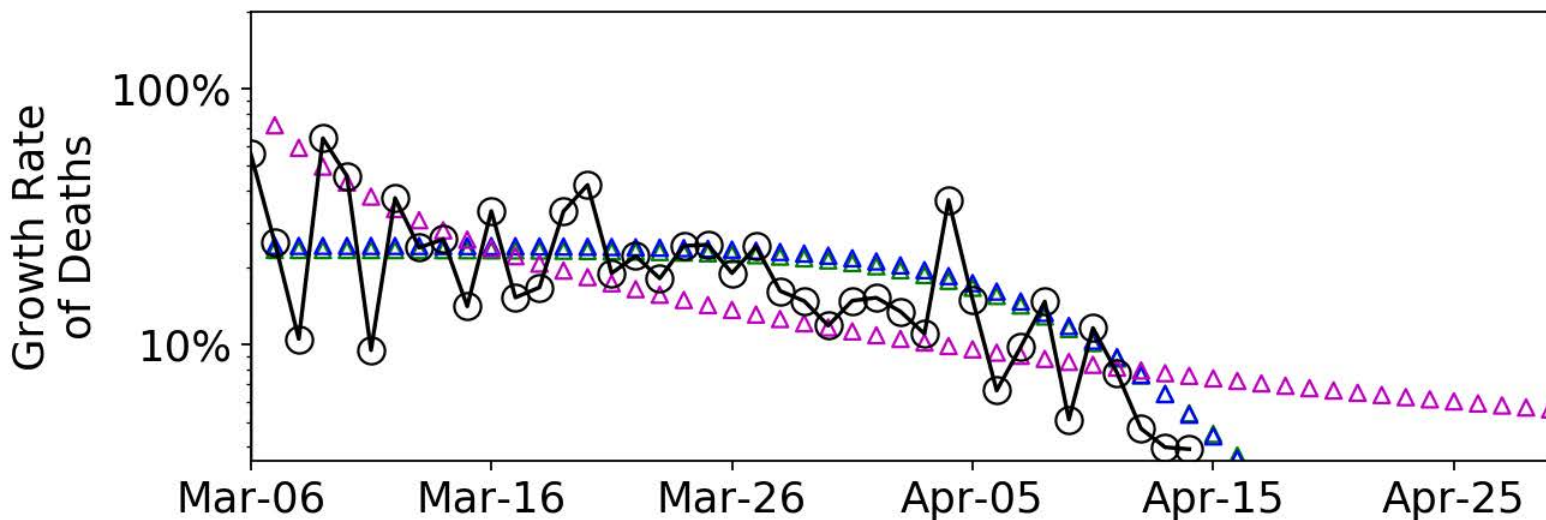
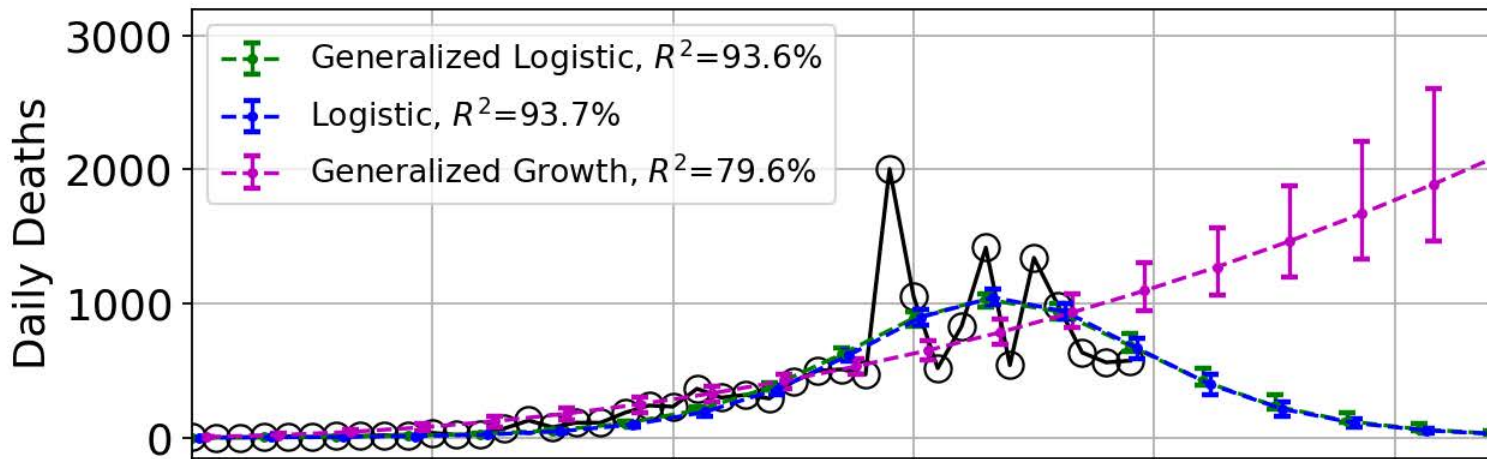
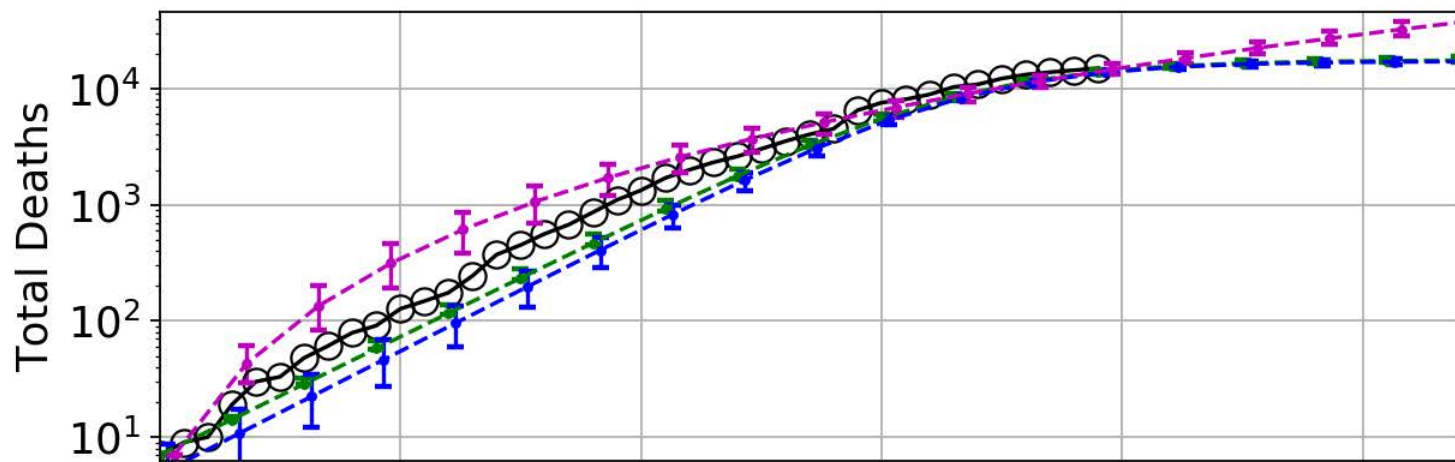


—○— Reported	—■— Logistic C0=120, K=3836, r=0.21
—■— GLM K=3871, r=0.21, p=1.00	—■— GGM r=3.72, p=0.51

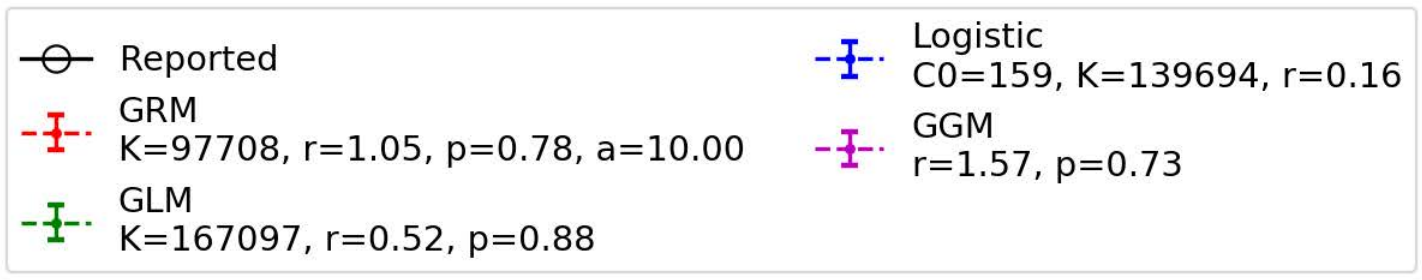
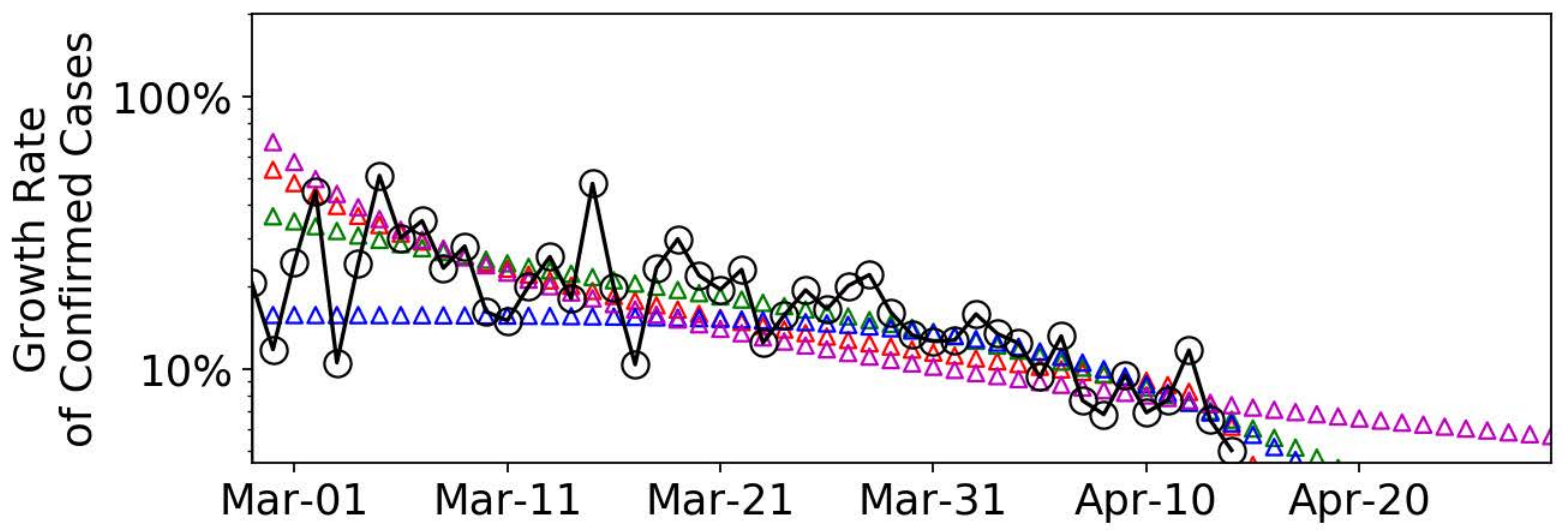
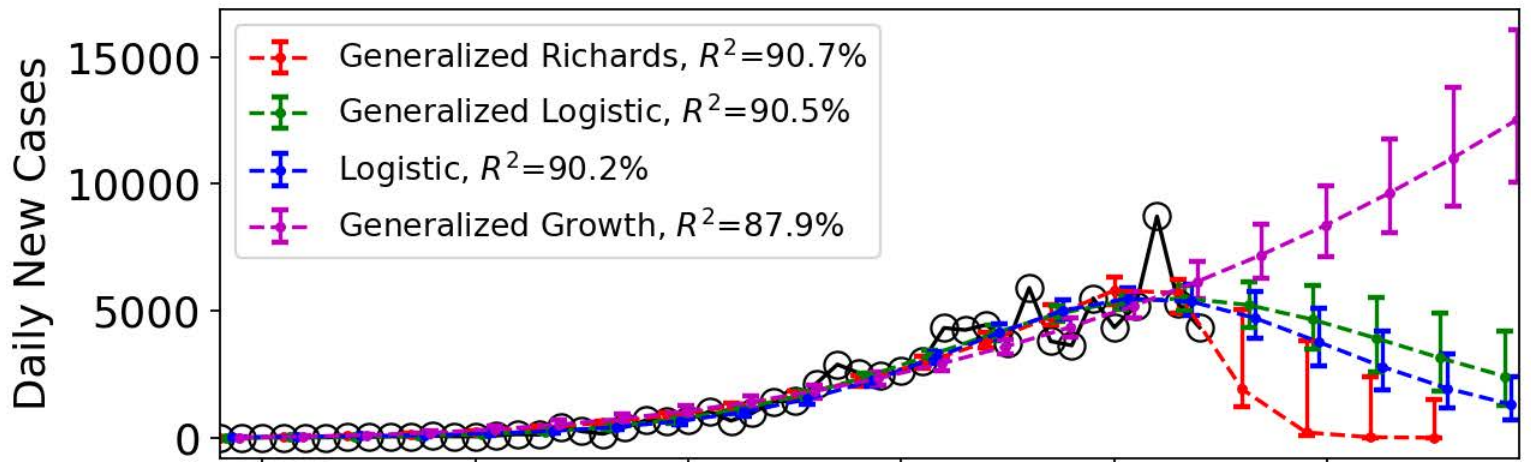
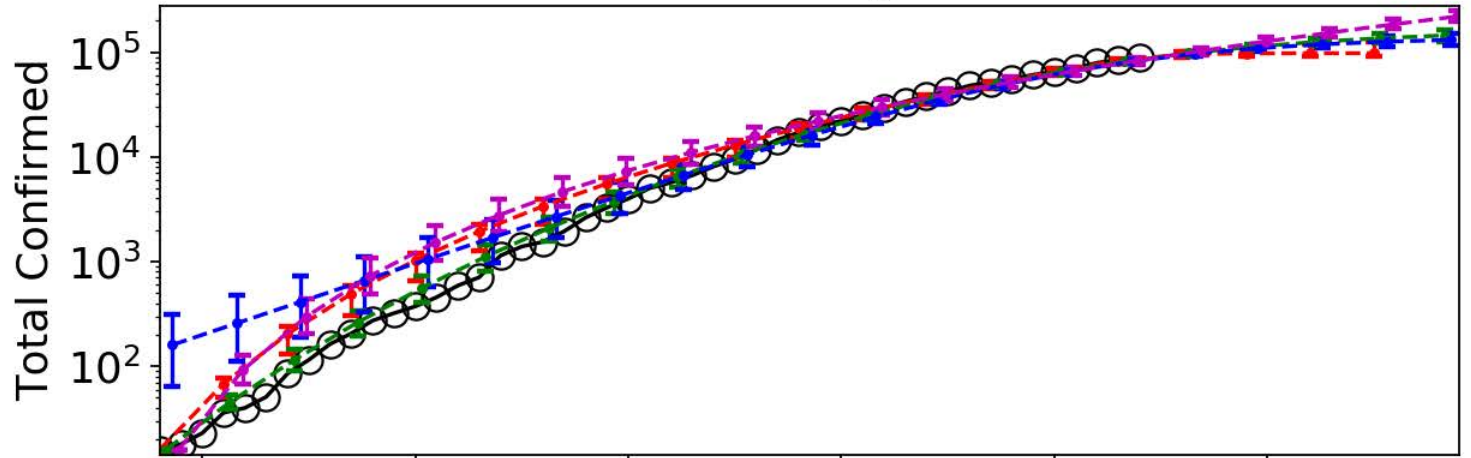
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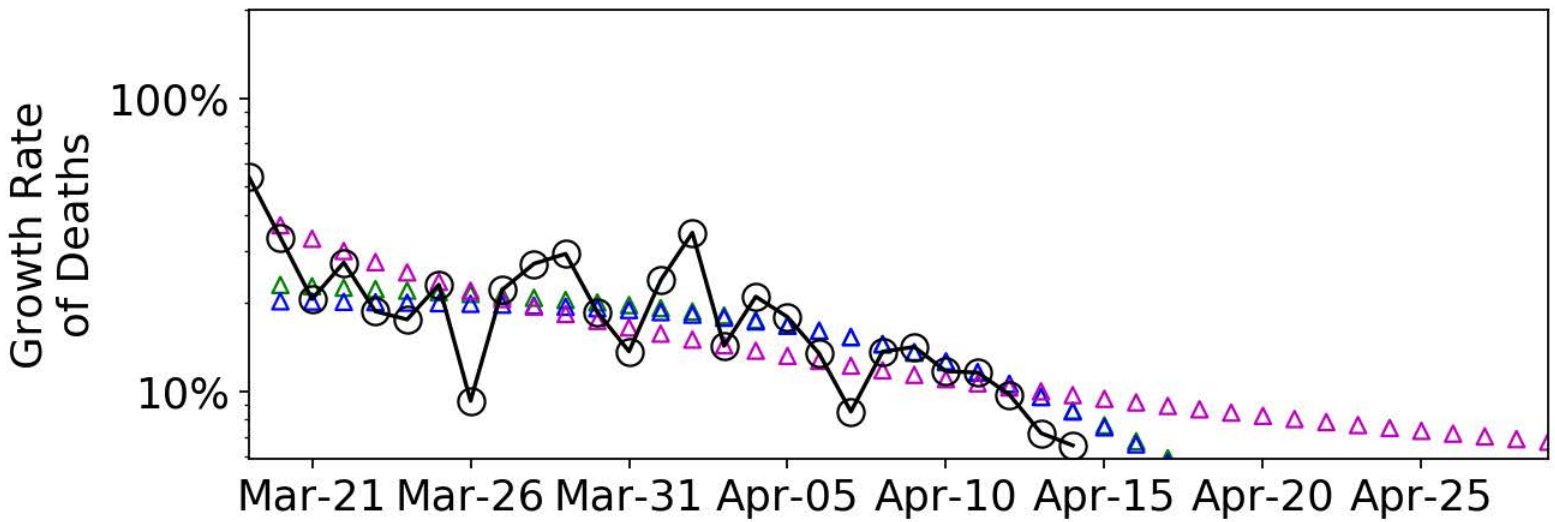
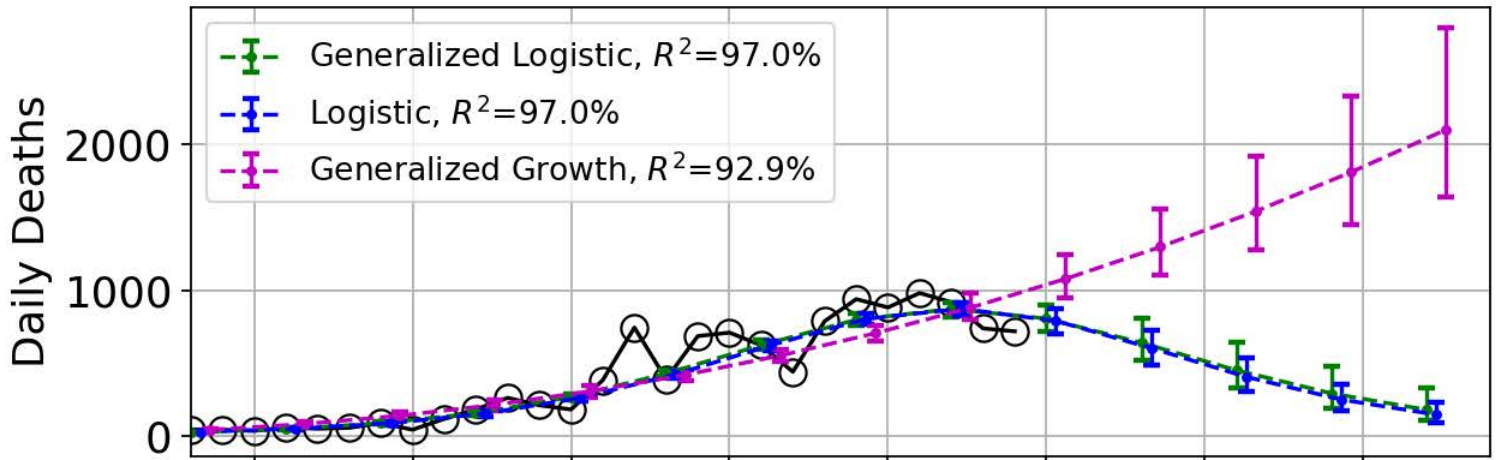
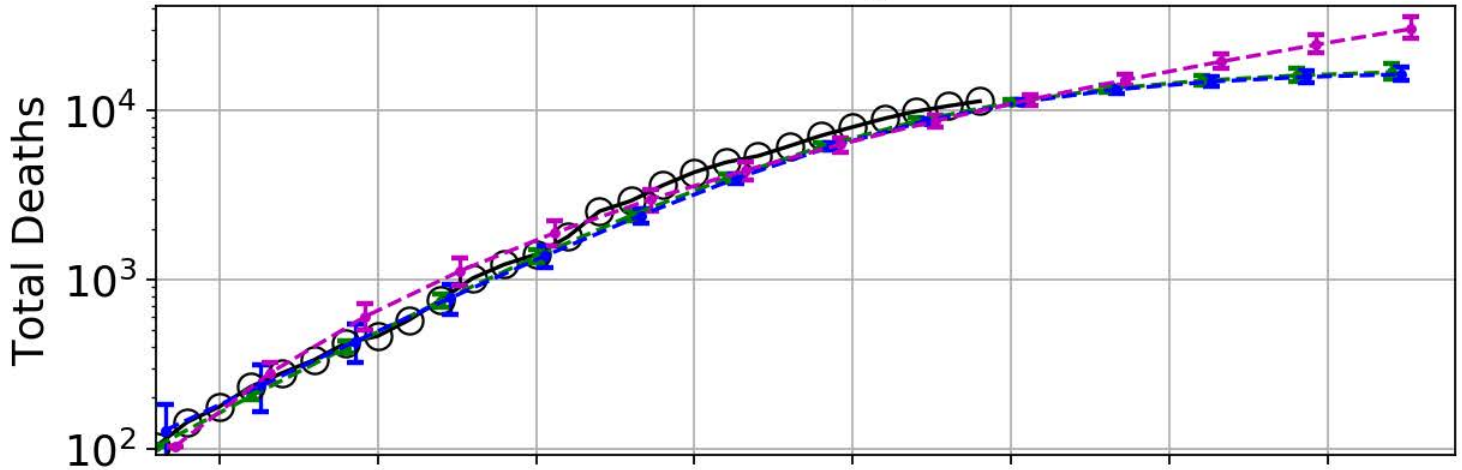
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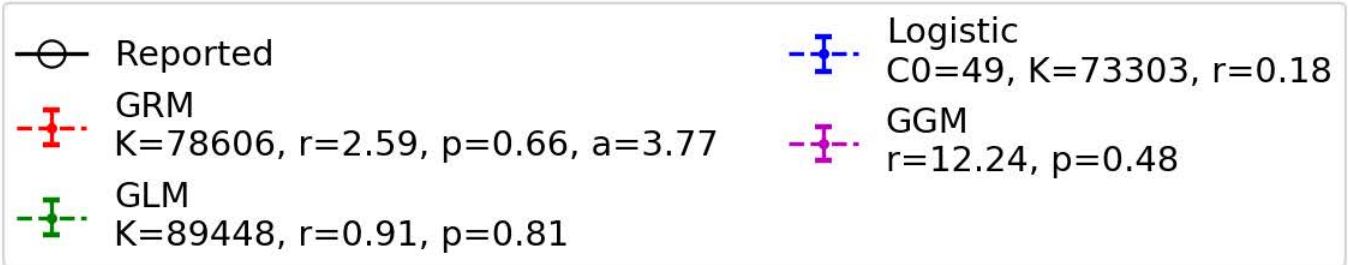
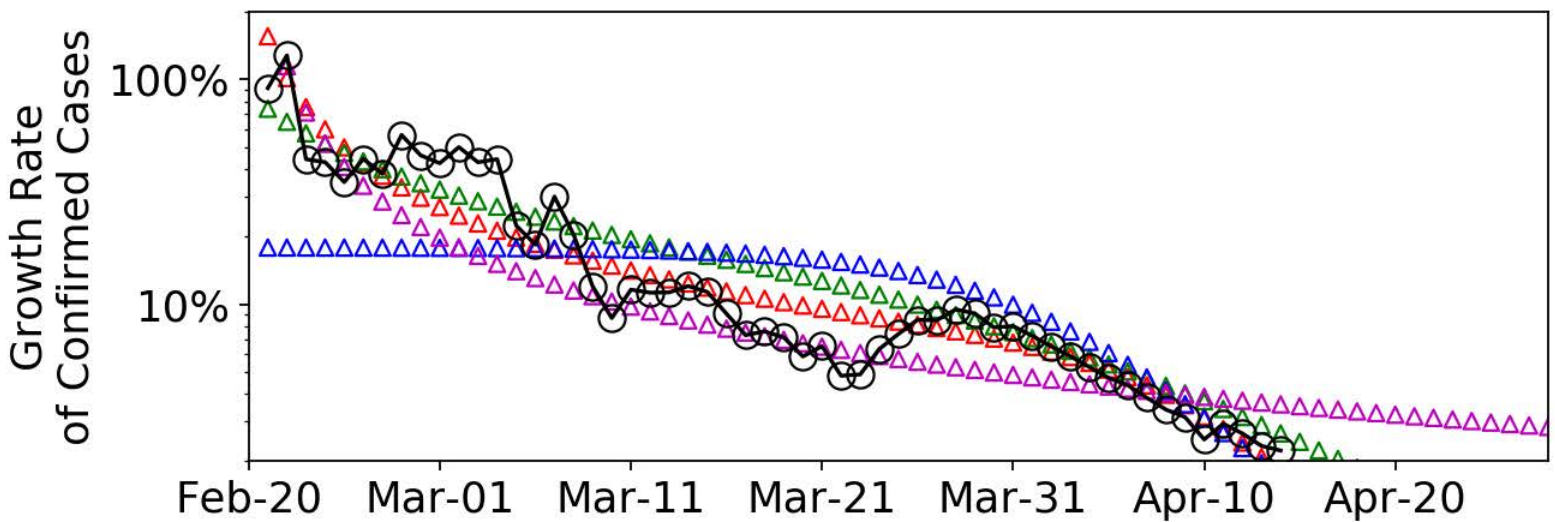
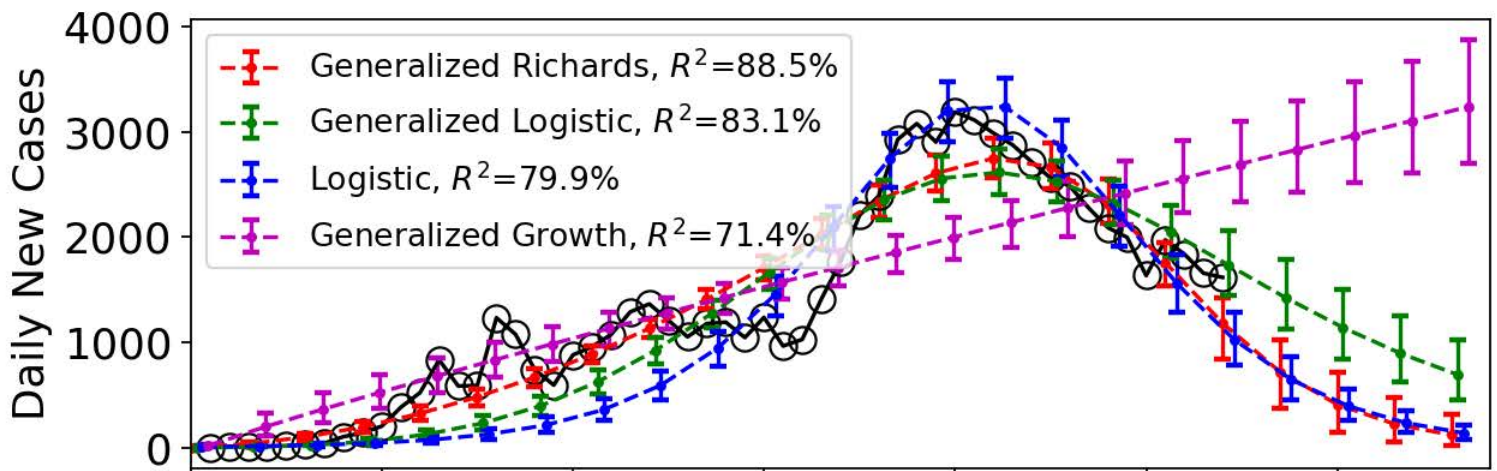
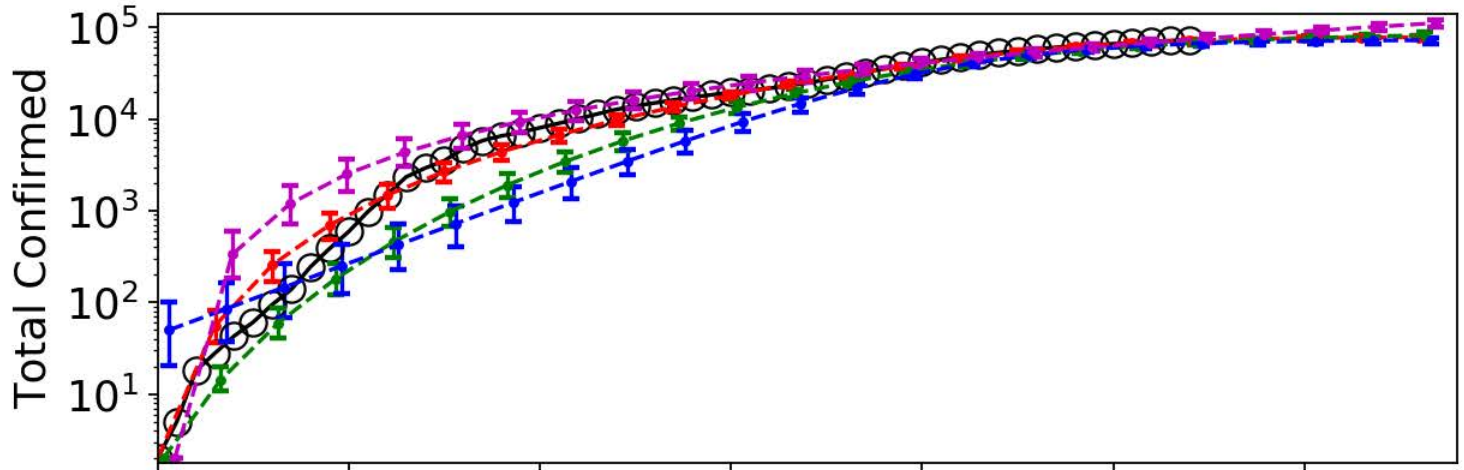
United Kingdom



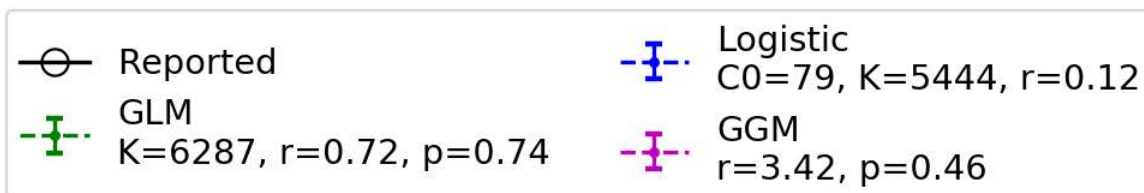
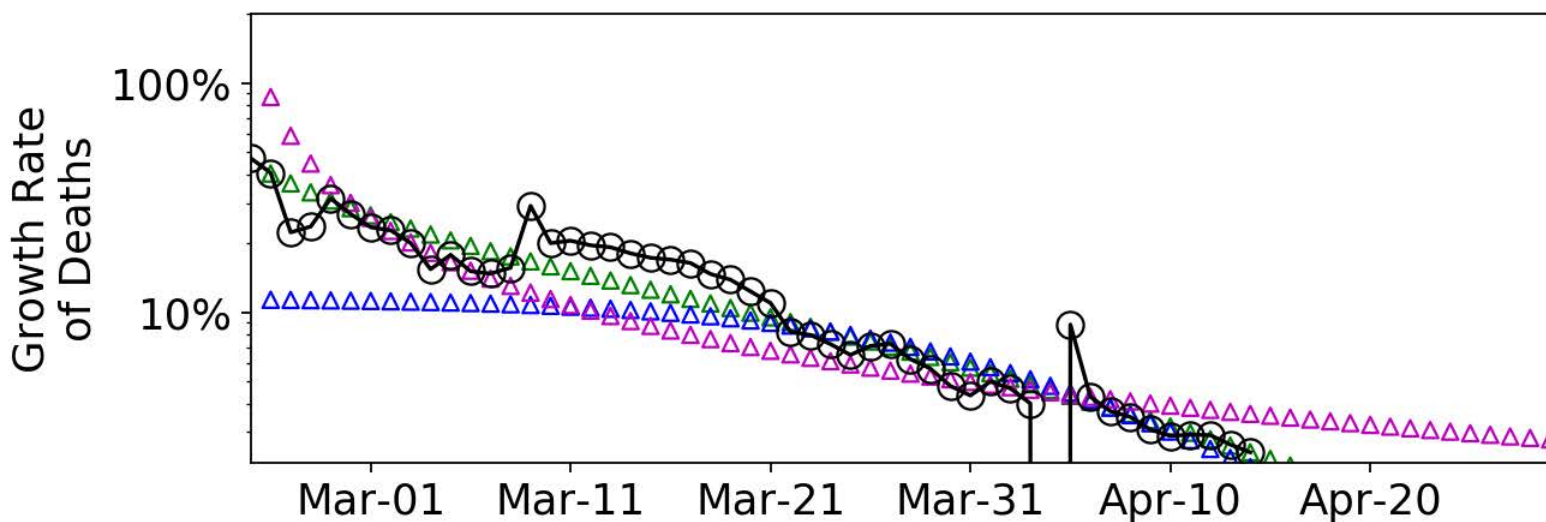
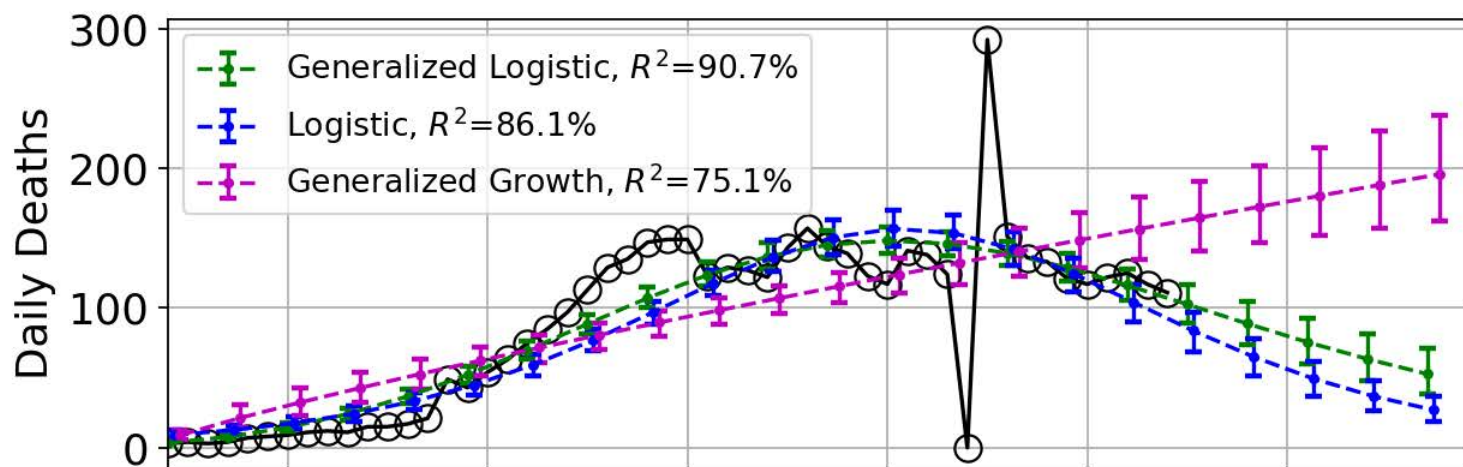
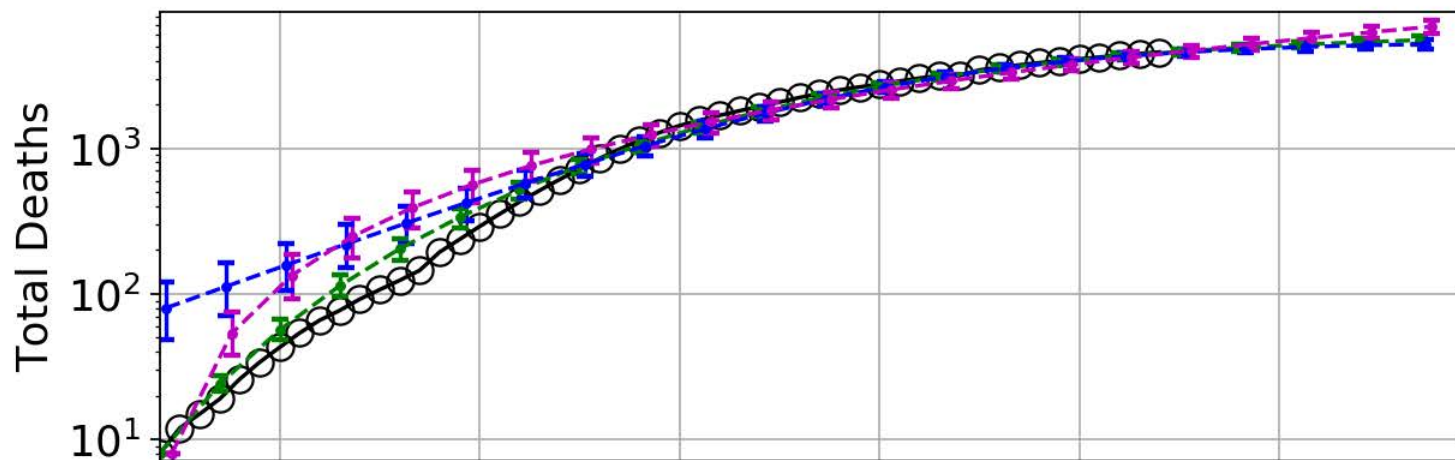
United Kingdom



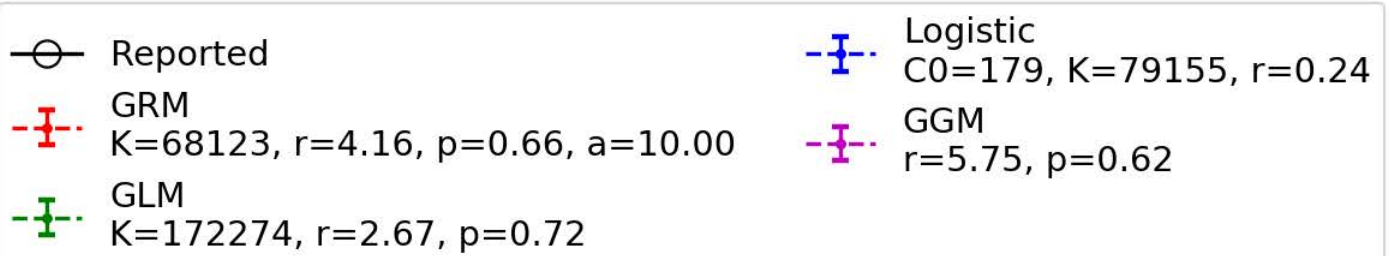
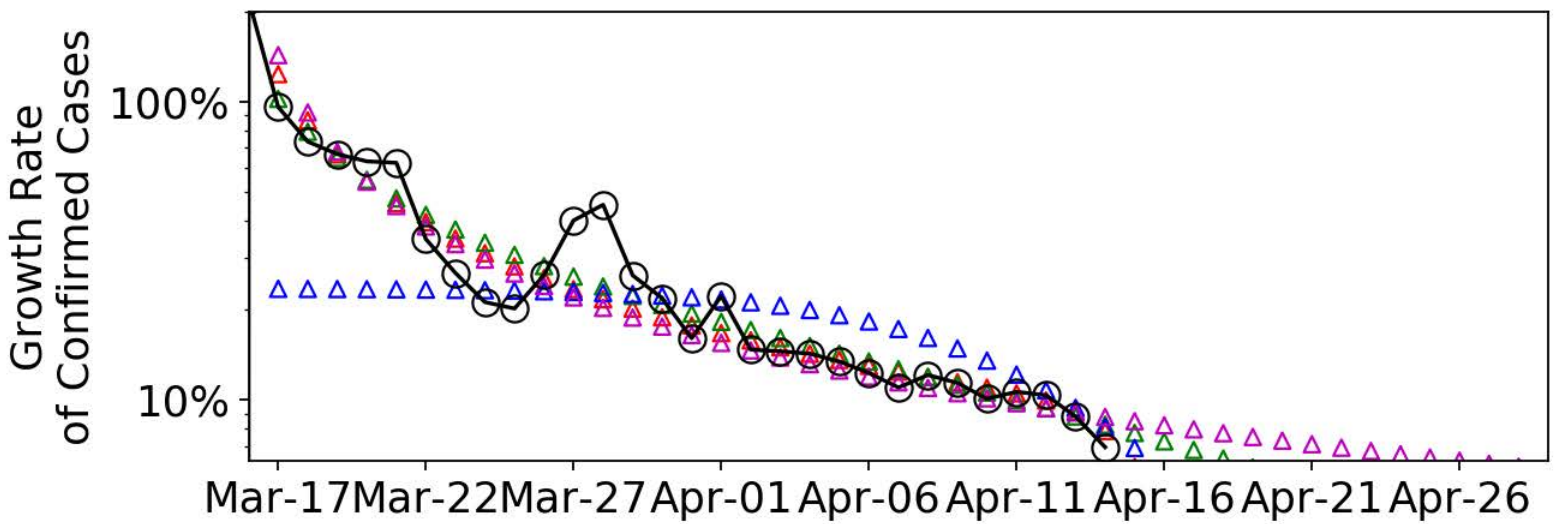
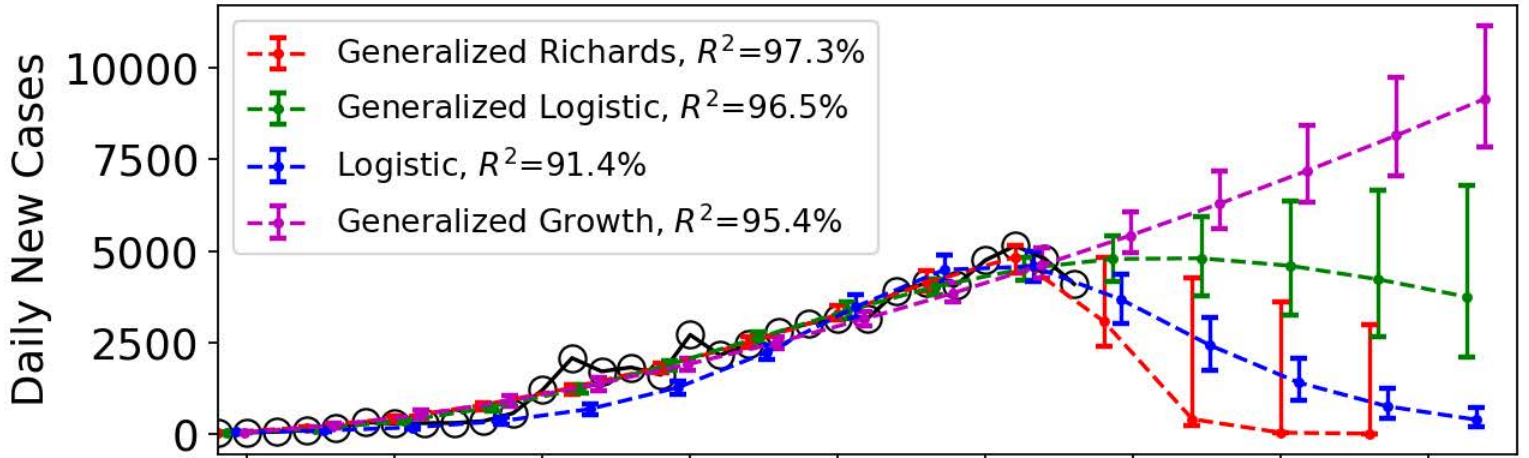
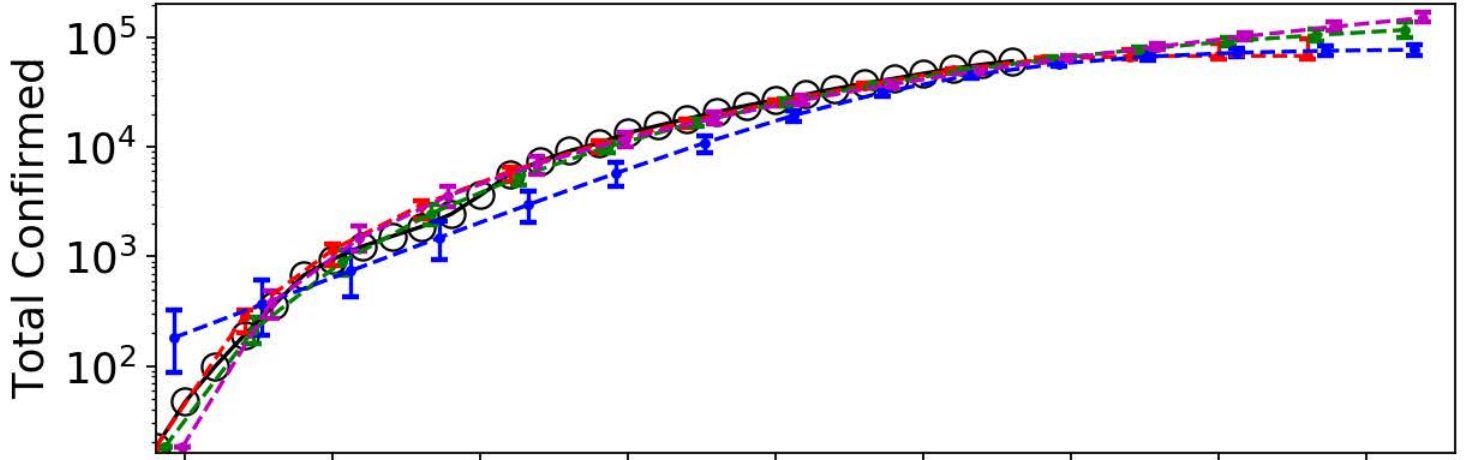
Iran



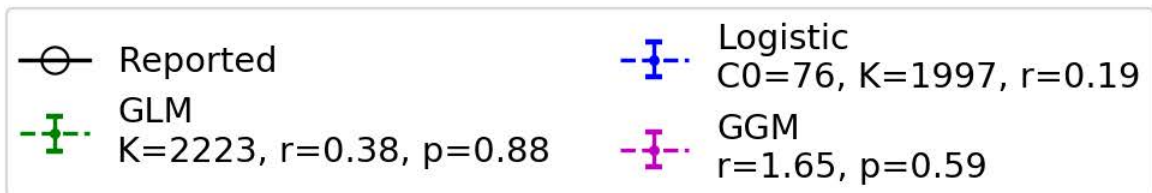
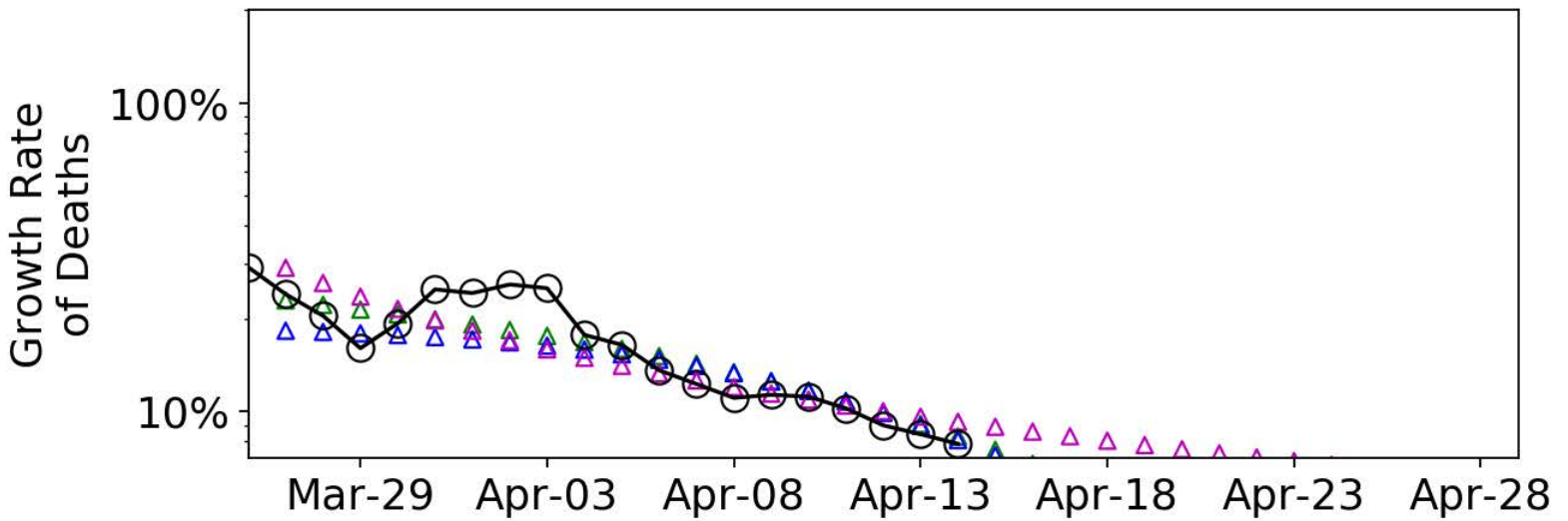
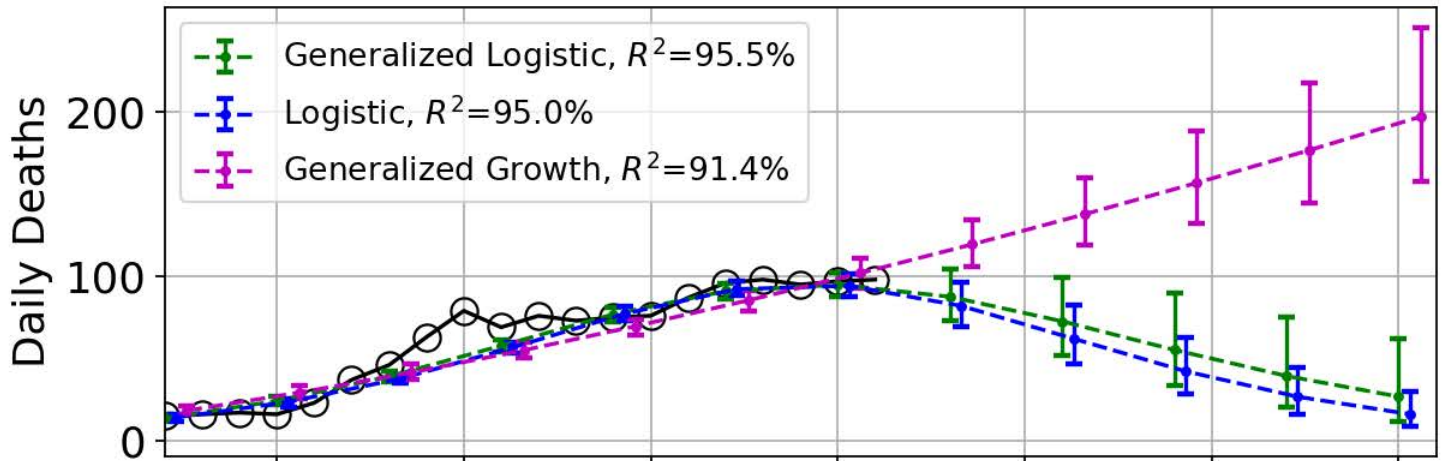
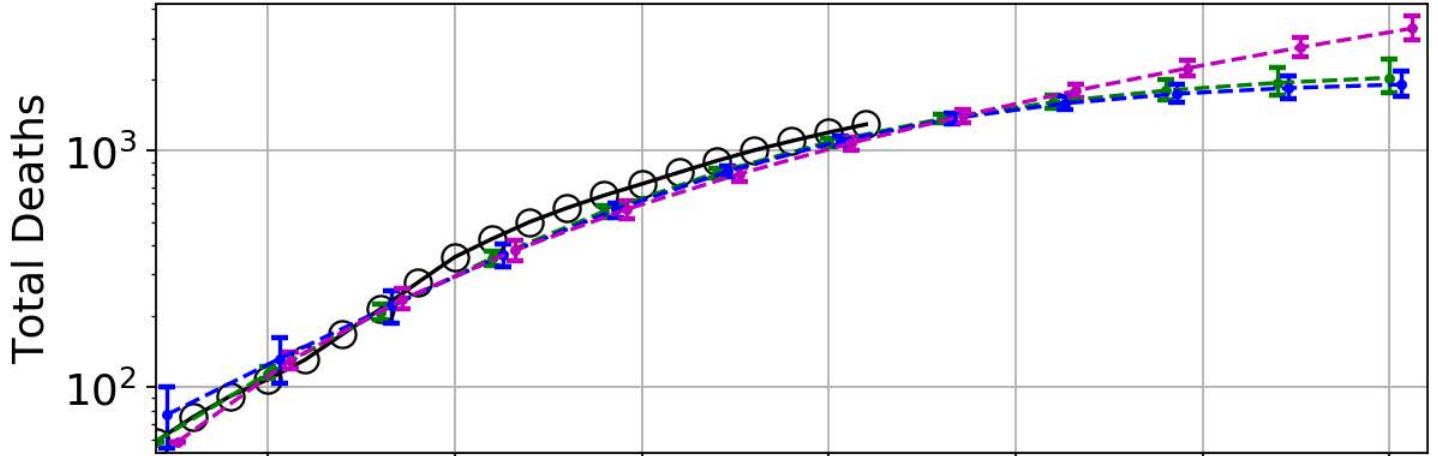
Iran



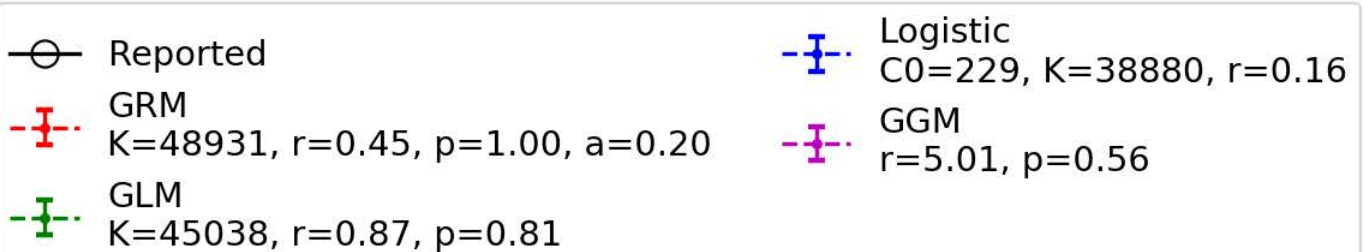
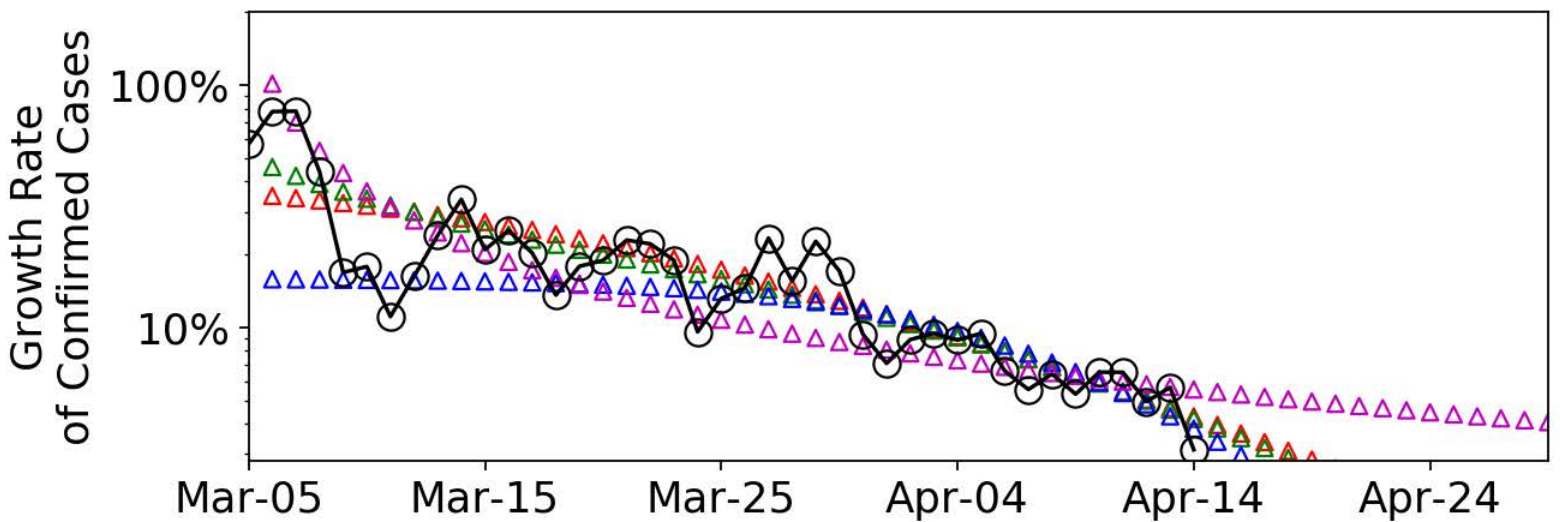
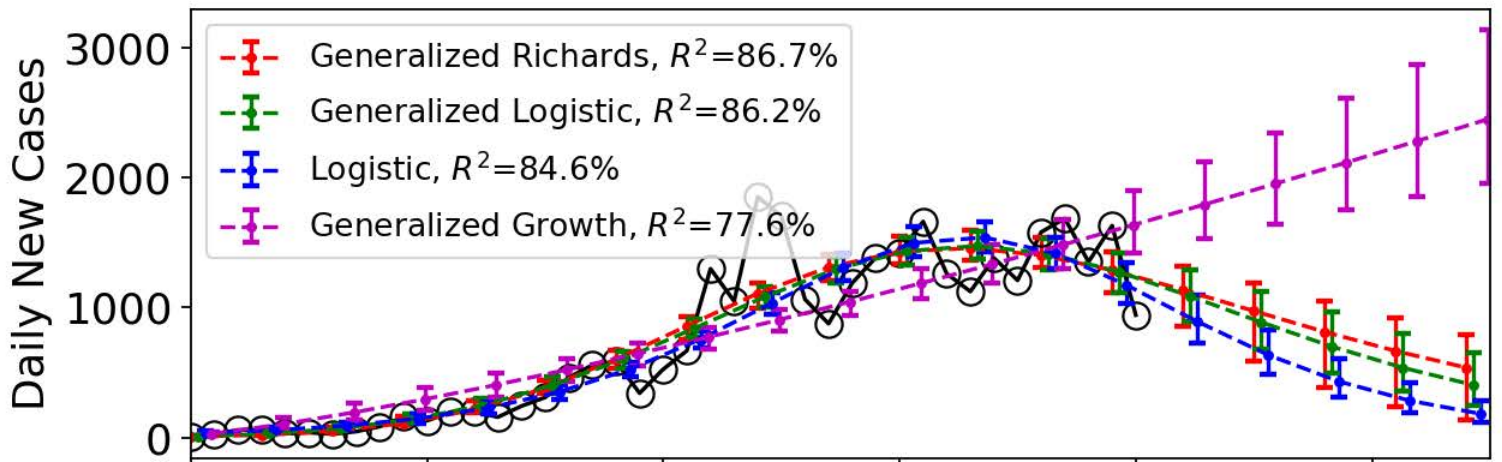
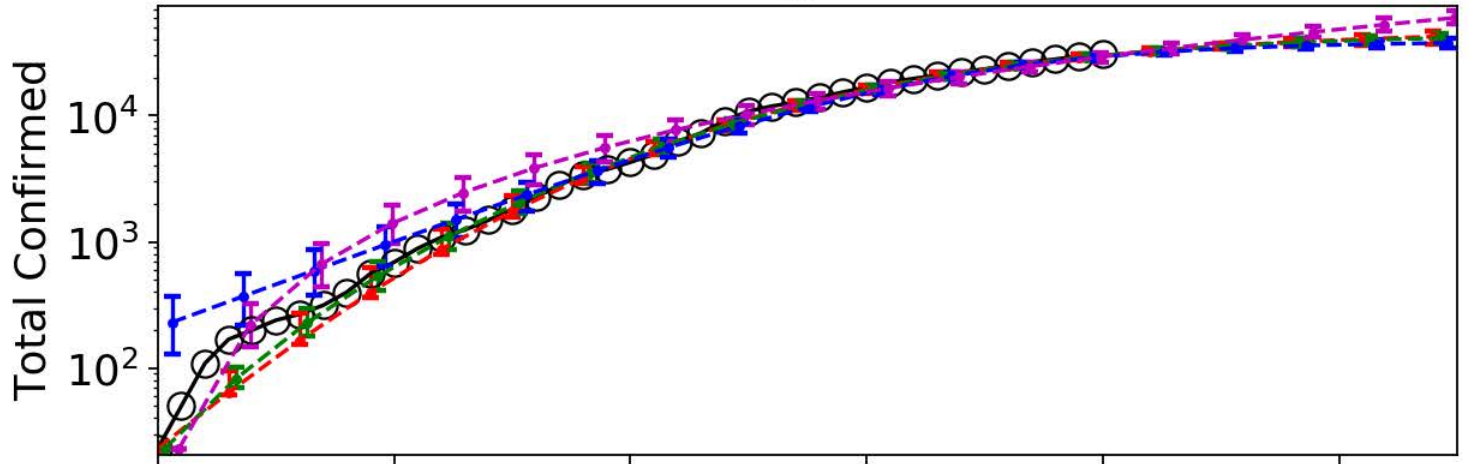
Turkey



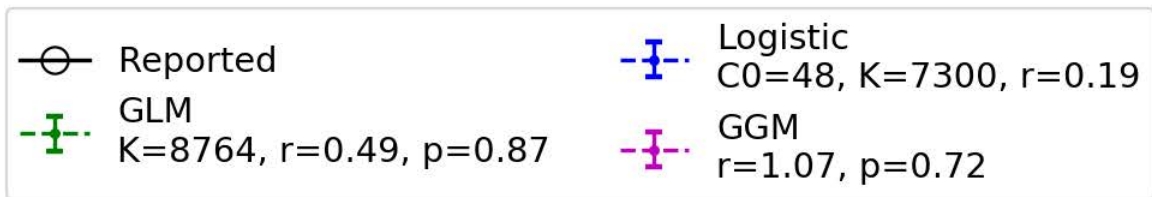
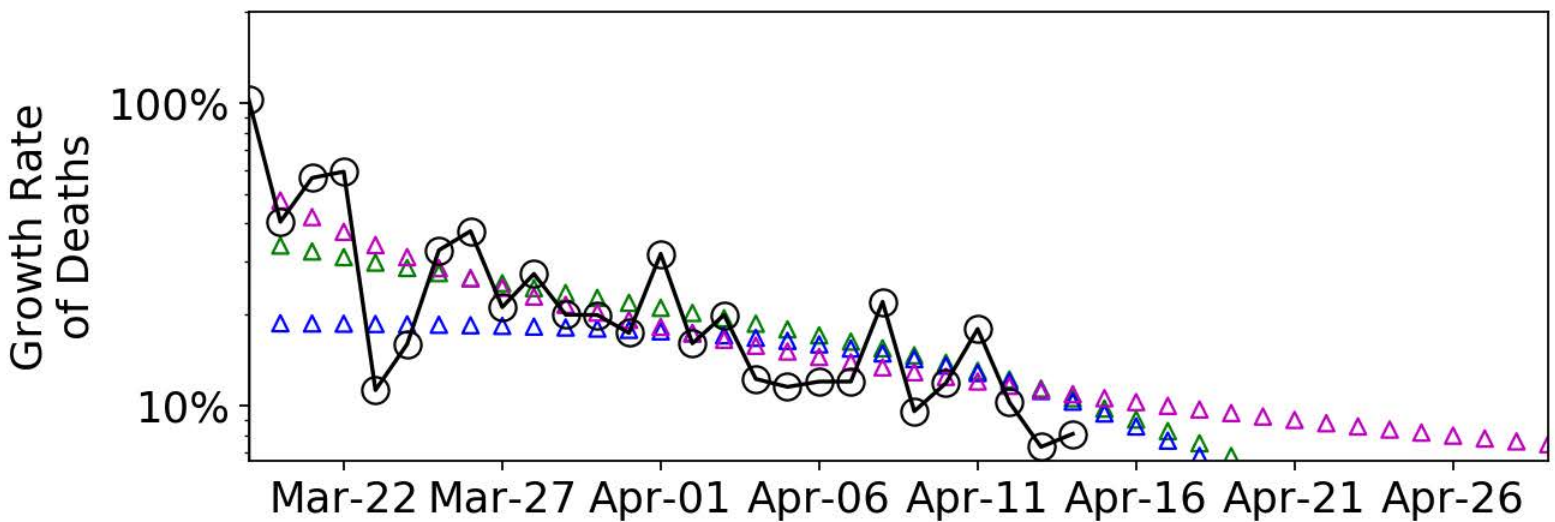
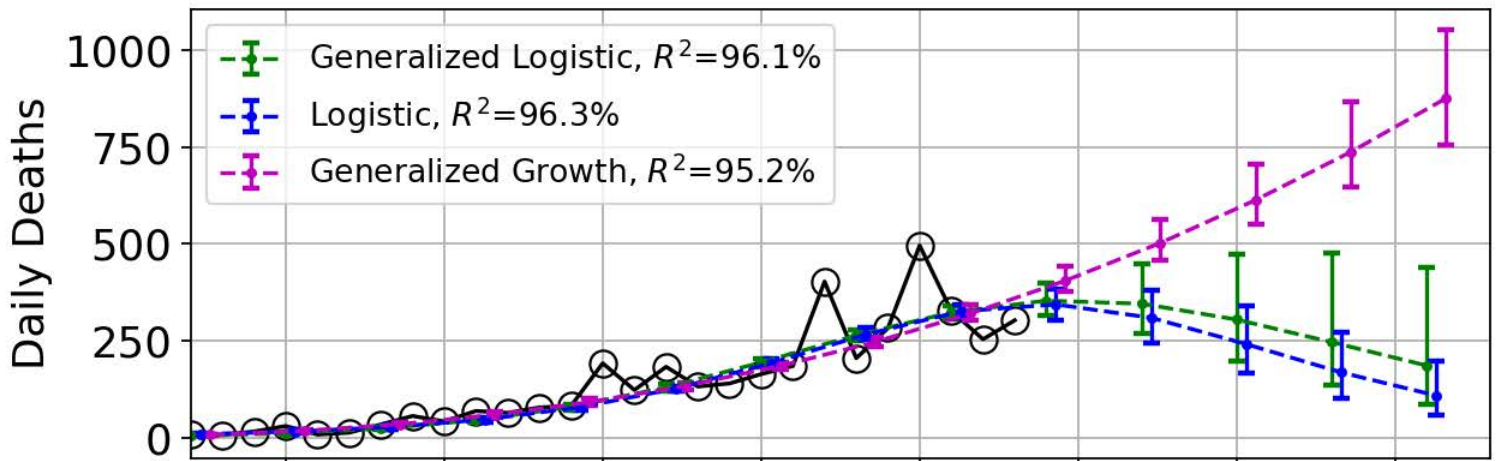
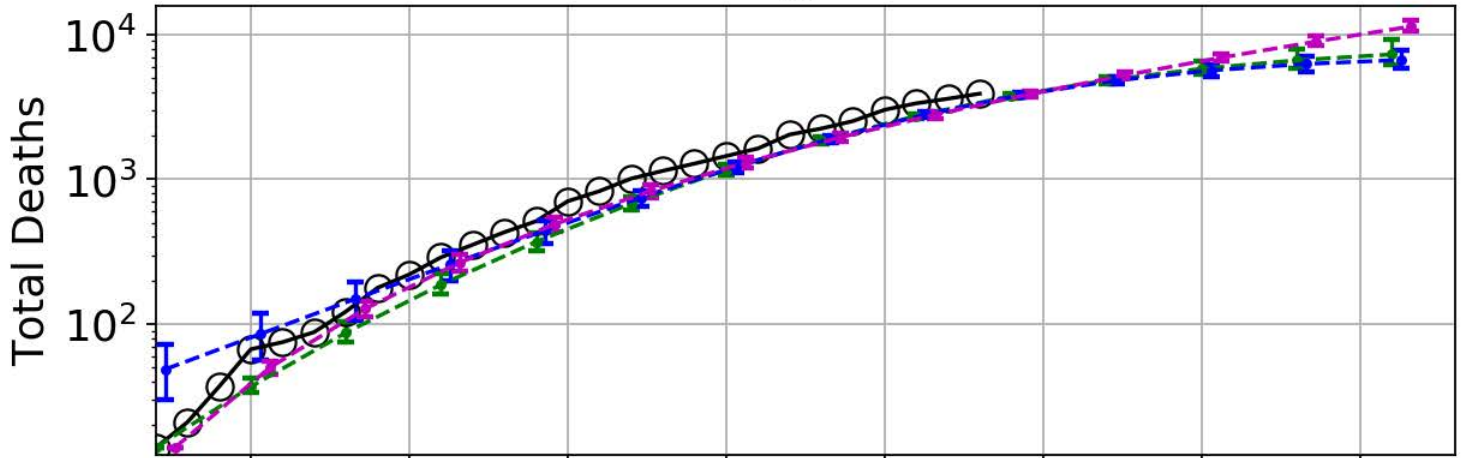
Turkey



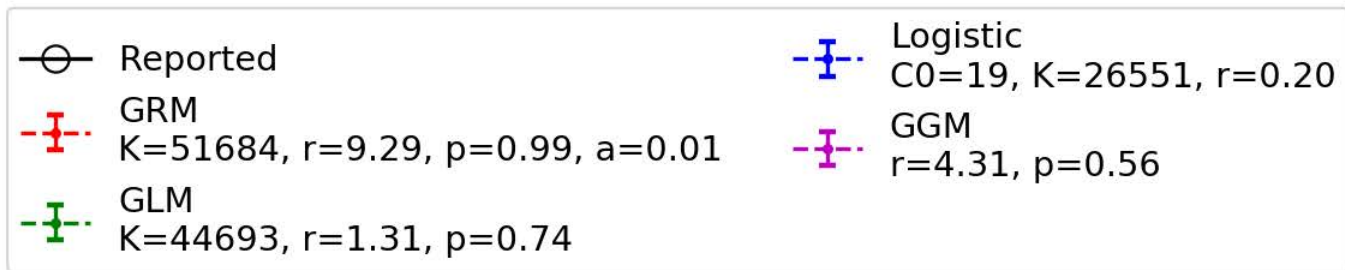
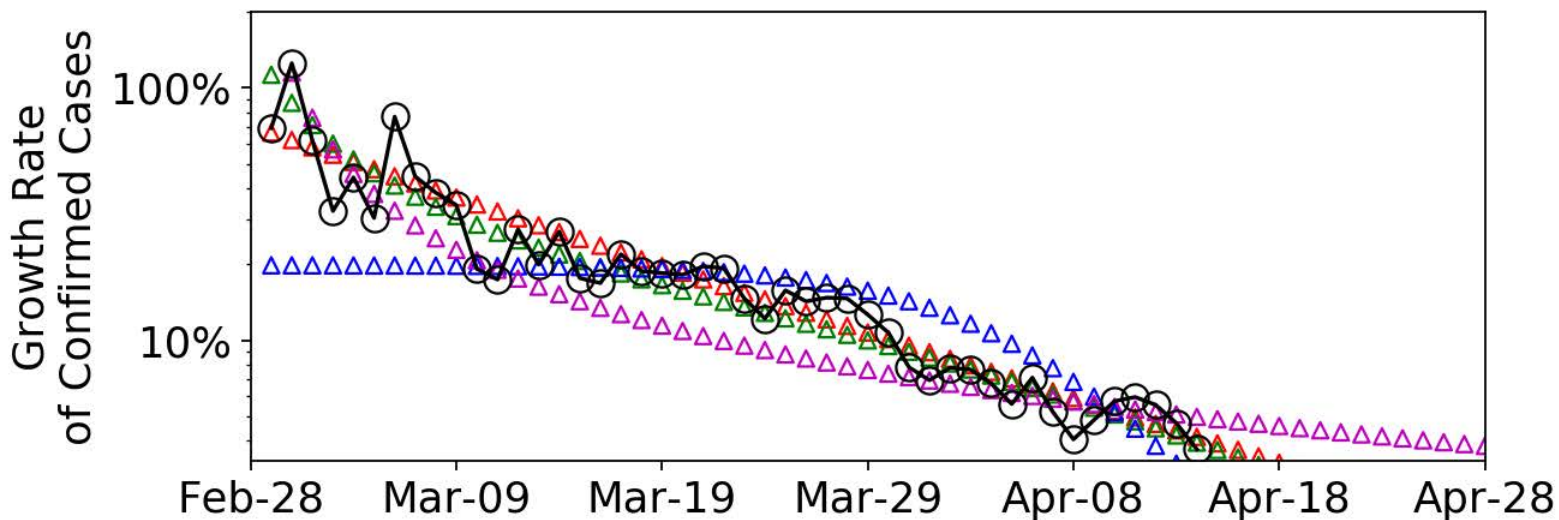
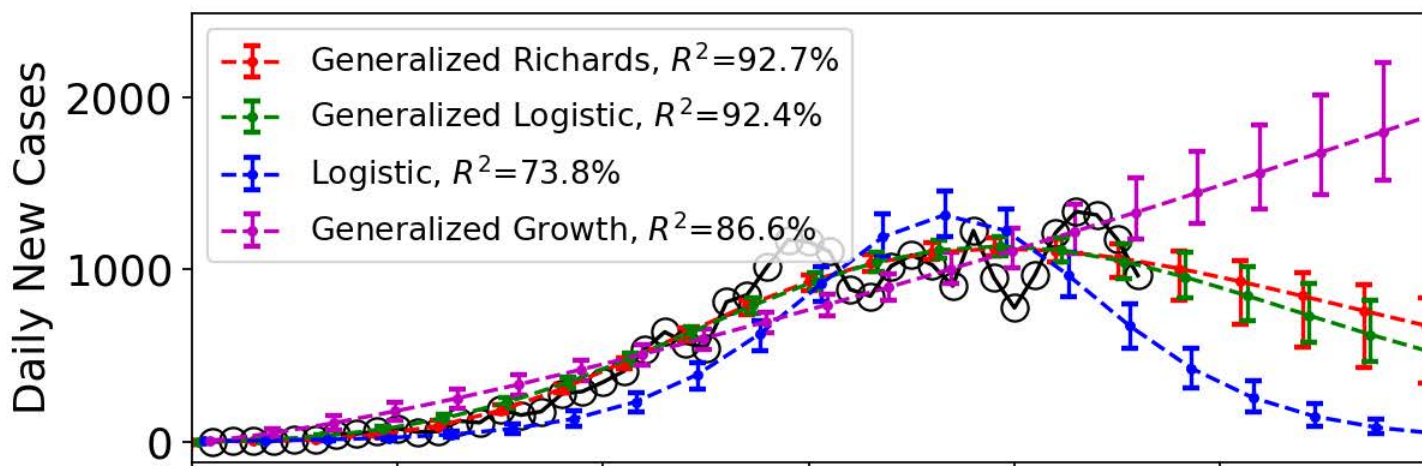
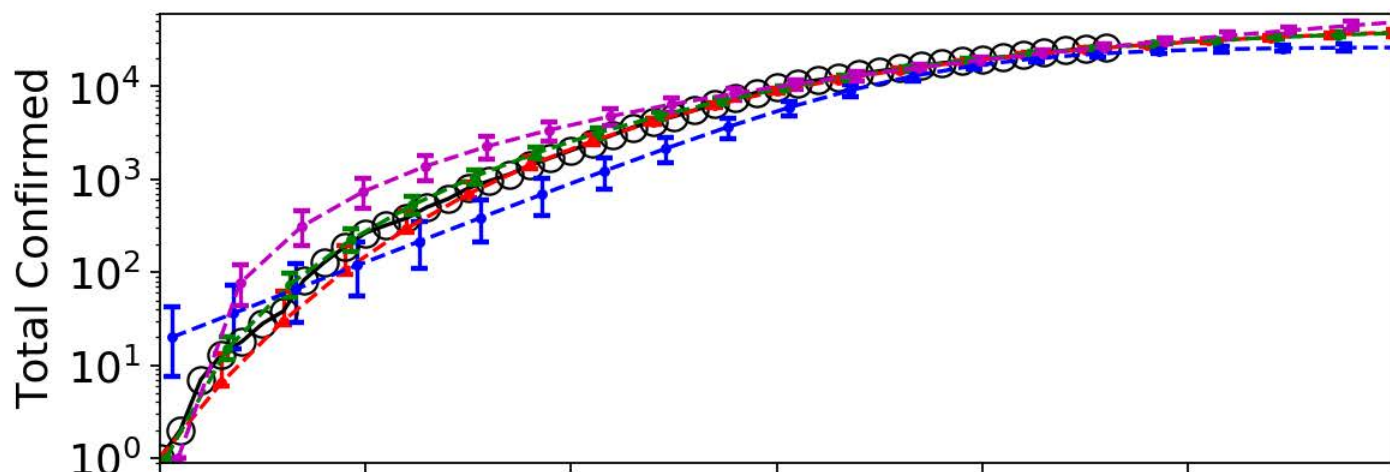
Belgium



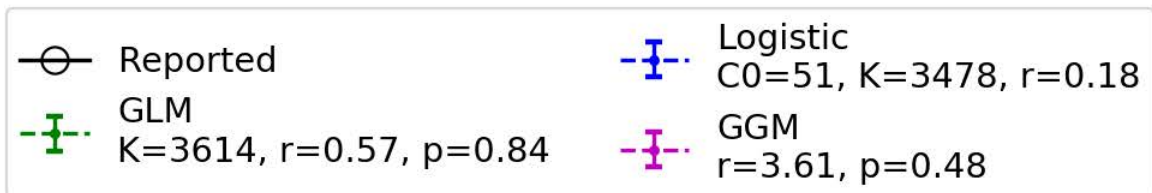
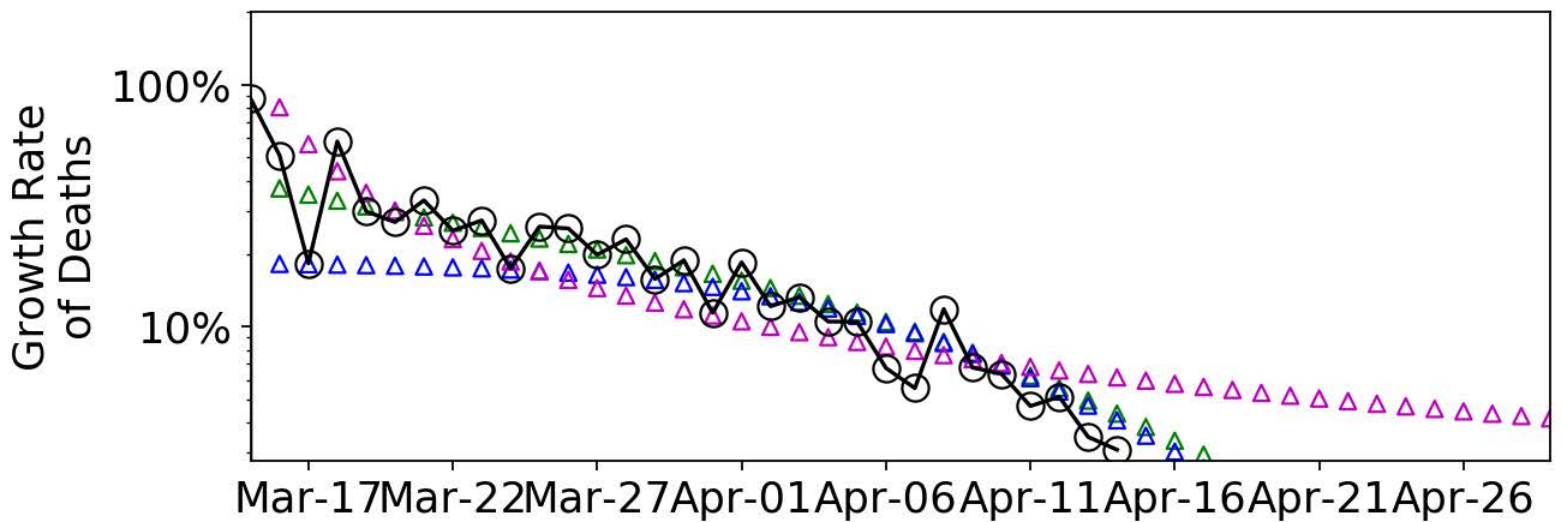
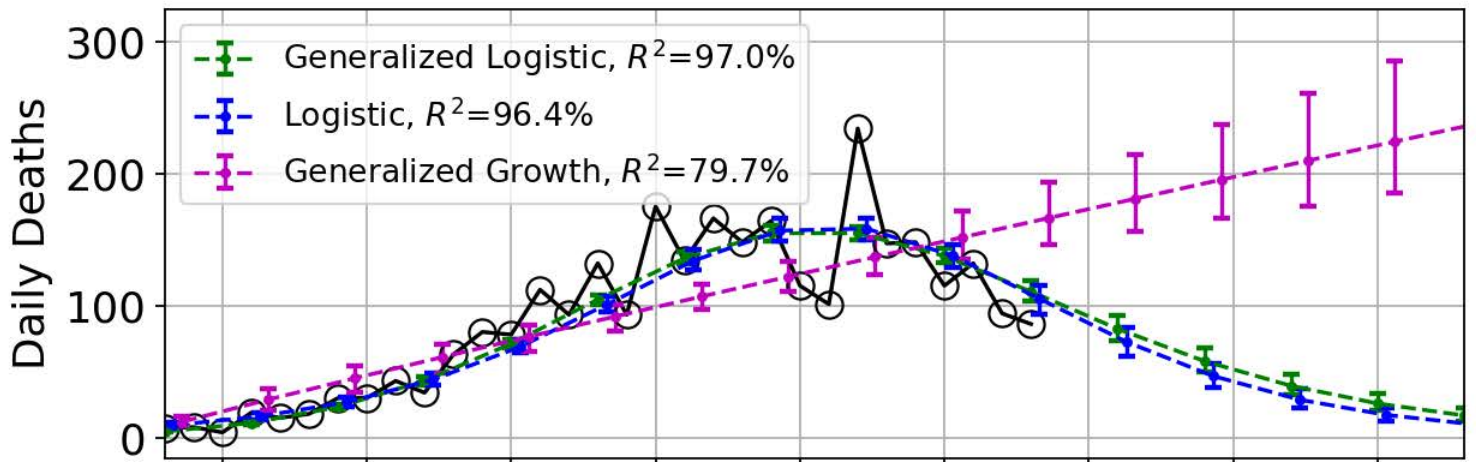
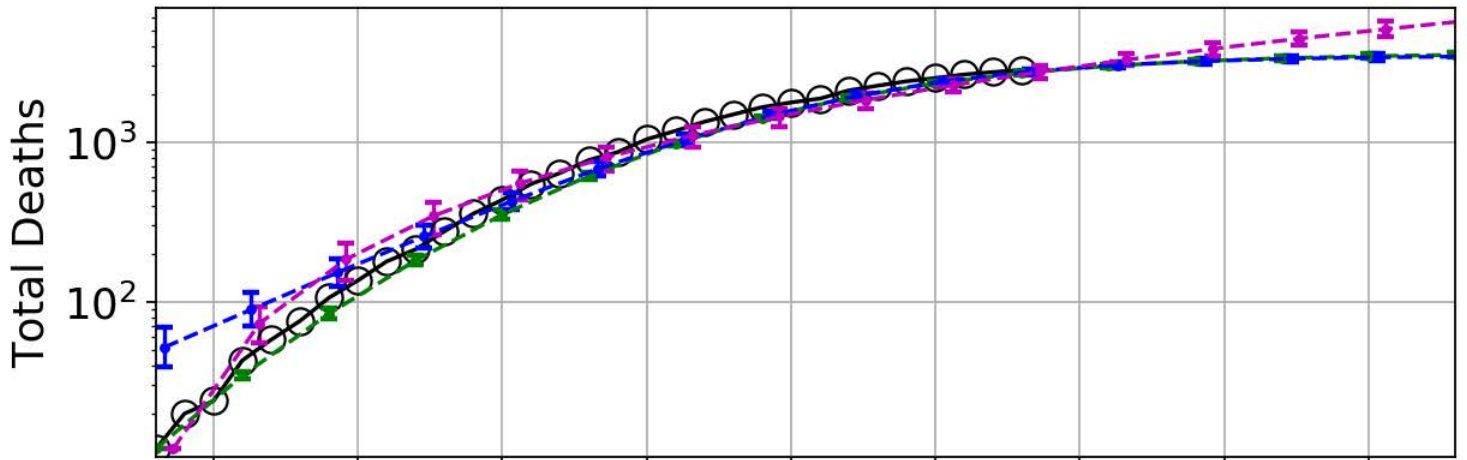
Belgium



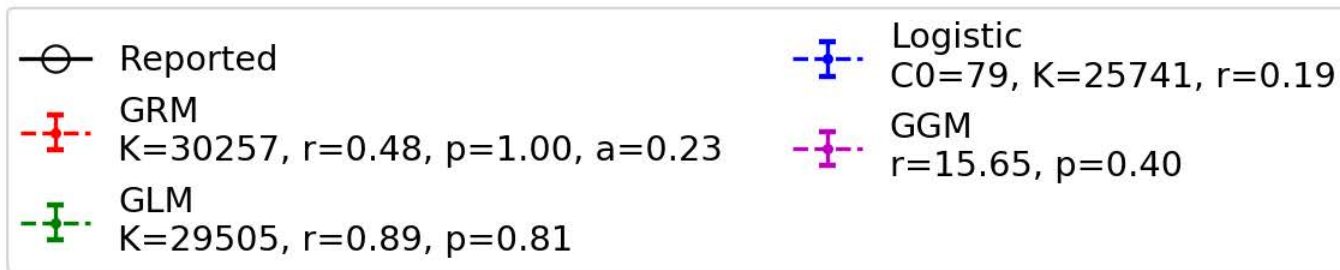
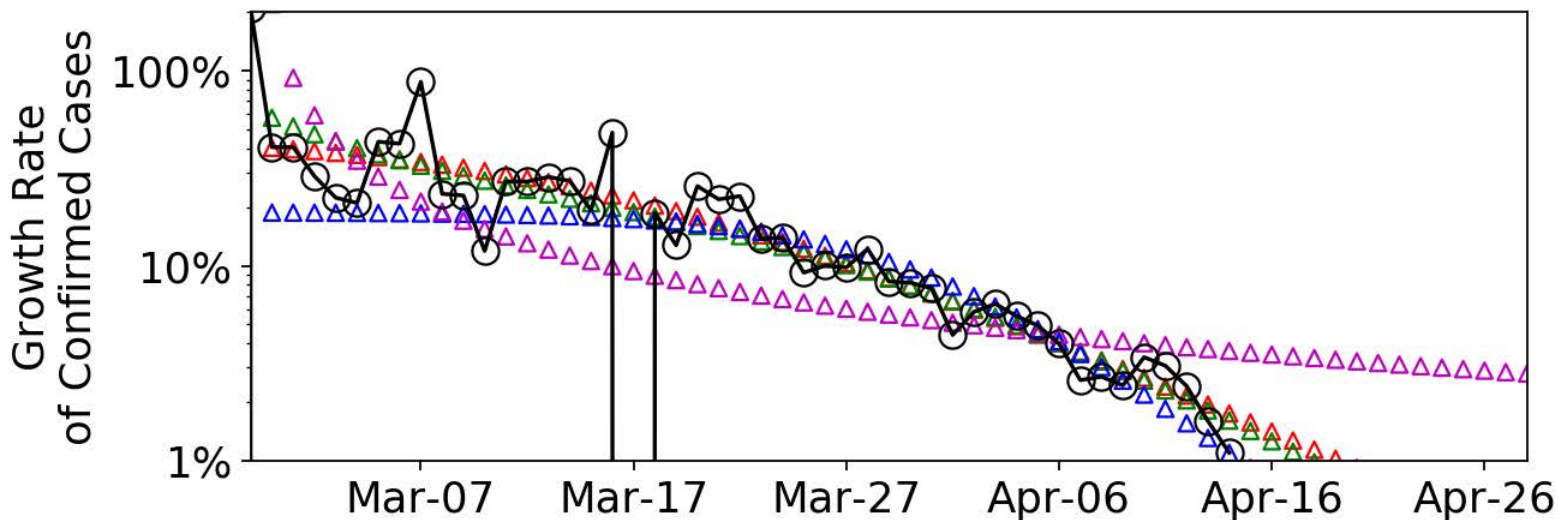
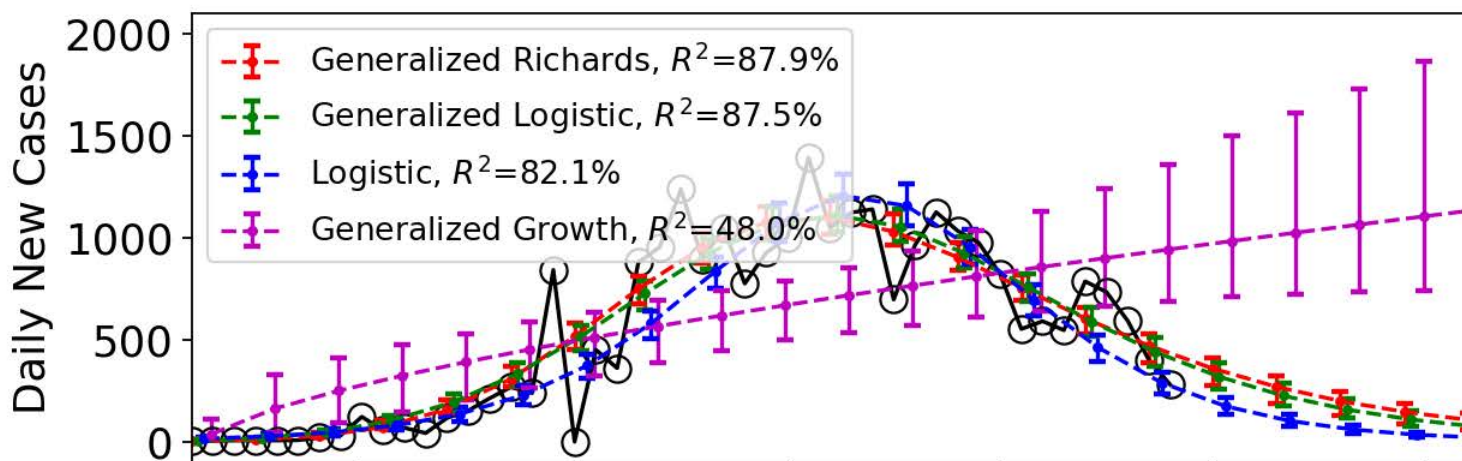
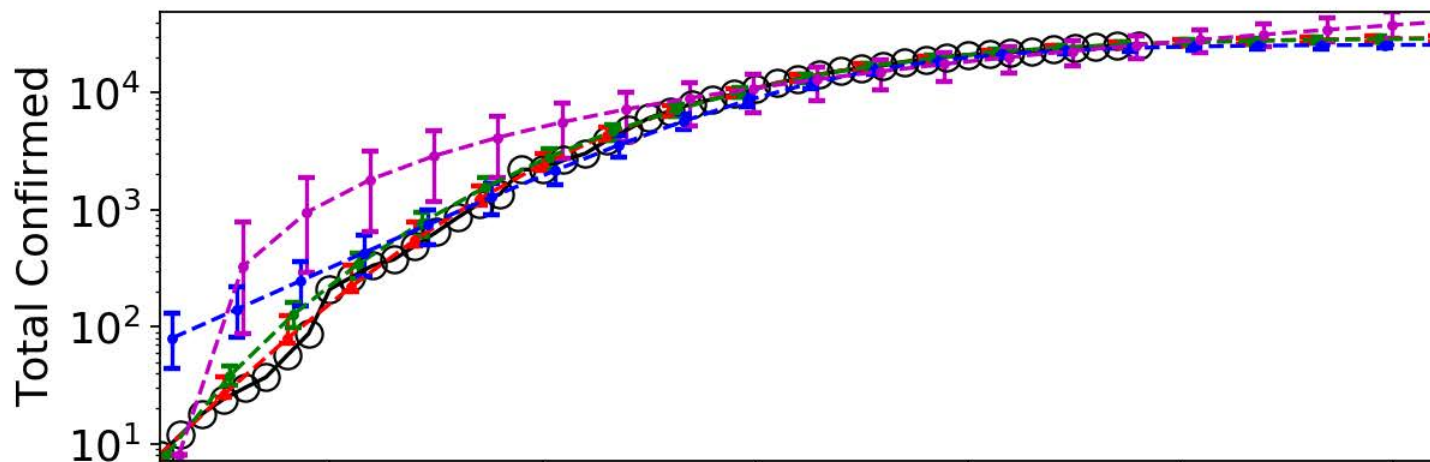
Netherlands



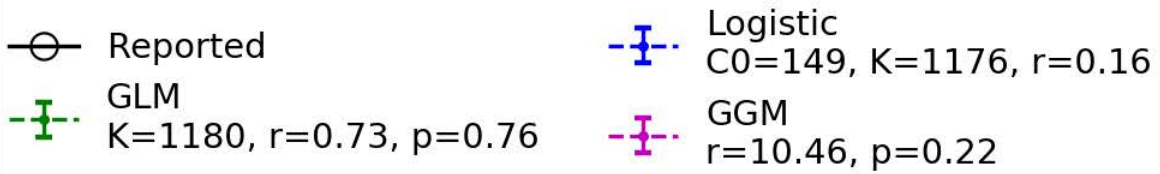
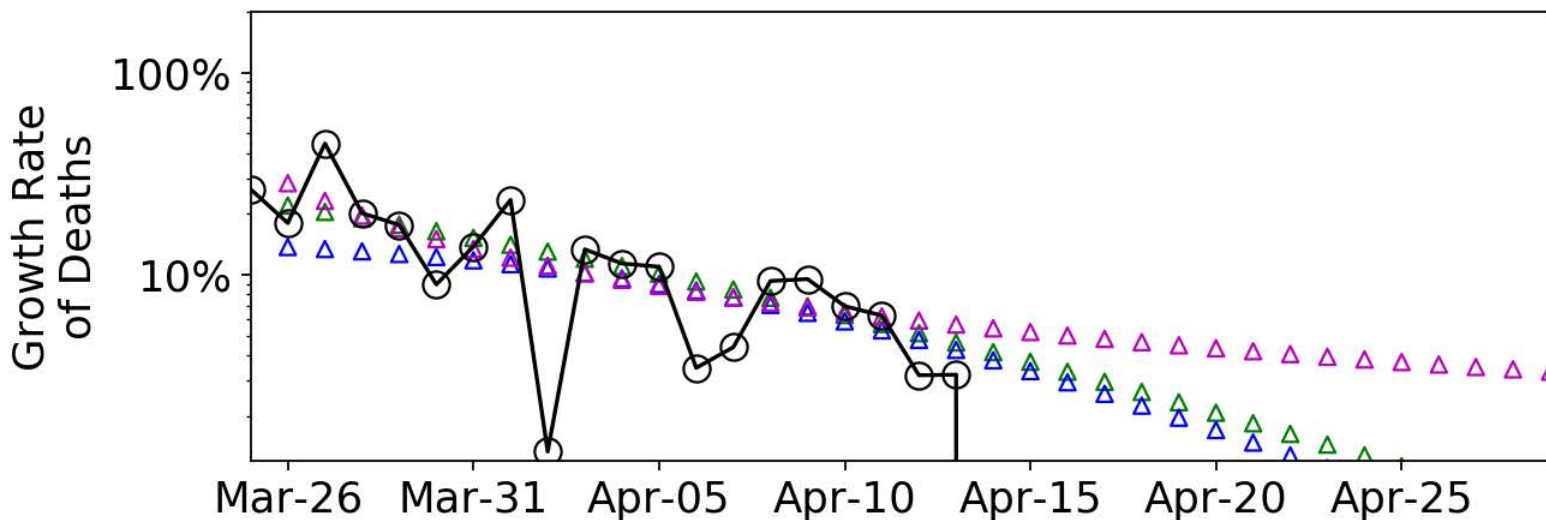
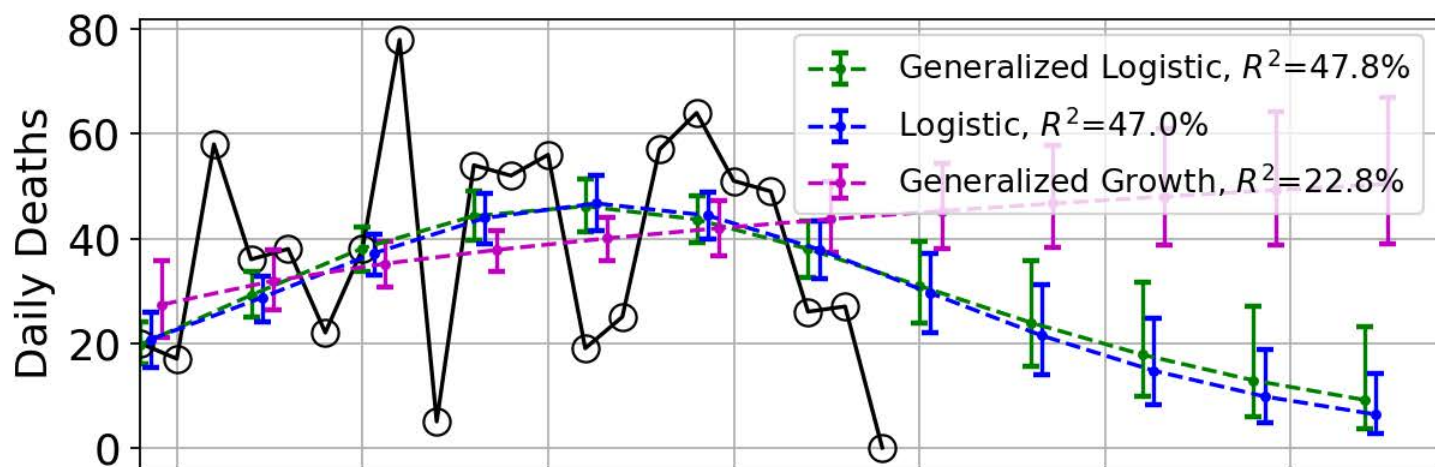
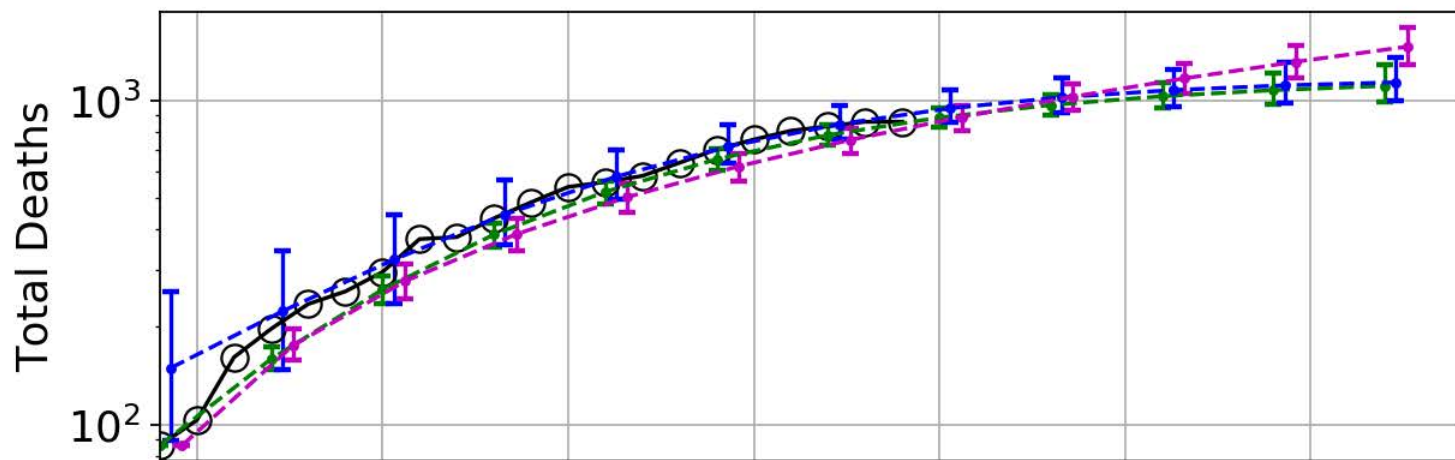
Netherlands



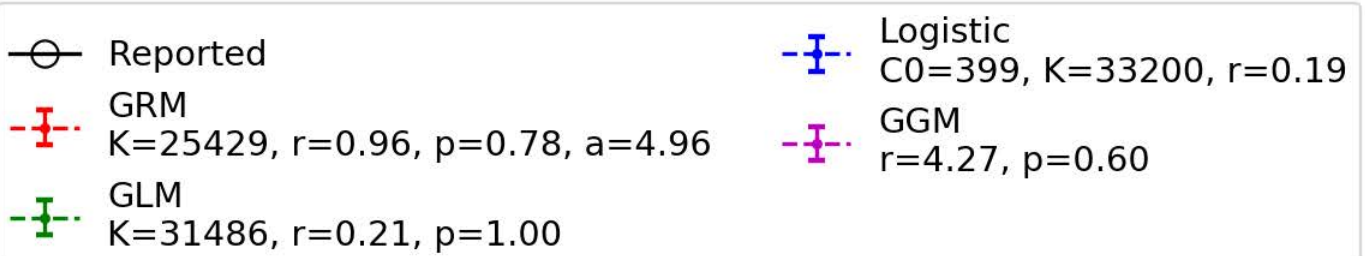
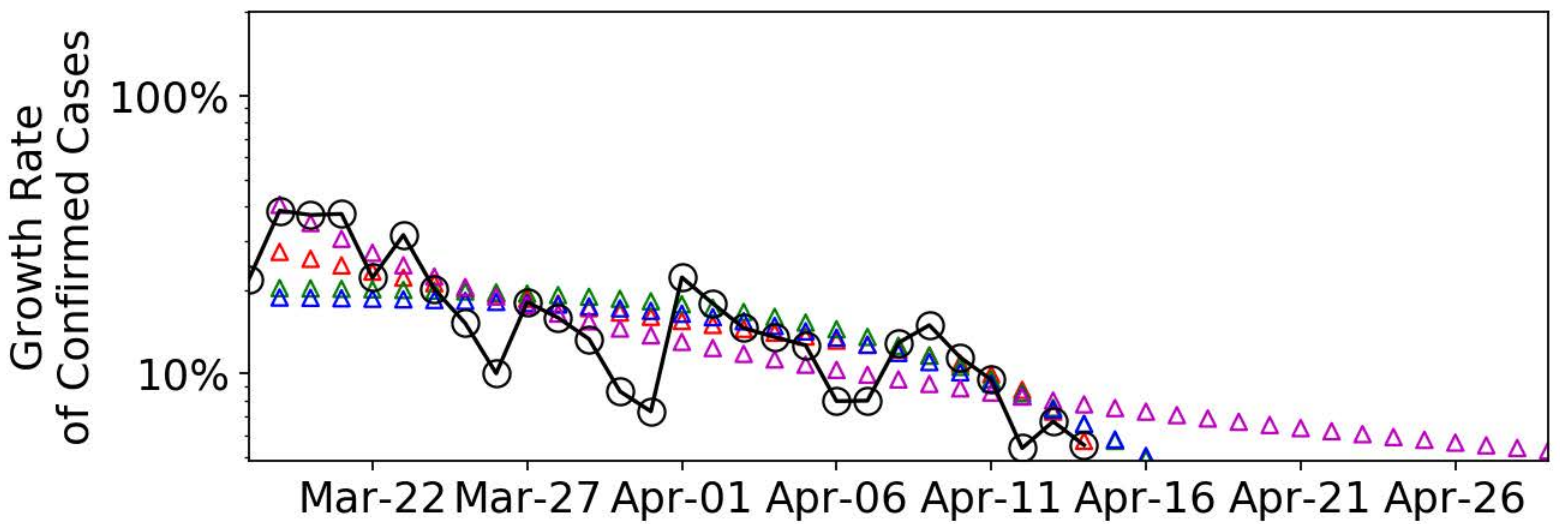
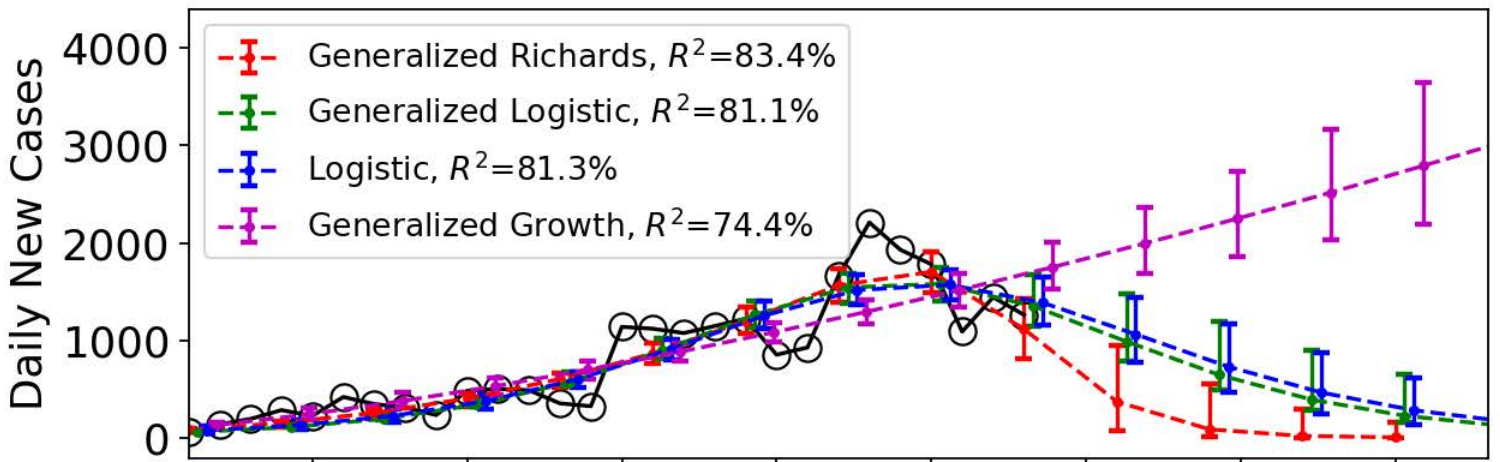
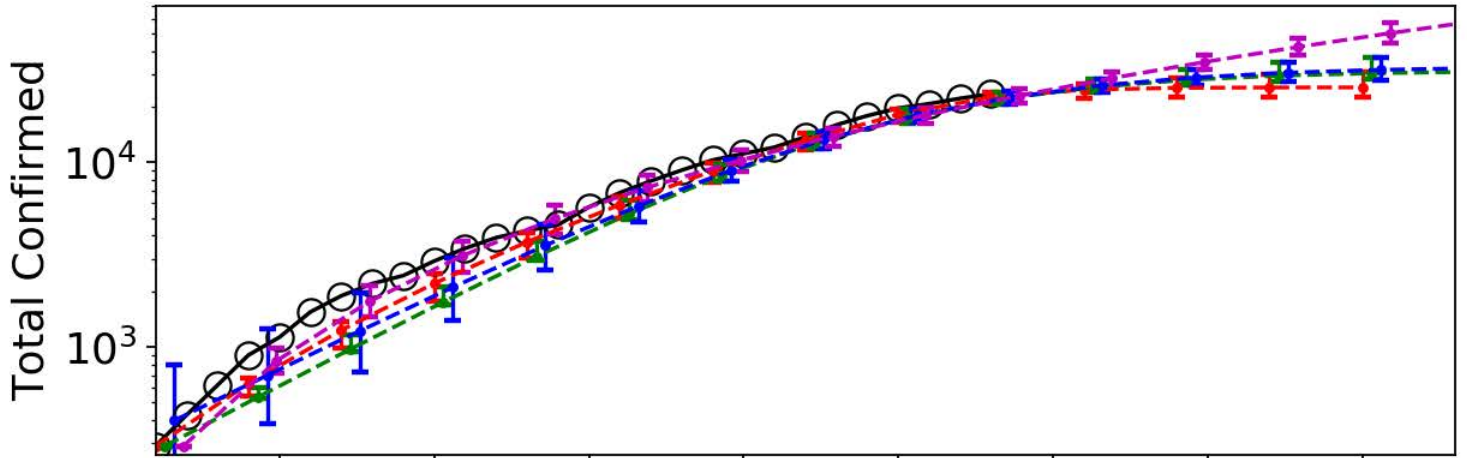
Switzerland



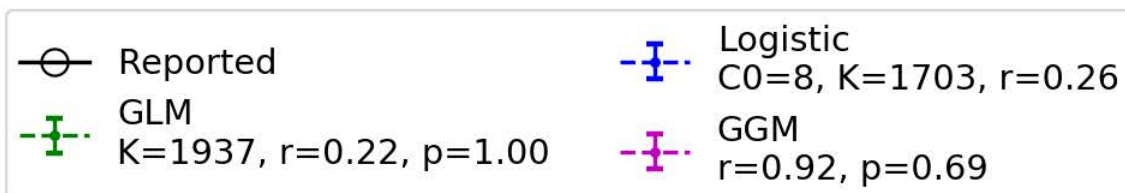
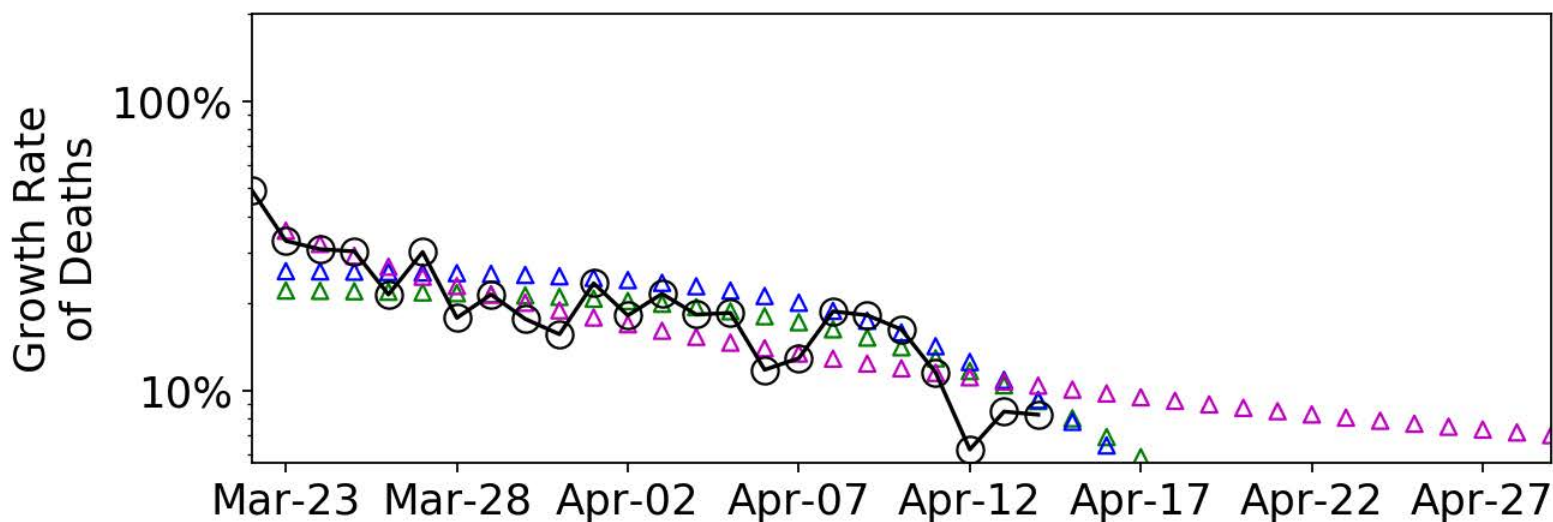
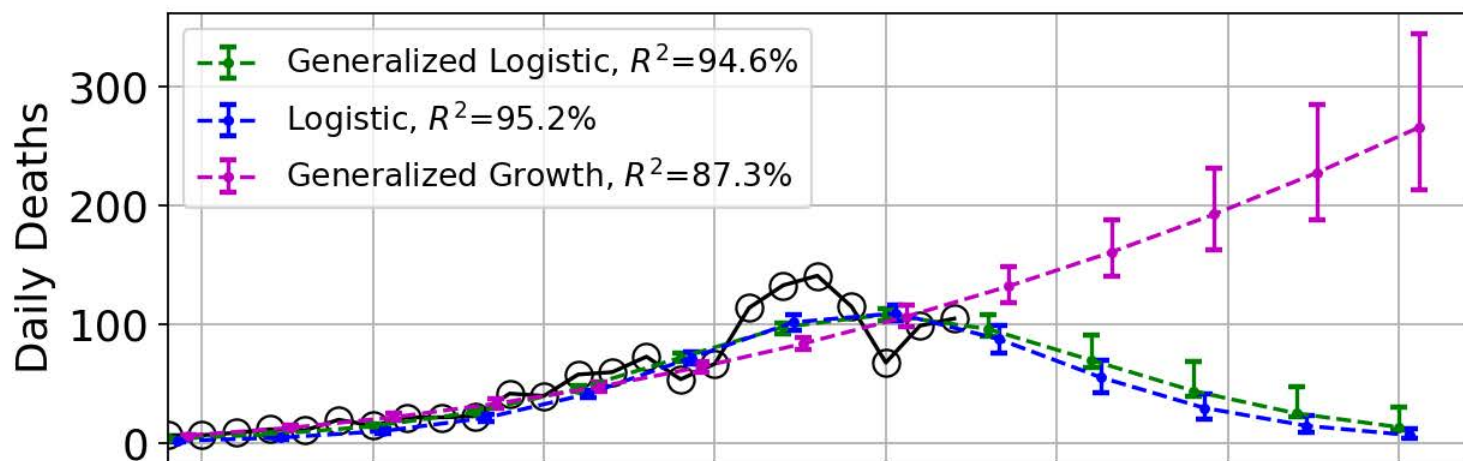
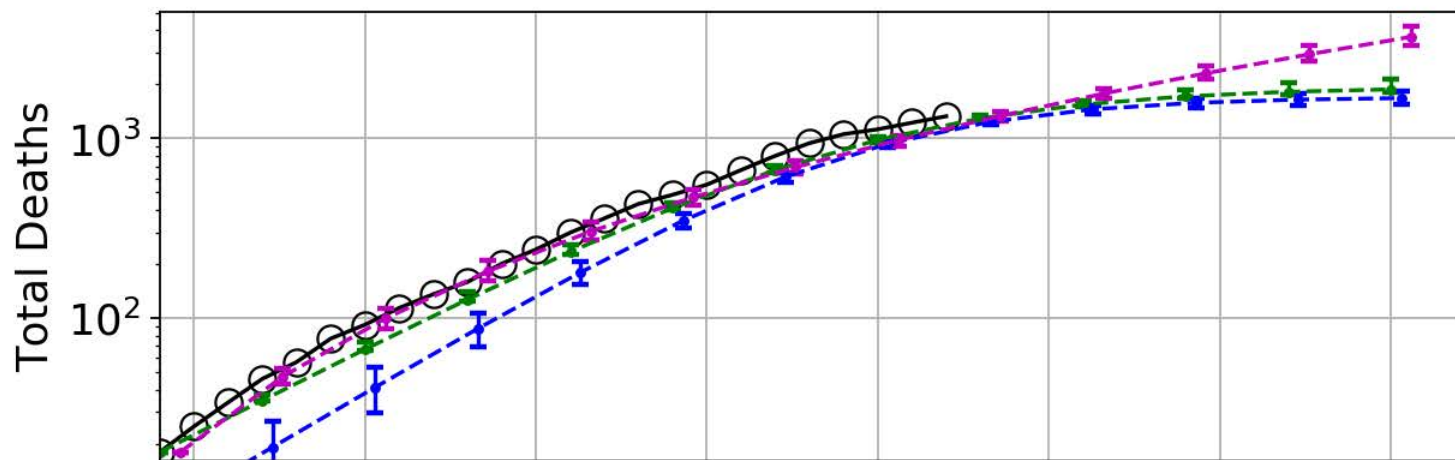
Switzerland



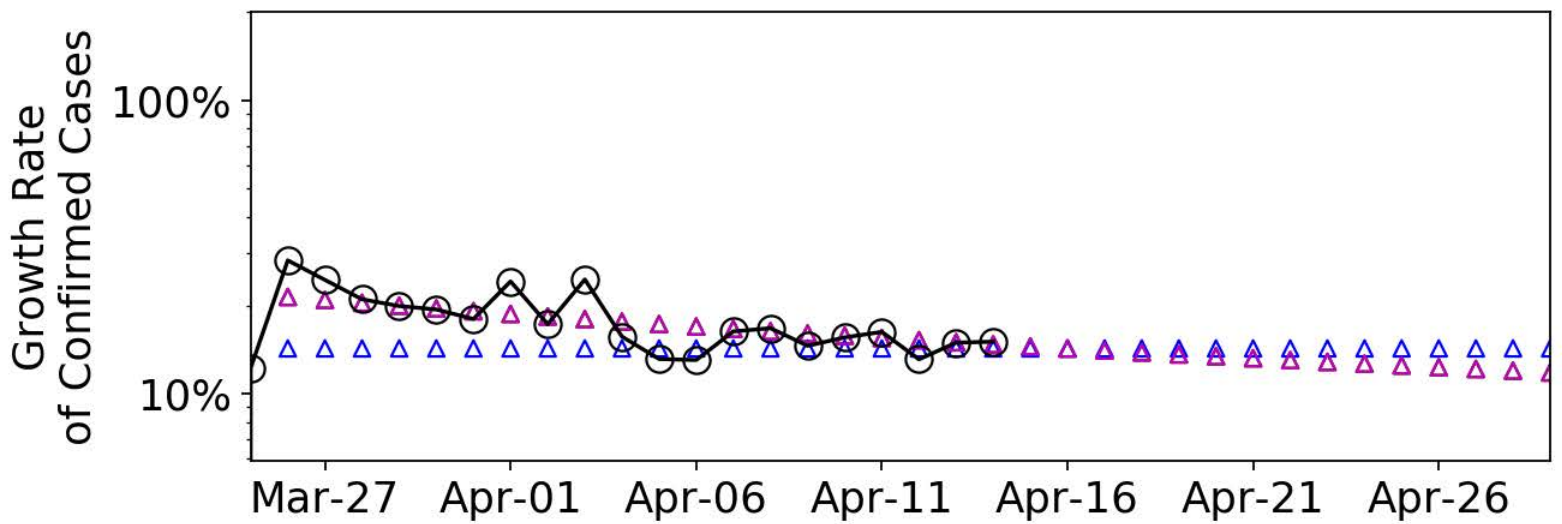
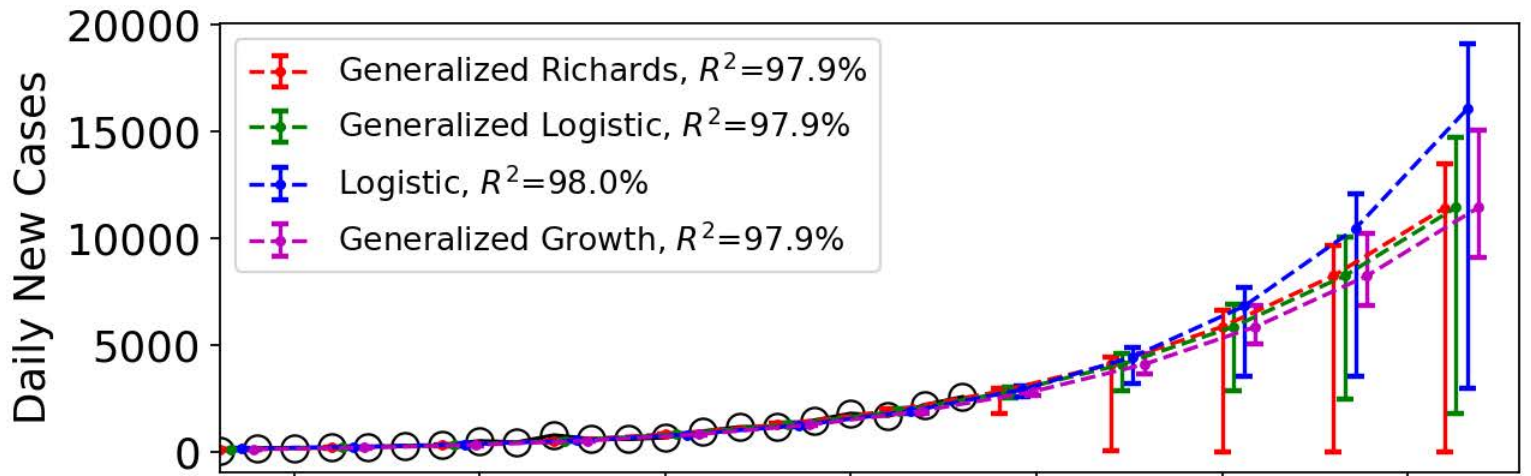
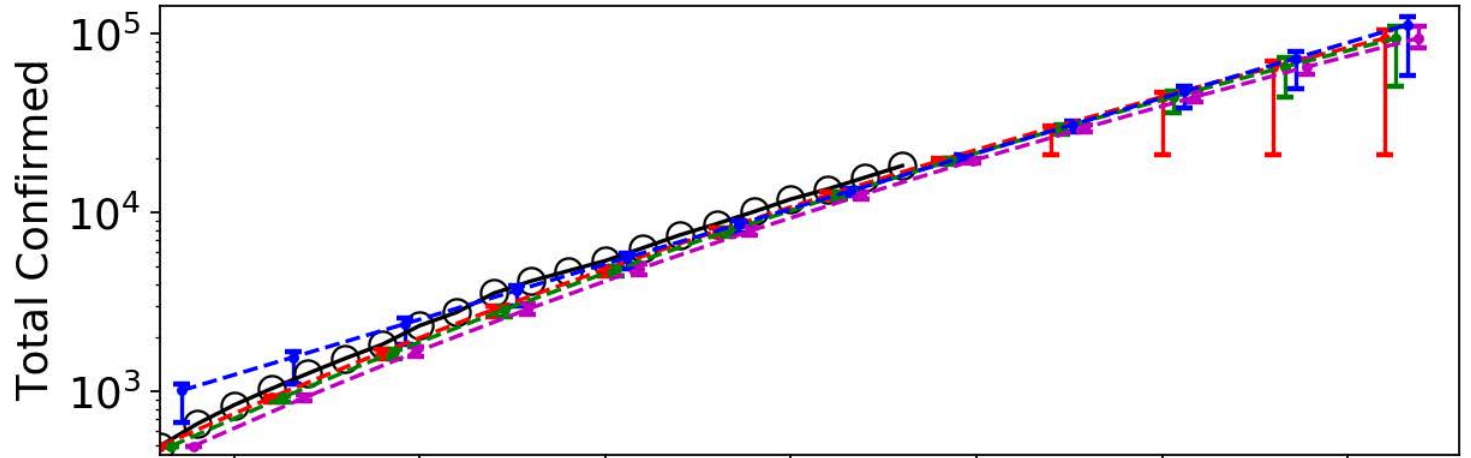
Brazil



Brazil

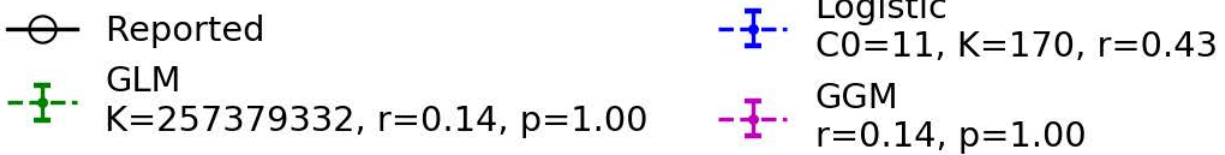
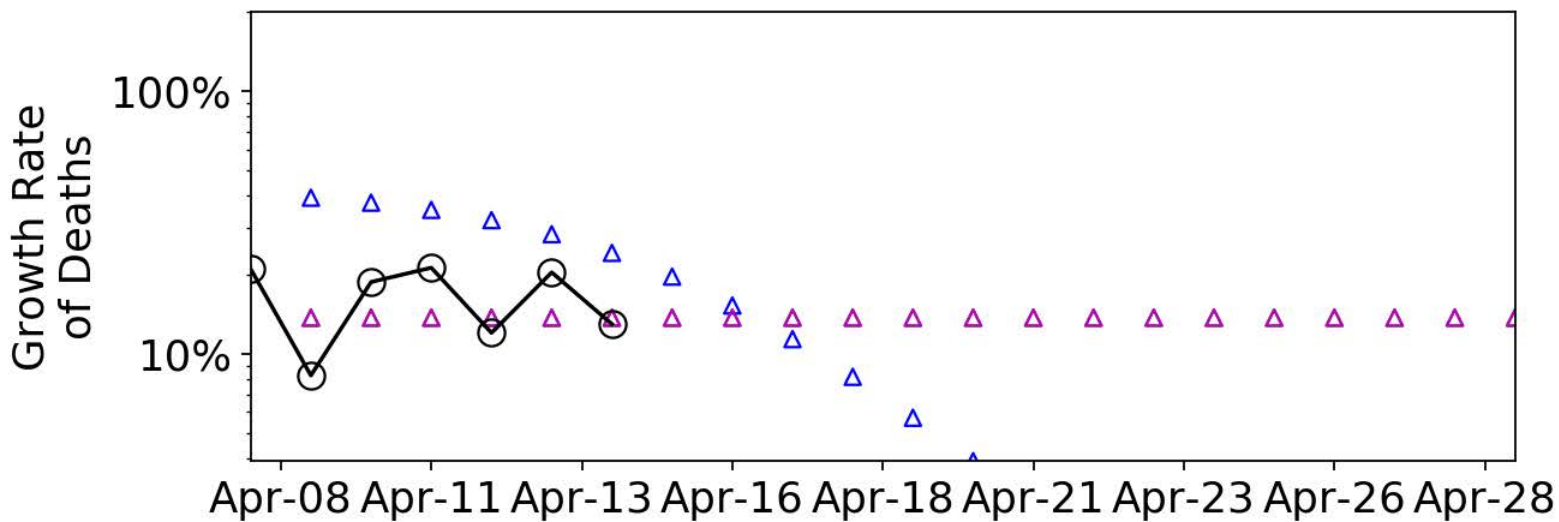
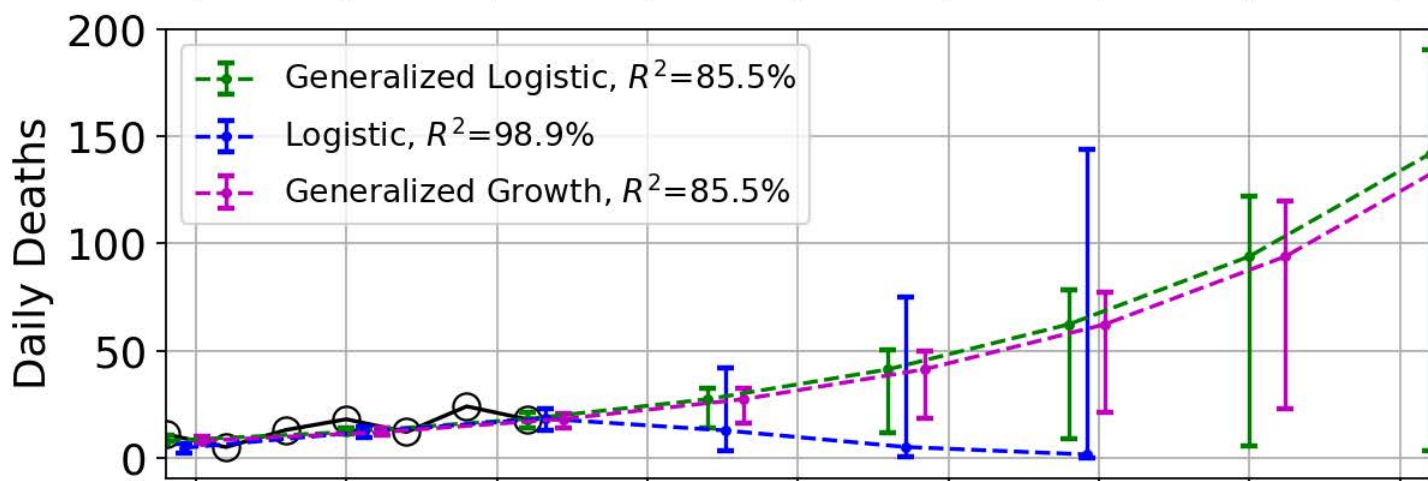
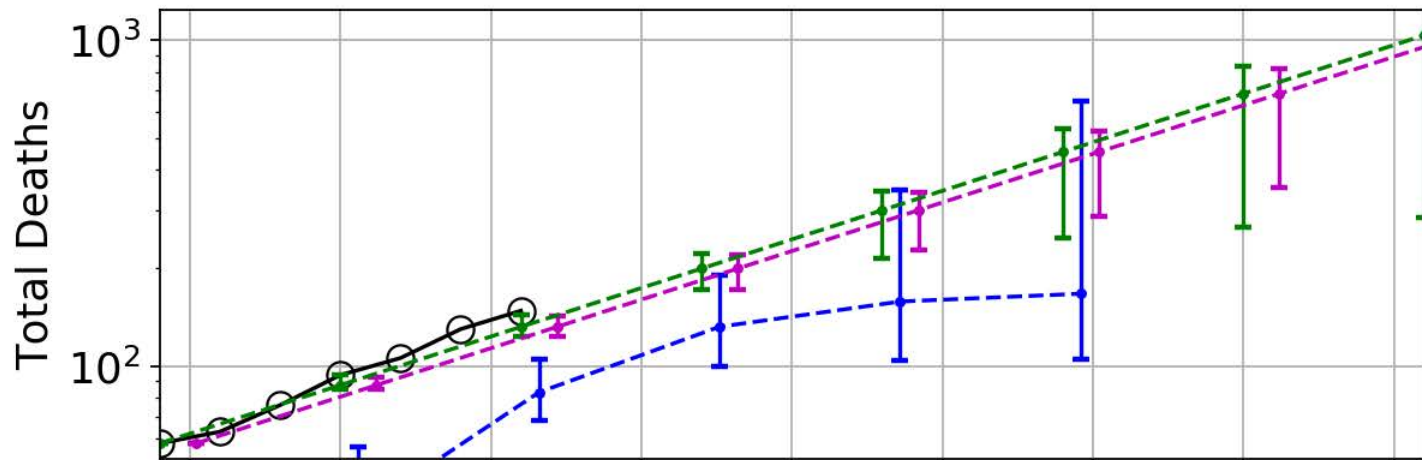


Russia

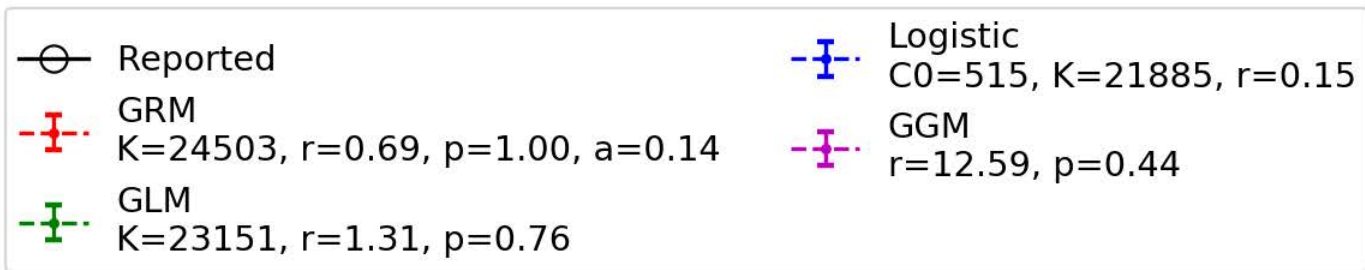
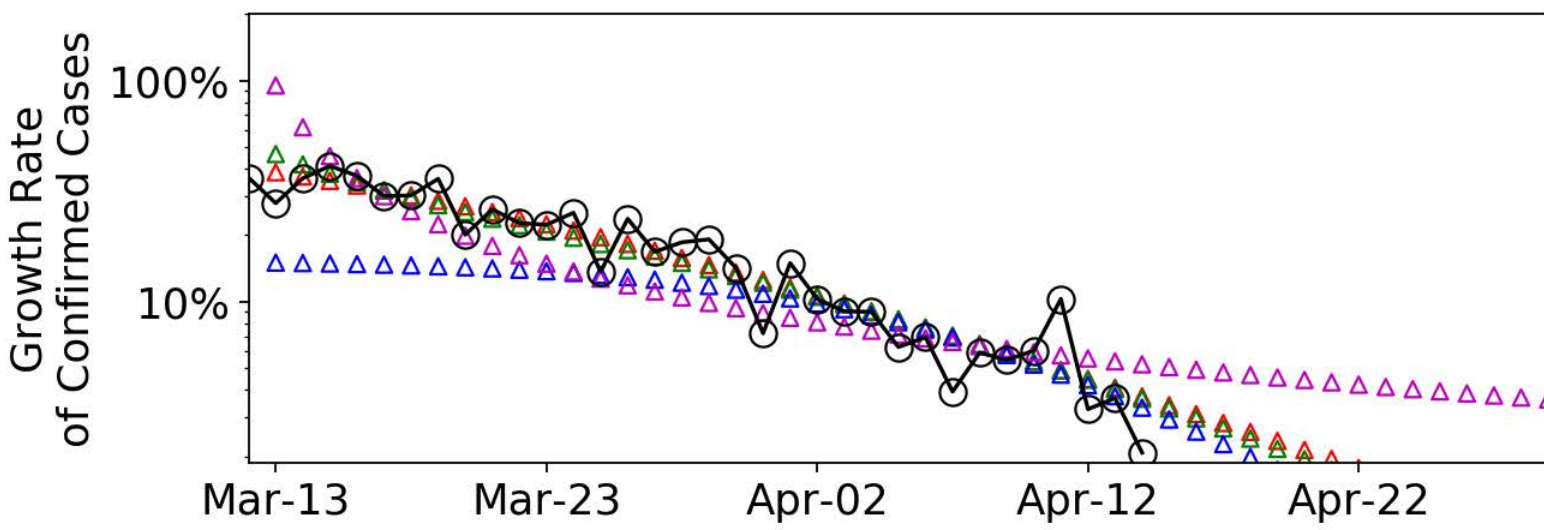
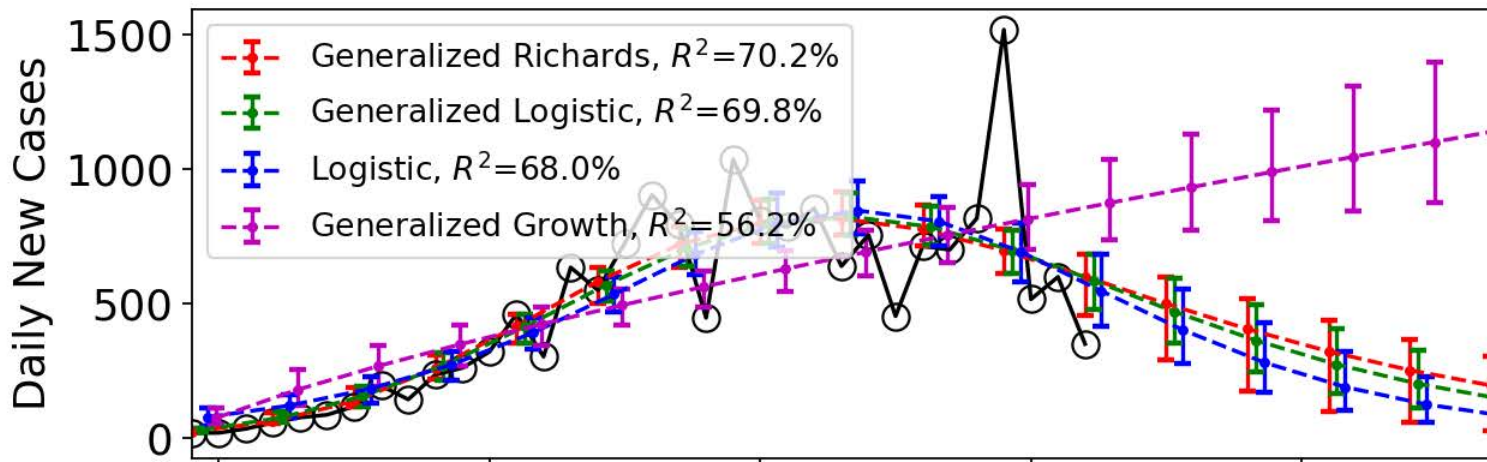
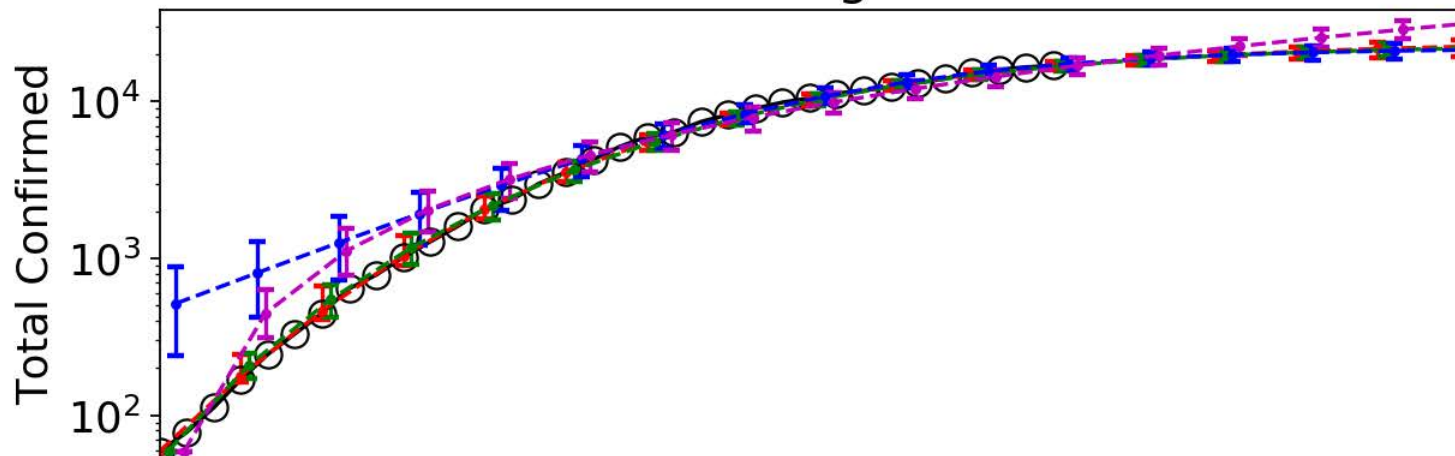


- Reported
- GRM
K=210838, $r=0.43$, $p=0.89$, $a=10.00$
- GLM
K=17892525568, $r=0.43$, $p=0.89$
- Logistic
C0=1015, K=12984797022, $r=0.14$
- GGM
 $r=0.43$, $p=0.89$

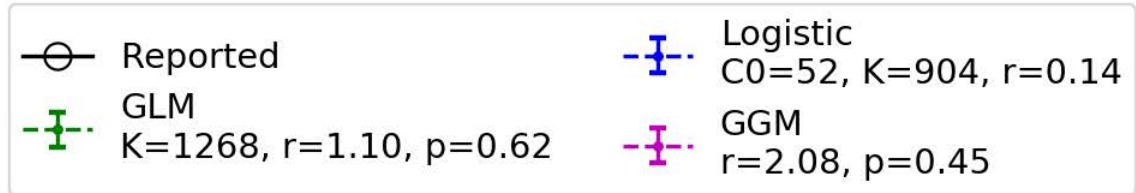
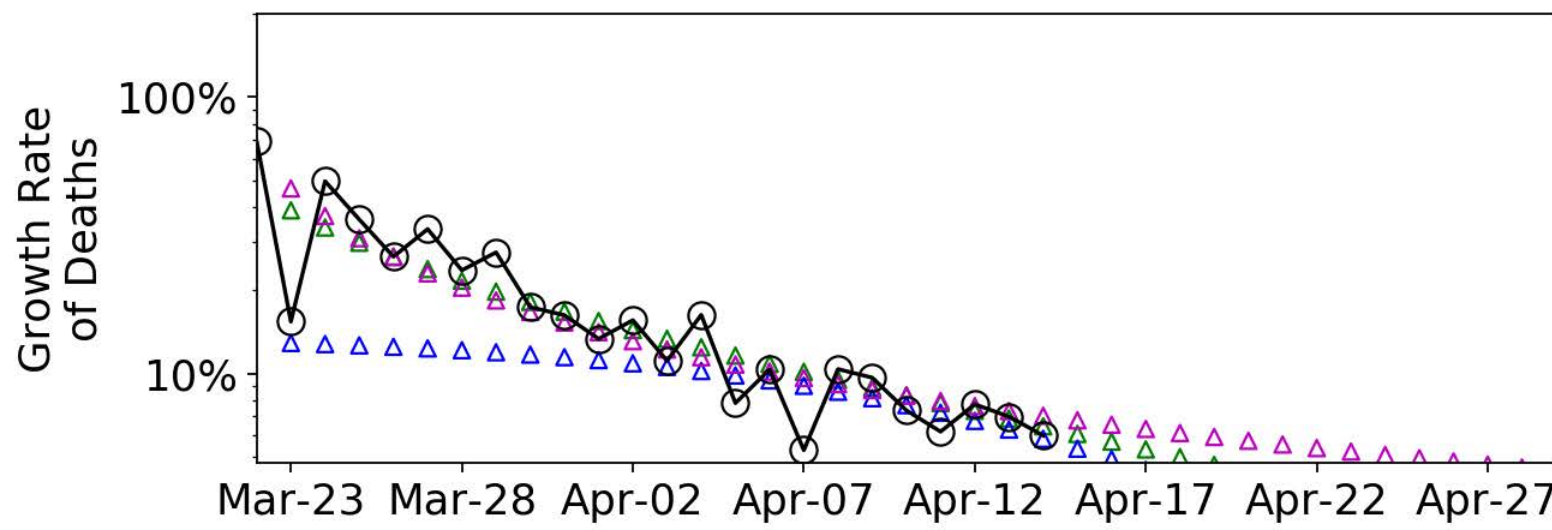
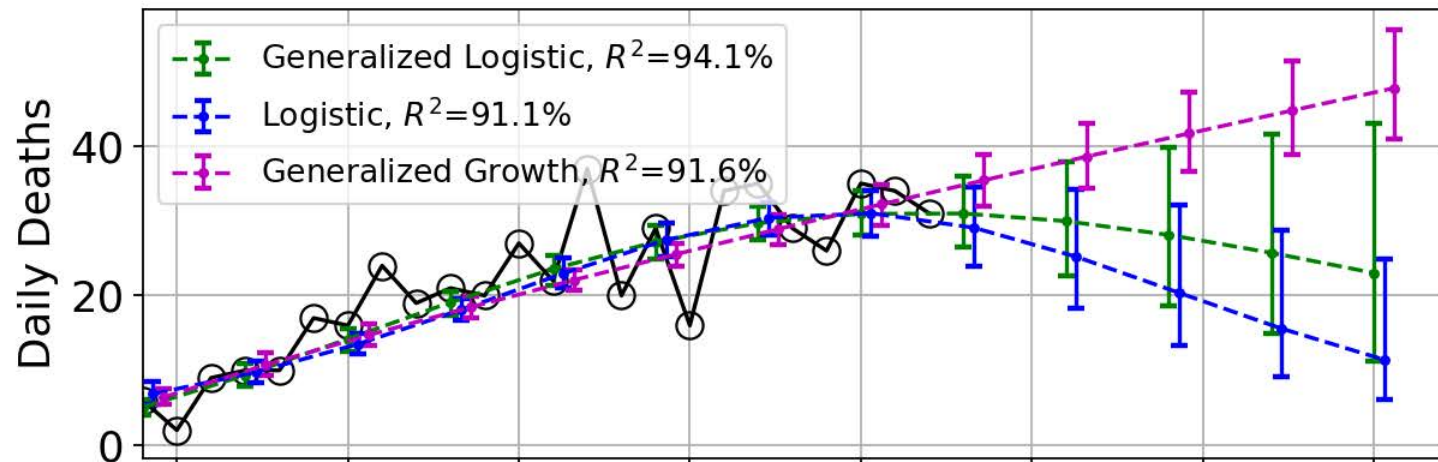
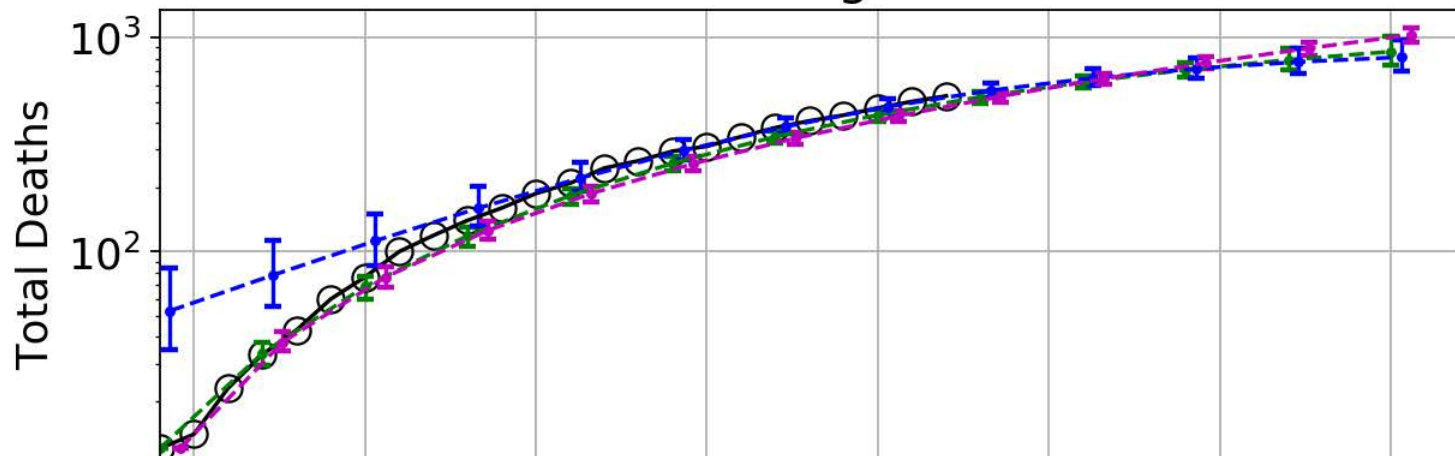
Russia



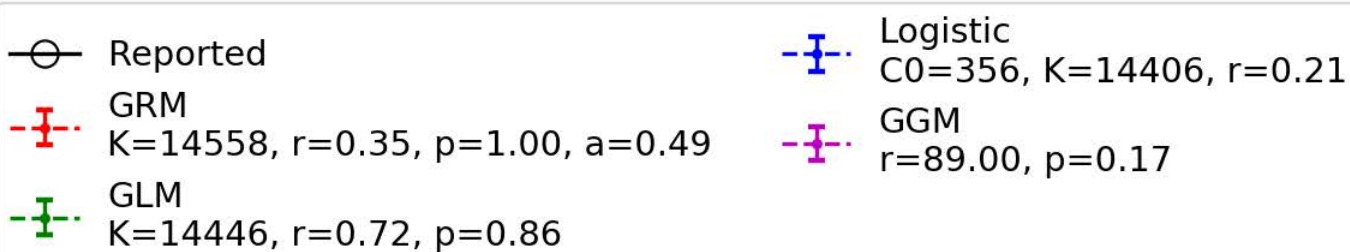
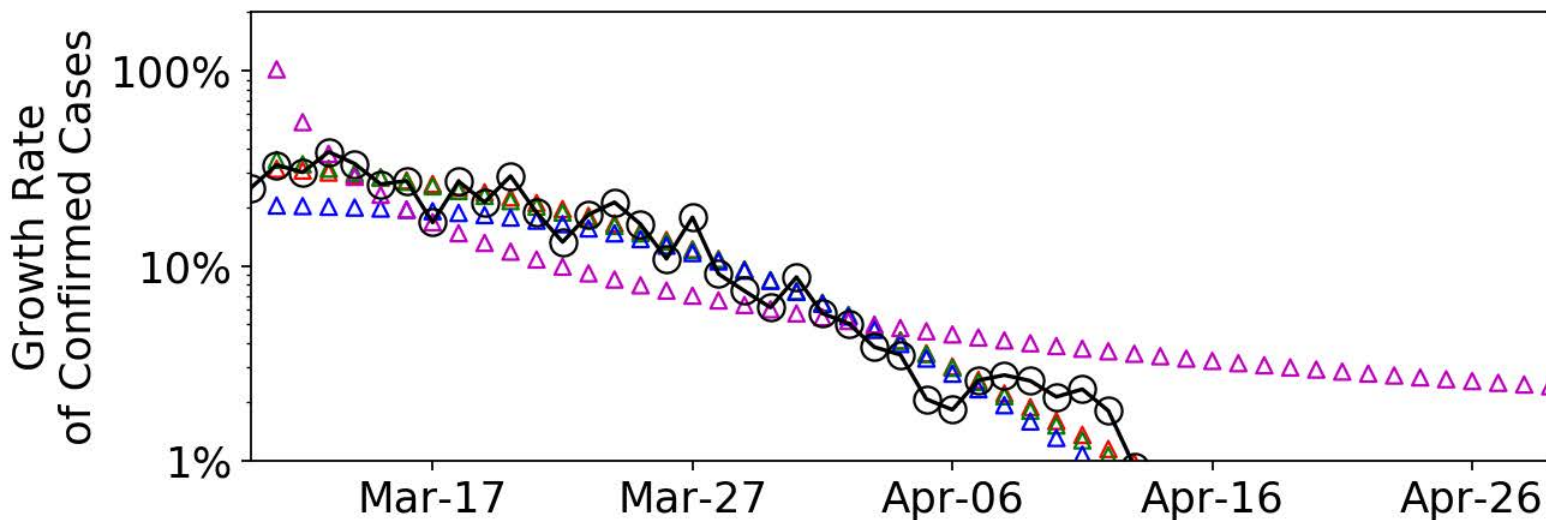
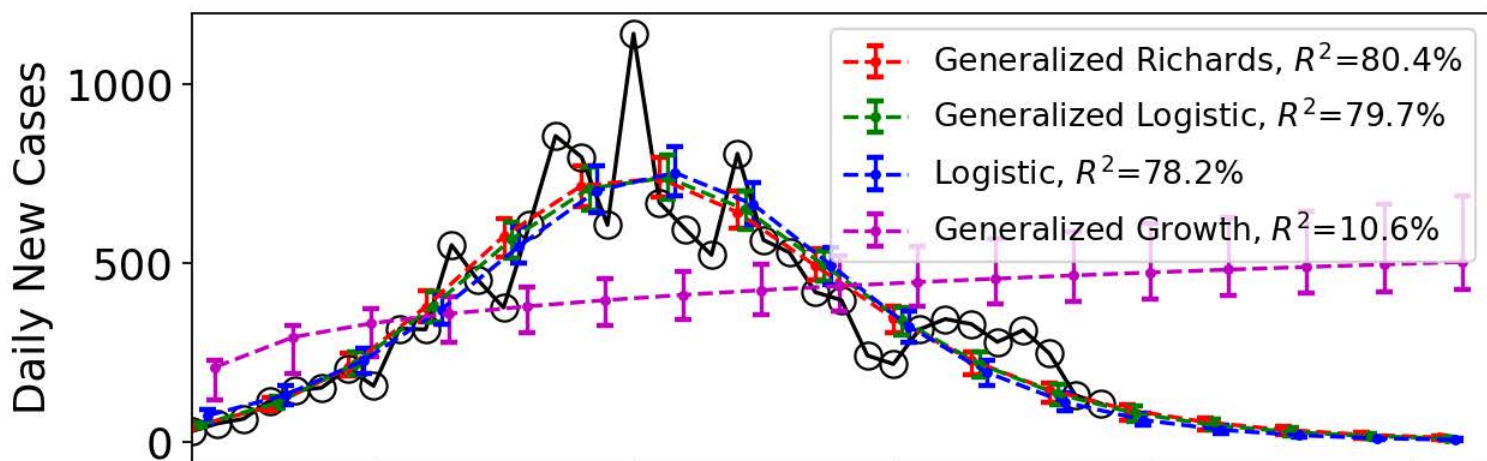
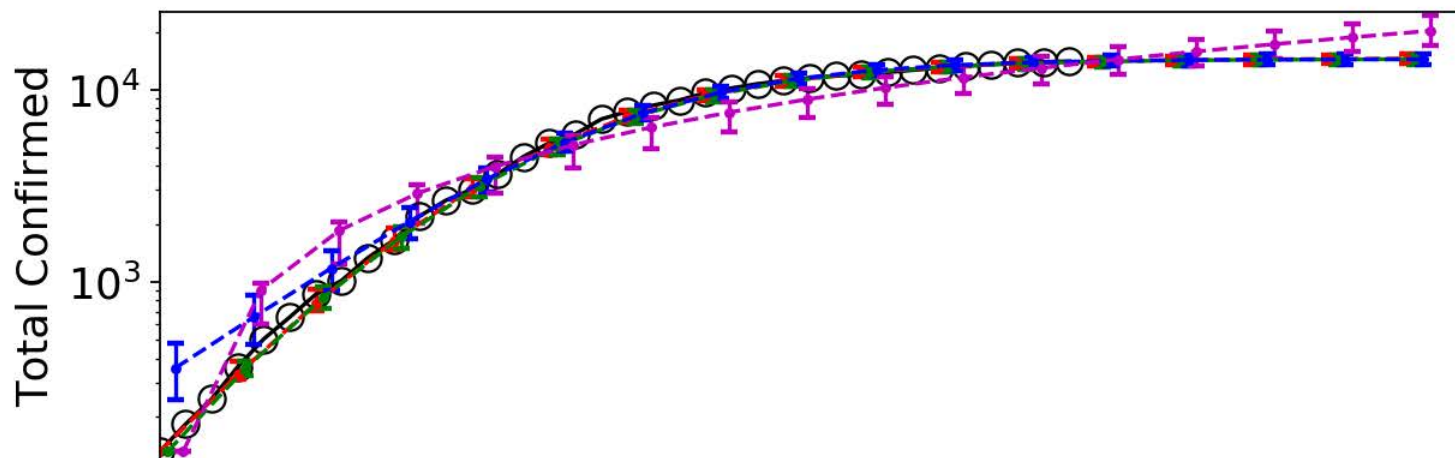
Portugal



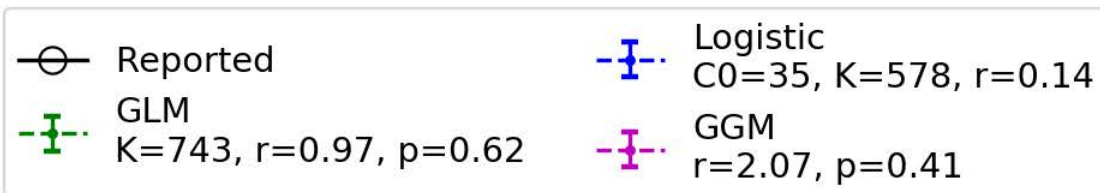
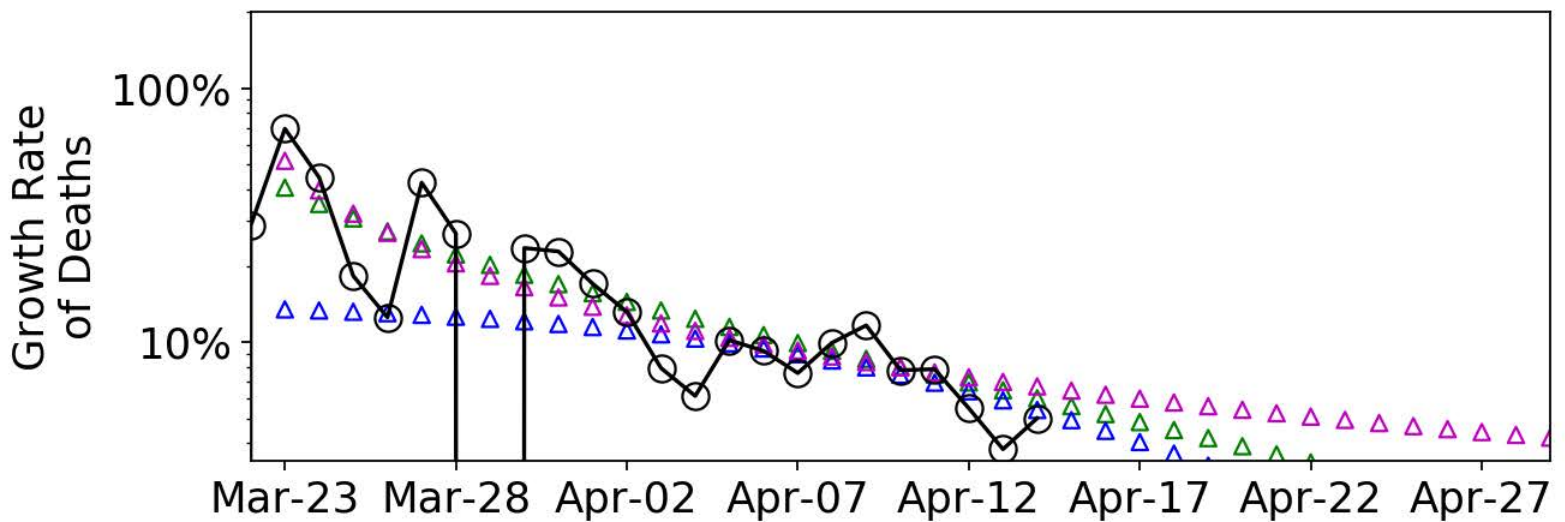
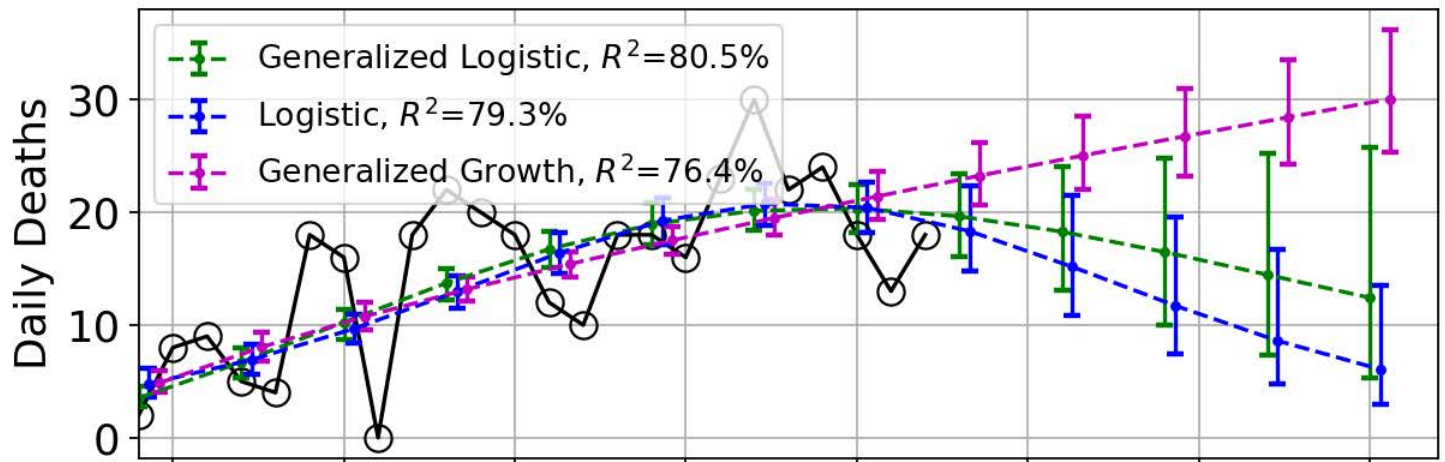
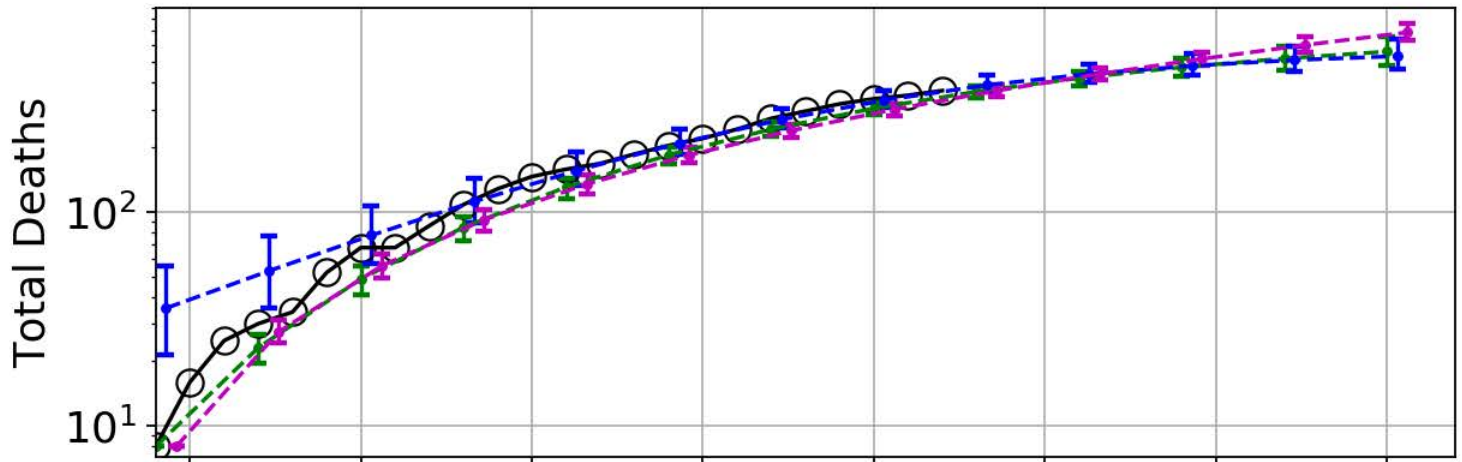
Portugal



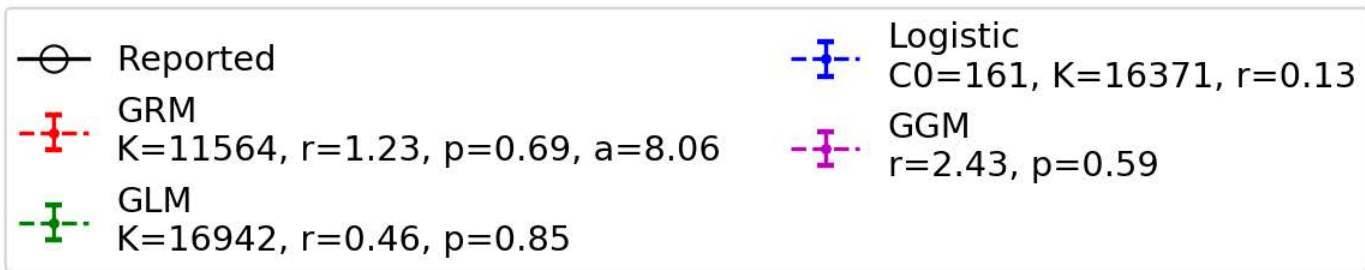
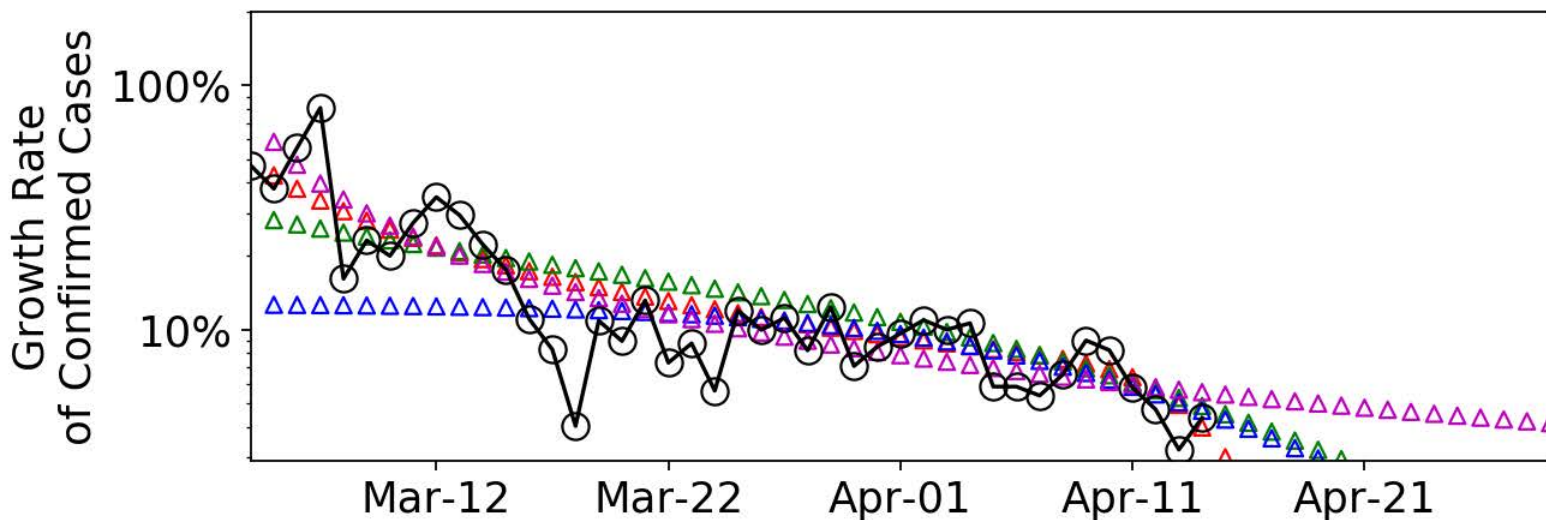
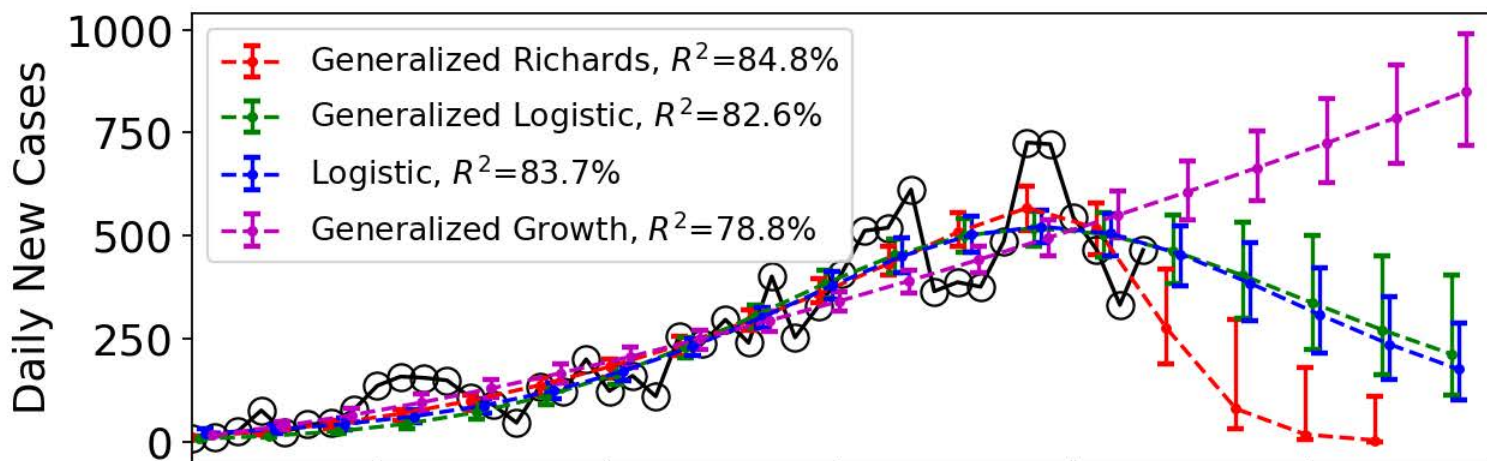
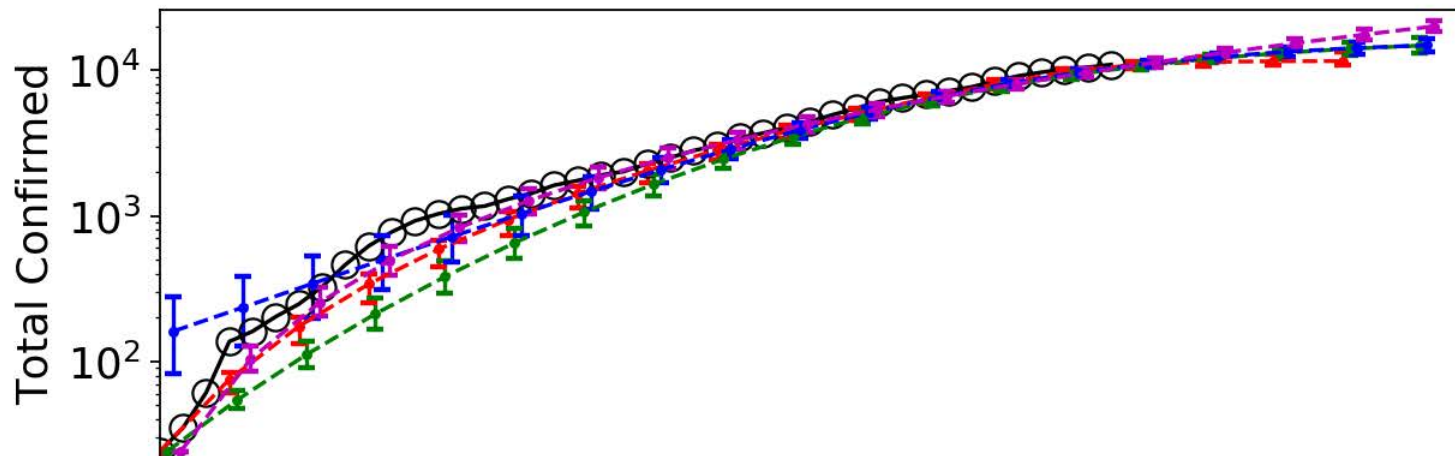
Austria



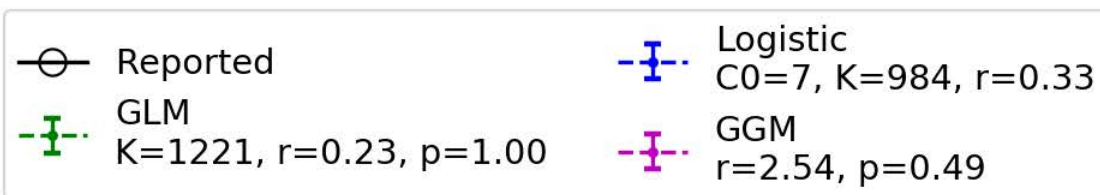
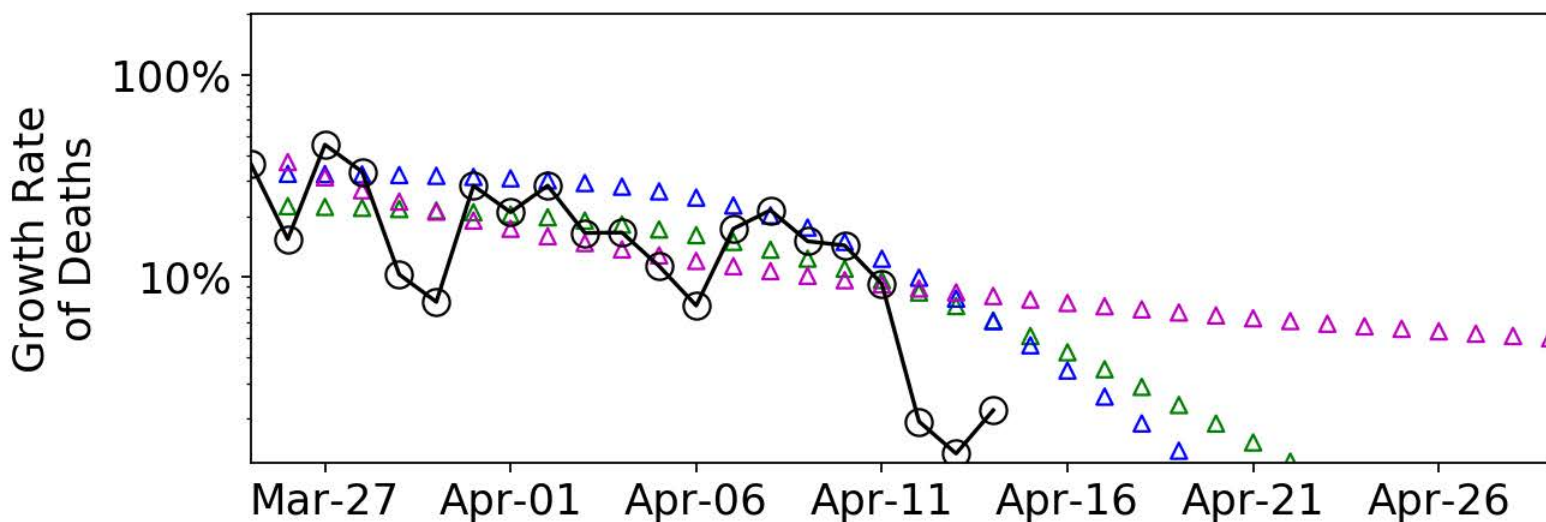
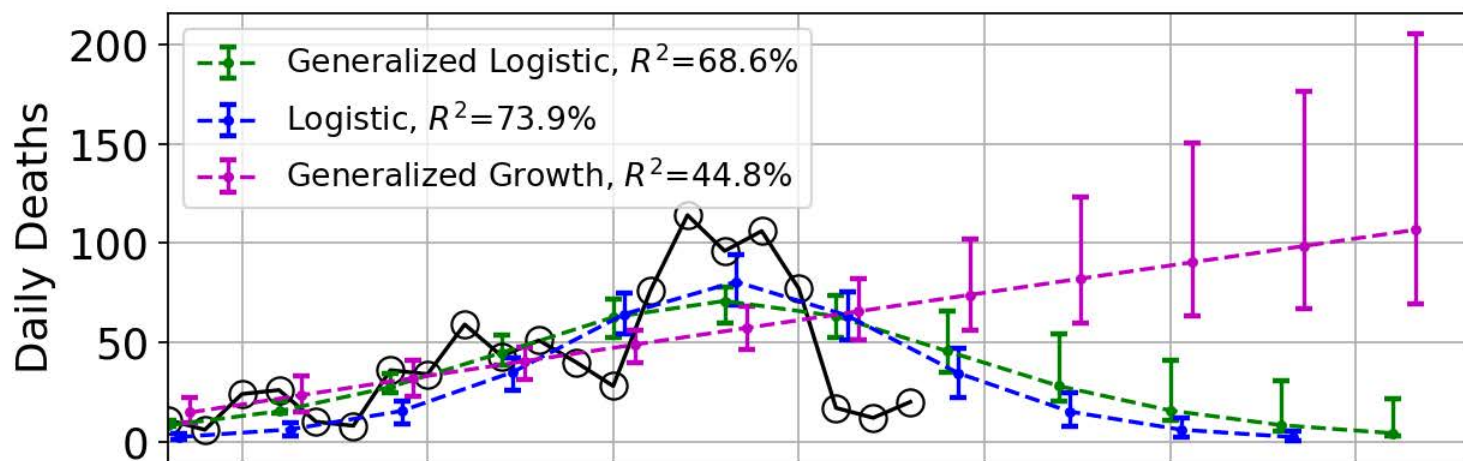
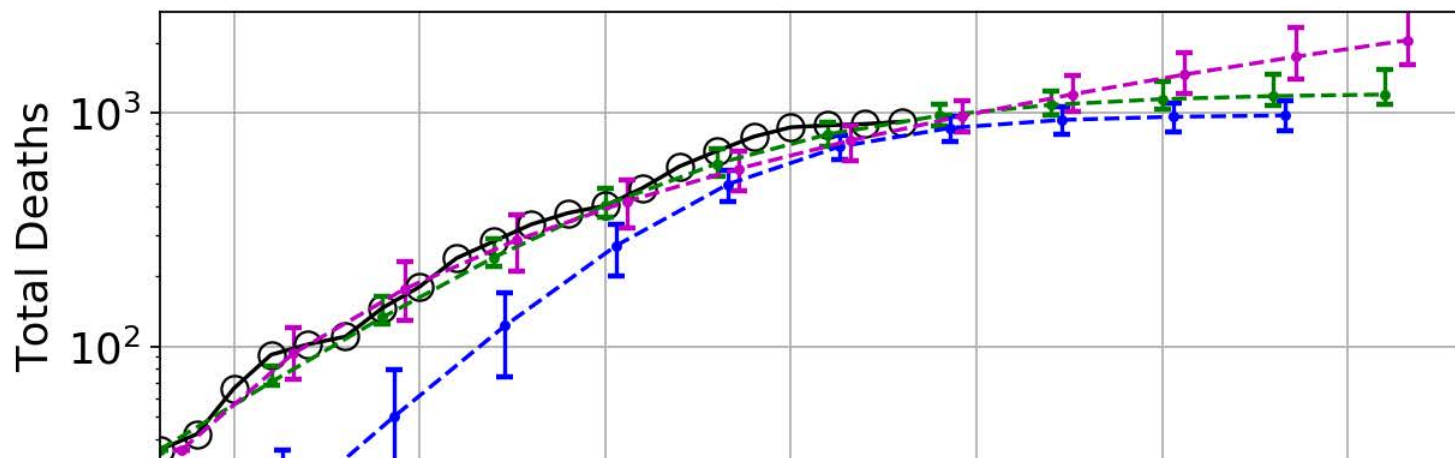
Austria



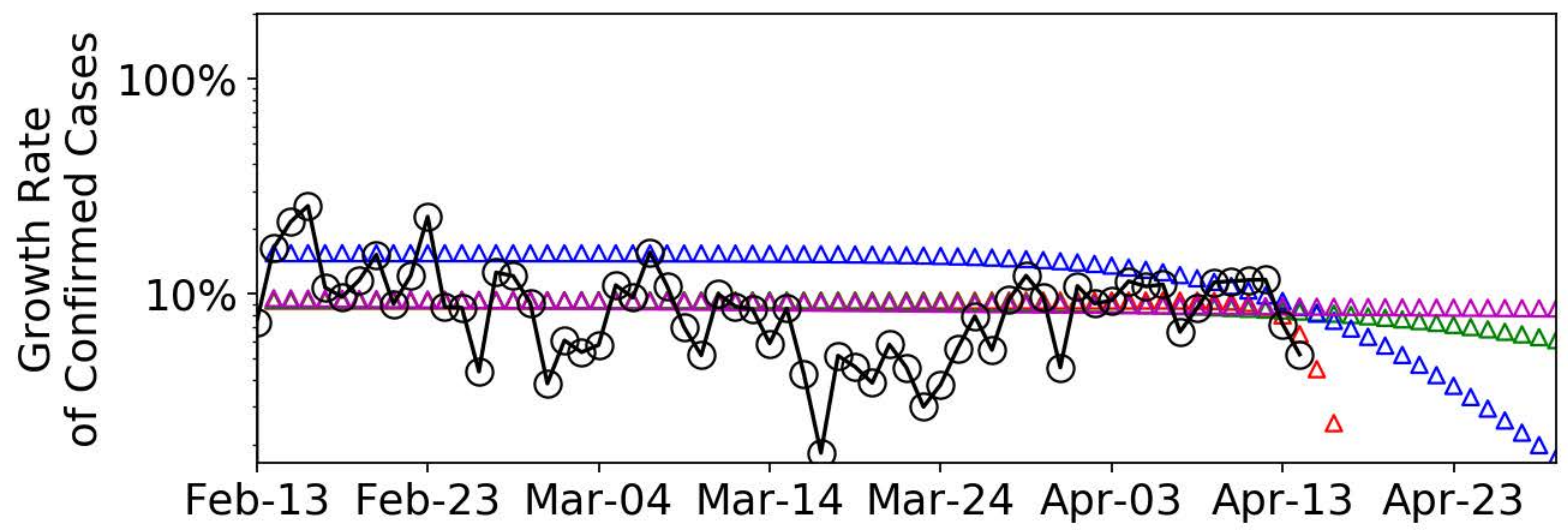
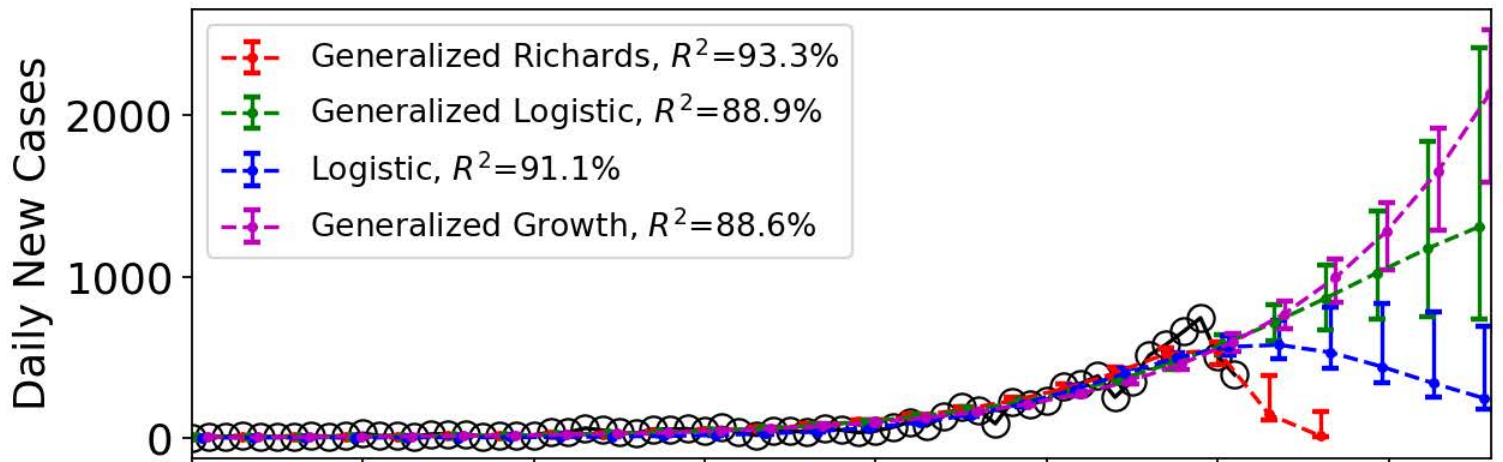
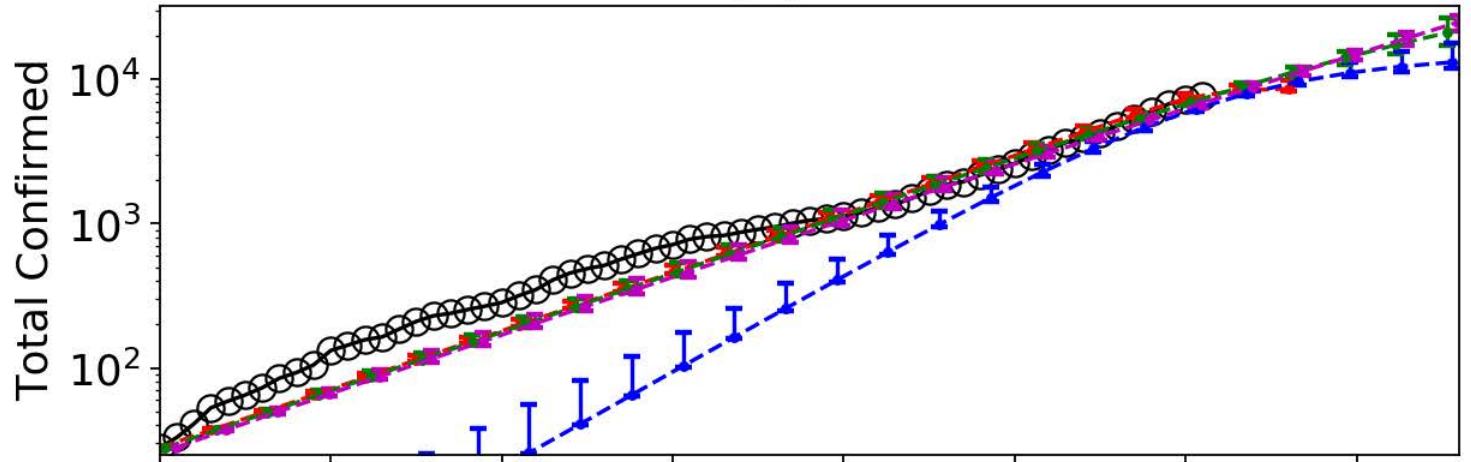
Sweden



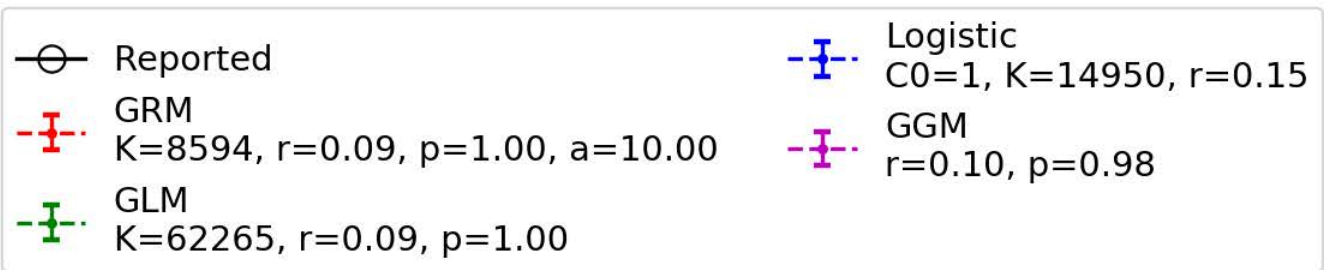
Sweden



Japan



Feb-13 Feb-23 Mar-04 Mar-14 Mar-24 Apr-03 Apr-13 Apr-23



Japan

