

COVID-19 Confirmed Cases and Cumulative Mortality Predictions as of May 1, 2020

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Summary of the situation:

- Europe reached 1.43 million confirmed cases today with a 1.8% growth rate, compared with 1.7% yesterday. The decay of the after-peak trajectory continues slowly, as shown from the small estimated parameter "a" (=0.18) in the generalized Richards model. It is also important to understand that confirmed infections undershoot actual infections by a very large margin (see Supplements to COVID-19 Confirmed Cases Prediction: April 15, 2020¹). Figure 1 allows us to suggest that the distributions of final confirmed cases in all countries except Brazil and Sweden have converged. The distributions of final deaths have not converged in Brazil, Ireland, Russia and Japan.
- The US reached 1.07 million total confirmed cases today, with a 2.9% growth rate, compared with 2.7% yesterday. Both the confirmed cases and mortality curve in the USA seem to have reached the inflection point². Similar to Europe, the decay of after-peak trajectory is expected to be slow, likely linked to the patients on ventilators that continue to die for several weeks. See [1] for further analysis on US test numbers and confirmed case numbers.
- Austria, Switzerland, Spain, France, Germany, Italy, Ireland, Portugal, Turkey, Netherlands and Belgium are the countries with most mature outbreaks with strong signs that inflection points have been passed. They all have an outbreak progress larger than 80% in medium scenario, and also converged distribution of final confirmed cases and deaths, except for Ireland
- Japan, the UK and the US are less matured with outbreak progress in the range 60-80% in medium scenario. They may continue to follow the generalized exponential model, resulting in high uncertainties. However, the UK and the US have their distributions of final confirmed cases and deaths converged. The UK changed the reporting standard of death statistics to include some deaths from care homes on 29 April. Health Secretary Matt Hancock said 4300 care home deaths would be added. Our middle logistic projection for the UK has increased as a result from 25,800 on 27 April to 33,600 today. UK estimates do not yet include community deaths and there are grounds to believe that both care home and community deaths are currently under reported.
- Russian and Sweden have developed signs of reaching their inflections points with the outbreak progress around 50%, while Brazil is still far from the inflection point. All of them have uncertain future projections, as shown by their non-converged or highly dispersed ensemble distributions of final confirmed cases (Figure 1). However, in terms of per capita deaths, Russia, Brazil and Japan do not yet have significant epidemics compared to West European countries.
- Our predictions for confirmed cases yesterday are correct in most countries, with again an undershot in Brazil and Russian, and an overshoot for Japan (see figure 2).

-Let us take the example of Switzerland. Figure 1 (top panel) and Table 2 show that the predicted final number of cases is 3600 per million for the medium scenario. The bottom panel of Figure 1 and Table 3 shows that the predicted number of deaths attributed to the Covid-19 epidemics is 230 deaths per million for the medium scenario. Taking the ratio of these two numbers gives the scary estimate of 6.4% for the infected fatality ratio (IFR), which is shown in the 5th column of Table 1. However, there are two serious problems with this estimation. First, tests are not representative of the whole population and, depending on countries, are targeted to those who exhibit symptoms, which then makes the IFR becoming closer to a case fatality rate (CFR). The second problem is that there are multiple pieces of evidence that the real number of infections is many times larger than reported, perhaps by a factor of

¹https://ethz.ch/content/dam/ethz/special-interest/mtec/chair-of-entrepreneurial-risks-dam/documents/Covid-19/Covid_Supplements_15April2020.pdf

²On 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.

10 or more, which would then decrease the IFR or CFR by the corresponding factor, bringing it closer to the rates seen in bad seasonal flu.

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, since today we use 7 days moving average for the fitting and simulations to account for weekly seasonality, instead of 3 days moving average. 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 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.

- At the end of this report, we present two figures for each country, where the total number of confirmed cases/deaths are in the upper panel (log scale), the daily confirmed cases / deaths in the middle panel, and the daily growth rate of confirmed cases / deaths in the lower panel (log scale), respectively. The empirical data is marked by the empty circles. The blue, red, purple and green lines in the upper, middle and lower left panels show the fits with the Logistic Growth Model, Generalized Richards Model (GRM), Generalized Growth Model (GGM) and Generalized Logistic Model (GLM) respectively.

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.

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 April 1st, all testing is to be targeted at health sector staff and this will obviously bias future data compared with past data.

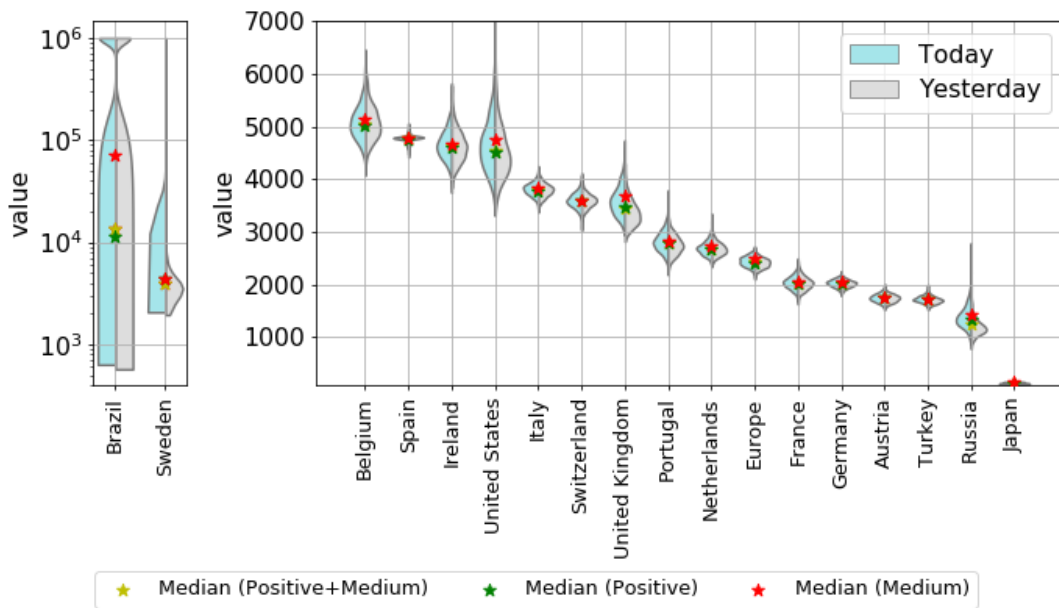
Table 1. Current confirmed cases per million population and estimated outbreak progress in positive and medium scenarios (today's confirmed cases divided by the estimated total final confirmed cases in positive and medium scenario). The ranking is in terms of outbreak progress in medium scenario. Numbers 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 estimated final case fatality rate in medium scenario is reported in the 5th column. The number of tests per million population and confirmed cases per test are presented in the last two columns based on the information from Wikipedia [3]. Sweden poses a puzzle with regards to the relationship between stringency of lockdown and outbreak progress.⁵

	Confirmed per Million Population (May-01)	Outbreak Progress in Positive Scenario	Outbreak Progress in Medium Scenario	Estimated Final Case Fatality Rate in Medium Scenario	Tests per Million Population (update date in brackets)	Confirmed Cases per Test (update date in brackets)
Austria	1747	100.0% (94.6%, 100.0%)	99.8% (94.3%, 100.0%)	4.5%	29663 (May 01)	5.9% (May 01)
Switzerland	3464	96.5% (91.7%, 100.0%)	96.0% (91.5%, 100.0%)	6.4%	30396 (Apr 29)	11.2% (Apr 29)
Spain	4568	96.2% (93.5%, 99.0%)	95.4% (95.1%, 95.7%)	12.1%	19905 (Apr 27)	15.6% (Apr 27)
Germany	1939	95.6% (91.2%, 100.0%)	94.8% (91.2%, 99.2%)	4.9%	30632 (Apr 27)	6.1% (Apr 27)
France	1934	95.3% (88.4%, 100.0%)	94.5% (87.8%, 100.0%)	18.9%	8880 (Apr 21)	19.3% (Apr 21)
Ireland	4247	92.1% (85.3%, 98.8%)	91.0% (83.9%, 97.7%)	Not reliable	31099 (Apr 28)	12.8% (Apr 28)
Italy	3400	89.9% (86.2%, 93.6%)	88.4% (85.4%, 91.6%)	13.8%	32790 (Apr 30)	10.3% (Apr 30)
Portugal	2437	86.9% (79.6%, 94.7%)	86.4% (77.7%, 93.5%)	4.8%	38512 (Apr 30)	6.2% (Apr 30)
Turkey	1460	84.8% (80.4%, 88.9%)	84.5% (80.9%, 87.7%)	3.2%	12430 (Apr 30)	11.4% (Apr 30)
Netherlands	2282	85.7% (81.8%, 90.0%)	83.6% (78.1%, 89.4%)	12.7%	10801 (Apr 25)	19.4% (Apr 25)
Belgium	4248	84.8% (78.6%, 90.9%)	82.8% (76.0%, 90.1%)	14.4%	18046 (Apr 25)	21.3% (Apr 25)
Europe	1921	80.2% (76.4%, 83.7%)	76.8% (73.7%, 80.5%)	9.1%	NA	NA
Japan	113	92.1% (87.0%, 97.7%)	75.4% (69.0%, 80.7%)	Not reliable	1302 (Apr 26)	8.0% (Apr 26)
United Kingdom	2576	73.9% (67.6%, 80.0%)	69.7% (62.9%, 77.0%)	13.7%	13353 (Apr 30)	18.3% (Apr 30)
United States	3270	72.3% (62.3%, 81.2%)	68.9% (59.1%, 79.9%)	4.8%	18992 (Apr 30)	16.7% (Apr 30)
Russia	737	54.8% (47.1%, 61.1%)	52.0% (40.5%, 67.8%)	Not reliable	25376 (Apr 30)	2.7% (Apr 30)
Sweden	2071	48.0% (28.3%, 61.7%)	46.8% (22.4%, 84.6%)	8.1%	11542 (Apr 28)	15.9% (Apr 28)
Brazil	408	Not reliable	Not reliable	Not reliable	630 (Apr 20)	29.2% (Apr 20)
Iran	1157	Not reliable	Not reliable	7.0%	5197 (Apr 27)	20.9% (Apr 27)
South Korea	209	Not reliable	Not reliable	Not reliable	11717 (Apr 29)	1.8% (Apr 29)

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?

⁵Sweden should have highest R_0 and one way of thinking is that it should have a shorter outbreak. On the other hand, confinement shortens the outbreak duration by avoiding contacts, but with the risk of resurgence when deconfinement occurs. Could it then be that Sweden is more representative while other countries' data are biased by lockdown, giving an appearance of maturation, while a second wave will come as soon as deconfinement occurs? This would be a blow to and would tend to discredit confinement policies. Or is it that Sweden is more noisy due to pockets of contagions, in particular in care homes, which makes the analysis of its data less reliable?

Ensemble Distribution of Final Confirmed Cases per Million Population



Ensemble Distribution of Final Deaths per Million Population

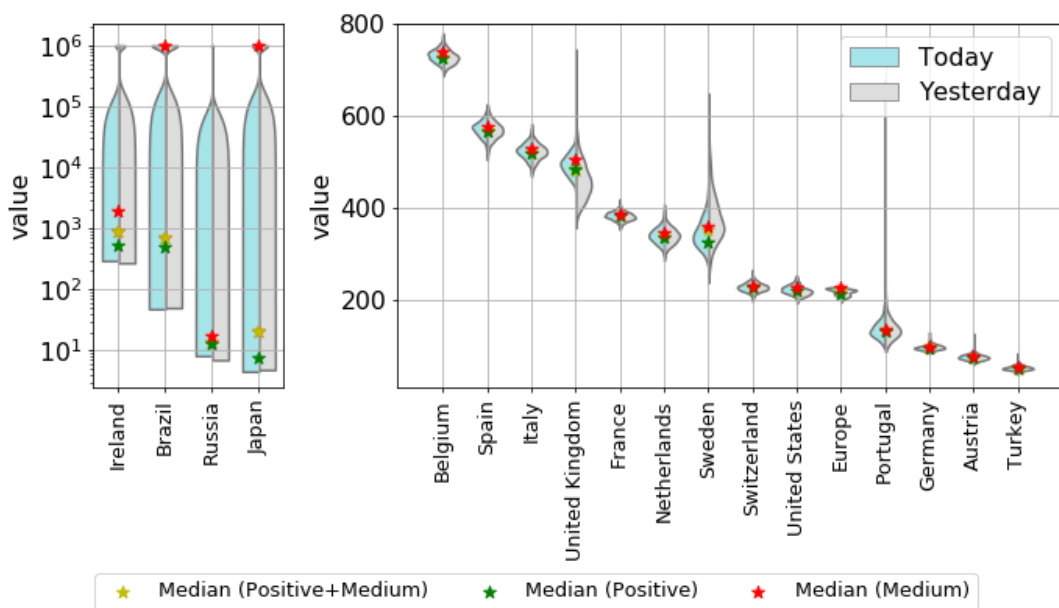


Figure 1. Violin plot of the distributions of the final total number of confirmed cases (upper panel) and deaths (lower panel) per million derived by combining the distributions of the positive and medium scenarios ⁶. The left side of each violin in cyan is today's distribution, while the right side 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 or deaths per 1 million of population, the results are deemed to be unreliable (Table 2 & 3).

⁶ Different countries have different standards and processes for reporting deaths, some reporting all deaths and some reporting a fraction. Thus, the ranking shown here is likely quite misleading. For instance, we have information that we need to roughly double UK numbers, which would put it a bad place, for instance compared with Sweden with no lock down.

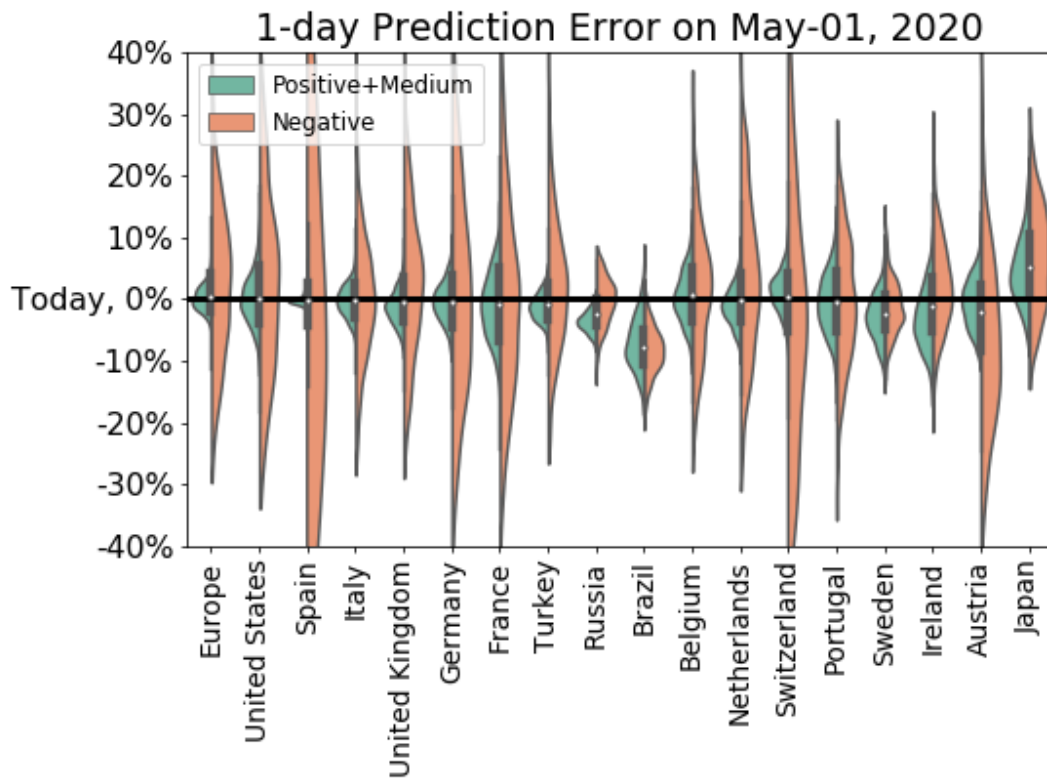


Figure 2. One-day prediction error of the forecast performed yesterday (April 30) for the total number of confirmed cases for the 13 countries/regions. The horizontal line corresponds to today’s empirical data. We show the full distribution of errors for each of the two scenarios.

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	2-May	6-May	11-May	Final Total Confirmed
Europe	Positive	(1400, 1490) 1430	1470 (1420, 1510)	1540 (1490, 1590)	1610 (1550, 1660)	1790 (1710, 1880)
	Medium	(1400, 1470) 1430	1460 (1430, 1490)	1540 (1500, 1570)	1610 (1580, 1650)	1870 (1780, 1940)
	Negative	(1230, 1700) 1430	1480 (1250, 1710)	1640 (1390, 1900)	1860 (1570, 2160)	Not Reliable
United States	Positive	(1010, 1140) 1070	1110 (1030, 1170)	1190 (1100, 1260)	1270 (1170, 1350)	1480 (1320, 1720)
	Medium	(1020, 1110) 1070	1100 (1050, 1150)	1180 (1130, 1240)	1270 (1190, 1340)	1550 (1340, 1810)
	Negative	(881, 1320) 1070	1110 (914, 1330)	1270 (1050, 1520)	1490 (1210, 1820)	Not Reliable
Spain	Positive	(209, 220) 213	216 (210, 222)	218 (212, 224)	220 (214, 226)	222 (216, 228)
	Medium	(212, 213) 213	214 (214, 215)	217 (217, 218)	220 (219, 220)	224 (223, 224)
	Negative	(131, 299) 213	213 (129, 312)	244 (147, 354)	280 (166, 433)	Not Reliable

Italy	Positive	(198, 213) 205	208 (200, 215)	213 (205, 220)	218 (209, 225)	229 (220, 238)
	Medium	(198, 211) 205	206 (201, 212)	212 (206, 218)	217 (211, 224)	232 (224, 241)
	Negative	(180, 231) 205	206 (182, 231)	224 (197, 252)	248 (217, 278)	Not Reliable
United Kingdom	Positive	(163, 176) 171	176 (169, 184)	189 (181, 198)	202 (192, 213)	232 (214, 253)
	Medium	(164, 174) 171	175 (170, 182)	190 (183, 197)	204 (196, 213)	246 (222, 272)
	Negative	(147, 203) 171	180 (156, 208)	207 (179, 238)	242 (209, 281)	Not Reliable
Germany	Positive	(153, 167) 161	162 (154, 169)	164 (156, 171)	166 (157, 173)	168 (159, 176)
	Medium	(154, 166) 161	161 (155, 168)	164 (157, 170)	166 (159, 173)	170 (162, 176)
	Negative	(126, 200) 161	160 (127, 196)	176 (140, 216)	197 (156, 245)	Not Reliable
France	Positive	(119, 138) 130	130 (120, 139)	132 (122, 142)	134 (123, 143)	136 (125, 147)
	Medium	(120, 137) 130	129 (121, 139)	132 (123, 142)	134 (125, 144)	137 (127, 148)
	Negative	(103, 159) 130	129 (103, 160)	143 (113, 175)	160 (126, 196)	Not Reliable
Turkey	Positive	(116, 123) 120	121 (118, 125)	128 (124, 132)	133 (129, 138)	142 (135, 150)
	Medium	(115, 122) 120	121 (118, 125)	127 (124, 132)	133 (130, 138)	142 (137, 149)
	Negative	(107, 139) 120	123 (109, 142)	141 (124, 162)	165 (144, 190)	Not Reliable
Russia	Positive	(100, 105) 106	110 (108, 113)	133 (129, 138)	156 (149, 165)	194 (174, 226)
	Medium	(100, 105) 106	110 (108, 113)	134 (128, 138)	157 (144, 168)	205 (157, 263)
	Negative	(101, 112) 106	114 (108, 119)	148 (140, 156)	200 (188, 214)	Not Reliable
Brazil	Positive	(76.2, 85.4) 85.4	84.1 (79.4, 88.9)	112 (103, 120)	154 (131, 173)	2370 (2050, 3380)
	Medium	(73.7, 82.7) 85.4	88.4 (83.9, 93.4)	119 (111, 127)	172 (149, 190)	15000 (3120, 31300)
	Negative	(74, 82.6) 85.4	84.5 (80.2, 89.3)	114 (107, 120)	161 (149, 173)	Not Reliable
Belgium	Positive	(46.1, 51.6) 48.5	49.3 (46.7, 52.2)	51.5 (48.7, 54.7)	53.4 (50.3, 56.9)	57.2 (53.4, 61.7)
	Medium	(45.9, 51.4) 48.5	49.1 (46.5, 52.1)	51.4 (48.6, 54.5)	53.5 (50.4, 56.9)	58.6 (53.8, 63.9)
	Negative	(42.3, 55.5) 48.5	49.6 (43.2, 57.1)	55.3 (47.8, 63.8)	62.6 (54.1, 72.4)	Not Reliable
Netherlands	Positive	(38, 41.1) 39.3	40.1 (38.5, 41.7)	41.6 (40, 43.3)	42.9 (41.2, 44.7)	45.9 (43.7, 48.1)
	Medium	(37.5, 40.9) 39.3	39.7 (38.2, 41.4)	41.4 (39.7, 43.2)	42.9 (41.3, 44.8)	47 (44, 50.3)
	Negative	(34.9, 49.2) 39.3	41.9 (35.9, 48.4)	46.4 (39.3, 53.6)	51.9 (43.9, 60.8)	Not Reliable
Switzerland	Positive	(28.4, 31.5) 29.5	30.1 (28.5, 31.6)	30.3 (28.7, 31.8)	30.4 (28.8, 32)	30.6 (29, 32.2)
	Medium	(28.7, 31.2) 29.5	30.1 (28.8, 31.5)	30.3 (29.1, 31.7)	30.5 (29.3, 31.9)	30.7 (29.5, 32.3)
	Negative	(20.8, 38.3) 29.5	29 (20.7, 38.9)	31.8 (22.6, 42.5)	35.4 (25.4, 47.6)	Not Reliable
Portugal	Positive	(23.3, 26.5) 25.1	25.4 (23.8, 27.2)	26.3 (24.6, 28.2)	27.2 (25.3, 29.1)	28.8 (26.4, 31.5)

	Medium	(23.4, 26.6) 25.1	25.3 (23.8, 27.1)	26.3 (24.6, 28.1)	27.1 (25.4, 29.1)	29 (26.8, 32.2)
	Negative	(21.6, 28.4) 25.1	25.4 (22.1, 29)	28 (24.3, 32.1)	31.5 (27.3, 36)	Not Reliable
Sweden	Positive	(19.5, 21.5) 21.1	21.4 (20.2, 22.5)	23.7 (22.4, 25)	26.4 (24.8, 28.3)	44 (34.2, 74.5)
	Medium	(19.3, 21.6) 21.1	21.3 (20.3, 22.4)	23.6 (22.3, 24.9)	26.1 (23.9, 28.1)	45.1 (24.9, 94.1)
	Negative	(19.7, 21.9) 21.1	21.6 (20.5, 23.1)	24.6 (23.3, 26.2)	28.6 (27, 30.5)	Not Reliable
Ireland	Positive	(18.5, 21) 20.6	20.1 (18.9, 21.3)	21 (19.7, 22.3)	21.6 (20.3, 23.1)	22.4 (20.9, 24.2)
	Medium	(18.9, 21.6) 20.6	20.5 (19.2, 22)	21.4 (20, 23)	22 (20.5, 23.7)	22.7 (21.1, 24.6)
	Negative	(19.2, 23.1) 20.6	21.3 (19.4, 23.3)	24.1 (22.1, 26.4)	27.9 (25.3, 30.6)	Not Reliable
Austria	Positive	(14.5, 16.2) 15.5	15.4 (14.6, 16.3)	15.4 (14.6, 16.3)	15.5 (14.6, 16.3)	15.5 (14.6, 16.3)
	Medium	(14.5, 16.2) 15.5	15.4 (14.6, 16.3)	15.4 (14.6, 16.4)	15.5 (14.6, 16.4)	15.5 (14.6, 16.4)
	Negative	(11.7, 17.2) 15.5	14.3 (11.9, 17.3)	15.6 (13, 19.1)	17.3 (14.4, 21.2)	Not Reliable
Japan	Positive	(13.8, 15.2) 14.3	14.7 (14, 15.4)	15.1 (14.3, 15.9)	15.3 (14.5, 16.2)	15.5 (14.6, 16.4)
	Medium	(14.3, 16.4) 14.3	15.6 (14.6, 16.6)	16.5 (15.6, 17.6)	17.4 (16.3, 18.6)	19 (17.7, 20.7)
	Negative	(13.6, 16.9) 14.3	15.4 (13.8, 17.2)	17.5 (15.7, 19.5)	20.4 (18.2, 22.9)	Not Reliable
Iran	Positive	(89.1, 96.4) 94.6	93.6 (89.8, 97.4)	95.5 (91.6, 99.4)	97.2 (93.2, 101)	100 (95.6, 105)
	Medium	(88.1, 95) 94.6	92.5 (88.9, 96.6)	94.7 (91.1, 99)	96.8 (93, 101)	101 (96.7, 106)
	Negative	(83.4, 114) 94.6	98.2 (84.3, 114)	107 (91.7, 124)	117 (101, 137)	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	2-May	6-May	11-May	Final Total Confirmed
Europe	Positive	(125, 131) 138	134 (131, 137)	142 (138, 145)	148 (145, 152)	161 (156, 166)
	Medium	(126, 128) 138	133 (132, 134)	141 (140, 142)	149 (148, 150)	169 (167, 171)
	Negative	(110, 158) 138	138 (111, 167)	158 (126, 189)	184 (146, 220)	Not Reliable
United States	Positive	(54.8, 57.6) 63	58.2 (56.8, 59.7)	63.3 (61.6, 65.2)	67.5 (65.4, 69.8)	72.7 (69.7, 76)
	Medium	(54.9, 57.3) 63	57.8 (56.8, 59.1)	63.3 (62, 64.8)	68 (66.1, 69.9)	74.7 (71, 78.9)
	Negative	(52, 67) 63	60.8 (53.4, 69.3)	72.8 (63.7, 82.4)	89.6 (77.3, 102)	Not Reliable
Spain	Positive	(23.1, 24.9) 24.5	24.3 (23.4, 25.3)	25 (24.1, 26)	25.6 (24.6, 26.6)	26.6 (25.5, 27.8)
	Medium	(23.4, 24.7) 24.5	24.3 (23.6, 24.9)	25.1 (24.4, 25.8)	25.7 (25, 26.5)	27 (26, 27.8)
	Negative	(21, 27.7)	24.1	27	30.3	Not Reliable

		24.5	(21, 27.8)	(23.3, 31)	(26.1, 35)	
Italy	Positive	(26.3, 28.1) 28	27.5 (26.7, 28.5)	28.5 (27.6, 29.5)	29.4 (28.4, 30.4)	31.4 (30.1, 32.8)
	Medium	(26.5, 27.7) 28	27.5 (26.8, 28.1)	28.5 (27.8, 29.2)	29.5 (28.8, 30.2)	32.1 (31.1, 33.2)
	Negative	(24.2, 31.4) 28	27.9 (24.5, 31.6)	30.6 (26.8, 34.8)	34 (29.7, 38.7)	Not Reliable
United Kingdom	Positive	(21, 22.9) 26.8	25.5 (24.7, 26.2)	27.5 (26.6, 28.3)	29.3 (28.2, 30.3)	32.4 (30.6, 34)
	Medium	(21.1, 22.6) 26.8	25.4 (24.9, 25.9)	27.6 (26.9, 28)	29.5 (28.7, 30.2)	33.6 (31.8, 35.2)
	Negative	(20.1, 25) 26.8	26.1 (23, 29.1)	30.6 (26.9, 34.1)	36.5 (31.9, 41.1)	Not Reliable
Germany	Positive	(5.83, 6.11) 6.29	6.1 (5.96, 6.24)	6.61 (6.44, 6.77)	7.08 (6.88, 7.26)	7.92 (7.58, 8.26)
	Medium	(5.85, 6.08) 6.29	6.08 (5.98, 6.19)	6.62 (6.5, 6.75)	7.13 (6.96, 7.29)	8.23 (7.77, 8.69)
	Negative	(5.59, 6.56) 6.29	6.25 (5.73, 6.79)	7.26 (6.63, 7.9)	8.64 (7.83, 9.48)	Not Reliable
France	Positive	(22.7, 24) 24.4	23.8 (23, 24.4)	24.5 (23.8, 25.2)	25 (24.3, 25.8)	25.6 (24.8, 26.4)
	Medium	(22.8, 23.8) 24.4	23.7 (23.2, 24.2)	24.5 (24, 25)	25.2 (24.6, 25.7)	26 (25.3, 26.6)
	Negative	(19.8, 29) 24.4	24.4 (20.1, 29.8)	28 (22.7, 34.1)	32.7 (26.3, 40.2)	Not Reliable
Turkey	Positive	(2.83, 2.98) 3.17	3.01 (2.93, 3.07)	3.35 (3.26, 3.43)	3.68 (3.55, 3.8)	4.35 (4.04, 4.73)
	Medium	(2.85, 2.98) 3.17	3.01 (2.94, 3.08)	3.36 (3.27, 3.45)	3.69 (3.56, 3.85)	4.5 (4.01, 5.11)
	Negative	(2.8, 3.13) 3.17	3.06 (2.89, 3.23)	3.61 (3.41, 3.83)	4.36 (4.09, 4.66)	Not Reliable
Russia	Positive	(0.743, 0.831) 1.07	0.878 (0.825, 0.925)	1.15 (1.05, 1.26)	1.45 (1.26, 1.72)	1.91 (1.49, 3.22)
	Medium	(0.786, 0.861) 1.07	0.897 (0.858, 0.936)	1.21 (1.13, 1.28)	1.6 (1.41, 1.88)	Not Reliable
	Negative	(0.784, 0.852) 1.07	0.895 (0.855, 0.934)	1.25 (1.19, 1.32)	1.84 (1.7, 1.99)	Not Reliable
Brazil	Positive	(4.54, 4.99) 5.9	5.13 (4.91, 5.37)	6.92 (6.51, 7.29)	9.93 (8.62, 10.8)	Not Reliable
	Medium	(4.4, 4.62) 5.9	4.88 (4.76, 4.99)	6.51 (6.3, 6.69)	9.11 (8.41, 9.48)	Not Reliable
	Negative	(4.42, 4.64) 5.9	4.89 (4.77, 5.01)	6.57 (6.39, 6.74)	9.25 (8.92, 9.59)	Not Reliable
Belgium	Positive	(7.03, 7.25) 7.59	7.3 (7.18, 7.41)	7.7 (7.58, 7.82)	8 (7.86, 8.13)	8.31 (8.15, 8.49)
	Medium	(7, 7.23) 7.59	7.27 (7.17, 7.37)	7.69 (7.57, 7.82)	8.03 (7.88, 8.17)	8.44 (8.21, 8.65)
	Negative	(6.63, 8.21) 7.59	7.57 (6.74, 8.49)	8.76 (7.85, 9.84)	10.4 (9.26, 11.9)	Not Reliable
Netherlands	Positive	(4.41, 4.75) 4.8	4.67 (4.5, 4.82)	4.95 (4.77, 5.12)	5.22 (5.01, 5.4)	5.8 (5.48, 6.11)
	Medium	(4.46, 4.68) 4.8	4.66 (4.54, 4.78)	4.95 (4.82, 5.09)	5.23 (5.08, 5.39)	5.97 (5.61, 6.31)
	Negative	(4.06, 5.16) 4.8	4.68 (4.18, 5.32)	5.29 (4.73, 6.05)	6.08 (5.46, 6.96)	Not Reliable
Switzerland	Positive	(1.64, 1.77) 1.75	1.72 (1.66, 1.79)	1.79 (1.72, 1.86)	1.84 (1.77, 1.92)	1.94 (1.85, 2.03)
	Medium	(1.65, 1.76) 1.75	1.72 (1.68, 1.78)	1.79 (1.74, 1.85)	1.85 (1.79, 1.92)	1.96 (1.88, 2.06)
	Negative	(1.49, 1.93) 1.75	1.73 (1.52, 1.95)	1.93 (1.71, 2.18)	2.19 (1.93, 2.48)	Not Reliable
Portugal	Positive	(0.905, 0.98)	0.966	1.05	1.13	1.38

		0.989	(0.926, 1.01)	(0.998, 1.09)	(1.06, 1.2)	(1.15, 1.76)
	Medium	(0.899, 0.976) 0.989	0.965 (0.921, 0.998)	1.05 (0.996, 1.09)	1.14 (1.07, 1.19)	1.4 (1.26, 1.64)
	Negative	(0.908, 0.984) 0.989	0.97 (0.933, 1.01)	1.1 (1.06, 1.14)	1.27 (1.21, 1.32)	Not Reliable
Sweden	Positive	(2.25, 2.38) 2.59	2.46 (2.35, 2.56)	2.73 (2.6, 2.85)	2.96 (2.8, 3.15)	3.33 (3.07, 3.7)
	Medium	(2.25, 2.38) 2.59	2.39 (2.32, 2.46)	2.69 (2.61, 2.78)	2.99 (2.87, 3.12)	3.66 (3.35, 4.12)
	Negative	(2.21, 2.49) 2.59	2.42 (2.28, 2.6)	2.88 (2.71, 3.09)	3.51 (3.28, 3.78)	Not Reliable
Ireland	Positive	(1.02, 1.2) 1.23	1.16 (1.08, 1.26)	1.42 (1.3, 1.57)	1.71 (1.51, 2.03)	2.5 (1.81, 5.91)
	Medium	(1.03, 1.11) 1.23	1.13 (1.09, 1.18)	1.42 (1.36, 1.49)	1.83 (1.69, 1.96)	Not Reliable
	Negative	(1.03, 1.11) 1.23	1.14 (1.09, 1.19)	1.45 (1.39, 1.51)	1.9 (1.8, 1.99)	Not Reliable
Austria	Positive	(0.523, 0.583) 0.584	0.563 (0.534, 0.595)	0.594 (0.563, 0.627)	0.621 (0.589, 0.658)	0.678 (0.626, 0.739)
	Medium	(0.526, 0.586) 0.584	0.568 (0.536, 0.597)	0.599 (0.565, 0.634)	0.629 (0.587, 0.669)	0.696 (0.62, 0.775)
	Negative	(0.514, 0.604) 0.584	0.572 (0.521, 0.616)	0.641 (0.586, 0.698)	0.731 (0.665, 0.801)	Not Reliable
Japan	Positive	(0.334, 0.381) 0.432	0.378 (0.349, 0.407)	0.487 (0.446, 0.537)	0.62 (0.547, 0.749)	0.943 (0.718, 1.98)
	Medium	(0.379, 0.438) 0.432	0.414 (0.384, 0.444)	0.545 (0.498, 0.586)	0.759 (0.669, 0.834)	Not Reliable
	Negative	(0.381, 0.441) 0.432	0.414 (0.386, 0.444)	0.547 (0.506, 0.59)	0.772 (0.705, 0.846)	Not Reliable
Iran	Positive	(5.68, 6.11) 6.03	5.95 (5.71, 6.19)	6.16 (5.92, 6.41)	6.37 (6.12, 6.64)	6.96 (6.61, 7.31)
	Medium	(5.72, 6.05) 6.03	5.97 (5.78, 6.14)	6.19 (6, 6.38)	6.41 (6.21, 6.6)	7.09 (6.76, 7.48)
	Negative	(5.3, 6.5) 6.03	5.96 (5.39, 6.63)	6.49 (5.88, 7.22)	7.16 (6.49, 7.96)	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.

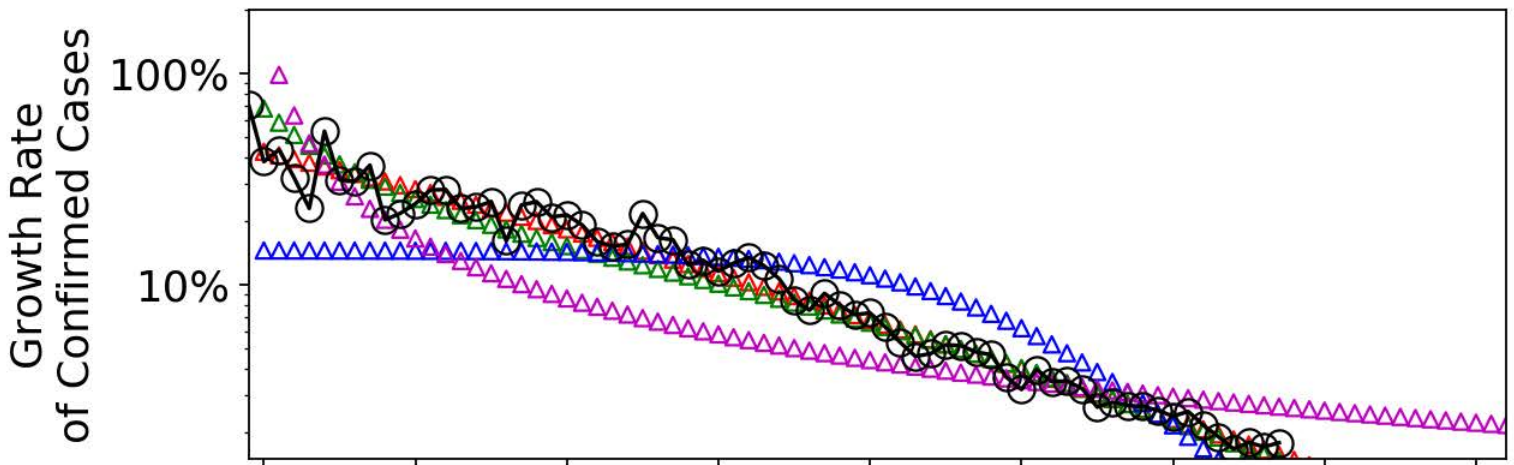
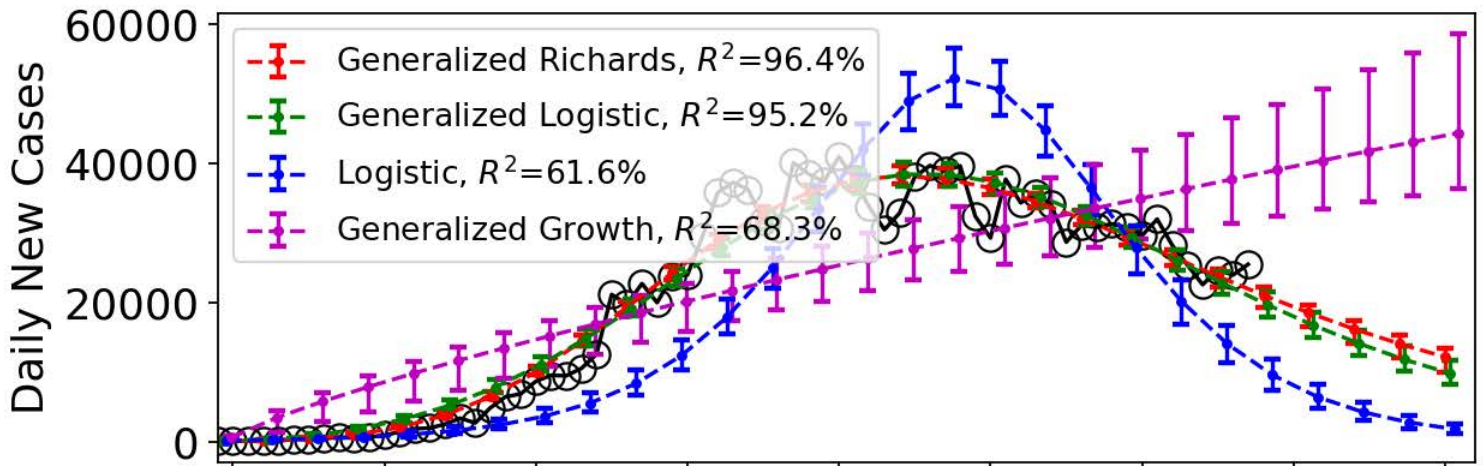
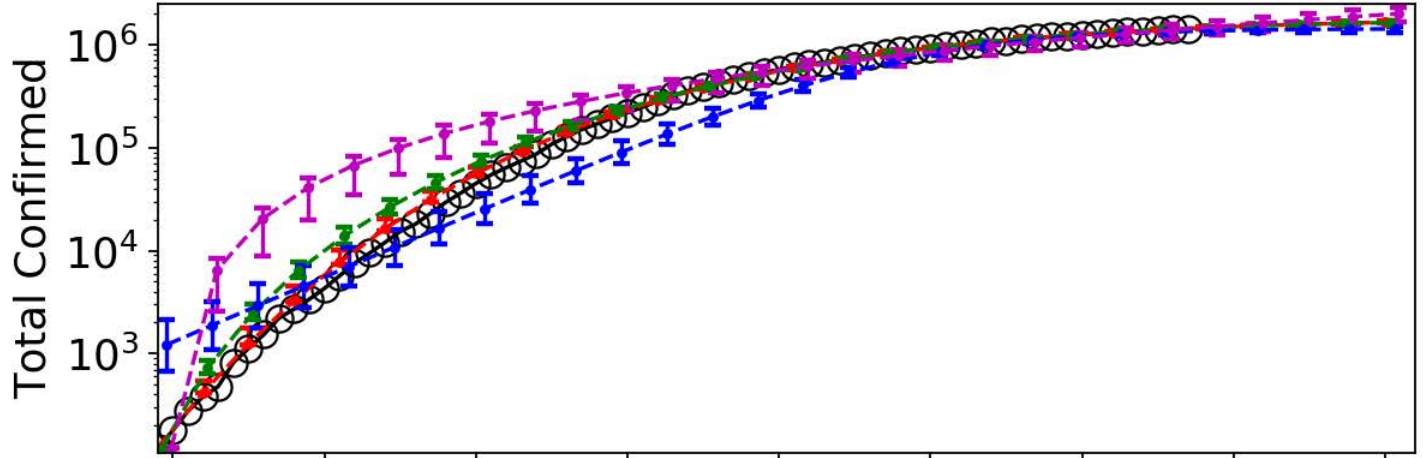
We anticipate that, over time, our methodology will improve and will provide a more accurate picture of the true levels of infection and where they are headed.

[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>

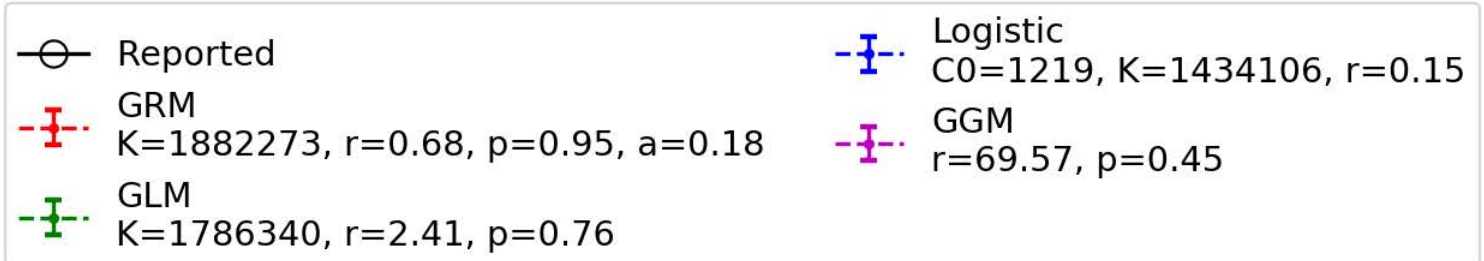
[2] <https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases>

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

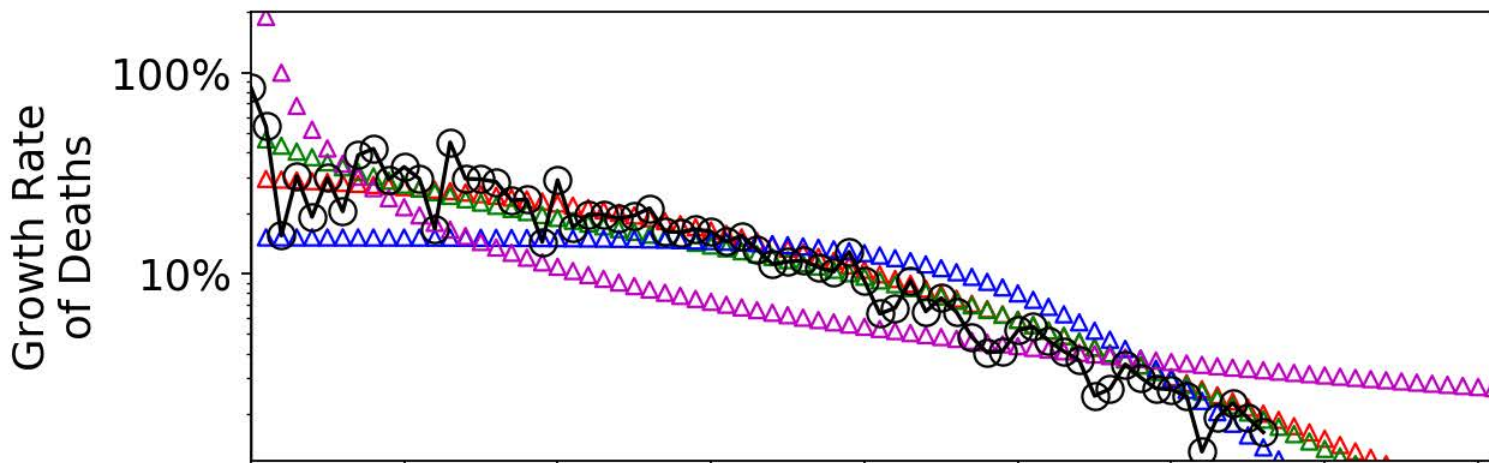
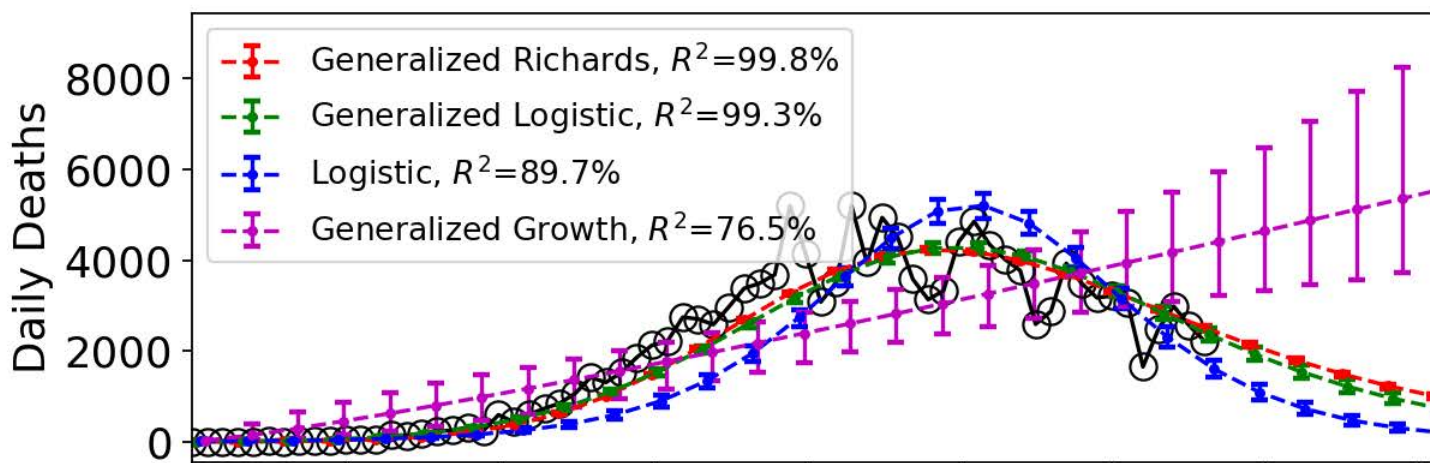
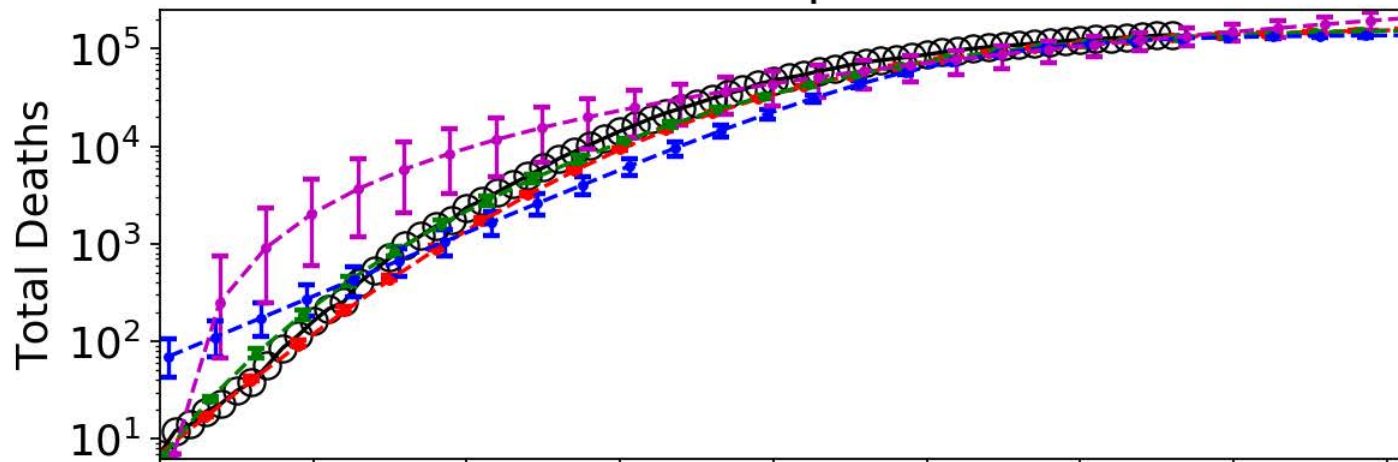
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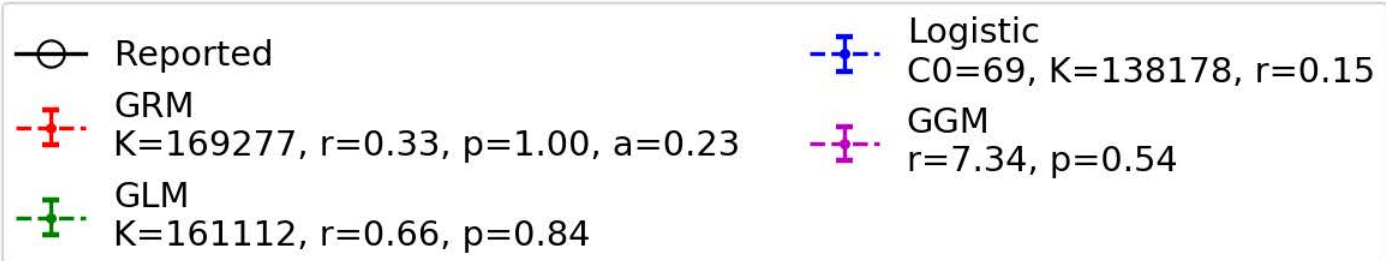
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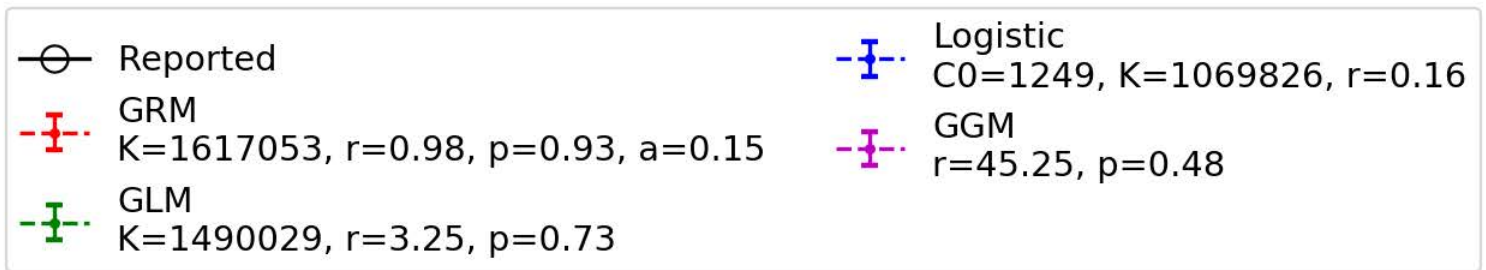
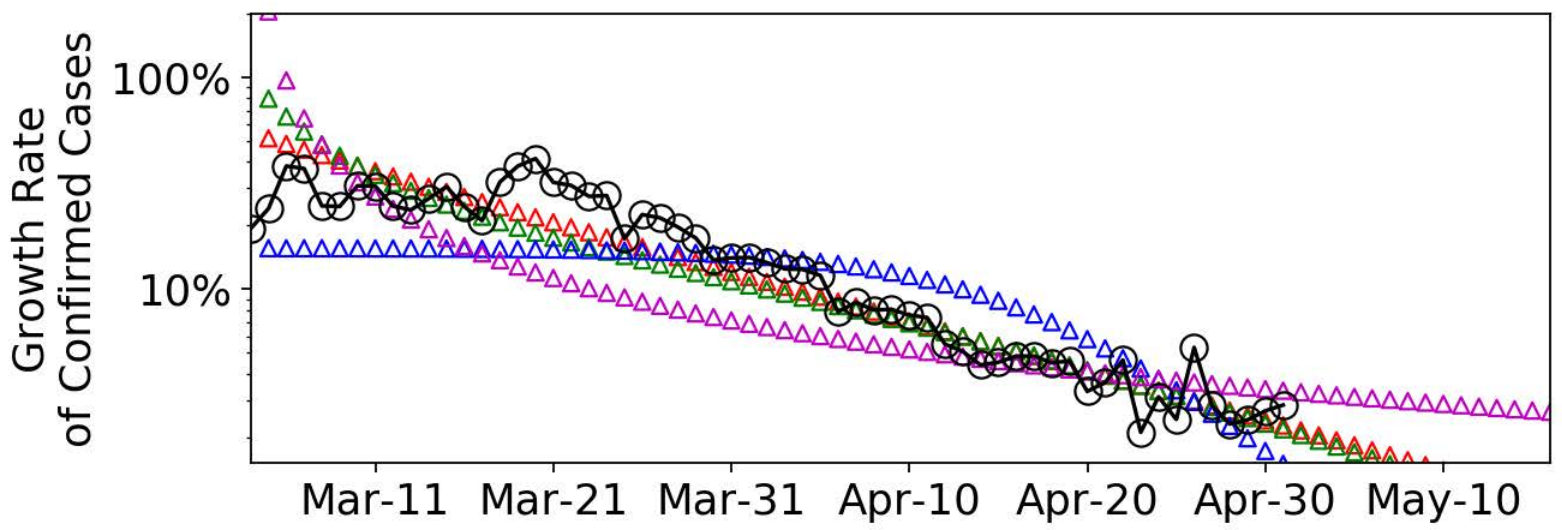
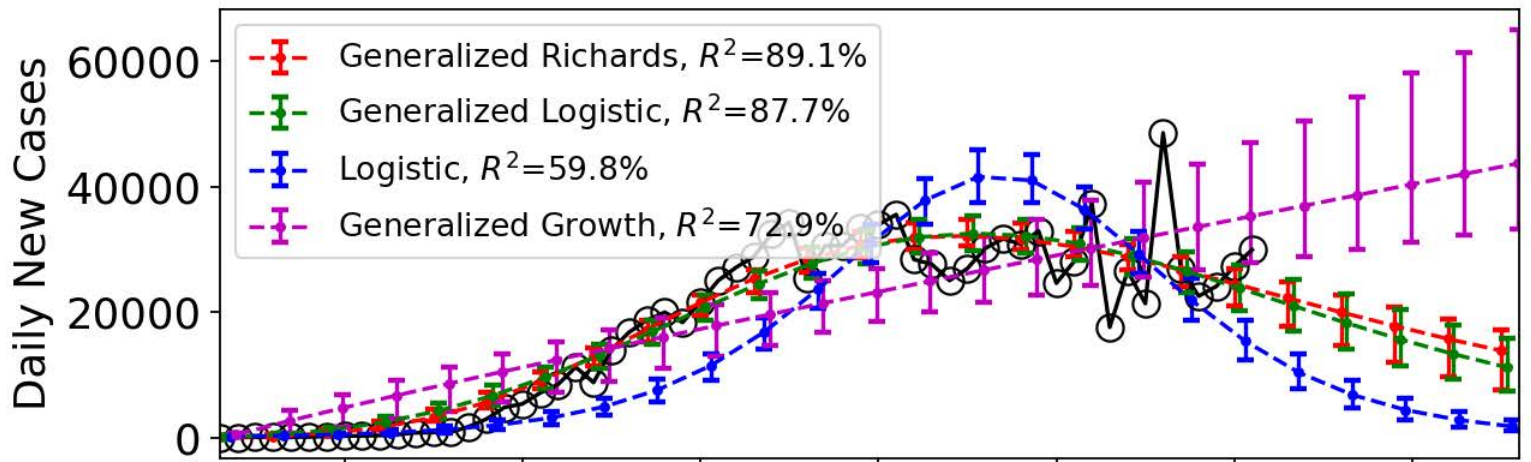
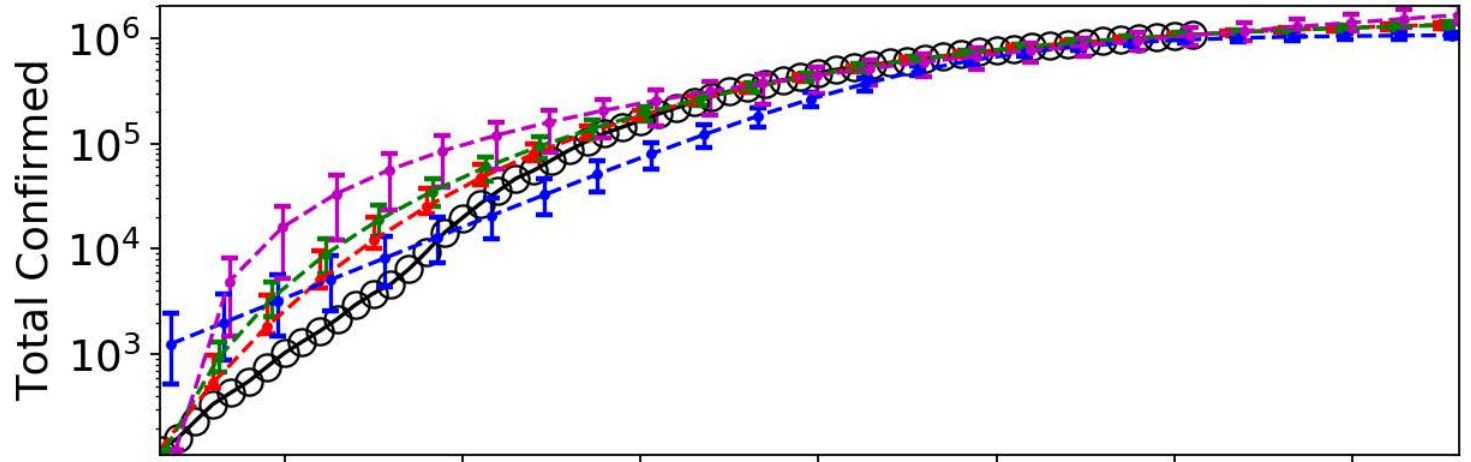
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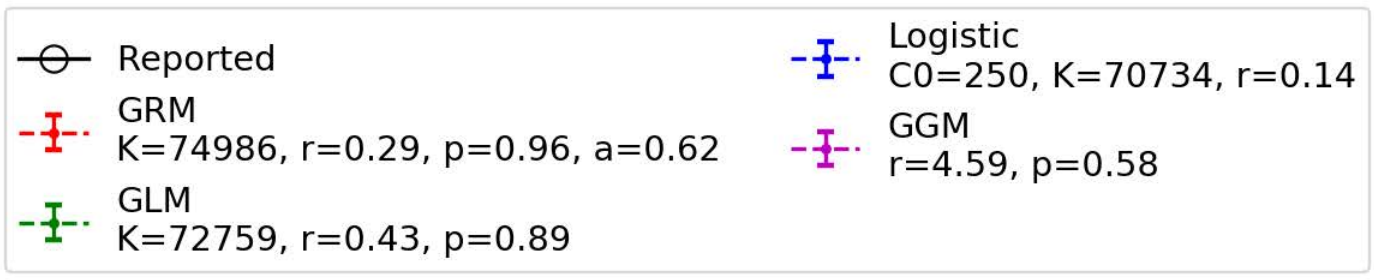
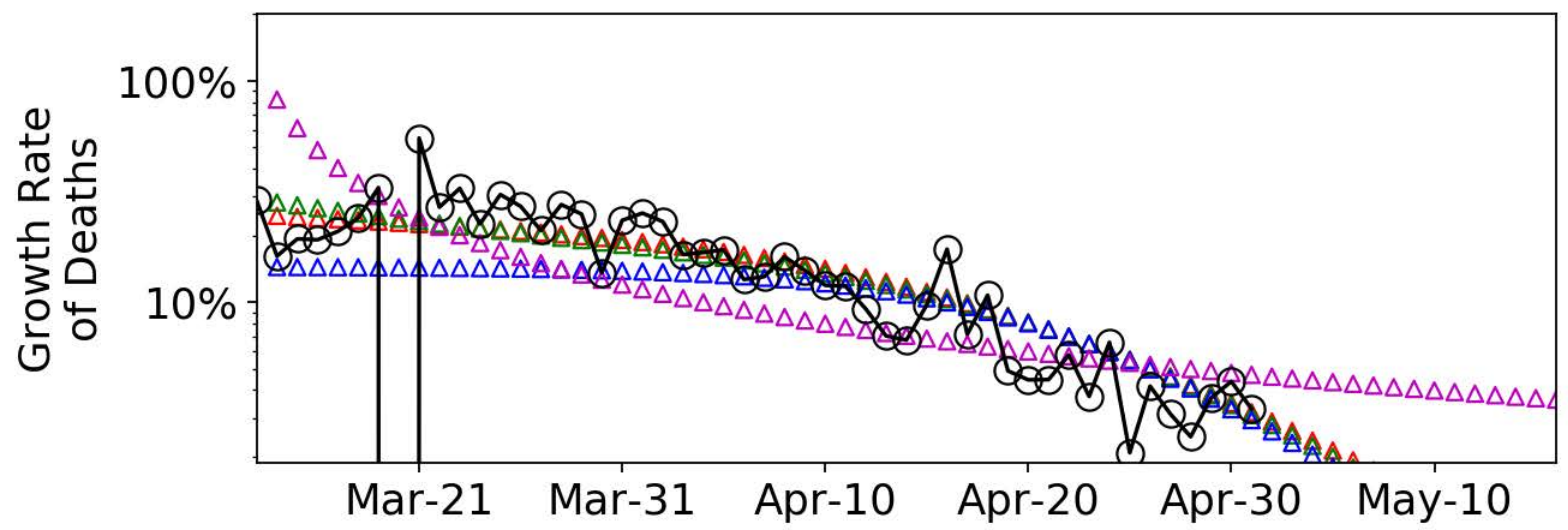
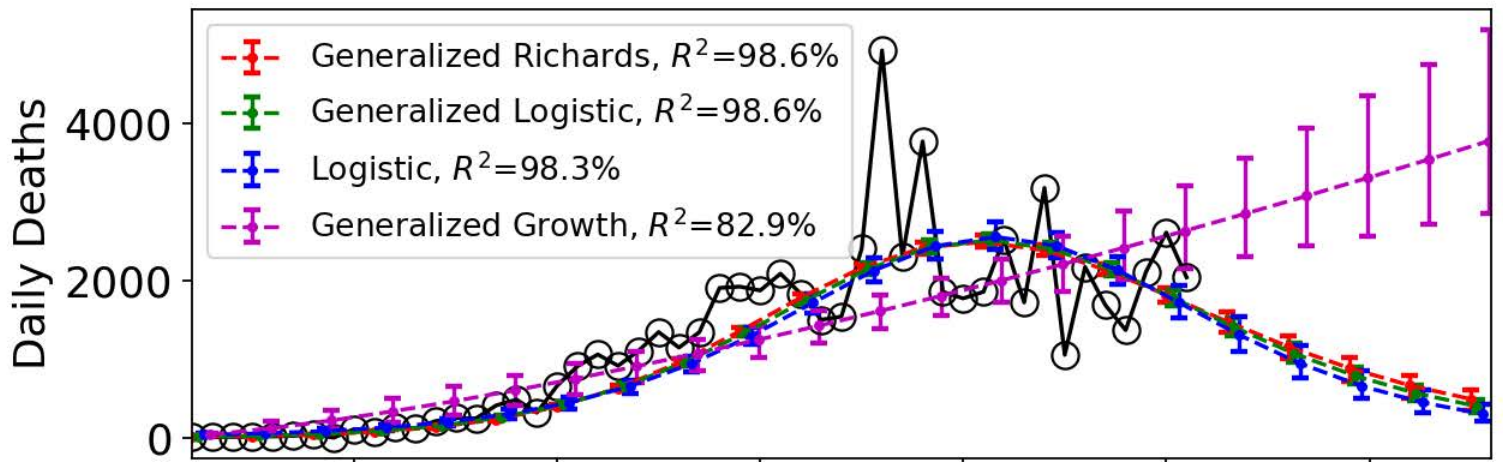
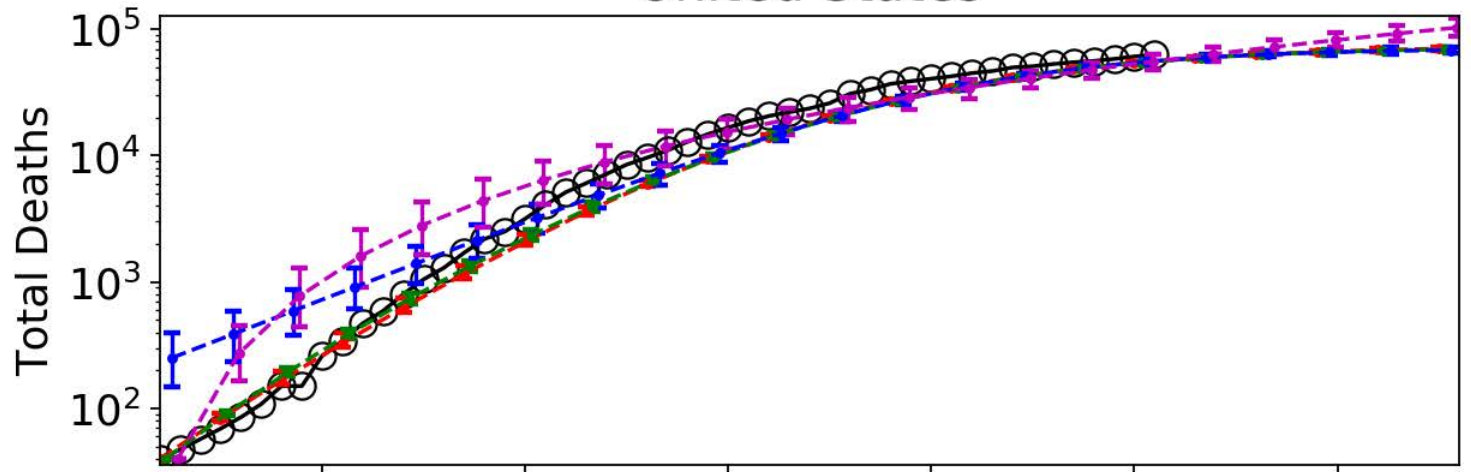
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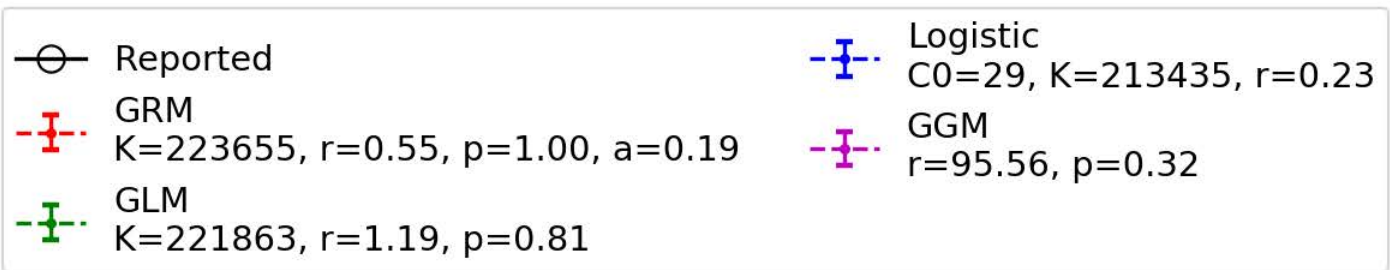
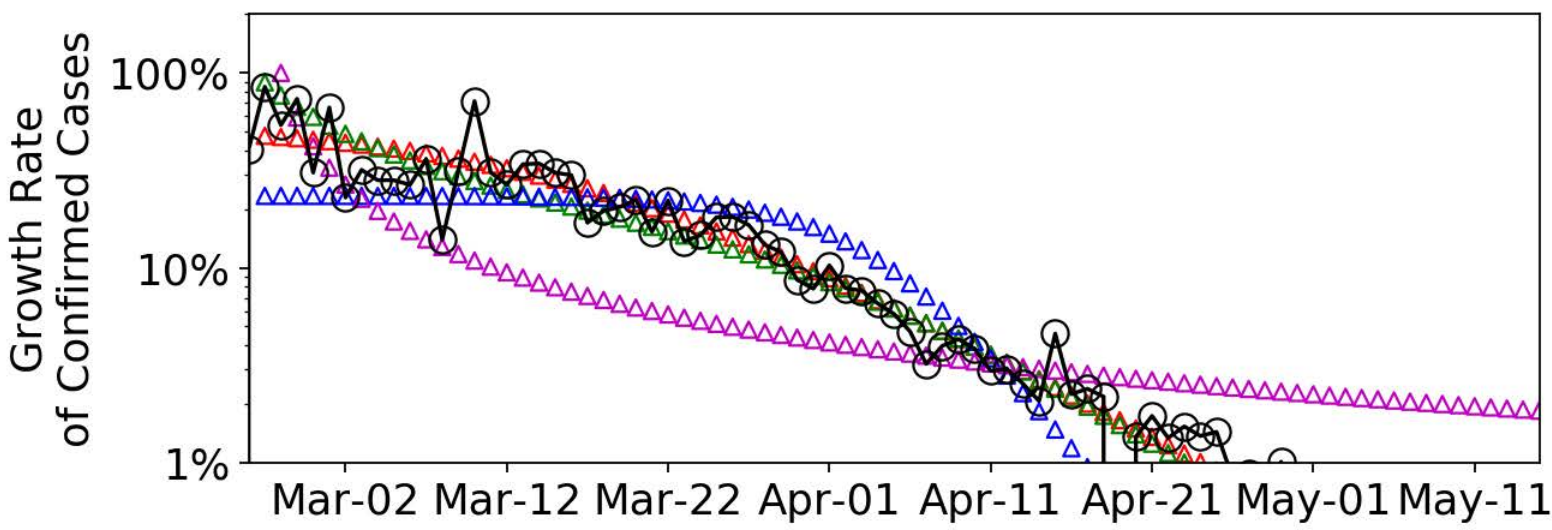
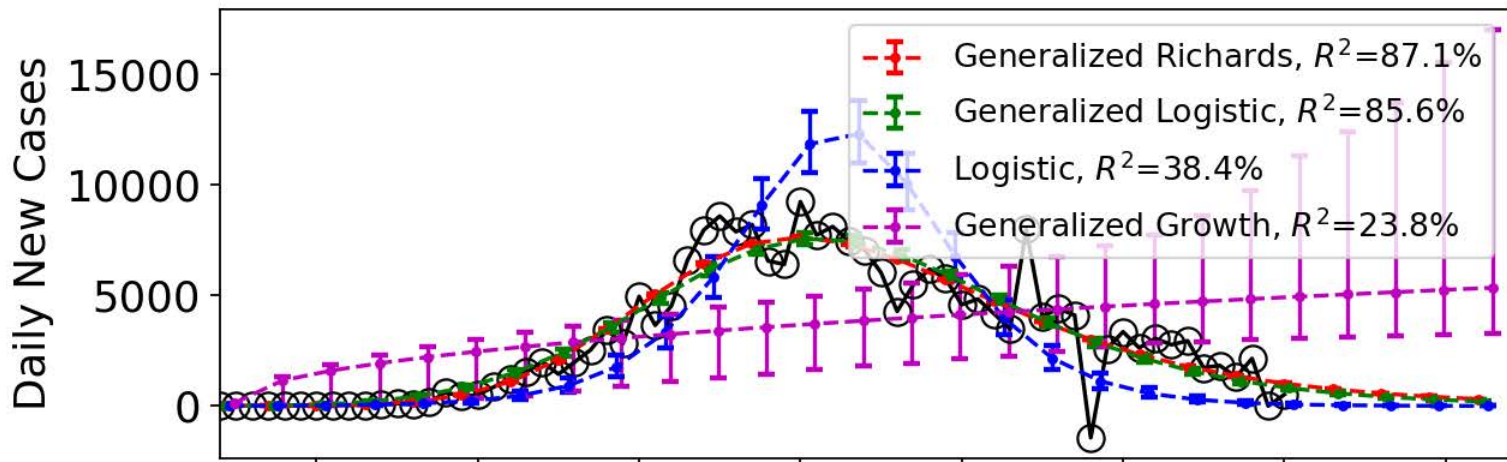
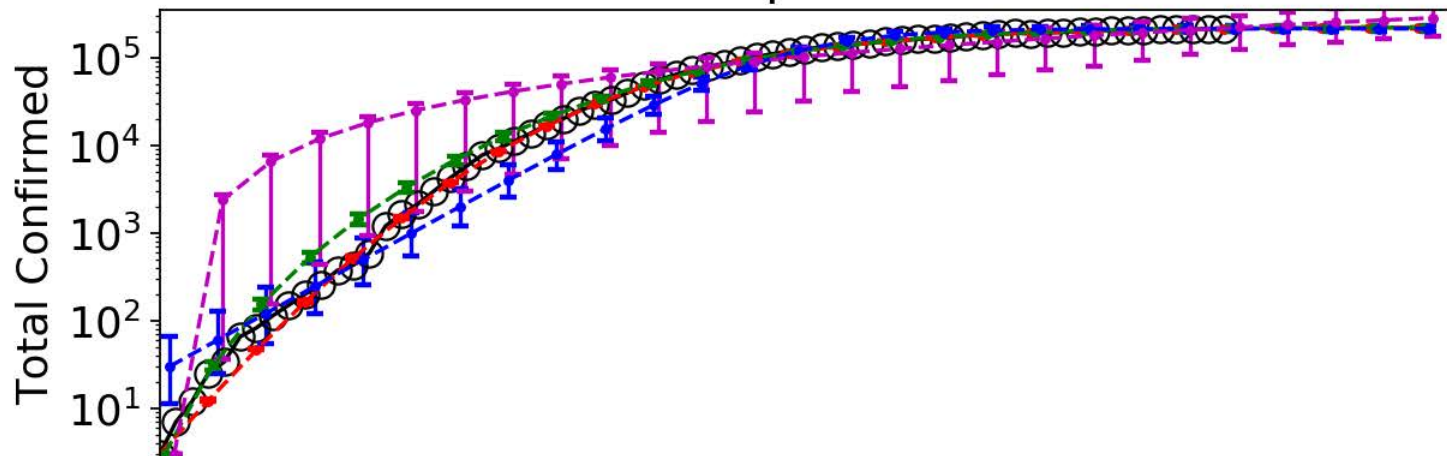
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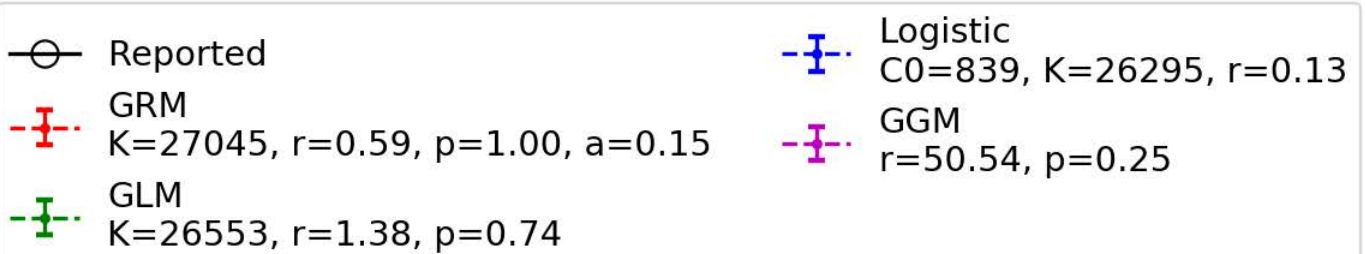
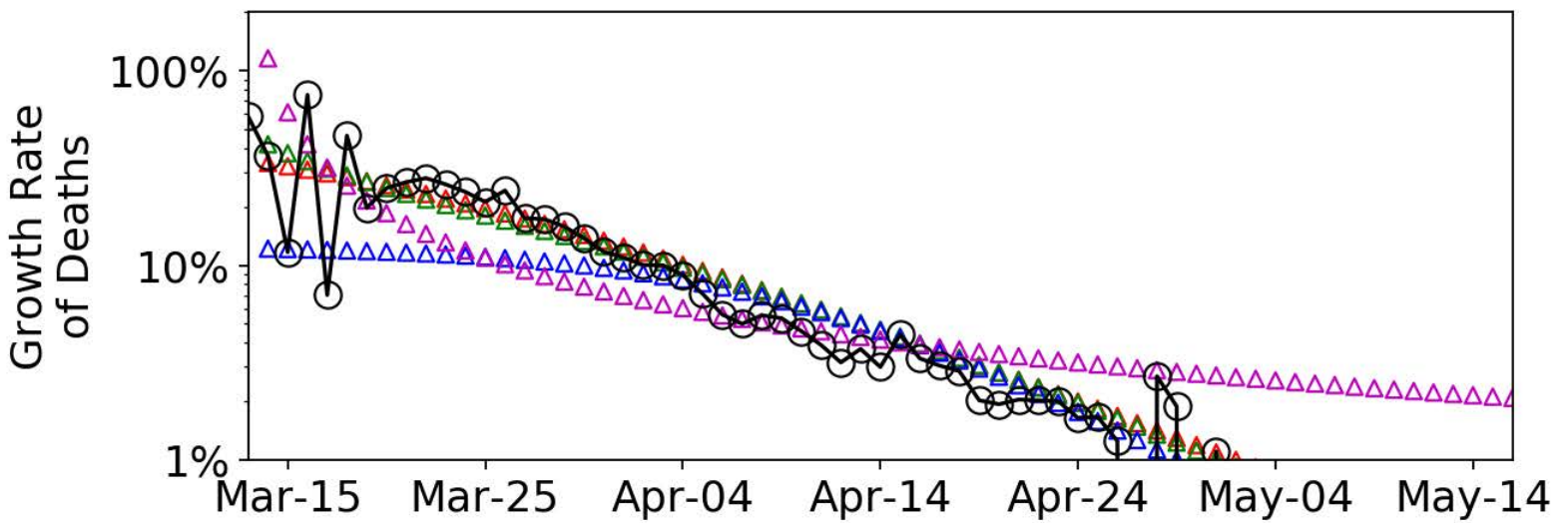
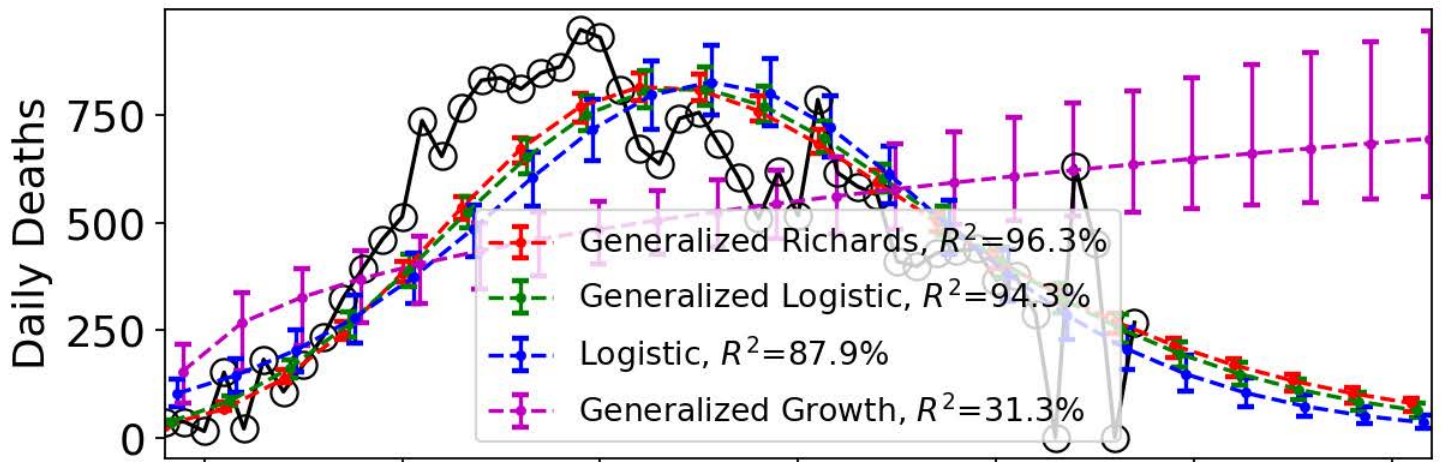
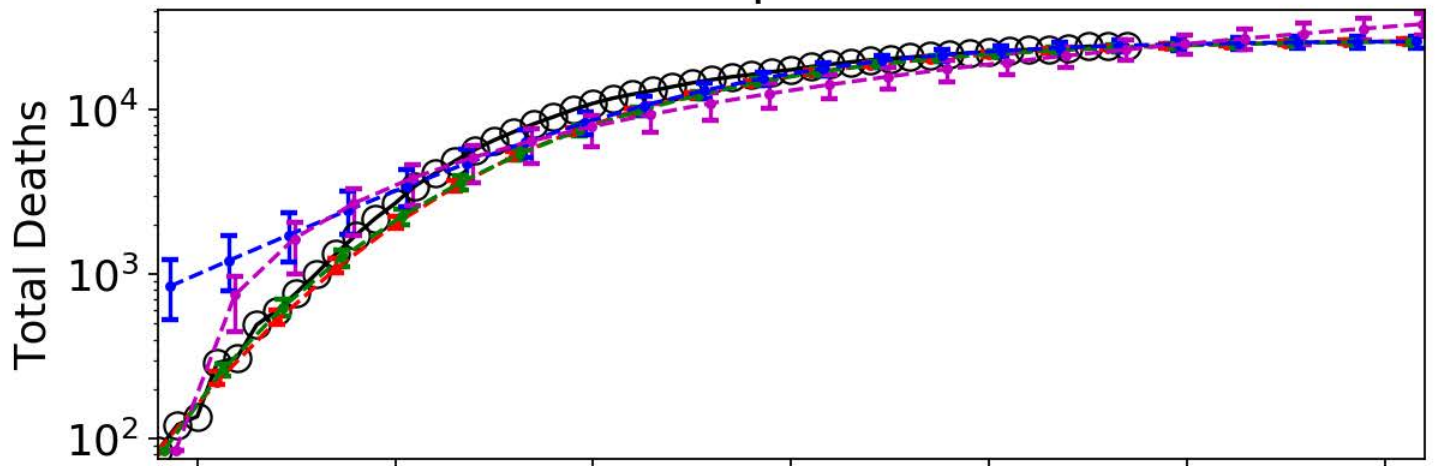
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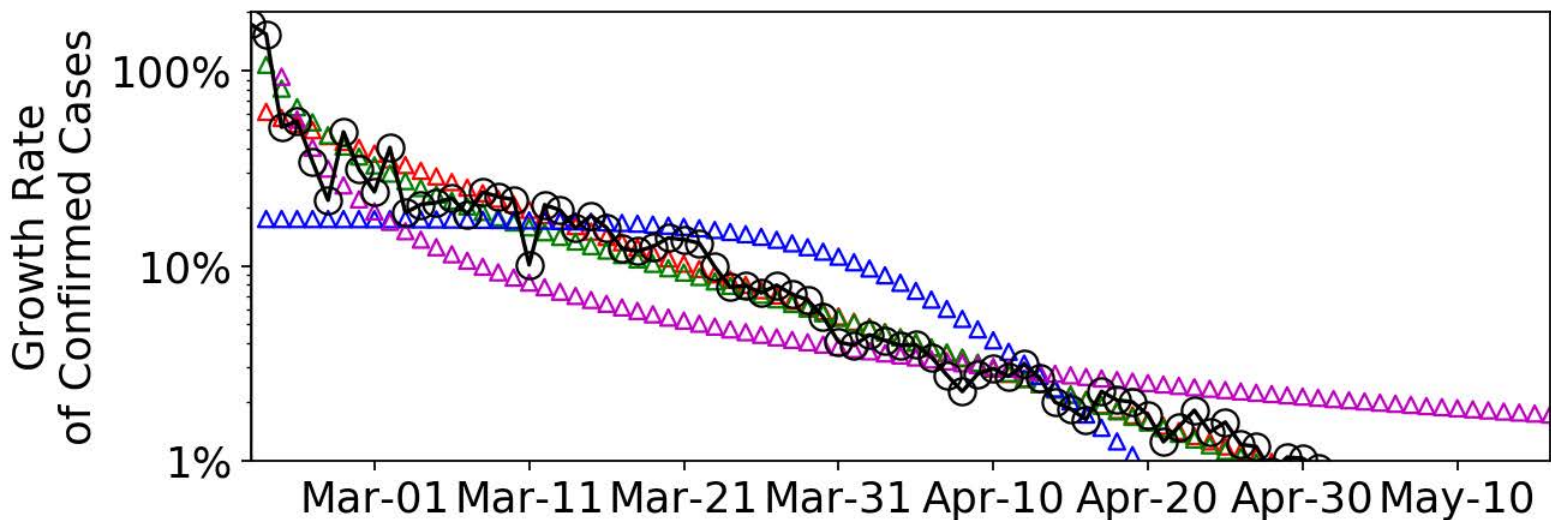
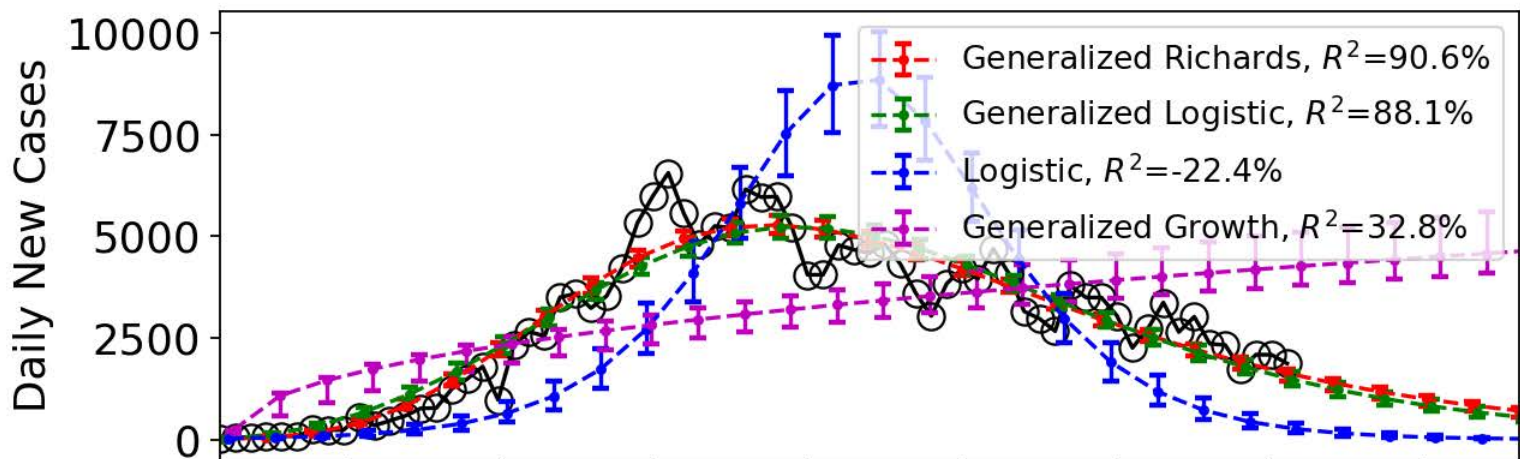
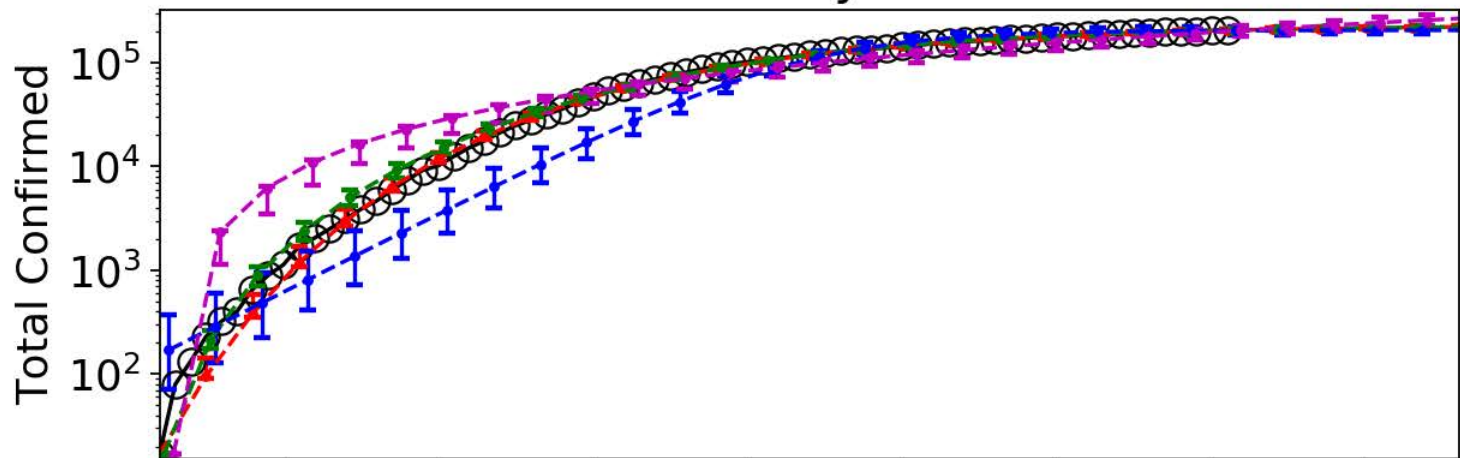
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Spain

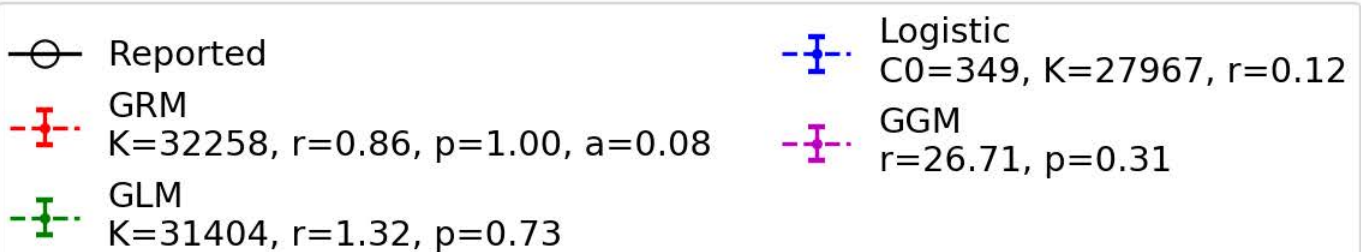
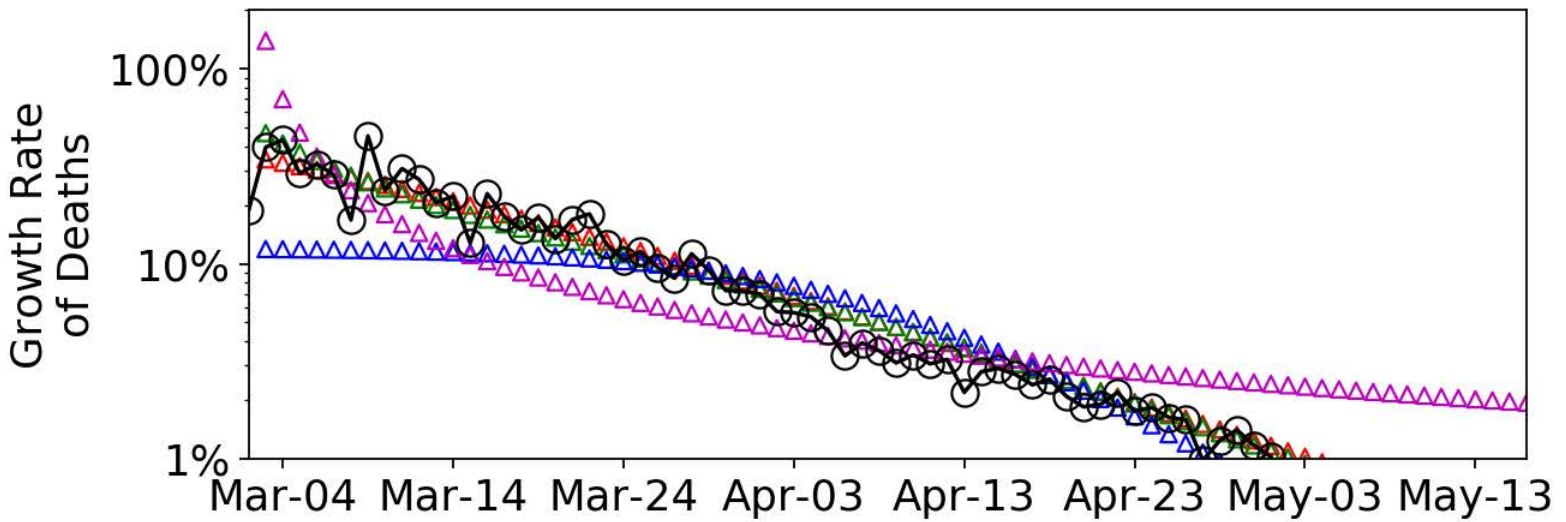
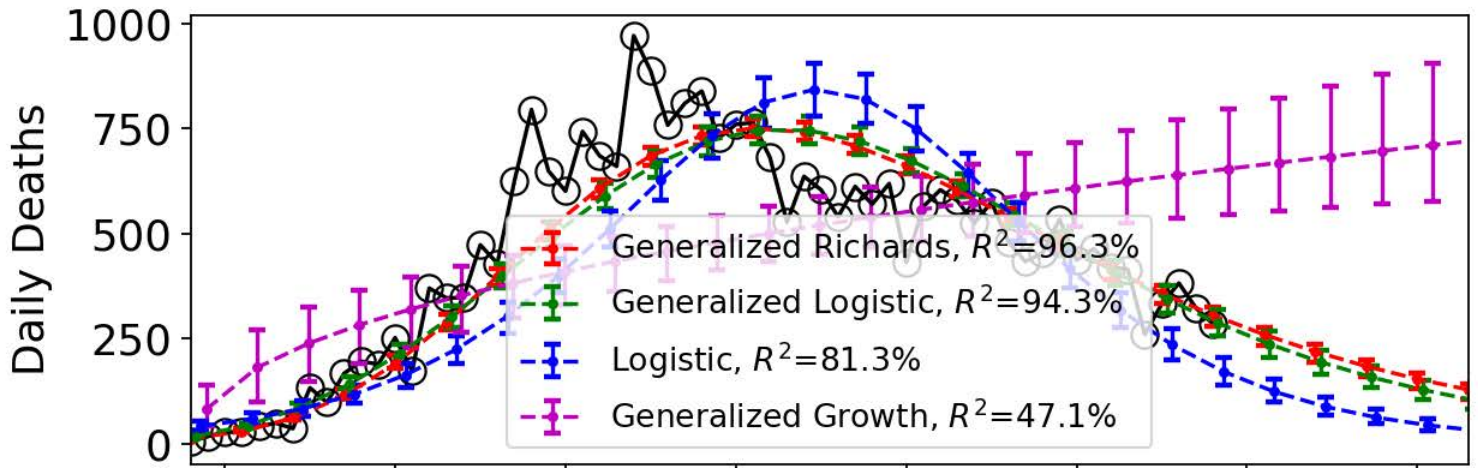
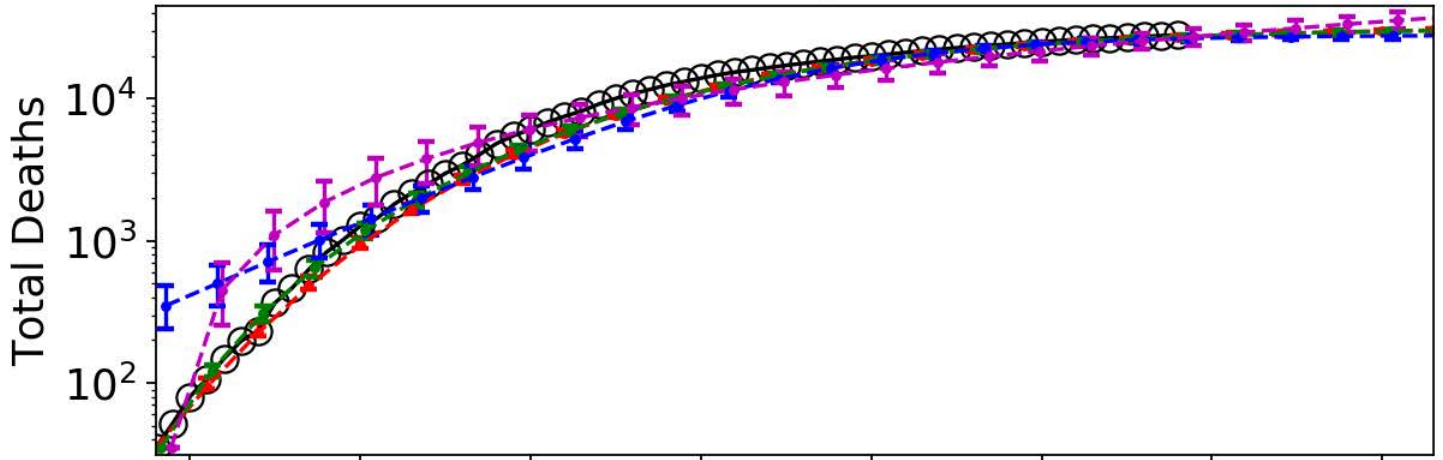


Italy

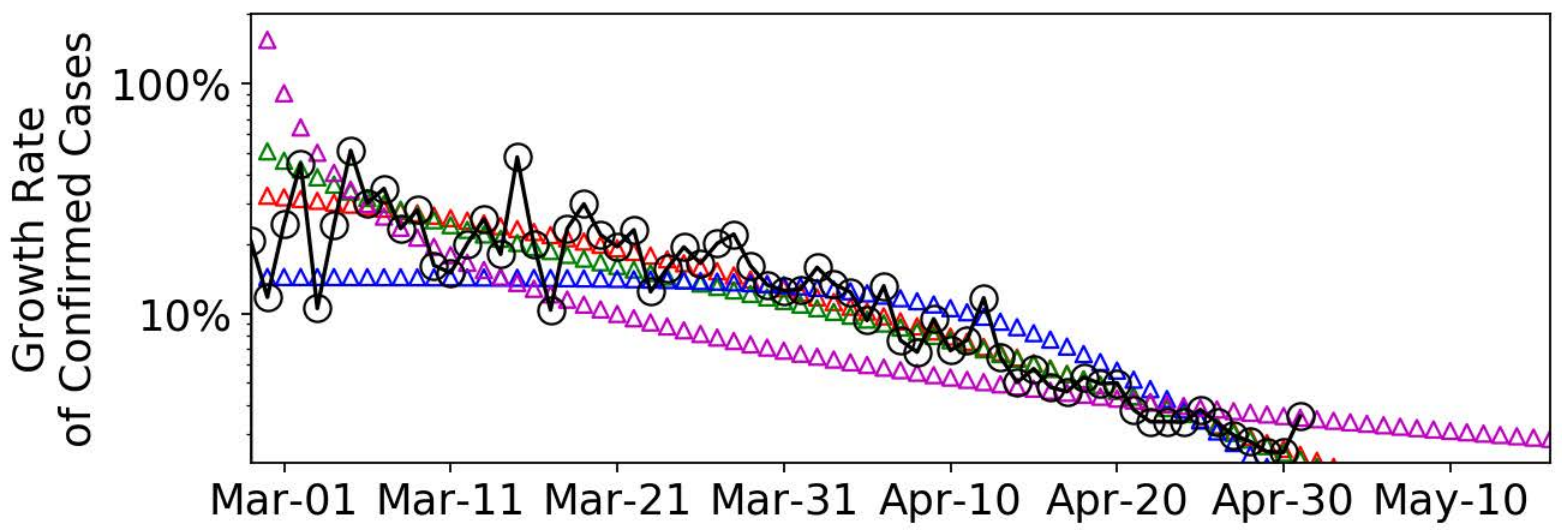
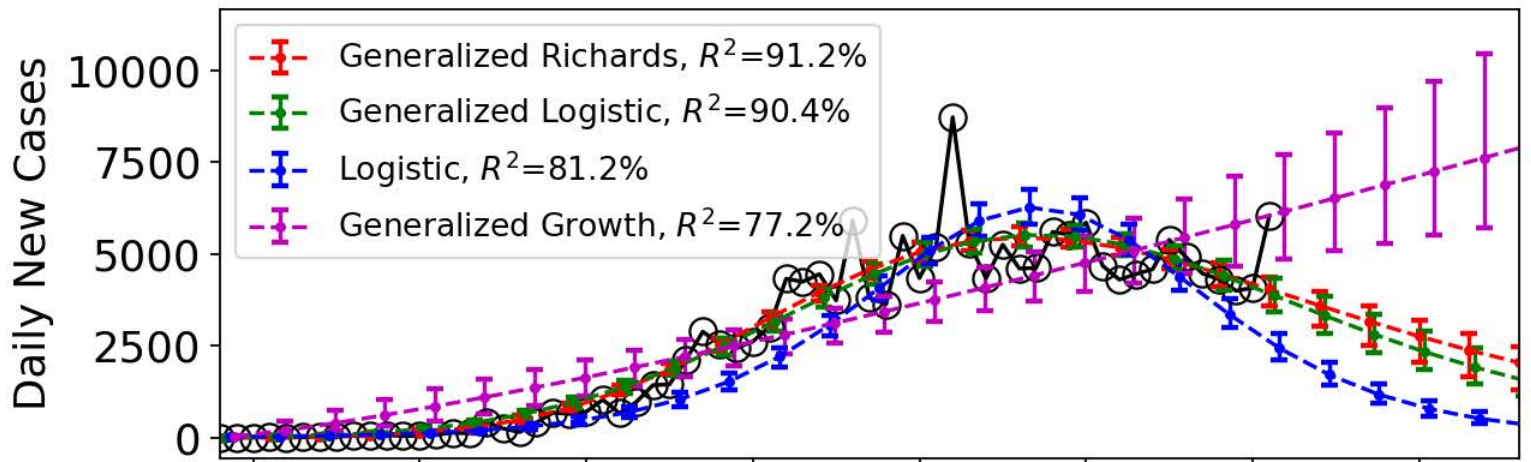
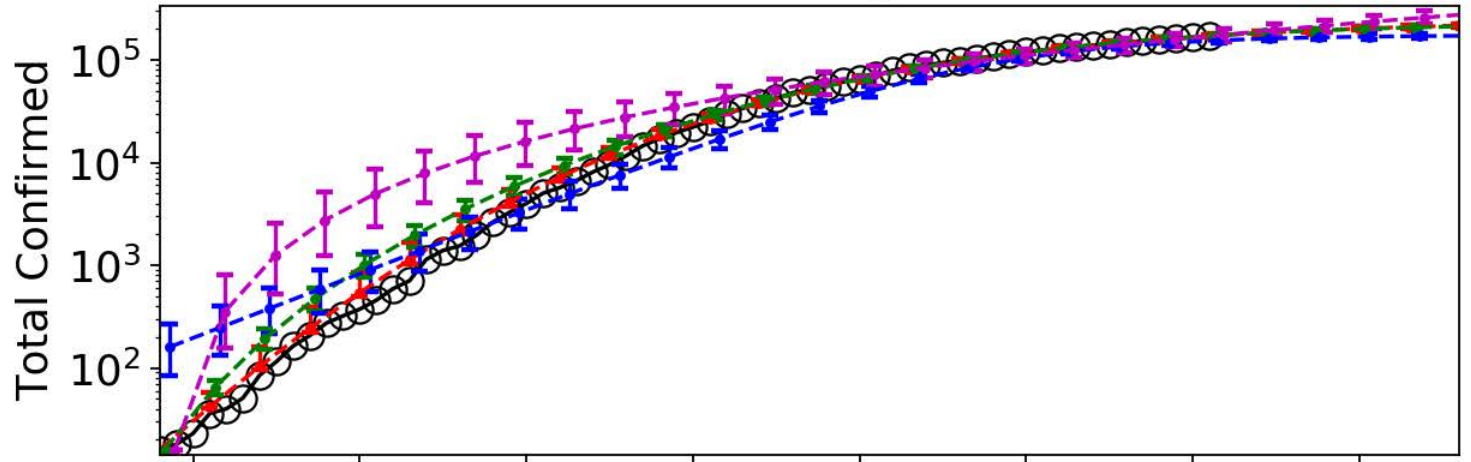


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- GLM
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- Logistic
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- GGM
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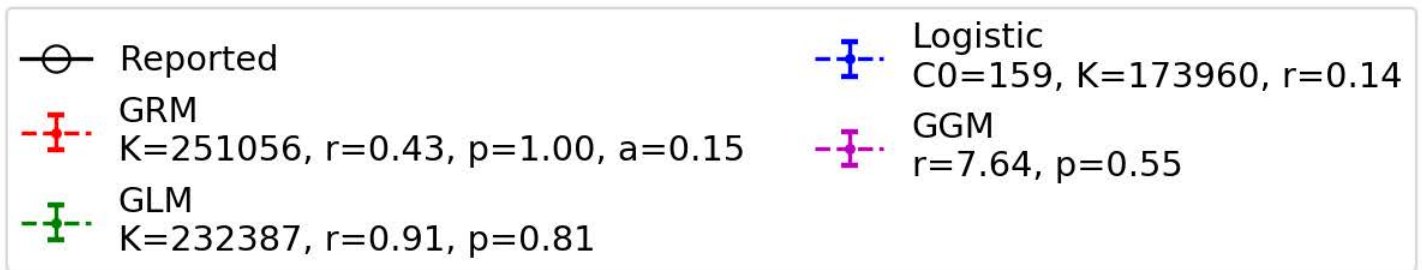
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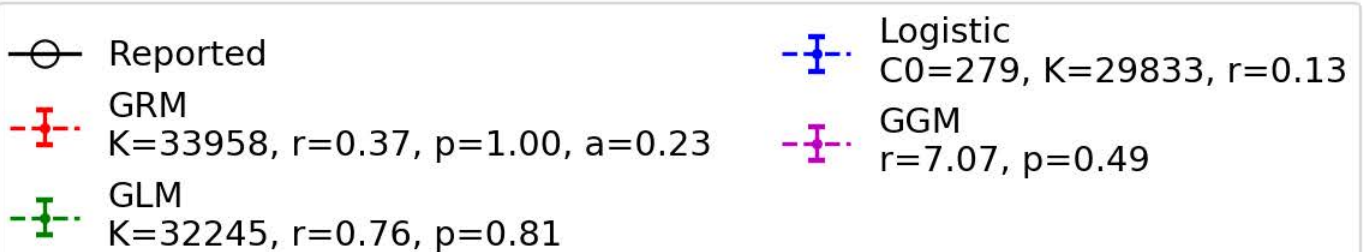
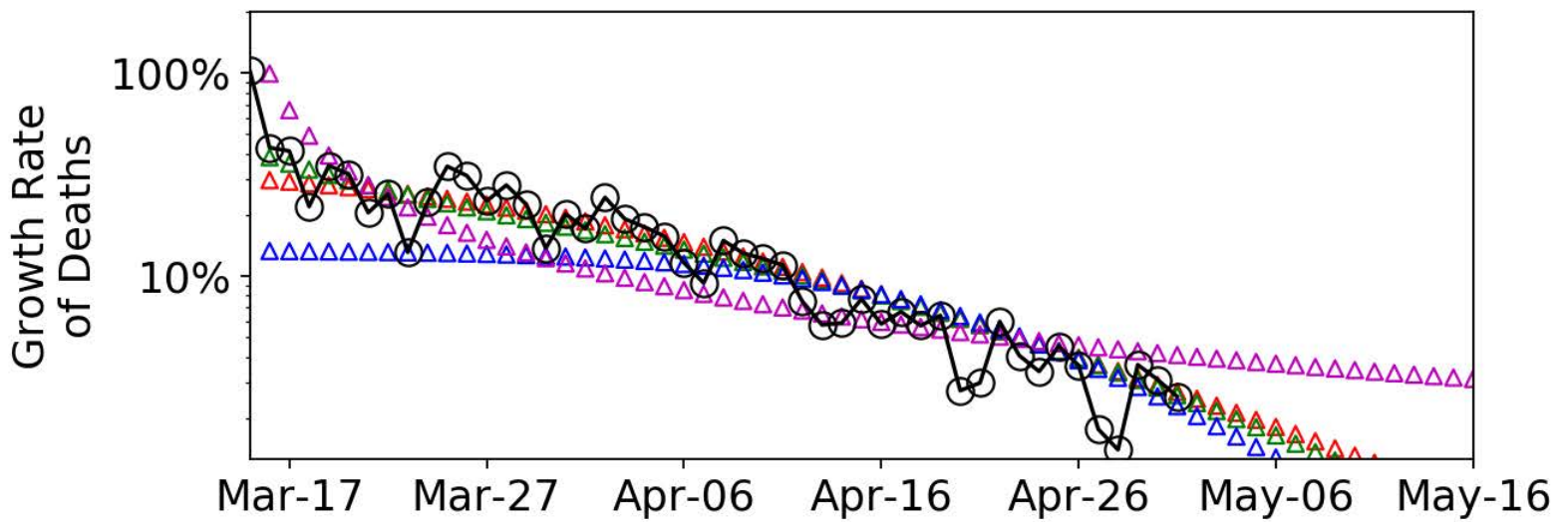
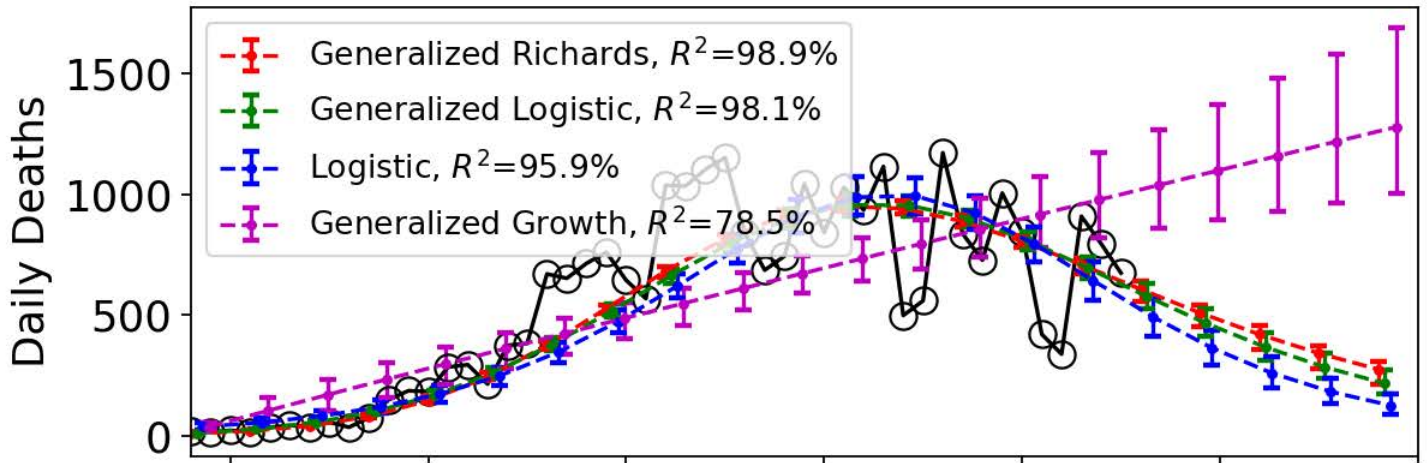
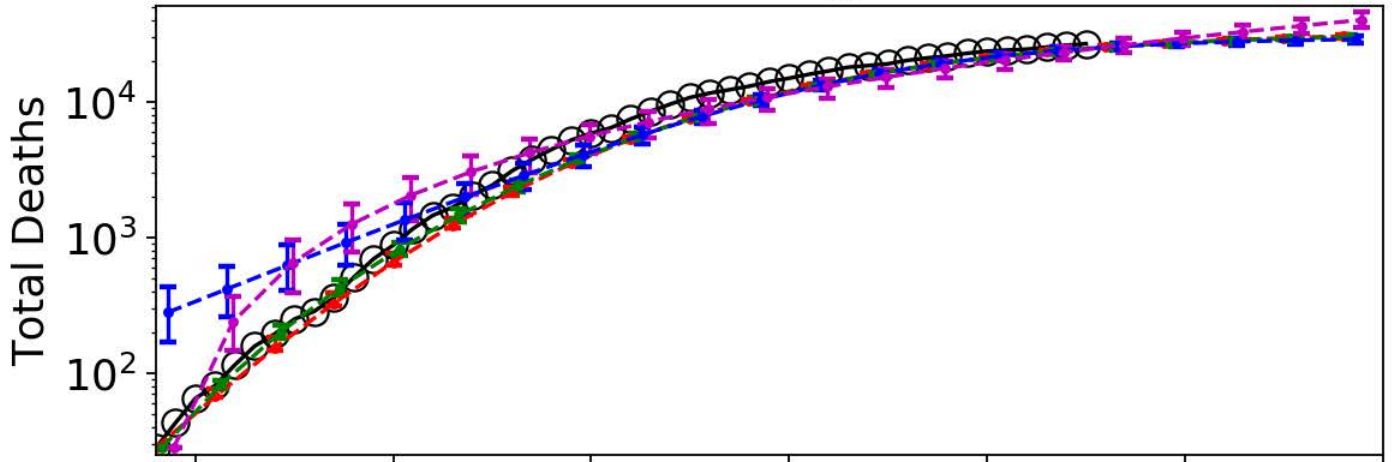
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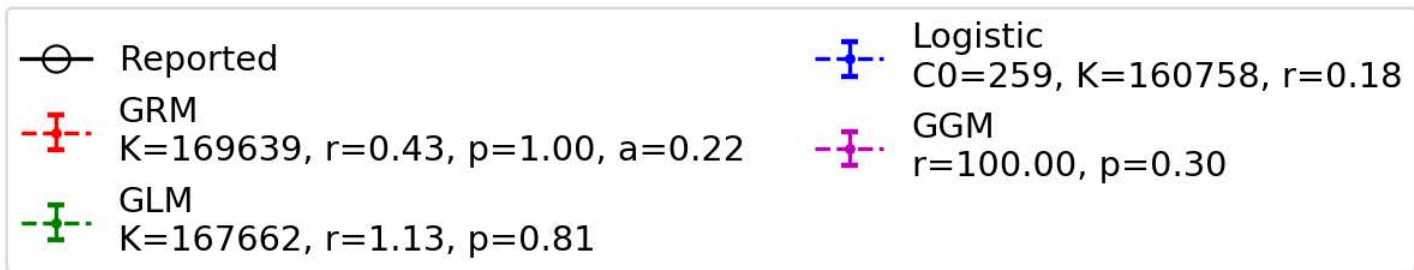
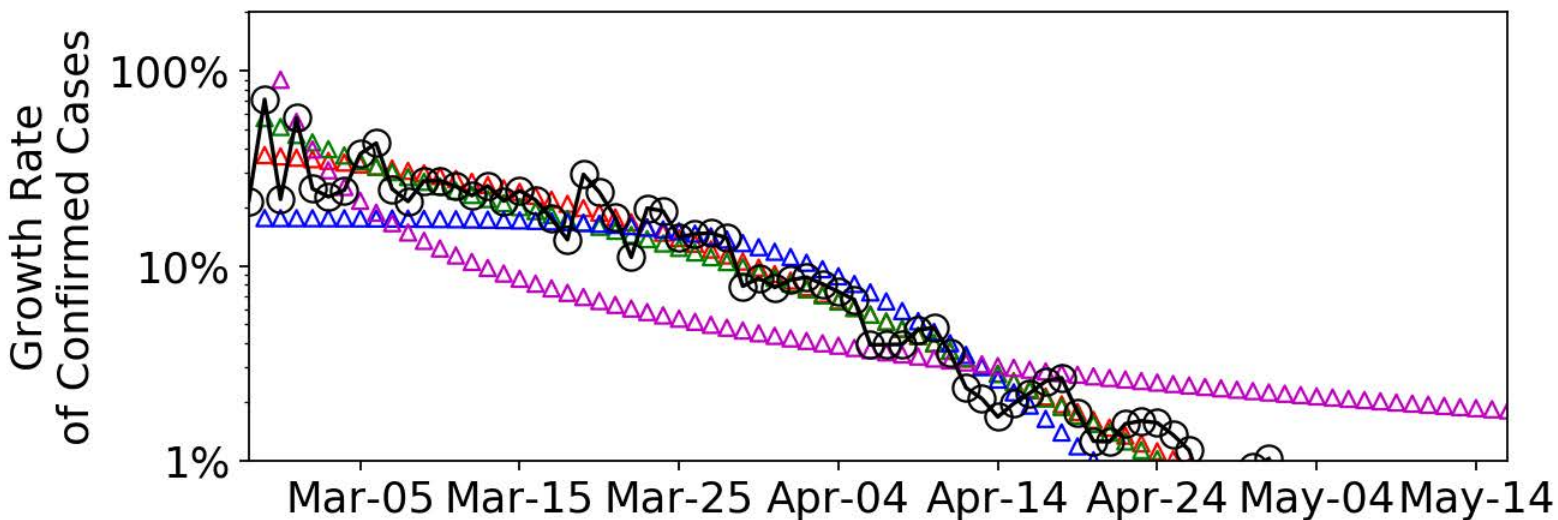
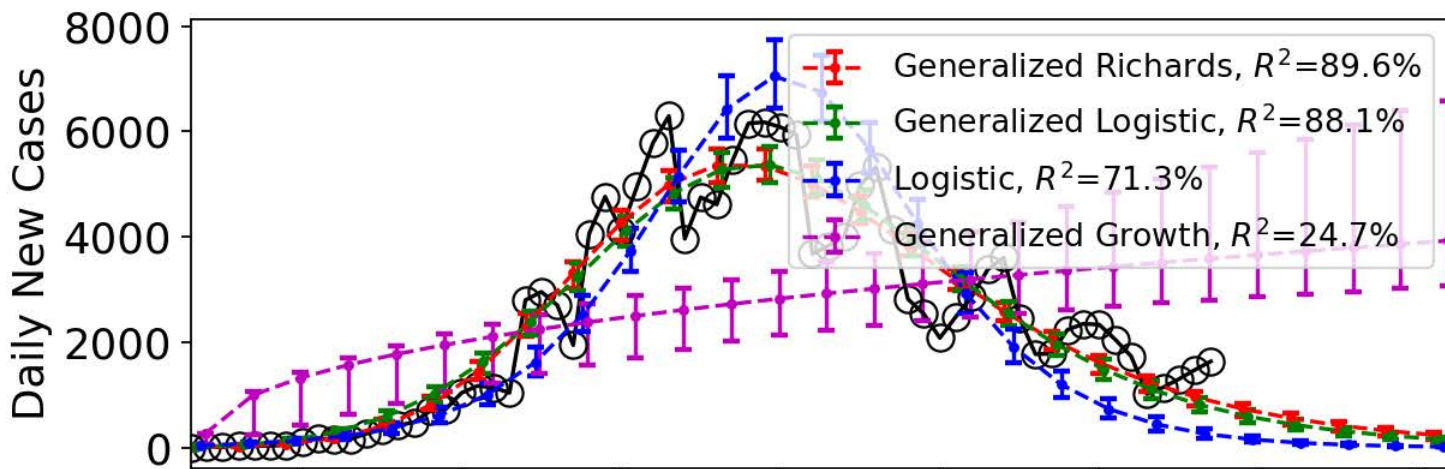
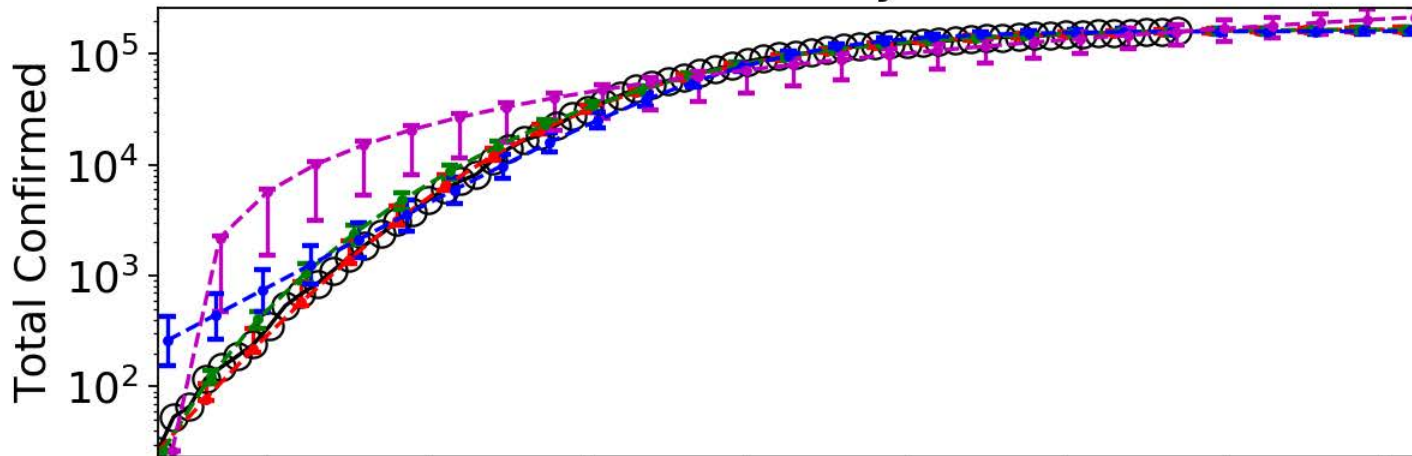
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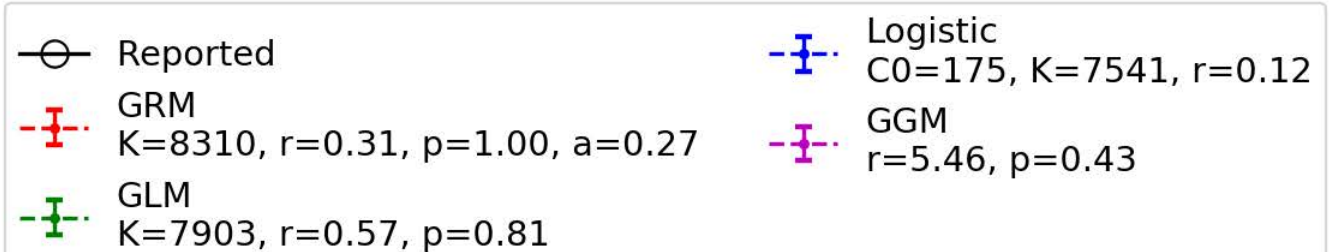
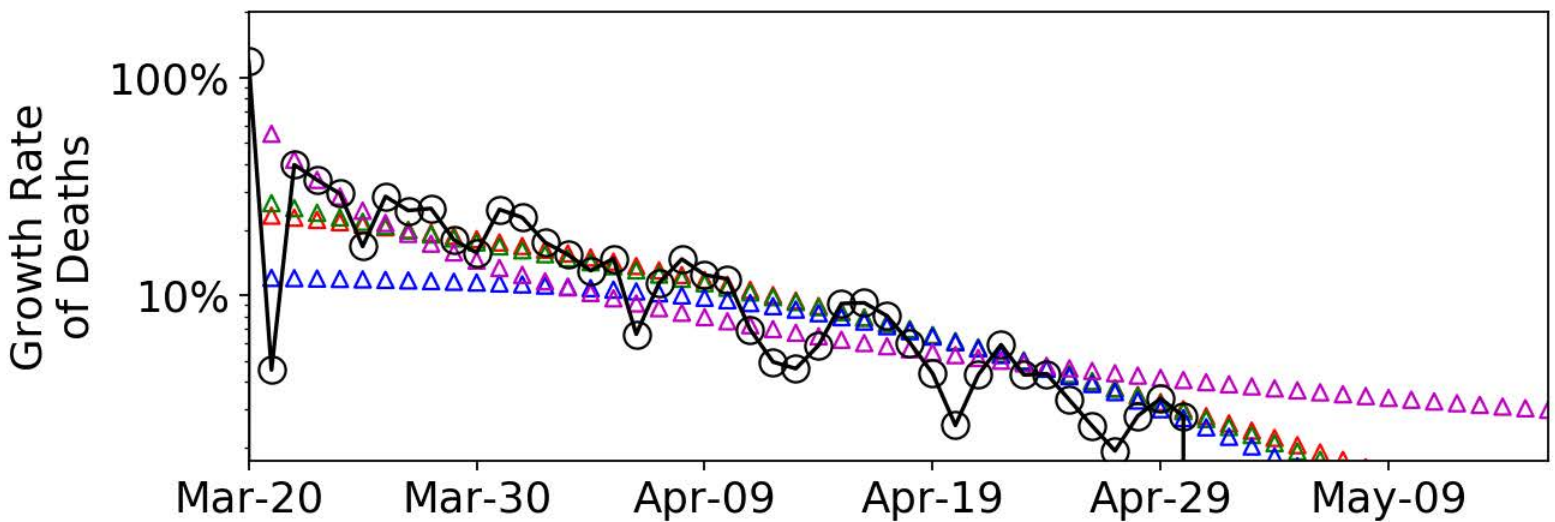
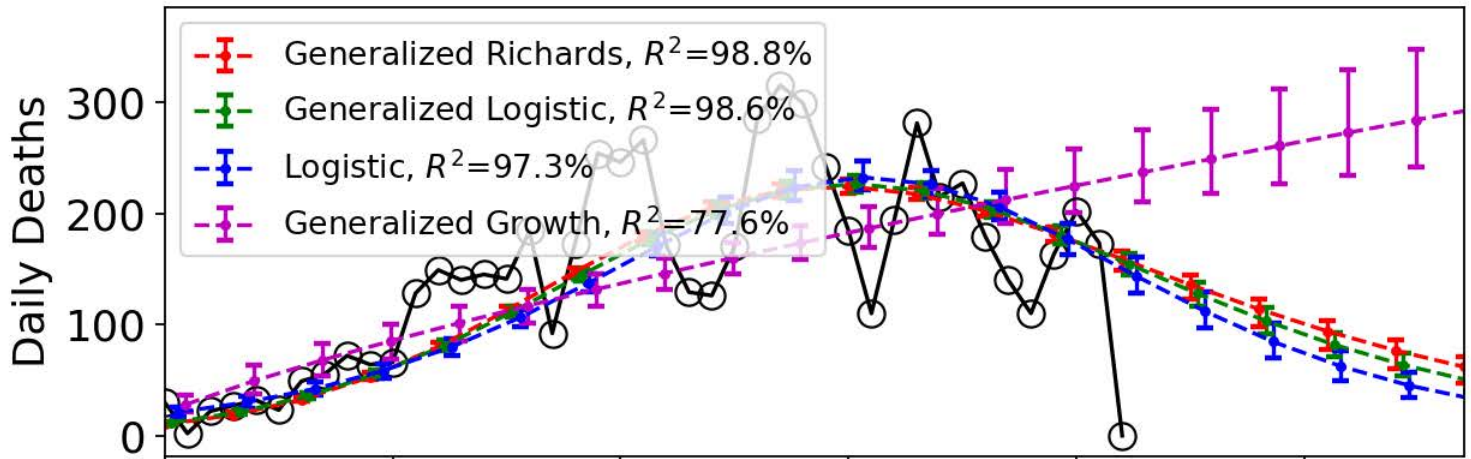
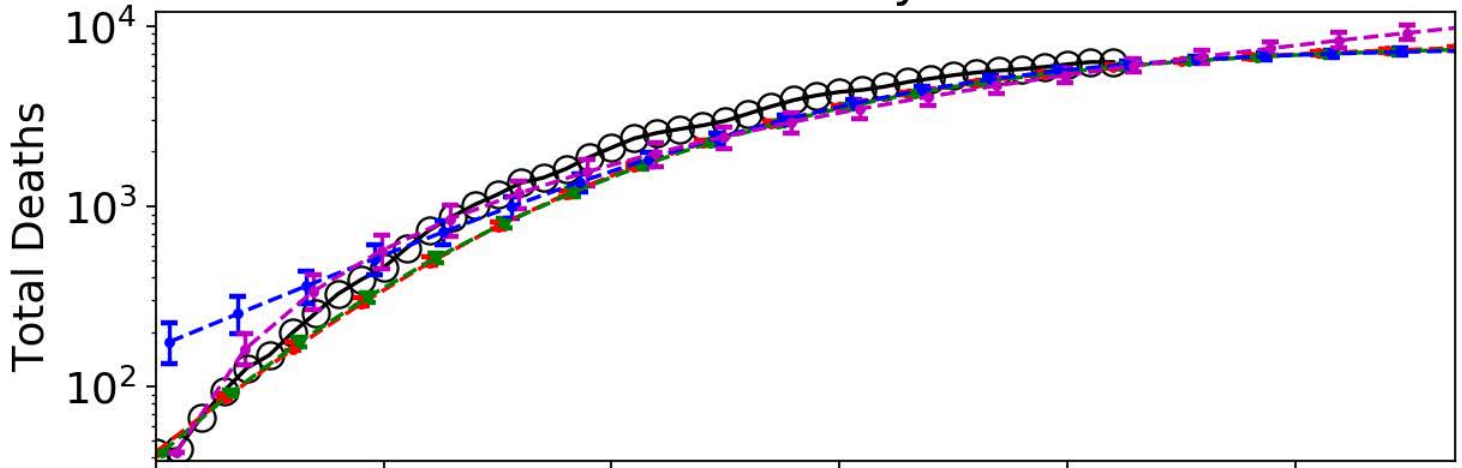
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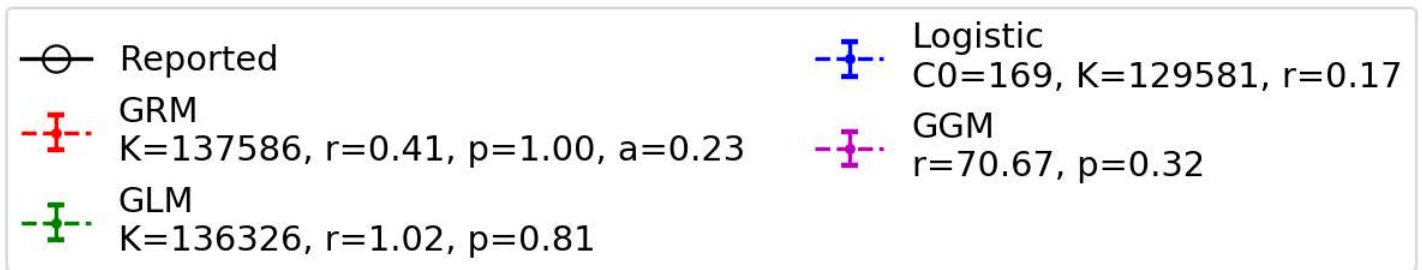
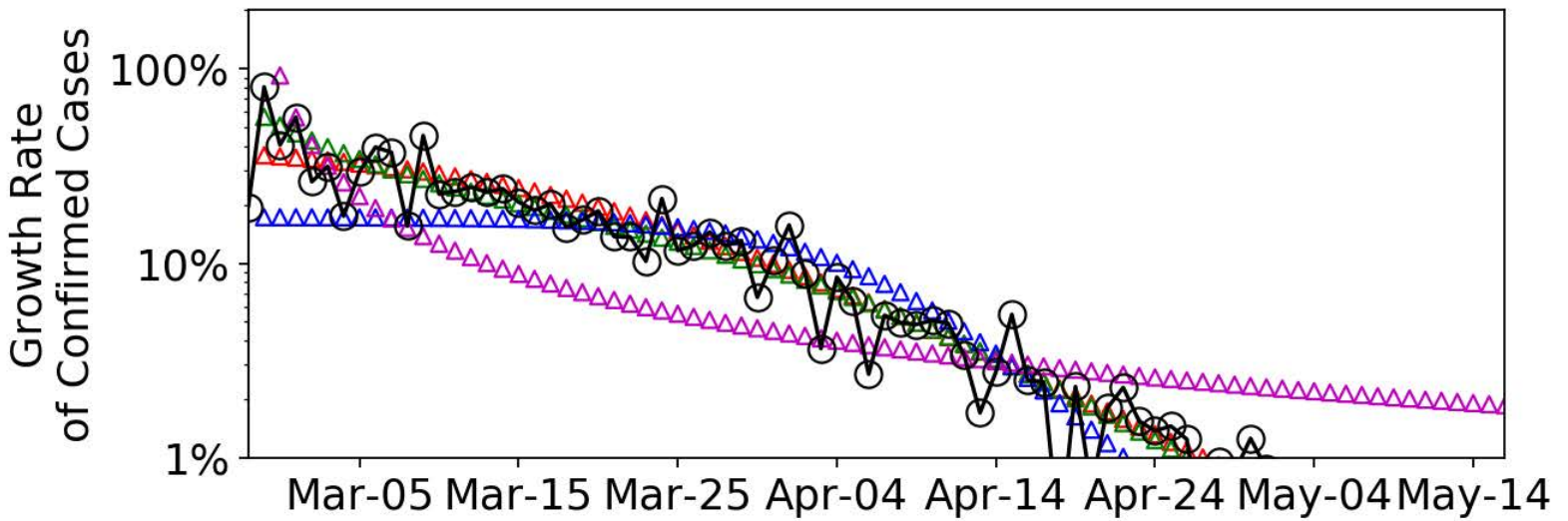
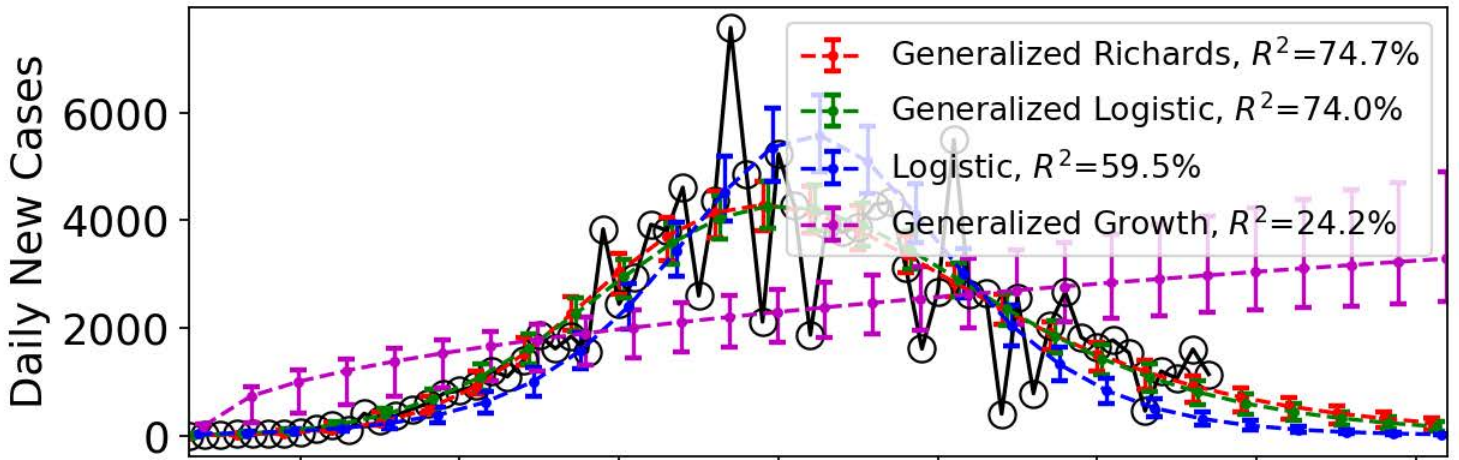
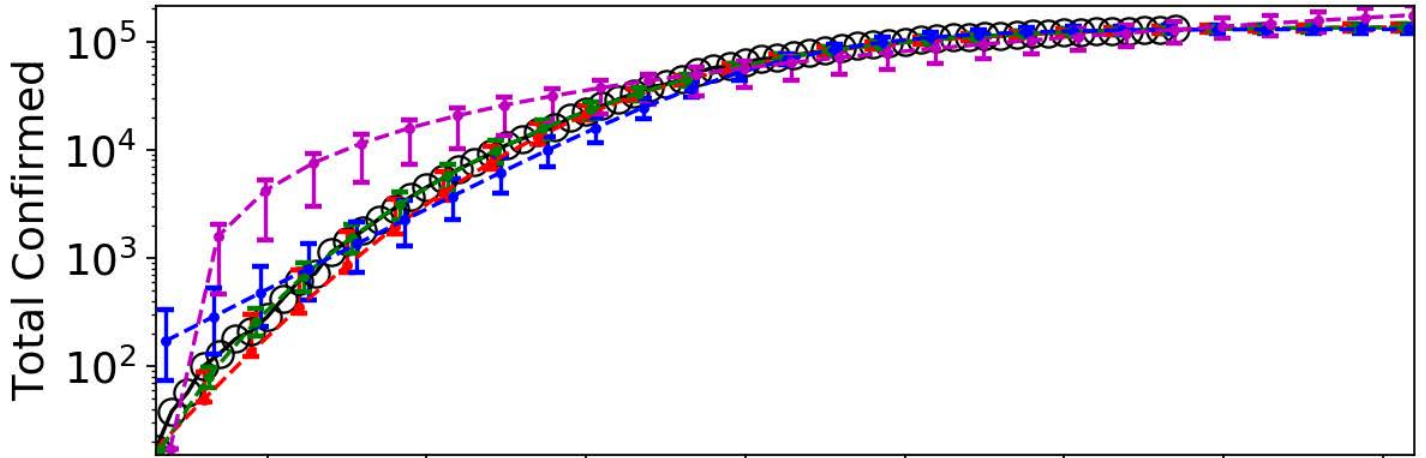
Germany



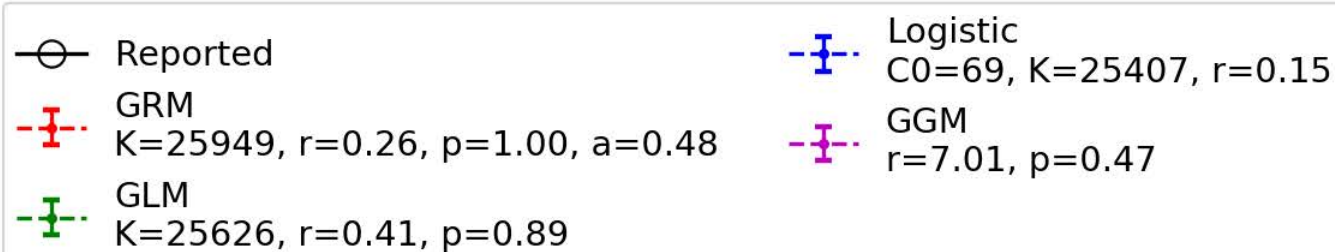
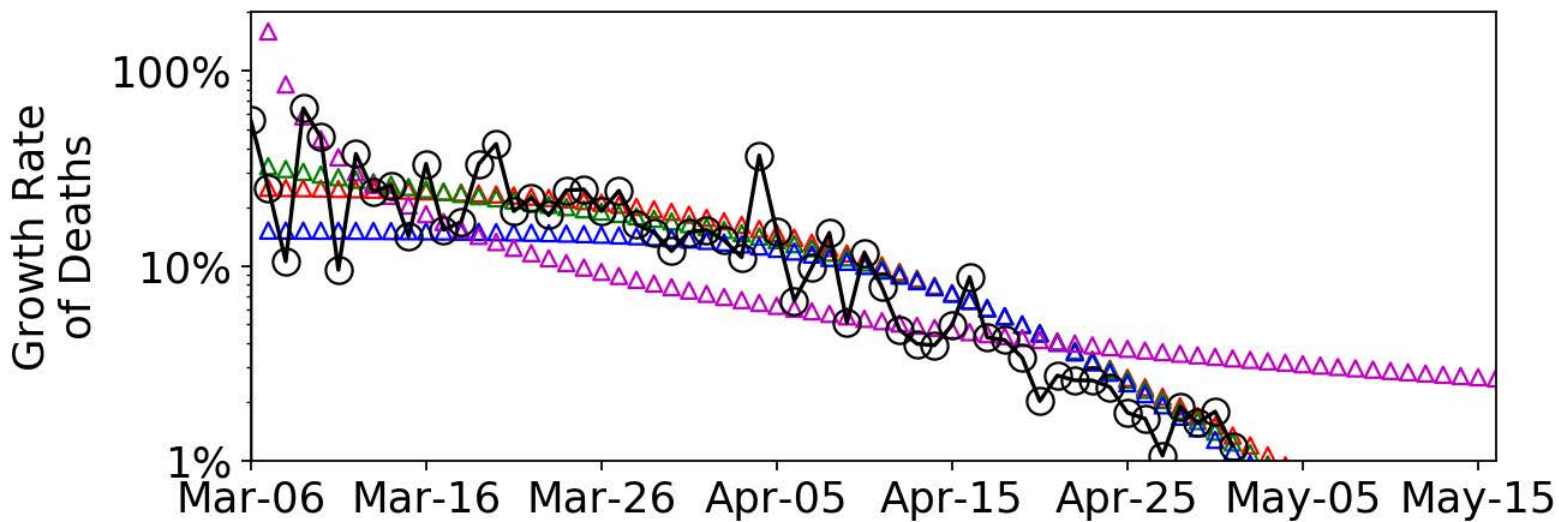
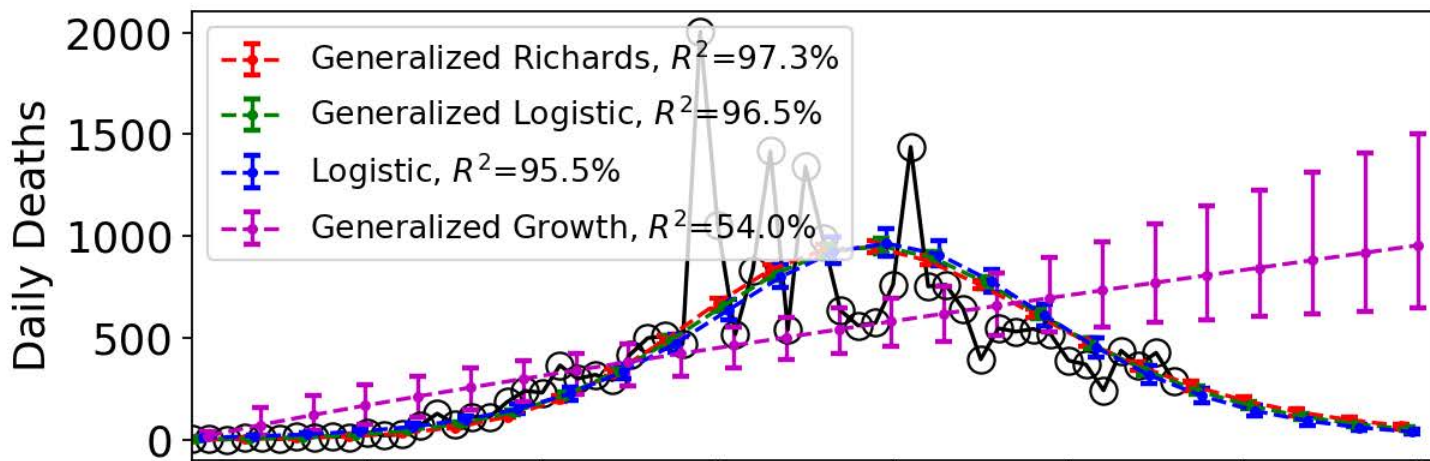
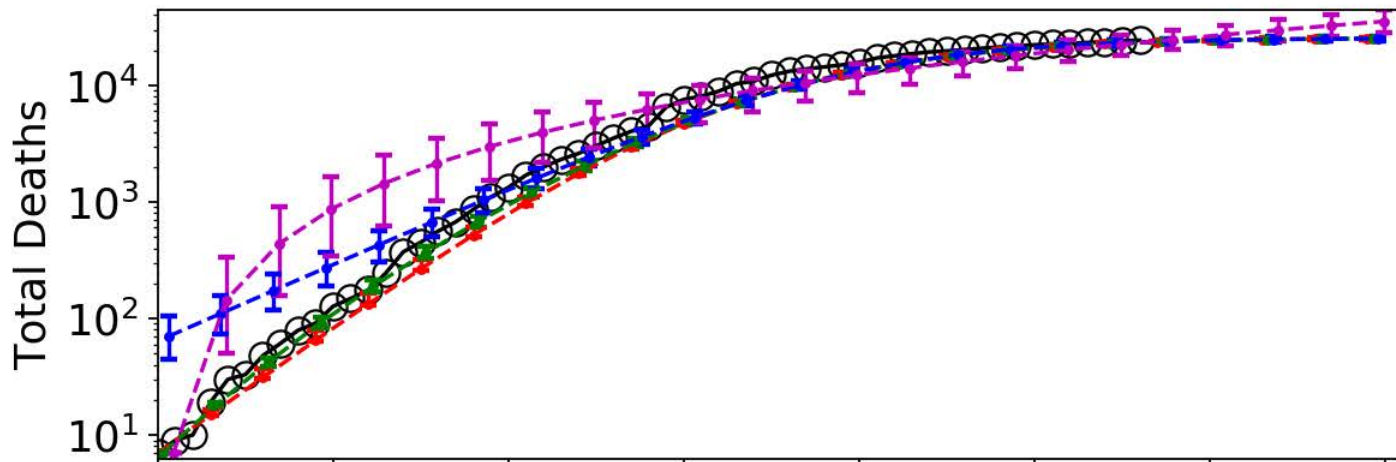
Germany



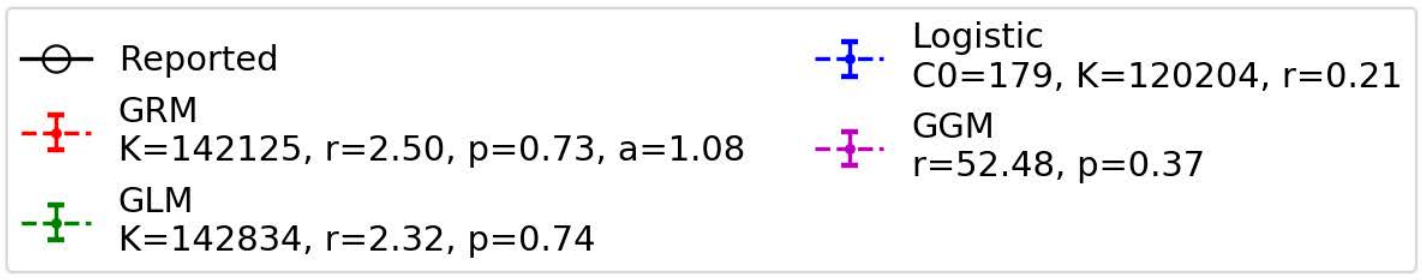
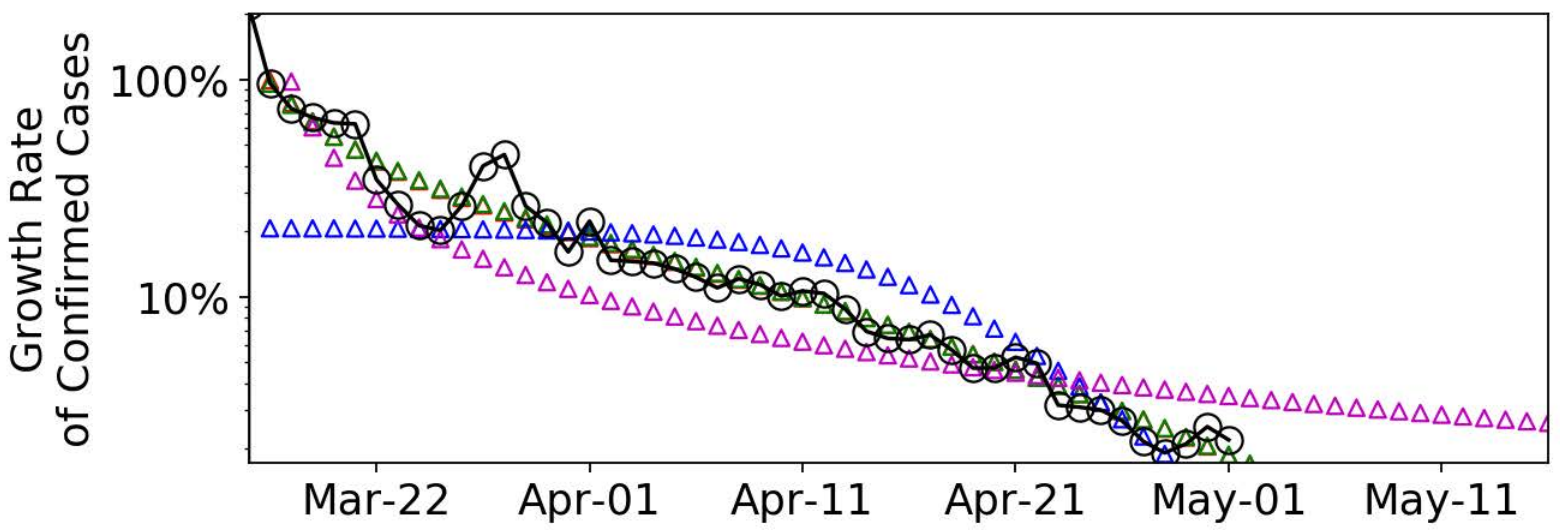
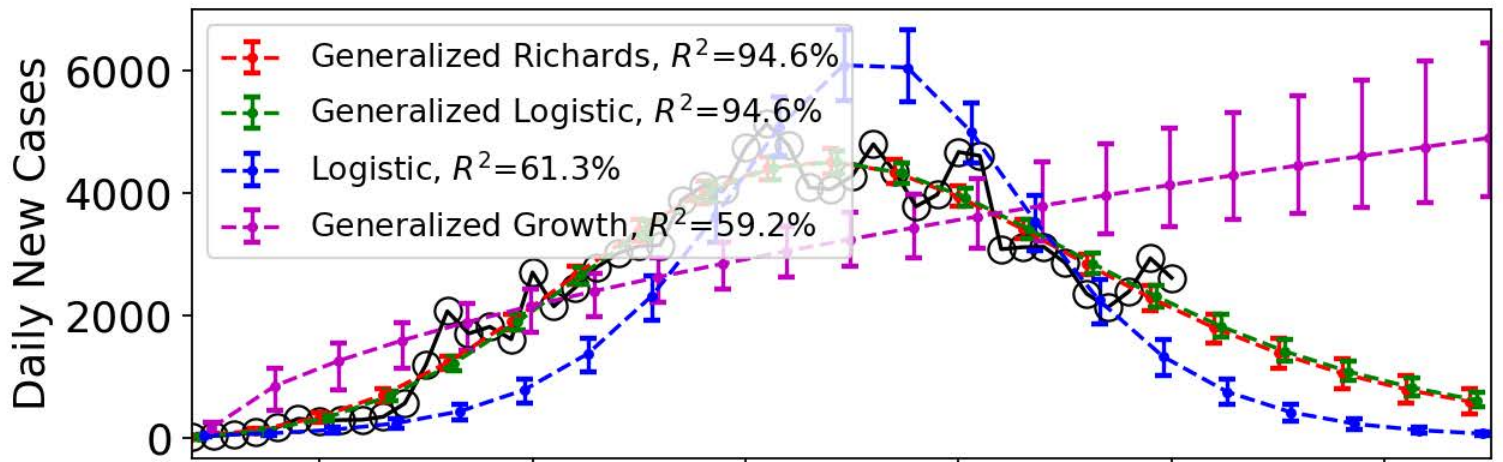
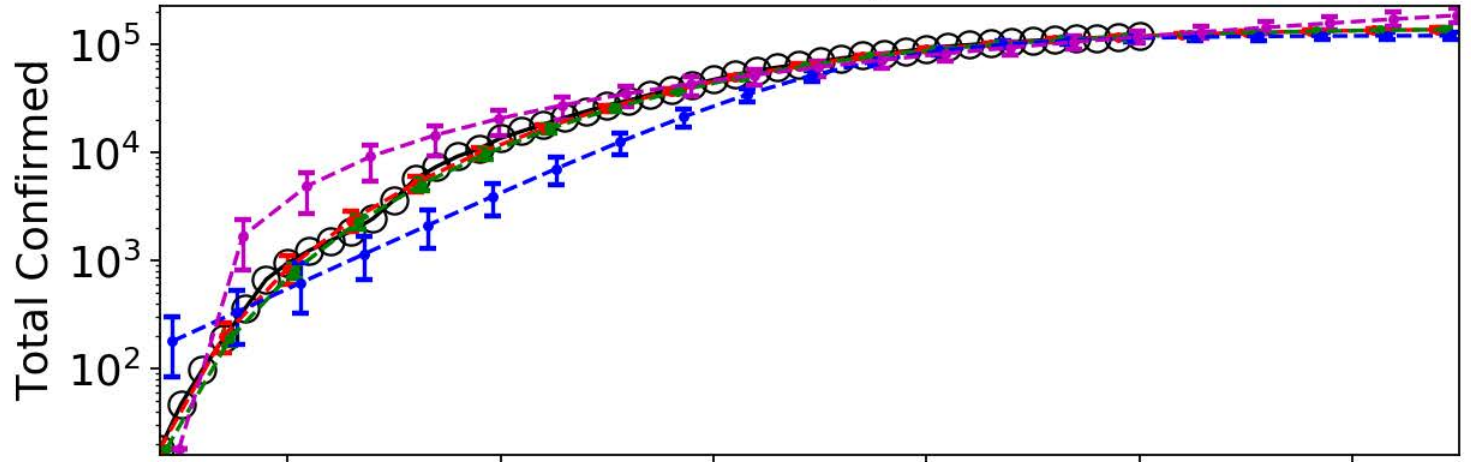
France



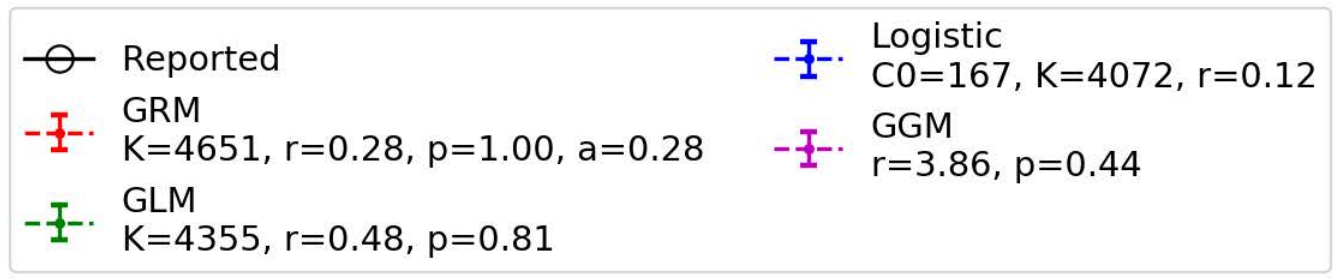
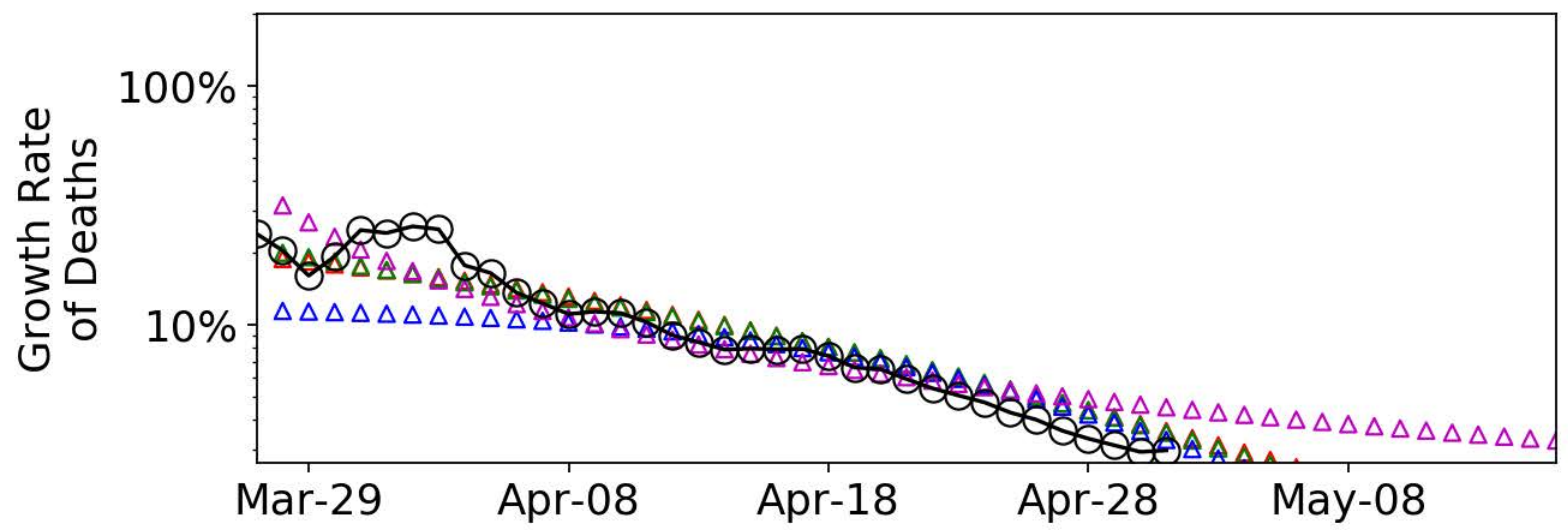
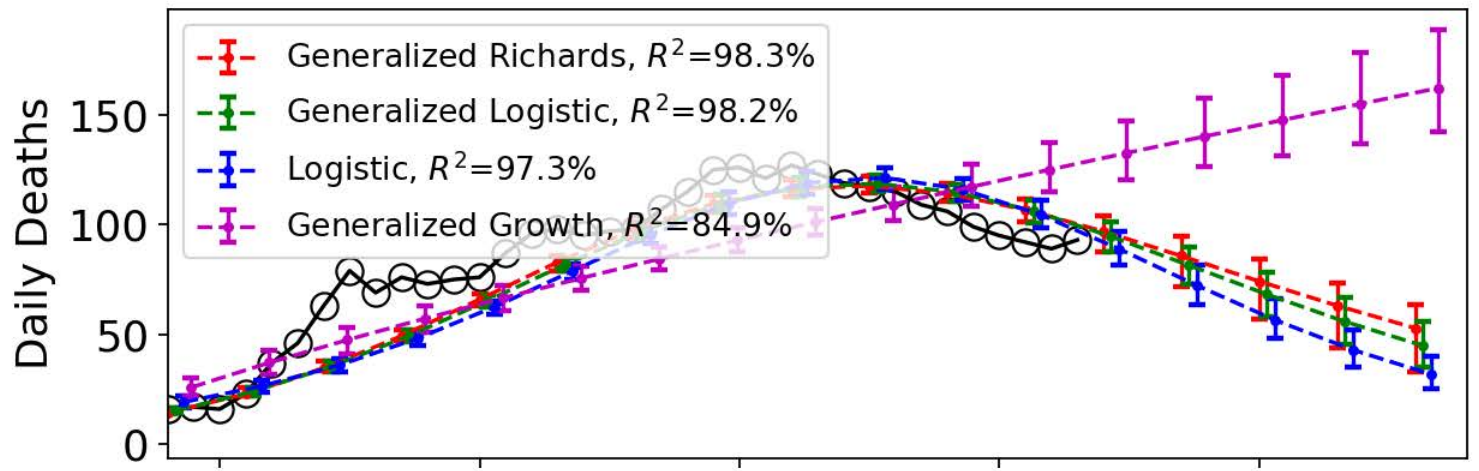
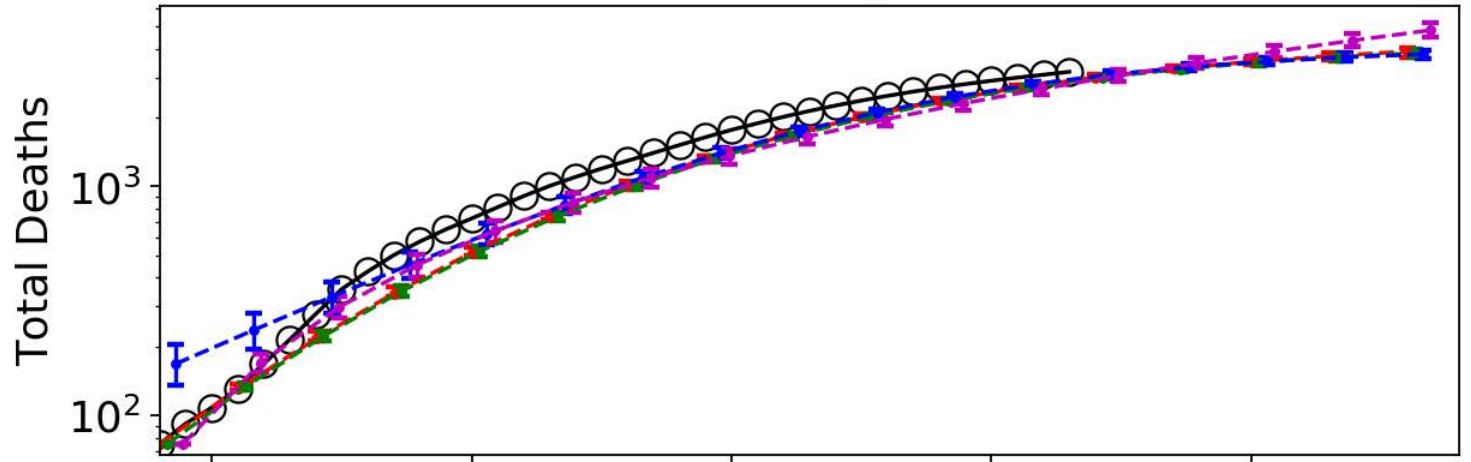
France



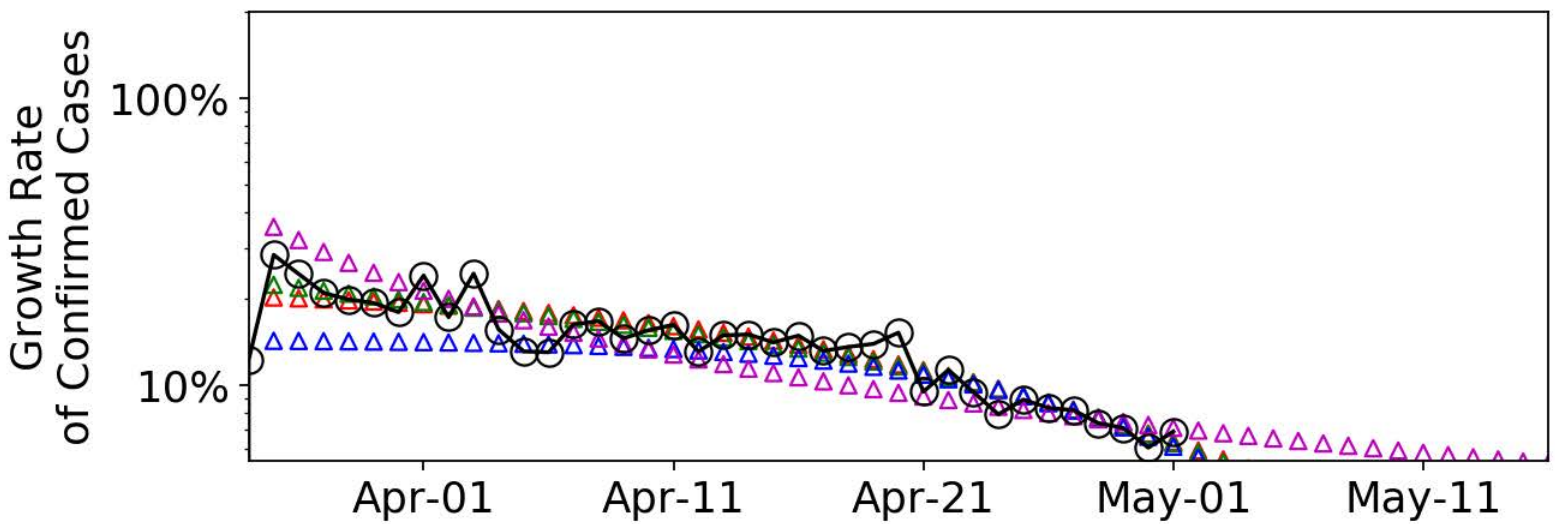
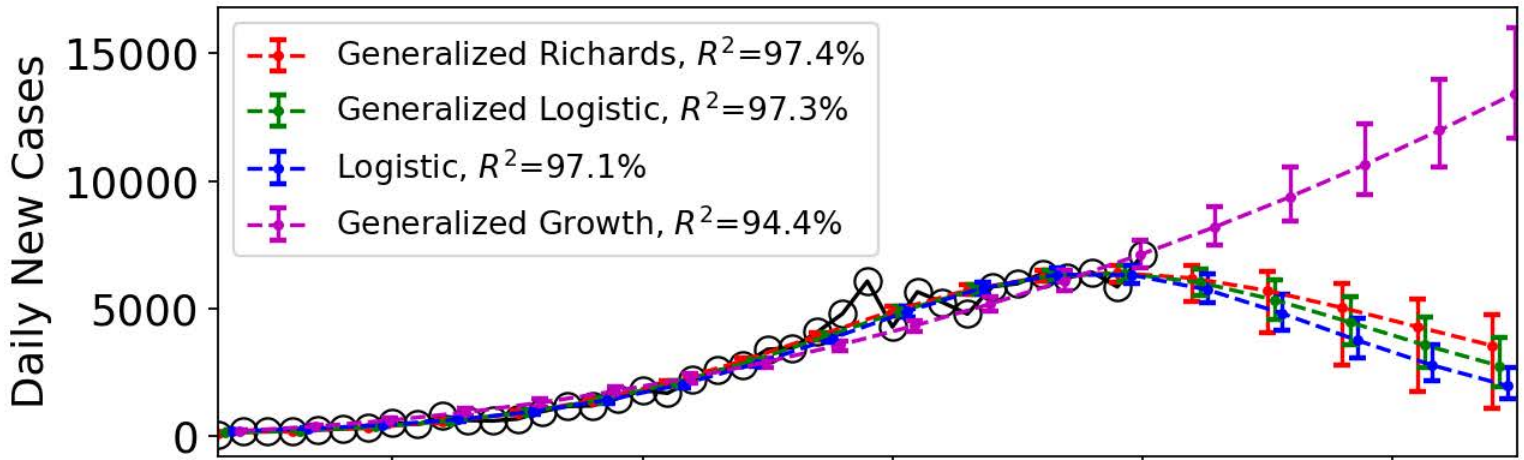
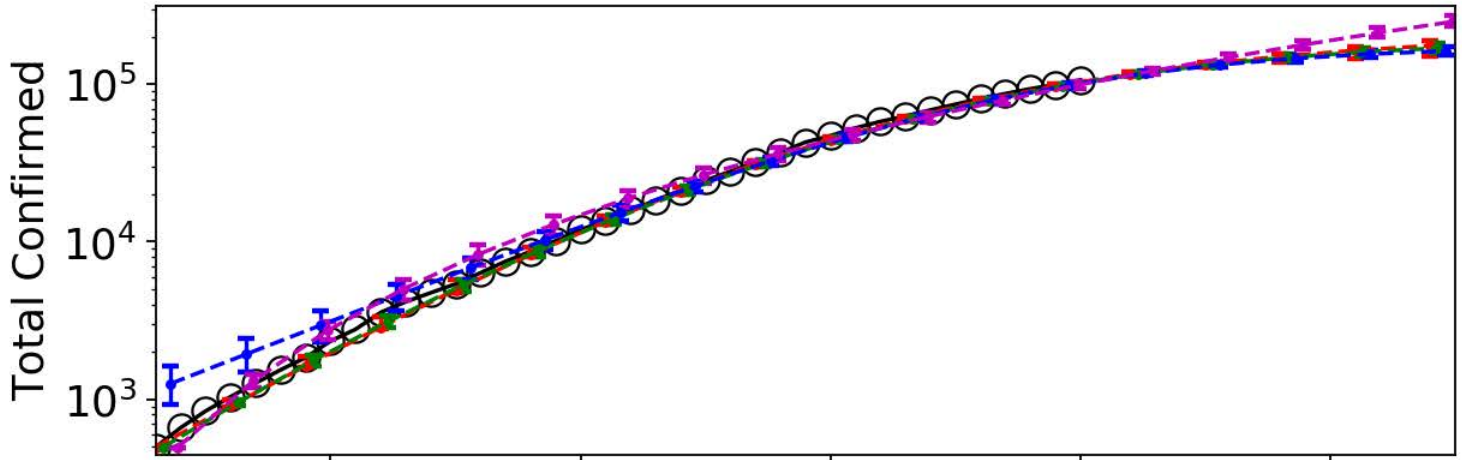
Turkey



Turkey

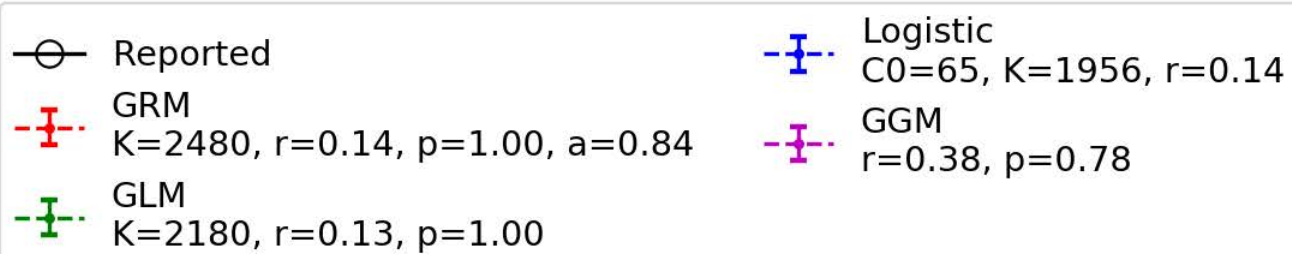
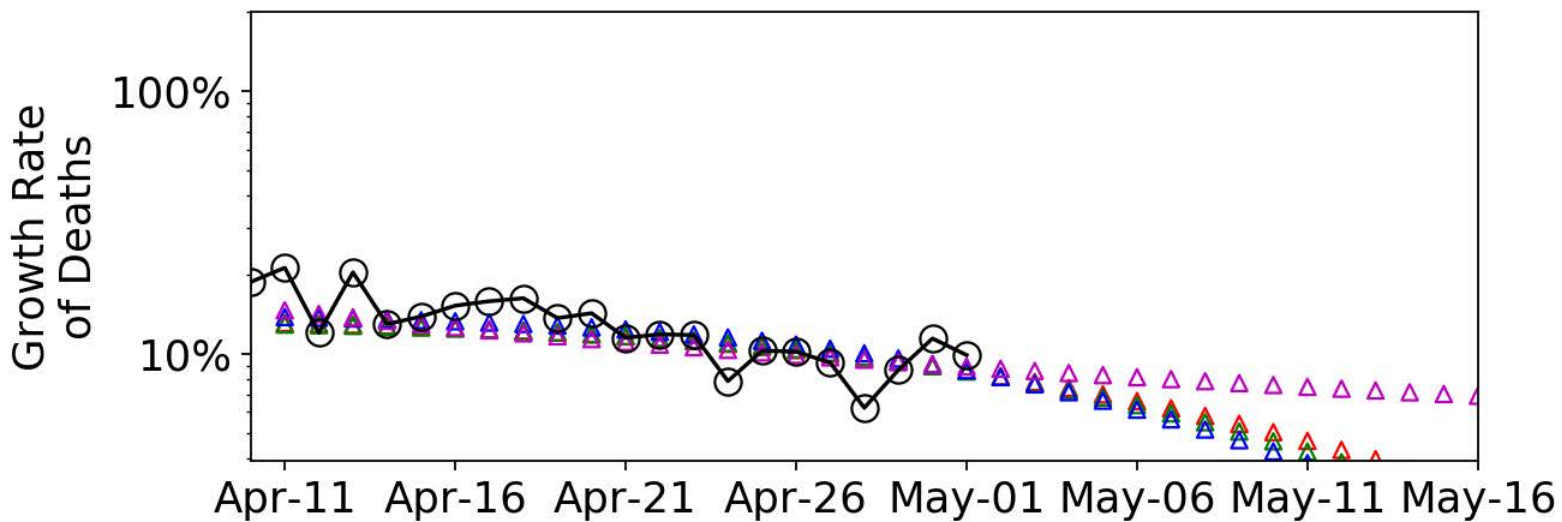
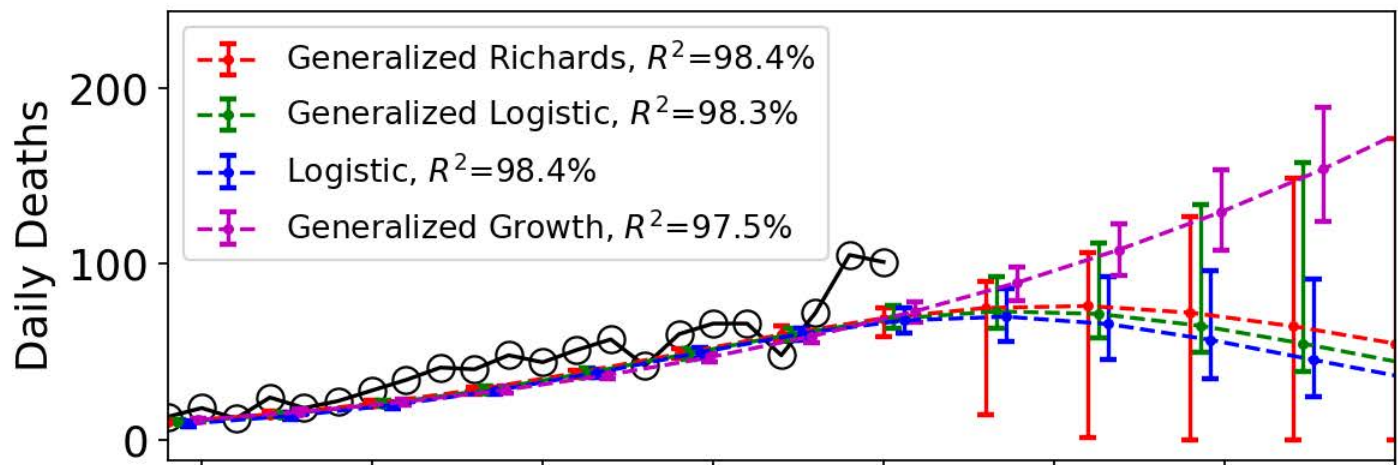
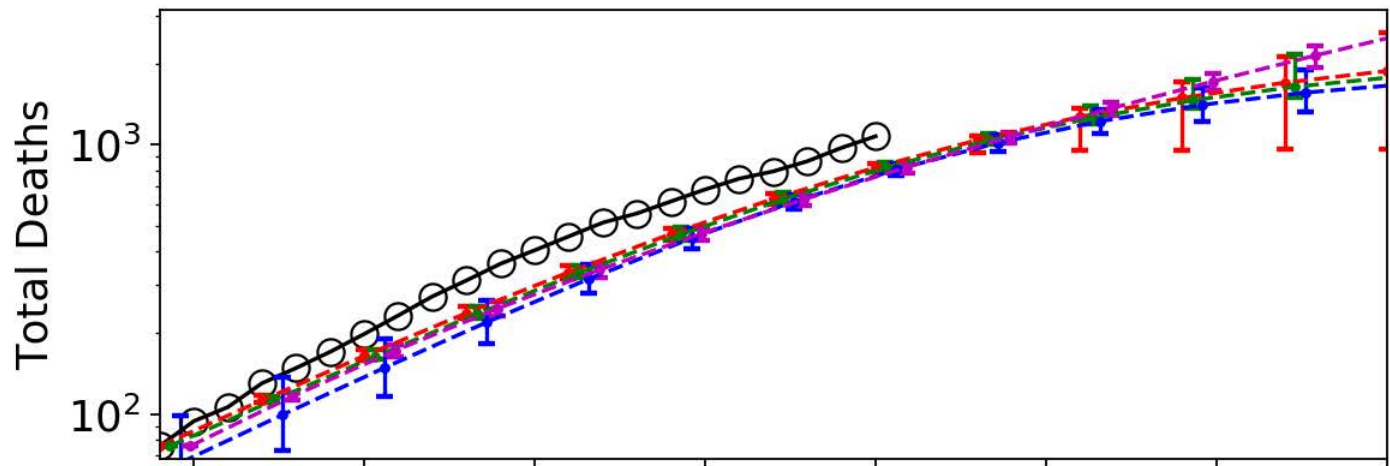


Russia

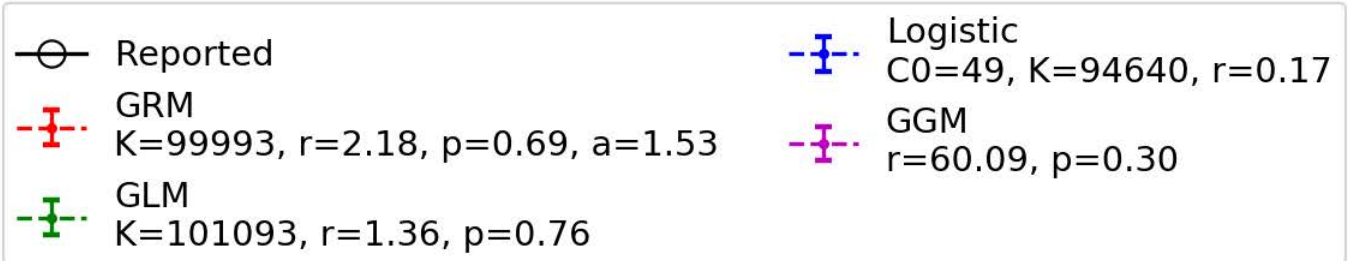
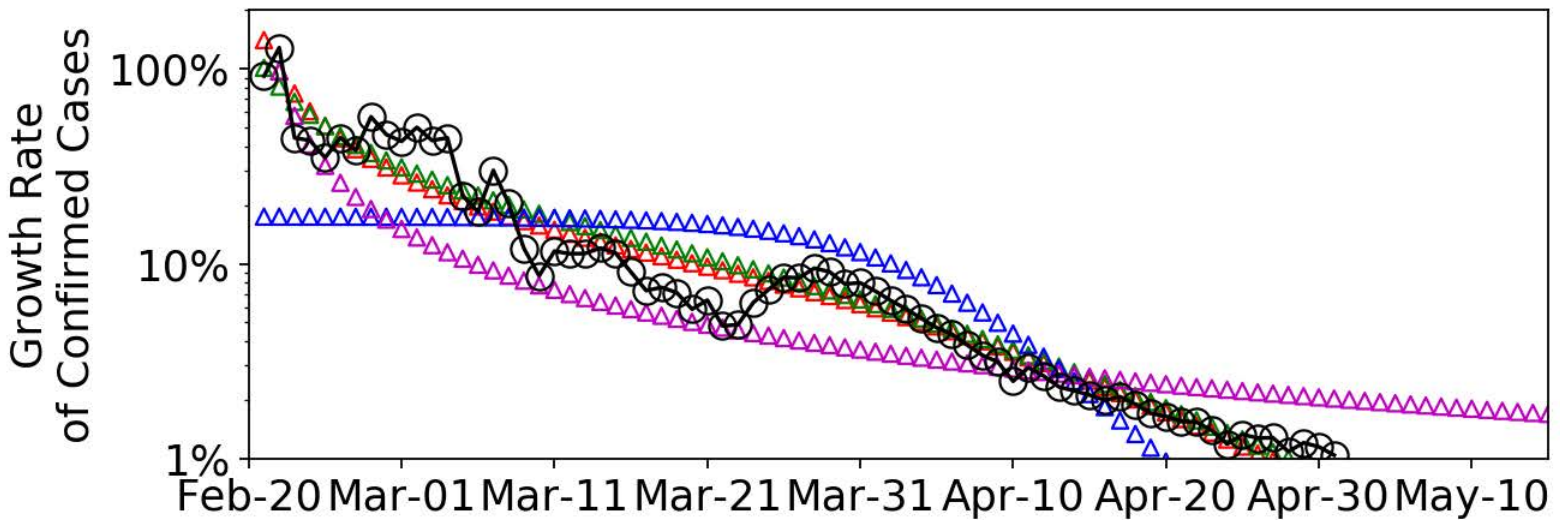
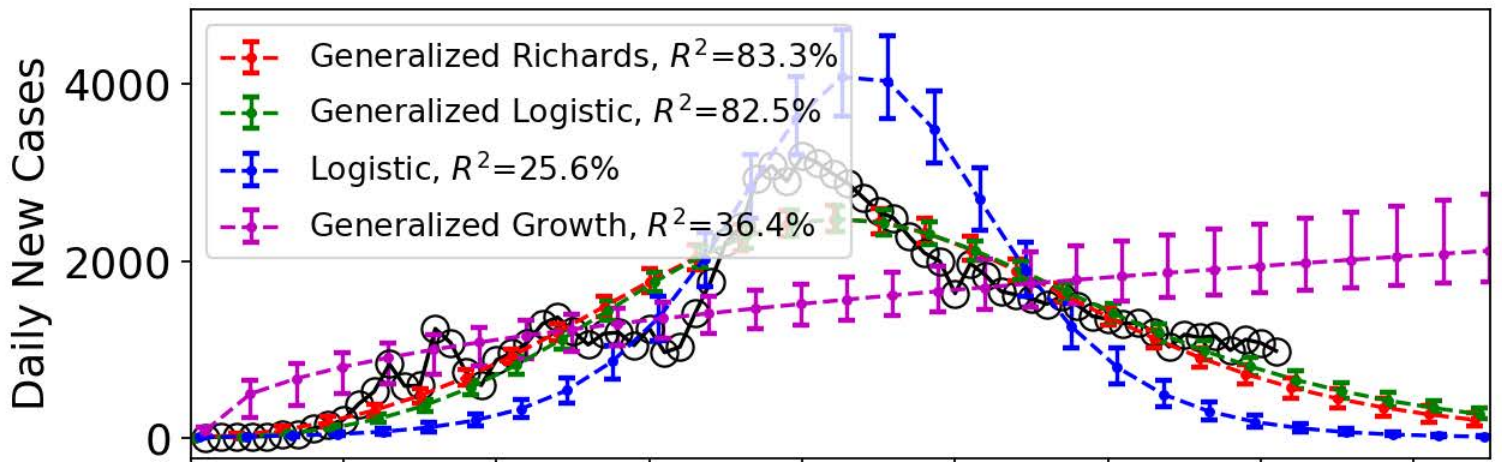
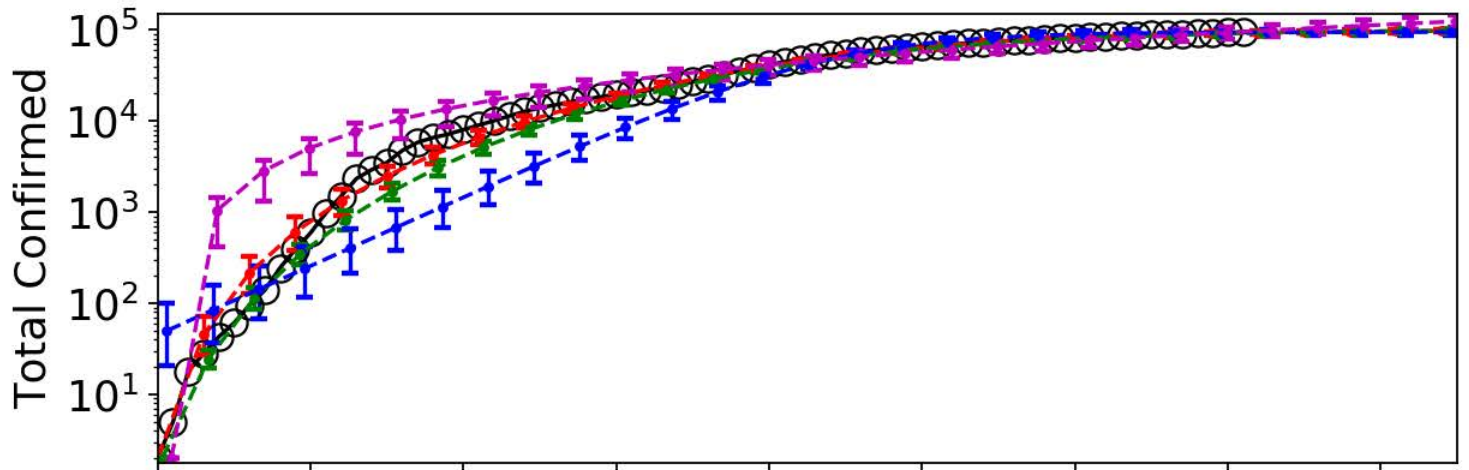


- | | |
|---|--|
| ○ Reported | - - - Logistic
$C_0=1253, K=177552, r=0.14$ |
| - - - GRM
$K=218951, r=0.22, p=1.00, a=0.44$ | - - - GGM
$r=2.63, p=0.69$ |
| - - - GLM
$K=195195, r=0.44, p=0.90$ | |

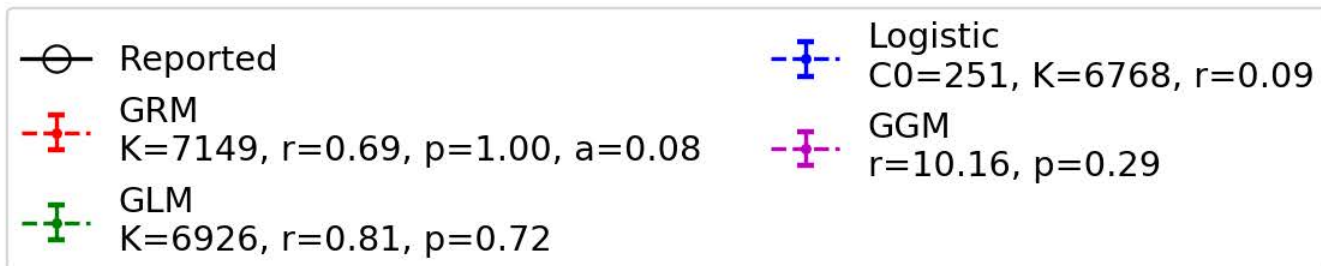
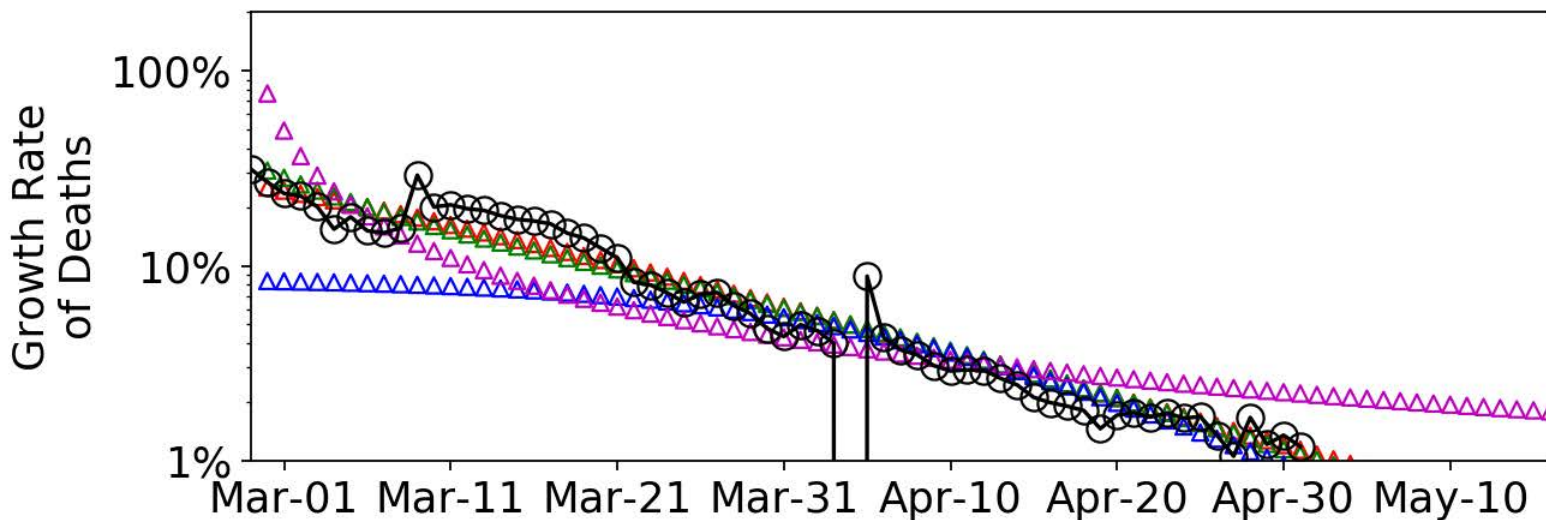
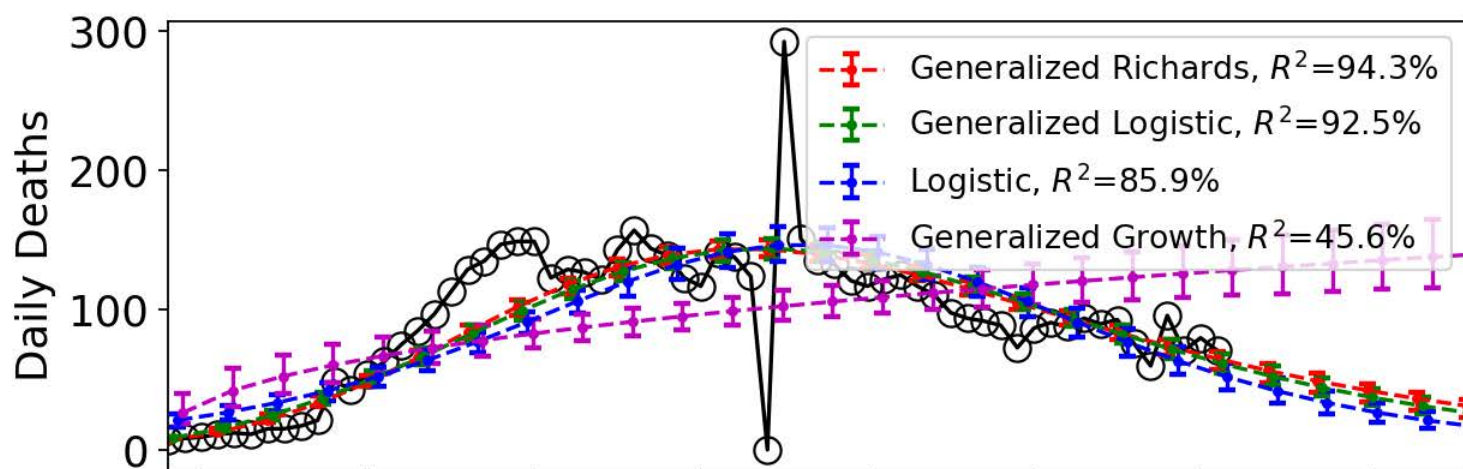
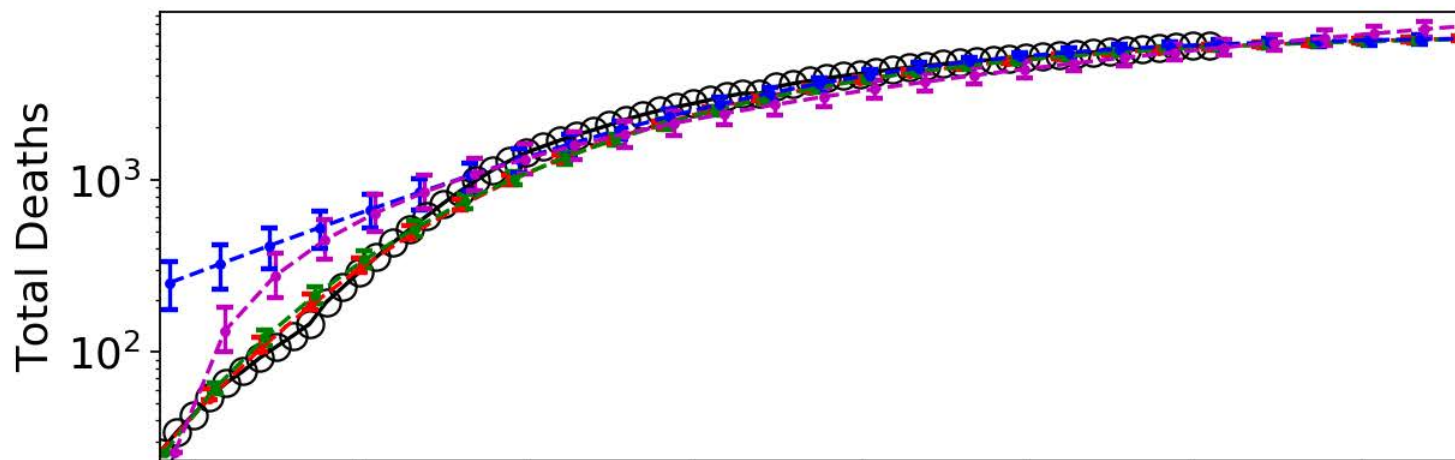
Russia



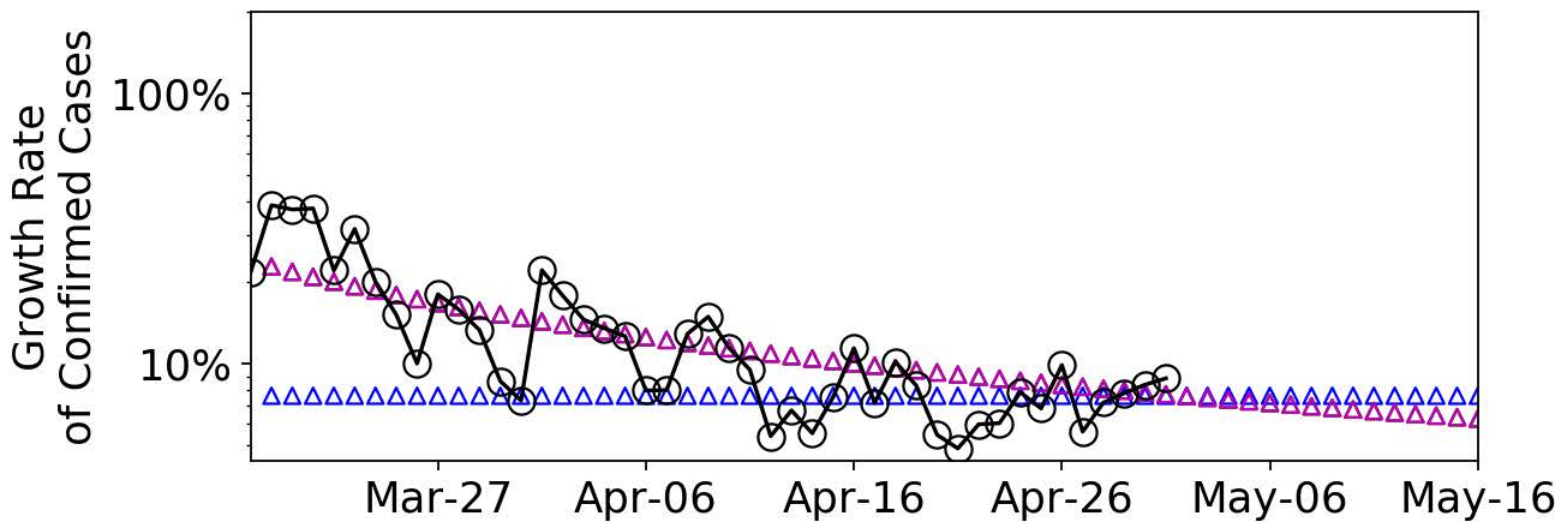
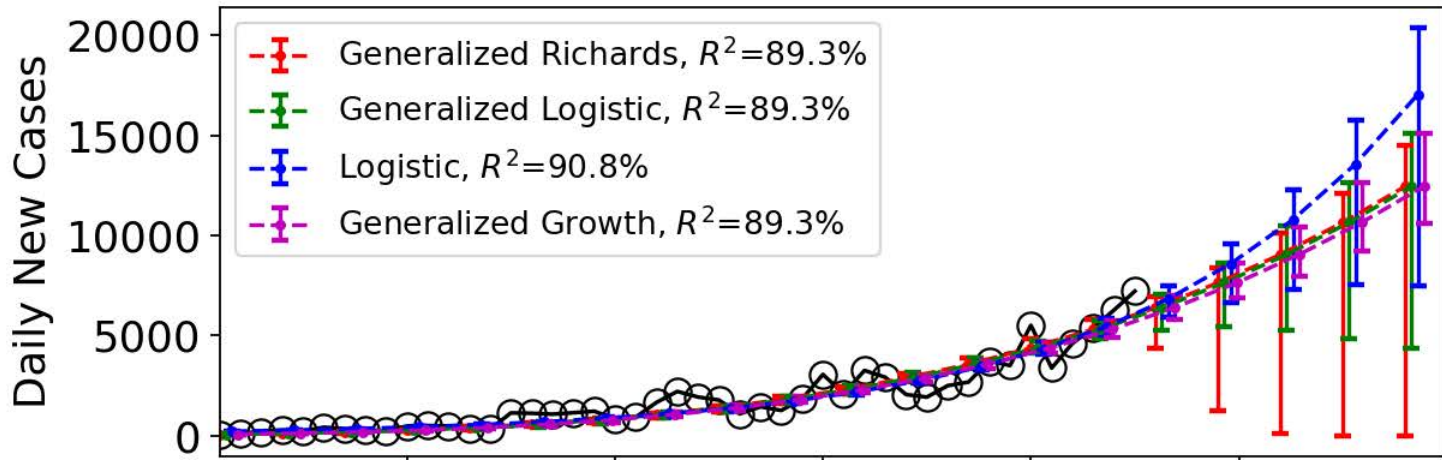
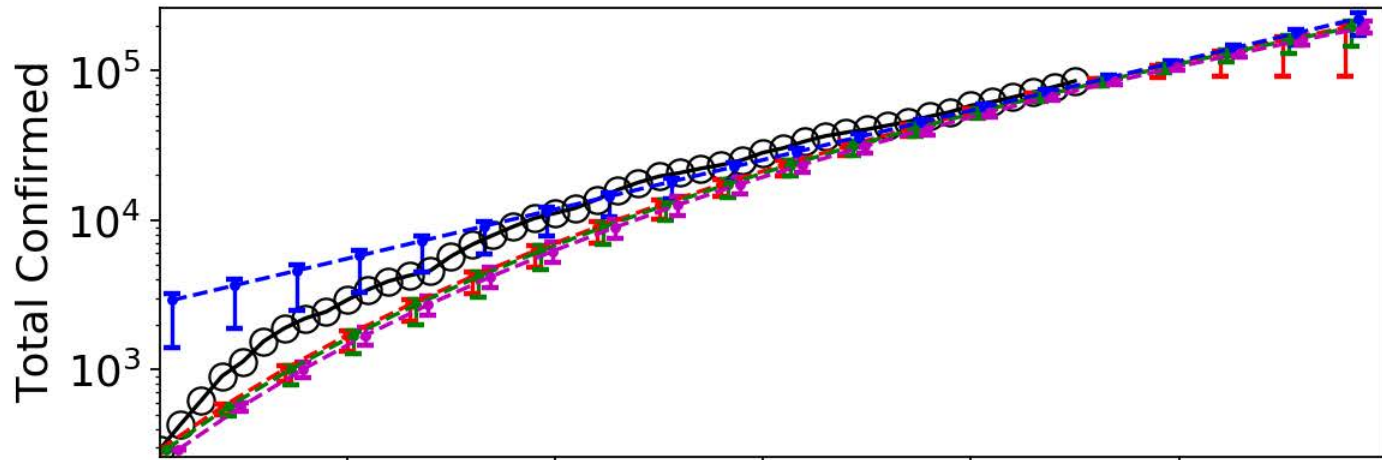
Iran



Iran



Brazil



○ Reported

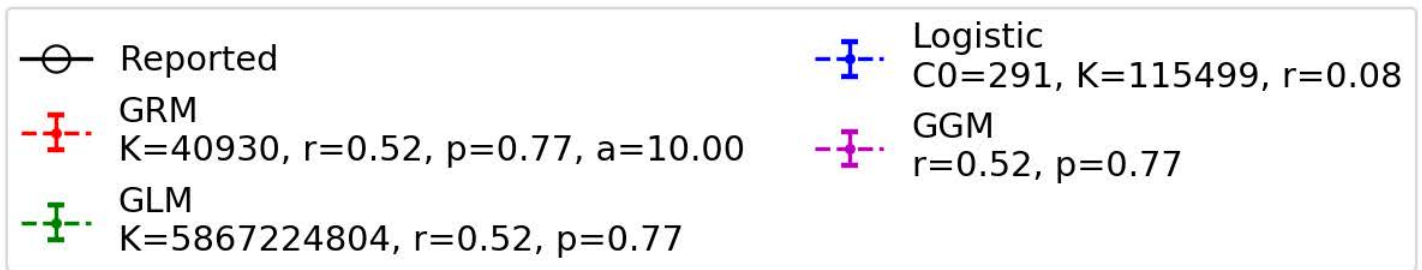
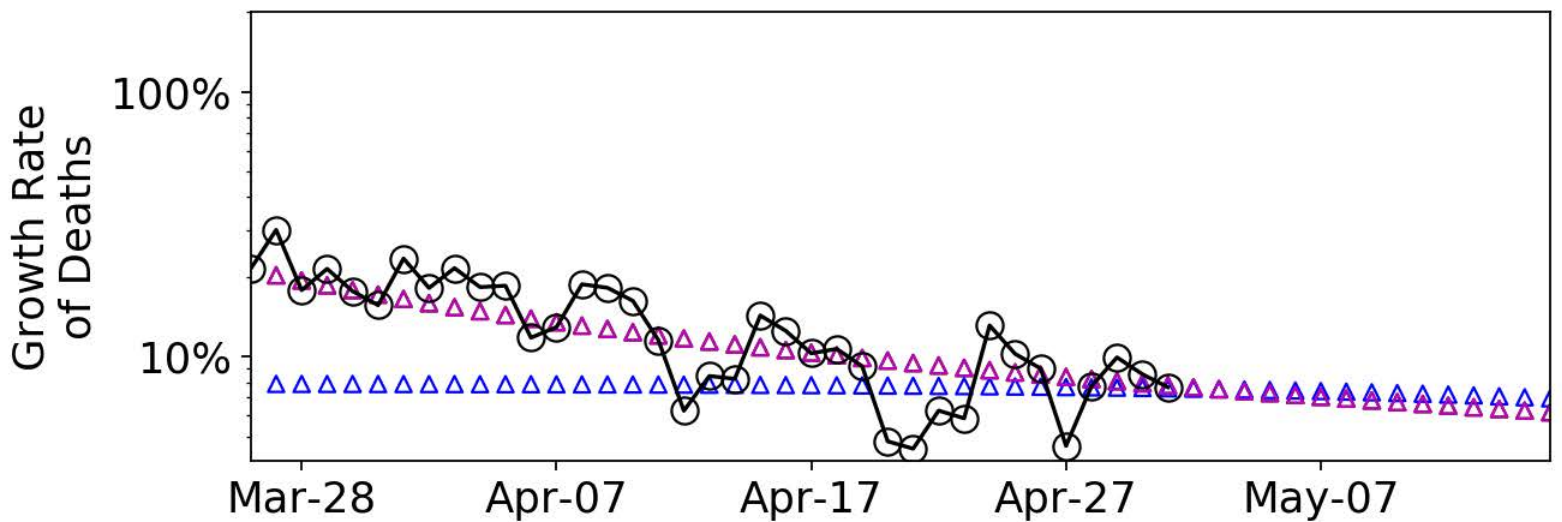
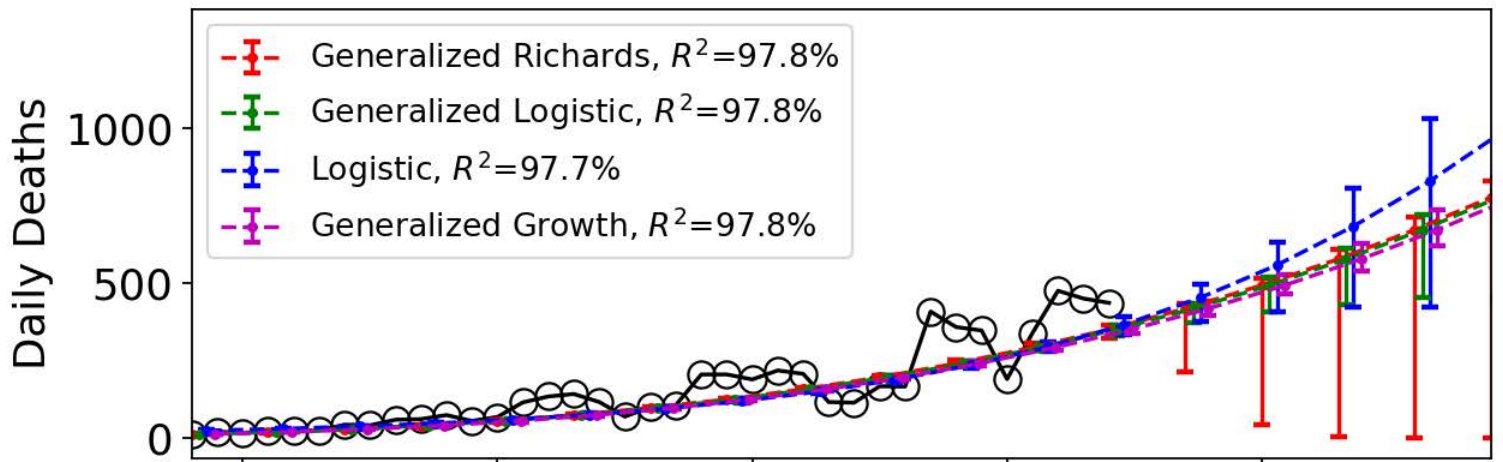
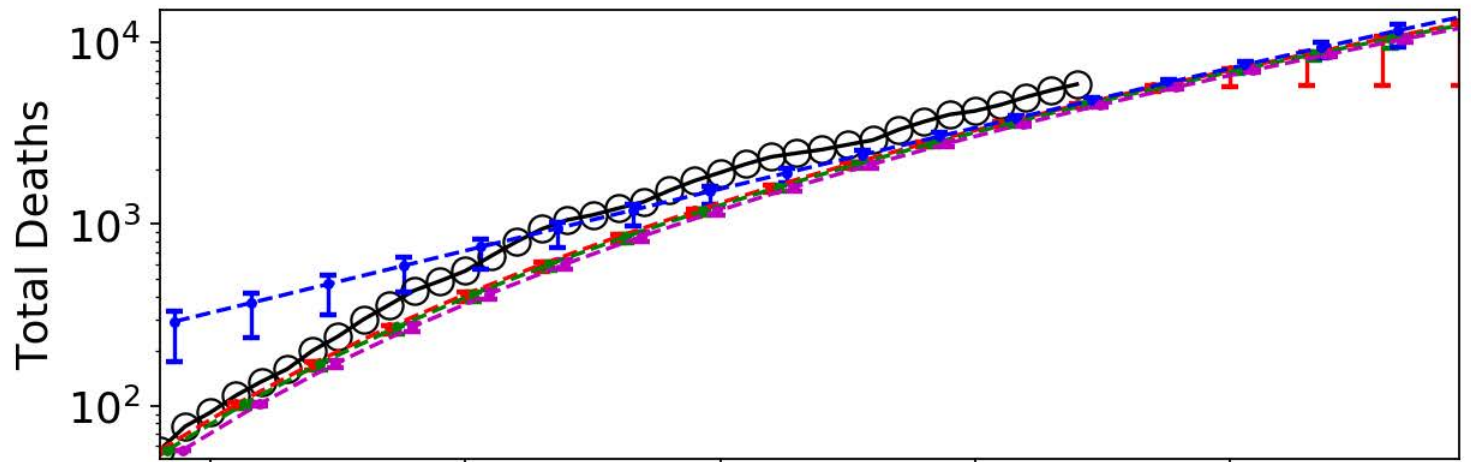
-I- GRM
 $K=596144, r=0.73, p=0.80, a=10.00$

-I- GLM
 $K=15232935789, r=0.73, p=0.80$

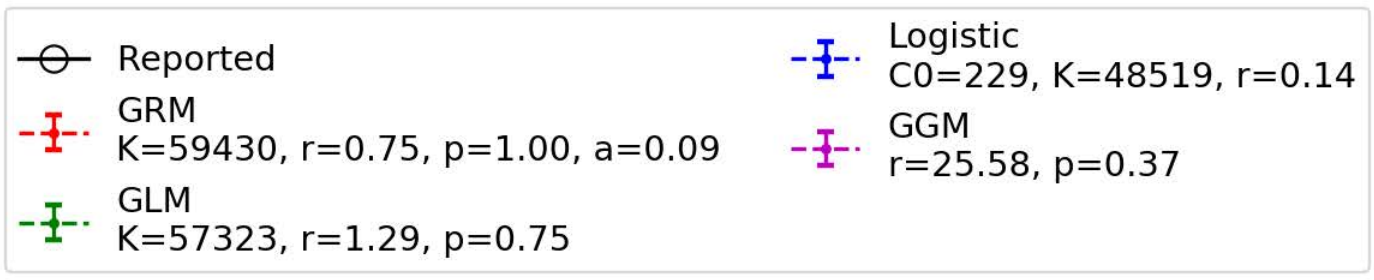
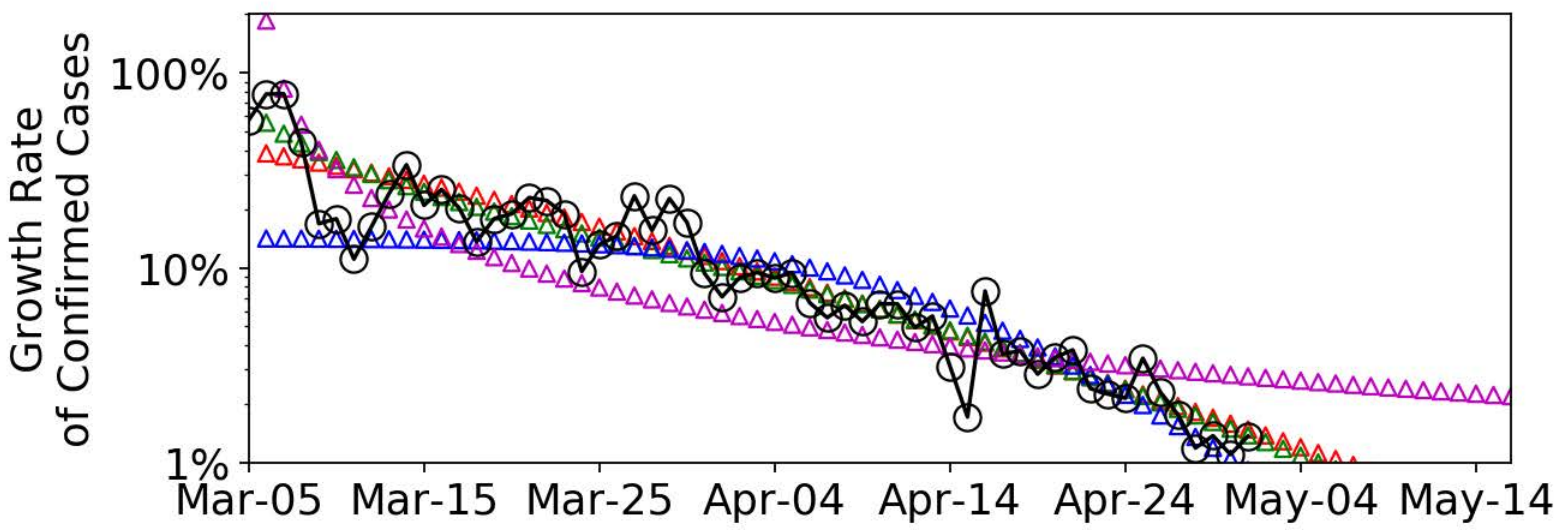
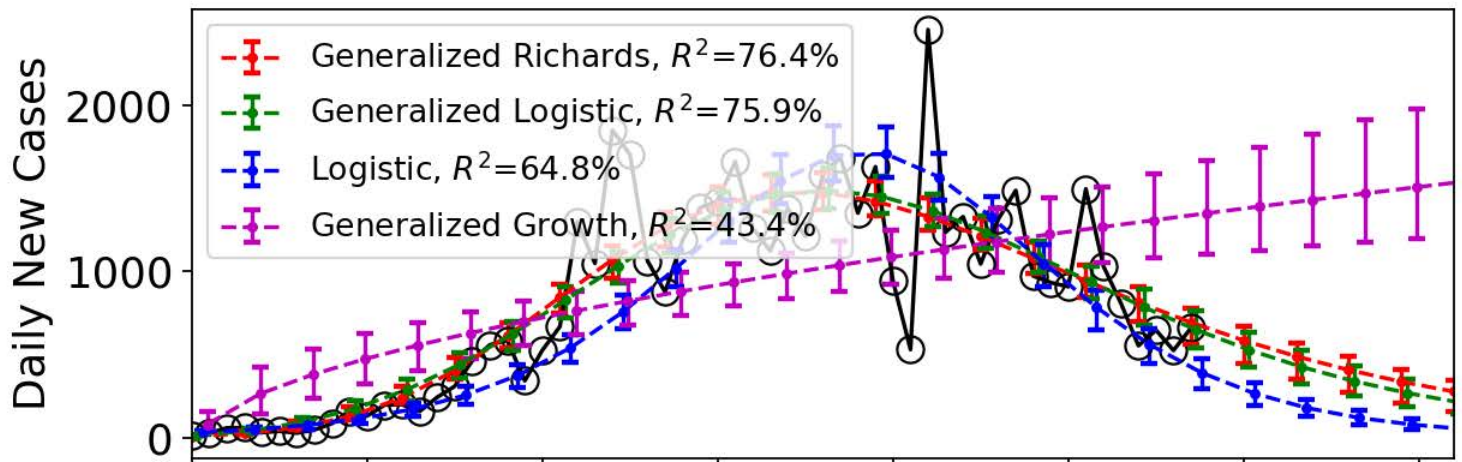
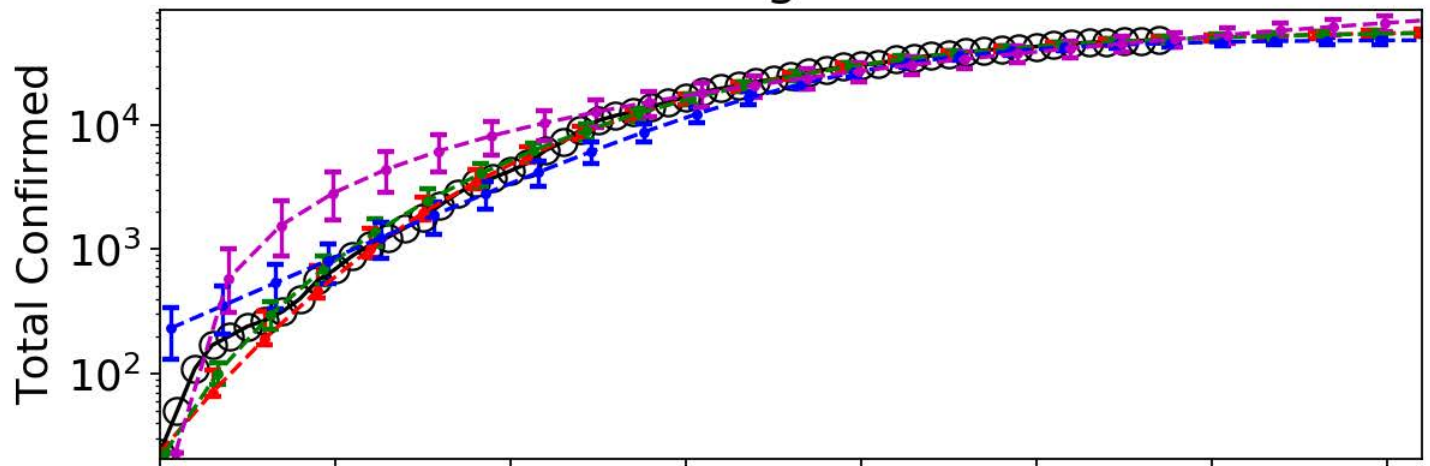
-I- Logistic
 $C_0=2909, K=12783697007, r=0.08$

-I- GGM
 $r=0.73, p=0.80$

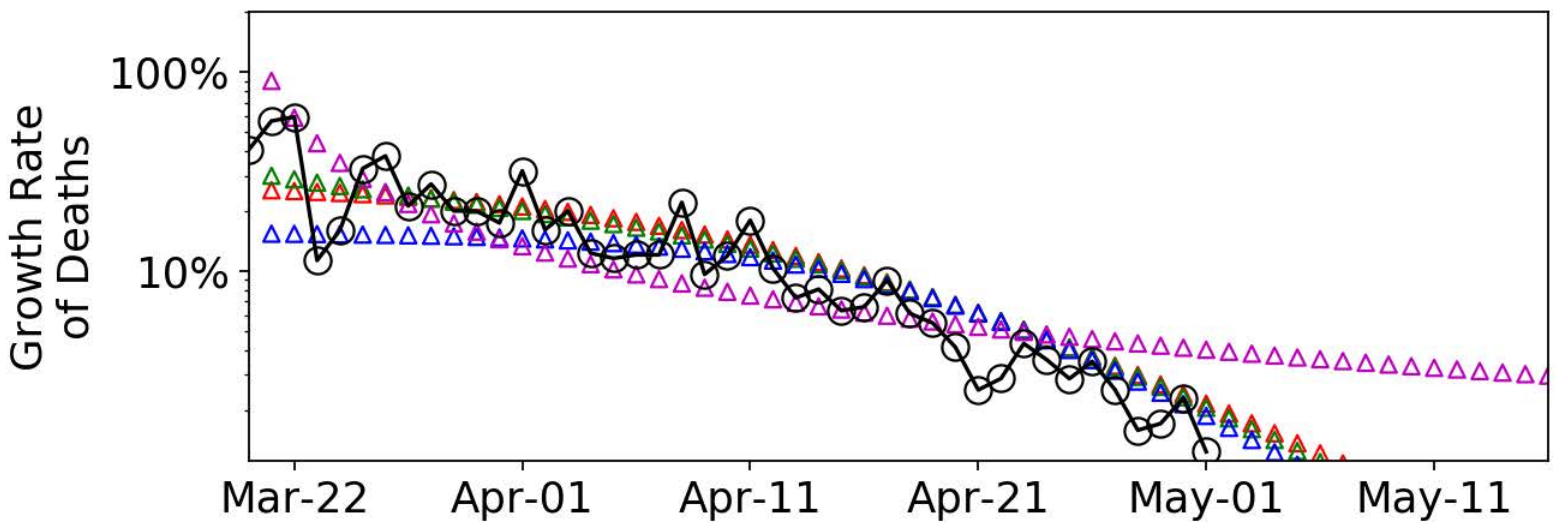
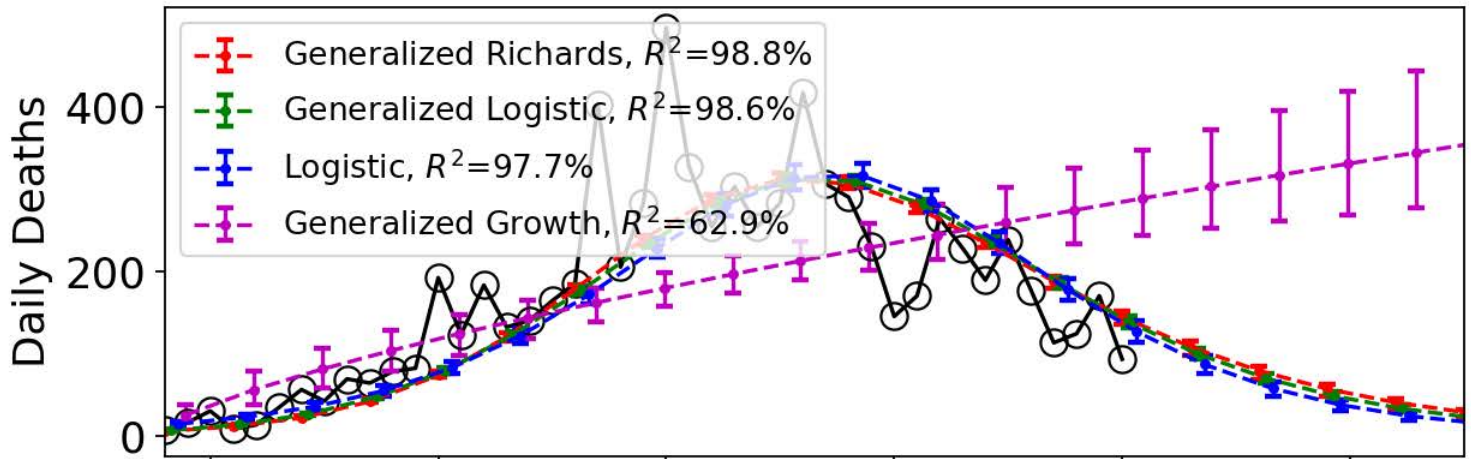
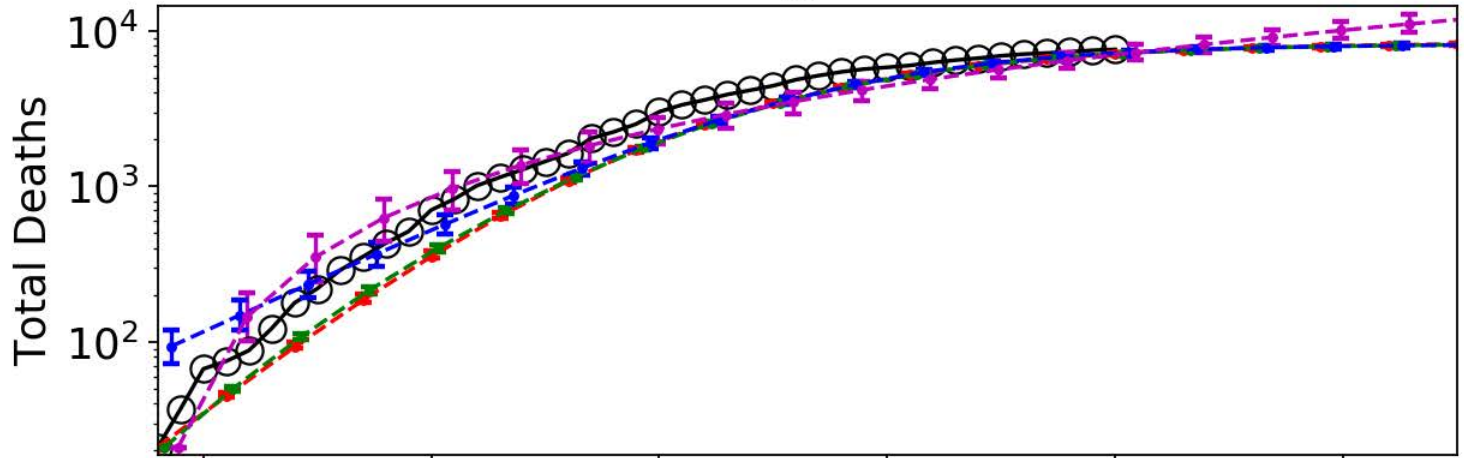
Brazil



Belgium

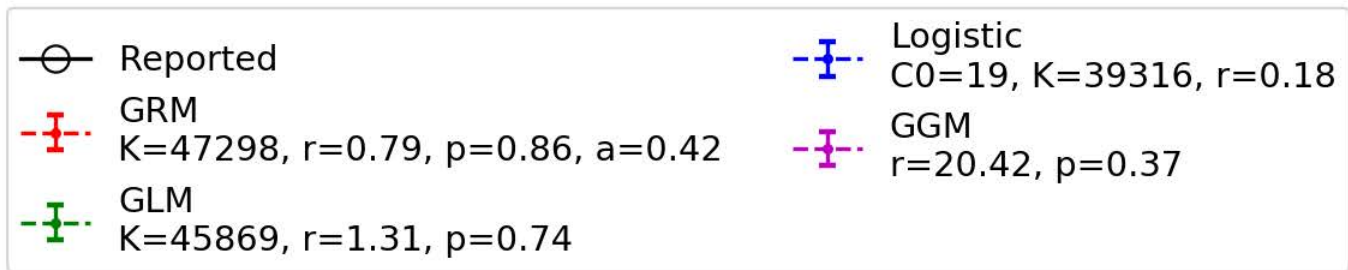
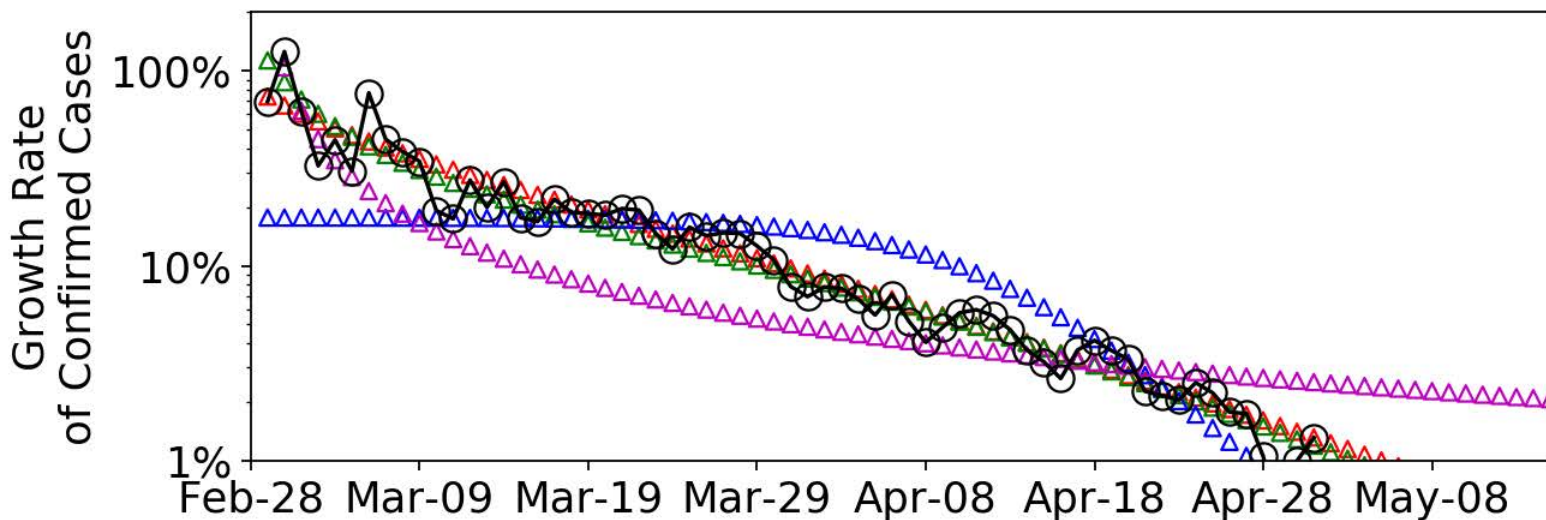
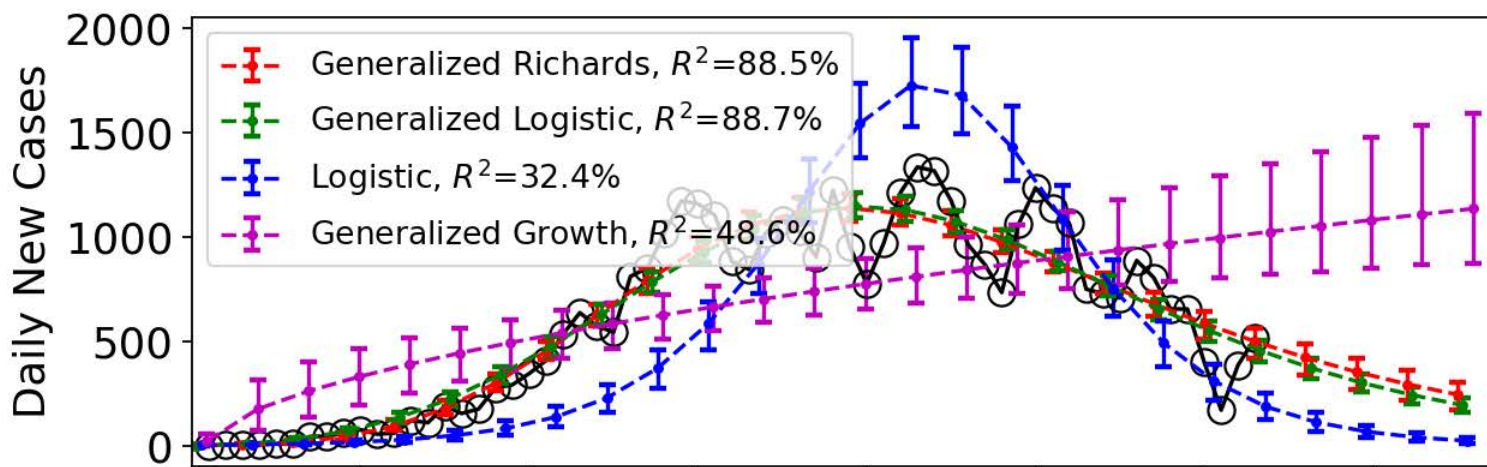
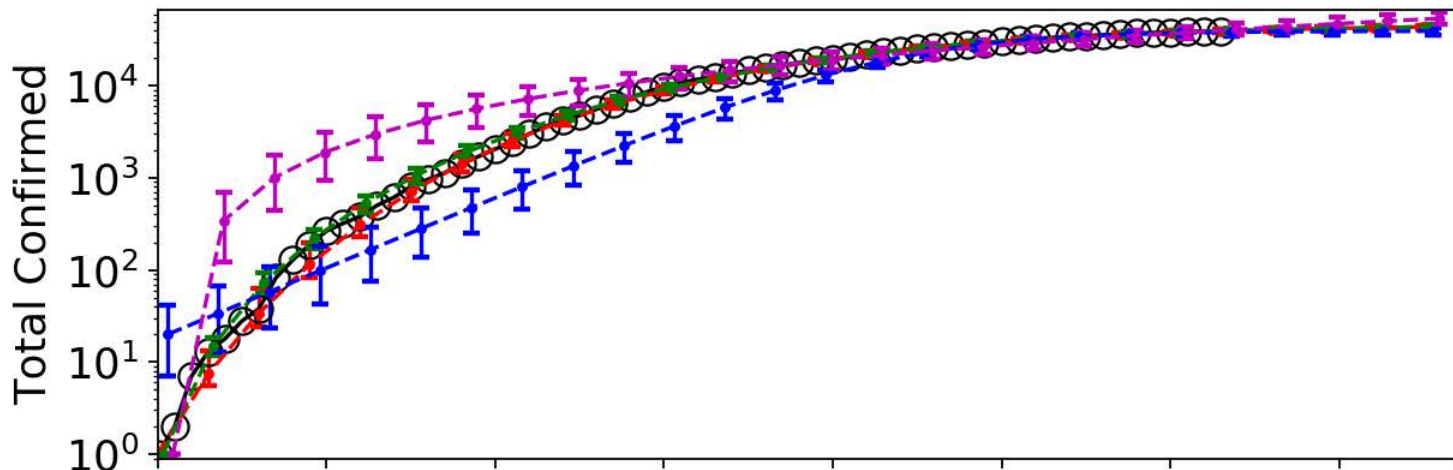


Belgium

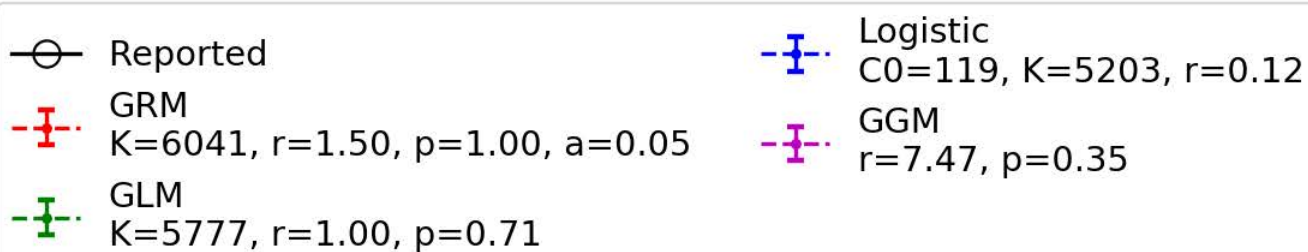
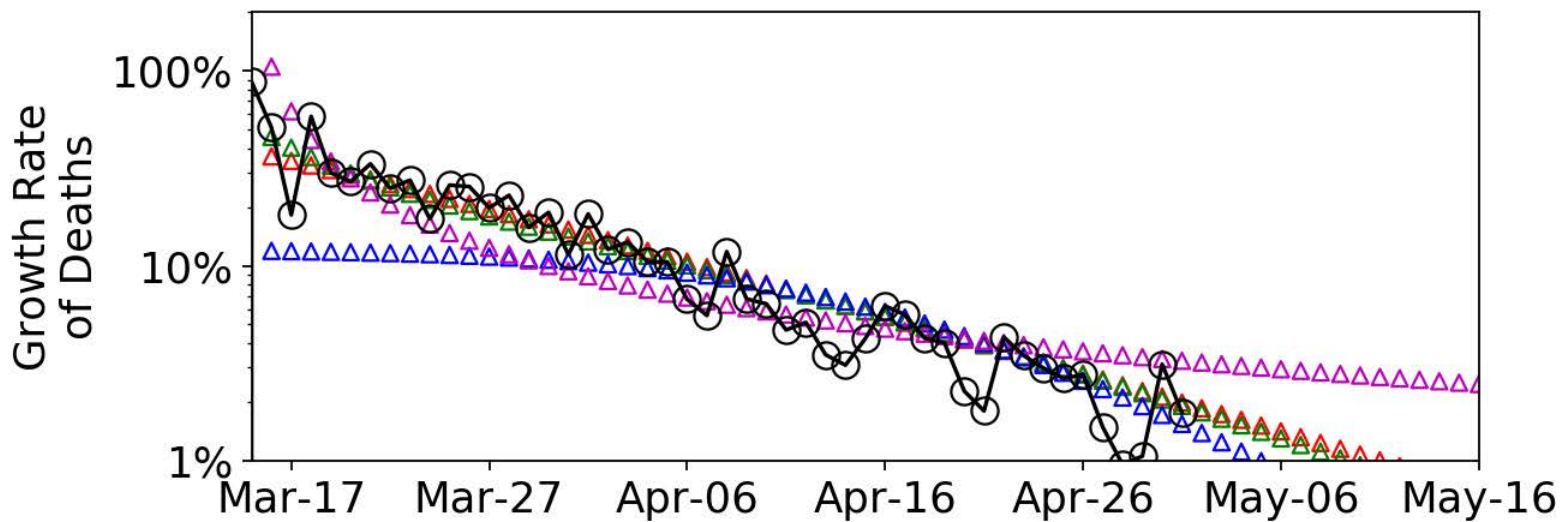
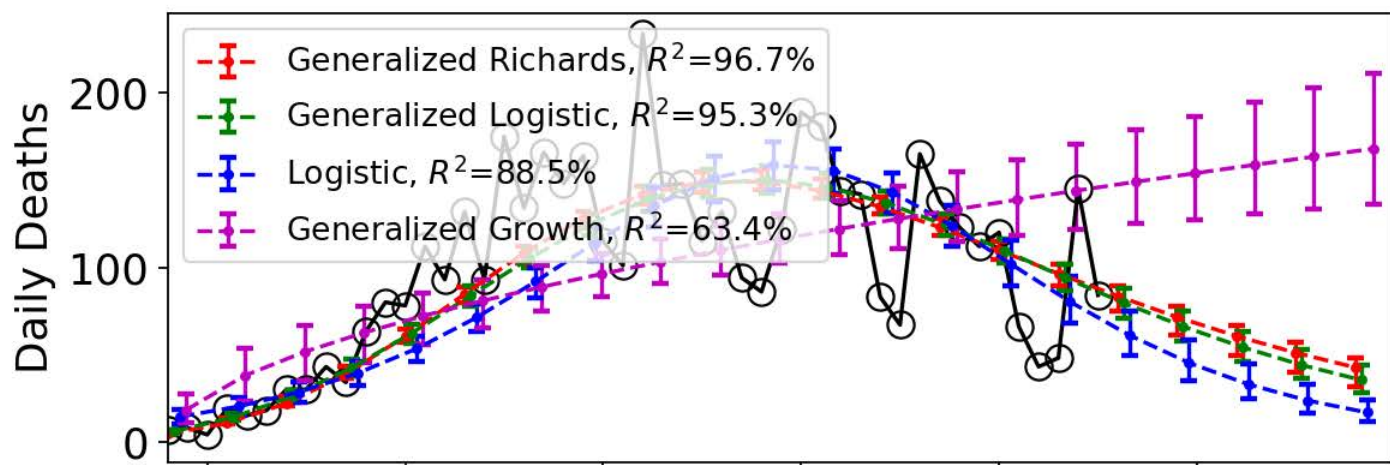
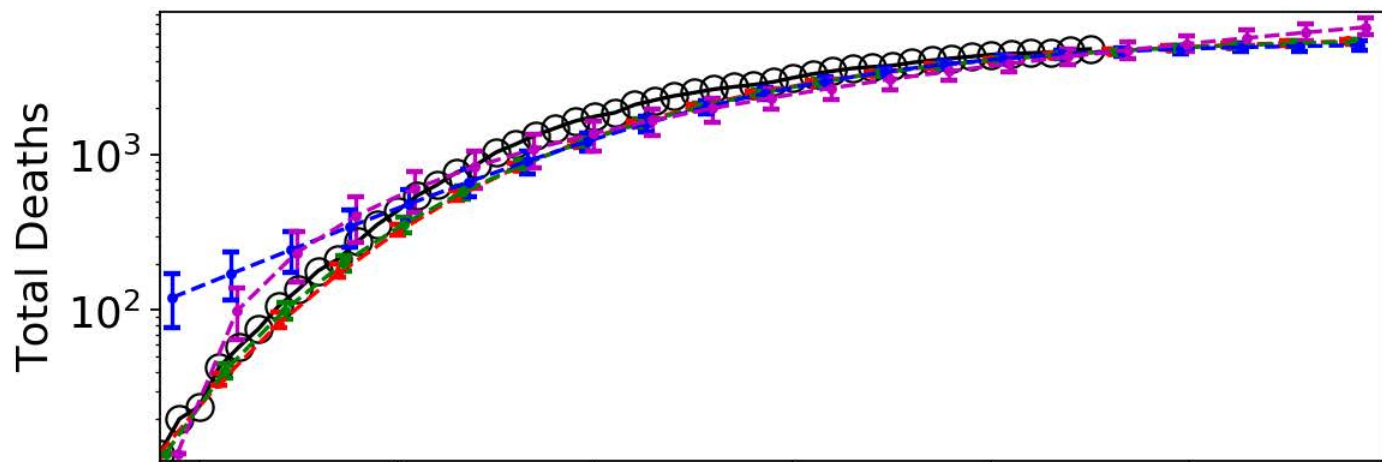


- Reported
- GRM
K=8469, $r=0.27$, $p=1.00$, $a=0.45$
- GLM
K=8316, $r=0.46$, $p=0.86$
- Logistic
 $C_0=93$, $K=8209$, $r=0.16$
- GGM
 $r=6.93$, $p=0.42$

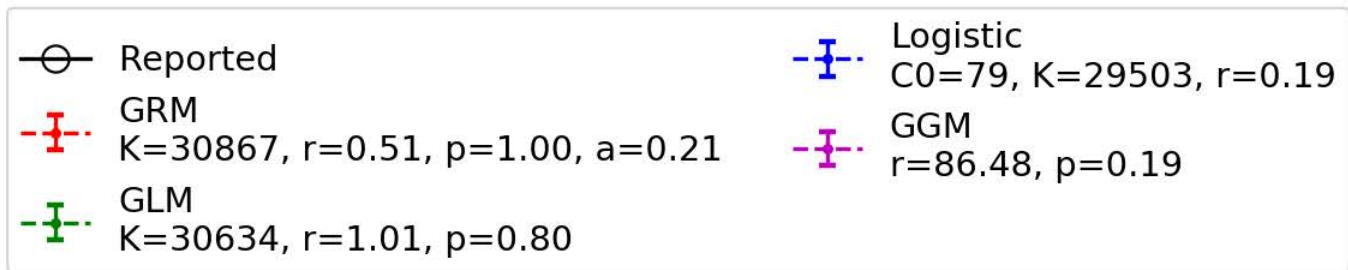
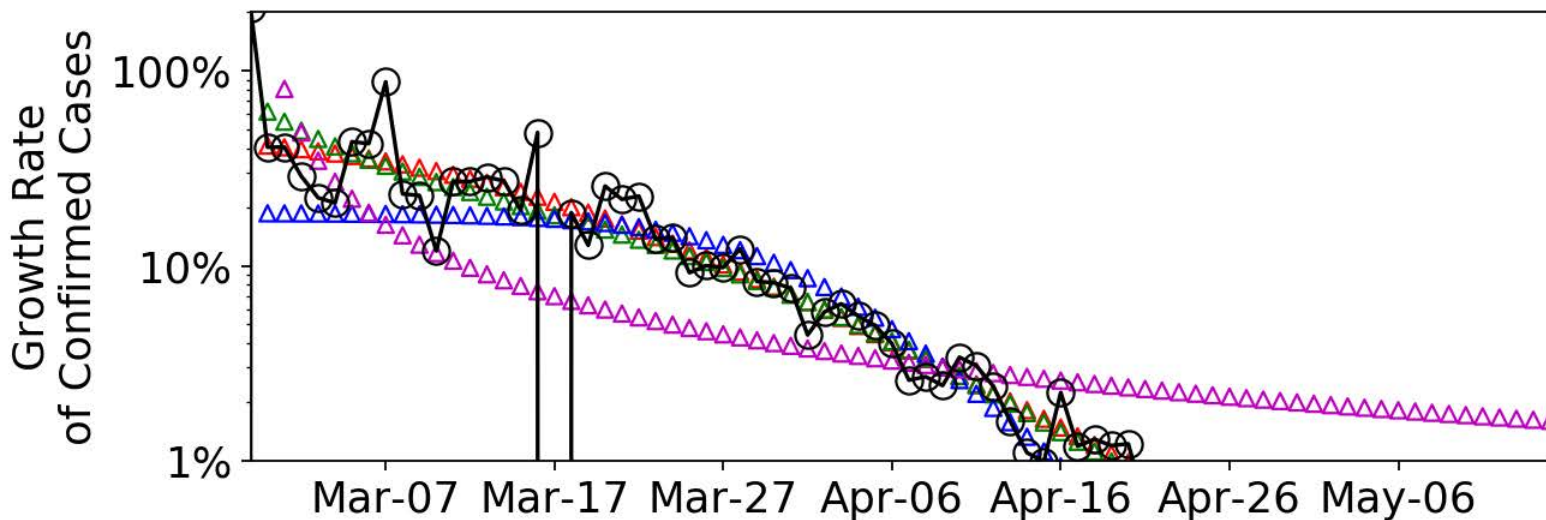
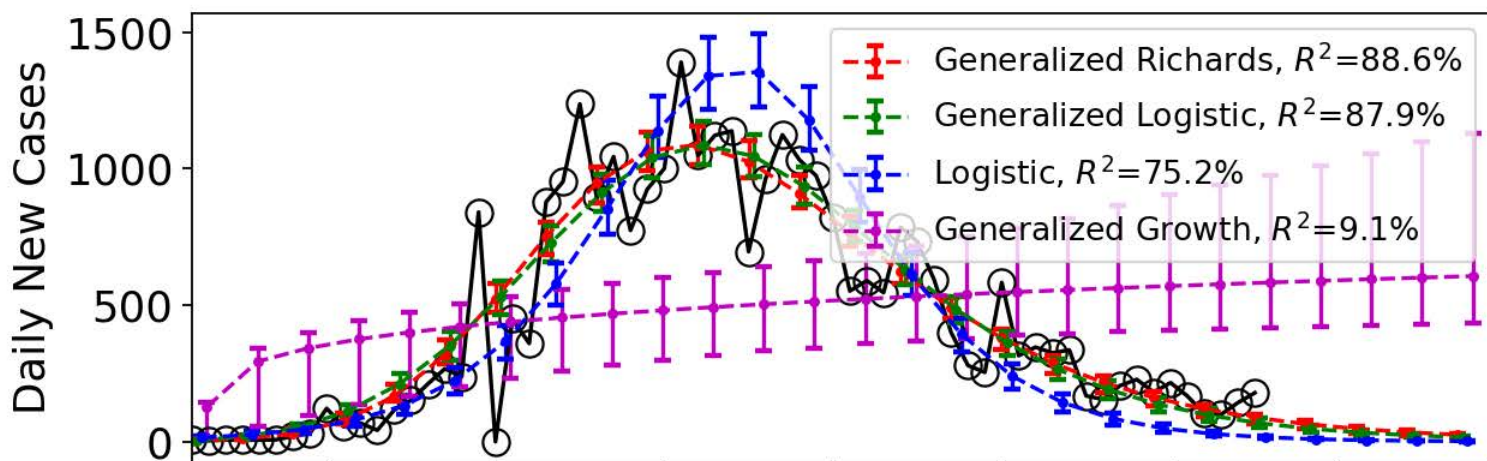
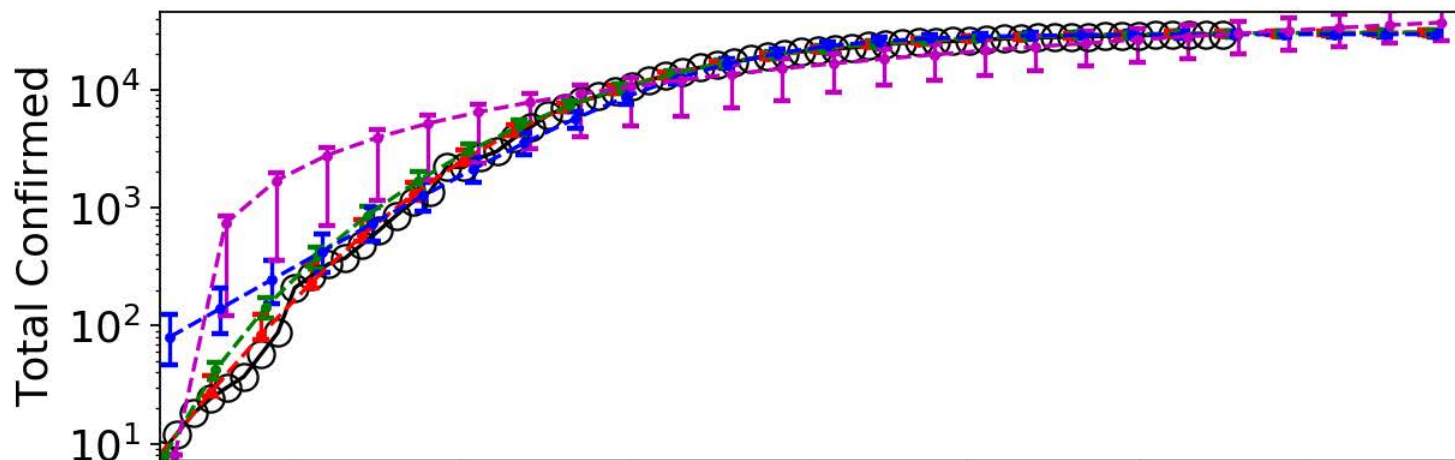
Netherlands



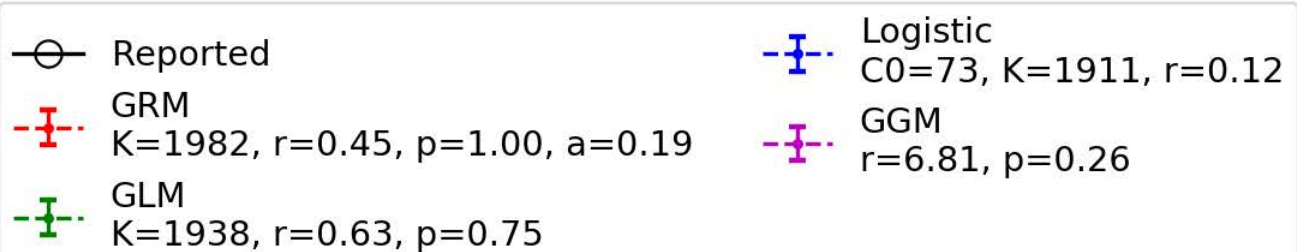
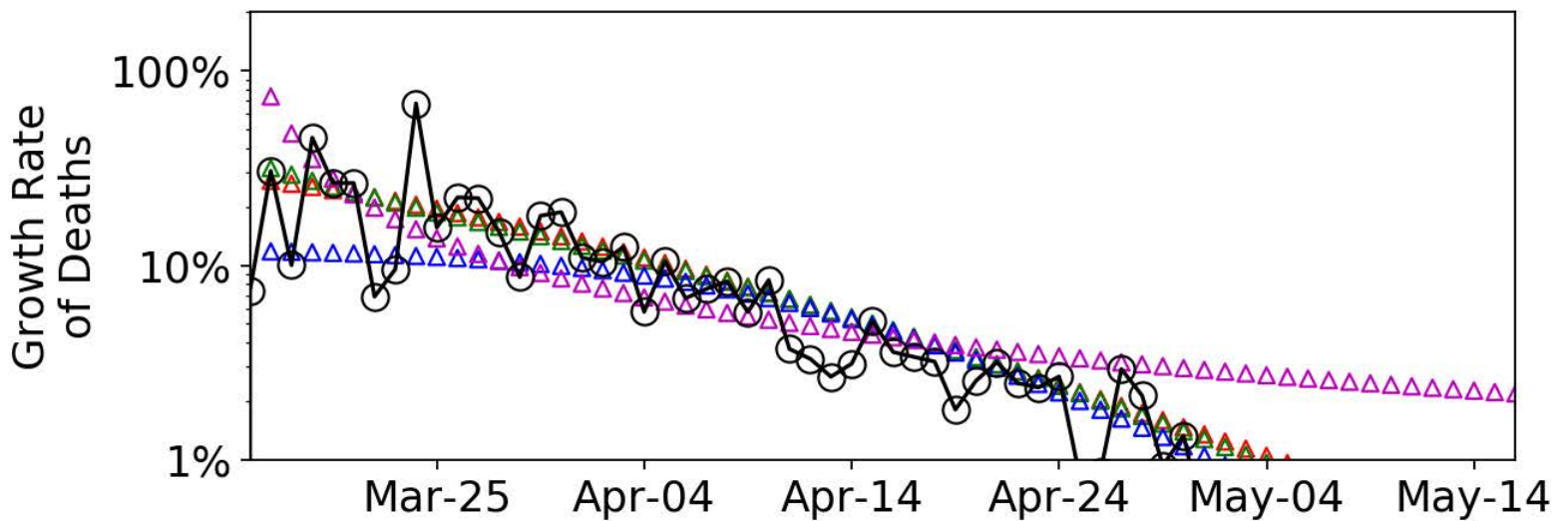
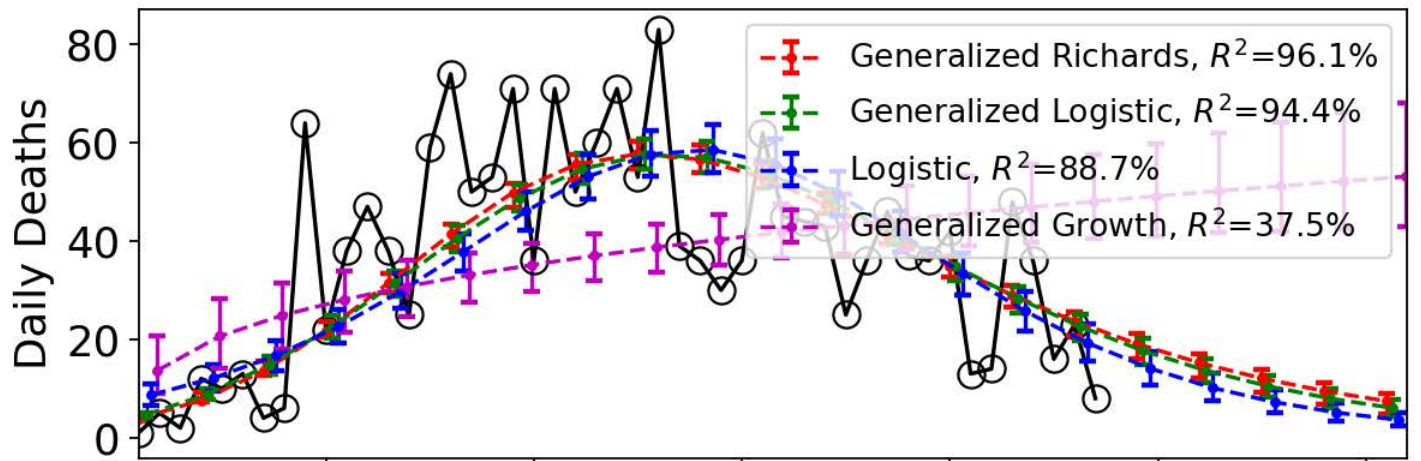
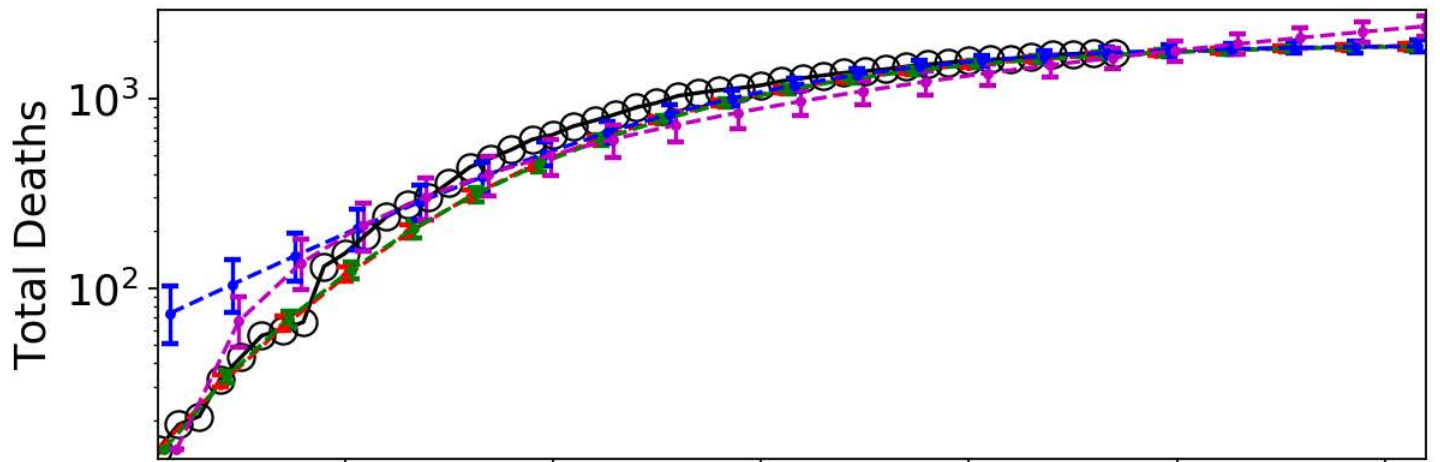
Netherlands



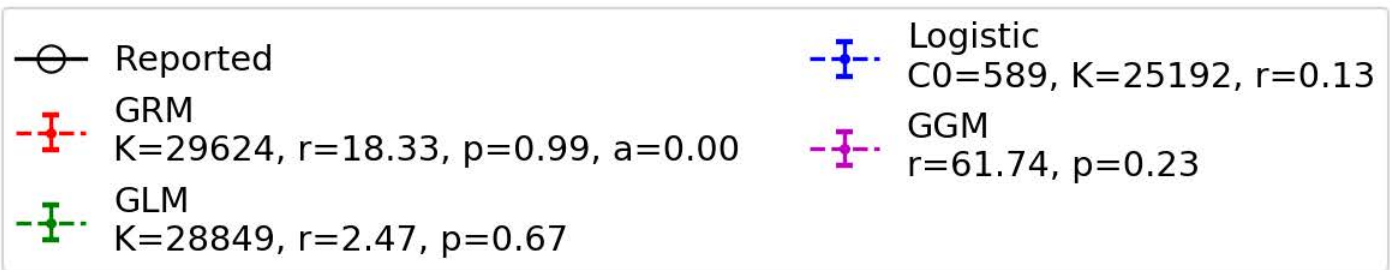
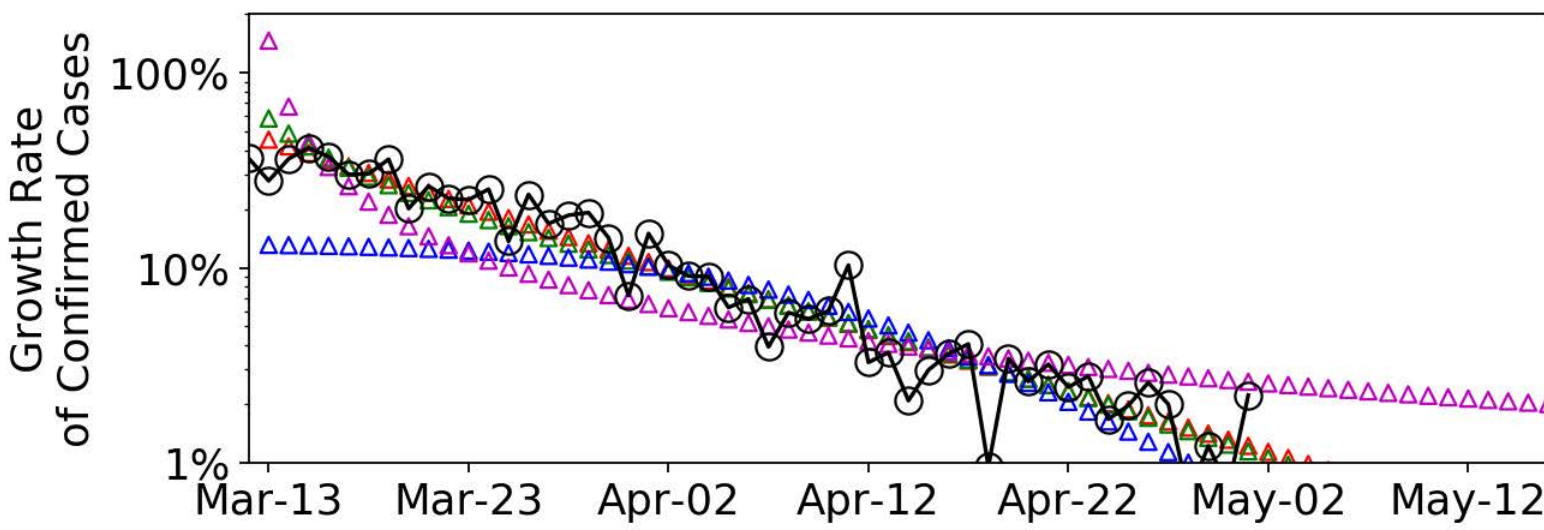
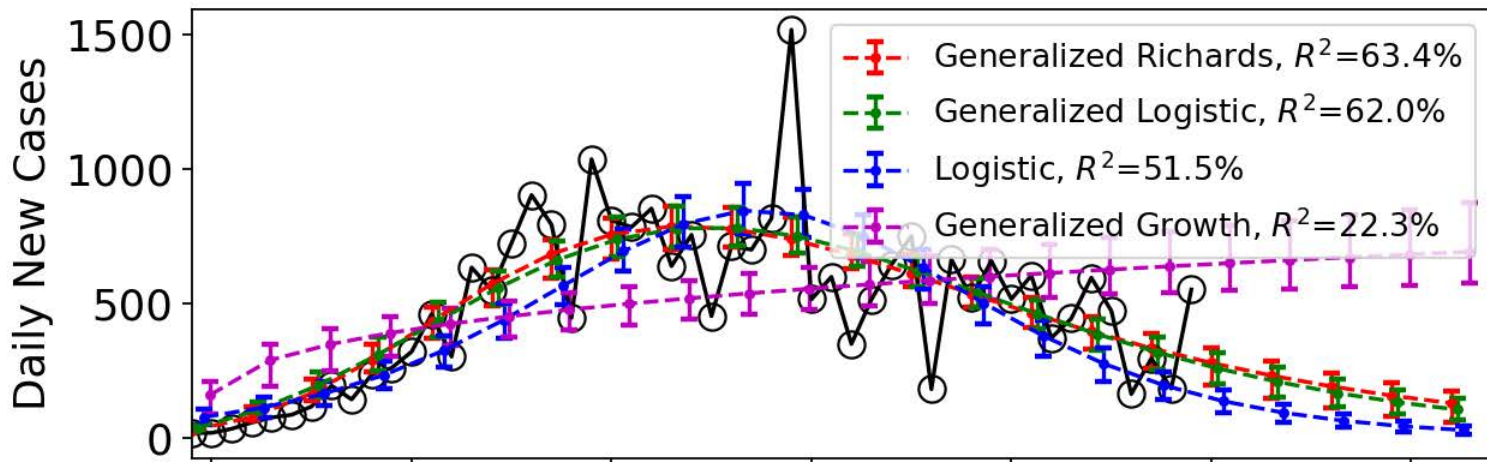
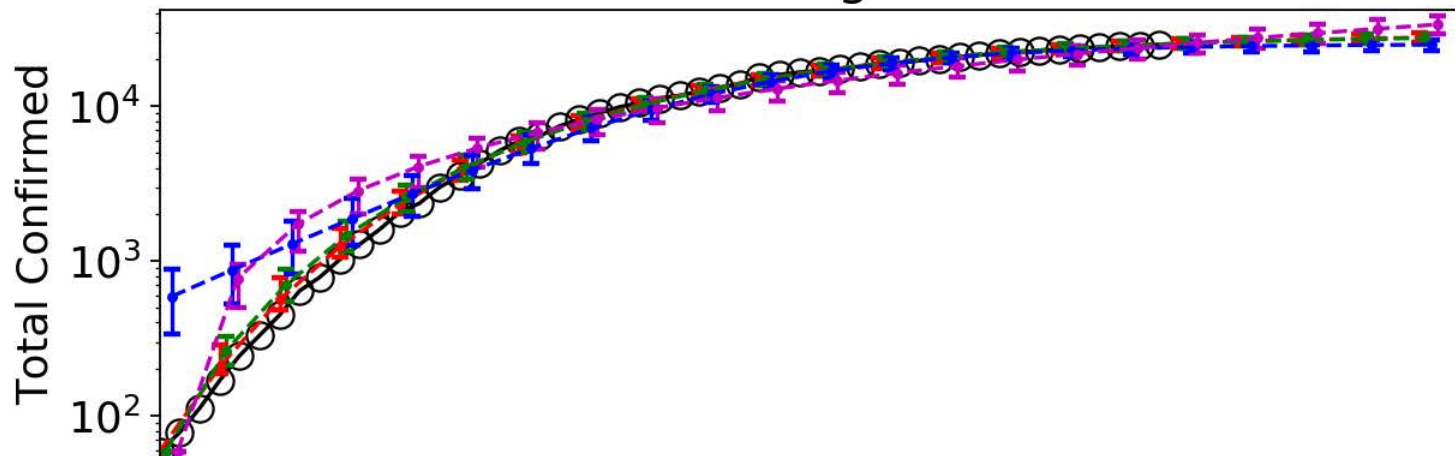
Switzerland



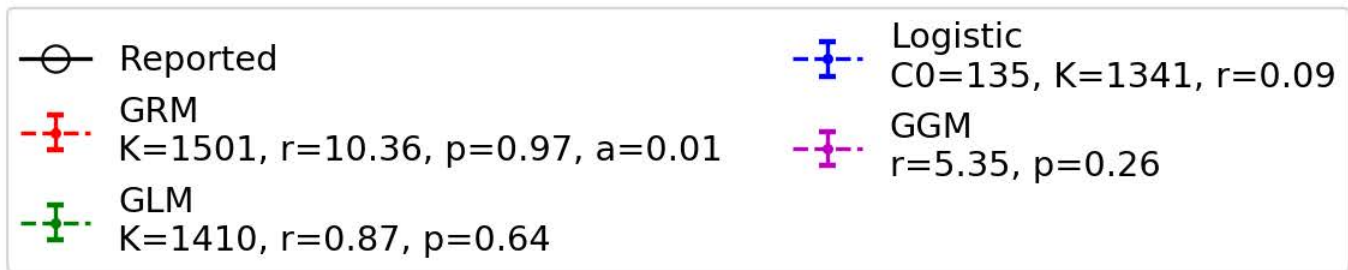
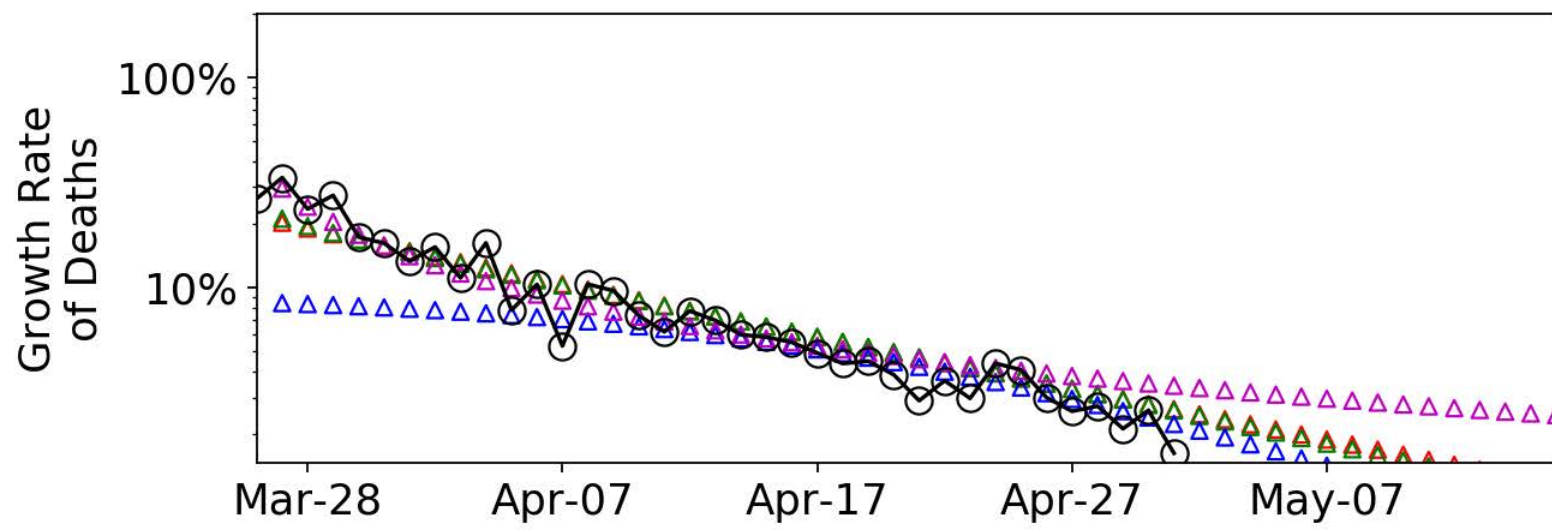
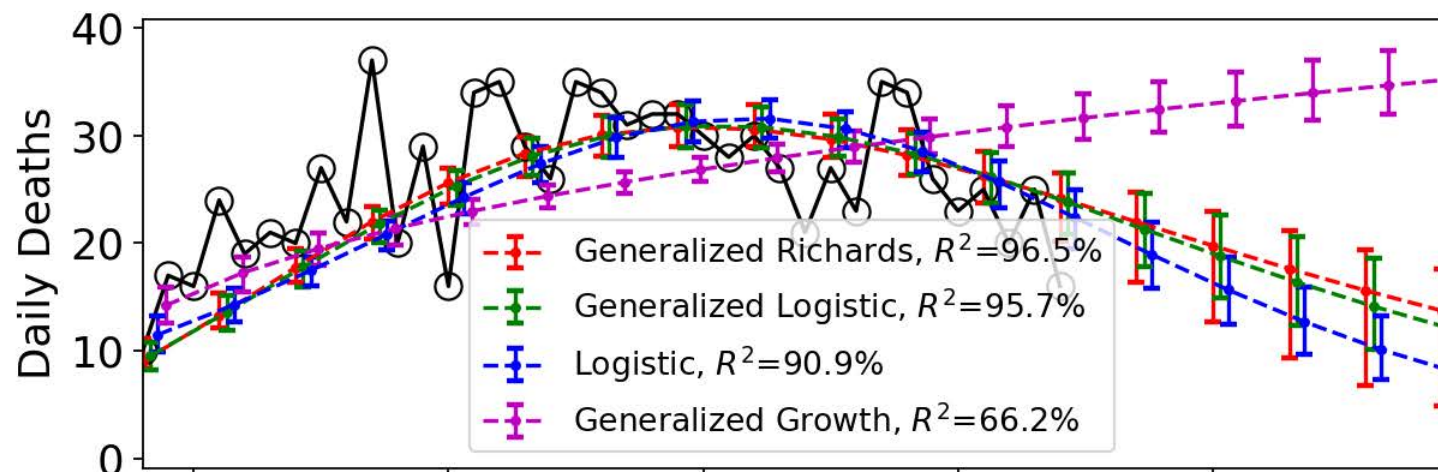
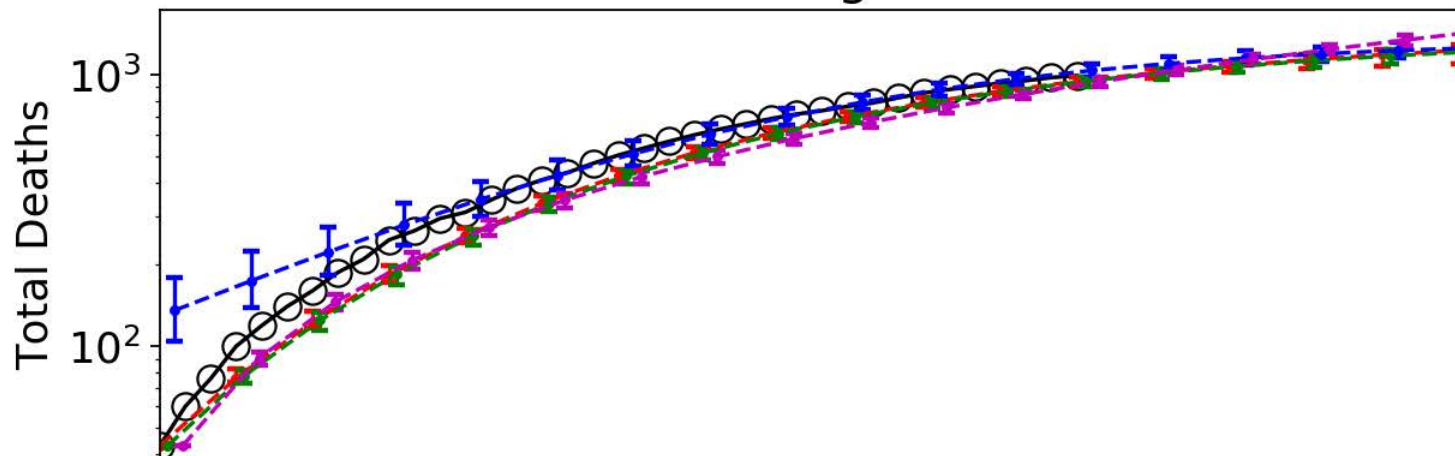
Switzerland



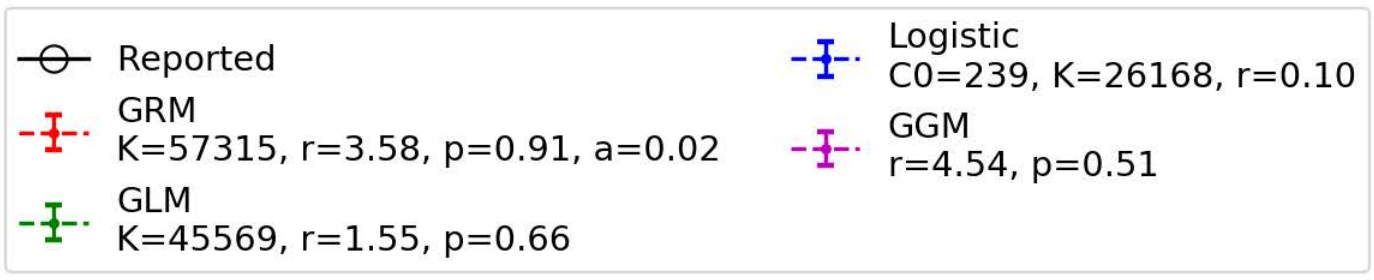
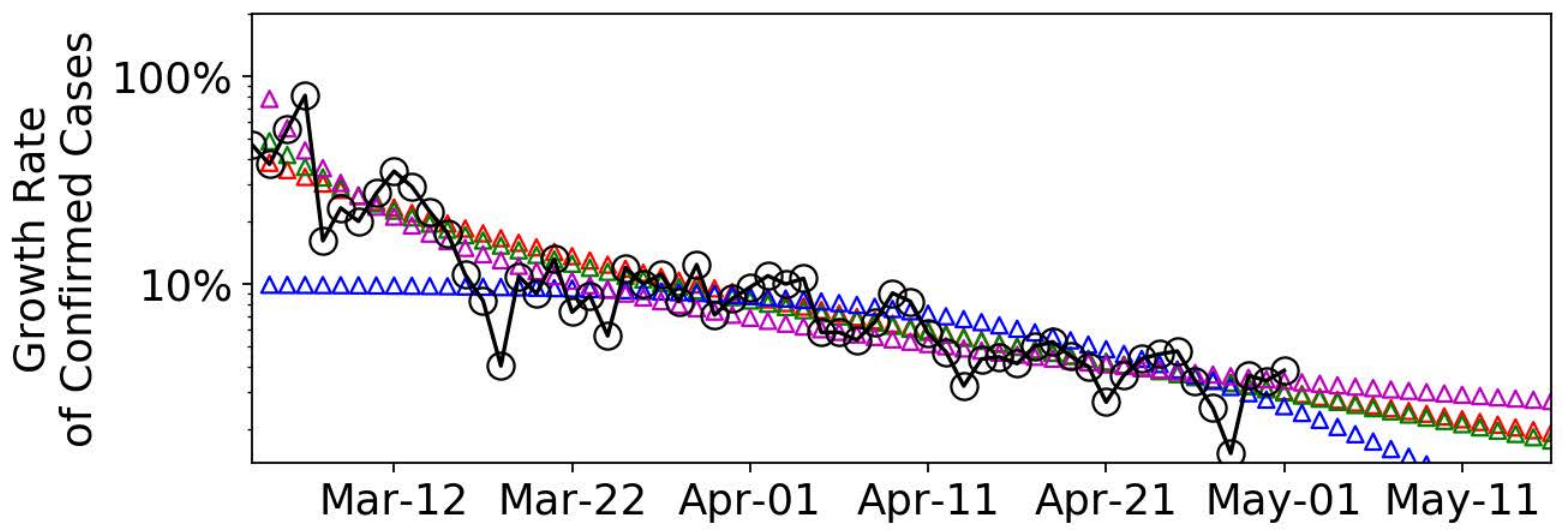
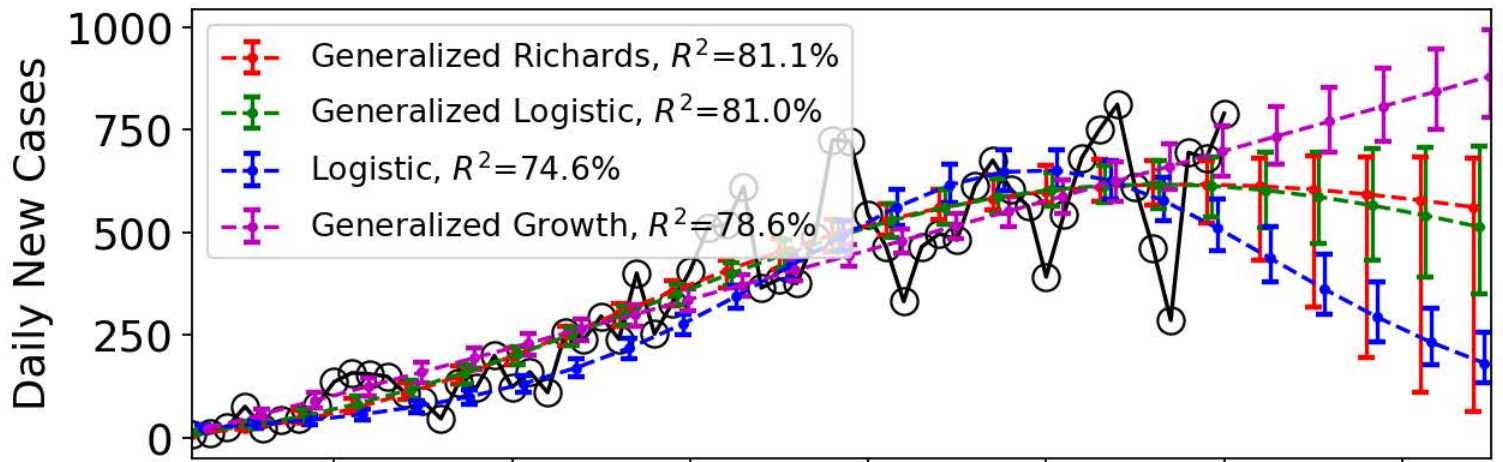
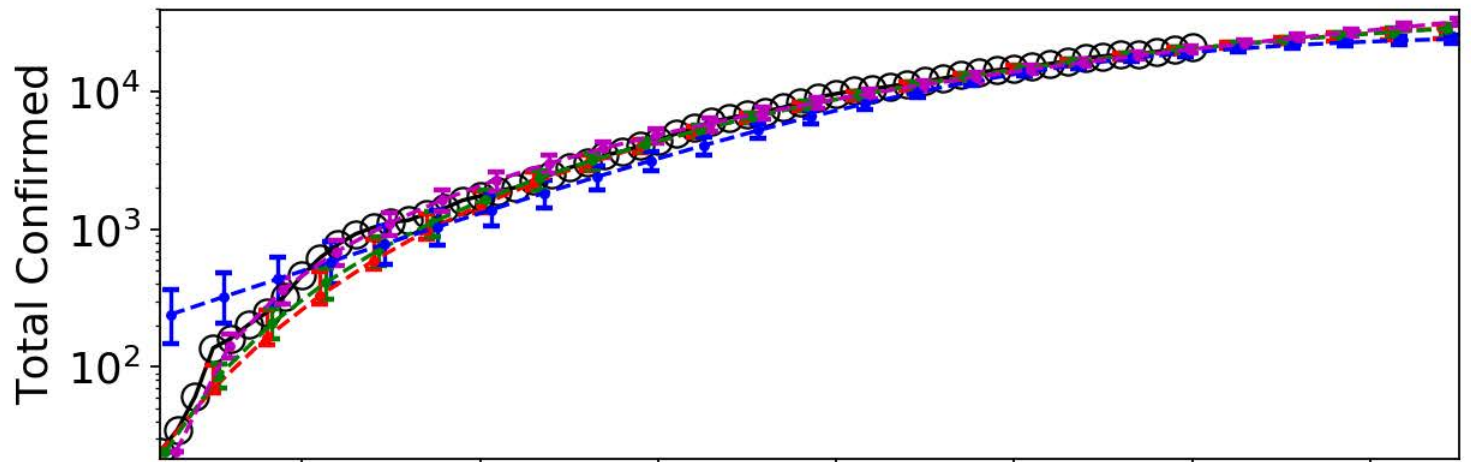
Portugal



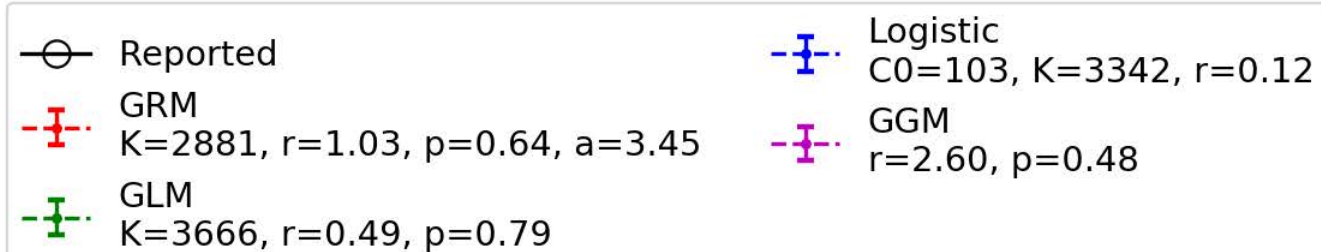
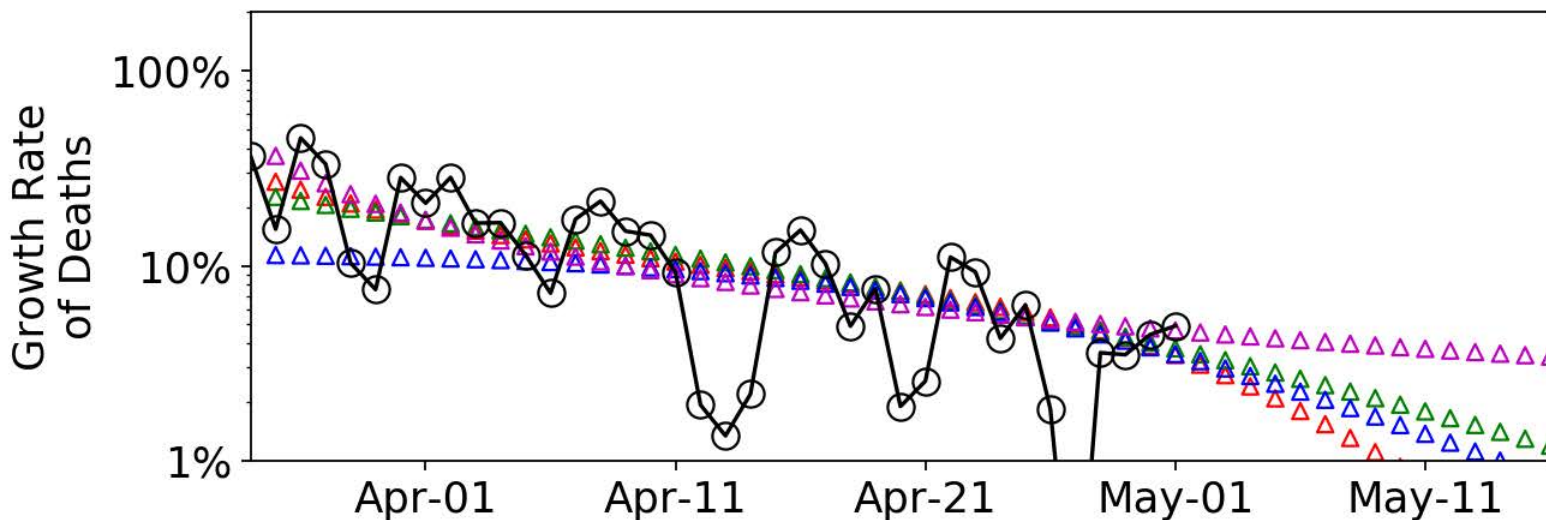
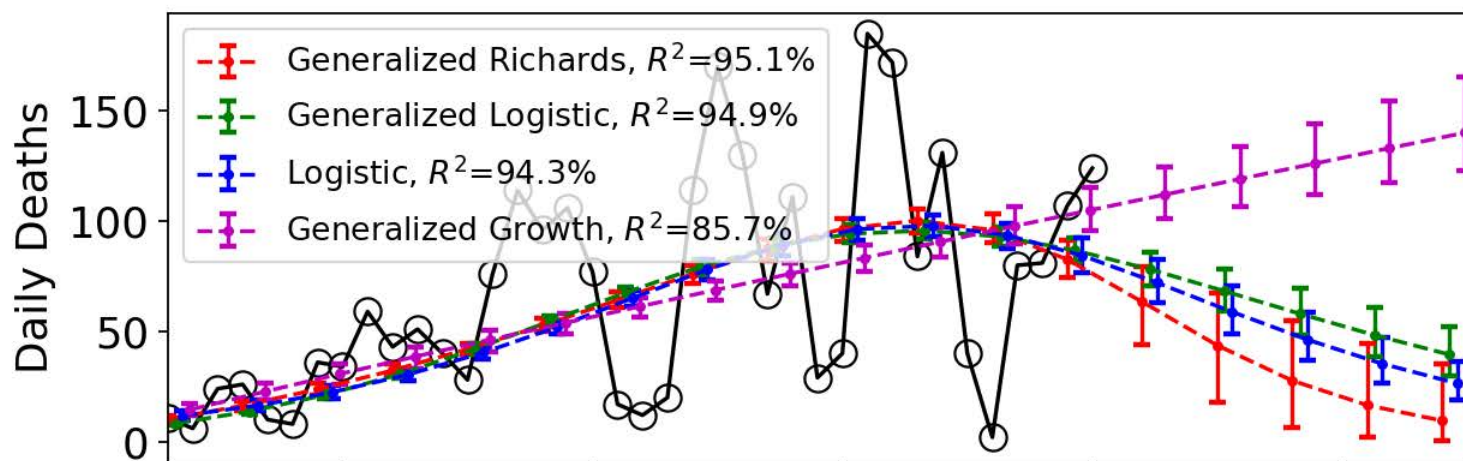
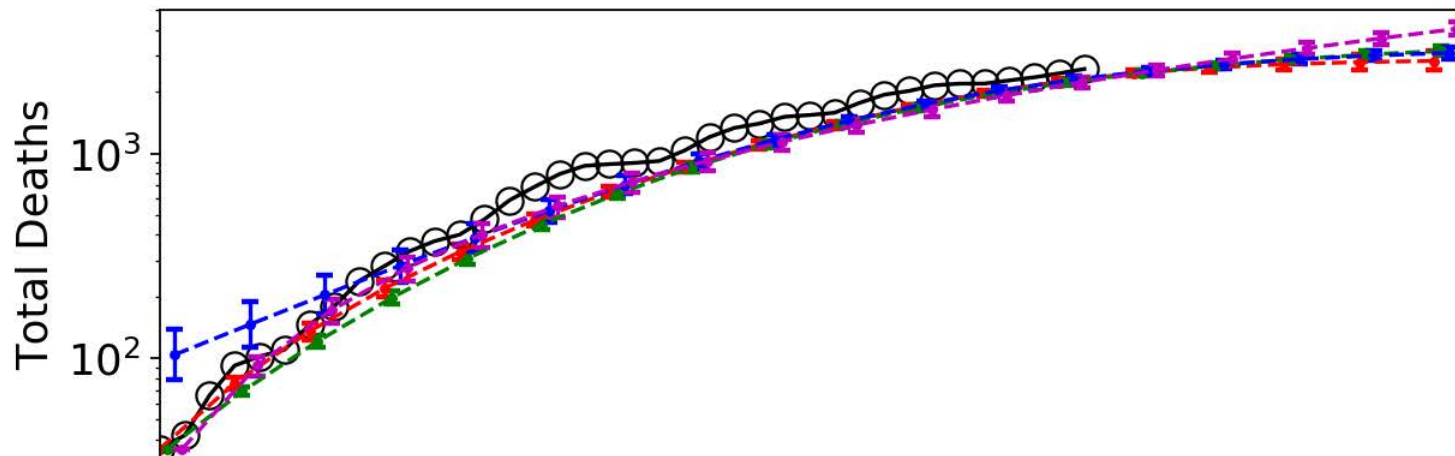
Portugal



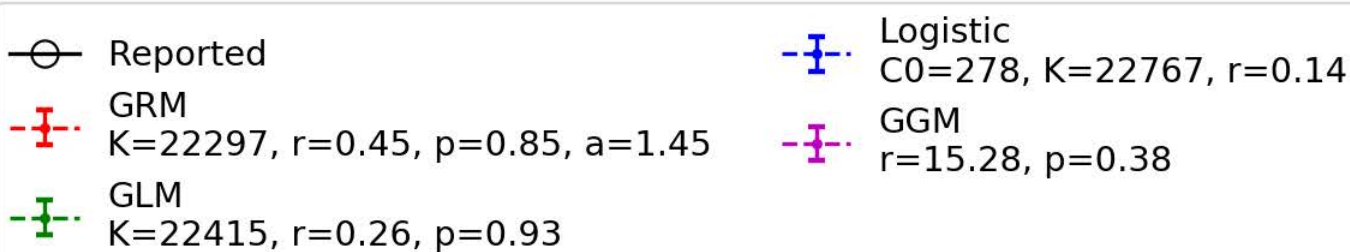
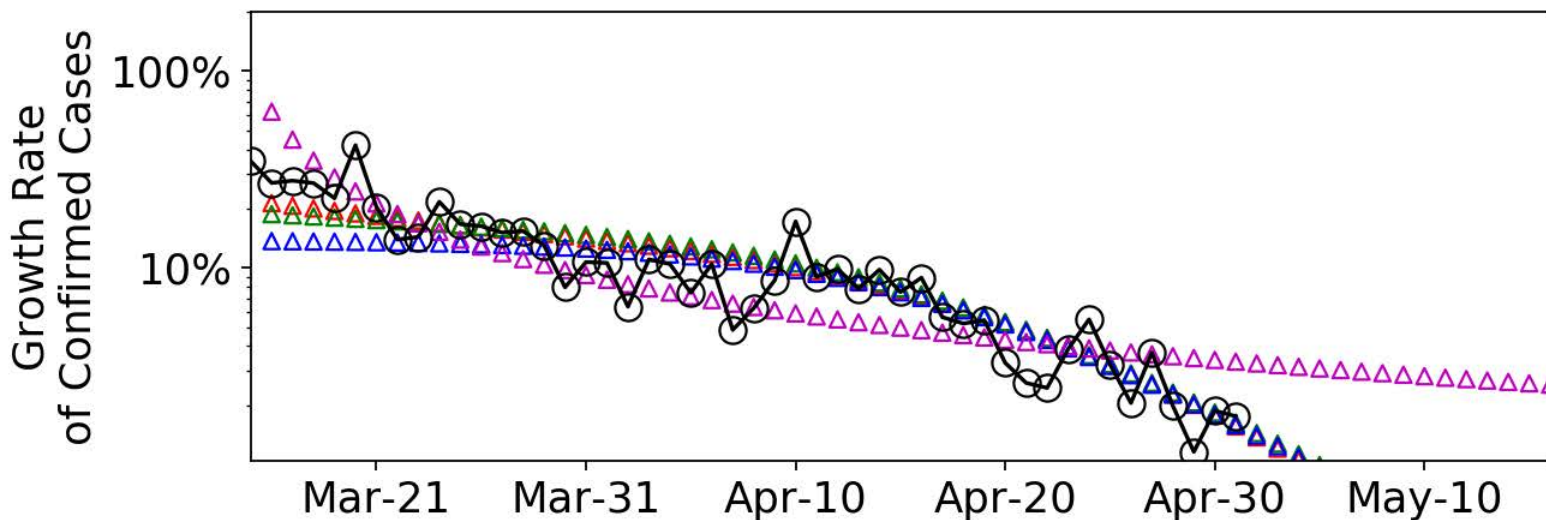
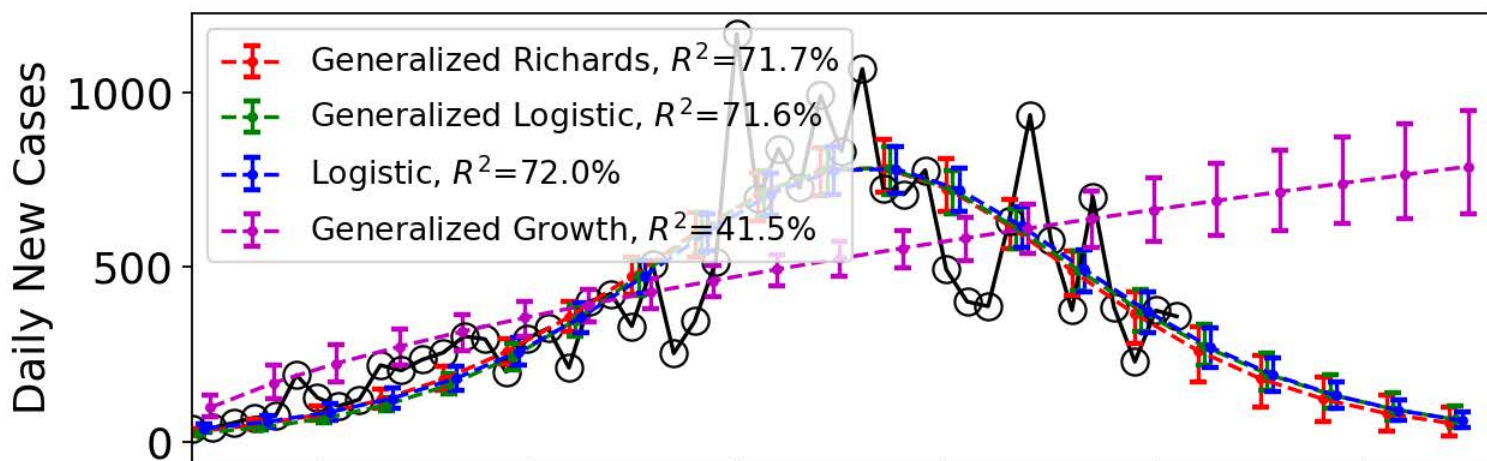
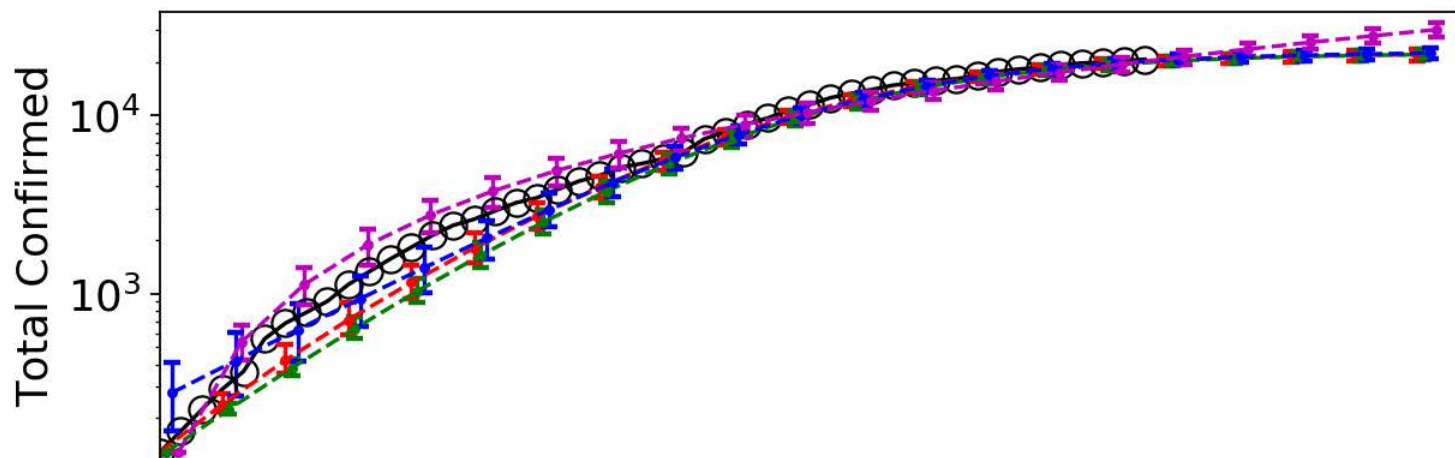
Sweden



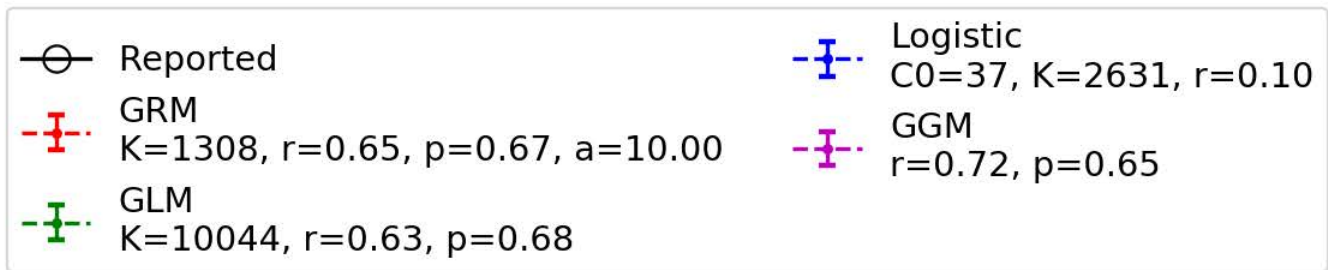
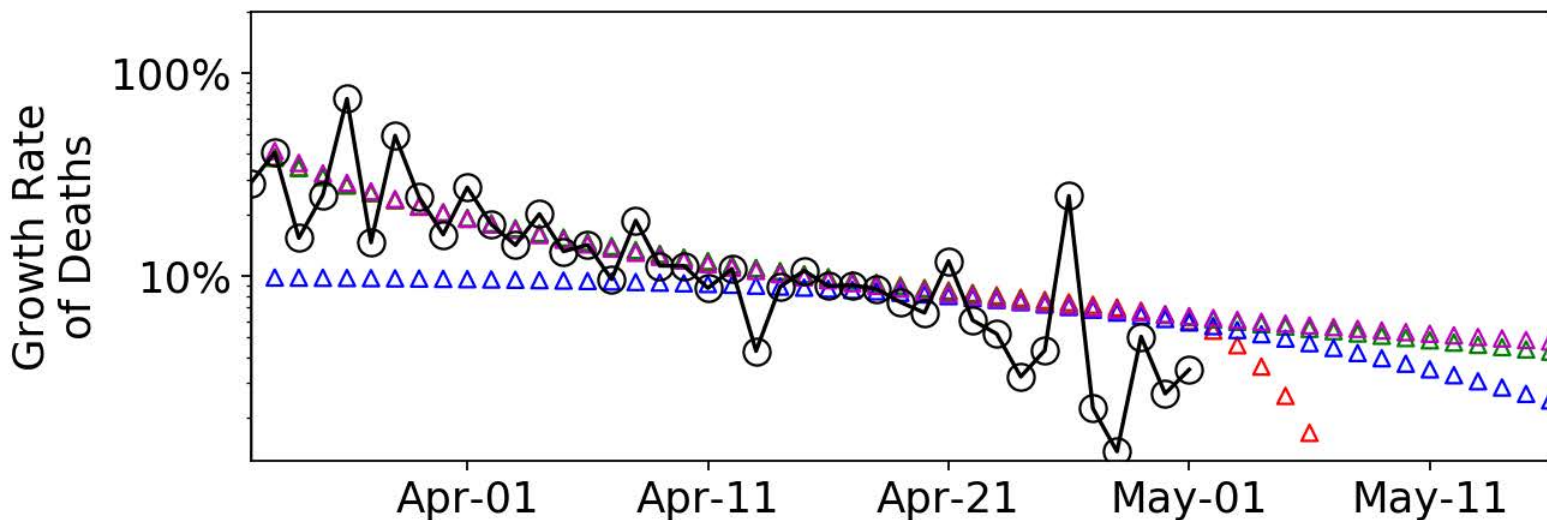
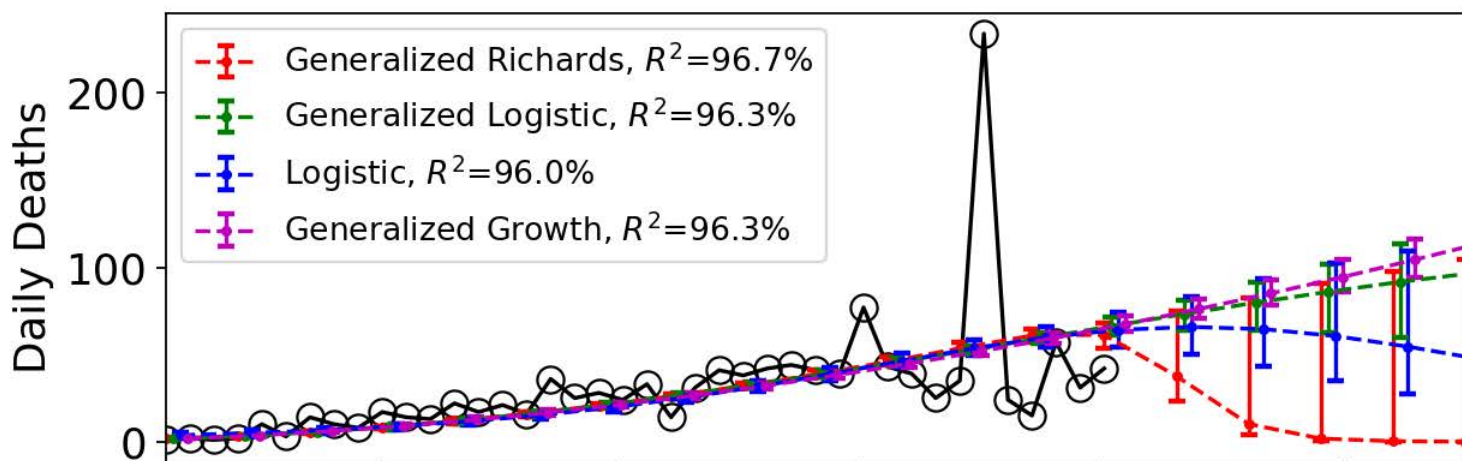
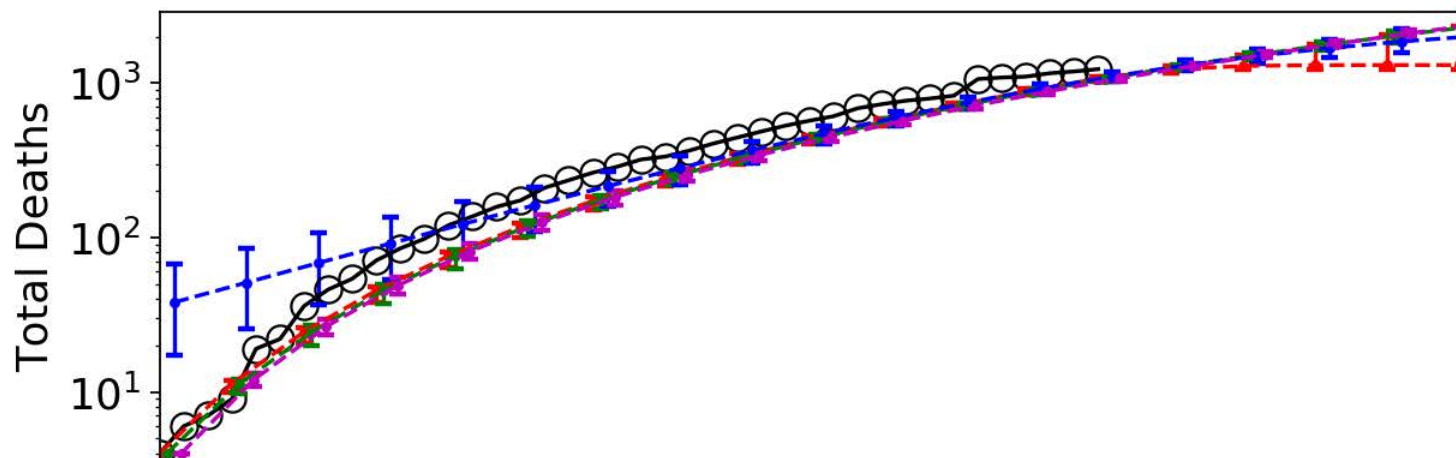
Sweden



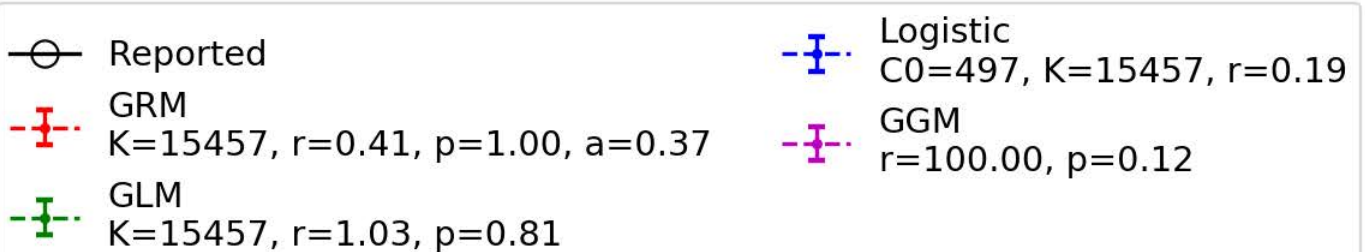
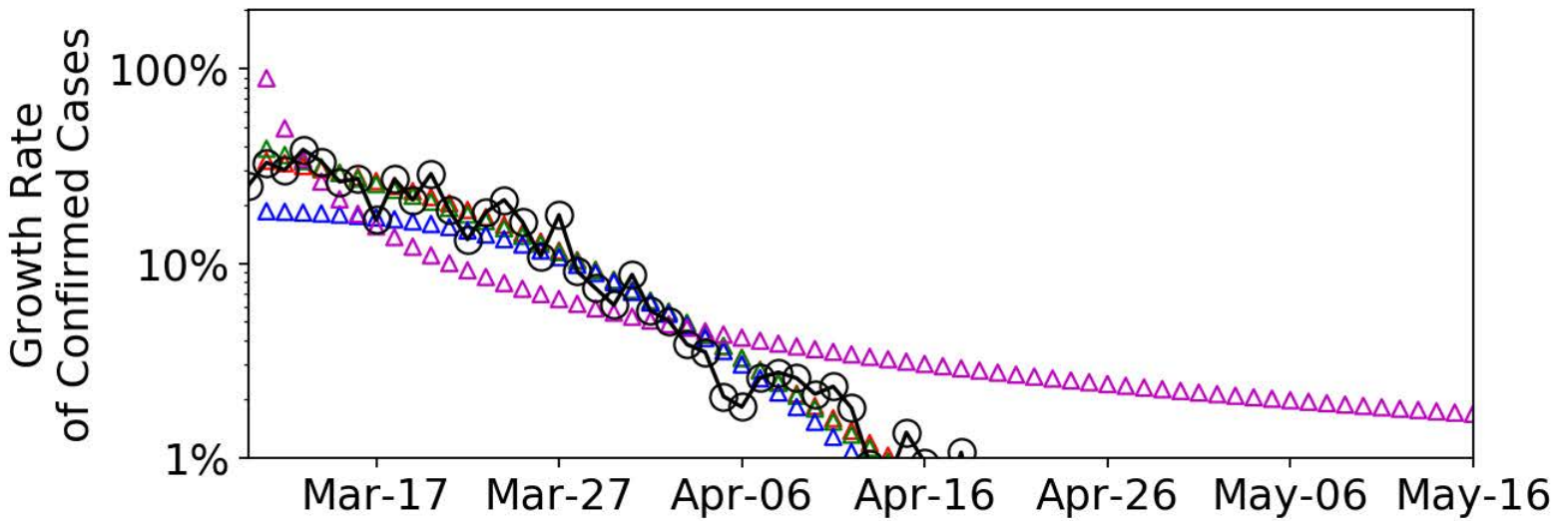
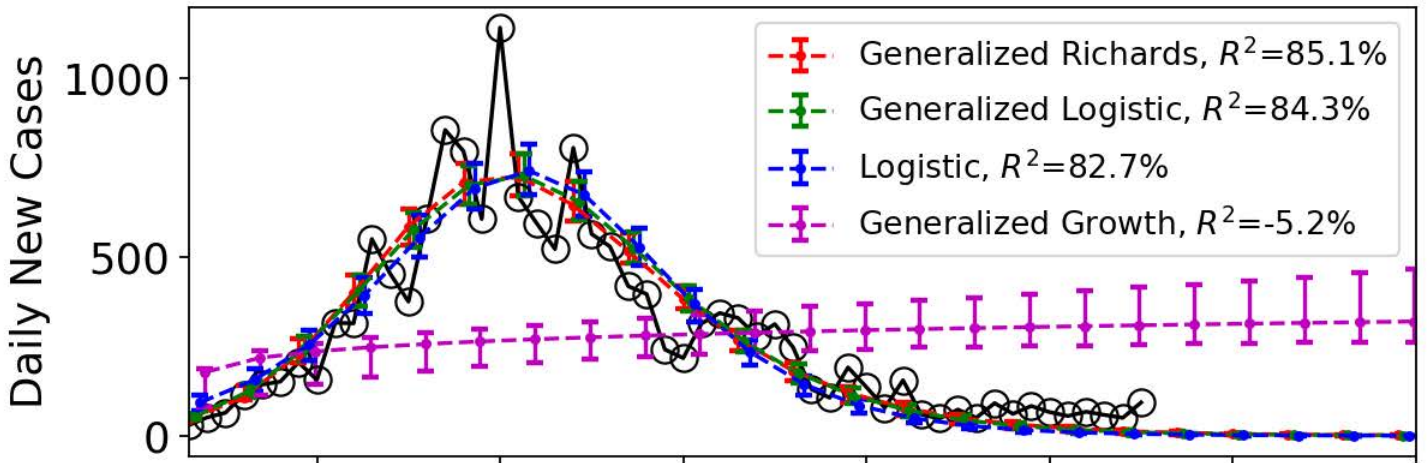
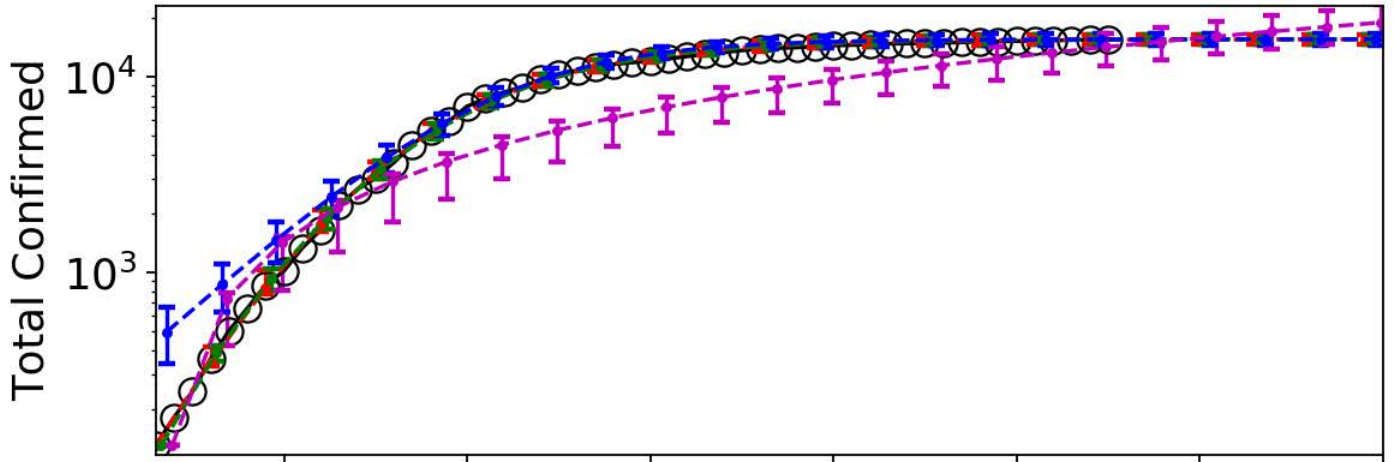
Ireland



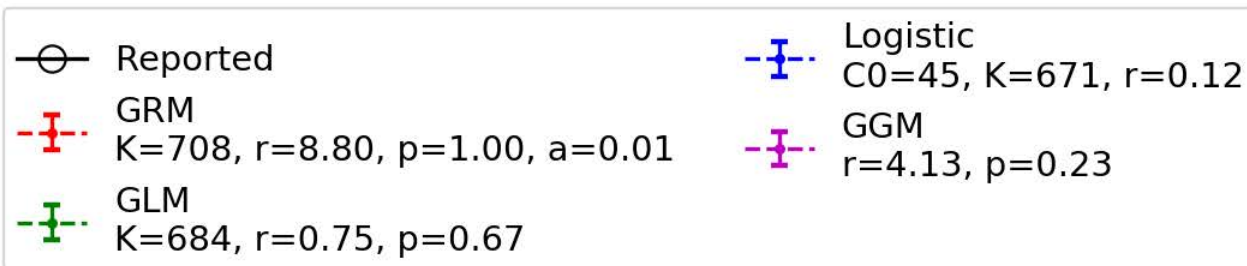
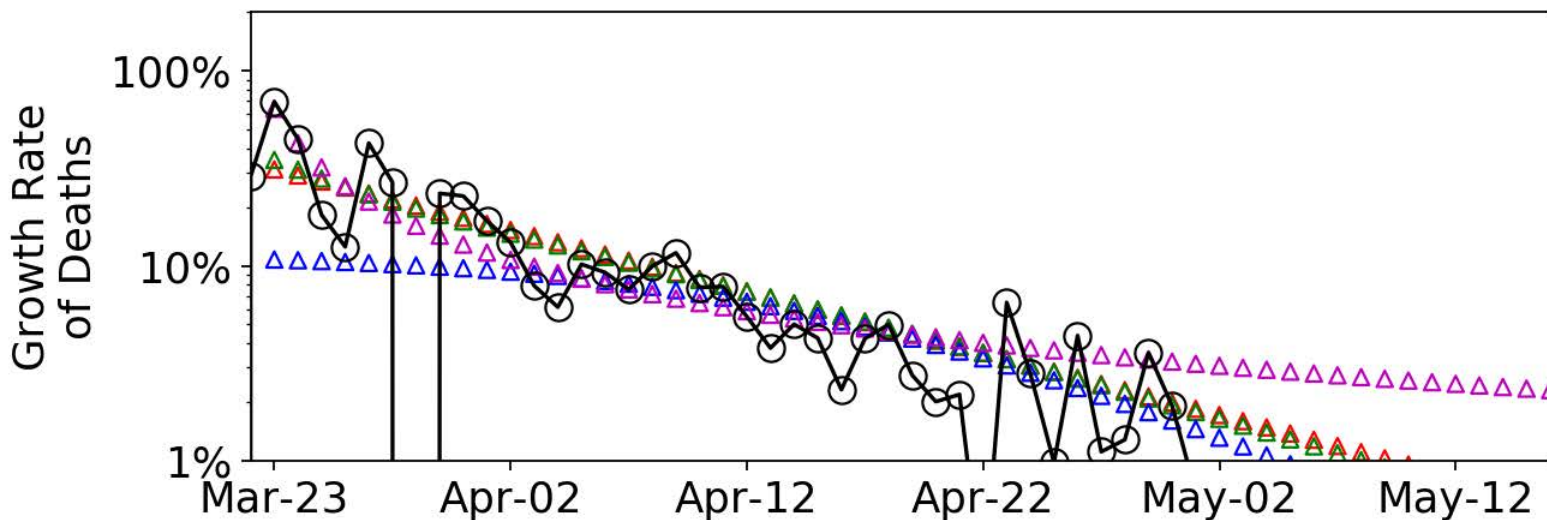
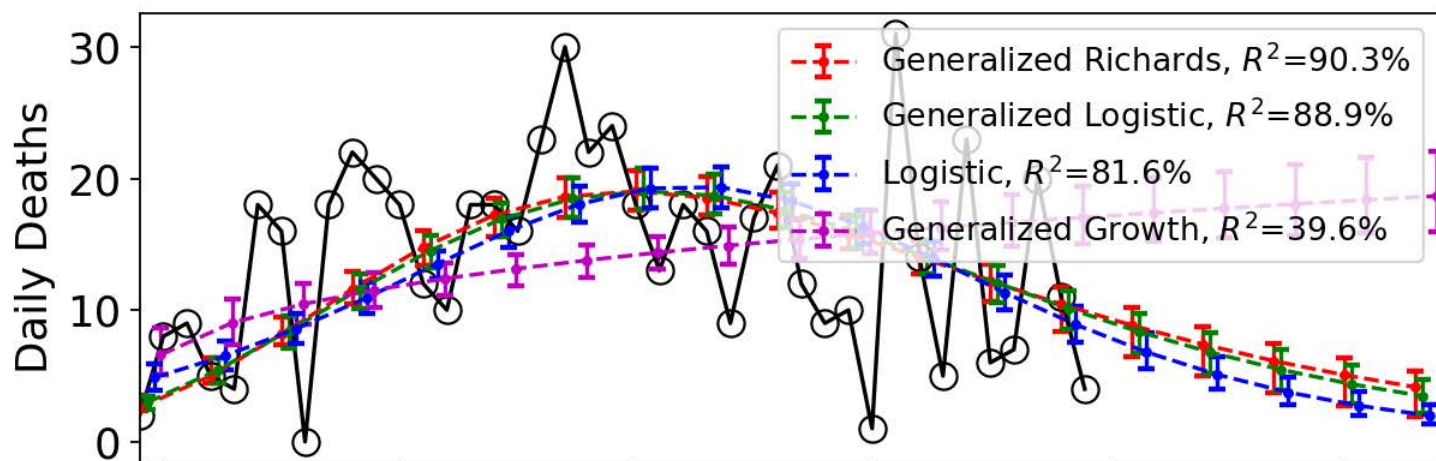
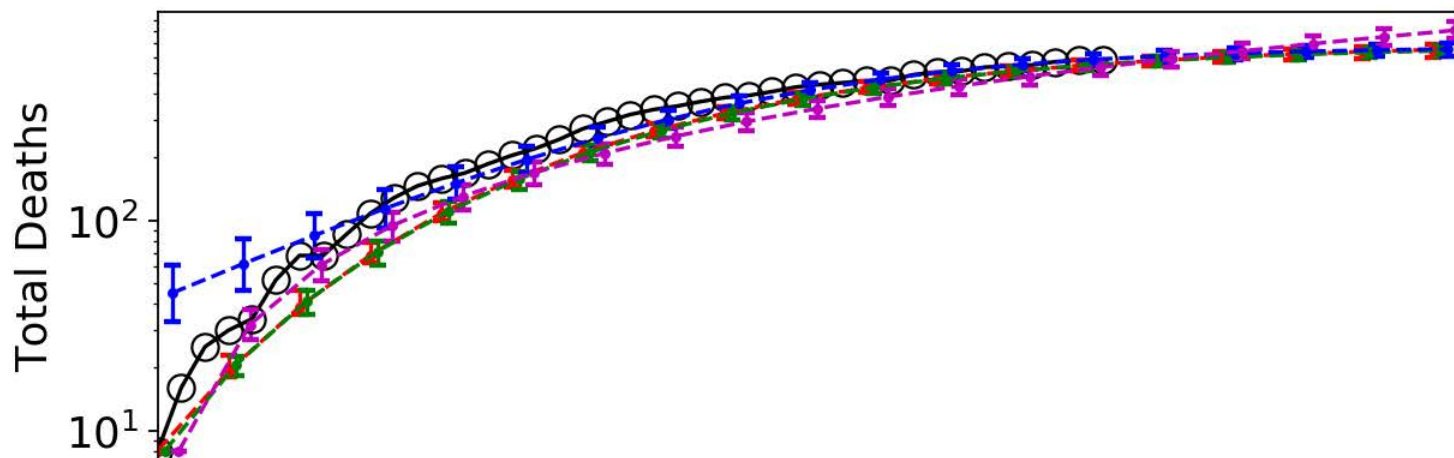
Ireland



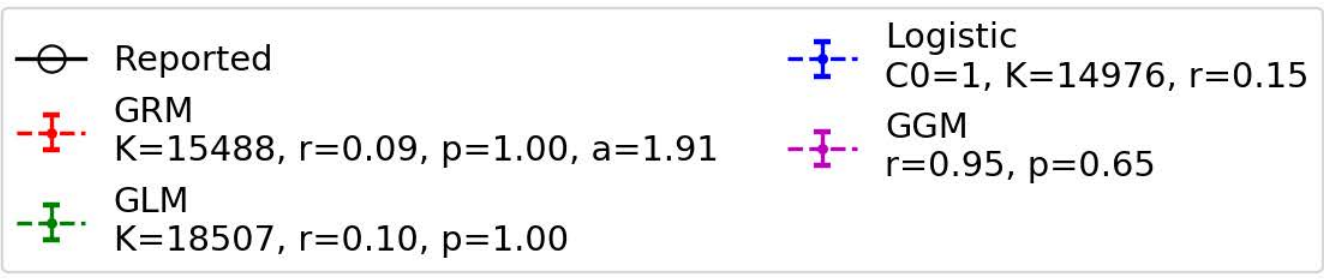
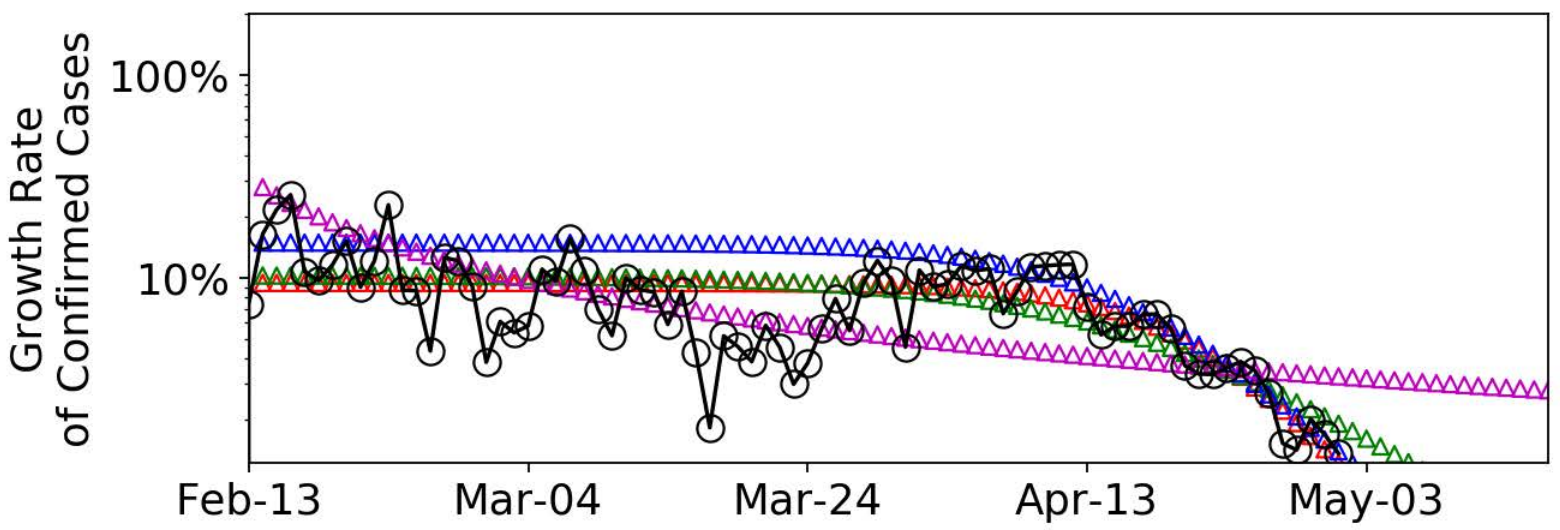
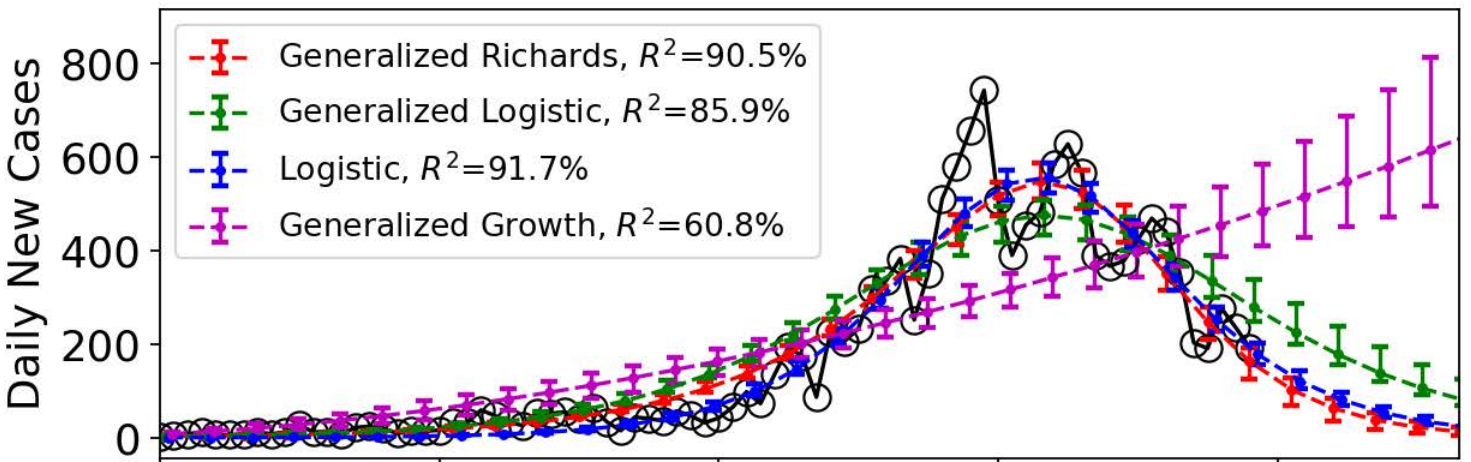
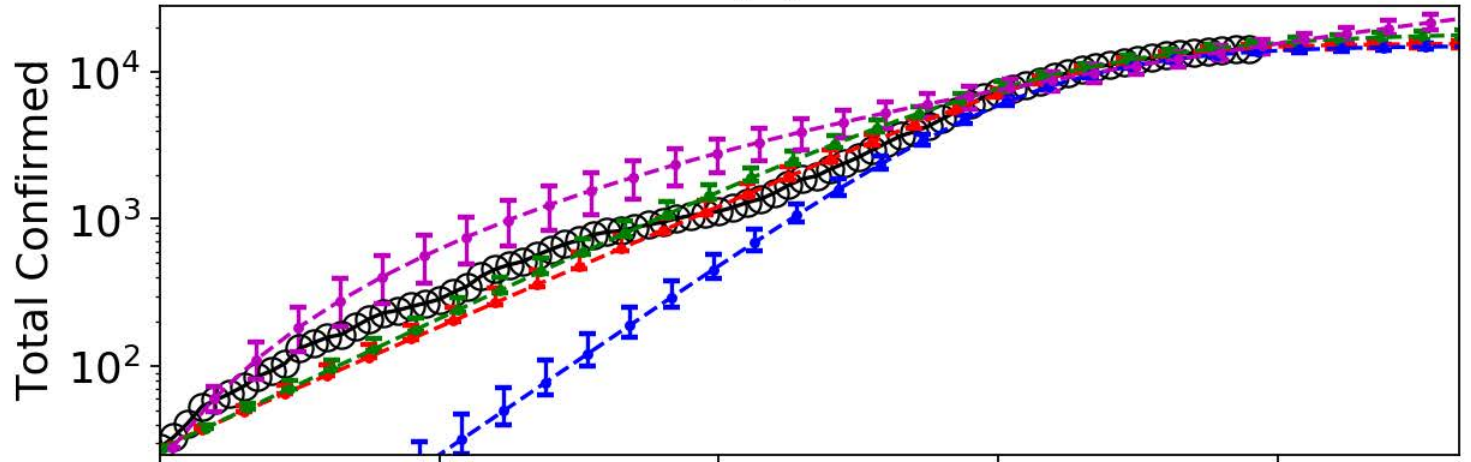
Austria



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